

Guidelines for the  
Measurement and Reporting of Emissions  
by Direct Participants in the  
UK Emissions Trading Scheme

# CONTENTS

<b>SECTION 1:</b>	<b>INTRODUCTION TO THE REPORTING GUIDELINES</b>	<b>1</b>
	PURPOSE OF THE REPORTING GUIDELINES	1
	DEVELOPMENT OF THE REPORTING GUIDELINES AND NON-CO <sub>2</sub> PROTOCOLS	1
	USE OF THIS DOCUMENT	1
<b>SECTION 2:</b>	<b>KEY PRINCIPLES</b>	<b>3</b>
<b>SECTION 3:</b>	<b>CONTEXT AND LINKS</b>	<b>5</b>
	NATIONAL AND INTERNATIONAL EMISSIONS INVENTORIES	6
	ENVIRONMENTAL REPORTING GUIDELINES	7
	CLIMATE CHANGE AGREEMENTS ('AGREEMENTS')	7
<b>SECTION 4:</b>	<b>COMPILING THE BASELINE</b>	<b>9</b>
	OVERVIEW OF STEPS FOR IDENTIFYING THE BASELINE	9
	ISSUES IN BASELINE DEFINITION	10
	SCOPE OF EMISSIONS TO BE INCLUDED	11
	DEFINITION OF A SOURCE	12
	CALCULATION OF THE BASELINE	13
	REGULATORY REQUIREMENTS	13
<b>SECTION 5:</b>	<b>TREATMENT OF UNCERTAINTY</b>	<b>15</b>
<b>SECTION 6:</b>	<b>REPORTING REQUIREMENTS</b>	<b>17</b>
<b>ANNEX A:</b>	<b>PROTOCOLS FOR ENERGY-RELATED CO<sub>2</sub> EMISSIONS</b>	<b>19</b>
	INTRODUCTION	19
	PROTOCOL A1: CALCULATING EMISSIONS FOR ENERGY RELATED CO <sub>2</sub>	20
	PROTOCOL A2: IMPORT OR EXPORT OF HEAT AND POWER	22
	PROTOCOL A3: RENEWABLE ENERGY	24
<b>ANNEX B:</b>	<b>PROCESS CO<sub>2</sub> EMISSIONS</b>	<b>28</b>
	INTRODUCTION	28
	PROTOCOL B1: CEMENT MANUFACTURE	29
	PROTOCOL B2: LIME PRODUCTION	31
	PROTOCOL B3: LIMESTONE AND DOLOMITE USE	32
	PROTOCOL B4: SODA ASH	33
	PROTOCOL B5: USE OF FUELS AS FEEDSTOCK (WHERE THE PRODUCT DOES NOT CONTAIN CARBON)	34
	PROTOCOL B6: METAL PRODUCTION	35
	PROTOCOL B7: WASTE INCINERATION – MUNICIPAL SOLID WASTE (MSW) AND SEWAGE	36
<b>ANNEX C:</b>	<b>OTHER APPROVED PROTOCOLS</b>	<b>37</b>
	INTRODUCTION	37
	PROTOCOL C1: MEASUREMENT OF HFCS AND PFCS FROM THE MANUFACTURE OF HF, CTF,	

	HCFC-22, HFC-125 AND HFC-134A	38
PROTOCOL C2:	MEASUREMENT OF HFC EMISSIONS FROM THE USE OF REFRIGERATION FROM THE MANUFACTURE OF HF, CTF, HCFC-22, HFC-125 AND HFC-134A	51
PROTOCOL C3:	MEASUREMENT OF HFC AND PFC EMISSIONS FROM INDUSTRIAL AND COMMERCIAL REFRIGERATION	61
PROTOCOL C4:	MEASUREMENT OF HFC EMISSIONS FROM THE MANUFACTURE OF DOMESTIC REFRIGERATION	66
PROTOCOL C5:	MEASUREMENT OF CO <sub>2</sub> AND CH <sub>4</sub> EMISSIONS FROM OFFSHORE OIL AND GAS OPERATIONS	69
PROTOCOL C6:	CALCULATION OF PROCESS CO <sub>2</sub> EMISSIONS IN BEER PRODUCTION	73
PROTOCOL C7:	MEASUREMENT OF CO <sub>2</sub> EMISSIONS FROM FUEL BURN FROM AVIATION	76
PROTOCOL C8:	MEASUREMENT OF CH <sub>4</sub> EMISSIONS FROM WORKING COAL MINES	76
PROTOCOL C9:	MEASUREMENT OF HFCS AND PFCs FROM CHEMICAL PROCESS OPERATIONS	90
PROTOCOL C10:	MEASUREMENT OF N <sub>2</sub> O, CH <sub>4</sub> AND CO <sub>2</sub> FROM THE MANUFACTURE OF NYLON	108

# SECTION 1: INTRODUCTION TO THE REPORTING GUIDELINES

## Purpose of the Reporting Guidelines

- 1.1 These Reporting Guidelines and annexed protocols provide both specific and general guidance to participants entering into the UK Emissions Trading Scheme through the financial incentive (Direct Participants) on the approach to calculating/estimating and reporting emissions<sup>1</sup>.
- 1.2 The purpose of the Reporting Guidelines is to:
  - specify the key principles which Direct Participants must follow when calculating/estimating and reporting emissions. These principles shall be taken into account in the development of any new protocols submitted by Direct Participants to DEFRA. These principles are given in section 2.
  - give practical guidance to Direct Participants on a number of the requirements of the Scheme outlined in the framework document, particularly developing their source lists and baselines. These are provided in sections 2-5.
  - provide the detailed steps for measuring and reporting emissions that participants must use. These are set out in the approved protocols contained in Annexes A, B and C

## Development of the Reporting Guidelines and non-CO<sub>2</sub> protocols

- 1.3 The Reporting Guidelines were published alongside the framework for the scheme in August 2001<sup>2</sup>, together with draft protocols covering CO<sub>2</sub> emissions from fuel related sources (Annex A) and from industrial processes (Annex B). Both documents together contained the material necessary to allow Direct Participants to prepare for entry into the scheme. Where Participants wished to include a source in its source list not already covered by the draft protocols, for example a non-CO<sub>2</sub> source, participants were required to inform DEFRA, and to submit a protocol for approval. As it was envisaged there would only be one ETS approved protocol for each source type, potentially with alternative methodologies, participants were encouraged to work together to produce a protocol where they had similar or identical sources. Draft additional protocols had to comply with the principles set out in the Reporting Guidelines and contain an estimate of the inherent uncertainty. DEFRA has now approved a number of these additional protocols for use in the scheme, and they are appended in Annex C.

## Use of this Document

- 1.4 Participants shall use these Reporting Guidelines and associated approved protocols to determine their emissions, as required by Parts 2 and 3 of Schedule 2 to the legal rules of the scheme<sup>3</sup>. The document now includes methodologies for calculating/estimating CO<sub>2</sub> emissions from fuel-related sources (Annex A) and from industrial processes (termed ‘process emissions’) (Annex B) as well as a number of other protocols covering CO<sub>2</sub> and non CO<sub>2</sub> gases which have

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<sup>1</sup> Emissions, as defined in the framework document are the greenhouse gases covered by the Kyoto Protocol: carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF<sub>6</sub>).

<sup>2</sup> ‘Framework for the UK Emissions Trading Scheme’ (DEFRA: August 2001)

<sup>3</sup> ‘The UK Greenhouse Gas Emissions Trading Scheme 2002’ ETS(01)06.rev1 (DEFRA: March 2002)

also been approved by DEFRA for use in the scheme (Annex C). The protocols included are intended to be consistent with the international reporting guidelines and good practices issued by the Intergovernmental Panel on Climate Change (the IPCC)<sup>4</sup>, as adopted in UK inventory reporting. They are also, therefore, consistent with UK Environmental Reporting guidelines.<sup>5</sup>

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<sup>4</sup> 'Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories', IPCC National Greenhouse Gas Inventories Programme 2000, available at <http://www.ipcc-ngip.iges.or.jp/public/gp/gpgaum.htm>

<sup>5</sup> 'Environmental Reporting - guidelines for company reporting on greenhouse gas emissions'. (DETR – Revised March 2001), available at [www.environment.defra.gov.uk/envrp/index.htm](http://www.environment.defra.gov.uk/envrp/index.htm).

## SECTION 2: KEY PRINCIPLES

2.1 This section sets out key principles underpinning the Reporting Guidelines. Direct Participants shall follow these when measuring and reporting Baseline and annual emissions. Therefore, verifiers will check that Direct Participants have measured and reported emissions against these principles when carrying out verification.

Faithful Representation	<ul style="list-style-type: none"> <li>Information shall represent faithfully the transactions and other events it either purports to represent or could reasonably be expected to represent.</li> <li>Uncertainties shall be quantified and data shall neither be systematically overestimated nor underestimated so far as can be judged.</li> <li>Uncertainties shall be reduced so as to be immaterial.</li> </ul>
Completeness	<ul style="list-style-type: none"> <li>Complete within the bounds of materiality<sup>6</sup> and the rules of the Scheme, such that information shall not be misleading or unreliable in terms of its relevance.</li> <li>All sources above the Size Threshold within the defined and chosen Source List shall be included in the Baseline and annual emissions.<sup>7</sup></li> <li>Leakage effects shall be accounted for.</li> </ul>
Consistency	<ul style="list-style-type: none"> <li>Consistent methodologies and measurements shall be used between the Baseline and subsequent years.</li> <li>Data shall be comparable over time.</li> <li>Estimates shall be comparable with the UK inventory estimates and with international guidelines including IPCC guidance.</li> </ul>
Reliability	<ul style="list-style-type: none"> <li>Baseline and annual emissions and related disclosures shall be free from material misstatement and bias and capable of being depended upon by users to represent faithfully that which it either purports to represent or could reasonably be expected to represent.</li> <li>Changes in methodologies shall derive from continuous improvement of data quality and shall be clearly stated and documented to allow for year-to-year comparisons.</li> </ul>
Transparency	<ul style="list-style-type: none"> <li>Reported data shall be replicable by a third party through provision of sufficient information and a clear audit trail.</li> <li>References and methodologies shall be clearly documented.</li> <li>Changes over time shall be clearly documented to allow clear understanding.</li> <li>Third party verification by an accredited verifier shall be undertaken.</li> </ul>

<sup>6</sup> Materiality in the context of the Scheme is explained in sections 4.12-4.17 of the framework document. Management control is explained in Annex A, sections A.2 to A.6 of the framework document.

<sup>7</sup> Section 2.17 of the framework document sets out the eight steps to be carried out for determining the Source List and Baseline.

- 2.2 The principles draw on existing statements of key principles in other GHG reporting guidelines and the qualitative characteristics of financial statements within international accounting standards<sup>8</sup>. These existing principles and characteristics have been applied to the context of the UK Scheme.

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<sup>8</sup> The principles included in the Reporting Guidelines have been derived from a review of good practice in recent GHG reporting initiatives. Reference has been made to International Accounting Standards; the IPCC 2000 Good Practice Guidance (and in particular the Glossary in Annex 3); ‘Environmental Reporting - guidelines for company reporting on greenhouse gas emissions’ (DETR – revised March 2001); the UNEP/Imperial College/NPI work on creating a standard for a Corporate CO<sub>2</sub> indicator; the Greenhouse Gas protocol Initiative, an international partnership of businesses, NGOs, and governments co-convened by the World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI); OECD/IEA work on methodologies for emission baselines; ‘Operational Guidelines for Baseline Studies, Validation, Monitoring and Verification of Joint Implementation Projects’ (Ministry of Economic Affairs of the Netherlands).

## SECTION 3: CONTEXT AND LINKS

3.1 These Reporting Guidelines have interfaces with several other reporting initiatives and mechanisms, at the entity, national and international level as shown in Figure 3.1 below. Each of these reporting mechanisms has different aims, and is therefore structured in a different way. The Reporting Guidelines have been designed to fulfil certain requirements at the national and international level, whilst drawing on best practice at the entity level. This section should help identify some of the differences in approach between the Scheme requirements and other reporting initiatives with which a Direct Participant may be involved.

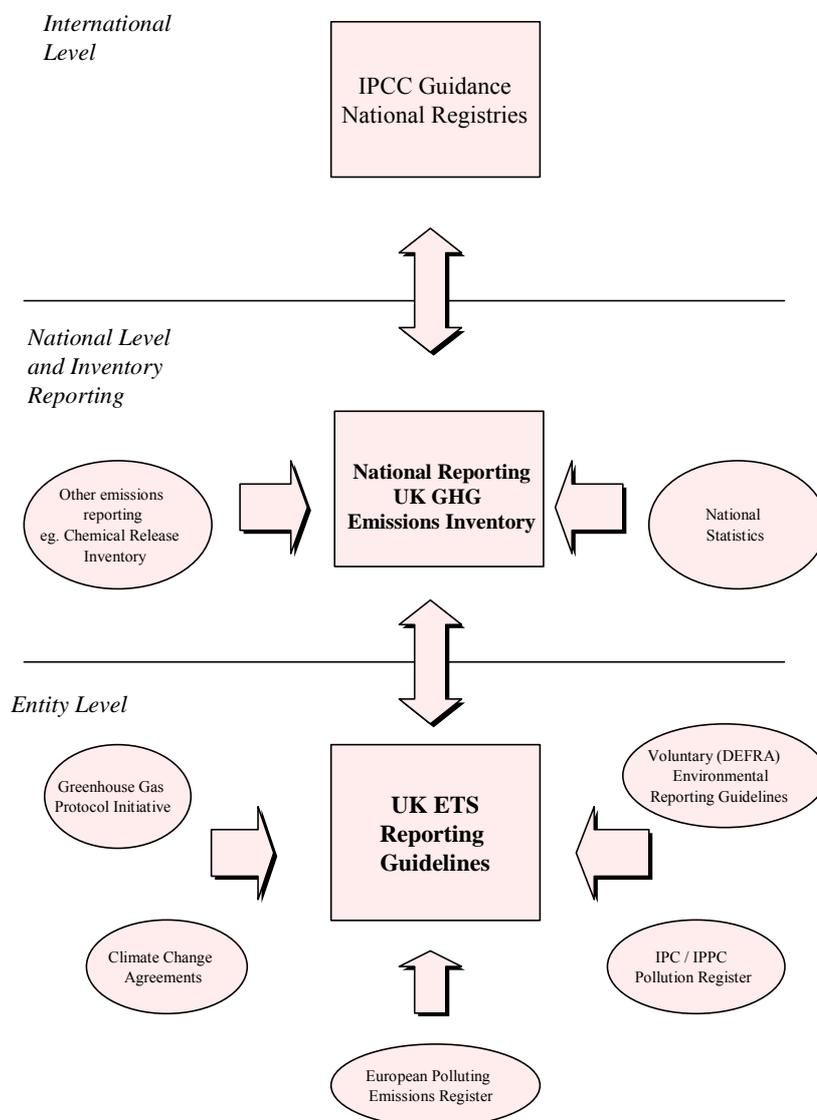


Figure 3.1. Entity, National and International Linkages

## National and international emissions inventories

- 3.2 For consistency with UK inventory reporting, the EU GHG monitoring mechanism<sup>9</sup>, and future international trading schemes, reporting should be consistent with IPCC guidelines and good practices. Data that Direct Participants use for emissions trading purposes shall also be consistent with any existing reporting requirements to the UK Pollution Inventory, or to the UK GHG Inventory. IPCC guidelines are designed for use at the national level, but the recommended methodologies for data collection, calculation of greenhouse gas emissions, reporting conventions, plus both data quality control/assurance and treatment of uncertainties in the data are also relevant for emissions trading.
- 3.3 The IPCC guidelines do not set any rules specific to entity level reporting. The main purpose of these Reporting Guidelines is therefore to harmonise entity level reporting, and ensure it is consistent with international reporting procedures and consistent with national reporting procedures.<sup>10</sup>
- 3.4 Absolute targets for Direct Participants will be measured in tonnes of carbon dioxide equivalent (tCO<sub>2</sub>e). Decision 2/CP.3 of the Kyoto Protocol specifies that the conversion rates for the five non-CO<sub>2</sub> gases into carbon dioxide equivalent – known as their global warming potential (GWP) – are those given by the IPCC in its Second Assessment Report<sup>11</sup>. To maintain consistency with Kyoto Protocol, these factors will be used in the Emissions Trading Scheme and are given in the table below.

Species	Chemical Formula	Global Warming Potential (100 year time horizon)
Carbon dioxide	CO <sub>2</sub>	1
Methane	CH <sub>4</sub>	21
Nitrous oxide	N <sub>2</sub> O	310
HFC-23	CHF <sub>3</sub>	11,700
HFC-32	CH <sub>2</sub> F <sub>2</sub>	650
HFC-41	CH <sub>3</sub> F	150
HFC-43-10mee	C <sub>5</sub> H <sub>2</sub> F <sub>10</sub>	1,300
HFC-125	C <sub>2</sub> HF <sub>5</sub>	2,800
HFC-134	C <sub>2</sub> H <sub>2</sub> F <sub>4</sub>	1,000
HFC-134a	CH <sub>2</sub> FCF <sub>3</sub>	1,300
HFC-152a	C <sub>2</sub> H <sub>4</sub> F <sub>2</sub>	140
HFC-143	C <sub>2</sub> H <sub>3</sub> F <sub>3</sub>	300
HFC-143a	C <sub>2</sub> H <sub>3</sub> F <sub>3</sub>	3,800
HFC-227ea	C <sub>3</sub> HF <sub>7</sub>	2,900

<sup>9</sup> Council Decision 1999/296/EC for a monitoring mechanism of Community Greenhouse Gas Emissions.

<sup>10</sup> Details of the UK national inventory procedures from which CO<sub>2</sub> emission factors for fuel use and process emissions have been defined are derived from the UK GHG inventory, 1990 to 1997 (NETCEN report). For fuel-based emissions, fuel subcategories are included within five principal areas, namely liquid, solid, gas, other fuels, and biomass. These have been adapted as a workable subset for use in the fuel emissions reporting part of the Reporting Guidelines and are consistent with the recently revised environmental reporting guidelines for company reporting on greenhouse gas emissions. For the expression of emission factors, the gross calorific value convention has been adopted in order to ensure consistency with the national protocol and negotiated agreement reporting under the Climate Change Levy. For process CO<sub>2</sub> emissions, emissions factors are defined on the basis of levels of activity, and include the following processes: cement manufacture; lime production; limestone and dolomite use, soda ash production and use, ammonia production, metal production, waste incineration – Municipal Solid Waste and sewage. The UK inventory in some cases uses IPCC default values and in other cases specific factors attributed to the UK processes. The Reporting Guidelines adopts UK specific factors covering all of the above sources, consistent with international reporting procedures.

<sup>11</sup> Climate Change 1995. The Science of Climate Change. Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change, available at [www.ipcc.ch](http://www.ipcc.ch).

HFC-236fa	C <sub>3</sub> H <sub>2</sub> F <sub>6</sub>	6,300
HFC-245ca	C <sub>3</sub> H <sub>3</sub> F <sub>5</sub>	560
Chloroform	CHCl <sub>3</sub>	4
Methylene chloride	CH <sub>2</sub> Cl <sub>2</sub>	9
Perfluoromethane	CF <sub>4</sub>	6,500
Perfluoroethane	C <sub>2</sub> F <sub>6</sub>	9,200
Perfluoropropane	C <sub>3</sub> F <sub>8</sub>	7,000
Perfluorobutane	C <sub>4</sub> F <sub>10</sub>	7,000
Perfluoropentane	C <sub>5</sub> F <sub>12</sub>	7,500
Perfluorohexane	C <sub>6</sub> F <sub>14</sub>	7,400
Perfluorocyclobutane	c-C <sub>4</sub> F <sub>8</sub>	8,700
Sulphur hexafluoride	SF <sub>6</sub>	23,900

## Environmental Reporting Guidelines

- 3.5 The existing DEFRA Environmental Reporting Guidelines for company reporting on greenhouse gas emissions provide an entity-level GHG reporting approach consistent with UK national reporting as described above. As these guidelines are already established and are used by many entities for environmental reporting purposes, the same methodology has been used in the Reporting Guidelines for the estimation/calculation of energy-related CO<sub>2</sub> emissions. The approach used in the Scheme is different, however. As described in the framework document, the Scheme has to be more prescriptive than the Environmental Reporting Guidelines on issues such as eligibility, scope, inclusion of sources, boundaries, and double counting.

## Climate Change Agreements (‘Agreements’)

- 3.6 The framework document set out the principles of entry to the Scheme for Agreement Participants (<http://defraweb/environment/climatechange/trading/index.htm>). In order to either sell allowances or to use allowances purchased via the UK Emissions Trading Registry to meet their targets, Agreement Participants must be able to convert targets to a common unit – i.e. tonnes of CO<sub>2</sub> equivalent. Guidelines for carrying out this conversion are given in Climate Change Levy technical guidance notes NA(99)30 and NA(00)07. For Agreement Participants with energy efficiency targets, this conversion will need to take account of both the average emission factor, and the annual production level.

- 3.7 According to NA(00)07, the minimum reporting requirements for the Agreements are:

- Energy use by fuel (including fuel ascribed to bought-in heat or electricity from CHP or other dedicated plant and excluding fuel ascribed to heat or electricity exports)
- Volume of allowances bought or sold in the Scheme
- Qualitative performance measures (where these form part of the agreed target)
- Measure of output (for sectors with efficiency targets)

- 3.8 The framework document states that an Agreement Participant wishing to sell allowances (stemming from over-achievement of a target) through the Scheme must have its energy use or emissions data verified by an accredited verifier, and where relevant, also have its output and product mix data verified by an accredited verifier. Verifiers will need to be satisfied that the data has been compiled in accordance with the key principles set out in section 2 of the Reporting Guidelines. This may require access to supporting evidence in addition to the

minimum reporting requirements shown above, and evidence of a systematic approach to data management.

- 3.9 Agreements contain targets for facilities as defined under IPPC rather than whole sites or whole companies. Agreement Participants may enter those sources that are not covered by an existing target unit via the direct entry route. In cases where such sources are located on the same site as the target unit, a clear definition of the boundary shall be needed. In such cases, the recommendation made in guidance to the Agreements (reproduced in the box below) might be particularly useful.

**Reproduced from guidance on the Agreements (draft CCA(01)03)**

*It is recommended that facility or site maps or other equivalent information should be available for inspection, and should indicate:*

- *the boundary of the energy intensive installation(s) in relation to the boundary of the facility, for all facilities;*
- *for facilities that do not occupy an entire site, the boundaries of the site and the energy intensive facility within it;*
- *location of incoming energy supplies and location of utilities meters;*
- *in-situ generated sources of energy;*
- *location of meters recording exports;*
- *location of sub-meters within the facility.*

*The map should be updated if changes in energy facilities or metering are made, or if boundaries of the energy intensive installation and/or facility change.*

- 3.10 In the Agreements, energy figures will be reported in terms of primary energy units<sup>12</sup>, with a standard set of conversion factors given in NA(00)07 to convert to delivered energy. Emission factors are as far as possible identical between the Scheme and the Agreements. There are two exceptions; LPG (where a figure of 0.21 kgCO<sub>2</sub>/kWh is used in the Reporting Guidelines rather than 0.23 kgCO<sub>2</sub>/kWh) and coke (where a figure of 0.37 kgCO<sub>2</sub>/kWh is used in the Reporting Guidelines rather than 0.43 kgCO<sub>2</sub>/kWh). The figures used in the Reporting Guidelines are based on the latest figures from the national inventory.

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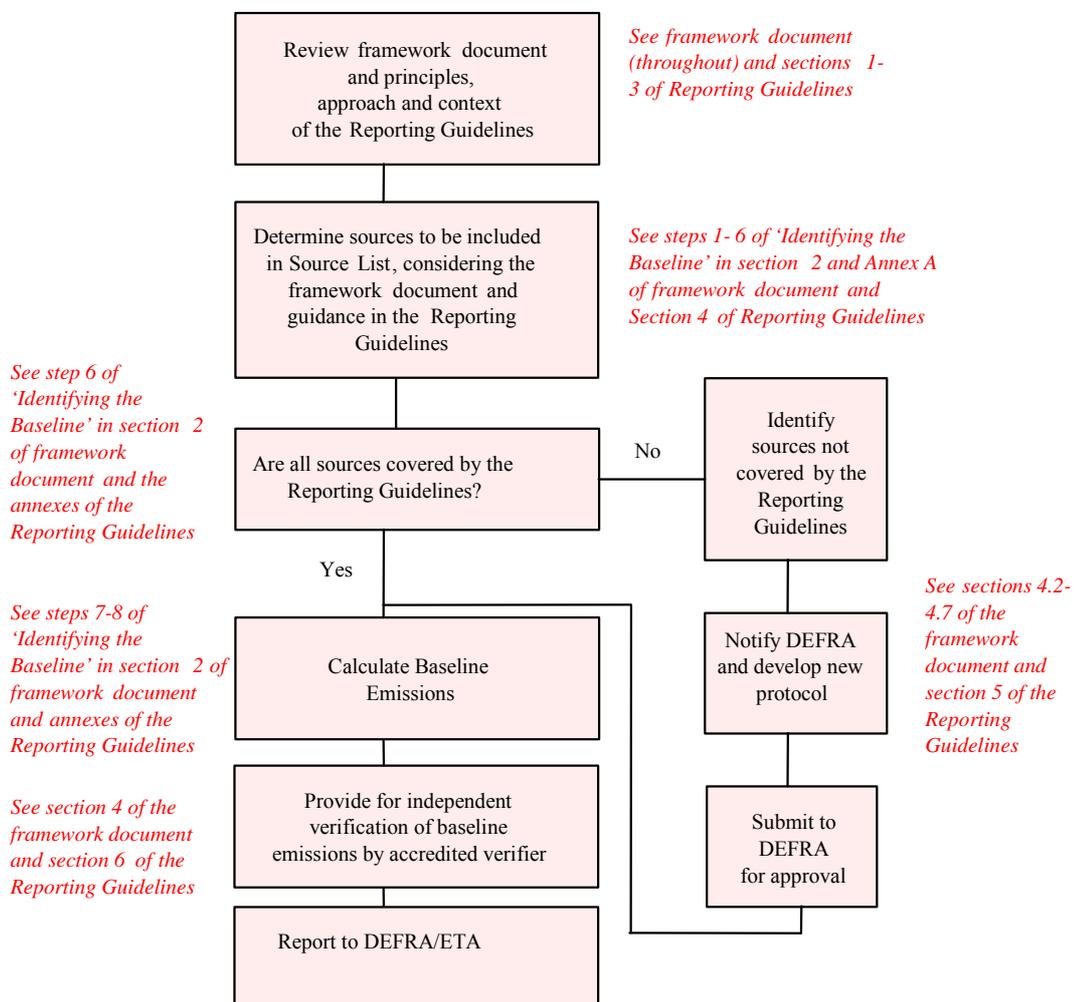
<sup>12</sup> On the issue of units, where an agreement is set in terms of an energy or energy efficiency target, the reported quantity is primary energy (i.e. losses associated with delivery of the energy are associated with the end-user). In practice, only electricity has a non-unit conversion factor for primary energy in the Agreements. From a verification point of view, since delivered energy is the measured quantity, this is reported separately. Since delivered energy is measured (and necessary for deriving primary energy anyway) this should not impose significant additional burden to the Participant.

# SECTION 4: COMPILING THE BASELINE

## Overview of steps for identifying the baseline

4.1 This section provides additional practical guidance, expanding on the steps described in the framework document for identifying the Baseline. Figure 4.1 below provides an overview of the process mapped out in the framework document.

**Figure 4.1. Overview of the steps to defining and identifying the baseline**



4.2 The process to define and identify the Baseline for Direct Participants is laid out in section 2.17 of the framework document, and is reproduced in the box below. Some aspects of this process are then discussed in more detail in the following sections.

### **Identifying the Source List and calculating Baseline emissions**

(the following text is extracted from the framework document section 2.17)

A Baseline is made up of emissions from individual sources. Therefore, a Direct Participant must identify the sources it is bringing into the Scheme (its Source List) before it can calculate Baseline emissions. There are six steps to identifying the Source List, and a further two steps to calculating the Baseline. Direct Participants should keep a written record of the decisions taken at each step.

#### Management control

1. Identify all sources over which it has management control.

#### Sources within a sector

2. Separate the sources in step one into their different industrial sectors. Decide which sectors will be brought into the Scheme, and which sectors will remain out of the Scheme.

#### Emissions data

3. Identify the subset of the sources in step two that have verifiable emissions data for the Baseline period.

#### Eligibility for entry

4. Identify the subset of the sources in step three that are eligible for entry into the Scheme (see section 2.4 of the framework document).

#### Coverage of greenhouse gases

5. Identify EITHER the subset of the sources in step four which emit carbon dioxide OR make no further changes to the sources in step four, thereby entering all greenhouse gas sources.

#### Coverage within the reporting guidelines

6. Identify the subset of the sources in step five that are covered by the draft protocols appended to the Reporting Guidelines. EITHER decide to exclude some/all the sources not covered by the draft protocols OR make no further changes to the sources in step five, thereby deciding to include these sources. **After taking steps one to six, the Direct Participant will have completed its Source List.**

#### Calculating the Baseline

7. The final two steps result in calculation of the Baseline. Estimate average annual emissions over the Baseline period from the sources in the Source List. Identify those Sources whose average emissions over the Baseline period are individually less than the Size Threshold: 10,000 tonnes of CO<sub>2</sub> equivalent (tCO<sub>2</sub>e) *or* 1 per cent of the Source List total (whichever is less).

For each of these sources EITHER decide to exclude them from the Baseline OR decide to include them in the Baseline. If any sources included in the Baseline are not covered by the draft protocols appended to the Reporting Guidelines, the Direct Participant must notify the Government and make preparations for developing an additional protocol to append to the Reporting Guidelines.

8. After taking steps one to seven, and calculating the emissions from the remaining individual sources using approved protocols, the Direct Participant will have completed its Baseline. This will be an emissions figure denominated in tonnes of CO<sub>2</sub> equivalent (tCO<sub>2</sub>e).

## Issues in Baseline Definition

- 4.3 Guidance is provided below which will help Direct Participants to understand some of the issues which have guided the development of the Scheme rules. The key principles listed in section 2 of the Reporting Guidelines are also relevant when considering the issues below.

- **Double Counting.** It is not acceptable for more than one Direct Participant to claim responsibility for a single emissions source. This is of primary importance for Direct Participants when determining the sources over which they have management control.
- **Verifiability.** The Baseline and any claimed emission reduction from a source shall be supported by data of sufficient quality. Consideration of the key principles underpinning the Reporting Guidelines should help guide Participants towards obtaining data of sufficient quality to satisfy an independent accredited verifier. Information which is, as far as possible, complete, consistent, transparent and reliable, and which is a faithful representation of transactions or events will help provide assurance that the GHG emissions and GHG savings claimed are ‘real’. The information relating to Baselines and annual emissions, which Participants are required to report, is listed in section 4 of the framework document.
- **‘Cherry Picking’.** Participants shall not be allowed to include only those elements of their operations which they consider would provide the easiest scope for emissions reductions. There is an obligation to present the complete picture of emissions in order to prevent organisations from claiming emissions reductions in one area of their operations while simultaneously increasing emissions from other areas.
- **National boundary.** Since the Scheme is to contribute to UK emissions reduction (and hence to the UK’s target under the Kyoto Protocol), the scope for reporting emissions under the Scheme will not extend beyond the scope of the UK inventory<sup>13</sup>. Multinational corporations wishing to compile emissions inventories for their whole organisation may use the methodology described in this document, but for the purposes of the UK Scheme, the emissions associated with UK-based operations must be separately identifiable.
- **Leakage.** Having defined the Source List for reporting emissions, it is important to ensure that Participants cannot simply claim emissions reductions by shifting the responsibility outside their Source List. One example of this would be to outsource a product or service which transfers accountability of the associated GHG emissions to another organisation. Such changes need to be accounted for, and are dealt with in section 2 and Annex B of the framework document.

## Scope of emissions to be included

4.4 The framework document outlines the eligibility criteria for emissions to be included within the Scheme. For most Direct Participants using commercial fuel supplies, emission sources will include the following:

- On-site combustion of fossil fuels for on-site use
- On-site consumption of electricity that is generated off-site
- On-site consumption of electricity generated on-site
- On-site consumption of heat or steam generated off-site
- On-site consumption of heat or steam generated on-site.

4.5 Any heat or electricity exported from a site will not be counted in a Direct Participant’s sources - provision needs to be made to subtract the corresponding emissions according to the method described in Annex A2 of these Reporting Guidelines.

In general, on-site generation of heat or electricity will be accounted for by calculating emissions associated with the fuel inputs to the generating equipment.

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<sup>13</sup> Under the 1996 IPCC Guidelines, this includes emissions within the UK national boundary, domestic aviation and shipping, and emissions from surface transport fuel sold within the UK. But it excludes emissions from international aviation and shipping and CO<sub>2</sub> from biomass energy.

The only type of indirect emissions in the Scheme will be those associated with energy usage – other types of indirect emission will not be included.

## Definition of a Source

### **Definition of a ‘source’<sup>14</sup>**

- a ‘point source’ means any separately identifiable point from which greenhouse gases are emitted
- a ‘source’ means a point source or a collection of point sources of the same type on the same site
- a ‘site’ means (i) a building or other substantial structure; or (ii) a stationary technical unit (subject to certain restrictions)

- 4.6 Sources do not have to be defined down to the level of an individual meter for example, but can be aggregated to a level which makes sense in the context of the business activities of the Direct Participant. For example, sources could be defined in such a way as to represent whole elements of a manufacturing process, or a whole building etc. even if the process/building were sub-metered.
- 4.7 Participants shall be reporting emission reductions at the source level. The definition used for a source will therefore have a strong bearing on what companies will be able to count as a valid emission reduction. Part of the approval process the Direct Participant will have to undertake with DEFRA during the pre-registration period will be to agree the Source List used to make up the Baseline.
- 4.8 In aggregating point sources, Participants shall bear in mind the principle of transparency and the requirement for verification. Companies shall be able to measure emission reductions from a source, and shall be able to account for such a reduction to a verifier.
- 4.9 Participants shall also bear in mind the need for completeness in their information, and the general issue of ‘leakage’. Changes in the management control of a source - such as through closure or outsourcing - will all require adjustments to the Baseline. Sources shall therefore be defined in a way that allows such changes in business structure to be accounted for.
- 4.10 For clarity, process-based emissions and energy-related emissions shall not be combined within a single source.

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<sup>14</sup> Legal Rules for the UK Emissions trading Scheme, Schedule 2. DEFRA, March 2002.

## Calculation of the Baseline

### Definition of the Baseline

(reproduced from the framework document section 2.16)

‘The Baseline for Direct Participants will be **average annual emissions in the three years up to and including 2000**. In other words, the Baseline for each Direct Participant will be calculated on the basis of historic emission levels. Where Direct Participants can satisfy accredited verifiers that information on individual sources is not available to produce verifiable emissions data for all three years, they can instead submit emissions data for 1999-2000, or just for 2000.’

### Emission sources subject to a regulatory requirement

‘The baseline emissions from a source subject to a regulatory requirement will be calculated as for all direct participants....., *unless* the emissions in any of these years were above those which would have resulted from compliance with the relevant regulatory requirement.

Where emissions reductions necessary to comply with the regulatory requirement would have resulted in lower emissions than measured emissions in any of the baseline years, the emission level implied by those regulatory requirements will be substituted for the measured emissions in the relevant year(s). The baseline will then be calculated in the normal way apart from this substitution.’<sup>15</sup>

- 4.11 A justification for using either 1999-2000 data or just 2000 data can be made on a source-by-source basis. This allows, for example, the addition of sources to the Baseline where information was only gathered for 1999-2000 or 2000. The Baseline is the sum of the average emissions from each source. These averages could be calculated using a different Baseline period for different sources.
- 4.12 Where a Direct Participant has divested management control over a source during the period 1998-2000, and will not gain management control again before April 2002, then this source shall not be included in the Source List.
- 4.13 Annex B of the framework document outlines the procedures for adjusting Source Lists, and Baselines. The same approaches should be used in accounting for any changes during the Baseline period for that source. For example, divestment of a source during the Baseline period would mean that the source is excluded from the Source List, unless the divested source was replaced by a new substitute source. In this case, the average emissions for the Baseline period should be calculated as the average of both the original and the substitute sources over the full Baseline period.

## Regulatory Requirements

- 4.14 An adjusted approach is used for calculating baselines for Direct Participants with regulatory requirements. This is to ensure that the Emissions Trading Scheme delivers environmental benefits greater than those which would have resulted from the fulfilment of the regulatory requirement. Since the strictness of a direct participants’ emissions limitation commitment is determined by reference to their baseline, it is necessary to depart from the general approach to baseline calculation. Where emissions reductions necessary to comply with the regulatory requirement would have resulted in lower emissions than measured emissions in any of the baseline years, the emission level implied by those regulatory requirements will be substituted for the measured emissions in the relevant year(s). The baseline is then calculated in the normal

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<sup>15</sup> Treatment of regulatory requirements in the UK Emissions Trading Scheme. DEFRA, April 2002.

way apart from this substitution. See also separate guidance note ETS(02)08 for additional explanation<sup>16</sup>.

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<sup>16</sup> Treatment of regulatory requirements in the UK Emissions Trading Scheme. DEFRA, April 2002.

## SECTION 5: TREATMENT OF UNCERTAINTY

- 5.1 There is a degree of uncertainty inherent in the use of any protocol used to measure and report greenhouse gas emissions. Such uncertainty could lead to errors of over-reporting or under-reporting of baseline and annual emissions, and potentially undesirable increases in actual emissions above target levels. The draft protocols appended to the first release of these Reporting Guidelines (those in Annexes A and B) were designed to be consistent with IPCC Good Practice guidance on uncertainty management.

.12 'Materiality' is an expression of the relative significance or importance of any individual matter in the context of a Direct Participant's total Baseline or annual emissions figure. A matter is material if its misstatement in the Direct Participant's total emissions figure and related disclosures would reasonably influence any decision or action taken by the Government or any economic decision or economic action taken by any other user of that Direct Participant's verification statement.

.13 A verifier's assessment of materiality will include consideration of both the amount and nature of misstatements. For example, a relatively small omission or error repeated frequently could, once accumulated, have a material impact on the total emissions figure. A verifier will assess the materiality both of any individual misstatement *and* of the aggregate of uncorrected misstatements.

.14 Therefore, verifiers will take into account any omission or error that could lead to material misstatement in total Baseline or annual figures. A source of such misstatement could be, for example, a poor reporting system (i.e. not following the reporting protocol accurately, recording data unsystematically, and using spreadsheets containing errors) that produces non-transparent, biased or inconsistent figures.

.15 As a broad guide, a verifier will tend to class a misstatement in the total emissions figure as being material if it leads to aggregate uncertainty in the total emissions figure being greater than 5 per cent. If aggregate uncertainty is thought to be material, the verifier will not be able to sign off the Direct Participant's verification statement. In this situation, the Direct Participant should adjust its emissions data until the verifier judges any misstatement to be immaterial. If the Direct Participant does not adjust its emissions data, it will not have verified emissions data, and will therefore not be in compliance with the rules of the Scheme.

.16 Verifiers will *not* take into account any uncertainty inherent in accurately following the protocols appended to the Reporting Guidelines.

- 5.2 To enable it to determine whether the inherent uncertainty in ETS protocols would significantly compromise the environmental integrity of the scheme, the Government commissioned a study

to assess the inherent uncertainty in the protocols in Annexes A and B<sup>17</sup>. Also, Direct Participants submitting a draft additional protocol for approval to DEFRA were required to provide an estimate of the inherent uncertainty in the protocol. The uncertainties in these protocols were found to be of a similar order to, and not significantly greater than, the uncertainties associated with the protocols in Annexes A and B.

- 5.3 The Government considers that the inherent uncertainties in the approved ETS protocols have been minimised and are acceptable within context of a voluntary participation scheme aimed at learning by doing, such as the UK Emissions Trading Scheme. Participants and their verifiers are not, therefore, required to make any adjustments to account for inherent uncertainty in ETS approved protocols in reported baseline and annual emissions. This also keeps the system simple and transparent. However, if further protocols are subsequently developed for use within the Emissions Trading Scheme which have significantly greater uncertainties, then an adjustment methodology may be considered (see ICF report<sup>18</sup>).

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<sup>17</sup> Estimating Statistical Uncertainties in the Greenhouse Gas Emissions Measurement and Reporting Protocols for the UK Trading Scheme. Final Report, ICF Consulting, February 2002.

<sup>18</sup> Estimating Statistical Uncertainties in the Greenhouse Gas Emissions Measurement and Reporting Protocols for the UK Trading Scheme. Final Report, ICF Consulting, February 2002.

## SECTION 6: REPORTING REQUIREMENTS

- 6.1 The information that must be reported on an annual basis, in accordance with the Scheme rules, is set out in the framework document. As stated in the framework document, this information will be subject to independent verification, provided in the Scheme by accredited verifiers. The information is the responsibility of management, and the reporting requirements include the stipulation that management or a designated representative declare that the information reported is a faithful representation of the Participant's emissions.
- 6.2 In preparing the required information and in providing such information to verifiers, Participants shall take account of the principles in section 2 of the Reporting Guidelines. They shall also be required to have an effective data management system, so that adherence to the principles in section 2 is easily demonstrable. Having a recognised environmental management system, such as those accredited under ISO 14001 or the EU Eco-Management and Audit Scheme (EMAS), may therefore ease the process of verification.
- 6.3 For organisations which do not have formally recognised management systems, the elements of a system which will demonstrate adherence to the principles in section 2, and facilitate the verification process include:
- Clearly defined responsibilities for issues such as data collection, collation, aggregation, and quality control
  - The existence of appropriate tools or procedures to support consistency in data estimation and collation within an organisation
  - Methods for systematic data archiving and process documentation
  - Processes for internal audit, data checking, and quality assurance.
  - Processes for taking corrective and preventative actions.
  - Clearly articulated methods of data interpretation.
  - Processes for periodic review of the data management system itself.
- 6.4 The tables below set out example templates for recording and calculating Baseline and annual emissions. These are provided for illustration only.

### Example Template for Calculating Baseline Emissions

<b>A</b>	<b>B</b>	<b>C</b>	<b>D (Baseline)</b>
Source List	Baseline period used	Average annual emissions over Baseline period	Average annual emissions over Baseline period (all sources in the Source List, or at a minimum those meeting the Size Threshold)
Source 1	98-00	---	---
Source 2	99-00	---	---
Source 3	00	---	---
Source 4	99-00	---	---
etc	etc	etc	etc
<b>TOTAL</b>		Source List Total	Baseline

### Example Template for Calculating Annual Emissions (Year X)

<b>A-D</b>	<b>E</b>	<b>H</b>
Recalculate figures in columns A-D above highlighting any changes since previous year	Annual emissions for year X	Annual emissions for year X (all sources in the Source List, or at a minimum those meeting the Size Threshold)
Source 1	---	---
Source 2	---	---
Source 3	---	---
Source 4	---	---
etc	etc	etc
<b>TOTAL</b>	Source List Total	Annual Emission Total

6.5 In order to track adjustments to Baselines, Source Lists and targets in accordance with the rules laid out in Annex B of the framework document, Direct Participants shall also record the following:

- Identify any changes in management control to individual sources within the Source List that are above the Change Threshold as defined in the framework document
- Identify whether the cumulative effect of changing management control of sources within the Source List meets or exceeds the Change Threshold as defined in the framework document
- Provide evidence showing whether sources within the Source List have been divested to another Direct Participant or divested in any other way (including closure)
- Provide evidence of any contractual arrangements for maintaining a source in the Baseline in the case of divestment or acquisition from another Direct Participant
- If substitute sources are added to the Source List, evidence shall be provided showing details of this substitution.

# ANNEX A: PROTOCOLS FOR ENERGY-RELATED CO<sub>2</sub> EMISSIONS

## Introduction

This Annex provides guidance on best practice methodology for the calculation of CO<sub>2</sub> emissions from fuel use and on-site generation of heat or electricity and indirect emissions from the use of imported energy.

Imports of heat, steam and electricity from third parties are eligible for inclusion under the scheme., whereas exports of heat, steam and electricity are not eligible. Protocol A2 outlines how to calculate the emissions associated with such imports/exports. These emissions can then be added/subtracted from the Source List as appropriate.

The protocols cover:

- Emissions for energy related CO<sub>2</sub>
- Import or export of heat and power
- Renewable energy

## Protocol A1: Calculating emissions for energy related CO<sub>2</sub>

The energy consumed by each source will be recorded, broken down by fuel type. The methodology for calculating CO<sub>2</sub> emissions from each fuel type is as follows:

$\text{CO}_2 \text{ Emissions from each fuel (tonnes)} = \text{Energy consumption of fuel (kWh)}$ $\quad \times \text{Emission factor for each fuel (kgCO}_2\text{/kWh)}$ $\quad \times 0.001$
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The emission factors for different fuels are shown in Table A1 below<sup>19</sup>.

Energy / Fuel	<i>Emission Factor (kgCO<sub>2</sub>/kWh)</i>
Electricity*	0.43
Natural Gas	0.19
Gas/Diesel Oil	0.25
Petrol	0.24
Heavv Fuel Oil	0.26
Coal	0.30
Coking Coal	0.30
Coke	0.37
LPG	0.21
Jet Kerosene	0.24
Ethane	0.20
Naphtha	0.26
Waste Lubricants	0.25
Petroleum Coke	0.34
Refinery Gas	0.20
Other Oil Products	0.24
Renewables	0.00

**Table A1 CO<sub>2</sub> emission factors for energy-related emissions**

\*A common emission factor is used for all electricity supplied from public supply network (except for eligible renewable sources – see Annex A3). This emission factor does not vary from year to year.

Entities wishing to apply emission factors used in local reporting that differ to those given in Table A1 must make the case for this to DEFRA for approval. The case should include evidence that the emission factor is representative, free of bias and represents a material improvement on the accuracy and precision of values provided in Table A1.

Energy consumption may be measured in different units. Table A2 below gives standard conversion factors for converting between units.

1 tonne oil equivalent	=	11630 KWh
1 therm	=	29.31 KWh
1 Giga Joule	=	277.8 KWh

**Table A2 Standard Conversion Factors for Energy Units**

Where fuels are purchased or measured on a volumetric or weight basis, an average gross

<sup>19</sup> These factors are taken from the DEFRA environmental reporting guidelines for company reporting on greenhouse gas emissions. An additional entry is provided for coke, and the new factor for LPG is used derived from the latest national inventory figures.

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calorific value will be needed to convert to energy units. The gross calorific value specified by the fuel supplier should be used to carry out this conversion. If data on calorific value is not available, the default values in Table A3 may be used. Evidence of the factors used may be required by the verifiers, and records should therefore be kept.

	<b>BY WEIGHT</b>		<b>BY VOLUME</b>
<b>Solid Fuels</b>	<b>kWh per tonne</b>		
Coal (weighted average)	7583		
Coke	8277		
<b>Liquid Fuels</b>	<b>kWh per tonne</b>	<b>Litres per Tonne</b>	<b>KWh per Litre</b>
Crude Oil (weighted av)	12694	1190	10.7
Petroleum Products (weighted av)	12555		
Ethane	14083	2730	5.2
LPG	13722	1850	7.4
Aviation turbine fuel	12833	1248	10.3
Motor Spirit	13083	1361	9.6
Gas/Diesel oil	12666	1170	10.8
Fuel Oil	11999	1011	11.9
Lubricating Oils	12555	1133	11.1
Orimulsion	8250		
Naptha	13249		
<b>Gaseous Fuels</b>			<b>kWh per m3</b>
Natural Gas			11.0
COG			5.6
BFG			0.8
Landfill Gas			10.7
Sewage Gas			10.7
<b>Solid Renewables</b>	<b>kWh per tonne</b>		
Domestic wood	2778		
Industrial wood	3305		
Straw	4166		
Poultry Litter	2444		
General Industrial Waste	4444		
Hospital Waste	3889		
Municipal solid waste	2639		
Refuse derived waste	5194		
Tyres	8888		

**Table A3 Default Calorific Values<sup>20</sup>** – to be used when fuel specific values are not available (see text).

<sup>20</sup> Data from Digest of UK Energy Statistics 2000, DTI

## Protocol A2: Import or export of heat and power

The direct emissions associated with imports of heat, steam and electricity from third parties will count towards the total emissions of scheme participants. In a similar way, the emissions associated with exports of heat, steam and electricity will be subtracted from the direct emissions of scheme participants. The following methodology explains how to calculate the emissions associated with such imports/exports so that these emissions can be added/subtracted from the baseline and annual emissions total as appropriate. The appropriate amount of emissions to add or subtract should be calculated as follows:

$$\begin{aligned} \text{CO}_2 \text{ Emissions (tonnes)} &= \text{Units of Heat, Steam or Electricity (kWh)} \\ &\quad \times \text{Emission Factor for Imports/Exports (kgCO}_2\text{/kWh)} \\ &\quad \times 0.001 \end{aligned}$$

### Emission Factors for Imports/Exports other than those derived from Combined Heat and Power (CHP)

For steam, heat and electricity supplied by means other than the public supply network, it is necessary to obtain information on the fuels used for the generation. This information should be used to calculate a weighted average emission factor in kgCO<sub>2</sub>/kWh, taking into account the fraction of each type of fuel, and the appropriate emission factor for each fuel taken from Table A1. Information on the efficiency of generation is also required. The emission factor is then calculated using the formula:

$$\begin{aligned} \text{CO}_2 \text{ emission factor (kgCO}_2\text{/kWh)} \\ = & \frac{\text{Weighted average emission factor for fuel used in generation (kgCO}_2\text{/kWh)}}{\text{Efficiency of generation (\%)}} \end{aligned}$$

### Emission Factors for Imports/Exports derived from CHP

In the case of **CHP** which produces both heat and electricity simultaneously, the convention used in these Reporting Guidelines is that the efficiency of heat generation is twice that of electricity generation (this is the convention used in the DEFRA reporting guidelines<sup>21</sup> and the Climate Change Agreements<sup>22</sup>). The following formulae therefore need to be used to calculate the associated emissions:

CO<sub>2</sub> emissions factor (kgCO<sub>2</sub>/kWh) for **electricity**

$$= \frac{\text{Twice total emissions (in kgCO}_2\text{)}}{\text{Twice total electricity produced (in kWh) + total heat produced (in kWh)}}$$

CO<sub>2</sub> emissions factor (kgCO<sub>2</sub>/kWh) for **steam or heat**

$$= \frac{\text{Total emissions (in kgCO}_2\text{)}}{\text{Twice total electricity produced (in kWh) + total heat produced (in kWh)}}$$

If all the output from a CHP plant is used on site (i.e. there are no exports), emissions do not need to be assigned between heat and electricity – the emissions simply need to be recorded from the total

<sup>21</sup> DEFRA reporting guidelines can be found at [www.defra.gov.uk/environment/envrp/index.htm](http://www.defra.gov.uk/environment/envrp/index.htm)

<sup>22</sup> See document PP3.02 at [www.defra.gov.uk/environment/ccl/index.htm](http://www.defra.gov.uk/environment/ccl/index.htm)

fuel used in the plant as described in Annex A1.

Where there are exports of heat and/or electricity by a scheme participant, direct emissions from the CHP plant should be apportioned to users in proportion to the quantity of electricity or heat supplied. The emissions associated with any exports can be calculated using the emissions factors above and subtracted from the total emissions. All losses in generation and distribution between users must be included so that the total direct emissions from the CHP unit are attributable to the users supplied by the unit.

### **Re-Allocation of CO<sub>2</sub> Benefits of Export to Public Supply**

If some of the electricity from the CHP scheme is exported to the public supply (and not directly to a known user), this is treated as displacing grid electricity using a standard factor of 0.43 kgCO<sub>2</sub>/kWh. The CO<sub>2</sub> benefit of this export should be credited to the known users of heat from the CHP scheme (following the same convention as used in the Climate Change Agreements). Under such circumstances, the CO<sub>2</sub> associated with CHP heat use can be revised using the following steps:

1) CO<sub>2</sub> associated with CHP power export (kgCO<sub>2</sub>) =

$$\text{Electricity exported (in kWh)} \times \text{CO}_2 \text{ Emissions factor for electricity (kgCO}_2\text{/kWh)}$$

2) Total CO<sub>2</sub> savings associated with CHP power export (kgCO<sub>2</sub>) =

$$\text{Electricity exported (in kWh)} \times 0.43 - \text{CO}_2 \text{ from export (kgCO}_2\text{) (from step 1)}$$

3) CO<sub>2</sub> savings allocated to heat user A (kgCO<sub>2</sub>) =

$$\text{Total CO}_2 \text{ savings (kgCO}_2\text{) (from step 2)} \times \frac{\text{Units of heat used by user A (in kWh)}}{\text{Total heat produced (in kWh)}}$$

4) Revised CO<sub>2</sub> from heat use for user A (kgCO<sub>2</sub>) =

$$\text{Heat used by user A (in kWh)} \times \text{CO}_2 \text{ emissions factor for heat (kgCO}_2\text{/kWh)} \\ - \text{CO}_2 \text{ savings allocated to heat user A (kgCO}_2\text{) (from step 3)}$$

## Protocol A3: Renewable energy

Table A1 overleaf shows that eligible renewable energy has an emission factor of zero. There are three ways in which renewable energy may be incorporated into the Scheme:

1. Electricity or heat produced on site from a renewable energy source;
2. Electricity which is certified by the participant's supplier as being from eligible renewable energy sources and as being electricity which the supplier is not relying upon for the purpose of fulfilling any obligation imposed upon it by any enactment in relation to the generation of such electricity.
3. By purchasing Renewable Obligation Certificates independently of the power that gave rise to their issue.

### 1. Which renewable technologies are eligible?

For the purposes of bullet (1) above, renewable energy sources are defined in accordance with the Climate Change Levy (General) Regulations 2001<sup>23</sup> as "sources of energy other than fossil fuel or nuclear fuel and includes waste provided that it is not waste with an energy content 90 per cent. or more of which is derived from fossil fuel."

For the purpose of bullet (2) above, "eligible renewable energy supplies" includes renewable energy sources either eligible for the Renewables Obligation (RO)<sup>24</sup> and/or exempt from the Climate Change Levy (CCL)<sup>25</sup>. This means that all RO eligible and CCL exempt electricity will be eligible for use in the ETS, subject to the conditions outlined below. Based on these definitions, the renewable source technologies eligible in the emissions trading scheme at the time of printing are:

- wind energy;
- hydro power, up to 20MW output;
- tidal power;
- wave energy;
- photovoltaics;
- photoconversion;
- geothermal hot dry rock;
- geothermal aquifers;
- municipal and industrial wastes;
- landfill gas;
- agriculture and forestry wastes;
- sewage gas; and
- biomass, including energy crops.

The Secretary of State reserves the right to revise the list of eligible renewable technologies, in line with any revisions made to eligibility under the CCL and the RO.

### 2. Accounting for the use of renewables

#### On-site renewables

Where energy is generated from on-site renewables, there is no need for associated emissions, if any, to be counted as part of a participant's total emissions. Where such generation involves combustion (biomass or waste fuelled plant, for example) participants should supply documentary evidence to

<sup>23</sup> Statutory Instrument 2001/838

<sup>24</sup> In accordance with the Renewables Obligation Order 2002 (Statutory Instrument 2002/914) and the Renewables Obligation (Scotland) Order (Scottish Statutory Instrument/163) regarding eligibility of renewable sources for fulfilment of the Renewables Obligation.

<sup>25</sup> In accordance with the Climate Change Levy (General) Regulations 2001 regarding renewable supplies exempt from the Climate Change Levy.

their verifier demonstrating that the fuels used satisfy the eligibility requirements as defined in the Renewables Obligation or the Climate Change Levy . They will also need to provide a declaration applicable to the relevant power stating that it has not been sold to a licensed supplier nor sold as an unlicensed supply.

On-site sources partly fuelled by renewable energy

In the case of power generated using partly renewable sources and partly fossil fuel, only the proportion attributable to the renewable sources is eligible for an emission factor of zero.

Off-site renewables

In order for power purchased from a supplier to be eligible for use in the scheme, the participant must fulfil two conditions:

1. they must demonstrate that the power is from an eligible renewable source; and
2. in the case of electricity, they must demonstrate that it is not being relied upon for the purpose of fulfilling any obligation imposed upon it by any enactment in relation to the generation of such electricity. Relevant obligations include the Renewables Obligation and the Renewables (Scotland) Obligation.

These requirements can be fulfilled either by possession of a Renewable Obligation Certificate (ROC), or by virtue of a suitable declaration from the supplier or generator.

Renewable electricity covered by the RO

RO-eligible electricity can only be zero-rated for the purposes of the emissions trading scheme if accompanied by a ROC. Participants wishing to use an emissions factor of zero for RO-eligible electricity must surrender the associated ROCs using the procedure below. The same procedure is also to be used for ROCs purchased independently.

- (1) The participant must notify the Secretary of State that they wish to use renewable electricity covered by the Renewables Obligation and provide her with the following details -
  - (a) the identification number of the certificates in question; and
  - (b) the total amount of renewable electricity covered by the certificates.

- (2) The registered holder of the certificates must submit a request to the Gas and Electricity Markets Authority asking it to substitute the Secretary of State as the registered holder for the certificates in accordance with the Renewable Obligation Order 2002<sup>26</sup>. Within five business days of receiving a notice under paragraph (1), the Secretary of State will submit the relevant request in accordance with the order.

- (3) Within five business days of receiving notification from the Gas and Electricity Markets Authority that the substitution has taken place, the Secretary of State will request that the certificates be deleted from the relevant register established by the Gas and Electricity Markets Authority.

- (4) Within five business days of receiving notification from the Gas and Electricity Markets Authority that the certificates have been deleted, the Secretary of State will notify the participant in writing that the certificates have been cancelled and that the participant is now able to count the electricity usage covered by the certificates at emission factor of zero.

- (5) Verifiers shall take the letter from the Secretary of State as evidence that the electricity concerned is eligible to be counted as a renewable.

Renewable electricity not covered by the Renewables Obligation

In order to claim a zero emission factor for the use of renewable electricity that is CCL-exempt but not RO-eligible, the participant will need to have a “renewable source declaration” from the electricity

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<sup>26</sup> Renewables Obligation Order 2002, Schedule 2, Paragraph 6.

supplier, made in accordance with the Finance Act 2000<sup>27</sup>. They will also need a declaration that the renewable electricity is not being relied upon for the purpose of fulfilling any obligation imposed upon it by any enactment in relation to the generation of such electricity.

#### Renewable electricity contracts and accounting for renewable electricity purchases

For levy exempt electricity, two types of energy contracts exist, one which specifically states where the renewable energy is to be used and the other which does not state where the renewable energy is to be used. Where the contract specifically allocates renewable units to a certain source, then the amount of eligible renewable electricity for the source in question is based on the allocation specified in the contract. Where the contract does not specify the allocation of electricity, then the amount of eligible renewable electricity should be allocated across all uses equally, regardless of whether all uses are included in the participant's source list. For example, if a participant has a supply contract which specifies that 10% of its power comes from renewable sources but does not allocate these units to specific sources, and only 65% of the electricity supplied under this contract is used by sources within its source list, then only 65% of the renewable supply can count as zero-rated. This is consistent with the approach used to allocate exempt electricity under the CCL (see HM Customs and Excise notice CCL1).

#### Accounting for renewable electricity generated from waste

Where the renewable sources used to fuel a generating station includes waste (whether or not the generating station is fuelled by waste in combination with other renewable sources or fossil fuel) the amount of renewable source electricity which is to be regarded as generated from that waste in any period is to be calculated in accordance with regulations 47(7) - 47(9) of the Climate Change Levy (General) Regulations 2001.

#### Electricity purchases other than from a licensed supplier

If a participant purchases power other than from a licensed supplier (direct from a generator, for example) then:

- (1) if the source is covered by the RO then the electricity supplied can only be zero-rated if the corresponding ROCs are cancelled as above;
- (2) if the source is not covered by the RO, then the generator must issue a declaration stating that:
  - (a) the renewable electricity supplied to the participant has been generated from an eligible source, and;
  - (b) the renewable electricity is not being relied upon for the purpose of fulfilling any obligation imposed upon it by any enactment in relation to the generation of such electricity.

#### Reporting the use of renewables

Participants that have used eligible renewables must supply documentation of this to their verifier. This documentation must include:

- With regard to RO-eligible electricity, a letter from the Secretary of State regarding the cancellation of ROCs;
- With regard to sources ineligible or otherwise not covered by the RO, a renewable source declaration from a supplier or generator and evidence that the renewable energy is not covered by the RO;
- With regard to on-site renewables, evidence that any fuels used do qualify as renewable.

#### Electricity from landfill or sewage gas

If participants in the emissions trading scheme use zero-rated electricity from the above sources instead of electricity from the grid the renewable electricity has an effective carbon intensity of -0.43 kg CO<sub>2</sub>/kwh<sup>28</sup>. However this does not take into account the positive impact of methane abatement.

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<sup>27</sup> The Finance Act 2000, Schedule 6, Paragraph 19(2)

<sup>28</sup> Corresponding to the standard emissions factor for grid electricity.

## APPROVED

With a global warming potential of 21, capturing and burning methane generates a considerable greenhouse gas emissions saving in addition to any displacement of fossil fuel-powered generation. However, there is no scope for credit for this saving to be ascribed to electricity users. When entry to the emissions trading scheme via the projects route becomes available then abatement projects of this nature may be eligible to gain additional credit.

# ANNEX B: PROCESS CO<sub>2</sub> EMISSIONS

## Introduction

Some industrial processes emit CO<sub>2</sub> as a chemical by-product - these are termed process emissions. For example, in cement production, calcium carbonate is (CaCO<sub>3</sub>) is broken down in a cement kiln to produce lime (CaO), and carbon dioxide emitted as a by-product.

This Annex covers the main types of process CO<sub>2</sub> emissions found in the UK. Each part of the Annex provides guidance on best practice methodology for the calculations following guidance from IPCC, the UK GHG Emissions Inventory and the GHG Protocol Initiative led by the WRI/WBCSD.

Sections 2.17 (6), 2.30, and annexes A.13-A.14 of the framework document set out the conditions under which Direct Participants may apply to use a methodology additional to those laid out below.

The following annexes each cover a separate type of process emission, and provide a methodology for calculating an emission factor in terms of CO<sub>2</sub> emissions per unit of production. The total annual CO<sub>2</sub> emitted can then be calculated by multiplying the emission factor by the total annual production of that process.

The protocols cover:

- Cement manufacture
- Lime production
- Limestone and dolomite use
- Soda ash
- Use of fuels as feedstock (where the product does not contain carbon)
- Metal production
- Waste incineration – Municipal solid waste and sewage

## Protocol B1: Cement manufacture

Carbon dioxide (CO<sub>2</sub>) is emitted from both the chemical process and the energy consumption associated with the cement manufacturing process. The CO<sub>2</sub> associated with the energy consumption for cement manufacture (fossil fuel combustion and electrical energy usage) is not subject to this protocol.

During cement manufacture, CO<sub>2</sub> derives from a process known as calcination or decarbonation of calcium carbonate (or limestone; CaCO<sub>3</sub>). Cement kiln feed is a mix containing around 78% calcium carbonate with a balance of silica bearing material. During the calcination process, the cement kiln feed is exposed to high temperatures on which the calcium carbonate component in the feed is decomposed to form lime (CaO) and CO<sub>2</sub>. The latter is released to the atmosphere as a by-product.

Most cement raw materials also contain small proportions of magnesium carbonates which act in exactly the same way as calcium carbonates, although decarbonating at slightly lower temperatures than its calcium equivalent.

Following calcination, the resulting activated lime combines with the silica bearing component in the kiln feed raw materials forming the clinker minerals calcium di- and tri- silicate characteristic of Portland cement clinker. Clinker itself is an intermediate product, which is then inter-ground with a small amount of gypsum to control setting time and produce Portland cement. Masonry cement production requires the addition of a lime bearing material to the clinker. However, since the limestone ground in for masonry cement production is not subjected to decarbonation temperatures, no further CO<sub>2</sub> emissions are associated with the manufacture of this product.

In this protocol, the CO<sub>2</sub> emitted from the calcination process is calculated from the stoichiometry of the decarbonation processes of the kiln feed materials calcium and magnesium carbonate (theoretical mass loss on ignition; LOI). The mass of calcium and magnesium carbonate is determined from the content of calcium and magnesium oxides in the cement kiln feed, as the respective oxides can be analysed directly using X-ray fluorescence (XRF).

A small amount of raw material leaves the calcination process in a partially decarbonated form known as CKD (cement kiln dust), due to partially inefficient calcination. The CKD represents the mass of raw material which was not converted to clinker and CO<sub>2</sub>. In most modern processes the CKD is 100% recycled, i.e. it is returned to the calcination process mixed in with the cement kiln raw material feed and will be able to release CO<sub>2</sub> during subsequent calcination processes. When the CKD is recycled, it will not need to be accounted for in the calculation of total CO<sub>2</sub> emissions. However, if the CKD is not recycled, the CO<sub>2</sub> that remained unreleased in the CKD fraction is subtracted from the calculated theoretical CO<sub>2</sub> content in the kiln feed raw material (see equation below). The CO<sub>2</sub> content in the CKD is calculated from the experimentally determined loss on ignition factor (mass loss at 975oC).

$$\text{Total CO}_2 \text{ Emissions (tonnes)} = (\text{Raw Material} * \text{LOI of Raw Material}/100) - (\text{CKD from Kiln} * \text{LOI CKD from Kiln}/100)$$

where:

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<b>Raw Material</b>	= This represents the tonnage of milled raw materials (excluding fuels) fed to the kiln over the given period of time.
<b>CKD from Kiln</b>	= This represents the tonnage of cement kiln dust which leaves the kiln system over a given period of time. This excludes any recycled cement kiln dust within the kiln system
<b>LOI Raw Material</b>	=CaO (%) in kiln feed raw material x 44.01/56.08 + MgO (%) in kiln feed raw material x 44.01/40.3See exception below.
<b>LOI CKD from Kiln</b>	= The percentage loss on ignition which represents the loss in weight which occurs when a sample of cement kiln dust is heated to 975°C (± 25°C) in a furnace.

In addition to magnesium and calcium carbonate, there are other minor contributions to CO<sub>2</sub> emissions from the kiln feed raw material, due to impurities in the naturally occurring feeds. These are disregarded when calculating the stoichiometric LOI, as they are difficult to quantify due to their variability in type and quantity. Hence, the calculated LOI is 2 to 3 % lower than actual LOI.

### *Calibration and quality control*

CaO and MgO are determined at each works using calibrated XRF analysers. Results are reported on the Lafarge Laboratory systems. Standards for XRF calibrations used at each works are traceable back to the UKAS accredited Lafarge Quality Support Laboratory at Greenhithe. Measurement and calibration of CaO and MgO concentrations are subject to the plant's quality control procedures. The data is stored on central or plant specific databases.

### **Modification to the protocol: Emissions Measurement at the Aberthaw Plant**

At Aberthaw the kiln feed material LOI data is measured using a procedure based on British Standard, BSEN 196-2:1995, clause 7 with amendments supported by accredited exceptions from Lafarge Quality support laboratory at Greenhithe.

This procedure is also used for determining CKD LOI where relevant.

## Protocol B2: Lime production

Lime is produced in a three-step process: stone preparation, calcination, and hydration. Calcination is the process by which limestone, which is mostly calcium carbonate ( $\text{CaCO}_3$ ) is heated in a kiln to produce lime. Carbon dioxide is a by-product of this reaction and is usually emitted to the atmosphere. However, some facilities recover a portion of the emissions for use in precipitated calcium carbonate production. In the case of sugar refining, all of the  $\text{CO}_2$  emitted during calcination is required to carbonate the calcium oxide.

The mass of  $\text{CO}_2$  produced per unit of lime manufactured may be estimated from the molecular weights and the lime content of products according to the following formula:

$\begin{aligned} \text{CO}_2 \text{ Emissions (tonne)} &= \text{Lime Production (tonne)} \\ &\quad \times \text{Stoichiometric Ratio of CO}_2/\text{CaO} \\ &\quad \times \text{CaO or (CaO+MgO) Content of Lime} \end{aligned}$
--

If plant-specific information on these factors is not available, the following defaults may be used.

### Stoichiometric Ratios (tonne $\text{CO}_2$ /tonne of lime):

High-Calcium Lime	0.79
Dolomitic Lime	0.91
Hydraulic Lime	0.79

### Default CaO or CaO+MgO Content (%):

High-Calcium Lime	95%
Dolomitic Lime	90%
Hydraulic Lime	75%

The consumption of lime may, in some cases, result in the removal of  $\text{CO}_2$  from the atmosphere. The use of hydrated lime (for water softening) for example, results in  $\text{CO}_2$  reacting with lime to form calcium carbonate. Lime is also used as a  $\text{CO}_2$  absorbent for atmospheric control in the storage of fruit. At this time, data is not available to reliably estimate the extent of atmospheric  $\text{CO}_2$  removal from the use of lime.

## Protocol B3: Limestone and dolomite use

The mass of CO<sub>2</sub> emitted from the use of limestone and dolomite may be estimated from a consideration of consumption, purity of the raw materials and the stoichiometry of the chemical processes.

$$\text{CO}_2 \text{ Emissions (tonnes)} = \text{Limestone use (tonnes)} \times \text{EF}_{\text{limestone}} + \text{Dolomite use (tonnes)} \times \text{EF}_{\text{dolomite}}$$

The emission factor for limestone use is:

$$\begin{aligned} \text{EF}_{\text{limestone}} &= f \times [44.01 \text{ g/mole CO}_2] / [(100.09 \text{ g/mole CaCO}_3)] \\ &= \mathbf{(0.440 \times f)} \text{ tonne CO}_2 / \text{tonne limestone} \end{aligned}$$

Emission factor for dolomite use is:

$$\begin{aligned} \text{EF}_{\text{dolomite}} &= f \times [2 \times 44.01 \text{ g/mole CO}_2] / [(184.41 \text{ g/mole CaCO}_3, \text{MgCO}_3)] \\ &= \mathbf{(0.477 \times f)} \text{ tonne CO}_2 / \text{tonne dolomite} \end{aligned}$$

where:

**f** is the fractional purity in CaCO<sub>3</sub> per tonne of total raw material weight (if unknown, the default factor for f is equal to 1).

## Protocol B4: Soda ash

From stoichiometric considerations, the industrial process emission of CO<sub>2</sub> associated with the Solvay process is **zero**. For processes utilising Trona, emissions can be calculated by the following formula:

$$\text{CO}_2 \text{ Emissions (tonnes)} = \text{Soda ash production (tonnes)} \times \text{EF}_{\text{Trona}}$$

$$\text{EF}_{\text{Trona}} = \mathbf{0.097} \text{ tonne CO}_2 / \text{tonne of Trona}$$

For each mole of **soda ash use**, one mole of CO<sub>2</sub> is emitted, so that the mass of CO<sub>2</sub> emitted from the use of soda ash may be estimated from a consideration of consumption data and the stoichiometry of the chemical process as follows:

$$\text{CO}_2 \text{ Emissions (tonnes)} = \text{Soda ash use (tonnes)} \times \text{EF}_{\text{soda-ash-use}}$$

$$\begin{aligned} \text{EF}_{\text{soda-ash-use}} &= 44.01 \text{ g/mole CO}_2 / 105.99 \text{ g/mole Na}_2\text{CO}_3 \\ &= \mathbf{0.415} \text{ tonne CO}_2 / \text{tonne Na}_2\text{CO}_3 \end{aligned}$$

## Protocol B5: Use of fuels as feedstock (where the product does not contain carbon)

Anhydrous ammonia is synthesized by reacting hydrogen with nitrogen at a molar ratio of 3 to 1, then compressing the gas and cooling. Nitrogen is obtained from the air, while hydrogen is obtained from either the catalytic steam reforming of natural gas (methane CH<sub>4</sub>), or other kinds of fossil fuels. Emissions of CO<sub>2</sub> will depend on the amount and composition of these fossil fuels used in the process. It is assumed that all carbon will be emitted to air as CO<sub>2</sub>.

Where fuel is measured in terms of mass, the method of calculation is:

$$\text{Emission of CO}_2 \text{ (t)} = \text{Consumption of fuel (t)} \times \% \text{ carbon content of fuel} \times 44/12$$

If fuel is measured in terms of energy content, the method of calculation is:

$$\text{Emission of CO}_2 \text{ (t)} = \text{Consumption of fuel (kWh)} \times \text{Emission Factor from Table A1 (kgCO}_2\text{/kWh)} \times 0.001$$

In order to avoid double counting, the quantities of oil or gas used must be subtracted from the quantity reported under energy consumption dealt with in Annex A.

Some CO<sub>2</sub> is sold to the food industry and the nuclear industry where it will be ultimately emitted. The emission of this CO<sub>2</sub> will become the responsibility of the final user.

Process integration associated with ammonia production will tend to reduce CO<sub>2</sub> emissions overall but can complicate accounting for CO<sub>2</sub>. It may mean that not all the carbon associated with the fuel consumption is actually emitted to atmosphere. In this case it is necessary for the operator to estimate the CO<sub>2</sub> emissions that occur from the operator's site.

### Emission Factor Information

The carbon content of fossil fuels may vary, and it is recommended that, if possible, emission factors are determined for each separate plant. Default emission factors shown below can be used if these are unavailable. These defaults are based on values used in Annex A for net calorific value and emission factors for different fuels. The resulting carbon content figures have been rounded for the sake of simplicity.

	Emission Factor	Emission Factor	Carbon content of fuel
	kgCO <sub>2</sub> /kWh	kgCO <sub>2</sub> /GJ	%
Gas oil	0.25	69	85%
Heavy fuel oil	0.26	72	85%
Naphtha	0.26	72	85%
Natural gas	0.19	53	75%

## Protocol B6: Metal production

With a few exceptions, commercial production of metals from ores requires the use of carbon as a reducing agent. If the ore contains carbonate, CO<sub>2</sub> originating from the ore will also be emitted during production. On the other hand, carbon may also be sequestered in the metal.

The metal may be reduced by using coal, coke, prebaked anodes and carbon electrodes. Coke is produced from coal or refinery residuals (petrol coke). Prebaked anodes and electrodes are produced from coal. By-product fuel (coke oven gas and blast furnace gas) are produced in some of the processes. These fuels may be sold or used within the plant. They may or may not be included in the energy balance. Care shall consequently be taken not to double count emissions.

The following general formula may be used to estimate the emissions:

$$\text{Emission (tonnes CO}_2\text{)} = \text{tonne Reducing Agent} \times \text{Emission Factor} + (\text{tonne carbon in ore} - \text{tonne carbon in metal}) \times 44/12$$

The first part of this formula (the amount of reducing agent used combined with an emission factor) will usually be most important. This mass of reducing agent will include the mass of carbon electrodes in arc furnaces and electrolysis processes. Emission factors for these are shown in the table below.

### CO<sub>2</sub> EMISSION FACTORS FOR METAL PRODUCTION

Reducing Agent	Emission Factor (tonne CO <sub>2</sub> /tonne Reducing Agent) <sup>29</sup>
Coal	2.6
Coke from coal	3.0
Petrol coke	3.6
Prebaked anodes and coal electrodes	3.6

In the case of blast furnace production of iron and steel, the reducing agent is usually coke, and this will probably have been accounted for in the energy-related emissions. Care shall therefore be taken not to double count this item. Emission factors for this are suggested in Annex A.

The second part of the formula requires a mass balance of carbon. This is based on the difference in the carbon content of the feedstock ore and the metal product. The factor of 3.67 simply converts the result from carbon to CO<sub>2</sub>. This information will be process specific, and will require information to be provided by the entity.

In addition, CO<sub>2</sub> will be emitted from baking (prebaked anodes). In the aluminium industry about 5 per cent of the non-combustion CO<sub>2</sub> emissions using the prebaking technology will be from baking.

<sup>29</sup> Factors taken from the UK Greenhouse Gas Inventory.

## Protocol B7: Waste incineration – municipal solid waste (MSW) and sewage

Certainly waste incineration produces CO<sub>2</sub>, but it is difficult to identify the portion which should be considered **net** emissions. A large fraction of the carbon in waste combusted (e.g., paper, food waste) is derived from biomass raw materials which are replaced by regrowth on an annual basis. These emissions should not be considered net anthropogenic CO<sub>2</sub> emissions in the Scheme.

On the other hand, some carbon in waste is in the form of plastics or other products based on fossil fuel. Combustion of these materials, like fossil fuel combustion, releases net CO<sub>2</sub> emissions.

In estimating emissions from waste incineration, the desired approach is to separate carbon in the incinerated waste into biomass and fossil fuel based fractions. Only the fossil based portion should be considered net carbon emissions. Any such detailed analysis should ensure that carbon emissions are not double counted in the treatment of stored carbon under energy emissions. In the absence of specific emission factors for the waste, a suitable default factor for MSW is:

$$\text{CO}_2 \text{ emissions (tonnes)} = \mathbf{0.275} \times \text{MSW combusted (tonnes)}$$

A default for sewage is that its combustion results in zero net CO<sub>2</sub> emissions. Hence, only the CO<sub>2</sub> emissions arising from any fossil fuels used to burn the sewage sludge should be accounted for using factors given in Annex A1.

# ANNEX C: OTHER APPROVED PROTOCOLS

## Introduction

The Reporting Guidelines now include protocols developed initially by participants covering a number of both CO<sub>2</sub> and non-CO<sub>2</sub> process emissions.

The protocols cover:

- Manufacture of domestic refrigeration
- Industrial and commercial refrigeration
- Refrigeration – Process operations
- Off-shore oil and gas
- Beer manufacture
- Aviation emissions
- Coal mine methane from working mines

## Protocol C1: Measurement of HFCs and PFCs from the manufacture of HF, CTF, HCFC-22, HFC-125 and HFC-134a

The methodology is based on *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* developed and published by IPCC. The most apposite section of this deals with emission of HFC-23 and an extract of the *Guidance* on this topic is in Appendix 1. This methodology, while focused on HFC-23, is applicable to all process emissions of HFCs and PFCs.

At the outset, the complete process should be examined, with a view to:

1. Assigning its external boundaries - the "total box" - generally the whole area over which the proprietor has management control,
2. Assigning internal boundaries; generally the management accounting subdivisions within which data that will be useful to the inventory is collected in the normal course of operations,
3. Establishing the physical sources of each emission and
4. their approximate relative sizes, in order to prioritise resources, recognising that an "emission" in this context is weighted by the GWP of the constituent gases.<sup>30</sup>

All emissions need to be considered at this stage, not only the current absolute values but their trends too. This should enable rational decisions on the materiality of each source to be taken at an early stage, avoiding waste of effort.

Emissions of HFCs and PFCs are gaseous; either directly from vent streams discharging to atmosphere or indirectly as components of aqueous, liquid or solid waste. HFCs are sufficiently volatile to be released into the atmosphere by vaporisation and degassing from waste that enters the environment.

Where the process chemistry is well known and there are only one or two stages in the conversion of raw material into product sold (as is the case for conversion of chloroform into HCFC-22) and one greenhouse gas dominates the emissions (in this case, HFC-23), the total amount formed may be estimated from records of process (in)efficiency. This corresponds to **Tier 1** methodology in the *Guidance*.

In most cases, there are likely to be more complex releases to atmosphere, with multiple venting arrangements and a range of possible greenhouse gases, so that the composition of each vent stream and its flowrate needs to be established. This corresponds to **Tier 2** methodology in the *Guidance*.

In this context vents streams include, along with releases from the process that are part of its normal operation, fugitive emissions (for example from leaks or maintenance), losses during transfer and sampling and any other activity that releases material into the environment. Such stochastic process emissions are handled in the methodology using a mass emission per event.

In the cases where, having been generated within one of the operating units assigned in 2.2, the vents stream may be treated from time to time to remove the GHG component, the operational efficiency of the treatment process and the length of time that it is in use need to be established.

In all cases, the combined releases from the total box (established in 1.) should be reported as quantities of each individual HFC, together with the uncertainty of the estimate by that method. The estimate with the smallest uncertainty should generally be used but those having larger uncertainty may have value in verification.

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<sup>30</sup> Information concerning both 2.3 and 2.4 should be readily available from the Company's submissions under IPC legislation.

All measurements and estimates must be adequately documented with a clear and auditable provenance in process records (see Appendix 2). This is particularly important when changes in process operation, conditions or measurement parameters give rise to a significant change in emissions. Where the emission involves a third party (for example a maintenance contractor), the documentation of the third party must provide the information required and must be capable of being audited.

### Tier 1

This is most applicable where one material dominates emissions but may be applied to multicomponent emissions if the fractional losses of the components do not vary significantly in time. The basis of the methodology is the use of process efficiency measurements and sound knowledge of process chemistry and engineering to estimate emissions. Total emissions are the sum of potential emissions that are released into the atmosphere without treatment plus the quantities that are released from the treatment plant. In many cases, the parameters will relate to a whole year's operation but, where the operating year is subdivided, emissions during each period should be calculated separately and added together to provide an annual estimate.

Total Emissions of Each Component = Potential Emissions of Component x the time period that Emission occurs (discounting the time that Emissions are treated) + Emissions of Component that pass through Treatment

$$E_{t,i} = H \cdot (1 - h) \cdot E_{p,i} + H \cdot h \cdot (100 - X_h)/100 \cdot E_{p,i}$$

Where:

$E_{t,i}$  = total emission of HFC Greenhouse Gas component **i** during the fraction of the year represented by **H**,

**H** = 1 if the data are annually aggregated. Otherwise **H** is the fraction of the year represented by this portion of the data,

**h** = fraction of the operating period (the online time of the plant) in which an effluent treatment system is receiving the vent stream(s) from the process,

$X_h$  = efficiency of removal of HFCs and PFCs by the effluent treatment system, expressed as percent. It is assumed that the efficiency of removal by the effluent treatment system is the same for all HFCs and PFCs, does not vary in time and has trivial uncertainty.

$E_{p,i}$  = potential emission of component **i**. This can be calculated from both the carbon efficiency (see below) and the fluorine efficiency (see below) and  $E_{p,i}$  should normally be the average of these two values unless there are overriding considerations (such as a much lower uncertainty of one of the efficiency measures) that can be adequately documented.

Potential Emission of Component (calculated from carbon balance) = Production x Inefficiency from Carbon Balance x Factor to assign efficiency loss to this Component x Factor for the Carbon content of this Component

$$E_{p,i} = P \cdot Y_i \cdot (100 - X_C)/100 \cdot F_{C,i}$$

Where:

$E_{p,i}$  = potential emission of component **i**, calculated from the carbon efficiency,

**P** = quantity of product made in the plant during the study period and to which the efficiencies relate,

$Y_i$  = mass fraction of inefficiency that can be assigned to component **i** such that the sum of all  $Y_i$  is equal to one. It is assumed that the fractional loss of components remains constant, so that  $Y_i$  do not vary during the time period.

$X_C$  = carbon efficiency during this period, expressed as percent,

$F_{C,i}$  = factor to convert a mass loss of carbon into a loss of component **i**, (see below).

Potential Emission of Component (calculated from fluorine balance) = Production x Inefficiency from Fluorine Balance x Factor to assign efficiency loss to this Component x Factor to relate Fluorine to the Component

$$E_{n,i} = P \cdot Y_i \cdot (100 - X_F)/100 \cdot F_{F,i}$$

Where:

$E_{p,i}$  = potential emission of component  $i$ , calculated from the fluorine efficiency

$P$  = mass quantity of product made in the plant during the study period and to which the efficiencies relate,

$Y_i$  = mass fraction of inefficiency that can be assigned to component  $i$  such that the sum of all  $Y_i$  is equal to one. It is assumed that the fractional loss of components remains constant, so that  $Y_i$  do not vary during the time period.

$X_F$  = annual fluorine efficiency, expressed as percent,

$F_{F,i}$  = factor to convert a mass loss of fluorine into a loss of component  $i$  (see below).

Factor to convert Carbon loss into Component loss = Molecular weight of Component / [number of Carbon atoms in each molecule x 12]

$$F_{C,i} = M_i / (12 \cdot n_{C,i})$$

Where:

$F_{C,i}$  = factor to convert a mass loss of carbon into a loss of component  $i$ ,

$M_i$  = molecular weight of component  $i$ ,

$n_{C,i}$  = number of carbon atoms in a molecule of component  $i$ .

Factor to convert Fluorine loss into Component loss = Molecular weight of Component / [number of Fluorine atoms in each molecule x 19]

$$F_{F,i} = M_i / (19 \cdot n_{F,i})$$

Where:

$F_{F,i}$  = factor to convert a mass loss of fluorine into a loss of component  $i$ ,

$M_i$  = molecular weight of component  $i$ ,

$n_{F,i}$  = number of fluorine atoms in a molecule of component  $i$ .

Uncertainty of the estimate is expressed as a coefficient of variance (%). It is calculated by the root-squared sum of the individual uncertainties in production mass quantity and efficiencies, assuming the carbon and fluorine uncertainties are the same. Where the uncertainties in carbon and fluorine efficiency differ significantly (enough to cause a material difference to the calculated emission), the value with the lower uncertainty should be used throughout the calculation.

Total Uncertainty (Coefficient of Variance) = Square Root of [Square of Uncertainty of Production Mass Quantity + Square of the Effect of Uncertainties in Fluorine and/or Carbon on the Total Uncertainty]

$$U_E = \sqrt{(U_P)^2 + (U_X \cdot 100 / (100 - (X_C + X_F)/2))^2}$$

Where:

$U_E$ ,  $U_P$  and  $U_X$  = uncertainties in the total estimate, production mass and raw material efficiencies, respectively, expressed as coefficients of variance and  
 $X_C$  and  $X_F$  = annual carbon and fluorine efficiencies, expressed as percent.

**Tier 2**

This method depends on measuring flow and composition so that, in all cases of continuous or semi-continuous process vents, the quantity emitted to atmosphere is the mathematical product of the mass concentration of the component in the stream, the flowrate of the total stream and the length of time that this flow occurred.

Emission of Component = average Mass Fraction of Component x average Mass Flowrate x On-line Time

$$E_{Z,i} = C_{Z,i} \cdot R_Z \cdot T$$

Where:

$E_{Z,i}$  = mass emission of component  $i$  in vent stream  $Z$ ,

$C_{Z,i}$  = annual average mass fractional concentration of component  $i$  in vent stream  $Z$ ,

$R_Z$  = annual average mass flowrate of vent stream  $Z$  and

$T$  = annual on-line time of the plant (the operating year) in units consistent with the flowrate.

Where the venting is semi-continuous,  $R_Z$  may become the flowrate while the vent is in operation and  $T$  may become the actual total duration of venting for the year; otherwise  $R_Z$  should be adjusted for the length of time during the year that the flowrate at  $Z$  is zero and  $T$  should remain the on-line time of the plant.

Quantised emissions, where a specific volume or mass is released as a result of a particular procedure are special cases of the equation below;  $R_Z$  becomes the specific quantity of each incidence and  $T$  becomes the annual number of incidences. Otherwise, these emission sources are treated in the same way as more continuous sources.

Emission of Component = average Mass Fraction of Component x average Mass released per Incidence x Number of Incidences

$$E_{Z,i} = C_{Z,i} \cdot R_Z \cdot T$$

The overall emission is then given by the sums of emissions from those streams that are released to atmosphere without treatment (such as some of the quantised emissions from particular procedures) plus residual emissions arising after the effluent has been treated.

Total Emission = Sum of emissions from Streams that may be treated (discounted by the fraction that is treated and the removal efficiency) + Sum of Emissions from Streams that cannot be treated

$$E_{t,i} = (1 - h) \cdot (100 - X_h)/100 \cdot \sum E_{Za,i} + \sum E_{Zb,i}$$

Where:

$E_{t,i}$  = total emission of HFC Greenhouse Gas component  $i$  during the year,

**h** = fraction of the operating period (the online time of the plant) in which an effluent treatment system is receiving the vent stream(s) from the process,

**X<sub>h</sub>** is the efficiency of removal of HFCs and PFCs by the effluent treatment system, expressed as percent. It is assumed that the efficiency of removal by the effluent treatment system is the same for all HFCs and PFCs, does not vary in time and has trivial uncertainty.

**Za** streams are those that can pass to the effluent treatment plant and **Zb** are streams that are released to atmosphere with no possibility of treatment.

For each of these streams there will be an uncertainty as a consequence of uncertainties in measured concentration and flowrate and uncertainty in the duration of the flow. The combined uncertainty for each component in each stream is given by the equation below.

Uncertainty in Emission of Component in any one Stream = Square root of [Square of Concentration Measurement Error + Square of Flowrate Measurement Error + Square of Uncertainty of Duration of Flow]

$$U_{Z,i} = \sqrt{ME_{Czi}^2 + ME_{Rz}^2 + U_T^2}$$

Where:

**U<sub>Z,i</sub>** and **U<sub>T</sub>** = uncertainties of component *i* in, respectively, the emission from source **Z** and the length of time that there is a flow at source **Z**.

**ME<sub>Czi</sub>** = measurement error (combined instrumental and sampling errors) in the concentration of component **i**, expressed as coefficient of variance, and

**ME<sub>Rz</sub>** = instrumental measurement error in the flow at source **Z**, expressed as coefficient of variance.

Uncertainty in the estimate of total emission is the root square combined uncertainty of all of the emissions considered.

Total uncertainty = Square root of [Sum of the Squares of all individual Uncertainties]

$$U_{E,i} = \sqrt{(\sum U_{Z,i}^2)}$$

In this case, the calculation of uncertainty for individual components is valid.

### **Application to Ineos Fluor Rocksavage Site**

The process over which Ineos Fluor has management control encompasses the plants producing: HF, CTF, HCFC-22, HFC-125 and HFC-134a, together with the physical movement of products to the customers, which is contracted out.

From these plants, there are continuous vents streams that contain significant amounts of HFCs, particularly the stream of HFC-23 from the HCFC-22 plant. Continuous vents are treated in a thermal oxidising unit. There are also: an aqueous effluent stream that contains HFCs; losses of HFCs to atmosphere during transfer and storage of product, both inside the factory and *en route* to customers; losses during maintenance of the process and losses that occur as a consequence of removing samples for analysis. Both Tier 1 and Tier 2 methodologies can be applied.

The data requirements and calculated emissions and their uncertainties have been set out as Excel spreadsheets. These are attached in Appendix 4. It is anticipated that these, together with a set of references to source documentation will form the substance of the inventory of greenhouse gases from process operations.

Documentation of assumptions, insertion of missing data and mechanisms to cope with changes in the methods of calculating emissions are described in the *Guidance*, extracted in Appendices 1 to 3, and so the instructions are not duplicated here.

**Appendix 1. Extract of IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, Chapter 3 Industrial Processes**

**3.8 ESTIMATION OF HFC-23 EMISSIONS FROM HCFC-22 MANUFACTURE**

**3.8.1 Methodological issues**

Trifluoromethane (HFC-23 or CHF<sub>3</sub>) is generated as a by-product during the manufacture of chlorodifluoromethane (HCFC-22 or CHClF<sub>2</sub>)<sup>31</sup> and emitted through the plant condenser vent. There are a small number of HCFC-22 production plants globally and thus a discreet number of point sources of HFC-23 emissions.

**CHOICE OF METHOD**

The choice of *good practice* method will depend on national circumstances. The *IPCC Guidelines* (Vol. 3, Section 2.16.1, By-product Emissions) present two broad approaches to estimating HFC-23 emissions from HCFC-22 plants. The Tier 2 method is based on measurement of the concentration and flow-rate from the condenser vent at individual plants. The product of HFC-23 concentration multiplied by the volumetric flow-rate gives the mass rate of HFC-23 emissions. The Tier 1 method is relatively simple, involving the application of a default emissions factor to the quantity of HCFC-22 produced. This method can be applied at the plant level or the national level. In cases where there are Tier 2 data available for some plants, the Tier 1 method can be applied to the remainder to ensure complete coverage. Regardless of the method, emissions abated should be subtracted from the gross estimate to determine net emissions. It is *good practice* to use the Tier 2 method if possible. Direct measurement is significantly more accurate than Tier 1 because it reflects the conditions specific to each manufacturing facility. In most cases, the data necessary to prepare Tier 2 estimates should be available because facilities operating to good business practice perform regular or periodic sampling of the final process vent or within the process itself as part of routine operations. For facilities using abatement techniques such as HFC-23 destruction, verification of the abatement efficiency is also done routinely. The Tier 1 method should be used only in rare cases where plant-specific data are unavailable.

**CHOICE OF EMISSION FACTORS**

There are several measurement options within the Tier 2 method relating to the location and frequency of the sampling. In general, direct measurement of the emissions of HFC-23 provides the highest accuracy. Continuous or frequent measurement of parameters within the production process area itself is almost as accurate. In both cases, the frequency of measurement must be high enough to represent the variability in the process (e.g. across the life of the catalyst). Issues related to measurement frequency are summarised in Box 3.5, Plant Measurement Frequency. General advice on sampling and representativeness is provided in Chapter 8, Quality Assurance and Quality Control (see *Appendix 2*). In cases where plant-specific measurements or sampling are not available and Tier 1 methods are used, the default emission factor of 4% (tonnes of HFC-23 produced per tonne of HCFC-22 manufactured) presented in the *IPCC Guidelines* should be used, assuming no abatement methods.

**BOX 3.5: PLANT MEASUREMENT FREQUENCY**

The accuracy and precision of the estimates of annual HFC-23 emissions are directly correlated with the number of samples and the frequency of sample collection. Since production processes are not completely static, the greater the process variability, the more frequently plants need to measure. As a general rule, sampling and analysis should be repeated whenever a plant makes any significant process changes. Before choosing a sampling frequency, the plant should set a goal for accuracy and use statistical tools to determine the sample size necessary to achieve the goal. For example, a study of HCFC-22 producers indicates that sampling once per day is sufficient to achieve an extremely accurate annual estimate. This accuracy goal should then be revised, if necessary, to take into account the available resources.

RTI, Cadmus, *Performance Standards for Determining Emissions of HFC-23 from the Production of HCFC-22*, draft final report prepared for USEPA, February 1998.

**CHOICE OF ACTIVITY DATA**

When using the Tier 1 method, production data should be obtained directly from producers. There are several ways producers may determine their production levels, including shipment weights and measuring volume-times-density, using flow meters. These data should account for all HCFC-22 production for the year, whether for sale or for use internally as feedstock, and the plant should describe how the HCFC-22 production rate is determined.

**COMPLETENESS**

Review of plant data indicates that at properly run manufacturing facilities, fugitive emissions of HFC-23 (e.g. from valves, water scrubbers, and caustic washes) are insignificant (RTI, 1996). If information is available that indicates fugitive emissions are significant, they should be reported and well documented.

**DEVELOPING A CONSISTENT TIME SERIES**

<sup>31</sup> HCFC-22 is used as a refrigerant in several different applications, as a blend component in foam blowing, and as a chemical feedstock for manufacturing synthetic polymers.

Emission of HFC-23 from HCFC-22 production should be estimated using the same method for the entire time series. If data for any years in the time series are unavailable for the Tier 2 method, these gaps should be filled according to the guidance in *Appendix 3*.

#### **UNCERTAINTY ASSESSMENT**

The Tier 2 method is significantly more accurate than the Tier 1 default method. Regular Tier 2 sampling of the vent stream can achieve an accuracy of 1-2% at a 95% confidence level in HFC-23 emissions.

#### **3.8.2 Reporting and documentation**

It is *good practice* to document and archive all information required to produce the emissions inventory estimates as outlined in *Appendix 2*, Section 8.10.1, Internal Documentation and Archiving.

Some examples of specific documentation and reporting relevant to this source category are provided below:

To provide for completely transparent reporting, emissions of HFC-23 from HCFC-22 production should be reported as a separate item, rather than included with other HFC emissions.

Documentation should also include:

- (i) Methodological description;
- (ii) Number of HCFC-22 plants;
- (iii) HCFC-22 production (if multiple producers);
- (iv) Presence of abatement technology;
- (v) Emission factors.

#### **3.8.3 Inventory quality assurance/quality control (QA/QC)**

Quality control checks as outlined in Chapter 8, Section 8.7, Source Category-specific QC Procedures (Tier 2)(see *Appendix 2*), and quality assurance procedures are applicable. In addition to the guidance in *Appendix 2*, specific procedures of relevance to this sub-source category are outlined below:

##### **Direct emission measurement check**

Verification should confirm that internationally recognised, standard methods were used for plant measurements. If the measurement practices fail this criterion, then the use of these emissions data should be carefully evaluated. It is also possible that, where a high standard of measurement and QA/QC is in place at sites, the uncertainty of the emissions estimates may be revised downwards.

Each plant's QA/QC process should be evaluated to assess if the number of samples and the frequency of sample collection is appropriate given the variability in the process itself.

Where possible, all measured and calculated data should be verified by comparison with other systems of measurement or calculation. For example, emissions measurement within the process itself can be verified periodically with measurement of the vent stream. Inventory agencies should verify abatement system utilisation and efficiency.

## **Appendix 2. Extract of IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, Chapter 8, Quality Assurance and Quality Control**

### **8.7 SOURCE CATEGORY-SPECIFIC QC PROCEDURES (TIER 2)**

In contrast to general inventory QC techniques, source category-specific QC procedures are directed at specific types of data used in the methods for individual source categories and require knowledge of the emission source category, the types of data available and the parameters associated with emissions.

It is important to note that Tier 2 source category-specific QC activities are in addition to the general QC conducted as part of Tier 1 (i.e. include QC checks listed in Table 8.1). The source category-specific measures are applied on a case-by-case basis focusing on *key source categories* (see Chapter 7, Methodological Choice and Recalculation) and on source categories where significant methodological and data revisions have taken place. It is *good practice* that inventory agencies applying higher tier methods in compiling national inventories utilise Tier 2 QC procedures. Specific applications of source category-specific Tier 2 QC procedures are provided in the energy, agriculture, industrial processes and waste chapters of this report (Chapters 2 to 5).

Source category-specific QC activities include the following:

- Emission data QC;
- Activity data QC;
- QC of uncertainty estimates.

The first two activities relate to the types of data used to prepare the emissions estimates for a given source category. QC of uncertainty estimates covers activities associated with determining uncertainties in emissions estimates (for more information on the determination of these uncertainties, see Chapter 6, Quantifying Uncertainties in Practice).

The actual QC procedures that need to be implemented by the inventory agency will depend on the method used to estimate the emissions for a given source category. If estimates are developed by outside agencies, the inventory agency may, upon review, reference the QC activities of the outside agency as part of the QA/QC plan. There is no need to duplicate QC activities if the inventory agency is satisfied that the QC activities performed by the outside agency meet the minimum requirements of the QA/QC plan.

#### **8.7.1.3 DIRECT EMISSION MEASUREMENTS**

Emissions from a source category may be estimated using direct measurements in the following ways:

Sample emissions measurements from a facility may be used to develop a representative emission factor for that individual site, or for the entire category (i.e. for development of a national level emission factor);

Continuous emissions monitoring (CEM) data may be used to compile an annual estimate of emissions for a particular process. In theory, CEM can provide a complete set of quantified emissions data across the inventory period for an individual facility process, and does not have to be correlated back to a process parameter or input variable like an emission factor.

Regardless of how direct measurement data are being used, the inventory agency should review the processes and check the measurements as part of the QC activities. Use of standard measurement methods improves the consistency of resulting data and knowledge of the statistical properties of the data. If standard reference methods for measuring specific greenhouse gas emissions (and removals) are available, inventory agencies should encourage plants to use these. If specific standard methods are not available, the inventory agency should confirm whether nationally or internationally recognised standard methods such as ISO 10012 are used for measurements and whether the measurement equipment is calibrated and maintained properly.

For example, ISO has published standards that specify procedures to quantify some of the performance characteristics of all air quality measurement methods such as bias, calibration, instability, lower detection limits, sensitivity, and upper limits of measurement (ISO, 1994). While these standards are not associated with a reference method for a specific greenhouse gas source category, they have direct application to QC activities associated with estimations based on measured emission values.

Where direct measurement data from individual sites are in question, discussions with site managers can be useful to encourage improvement of the QA/QC practices at the sites. Also, supplementary QC activities are encouraged for bottom-up methods based on site-specific emission factors where significant uncertainty remains in the estimates. Site-specific factors can be compared between sites and also to IPCC or national level defaults. Significant differences between sites or between a particular site and the IPCC defaults should elicit further review and checks on calculations. Large differences should be explained and documented.

#### **8.7.1.4 EMISSION COMPARISONS**

It is standard QC practice to compare emissions from each source category with emissions previously provided from the same source category or against historical trends and reference calculations as described below. The objective of these comparisons (often referred to as ‘reality checks’) is to ensure that the emission values are not wildly improbable or that they fall within a range that is considered reasonable. If the estimates seem unreasonable, emission checks can lead to a re-evaluation of emission factors and activity data before the inventory process has advanced to its final stages.

The first step of an emissions comparison is a consistency and completeness check using available historical inventory data for multiple years. The emission levels of most source categories do not abruptly change from year to year, as changes in both activity data and emission factors are generally gradual. In most circumstances, the change in emissions will be less than 10% per year. Thus, significant changes in emissions from previous years may indicate possible input or calculation errors. After calculating differences, the larger percentage differences (in any direction) should be flagged, by visual

inspection of the list, by visual inspection of the graphical presentation of differences (e.g. in a spreadsheet) or by using a dedicated software programme that puts flags and rankings in the list of differences.

It is *good practice* to also check the annual increase or decrease of changes in emissions levels in significant sub-source categories of some source categories. Sub-source categories may show greater percentage changes than the aggregated source categories. For example, total emissions from petrol cars are not likely to change substantially on an annual basis, but emissions from sub-source categories, such as catalyst-equipped petrol cars, may show substantial changes if the market share is not in equilibrium or if the technology is changing and rapidly being adopted in the marketplace.

It is *good practice* to check the emissions estimates for all source categories or sub-source categories that show greater than 10% change in a year compared to the previous year's inventory. Source categories and sub-source categories should be ranked according to the percentage difference in emissions from the previous year. Supplementary emission comparisons can also be performed, if appropriate, including order-of-magnitude checks and reference calculations.

### 8.7.2 Activity data QC

The estimation methods for many source categories rely on the use of activity data and associated input variables that are not directly prepared by the inventory agency. Activity data is normally collated at a national level using secondary data sources or from site-specific data prepared by site or plant personnel from their own measurements. Inventory agencies should take into account the practical considerations discussed above when determining the level of QC activities to undertake.

#### 8.7.2.2 SITE-SPECIFIC ACTIVITY DATA

Some methods rely on the use of site-specific activity data used in conjunction with IPCC default or country-specific emission factors. Site or plant personnel typically prepare these estimates of activity, often for purposes other than as inputs to emissions inventories. QC checks should focus on inconsistencies between sites to establish whether these reflect errors, different measurement techniques, or real differences in emissions, operating conditions or technology.

A variety of QC checks can be used to identify errors in site-level activity data. The inventory agency should establish whether recognised national or international standards were used in measuring activity data at the individual sites. If measurements were made according to recognised national or international standards and a QA/QC process is in place, the inventory agency should satisfy itself that the QA/QC process at the site is acceptable under the inventory QA/QC plan and at least includes Tier 1 activities. Acceptable QC procedures in use at the site may be directly referenced. If the measurements were not made using standard methods and QA/QC is not of an acceptable standard, then the use of these activity data should be carefully evaluated, uncertainty estimates reconsidered, and qualifications documented. Comparisons of activity data from different reference sources may also be used to expand the activity data QC. For example, in estimating PFC emissions from primary aluminium smelting, many inventory agencies use smelter-specific activity data to prepare the inventory estimates. A QC check of the aggregated activity data from all aluminium smelters can be made against national production statistics for the industry. Also, production data can be compared across different sites, possibly with adjustments made for plant capacities, to evaluate the reasonableness of the production data. Similar comparisons of activity data can be made for other manufacturing-based source categories where there are published data on national production. If outliers are identified, they should be investigated to determine if the difference can be explained by the unique characteristics of the site or there is an error in the reported activity.

### 8.7.3 QC of uncertainty estimates

It is *good practice* for QC procedures to be applied to the uncertainty estimations to confirm that calculations are correct and that there is sufficient documentation to duplicate them. The assumptions on which uncertainty estimations have been based should be documented for each source category. Calculations of source category-specific and aggregated uncertainty estimates should be checked and any errors addressed. For uncertainty estimates involving expert judgement, the qualifications of experts should also be checked and documented, as should the process of eliciting expert judgement, including information on the data considered, literature references, assumptions made and scenarios considered.

#### 8.10.1 Internal documentation and archiving

As part of general QC procedures, it is *good practice* to document and archive all information required to produce the national emissions inventory estimates. This includes:

- Assumptions and criteria for selection of activity data and emission factors;
- Emission factors used, including references to the IPCC document for default factors or to published references or other documentation for emission factors used in higher tier methods;
- Activity data or sufficient information to enable activity data to be traced to the referenced source;
- Information on the uncertainty associated with activity data and emission factors;
- Rationale for choice of methods;
- Methods used, including those used to estimate uncertainty;
- Changes in data inputs or methods from previous years;
- Identification of individuals providing expert judgement for uncertainty estimates and their qualifications to do so;
- Details of electronic databases or software used in production of the inventory, including versions, operating manuals, hardware requirements and any other information required to enable their later use;
- Worksheets and interim calculations for source category estimates and aggregated estimates and any re-calculations of previous estimates;
- Final inventory report and any analysis of trends from previous years;
- QA/QC plans and outcomes of QA/QC procedures.

## APPROVED

It is *good practice* for inventory agencies to maintain this documentation for every annual inventory produced and to provide it for review. It is *good practice* to maintain and archive this documentation in such a way that every inventory estimate can be fully documented and reproduced if necessary. Inventory agencies should ensure that records are unambiguous; for example, a reference to 'IPCC default factor' is not sufficient. A full reference to the particular document (e.g. *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*) is necessary in order to identify the source of the emission factor because there may have been several updates of default factors as new information has become available. Records of QA/QC procedures are important information to enable continuous improvement to inventory estimates. It is *good practice* for records of QA/QC activities to include the checks/audits/reviews that were performed, when they were performed, who performed them, and corrections and modifications to the inventory resulting from the QA/QC activity.

**Appendix 3. Extract of IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, Chapter 7 Methodological Choice and Recalculation**

**7.3.2.2 ALTERNATIVE RECALCULATION TECHNIQUES**

Several alternative recalculation techniques are available if full recalculation using the same method is not possible. Each technique is appropriate in certain situations, as determined by considerations such as data availability and the nature of the methodological modification. Selecting an alternative technique requires evaluating the specific circumstances, and determining the best option for the particular case.

The principal approaches for inventory recalculations are summarised in Table 7.5 below and described in more detail below. These approaches can be applied at the level of the method (in the case of a methodological change) or at the level of the underlying data (in the case of a methodological refinement).

**TABLE 7.5: SUMMARY OF APPROACHES TO RECALCULATIONS**

Approach	Applicability	Comments
Overlap	Data necessary to apply both the previously used and the new method must be available for at least one year.	Most reliable when the overlap between two or more sets of annual emissions estimates can be assessed. If the relationship observed using the two methods is inconsistent, the recalculation should be based on two or more annual emissions estimates. If the emission trends observed using the previously used and new methods are inconsistent and random, this approach is not <i>good practice</i> .
Surrogate Method	Emission factors or activity data used in the new method are strongly correlated with other well-known and more readily available indicative data.	Multiple indicative data sets (singly or in combination) should be tested in order to determine the most strongly correlated. Should not be done for long periods.
Interpolation	Data needed for recalculation using the new method are available for intermittent years during the time series.	Emissions estimates can be linearly interpolated for the periods when the new method cannot be applied.
Trend Extrapolation	Data for the new method are not collected annually and are not available at the beginning or the end of the time series.	Most reliable if the trend over time is constant. Should not be used if the trend is changing (in this case, the surrogate method may be more appropriate). Should not be done for long periods.

**OVERLAP**

When a method is changed or modified, the estimates prepared using both the previously used and the new method should be compared in terms of the level and the trend. If the new method cannot be used for all years, it may be possible to develop a time series based on the relationship (or overlap) observed between the two methods during the years when both can be used. Essentially, the time series is constructed by assuming that there is a consistent relationship between the results of the previously used and new method. The emissions estimates for those years when the new method cannot be used directly are developed by proportionally adjusting the previously developed emissions estimates, based on the relationship observed during the period of overlap. The overlap method is most commonly used when there is a proportional relationship between the two methods.

In this case, the emissions associated with the new method are estimated according to Equation 7.5:

**EQUATION 7.5**

$$y_0 = x_0 \left( \frac{\sum y_i (m \text{ to } n)}{\sum x_i (m \text{ to } n)} \right)$$

Where:

$y_0$  is the recalculated emission estimate computed using the overlap method

$x_0$  is the estimate developed using the previously used method

$\sum y_i$  and  $\sum x_i$  are the estimates prepared using the new and previously used methods during the period of overlap, as denoted by years  $m$  through  $n$

A relationship between the previously used and new methods can be evaluated by comparing the overlap between only one set of annual emissions estimates, but it is preferable to compare multiple years. This is because comparing only one year may lead to bias and it is not possible to evaluate trends. Other relationships between the old and new estimates may also be observed through an assessment of overlap. For example, a constant difference may be observed. In this case, the emissions associated with the new method are estimated by adjusting the previous estimate by the constant amount. For more information on the overlap method of recalculating (which can also be called ‘splicing methodologies’), refer to Annex 1, Conceptual Basis for Uncertainty Analysis.

**SURROGATE METHOD**

The surrogate method relates emissions estimates to underlying activity or other indicative data. Changes in these data are used to simulate the trend in emissions. The estimate should be related to the statistical data source that best explains the time variations of the emission source category. For example, mobile source emissions may be related to trends in vehicle distances travelled, emissions from domestic wastewater may be related to population, and industrial emissions may be related to production levels in the relevant industry.

In its simplest form, the emissions estimate will be related to a single type of data as shown in Equation 7.6:

**EQUATION 7.6**

$$y_t = y_0 (s_t / s_0)$$

Where:

y is the emission estimate in years 0 and t

s is the surrogate statistical parameter in years 0 and t

In some cases, more accurate relationships may be developed by relating emissions to more than one statistical parameter. Regression analysis may be useful in selecting the appropriate surrogate data parameters. Using surrogate methods to estimate otherwise unavailable data can improve the accuracy of estimates developed by the interpolation and trend extrapolation approaches discussed below.

**INTERPOLATION**

In some cases it may be possible to apply a method intermittently throughout the time series. For example, necessary detailed statistics may only be collected every few years, or it may be impractical to conduct detailed surveys on an annual basis. In this case, estimates for the intermediate years in the time series can be developed by interpolating between the detailed estimates. If information on the general trends or underlying parameters is available, then the surrogate method is preferable.

**TREND EXTRAPOLATION**

When detailed estimates have not been prepared for the base year or the most recent year in the inventory, it may be necessary to extrapolate from the closest detailed estimate. Extrapolation can be conducted either forward (to estimate more recent emissions) or backward (to estimate a base year). Trend extrapolation simply assumes that the observed trend in emissions during the period when detailed estimates are available remains constant over the period of extrapolation. Given this assumption, it is clear that trend extrapolation should not be used if the emission growth trend is not constant over time. Extrapolation should also not be used over long periods of time without detailed checks at intervals to confirm the continued validity of the trend.

**SPECIFIC SITUATIONS**

In some cases, it may be necessary to develop a customised approach in order to best estimate the emissions over time. For example, the standard alternatives may not be valid when technical conditions are changing throughout the time series (e.g. due to the introduction of mitigation technology). In this case, revised emission factors may be needed and it will also be necessary to carefully consider the trend in the factors over the period. Where customised approaches are used, it is *good practice* to document them thoroughly, and in particular to give special consideration to how the resultant emissions estimates compare to those that would be developed using the more standard alternatives.

**7.3.3 Documentation**

Clear documentation of recalculations is essential for transparent emissions estimates, and to demonstrate that the recalculation is an improvement in accuracy and completeness. In general, the following information should be provided whenever recalculations are undertaken:

The effect of the recalculations on the level and trend of the estimate (by providing the estimates prepared using both the previously used and new methods);

The reason for the recalculation (see Section 7.3.1, Reason for Recalculations);

A description of the changed or refined method;

Justification for the methodological change or refinement in terms of an improvement in accuracy, transparency, or completeness;

The approach used to recalculate previously submitted estimates;

The rationale for selecting the approach which should include a comparison of the results obtained using the selected approach and other possible alternatives, ideally including a simple graphical plot of emissions vs. time or relevant activity data or both.

## Protocol C2: Measurement of HFC emissions from the use of refrigeration from the manufacture of HF, CTF, HCFC-22, HFC-125 and HFC-134a

The methodology is based on *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* developed and published by IPCC. The most apposite section of this deals with emission of HFCs from Stationary Refrigeration and an extract of the *Guidance* on this topic is in Appendix 1.

At the outset, the complete process should be examined, with a view to:

1. Assigning its external boundaries - the "total box" - generally the whole area over which the proprietor has management control,
2. Assigning internal boundaries; generally the management accounting subdivisions within which data that will be useful to the inventory is collected in the normal course of operations,
3. Establishing the physical sources of each emission and
4. their approximate relative sizes, in order to prioritise resources, recognising that an "emission" in this context is weighted by the GWP of the constituent gases.<sup>32</sup>

All emissions need to be considered at this stage, not only the current absolute values but their trends too. This should enable rational decisions on the materiality of each source to be taken at an early stage, avoiding waste of effort.

Emissions of HFCs and PFCs are gaseous; either directly from leaks discharging to atmosphere or indirectly as components of aqueous, liquid or solid waste. HFCs are sufficiently volatile to be released into the atmosphere by vaporisation and degassing from waste that enters the environment.

The preferred methodology can be described as "top-down" and "**Tier 2**" (as described in Appendix 1). In this it is assumed that any refrigerant fluid that is added to the system during its operational life is, in effect, replacing fluid already lost to atmosphere. The physical losses are therefore accounted by the quantity recharged and the quantity lost on disposal. The "bottom-up" methodology, in which losses are related to a series of default emission factors, is also described in Appendix 1. This is an inferior accounting method that will result, almost certainly, in uncertainties that are significantly higher than the "top-down" method and its use in establishing emissions inventories sufficiently accurately to underpin Emissions Trading is questionable. However, it may be applied using the descriptions and factors outlined in Appendix 1.

In all cases, the combined releases from the total box (established in 1.) should be reported as quantities of each individual HFC or PFC, together with the uncertainty of the estimate by that method. The estimate with the smallest uncertainty should generally be used but those having larger uncertainty may have value in verification.

All measurements and estimates must be adequately documented with a clear and auditable provenance in process records (see Appendix 2). This is particularly important when changes in process operation, conditions or measurement parameters give rise to a significant change in emissions. Where the emission involves a third party (for example a maintenance contractor), the documentation of the third party must provide the information required and must be capable of being audited.

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<sup>32</sup> Information concerning both 2.3 and 2.4 should be readily available from the Company's submissions under IPC legislation.

**Tier 2**

This method depends on records of the quantity contained in the equipment, annual usage for recharging and losses on disposal. For each component in the refrigeration system, annual loss is the net annual use (difference in the year between refrigerant introduced during servicing and refrigerant recovered for re-use or disposal) plus the change in inventory in the refrigeration system (difference between the charge at the beginning and end of the period). In most circumstances the charge could be assumed to remain constant throughout the service life of the system so that the emission accounted by this method is the difference between the initial charge and the quantity recovered when the system is finally scrapped. The equation below describes the case where the system is in continuing operation (first box) and at the end of its service life (second box).

For each refrigeration system, for each Component, Emission = Quantity purchased within the year for servicing - Quantity recovered within the year from the charge

$$E_{Z,i} = A_{Z,i}$$

Where:

$E_{Z,i}$  = mass emission of component **i** from refrigeration system **Z**,

$A_{Z,i}$  = net annual use (purchases less quantities recovered) of refrigerant component **i** in refrigeration system **Z**.

For each refrigeration system, for each Component, Emission = Quantity purchased within the year for servicing - Quantity recovered within the year from the charge + Original Charge - Quantity recovered on Disposal

$$E_{Z,i} = A_{Z,i} + F_{Z,i} - D_{Z,i}$$

Where:

$E_{Z,i}$  = mass emission of component **i** from refrigeration system **Z**,

$A_{Z,i}$  = net annual use (purchases less quantities recovered) of refrigerant component **i** in refrigeration system **Z**,

$F_{Z,i}$  = quantity of refrigerant component **i** originally contained in refrigeration system **Z** and

$D_{Z,i}$  = quantity of refrigerant component **i** recovered at disposal of system **Z**.

In cases where the recovery on disposal is not known, the default is zero; equivalent to total loss of the original charge.

The total emission of each component from all refrigeration systems within the management boundary is the arithmetic sum of all mass emissions of that component from all of the refrigeration systems.

Uncertainty in the estimate of total emission of each component from each system is the combined uncertainty of all of the emissions considered.

Combined uncertainty = Square root of [Square of uncertainty in Annual use + Square of uncertainty in Original Fill + Square of uncertainty in Quantity recovered at Disposal]

$$U_{Z,i} = \sqrt{(U_{A_{Z,i}})^2 + (U_{F_{Z,i}})^2 + (U_{D_{Z,i}})^2}$$

Where:

$U_{Z,i}$ ,  $U_{Azi}$ ,  $U_{Fzi}$  and  $U_{Dz}$  are uncertainties of component  $i$  in, respectively, the emission from system  $Z$ , the annual use, the original fill and the quantity recovered on disposal.

The overall uncertainty for each component in the sum of all refrigeration emissions from the process is the root square sums of the combined uncertainties that were calculated using the equation below.

Total uncertainty of Emission of each Component = Square root of [Square of Uncertainty of Emission from System 1 + Square of Uncertainty of Emission from System 2 +.....(up to the total number of systems in the study)]

$$U_{E,i} = \sqrt{(\sum U_{Z,i}^2)}$$

In this case, the calculation of uncertainty for individual components is valid.

### Application to Ineos Fluor Rocksavage Site

The process over which Ineos Fluor has management control encompasses the plants producing: HF, CTF, HCFC-22, HFC-125 and HFC-134a, together with the physical movement of products to the customers, which is contracted out.

Refrigeration equipment is part of the operating process in many of the plants and should be considered as potential sources of greenhouse gas emissions. Usage of fluids should be available from process records and purchases. If not, then default values from the *Guidance* should be used. The range of these is shown in Table 3.22 and the values that are typical for systems operated by the Company should be chosen from within the ranges.

The data requirements and calculated emissions and their uncertainties have been set out as Excel spreadsheets. These are attached in Appendix 4. It is anticipated that these, together with a set of references to source documentation will form the substance of the inventory of greenhouse gases from process operations.

Documentation of assumptions, insertion of missing data and mechanisms to cope with changes in the methods of calculating emissions are described in the *Guidance*, extracted in Appendices 1 to 3, and so the instructions are not duplicated here.

**Appendix 1. Extract of Industrial Processes Chapter 3, edited.**  
*IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*

**3.7.4 Stationary refrigeration sub-source category**

**3.7.4.1 Methodological issues**

1.1.1.1.1 CHOICE OF METHOD

The Tier 2 approach in the *IPCC Guidelines* is based on calculating emissions from assembly, operation, and disposal of stationary refrigeration equipment. The general equation is shown below:

**EQUATION 3.39**

Total Emissions = Assembly Emissions + Operation Emissions + Disposal Emissions

*Assembly emissions* include the emissions associated with product manufacturing, even if the products are eventually exported.

*Operation emissions* include annual leakage from equipment stock in use as well as servicing emissions. This calculation should include all equipment units in the country, regardless of where they were manufactured.

*Disposal emissions* include the amount of refrigerant released from scrapped systems. As with operation emissions, they should include all equipment units in the country where they were scrapped, regardless of where they were manufactured.

*Good practice* is to implement a top-down Tier 2 approach, using annual sales of refrigerant. The alternative approach, using bottom-up equipment data and multiple emission factors, is much more data intensive and is unlikely to improve accuracy, but it is still *good practice* under certain national circumstances. Table 3.22, Best Estimates (expert judgement) for Charge, Lifetime and Emission Factors for Stationary Refrigeration Equipment, describes the emission factors for the top-down and bottom-up approaches and the improvements to the default data in the Tier 2 method.

**Top-down approach**

For the top-down approach, the three emission stages are combined into the following simplified equation:

**EQUATION 3.40**

Emissions = (Annual Sales of New Refrigerant) - (Total Charge of New Equipment) + (Original Total Charge of Retiring Equipment) - (Amount of Intentional Destruction)

*Annual Sales of New Refrigerant* is the amount of a chemical introduced into the refrigeration sector in a particular country in a given year. It includes all the chemical used to fill or refill equipment, whether the chemical is charged into equipment at the factory, charged into equipment after installation, or used to recharge equipment at servicing. It does not include recycled chemical.

*Total Charge of New Equipment* is the sum of the full charges of all the new equipment that is sold in the country in a given year. It includes both the chemical required to fill equipment in the factory and the chemical required to fill the equipment after installation. It does not include charging emissions or chemical used to recharge equipment at servicing.

*Original Total Charge of Retiring Equipment* is the sum of the original full charges of all the equipment that are retired in the country in a given year. It includes both the chemical that was originally required to fill equipment in the factory and the chemical that was originally required to fill the equipment after installation. It does not include charging emissions or chemical used to recharge equipment at servicing.

By using data on current and historical sales of gas, rather than emission factors referenced from literature, the equation reflects assembly, operation, and disposal emissions at the time and place where they occur. Default emission factors are likely to be inaccurate because emissions rates may vary considerably from installation to installation.

## CHOICE OF EMISSION FACTORS

### Top-down approach (sales-based)

As this approach is based on chemical sales and not equipment leak rates, it does not require the use of emission factors.

### Bottom-up approach

*Good practice* for choosing bottom-up emission factors is to use factory-specific data, based on information provided by equipment manufacturers, service providers, and disposal companies. When data are unavailable, inventory compilers should use the default emission factors shown in Table 3.22, Best Estimates (expert judgement) for Charge, Lifetime and Emission Factors for Stationary Refrigeration Equipment, which summarises best estimates of equipment charge, lifetime, and emission factors. These default values reflect the current state of knowledge about the industry, and are provided as ranges rather than point estimates. Compilers should choose from the range according to factory-specific conditions, and document the reasons for their choices. If bottom-up data cannot be broken down into the equipment classes as in Table 3.21, Good Practice Documentation for Stationary Refrigeration, it is *good practice* to use expert judgement to estimate the relative share of each type of equipment, and choose default emission factors appropriate to the most common types of equipment (see Chapter 6, Quantifying Uncertainties in Practice, Section 6.2.5, Expert Judgement).

## DEVELOPING A CONSISTENT TIME SERIES

Emissions from stationary refrigeration should be calculated using the same method and data sources for every year in the time series. Where consistent data are unavailable for the more rigorous method for any years in the time series, these gaps should be recalculated according to the guidance provided in Chapter 7, Methodological Choice and Recalculation, Section 7.3.2.2, Alternative Recalculation Techniques.

## UNCERTAINTY ASSESSMENT

Table 3.22, Best Estimates (expert judgement) for Charge, Lifetime and Emission Factors for Stationary Refrigeration Equipment, presents emission factor ranges that highlight the uncertainty associated with this sector. Generally, bottom-up actual methods that rely on emission factors have more uncertainty than top-down methods that use chemical sales data. Inventory agencies should seek industrial advice on uncertainties, using the approaches to obtaining expert judgements outlined in Chapter 6, Quantifying Uncertainties in Practice.

### 3.7.4.2 Reporting and documentation

The supporting information necessary to ensure transparency in reported emissions estimates is shown in *Appendix 4*.

### 3.7.4.3 Inventory quality assurance/quality control (QA/QC)

It is *good practice* to conduct quality control checks as outlined in Chapter 8, Quality Assurance and Quality Control, Table 8.1, Tier 1, General Inventory Level QC Procedures, and an expert review of the emissions estimates. Additional quality control checks as outlined in Chapter 8, Section 8.7, Source Category-specific QC Procedures (Tier 2), and quality assurance procedures may also be applicable, particularly if higher tier methods are used to determine emissions from this source category. Compilers are encouraged to use higher tier QA/QC for *key source categories* as identified in Chapter 7, Methodological Choice and Recalculation. In addition to the guidance in Chapter 8, Quality Assurance and Quality Control, specific procedures of relevance to this sub-source category are outlined as follows:

If the bottom-up approach has been used, a simplified top-down approach will enable a cross-check of the final emission estimate.

It is particularly important to check the accuracy of emission factors used in the bottom-up method with top-down data, since emission factors are likely to have the highest associated uncertainty.

This technique will also minimise the possibility that certain end-uses will not be accounted for. This is similar to the 'Reference Approach' calculation in the Energy Sector. The combination uses the simple top-down approach as a cross-check of a more detailed technology and application-based method.

**TABLE 3.22**  
**BEST ESTIMATES (EXPERT JUDGEMENT) FOR CHARGE, LIFETIME AND EMISSION FACTORS FOR STATIONARY REFRIGERATION EQUIPMENT**

Application	Charge (kg)	Lifetimes (years)	Emission Factors (% of initial charge/year)		
			(k)	(x)	(z)
Factor in Equation	(Eicharge )	(n)	Initial Emission	Lifetime Emission	End-of-Life Emission (recovery efficiency)
Domestic Refrigeration	$0.05 \leq c \leq 0.5$	$12 \leq t \leq 15$	$0.2 \leq e \leq 1$	$0.1 \leq e \leq 0.5$	70% of remainder
Stand-alone Commercial Applications	$0.2 \leq c \leq 6$	$8 \leq t \leq 12$	$0.5 \leq e \leq 3$	$1 \leq e \leq 10$	$70 \leq r \leq 80\%$ of remainder
Medium & Large Commercial Refrigeration	$50 \leq c \leq 2000$	$7 \leq t \leq 10$	$0.5 \leq e \leq 3$	$10 \leq e \leq 30$	$80 \leq r \leq 90\%$ of remainder
Transport Refrigeration	$3 \leq c \leq 8$	$6 \leq t \leq 9$	$0.2 \leq e \leq 1$	$15 \leq e \leq 50$	$70 \leq r \leq 80\%$ of remainder
Industrial Refrigeration including Food Processing and Cold Storage	$10 \leq c \leq 10K$	$10 \leq t \leq 20$	$0.5 \leq e \leq 3$	$7 \leq e \leq 25$	$80 \leq r \leq 90\%$ of remainder
Chillers	$10 \leq c \leq 2000$	$10 \leq t \leq 30$	$0.2 \leq e = 1$	$2 \leq e \leq 15$	$80 \leq r \leq 95\%$ of remainder
Residential and Commercial A/C, including Heat Pumps	$0.5 \leq c \leq 100$	$10 \leq t \leq 15$	$0.2 \leq e \leq 1$	$1 \leq e \leq 5$	$70 \leq r \leq 80\%$ of remainder

Note: Distribution Losses = 2 to 10% of annual sales of refrigerant (heel left in the tanks from and losses during transfer (ICF 1998). Analysis of Refrigerant Emissions Resulting from Improper Disposal of 30-lb Cylinders. Prepared by ICF Incorporated, Washington, DC. June 2, 1998).

It should be noted that each country will use its own national data when preparing its national greenhouse gas inventory.

Source: Clodic (1999).

## **Appendix 2. Extract of IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, Chapter 8, Quality Assurance and Quality Control**

### **8.7 SOURCE CATEGORY-SPECIFIC QC PROCEDURES (TIER 2)**

In contrast to general inventory QC techniques, source category-specific QC procedures are directed at specific types of data used in the methods for individual source categories and require knowledge of the emission source category, the types of data available and the parameters associated with emissions.

It is important to note that Tier 2 source category-specific QC activities are in addition to the general QC conducted as part of Tier 1 (i.e. include QC checks listed in Table 8.1). The source category-specific measures are applied on a case-by-case basis focusing on *key source categories* (see Chapter 7, Methodological Choice and Recalculation) and on source categories where significant methodological and data revisions have taken place. It is *good practice* that inventory agencies applying higher tier methods in compiling national inventories utilise Tier 2 QC procedures. Specific applications of source category-specific Tier 2 QC procedures are provided in the energy, agriculture, industrial processes and waste chapters of this report (Chapters 2 to 5).

Source category-specific QC activities include the following:

- Emission data QC;
- Activity data QC;
- QC of uncertainty estimates.

The first two activities relate to the types of data used to prepare the emissions estimates for a given source category. QC of uncertainty estimates covers activities associated with determining uncertainties in emissions estimates (for more information on the determination of these uncertainties, see Chapter 6, Quantifying Uncertainties in Practice).

The actual QC procedures that need to be implemented by the inventory agency will depend on the method used to estimate the emissions for a given source category. If estimates are developed by outside agencies, the inventory agency may, upon review, reference the QC activities of the outside agency as part of the QA/QC plan. There is no need to duplicate QC activities if the inventory agency is satisfied that the QC activities performed by the outside agency meet the minimum requirements of the QA/QC plan.

#### **8.7.1.3 DIRECT EMISSION MEASUREMENTS**

Emissions from a source category may be estimated using direct measurements in the following ways:

Sample emissions measurements from a facility may be used to develop a representative emission factor for that individual site, or for the entire category (i.e. for development of a national level emission factor);

Continuous emissions monitoring (CEM) data may be used to compile an annual estimate of emissions for a particular process. In theory, CEM can provide a complete set of quantified emissions data across the inventory period for an individual facility process, and does not have to be correlated back to a process parameter or input variable like an emission factor.

Regardless of how direct measurement data are being used, the inventory agency should review the processes and check the measurements as part of the QC activities. Use of standard measurement methods improves the consistency of resulting data and knowledge of the statistical properties of the data. If standard reference methods for measuring specific greenhouse gas emissions (and removals) are available, inventory agencies should encourage plants to use these. If specific standard methods are not available, the inventory agency should confirm whether nationally or internationally recognised standard methods such as ISO 10012 are used for measurements and whether the measurement equipment is calibrated and maintained properly.

For example, ISO has published standards that specify procedures to quantify some of the performance characteristics of all air quality measurement methods such as bias, calibration, instability, lower detection limits, sensitivity, and upper limits of measurement (ISO, 1994). While these standards are not associated with a reference method for a specific greenhouse gas source category, they have direct application to QC activities associated with estimations based on measured emission values.

Where direct measurement data from individual sites are in question, discussions with site managers can be useful to encourage improvement of the QA/QC practices at the sites. Also, supplementary QC activities are encouraged for bottom-up methods based on site-specific emission factors where significant uncertainty remains in the estimates. Site-specific factors can be compared between sites and also to IPCC or national level defaults. Significant differences between sites or between a particular site and the IPCC defaults should elicit further review and checks on calculations. Large differences should be explained and documented.

#### **8.7.1.4 EMISSION COMPARISONS**

It is standard QC practice to compare emissions from each source category with emissions previously provided from the same source category or against historical trends and reference calculations as described below. The objective of these comparisons (often referred to as ‘reality checks’) is to ensure that the emission values are not wildly improbable or that they fall within a range that is considered reasonable. If the estimates seem unreasonable, emission checks can lead to a re-evaluation of emission factors and activity data before the inventory process has advanced to its final stages.

The first step of an emissions comparison is a consistency and completeness check using available historical inventory data for multiple years. The emission levels of most source categories do not abruptly change from year to year, as changes in both activity data and emission factors are generally gradual. In most circumstances, the change in emissions will be less than 10% per year. Thus, significant changes in emissions from previous years may indicate possible input or calculation errors. After calculating differences, the larger percentage differences (in any direction) should be flagged, by visual

inspection of the list, by visual inspection of the graphical presentation of differences (e.g. in a spreadsheet) or by using a dedicated software programme that puts flags and rankings in the list of differences.

It is *good practice* to also check the annual increase or decrease of changes in emissions levels in significant sub-source categories of some source categories. Sub-source categories may show greater percentage changes than the aggregated source categories. For example, total emissions from petrol cars are not likely to change substantially on an annual basis, but emissions from sub-source categories, such as catalyst-equipped petrol cars, may show substantial changes if the market share is not in equilibrium or if the technology is changing and rapidly being adopted in the marketplace.

It is *good practice* to check the emissions estimates for all source categories or sub-source categories that show greater than 10% change in a year compared to the previous year's inventory. Source categories and sub-source categories should be ranked according to the percentage difference in emissions from the previous year. Supplementary emission comparisons can also be performed, if appropriate, including order-of-magnitude checks and reference calculations.

### 8.7.2 Activity data QC

The estimation methods for many source categories rely on the use of activity data and associated input variables that are not directly prepared by the inventory agency. Activity data is normally collated at a national level using secondary data sources or from site-specific data prepared by site or plant personnel from their own measurements. Inventory agencies should take into account the practical considerations discussed above when determining the level of QC activities to undertake.

#### 8.7.2.2 SITE-SPECIFIC ACTIVITY DATA

Some methods rely on the use of site-specific activity data used in conjunction with IPCC default or country-specific emission factors. Site or plant personnel typically prepare these estimates of activity, often for purposes other than as inputs to emissions inventories. QC checks should focus on inconsistencies between sites to establish whether these reflect errors, different measurement techniques, or real differences in emissions, operating conditions or technology.

A variety of QC checks can be used to identify errors in site-level activity data. The inventory agency should establish whether recognised national or international standards were used in measuring activity data at the individual sites. If measurements were made according to recognised national or international standards and a QA/QC process is in place, the inventory agency should satisfy itself that the QA/QC process at the site is acceptable under the inventory QA/QC plan and at least includes Tier 1 activities. Acceptable QC procedures in use at the site may be directly referenced. If the measurements were not made using standard methods and QA/QC is not of an acceptable standard, then the use of these activity data should be carefully evaluated, uncertainty estimates reconsidered, and qualifications documented. Comparisons of activity data from different reference sources may also be used to expand the activity data QC. For example, in estimating PFC emissions from primary aluminium smelting, many inventory agencies use smelter-specific activity data to prepare the inventory estimates. A QC check of the aggregated activity data from all aluminium smelters can be made against national production statistics for the industry. Also, production data can be compared across different sites, possibly with adjustments made for plant capacities, to evaluate the reasonableness of the production data. Similar comparisons of activity data can be made for other manufacturing-based source categories where there are published data on national production. If outliers are identified, they should be investigated to determine if the difference can be explained by the unique characteristics of the site or there is an error in the reported activity.

### 8.7.3 QC of uncertainty estimates

It is *good practice* for QC procedures to be applied to the uncertainty estimations to confirm that calculations are correct and that there is sufficient documentation to duplicate them. The assumptions on which uncertainty estimations have been based should be documented for each source category. Calculations of source category-specific and aggregated uncertainty estimates should be checked and any errors addressed. For uncertainty estimates involving expert judgement, the qualifications of experts should also be checked and documented, as should the process of eliciting expert judgement, including information on the data considered, literature references, assumptions made and scenarios considered.

#### 8.10.1 Internal documentation and archiving

As part of general QC procedures, it is *good practice* to document and archive all information required to produce the national emissions inventory estimates. This includes:

- Assumptions and criteria for selection of activity data and emission factors;
- Emission factors used, including references to the IPCC document for default factors or to published references or other documentation for emission factors used in higher tier methods;
- Activity data or sufficient information to enable activity data to be traced to the referenced source;
- Information on the uncertainty associated with activity data and emission factors;
- Rationale for choice of methods;
- Methods used, including those used to estimate uncertainty;
- Changes in data inputs or methods from previous years;
- Identification of individuals providing expert judgement for uncertainty estimates and their qualifications to do so;
- Details of electronic databases or software used in production of the inventory, including versions, operating manuals, hardware requirements and any other information required to enable their later use;
- Worksheets and interim calculations for source category estimates and aggregated estimates and any re-calculations of previous estimates;
- Final inventory report and any analysis of trends from previous years;
- QA/QC plans and outcomes of QA/QC procedures.

It is *good practice* for inventory agencies to maintain this documentation for every annual inventory produced and to provide it for review. It is *good practice* to maintain and archive this documentation in such a way that every inventory estimate can be fully documented and reproduced if necessary. Inventory agencies should ensure that records are unambiguous; for example, a reference to 'IPCC default factor' is not sufficient. A full reference to the particular document (e.g. *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*) is necessary in order to identify the source of the emission factor because there may have been several updates of default factors as new information has become available. Records of QA/QC procedures are important information to enable continuous improvement to inventory estimates. It is *good practice* for records of QA/QC activities to include the checks/audits/reviews that were performed, when they were performed, who performed them, and corrections and modifications to the inventory resulting from the QA/QC activity.

**Appendix 3. Extract of IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, Chapter 7 Methodological Choice and Recalculation**

**7.3.2.2 ALTERNATIVE RECALCULATION TECHNIQUES**

Several alternative recalculation techniques are available if full recalculation using the same method is not possible. Each technique is appropriate in certain situations, as determined by considerations such as data availability and the nature of the methodological modification. Selecting an alternative technique requires evaluating the specific circumstances, and determining the best option for the particular case.

The principal approaches for inventory recalculations are summarised in Table 7.5 below and described in more detail below. These approaches can be applied at the level of the method (in the case of a methodological change) or at the level of the underlying data (in the case of a methodological refinement).

TABLE 7.5: SUMMARY OF APPROACHES TO RECALCULATIONS

Approach	Applicability	Comments
Overlap	Data necessary to apply both the previously used and the new method must be available for at least one year.	Most reliable when the overlap between two or more sets of annual emissions estimates can be assessed. If the relationship observed using the two methods is inconsistent, the recalculation should be based on two or more annual emissions estimates. If the emission trends observed using the previously used and new methods are inconsistent and random, this approach is <i>not good practice</i> .
Surrogate Method	Emission factors or activity data used in the new method are strongly correlated with other well-known and more readily available indicative data.	Multiple indicative data sets (singly or in combination) should be tested in order to determine the most strongly correlated. Should not be done for long periods.
Interpolation	Data needed for recalculation using the new method are available for intermittent years during the time series.	Emissions estimates can be linearly interpolated for the periods when the new method cannot be applied.
Trend Extrapolation	Data for the new method are not collected annually and are not available at the beginning or the end of the time series.	Most reliable if the trend over time is constant. Should not be used if the trend is changing (in this case, the surrogate method may be more appropriate). Should not be done for long periods.

**OVERLAP**

When a method is changed or modified, the estimates prepared using both the previously used and the new method should be compared in terms of the level and the trend. If the new method cannot be used for all years, it may be possible to develop a time series based on the relationship (or overlap) observed between the two methods during the years when both can be used. Essentially, the time series is constructed by assuming that there is a consistent relationship between the results of the previously used and new method. The emissions estimates for those years when the new method cannot be used directly are developed by proportionally adjusting the previously developed emissions estimates, based on the relationship observed during the period of overlap. The overlap method is most commonly used when there is a proportional relationship between the two methods.

In this case, the emissions associated with the new method are estimated according to Equation 7.5:

**EQUATION 7.5**

$$y_0 = x_0 \left( \frac{\sum y_i (m \text{ to } n)}{\sum x_i (m \text{ to } n)} \right)$$

Where:

$y_0$  is the recalculated emission estimate computed using the overlap method

$x_0$  is the estimate developed using the previously used method

sum of  $y_i$  and  $x_i$  are the estimates prepared using the new and previously used methods during the period of overlap, as denoted by years  $m$  through  $n$

A relationship between the previously used and new methods can be evaluated by comparing the overlap between only one set of annual emissions estimates, but it is preferable to compare multiple years. This is because comparing only one year may lead to bias and it is not possible to evaluate trends. Other relationships between the old and new estimates may also be observed through an assessment of overlap. For example, a constant difference may be observed. In this case, the emissions associated with the new method are estimated by adjusting the previous estimate by the constant amount. For more information on the overlap method of recalculating (which can also be called ‘splicing methodologies’), refer to Annex 1, Conceptual Basis for Uncertainty Analysis.

### **SURROGATE METHOD**

The surrogate method relates emissions estimates to underlying activity or other indicative data. Changes in these data are used to simulate the trend in emissions. The estimate should be related to the statistical data source that best explains the time variations of the emission source category. For example, mobile source emissions may be related to trends in vehicle distances travelled, emissions from domestic wastewater may be related to population, and industrial emissions may be related to production levels in the relevant industry.

In its simplest form, the emissions estimate will be related to a single type of data as shown in Equation 7.6:

### **EQUATION 7.6**

$$y_0 = y_t (s_0 / s_t)$$

Where:

y is the emission estimate in years 0 and t

s is the surrogate statistical parameter in years 0 and t

In some cases, more accurate relationships may be developed by relating emissions to more than one statistical parameter. Regression analysis may be useful in selecting the appropriate surrogate data parameters. Using surrogate methods to estimate otherwise unavailable data can improve the accuracy of estimates developed by the interpolation and trend extrapolation approaches discussed below.

### **INTERPOLATION**

In some cases it may be possible to apply a method intermittently throughout the time series. For example, necessary detailed statistics may only be collected every few years, or it may be impractical to conduct detailed surveys on an annual basis. In this case, estimates for the intermediate years in the time series can be developed by interpolating between the detailed estimates. If information on the general trends or underlying parameters is available, then the surrogate method is preferable.

### **TREND EXTRAPOLATION**

When detailed estimates have not been prepared for the base year or the most recent year in the inventory, it may be necessary to extrapolate from the closest detailed estimate. Extrapolation can be conducted either forward (to estimate more recent emissions) or backward (to estimate a base year). Trend extrapolation simply assumes that the observed trend in emissions during the period when detailed estimates are available remains constant over the period of extrapolation. Given this assumption, it is clear that trend extrapolation should not be used if the emission growth trend is not constant over time. Extrapolation should also not be used over long periods of time without detailed checks at intervals to confirm the continued validity of the trend.

### **SPECIFIC SITUATIONS**

In some cases, it may be necessary to develop a customised approach in order to best estimate the emissions over time. For example, the standard alternatives may not be valid when technical conditions are changing throughout the time series (e.g. due to the introduction of mitigation technology). In this case, revised emission factors may be needed and it will also be necessary to carefully consider the trend in the factors over the period. Where customised approaches are used, it is *good practice* to document them thoroughly, and in particular to give special consideration to how the resultant emissions estimates compare to those that would be developed using the more standard alternatives.

#### **7.3.3 Documentation**

Clear documentation of recalculations is essential for transparent emissions estimates, and to demonstrate that the recalculation is an improvement in accuracy and completeness. In general, the following information should be provided whenever recalculations are undertaken:

The effect of the recalculations on the level and trend of the estimate (by providing the estimates prepared using both the previously used and new methods);

The reason for the recalculation (see Section 7.3.1, Reason for Recalculations);

A description of the changed or refined method;

Justification for the methodological change or refinement in terms of an improvement in accuracy, transparency, or completeness;

The approach used to recalculate previously submitted estimates;

The rationale for selecting the approach which should include a comparison of the results obtained using the selected approach and other possible alternatives, ideally including a simple graphical plot of emissions vs. time or relevant activity data or both.

## Protocol C3: Measurement of HFC and PFC emissions from industrial and commercial refrigeration

The methodology is based on *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* developed and published by IPCC. This protocol is specifically relevant to stationary refrigeration, however, it may also be applied to air-conditioning and mobile equipment.

At the outset, the emissions calculation process should be examined, with a view to establishing the physical sources of each emission and their approximate relative sizes, in order to prioritise resources. The relative size should recognise that an "emission" in this context is weighted by the GWP of the constituent gases.<sup>33</sup> All emissions need to be considered at this stage, not only the current absolute values but their trends too. This should enable rational decisions on the materiality of each source to be taken at an early stage, avoiding waste of effort.

Emissions of HFCs and PFCs are gaseous; either directly from leaks discharging to atmosphere or indirectly as components of aqueous, liquid or solid waste. HFCs are sufficiently volatile to be released into the atmosphere by vaporisation and degassing from waste that enters the environment. Global Warming Potentials from the main refrigerant gases are provided in Table 1 of this protocol.

The preferred methodology for refrigeration systems assumes that any refrigerant fluid that is added to the system during its operational life is, in effect, replacing fluid already lost to atmosphere. The physical losses are therefore accounted by the difference between the quantity added to the system and the quantity removed under control throughout the systems life.

Management Control. The Framework for the UK Emissions Trading System requires that the boundary for calculating emissions is the extent of "management control". It is argued that the refrigeration system operator has control of all emissions directly associated with system, including the disposal and recovery of any refrigerant during decommissioning. This control occurs because of the general obligation on the operator to specify to the contractor the fate of the refrigerant. This is consistent with DEFRA guidelines which state "*a direct participant could exercise dominant influence over the emissions from a source by virtue of the terms and conditions contained in the contract governing the operation of the source.*"<sup>34</sup> If both parties, owner and contractor, are entered into the emissions trading scheme then the issue of management control is considered under the rules for joint ventures.

Accounting for emissions can potentially be done in two ways. Method 1 is based on mass balance, using actual information about quantities of refrigerant used during the period. Method 2 (known as the "bottom-up" methodology in IPCC terminology), estimates gas losses by a set of default emission factors. Method 2 is an inferior accounting method and is likely to result in uncertainties that are significantly higher than Method 1, potentially in excess of +/- 50%. This degree of error is unacceptable in the context of the UK ETS. For this reason, Method 2 should not be used to estimate releases from industrial and commercial fridge plants.

Even where Method 1 is used however, data may not be available for all sites owned by the company. Where this is the case emissions may be estimated from the sources without good quality data by using appropriate coefficients determined for the company in question from its complete data. Emissions may be estimated in this way for up to 10% of total baseline emissions. This is consistent

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<sup>33</sup> Where an industrial process is covered by IPC or IPPC legislation, information concerning gas releases should be readily available from the Company's submissions to the regulator.

<sup>34</sup> DEFRA, May 2001, Framework Document for the UK Emissions Trading Scheme. pg 44.

with the 90:10 rule for reporting of energy consumption under the Climate Change Agreements.

The company must ensure that any data used from external contractors is of sufficient quality. For general guidance on quality procedures for data collection and management the reader should refer to *IPPC Good Practice Guidance and Uncertainty Management in National Greenhouse Inventories (2000)*.

In all cases, the combined releases from the sources over which the participant has management control should be reported as quantities of each individual HFC or PFC, together with the uncertainty of the estimate by that method. The estimate with the smallest uncertainty should generally be used but those having larger uncertainty may have value in verification.

All measurements and estimates must be adequately documented with a clear and auditable data trail. This is particularly important when changes in process operation, conditions or measurement parameters give rise to a significant change in emissions. Where the emission involves a third party (for example a maintenance contractor), the documentation of the third party must provide the information required and must be capable of being audited.

When calculating baseline emissions and the calculated figure is subject material levels of uncertainty, the lower estimate of the range should be used.

### Summary of Methodology

The total baseline emissions are the arithmetic sum of all mass emissions of that refrigerant from all refrigeration systems under management control. Emissions include both those occurring during continuing operation as well as those occurring during decommissioning<sup>35</sup>. Emissions include all those from the system, irrespective of whether they occurred on or off the site of the operator.

For each company the total annual GWP emissions of HFC gases is given by the sum of all emissions from:

continuing operations + discontinued operations (see equations below)

### Emissions From Continuing Operations

The equation below describes the method for accounting for the annual releases of refrigerant from a company operating refrigeration systems. Emissions are equal to the difference between the amount of refrigerant added to the system during servicing minus the amount recovered for re-use or disposal. This is termed the *net annual use*.

For each company the total annual GWP emissions of refrigerant gases from continuing operations is given by:

$$\sum A_{i,z} \cdot GWP_i$$

<sup>35</sup> Emissions during commissioning should be recorded in the same way as those for continuing operation.

where:

$A_{iz}$  = net annual use of refrigerant type “i” added to system “z” within the year for servicing, and  
**GWP** = the global warming potential of each refrigerant type “i”.

### Emissions from Discontinued Operations

The equation describes the method for accounting for releases of refrigerant from a system that has been discontinued during the year. Emissions are equal to the difference between the initial charge of the system and the amount of refrigerant recovered for re-use or destroyed. The method assumes that material not recovered or destroyed is lost to atmosphere. Where the recovery on disposal is not known, or data cannot be verified, the default is zero, equivalent to the loss of the total charge.

For each company the total annual GWP emissions of refrigerant gases from system decommissioning is given by:

$$\sum_{i,z} (F_{i,z} - D_{i,z}) \cdot GWP_i$$

where:

$F_{iz}$  = quantity of refrigerant type “i” originally contained in refrigeration system “z”.

$D_{iz}$  = quantity of refrigerant type “i” recovered or destroyed from the decommissioning of system “z”,  
 and

**GWP** = global warming potential of each refrigerant type.

### Uncertainty Measurement

When compiling emissions data, operators should refer to the relevant procedures for uncertainty measurement and in the *IPCC Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2001)*. In particular, the quantity of refrigerant recovered by a contractor during decommissioning/disposal must be verified. If the quantity cannot be verified accurately – preferably according to the QA/QC procedures in the IPCC guidance (2001) – it should be assumed to be zero.

Refrigeration and air conditioning system operators should ensure that their contractors providing maintenance services faithfully record all usage of refrigerants on their systems and that these records are auditable. Specifically, maintenance contractors should ensure that the transport cylinders are weighed before and after recharging the system.

The overall uncertainty of emissions is the sum of the root sum of the squares of the uncertainties for each gas and system. This uncertainty calculation includes emissions from both continuing and discontinued operations.

Total uncertainty of emissions from continuing and discontinued operations = Sum for all systems of the square root of the sum of square of the uncertainty of emissions of refrigerant “i” in system “z”

$$U_{z,i} = \sqrt{(\sum U_{A,z,i}^2 + \sum U_{F,z,i}^2 + \sum U_{D,z,i}^2)}$$

## Global Warming Potentials

Table 1 gives the GWP of most commercially available refrigerant gases with either an HFC and/or PFC component.

**Table 1. GWP's of Common Refrigerant Gases**

Refrigerant Number	Description	% HFC & PFC	GWP <sub>100</sub> Kilograms of CO <sub>2</sub> Equivalent per kg of refrigerant due to HFCs
R-23	Trifluoromethane	100%	11,700
R-32	Difluoromethane	100%	650
R-125	Pentafluoroethane	100%	2,800
R-134a	1,1,1,2-Tetrafluoroethane	100%	1,300
R-143a	1,1,1,-Trifluoroethane	100%	3,800
R-152a	1,1,-Difluorethane	100%	140
R-401a	R22/152a/124	13%	18
R-401b	R22/152a/124	11%	15
R-401c	R22/152a/124	15%	21
R-402a	R22/125/290	62%	1,680
R-402b	R22/125/290	40%	1,064
R-403a	R22/218/290	20%	1,400
R-403b	R22/218/290	39%	2,730
R-404a	R125/143a/134a	100%	3,260
R-405a	R22/152a/142b/C318	50%	3,707
R-407a	R32/125/134a	100%	1,770
R-407b	R218/311/134	100%	2,285
R-407c	R404/497/134a	100%	1,526
R-408a	R22/R143a/125	53%	1,944
R-410a	R32/125	100%	1,725
R-410b	R32/125	100%	1,833
R-411b	R22/152a/1270	3%	4
R-413a	R134a/218/290	100%	1,774
R-503	R13/23	40%	4,692
R-507	R125/143a	100%	3,300
R-508a	R23/116	100%	10,175

(Sources: IPCC 1996, UNEP 1998):

The GWP quoted here is the total GWP for 1 kg of refrigerant due to the HFC and PFC components. The other components, such as HCFCs, which although do contribute to global warming are not included in the basket of global warming gases in the Kyoto Protocol and therefore have zero GWP in the context of the UK ETS.

If a refrigerant is not listed here it is the responsibility of the organisation concerned to provide adequate information concerning its HFC or PFC components from the manufacturer.

**References:**

*IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*, IPCC, 2001.

*Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, Reference Manual Volume 3, IPCC, 1996.

*Framework Document for the UK Emissions Trading Scheme*, DEFRA, 2001.

*Guidelines for the Measurement and Reporting of Emissions in the UK Emissions Trading Scheme (and associated protocols)*, DEFRA, August 2001.

1998 Assessment Report of the Air Conditioning and Heat Pumps Technical Options Committee (Annex III - Refrigerant Data), UNEP Technology and Economic Assessment Panel (TEAP)

## Protocol C4: Measurement of HFC emissions from the manufacture of domestic refrigeration

The methodology is based on :

- a. *Framework for the UK Emissions Trading Scheme - DEFRA Aug 2001*
- b. *Guidelines for the measurement and reporting of Emissions in the UK Emissions Trading Scheme – DEFRA Aug 2001*
- c. *Emissions Trading Scheme Draft Rules – DEFRA Dec 2001*
- d. *Two existing HFC submissions from Enviros and Ineos*

At the outset, the emissions calculation process all emissions should be examined, with a view to establishing the relative size of HFC emissions from each site under ‘management control’. The relative size should recognise that an ‘emission’ in this context is weighted by the GWP of the constituent gases (Table 1). This should enable rational decisions on the materiality of each source to be taken at an early stage, avoiding waste of effort.

Emissions of HFCs are gaseous; either directly from leaks discharging to atmosphere or indirectly as components of aqueous, liquid or solid waste. HFCs are sufficiently volatile to be released into the atmosphere by vaporisation and degassing from waste that enters the environment.

The Framework for the UK Emissions Trading System requires that the boundary for calculating emissions is the extent of “management control”. In the case of refrigeration manufacture, end of life disposal is not included. Also excluded is any refrigerant fluid replacement that takes place away from the manufacturing ‘site’ during the life of the appliance. However the controlled removal of refrigerant fluid at the manufacturing site as an ongoing part of a controlled recycling operation could be included. This is consistent with DEFRA guidelines for ‘Measurement and Reporting of Emissions in the UK Emissions Trading Scheme’ which states that “the only indirect emissions in the Scheme will be those associated with energy use – other types of indirect emissions will not be included”.

All measurements and estimates must be adequately documented with a clear and auditable data trail. This is particularly important when changes in process operation, conditions or measurement parameters give rise to a significant change in emissions.

Accounting for HFC emissions during the manufacture of domestic refrigeration products can potentially be done in two ways.

**Method 1** is based on mass balance, using actual information about quantities of refrigerant delivered to the site, and then ‘exported’ from the site within the finished refrigeration appliances, or otherwise, during the three baseline years.

**Method 2** accepts that emissions or ‘leakage’ of refrigerant gas within the site is inevitable during manufacturing, and involves the process mapping of the HFC from the delivery process until it leaves the site and the ‘management control’ of the manufacturer.

The leakage can be of two types.

- ‘Known or controlled leakage’, for example a small but measurable amount of gas that is lost to atmosphere during every refrigeration filling cycle.
- ‘Unknown or uncontrolled leakage’, for example a small undetectable leak from the underground refrigerant distribution pipes within the site.

Method 1 is the superior method as there are no uncertainties. However, method 2 is a further check on the result arising from method 1, and if all storage and distribution facilities are sound, the known or controlled leakage amount will equal the HFC emissions determined by method 1. However, if the unknown or uncontrolled leakage is found to be significant, the site would initiate and implement an improvement plan to reduce HFC emissions and improve its environmental performance.

### Summary of Methodology

The method for accounting for the annual releases of HFC refrigerant from a company manufacturing refrigeration products is described below.

$$\text{HFC emissions} = \boxed{\text{Delivered weight of HFC onto the site}} - \boxed{\text{Weight of HFC that is leaves site within the products, or is otherwise disposed of}}$$

The equation below is a further check that can be used for verification purposes, or forms the initial investigation into identifying a number of ‘point sources’ from which greenhouse gasses are emitted.

$$\text{HFC emissions} = \boxed{\text{Quantifiable losses of HFC from ‘point sources’}} + \boxed{\text{Non quantifiable losses of HFC from ‘point sources’}}$$

The average annual emissions from the ‘sources’ of HFC emissions would then be used as a reference point for future emission reductions.

### Estimate of Inherent Uncertainty in the Protocol

Referring back to the first equation , the uncertainty in the annual release of HFC emissions from the site can be shown as:

$$U_E = \sqrt{(U_{DW}^2 + U_{EXP}^2)}$$

$U_E$  = Uncertainty in HFC emissions  
 $U_{DW}$  = Uncertainty in the Delivered weight  
 $U_{EXP}$  = Uncertainty in the Exported weight from site  
 $U_{DW} = U_{WB}$  = Uncertainty in the Weighbridge  
 $U_{EXP} = (U_{FIL}^2 + U_{FILLGAGE}^2)$

By substituting into the above

$$U_E = \sqrt{(U_{WB}^2 + U_{FILL}^2 + U_{FILLGAGE}^2)}$$

## Global Warming Potentials

Table 1 gives the GWP of the most common HFC refrigerant gases.

**Table 1. GWP's of Common Refrigerant Gases**

Refrigerant Number	1.1.1.2 Description	% HFC	GWP <sub>100</sub> Kilograms of CO <sub>2</sub> Equivalent per kg of refrigerant
R-23	Trifluoromethane	100	11,700
R-125	Pentafluoroethane	100	2,800
R-134a	1,1,1,2-Tetrafluoroethane	100	1,300
R-503	R13/23	41	4,797*
R-507	R-125/143a	100	3,300
R-508A	R-23/116	39	3,822*
R-401A	R-22/152a/124	13	18,2*
R-401B	R-22/152a/124	11	15.4*
R-401C	R-22/152a/124	15	21*
R-402A	R-125/290/22	60	1,680*
R-402B	R-125/290/22	38	1,064*
R-404A	R-125/143a/134a	100	3,260
R-405A	R-22/152a/142b/C318	7	9.8*
R-407A	R-32/125/134a	100	1,770
R-407B	R-32/125/134a	100	2,285
R-407C	R-32/125/134a	100	1,526
R-408A	R-125/143a/22	53	1,982*
R-410A	R-32/125	100	1,725
R-410B	R-32/125	100	1,833
R-411B	R-22/152a/1270	3	4.2*
R-32	Difluoromethane	100	650
R-143a	1,1,1,-Trifluoroethane	100	3,800
R-152a	1,1-Difluoroethane	100	140

(Source: IPPC 1996):

\* These refrigerants are blends that include HFC refrigerants and other components. The GWP quoted here is the average for the total refrigerant taking into account the proportion of HFC in the fluid. The other gases, such as HCFCs, which although do contribute to global warming are not included in the basket of global warming gases in the Kyoto Protocol and therefore have zero GWP in the context of the UK ETS.

## Protocol C5: Measurement of CO<sub>2</sub> and CH<sub>4</sub> emissions from offshore oil and gas operations

The use of the UK Offshore Operators Association (UKOOA) / EEMS "Guidelines for the Compilation of an Atmospheric Emissions Inventory" (Document Ref:AD-D-UM-0020, Rev 3.0, December 1999) is proposed as the reporting protocol for calculating CO<sub>2</sub> and methane emissions from operations in this sector. UKOOA members use this guidance for reporting the atmospheric emissions inventory to DTI and NETCEN for inclusion in the UK National Atmospheric Emissions Inventory. These data are in the public domain. It is generally accepted that these guidelines represent best practice in the Upstream sector. Indeed, this guidance can form the standard for all UKCS oil and gas operators participating in the UK ETS scheme.

The guidance is available for downloading at <http://www.EEMS-database.co.uk/Download/Atguid3.doc>. Section 2.1 outlines the tiered approach to emissions reporting, with five tiers of quantification (labelled 1 to 5) that use increasingly accurate and reliable methods. The tiered approach encourages continuous improvement in data quality and UKOOA recommend the use of Tier 3 factors as a minimum for the annual industry report.

### Specific sections of guidance

For guidance to UK operators, the following source categories are initially being proposed for bringing into the UK ETS. The location of the specific guidance within the UKOOA guidelines is given. However, this does not preclude the inclusion of other sources which appear in the UKOOA guidelines now or at a later date. The provision of an emission source within the UKOOA guidelines or the tables below does not obligate an operator to include emissions from this source, as direct participants will still be able to exclude sources not covered by the original Annex A&B Draft protocols (August 2001), even if a protocol is subsequently approved for these sources. (section 4.7 of Framework document).

#### *Carbon Dioxide Emissions*

Carbon dioxide from onsite combustion of fossil fuels (including gas, oil, diesel etc. fuelled fixed combustion units)	Section 2.2: Default factors are provided for fuel gas (where composition data is not available) and diesel/gas oil in Appendix 1: Tables 10 and 11 and associated text.
Carbon Dioxide from gas flaring during production & processing	Appendix 1: Table 4 – Production gas flaring and associated text
Carbon Dioxide from gas flaring during well testing	Appendix 1: Table 12 – Well testing and associated text
Carbon dioxide from process vents	Section 2.2: Process Emissions

*Carbon dioxide from import of steam/electricity (including Mains electricity import and import from adjacent CHP plant) [onshore only]*

The UKOOA Guidelines do not cover “indirect emissions”. Imports of electricity from the public supply network are calculated according to DEFRA Protocol A2 using the Emission Factor provided in Protocol A1.

Imports of steam and electricity derived from CHP are calculated using DEFRA Protocol A2, but allowance is made for using a more sophisticated approach to use site specific emission factors where compositions are known and to allocate emissions between the generated steam and electricity as approved by DEFRA.

### **Methane Emissions**

It is recognised that the uncertainty in producing estimates of methane emissions is typically higher than for carbon dioxide. In many cases, it is necessary to make use of default factors to provide consistency in reporting. These factors are selected to provide “industry average” emissions even though this introduces uncertainty at the individual source level. The UKOOA Guidelines are designed to encourage open and transparent reporting of emissions data using best available methods and without waiting until methods with low uncertainty are developed.

Methane emissions from flaring	Section 2.2 – Flaring efficiency and Appendix 1: Table 4 – Production Gas Flaring, Table 12 – Well Testing and associated texts.
Methane emissions from direct venting	Section 2.2 – Venting and Appendix 1: Table 5 – Cold Venting and associated text
Methane emissions from process vents	Section 2.2 – Process Emissions
Methane emissions from crude oil tanker loading	Section 2.2 – Loading Operations and Table 14 – Crude Oil Loading

### **Uncertainty in estimating GHG emissions using UKOOA Guidelines (Tier 3)**

Where the default factor does not change from Tier 1 to Tier 2 to Tier 3, that UKOOA default factor will be used as per the Tier 3 guidelines.

This is a simplified analysis based on uncorrelated random variability assuming normal distribution. Individual uncertainty is based on expert judgement (excluding the upper & lower 5% of the distribution, as per the IPCC guidelines).

#### ***Carbon dioxide emissions***

##### *Carbon dioxide from fuel combustion*

Source accounts for: 75.0% of carbon dioxide emissions  
 Combustion of fuel gas  
 Sub-source accounts for: 90.0% of carbon dioxide emissions

Calculated from the product of two factors:

Total quantity of fuel gas consumed based on single point metering and integrating mass flow

Activity uncertainty: 10.0%

Fuel composition based on UKOOA Tier 1/3 Factor

Composition uncertainty: 5.0%

Sub-source uncertainty: 11.2%

Combustion of diesel/gas oil

Sub-source accounts for: 10.0% of carbon dioxide emissions

Calculated from the product of two factors:

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Total fuel used based on purchase records/tank dips	
<u>Activity uncertainty:</u>	<u>3.0%</u>
Composition factor based on UKOOA Tier 3/DEFRA	
<u>Composition uncertainty:</u>	<u>3.0%</u>
<u>Sub-source uncertainty:</u>	<u>4.2%</u>
<u>Source uncertainty:</u>	<u>10.1%</u>

*Carbon dioxide from flaring*

Source accounts for: 25.0% of carbon dioxide emissions

Calculated from the product of two factors

Total quantity of gas flared, routine, operational and emergency based on a combination of metered purge, measurement and estimation based on gas balance

Activity uncertainty: 20.0%

Flare gas composition based on UKOOA Tier 2/3 Factor

Composition uncertainty: 5.0%

Source uncertainty: 20.6%

Uncertainty in calculated carbon dioxide emission: 9.1% at UKOOA Tier 3 reporting

**Methane emissions**

*Methane from direct venting*

Source accounts for: 50.0% of methane emissions

Calculated from the product of two factors

Total quantity of gas vented, based on metered purge, measurement and estimation based on mass balance

Activity uncertainty: 30.0%

Composition factor based on UKOOA Tier 2/3

Composition uncertainty: 30.0%

Source uncertainty: 42.4%

*Methane from flaring*

Source accounts for: 25.0% of methane emissions

Calculated from the product of two/three factors

Total quantity of gas flared, routine, operational and emergency based on a combination of metered purge, measurement and estimation based on gas balance

Activity uncertainty: 20.0%

Flare gas composition based on UKOOA Tier 2/3

Composition uncertainty: 30.0%

Flare efficiency at 98%

This is FIXED by the protocol for consistency. However, some sources indicate likely range of efficiency is 95% to 100%

Source uncertainty: 36.1% Neglecting uncertainty in Flare efficiency

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*Process methane emissions*

Source accounts for: 15.0% of methane emissions

Calculated from the product of two factors

Quantity of gas vented per process calculated from process mass balance

Activity uncertainty: 20.0%

Gas composition for each process estimated based on process calculations

Composition uncertainty: 20.0%

Source uncertainty: 28.3%

*Methane from tanker loading*

Source accounts for: 10.0% of methane emissions

Calculated from the product of two factors

Total quantity of oil loaded (fiscally metered)

Activity uncertainty: 2.0%

UKOOA Tier 3 emission factor for methane

Emission factor uncertainty: 100.0% Using default factors

Emission factor uncertainty: 30.0% Using factors based on measurement studies

Source uncertainty: 30.1%

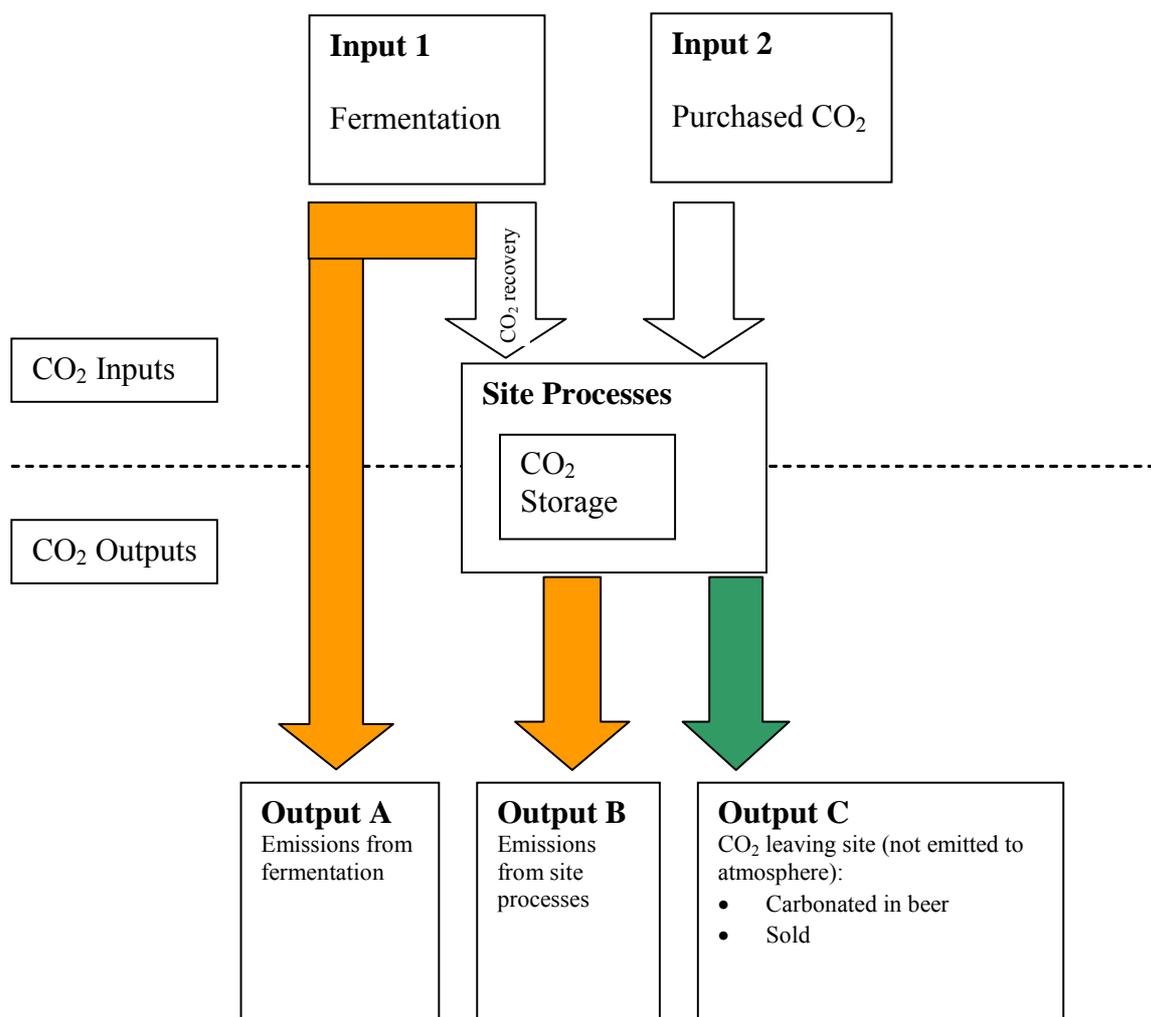
Uncertainty in calculated methane emission: 24.1% at UKOOA Tier 3 reporting

## Protocol C6: Calculation of process CO<sub>2</sub> emissions in beer production

The production of malt beverages, or beer, comprises four main stages: brewhouse operations, fermentation, ageing or secondary fermentation, and packaging.

Carbon dioxide (CO<sub>2</sub>) is an essential component of the beer production process. CO<sub>2</sub> is a constituent of the beer itself, naturally dissolving in the beer during the fermentation process and it may also be added to beer in the filtration stage prior to packaging. CO<sub>2</sub> is used during site processes to displace air from brewery vessels, pipework and packaging equipment.

The diagram below represents the flow of non energy related CO<sub>2</sub> through a typical brewery:



**Input 1: Fermentation.** CO<sub>2</sub> is generated from the fermentation process through breakdown of biomass (Input 1). This CO<sub>2</sub> source is part of the natural atmospheric carbon cycle (i.e. it is not a fossil fuel based carbon source). Therefore, Input 1 (and hence Output A) are not counted in the calculation of process CO<sub>2</sub> emissions.

**Input 2: Purchased CO<sub>2</sub>.** Purchased CO<sub>2</sub> is delivered to the brewery in bottles or by road tanker, supplied by industrial gases companies. These companies obtain CO<sub>2</sub> through steam reformation of

natural gas (methane) over a catalyst, according to the equation  $\text{CH}_4 + 2\text{H}_2\text{O} \rightarrow \text{CO}_2 + 4\text{H}_2$ . The other product of the process, hydrogen, is also sold commercially. Thus purchased  $\text{CO}_2$  comes from a fossil fuel source, and reducing the amount purchased by the brewery will count as a reduction in emissions under ETS rules.

**Output A.**  $\text{CO}_2$  from the fermentation process that is vented to atmosphere (Output A) comes from Input 1 (natural carbon cycle) and therefore does not count as a process emission for the purposes of the ETS.

**Output B** comprises emissions to atmosphere of  $\text{CO}_2$  used in site processes such as line filling, venting etc, and may originate in part from fermentation and in part from purchased  $\text{CO}_2$ .

**Output C** takes the form of sales of bottled beer and direct sales of  $\text{CO}_2$ . This results in an emission to atmosphere within a variable but typically relatively short period. There is thus no sequestration value for  $\text{CO}_2$  exported from the site.

**$\text{CO}_2$  recovery.** A  $\text{CO}_2$  recovery system captures and cleans  $\text{CO}_2$  produced during the fermentation stage for re-use downstream the beer production process. The effect of  $\text{CO}_2$  recovery from fermentation is to displace purchases of  $\text{CO}_2$  from sources outside the brewery.

### Emission calculation

Removing non-fossil  $\text{CO}_2$  inputs and outputs results in the following calculation of emissions:

Total fossil-based  $\text{CO}_2$  emissions from the brewery = Input 2 only

Annual  $\text{CO}_2$  emissions can therefore be calculated solely from records of  $\text{CO}_2$  purchases (kg) from industrial gases companies, taking due account of uncertainty.

**Assumptions.** This calculation method assumes that all bottled or tankered commercial  $\text{CO}_2$  supplies in GB come from fossil sources. This is a safe assumption<sup>36</sup>.

**Measurement.** In line with the Tier 2 methodology in the IPCC guidelines, the  $\text{CO}_2$  purchases are assessed from accounting records, not on the basis of theoretical calculation<sup>37</sup>.  $\text{CO}_2$  deliveries by tanker are measured using a weighbridge, and accounting records are based on these measurements. The accuracy of weighbridge measurement is discussed under the heading *uncertainty assessment* below.

**Uncertainty assessment.** Existing guidance from IPCC on quantifying uncertainty<sup>38</sup> relates to continuous monitoring of emissions, the determination of emission factors, the relationship between emissions and activity data, and the use of expert judgement. In the case of purchased  $\text{CO}_2$  no such uncertainty assessment is appropriate, since the only uncertainty present comes from the measurement of the delivered quantity.

$\text{CO}_2$  deliveries to the brewery are measured using a weighbridge. The Weights and Measures Act 1985, Section 11, specifies the accuracy that must be maintained by a weighbridge that is legally

<sup>36</sup> Taking advice from Entec, advisors to DEFRA on ETS participation

<sup>37</sup> Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, Reference Manual Volume 3, IPCC, 1996. (see <http://www.ipcc.ch/pub/guide.htm>)

<sup>38</sup> IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, IPCC, 2001. (see <http://www.ipcc.ch/pub/guide.htm>)

defined as ‘In use for Trade’, both at the point of commissioning, and in subsequent inspections by Trading Standards officials. These accuracies are summarised in the following table.

Weighbridge capacity	Maximum permissible error	
	On verification when first installed	On subsequent inspections
≤ 10 tonnes	± 0.5 divisions	± 1 division
10 ≤ tonnes ≤ 40	± 1 division	± 2 divisions
≥ 40 tonnes	± 1.5 divisions	± 3 divisions

A typical 50 tonne capacity weighbridge would show divisions of not more than 20kg (smaller capacity weighbridges could have smaller divisions). Thus we assume that the maximum permissible error for a weighbridge operated by Budweiser would be 3 divisions of 20kg, equal to 60kg. A typical tanker delivery<sup>39</sup> is 20 tonnes. Hence the maximum assumed error in the measured quantity delivered is 0.3%. Any weighbridge error is likely to be consistent, not random, but nevertheless should not lead to a cumulative error that reaches the indicative 5% threshold of materiality discussed in DEFRA’s ETS framework<sup>40</sup>.

We conclude that accounting records of CO<sub>2</sub> deliveries may be taken as equivalent to actual CO<sub>2</sub> delivered for the purposes of emissions reporting under the ETS.

### Quality Assurance and Quality Control

Existing guidance on quality assurance and quality control (QA/QC)<sup>41</sup> relate to the application of QA/QC to national GHG inventories and the measurement of emissions where this could be inaccurate. In the case of CO<sub>2</sub> deliveries to a brewery, we judge that all necessary and relevant QA/QC procedures are encompassed within existing legal procedures governed by the Weights and Measures Act 1985, and hence no further specific QA/QC procedures need to be devised in the context of emissions reporting under the ETS.

<sup>39</sup> Confirmed by Hydrogas, Budweiser’s usual CO<sub>2</sub> supplier

<sup>40</sup> Framework for the UK Emissions Trading Scheme, DEFRA, 2001. ‘Material misstatement within baseline and annual emissions’, sections 4.12 – 4.17 (see <http://www.defra.gov.uk/environment/climatechange/trading/index.htm>)

<sup>41</sup> IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, IPCC, 2001. (see <http://www.ipcc.ch/pub/guide.htm>)

## Protocol C7: Measurement of CO<sub>2</sub> emissions from fuel burn from aviation

This protocol only deals with domestic sector fuel burn. British Airways will arrive at its total domestic operation CO<sub>2</sub> emissions output by measuring and calculating the fuel burned purely on domestic operations. A fuel burn model has been formulated which will accurately and equitably isolate the domestic portion of the BA fleet's fuel burn. Two methods will be used to calculate domestic sector fuel burn; **Method 1** uses actual recorded fuel burn data and **Method 2** derives fuel burn from flights flown and unit burn data.

### Method 1 (Actual)

This model has been formulated to include all emissions from each phase of an aircraft's domestic sector - from start of engines at the beginning of a flight to the start of engines of the subsequent flight. The Domestic Sector Fuel Burn is determined by Actual Departure Fuel minus Calculated Arrival Fuel.

**Actual Departure fuel** is defined as the physical amount of fuel present in the aircraft's fuel tanks as measured by the aircraft's gauges once the fuel uplift for the domestic sector has been completed.

**Calculated Arrival Fuel** is determined by subtracting the physical Fuel Uplift for the subsequent sector from the Actual Departure Fuel of the subsequent sector. This yields a figure which is, in effect, an estimate of the pre-fuel uplift quantity. Actual Remaining Fuel is also captured on arrival at engine shutdown. However it is not used directly in this methodology as it does not account for any Auxiliary Power Unit (APU) ground running post arrival at stand/ engine shutdown and the start of the next sector. Actual Remaining Fuel is, however, used to help validate the Calculated Arrival Fuel as, on a majority of occasions, they are measuring similar quantities.

Note that all actual fuel measurements are subject to the accuracy of the aircraft's fuel measuring equipment. This accuracy varies between aircraft type and is also non-linear. However all BA mainline aircraft have a certified gauge accuracy to within +/-1%. The volumetric accuracy of the actual Fuel Uplift, measured by the refuel vehicle's flow gauges, is highly accurate and typically within +/- 0.2%.

All fuel data is stored in a Business Objects data repository and accessible using SQL query management tools to report on all domestic operations for a defined period. Further refined analysis and presentation is performed using MS Excel.

### Method 2 (Derived)

This method is used where Method 1 is not possible due to the absence of the requisite source data.

Actual flights flown for BA's subsidiary operators over the 3 year baseline period is available from the Customer Transaction Database (CTD). This database stores all commercial scheduled and non-scheduled operations by aircraft type and is used to report BA's commercial passenger statistics. Similar data on non-revenue flying (eg positioning, engineering test flts) is also available but sourced from BA's Operations Analysis system, OPSA. Data for the defined periods are downloaded into MS Excel and burn rate data applied in the following order;

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- I. where statistical data for city pair, aircraft type exists in the BA mainline operations database this will be used, failing that
- II. where a source of burn data for city pair, aircraft type from BRAL which is currently used for forecasting purposes this will be used, failing that
- III. use generic burn rate data for the aircraft type from BA, BRAL or another suitable and verifiable source (in that order). Suitable sources will include published technical data from the manufacturer or reputable journals ie Janes Aircraft. Generally the latter will be used for aircraft that are unique to them or aircraft that are no longer used by either operator.

Most occurrences will be covered by the first two categories. For those occurrences falling under the third category, generic burn data will be in the form of fuel burn per hour or burn per nautical mile flown.

Sector times will be taken from published timetables by the operator for the relevant aircraft type. Multiplying the sector time by the hourly burn rate will yield a fuel burn for that city pair. Where published sector times are not available, the distance method will be used to calculate the sector burn. City pair distance will be derived from either BA mainline statistical planned route distances or if unavailable, from the Great Circle distance factored up by a percentage that is typical of BA mainline's domestic operations. This factor accounts for the constraints of operating within an air traffic management environment.

The Excel spreadsheet used for the emissions calculation clearly identifies the source of any data and is designed so that all calculations are verifiable back to their original source.

BA do not have a data source for ground running usage (eg engine runs) nor charter operations. Ground running for BA mainline contributes about 2.2%. Applying this factor to non-mainline burn results in a contribution of less than 1% to BA Group burn and can therefore be excluded from the ETS. Similarly emissions arising from domestic charter operations for the non-mainline operators are thought to be <1% (based on next Summer and Winter planned schedule) and hence will not be included in the ETS.

### Assumptions

- British Airways uses the standard conversion factor for kerosene to CO<sub>2</sub> is 3.154 (The Intergovernmental Panel on Climate Change, "Aviation and the Global Atmosphere, 1999" uses two values 3.15 and 3.16).
- All kerosene uplifted by BA is subject to a standard specific gravity factor of 0.8 kg/litre.
- To measure and record exactly what portion of ground running should be allocated to a domestic sector or an international sector would be unfeasible in terms of the time required to carry out the calculations. It is therefore assumed that each portion of ground running is allocated to the previous sector. Over time this should result in the fair allocation of ground running to both domestic and international sectors.

### Data capture system

BA have in place a comprehensive data capture and validation system which provides the requisite actual fuel data for Method 1 above. Data is captured in a way that uniquely defines the operation that took place - by date, flight number and departing station. All BA mainline sectors flown, including domestic operations, are covered by this system regardless of the type of aircraft which operated the route on any given day.

### *Information Flow*

BA is in the process of changing the method by which fuel data is captured. The current method detailed below accounts for the majority of BA mainline operations.

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Stage	Data Capture Method	Errors created?	Data cleaned at this stage
1	<b>Refuel Sheet</b> Pilot receives a BA Refuel Sheet from fuelling operative containing uplift volume and tanks quantities	Yes but rare especially where refuelling companies have a high degree of system automation	No
2	<b>Technical Log</b> Pilots checks & manually enters fuel data from Refuel Sheet into the Log <sup>42</sup>	Yes. Most of the errors are administrative such as wrong flight number, next sector missing.	Mandatory checks are made which can lead to mistakes been discovered and corrected
3	<b>DISC Units</b> Data clerks enter data from Technical Log into DISC computerised system	Yes. Errors made on Technical Log entries are often transferred to DISC. Additionally DISC input personnel can incorrectly input data.	No
4	<b>FICO</b> FICO receives a daily electronic feed from DISC. FICO automatically checks data at a high level (eg does the flight exist?) and outputs an error list on a daily basis	No	Yes - FICO checks schedule information such as flight number, aircraft registration and gross checks on fuel quantities. These errors are manually investigated and corrected if necessary.
5	<b>TIFF</b> TIFF is BA's Fuel Management System. TIFF electronically receives "cleaned" data from FICO and performs more detailed verification checks on the fuel data.	No, although a few manually checked errors may still escape the cleaning process.	Yes TIFF automatically identifies and corrects, where possible, data which is considered 'unreasonable'. Those errors that cannot be resolved by TIFF are output for manual investigation/ rectification.
6	<b>Volume Reconciliation</b> This process is used to add inventory management controls on BA owned fuel stock.	No. This is a month end procedure and the final data check If volumes do not reconcile against those reported by the Into Plane Agent (which in turn is reconciled back to the airport hydrant company) then these are manually investigated/ rectified.	Yes Only performed on London Heathrow and Gatwick uplift volumes and, typically effect International operations, but domestic uplifts can on occasion be amended.

Note: Unreasonable data is always "cleaned" - or made reasonable - it is rarely corrected back the original value/s. Also, there is no history of any changes to the data that are made. There are however documented procedures and technical specifications on how data is cleaned.

<sup>42</sup> It is a legal (JAR-OPS) requirement to capture fuel data - Remaining fuel, uplifted fuel, calculated arrival fuel, departure fuel - in this Log.

*Error Factor*

An analysis over several month last year showed that about 15% of all data received by FICO was in error. This is cleaned via the above process such that it is reasonable to pass to the next stage. No macro analysis on the subsequent cleaning activities and their effectiveness is available except that the volume reconciliation process is usually within +/-0.3% every month.

*Future data integrity - BA Mainline*

The current data capture system is being revised to make it more efficient and effective. The essence of the change is to improve data capture at source rather than clean it after capture. This is achieved by entering data from the Technical Log directly into TIFF. TIFF performs detailed data validation on the user interface thus reducing the likelihood of errors being introduced. Currently around 35% of BA mainline data capture is now using this new method and this is planned to increase over the coming year to 100%.

The verification process is also planned to be enhanced later this year with further automation of the TIFF data cleaning process and enhanced computerised checking within the volume reconciliation process.

BA will adopt any enhancements to the data capture process in any future reporting within the ETS as long as the changes do not represent a fundamental change in emission derivation methodology.

Definitions and abbreviations

*Auxiliary Power Unit (APU)*

This is an auxiliary engine usually found in the tail of the aircraft which provides power and air-conditioning services whilst the aircraft is on the stand or in the air.

*Sector*

Sector, or city-pair, refers to the domestic sector and includes the following phases of flight: taxi to take-off runway, take-off run, take-off, cruise, descent, landing, taxi to stand. For the purposes completeness of CO<sub>2</sub> data being submitted to the UKETS, APU running on stand following a domestic sector is included in the domestic sector fuel burn model.

*Source*

The total domestic operation operated by each wholly-owned entity within the British Airways Group.

# Protocol C8: Measurement of CH<sub>4</sub> emissions from Working Coal Mines

## **METHANE EMISSIONS FROM WORKING COAL MINES**

UK COAL plc (formerly RJB Mining plc) acquired its deep mine collieries during the privatisation of British Coal in December 1994. The company is the largest coal producer in the UK accounting for about 60% of national production. The procedures for measuring methane emissions to atmosphere have been adopted as 'custom and practice', the results of which are reported to the Government departments for inclusion in the UK National Emissions Inventory.

UK COAL believes that methane savings at its collieries would be eligible for the UK Emissions Trading Scheme for the following reasons.

- I. Methane is released continually as part of normal colliery operations.
- II. It is measured in a controlled manner on a regular basis. Baseline measurements exist for 1998-2000
- III. Methane is utilised on site to generate electricity for colliery operations or to provide heat for colliery baths etc. Any future utilisation projects will be used for similar on site demand.

### Methodology for Current Emissions

Air samples are normally taken from within the upcast shaft with a hand filled sample capsule and sent away for analysis at an independent laboratory demonstrating traceability to standards held at the National Physical Laboratory (NPL). Should there be a problem with the hand sample they may be monitored via records kept from a tube bundle system, if available. If there is no tube bundle system suitable for use as a backup, handheld methanometer readings should be taken as a backup in case the capsule reading is returned as faulty, which can occasionally happen. Routine use of tube bundle or handheld methanometer readings is not acceptable. Because these measurements only give a spot reading, the following methodology is adopted to give an indicative weekly reading.

The level of methane emissions varies from working collieries throughout the week, depending on coaling operations and barometric pressure. Coal production is currently Monday to Friday and emissions build up to a peak on Friday before subsiding over the weekend. In order to estimate an average volume of gas being emitted in the airstream, measurements and readings are taken on Wednesday which, as discussed later in this document, is known to represent average working conditions to within about  $\pm 8\%$  for five day operation.

### Sources

Methane emitted from working coal mines can originate from two sources, the methane drainage system and the fan drifts:

- i) Methane Drainage System

The methane drainage system captures methane underground within the strata and transports the gas via pipe ranges to the surface, where it can be either utilised or vented to atmosphere. The system is constantly monitored for purity and flow, using differential pressure.

ii) Fan Drift (Upcast Shaft)

Methane released within the general body of air comprises strata gas not captured by the drainage system which migrates into the general airstream underground and is vented via the normal ventilation system. The concentration of gas within the shaft air stream is generally less than 1%, which is too low for utilisation or flaring

Purity is measured on a weekly basis at the same time as the airflow measurements either with approved hand held apparatus (methanometer or capsule) but as a backup may be monitored via a tube bundle system, if available. The flow of air is measured via an anemometer and a similar calculation is performed to the above.

### Methane Utilisation

Methane from the drainage system is utilised mainly to generate electricity on site. The main saving in greenhouse gas emissions will come from the difference in venting methane and using it for electricity generation. Methane is 21 times more potent than carbon dioxide on a mass basis. The mass ratio of carbon dioxide to methane is 2.75 (44/16). As one molecule of methane will be converted to carbon dioxide during the generation process the saving will be  $(21 - 2.75) = 18.25$  tonnes of carbon dioxide for every tonne of methane utilised.

The input of gas to the generator is calculated from the power output and engine efficiency. New generating engines are issued with a registered efficiency certificate from the manufacturer for use in this calculation.

It is impossible to utilise fully all the methane captured at collieries where generation and boilers exist on site due to variations in methane flow. Methane cannot be utilised at low purity levels due to the risk of explosion and high gas levels can lead to surpluses occurring. Gas levels can fluctuate due to variations in coal production, gas capture and barometric pressure. Captured gas, therefore, which is not utilised is vented to atmosphere.

In direct response to the UK Emissions Trading Scheme, UK COAL now intends to install modified landfill flares to reduce the volume of non-utilised methane vented to atmosphere via this route. The flares will be of an enclosed design with the methane being burnt in an enclosed combustion chamber. The flares are capable of safely flaring methane in a range 25 – 65% by volume. The height of the flare stack will be designed to provide the maximum dwell (residence) time and destruction efficiency for the gas in the combustion chamber, thus ensuring that all the methane is combusted. This enclosed system is of the type used on landfill sites<sup>43</sup> and provides much higher combustion efficiency than a traditional open flare.

As in the case of generation, each tonne of methane combusted results in the release of 2.75 tonnes of carbon dioxide and a net reduction of 18.25 tonnes of carbon dioxide for every tonne flared.

### Determination of Methane Percentages

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<sup>43</sup> Under Environment Agency 'Guidance on Landfill Gas Flaring' version 2.1, no open flares are permitted on landfill sites except in an emergency circumstances.

**Fan Drifts**

(a) Determination of Methane Percentage

A CRE capsule sample shall be obtained from the centre of the fan drift first flushing the capsule twice before taking sample. The capsule shall then be analysed by an independent laboratory demonstrating traceability to NPL standards. This is the normal measurement method.

Should the capsule sample provide a faulty reading, a historic backup reading may be obtained from the colliery tube bundle system. Readings from the sample point situated in the fan drift may only be used providing the necessary recovery tests (see next paragraph) have been carried out as well as the flow measurements described in (b) below.

Recovery Test: - Tube bundle systems can run for long distances between the sample point and where it is analysed. It is therefore possible that leakage or damage to the tube system could occur which would result in a non-representative reading being recorded. In order to ensure readings are representative every 3 months recovery tests are carried out. Here a sample of known methane concentration is released into the tube bundle system at the sample point and the reading at the analyser compared. If the reading is within 5% of the known concentration the system is taken to be within tolerance.

**1.1.1.3 As a backup system, should no tube bundle system exist at the colliery: Methane readings are also taken using a calibrated and approved hand held industry standard methanometer at the same time as the capsule sample.**

(b) Air Flow Measurement

Ensuring that a correct speed and recently calibrated anemometer and extension rod are available, find a relatively straight length of fan drift and measure the cross sectional area of the drift. Take four traverses of the drift, two left to right two right to left at a speed of one foot per second. Ensure all four readings in m/s are within 5% of the average speed, if not retake that reading until four are within 5% of average. The average air speed should then be calibrated using the calibration sheet supplied by an independent laboratory that demonstrates traceability to the NPL standards. Multiply calibrated air speed by cross sectional area to give reading in m<sup>3</sup>/s.

(c) To give flow of pure methane

The estimate is made as in the following example:

Given a tube analysis of 0.4% CH<sub>4</sub>  
and an air quantity of 260 m<sup>3</sup>/s

$$260 \times 0.4\% = 104 \div 100 = 1.04 \times 1000 = 1040 \text{ l/s}$$

Multiply this by 604.8 to give m<sup>3</sup>/per week

**Surface Methane Plant and Boiler Utilisation**

(a) Determination of Methane Percentage

A percentage of the methane shall be obtained using an industry standard continuous high concentration methane monitor. The monitor is checked on a monthly basis by an independent laboratory demonstrating traceability to the NPL standards, with records being kept on site.

(b) Vacuum

The vacuum (ie the pressure reduction below atmosphere applied to the drainage system) reading shall be obtained from the approved monitor sited on the inlet to the exhausters.

(c) Gas Flow

The differential pressure shall be obtained from the approved monitor sited on the inlet to the exhausters (ie across the permanent orifice plate.)

(d) Calculations to determine flow of methane through the Surface Methane Plant

The calculated gas flow is obtained automatically via the mine environmental monitoring system or by calculating manually, using consistently one or other of the following two methods.

With the observed vacuum, percentage and differential pressure the quantity of gas flowing can be determined by the differential pressure drop by means of a British Coal Metric Methane Flow Calculator or by means of the table shown in the British Coal Methane Drainage Measurement Record Book P122.

(e) Example of Calculation to determine weekly flow of methane through the Surface Methane Plant

This should be done as in the following example, which uses rounded numbers for simplicity; in actual cases measured values would be used.

Suppose Methane Plant runs for 10,000 minutes per week

Calculated Pure Flow Rate = (say) 1000 litres per second

$$\begin{aligned} \text{Weekly Pure Flow} &= 1000 \div 1000 = 1.00 \text{ m}^3/\text{sec} \\ &= 1.00 \times 60 = 60 \text{ m}^3/\text{min} \\ &= 60 \text{ m}^3/\text{min} \times \text{duration of plant running time} \\ &= 600\,000 \text{ m}^3/\text{week} \end{aligned}$$

This is converted to tonnes of methane using the conversion density 0.00067 tonne /m<sup>3</sup>.

**Generator Utilisation**

Methane utilisation is derived from the electricity output taken from the electricity meter, the manufacturer's declared test efficiency and the calorific value of methane.

Electricity output (MWh) / Test Efficiency % (HHV) = Fuel Input (MWh)

Methane tonnes =

Fuel Input (MWh) \* 3.6 GJ/MWh / 55.6 GJ/t (Methane calorific value HHV)

The above measurements are to be collated by Headquarters' staff and converted to tonnes of methane using the conversion density 0.00067 tonne /m<sup>3</sup>. Methane utilisation is to be subtracted from the total flow through the surface plant (gas calculated under section (e) to derive a figure vented to atmosphere.

Tonnes of methane \* 21 = tonnes of CO<sub>2</sub>

#### 1.1.1.3.1 Flaring

##### (a) Determination of Methane Percentage

Methane readings will be continuously obtained via a calibrated industry standard infra red monitor and sent to an on site processor.

##### (b) Gas Flow

The volume of gas passing into the flare will be continually determined by a calibrated industry standard flowmeter sited in the main gas flow and sent to an on site processor.

##### (c) Calculation to determine weekly flow of methane flared to atmosphere

All information from the flow and purity monitors will be received by an industry standard analysis software program which continually calculates the product of gas flow and concentration to calculate pure methane flow and file in a data archive. On a weekly basis the cumulative pure methane flow will be obtained and by subtracting the previous weeks total the weekly methane volume will be obtained.

The efficiency of the combustor within the flare stack will be greater than 99% and will be confirmed in the manufacturer's certificated combustion efficiency.

Therefore, the weekly methane volume will converted to tonnes of methane using the conversion density 0.00067 tonne/m<sup>3</sup> multiplied by the combustion efficiency of the combustors within the flare stack.

#### 1.1.2 Calculation of Total Emissions

Total methane emitted form a source is the summation of emissions from the fan drift and the methane drainage system less any gas utilised, where applicable, at the boiler, generator or flare. The total methane tonnage emitted is converted to equivalent tonnage of carbon dioxide by the application of the global warming potential, multiplication by 21.

As previously stated, any utilisation / flaring of methane at will produce CO<sub>2</sub> at the rate of 2.75 : 1. Therefore, for each tonne of methane utilised 2.75 tonnes of carbon dioxide will be produced.

Total carbon dioxide equivalent emissions are obtained as shown below:

Methane tonnage [fan drift + methane drainage – utilisation (boiler + generator + flare)] \*21 + methane tonnage [utilisation (boiler + generator + flare) \* 2.75]

## Uncertainty Analysis

### Fan Drift

#### 1. Methane Purity

##### a) Manual

Air samples are taken by hand held apparatus in the fan drift to determine methane purity. They are then sent to an independent laboratory demonstrating traceability to NPL standards for analysis. Infra red analysis is used with an accuracy of +/- 1%.

To take into account variations in methane concentrations caused by changes in production and barometric conditions during the working week a statistical precision will be applied to assess the confidence of estimating an annual mean. Based on historical colliery readings to determine the relationship between the concentration determined by mid-week sampling and the average determined by high frequency measurements -this figure will be +/- 8%.

##### b) Automatic

Continuous methane readings are sometimes available at some collieries via the 'tube bundle' system. Air samples are continually monitored via an infra red system to provide a digital read out at the colliery. The accuracy of this system is similar to the manual procedure at +/- 1%.

There is the possibility of an additional error occurring due to the dilution of methane concentrations due to leaks within the system. A recovery test as described above is to be carried out every 3 months to check the tube bundle system and is deemed satisfactory if within 5% of the known concentration.

#### 2. Air Flow Rates

Air flow is measured with an anemometer which is traversed across the cross section of the fan drift. Four readings are required within +/-5%, the mean of these readings is then used. The anemometers are calibrated annually by an independent laboratory demonstrating traceability to NPL standards and a calibration chart is issued for each instrument. The anemometers have an accuracy of +/- 1%.

As the air flow rate calculation involves averaging four readings, this will be accounted for by dividing by  $\sqrt{4}$ .

Variations in fan speed is estimated to be +/- 2%

## Methane Drainage System

#### 1. Methane Purity

Purity is continuously monitored via methanometers which are accurate to +/- 5% at full scale reading.

## 2. Air Flow Rates

A flow monitor measures the differential pressure across two orifice plates. This is accurate to +/- 5% at full scale reading.

## Methane Utilisation

Methane from the drainage system can be utilised either via a boiler to provide heat for the colliery or via a generating unit to produce electricity. Methane utilised via a boiler is measured in the same way as methane from drainage system and will carry the same uncertainty calculation.

For electricity generation the electricity meter is assumed to be accurate to better than 1% and will be used alongside the manufacturer's certificated net electrical efficiency on a high heating value basis, which will be uncertain to +/- 5% based on the Standard ISO 3046 (Part I 1995).

## Flaring

### 1. Methane Purity

Purity is continuously monitored via a calibrated industry standard infra red sensor which has an accuracy of +/- 2% of range. The manufacturers recommended calibration check is on a six monthly basis, purity monitors on site will be checked on a monthly basis by an independent laboratory demonstrating traceability to NPL standards, with records being kept on site.

### 2. Methane Flow Rates

The methane volume is determined by an industry standard integrated pitot tube flowmeter, which has an accuracy of +/- 1% of measured value. This instrument is based on an orifice plate principle and no calibration is required. The pitot tube will be inspected on an annual basis and cleaned as necessary.

### 3. Combustion

The efficiency of the combustor within the flare stack will be greater than 99% and is confirmed by the recent manufacturer's independent emission tests carried out under Environment Agency supervision. The test results are quoted in the Table 1. The calculation of the combustion efficiency is quoted in the Table 2.

Table 1  
Emission test results. Site E. July 2002. Source Biogas

	Total Hydrocarbons as C [mg/Nm <sup>3</sup> ]	Oxygen reference [% v/v]	Detection Limit [mg/Nm <sup>3</sup> ]
Test 1	4	3	0.71 (= 1 ppmv)
Test 2	0	3	0.71 (= 1 ppmv)

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Average	2	3	
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Table 2  
Calculation of the flare combustion efficiency. Site E. July 2002.

	Units	Value	Oxygen reference [% v/v]	Comments
Inlet methane concentration	% v/v	26	3	33% @ 7% O <sub>2</sub> ;
Inlet methane concentration	mg/Nm <sup>3</sup>	185714	3	
Outlet total hydrocarbons concentration as C	mg/Nm <sup>3</sup>	2	3	
Outlet total hydrocarbons concentration as CH <sub>4</sub>	mg/Nm <sup>3</sup>	2.67	3	12 mg/Nm <sup>3</sup> C = 16 mg/Nm <sup>3</sup> CH <sub>4</sub>
Destruction efficiency	%	99.99		

At present there is no standard monitoring protocol for testing enclosed flares exists. The proposed standard monitoring protocol is in public consultation. The quoted emission test results were obtained during the Environment Agency R&D Project P1-405 aiming at developing such a protocol. A copy of the consultation document is available from the Environment Agency website. Biogas Technology Limited fully co-operated with the Environment Agency and made operational flares available for tests during the course of this project. The emission tests were carried out by a reputable and independent third party contractor, appointed by the Environment Agency in a manner corresponding to the proposed testing protocol. The accuracy of the tests will be a combination of accuracy of the sampling and analytical techniques. The accuracy of the monitoring instrumentation on this test will be +/- 2%.

It is not expected that there will be any deterioration in the combustion efficiency of the flare over time due to the install of stainless steel burners and ceramic liners within the flare.

The test shows a destruction efficiency of 99.99% subject to a possible 2% error giving a range of between 98% and approaching 100%. UK Coal therefore intends to use 99% combustion efficiency in its calculations to determine quantities of methane flared.

#### Uncertainty Calculation

##### 1. Fan Drift (Hand held apparatus)

A = Uncertainty in methane purity sample

B = Uncertainty in air flow calibration

C = Variation in fan pressure

D = Error in air speed measurement  
 E = Sampling precision of weekly methane readings  
 Measurements - weekly

$$\text{Combined certainty} = \sqrt{(A^2 + B^2 + C^2 + D^2 + E^2)}$$

$$\begin{aligned} \text{Combined certainty} &= \sqrt{(1^2 + 1^2 + 2^2 + (5/\sqrt{4})^2 + 8^2)} \\ &= (\sqrt{76.25}) \\ &= 8.73 \end{aligned}$$

Level of uncertainty = +/- 8.7%

## 2. Fan Drift (Tube Bundle)

A = Uncertainty in methane purity sample  
 B = Uncertainty in air flow calibration  
 C = Variation in fan pressure  
 D = Error in air speed measurement  
 E = Sampling precision of weekly methane readings  
 F = Tube bundle recovery error  
 Measurements - weekly

$$\text{Combined certainty} = \sqrt{(A^2 + B^2 + C^2 + D^2 + E^2 + F^2)}$$

$$\begin{aligned} \text{Combined certainty} &= \sqrt{(1^2 + 1^2 + 2^2 + (5/\sqrt{4})^2 + 8^2 + 5^2)} \\ &= (\sqrt{101.25}) \\ &= 10.06 \end{aligned}$$

Level of uncertainty = +/- 10.1%

## 3. Methane Drainage System and Boiler Utilisation

X = Uncertainty in methane purity sample at full reading  
 Y = Uncertainty in air flow calibration at full reading  
 Measurements - weekly

$$\text{Combined certainty} = \sqrt{(X^2 + Y^2)}$$

$$\begin{aligned} \text{Combined certainty} &= \sqrt{(5^2 + 5^2)} \\ &= \sqrt{50} \\ &= 7.07 \end{aligned}$$

Level of uncertainty = +/- 7.1%

## 4. Electricity Generation

S = Uncertainty in the electricity meter (normally under 1% but assumed at 1%)  
 T = Uncertainty on net electrical efficiency

$$\text{Combined certainty} = \sqrt{(S^2 + T^2)}$$

$$\begin{aligned} \text{Combined certainty} &= \sqrt{(1^2 + 5^2)} \\ &= \sqrt{26} \\ &= 5.10 \end{aligned}$$

Level of uncertainty = +/- 5.1%

### 5. Flaring

U = Uncertainty in methane purity sample at full reading  
 V = Uncertainty in air flow calibration at full reading  
 W = Uncertainty on measurement of combustion efficiency  
 Measurements - weekly

$$\text{Combined certainty} = \sqrt{(U^2 + V^2 + W^2)}$$

$$\begin{aligned} \text{Combined certainty} &= \sqrt{(2^2 + 1^2 + 2^2)} \\ &= \sqrt{9} \\ &= 3.0 \end{aligned}$$

Level of uncertainty = +/- 3.0%

### 6. Total Emissions

*On average across all collieries, around 70% of the methane is vented to atmosphere from the fan drift whilst the drainage system captures the other 30%. Of the 30% methane captured by the drainage system it is expected that, after installation of flares, on average 50% will be vented, 30% will be flared, 15% will go to generation and the final 5% to boilers.*

*Applying these percentages to the above levels of uncertainty we can obtain a total uncertainty for the complete system.*

*H = Uncertainty in fan drift (assumed worst case tube bundle) 10.1% - (70% of total)*

*I = Uncertainty in vented from methane drainage system 7.1% - (15% of total)*

*J = Uncertainty in flaring 3.0% - (9% of total)*

*K = Uncertainty in generation 5.1% - (4.5% of total)*

*L = Uncertainty in boilers 7.1% - (1.5% of total)*

$$\begin{aligned} \text{Combined uncertainty} &= \sqrt{[(H*70\%)^2 + (I*15\%)^2 + (J*9\%)^2 + (K*4.5\%)^2 + (L*1.5\%)^2]} \\ &= \sqrt{[7.07^2 + 1.07^2 + 0.27^2 + 0.23^2 + 0.11^2]} \\ &= \sqrt{51.25} \\ &= 7.16 \end{aligned}$$

Total level of uncertainty = +/- 7.2%

# PROTOCOL C9: MEASUREMENT OF HFCs AND PFCs FROM CHEMICAL PROCESS OPERATIONS

## BASIS OF THE PROTOCOL

This Protocol replaces Protocol C9 and extends it to cover emissions abatement using a Thermal Oxidiser Plant. The methodologies apart from those dealing with the Thermal Oxidiser Plant are unchanged from those described in Protocol C9. As with Protocol C9, this Protocol is based on *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* developed and published by IPCC. The most relevant section of this deals with emission of HFC-23 and an extract of the *Guidance* on this topic is in Appendix 1. This methodology, while focused on HFC-23, applies to all process emissions of HFCs and PFCs.

The Framework for the UK Emissions Trading System requires that the boundary for calculating emissions is the extent of *management control*.

In the case of refrigerant manufacture, end of life disposal is not included.

At the outset, the complete process is examined, with a view to:

- 3.1 Assigning its external boundaries - generally the whole area over which the proprietor has management control,
- 3.2 Assigning internal boundaries; generally the management accounting subdivisions within which data that will be useful to the inventory is collected in the normal course of operations,
- 3.3 Establishing the physical sources of each emission and
- 3.4 Their approximate relative sizes, in order to prioritise resources, recognising that an "emission" in this context is weighted by the GWP of the constituent gases.

All emissions need to be considered at the outset, not only the current absolute values but their trends too. This will enable rational decisions on the materiality of each source to be taken at an early stage, avoiding waste of effort.

Emissions of HFCs and PFCs are gaseous; either directly from vent streams discharging to atmosphere or indirectly as components of aqueous, liquid or solid waste. HFCs are sufficiently volatile to be released into the atmosphere by vapourisation and degassing from waste that enters the environment.

All emissions must be calculated as accurately as possible using standard industrial instrumentation used for determining masses, flows and concentrations. Flows will be measured continuously and masses derived from the product of flow and concentration will be sufficiently disaggregated to avoid material errors from the variation of concentration with flow. HFC-23 emissions should be determined without any rounding of the measured parameters. Annual emissions should be rounded to the nearest 0.1 tonnes of gas. In the case of the baseline determination, the rounding should be down and for subsequent annual reporting, the rounding should be up.

Estimation of emissions during the manufacture and use of products, which contain HFCs, can be done in six ways, depending on circumstances.

### Method 1

This method relies on the continuous measurement of losses of HFC 23 from the main vent system on the HCFC 22 manufacturing process, and was used to determine emissions during the three baseline years. This is consistent with Tier 2 methodology in the *Guidance*. Method 1 is currently used for the existing vents from the HCFC 22 manufacture and will be used when the gaseous abatement system (thermal oxidiser) is not operating.

## **Method 2**

This method is based on the determination of losses associated with the transfer of products and uses the measured amount of product loss and the concentration of HFC components.

## **Method 3**

This method is used to determine the loss of HFC 23 from a process where HCFC 22 is used as a raw material and HFC 23 is a by-product of the reaction. The method involves the determination of the average loss factor per batch, which is then applied to each batch manufacture. Method 3 is less accurate than method 1, but is needed for batch reactions.

## **Method 4**

This method is used to determine the loss of HFC 23, which is dissolved and subsequently emitted from an aqueous by-product medium. The method uses the measured annual production of by-product and the average concentration of HFC 23 in the by-product.

## **Method 5**

This method is based on the continuous measurement of HFC 23 from the HCFC 22 manufacturing process passing into the gaseous effluent abatement system (the thermal oxidiser) and takes account of the destruction efficiency of this device based on commissioning trials to give the quantity of HFC 23 released to atmosphere.

## **Method 6**

This method is used in conjunction with Method 5 and establishes the carbon dioxide (as opposed to HFC 23) emissions exiting the gaseous effluent abatement system (thermal oxidiser) to atmosphere. It is based on the continuous monitoring of all carbon containing gases and their compositions entering the abatement system (both effluents and natural gas). Where sources to this are batched in without monitoring, the number of batches is used with carbon content taken from plant trials. All of the carbon containing gases are assumed to form carbon dioxide provided trials show destruction efficiencies greater than 99.9%, otherwise destruction efficiency will be taken into account and emissions of gas reported.

In the case of fugitive emissions (for example from leaks or maintenance), losses during transfer and sampling and any other activity that releases material into the environment, total losses should be estimated by mass balance.

In all cases, the combined releases from within the external boundary (established in 2.1) are reported as mass quantities of each individual HFC or PFC, weighted by GWP. Estimates with the smallest uncertainty should generally be used but those having larger uncertainty may have value in verification.

All measurements and estimates must be adequately documented with a clear and auditable provenance in process records (see Appendix 2). This is particularly important when changes in process operation, conditions or measurement parameters give rise to a significant change in emissions (see Appendix 3). Where the emission involves a third party (for example a maintenance contractor), the documentation of the third party must provide the information required and must be capable of being audited.

The introduction of new abatement equipment will require a reassessment of the methods and protocols for the relevant source. Suitable and sufficient validation of these methods must be carried out, in line with currently accepted practice for environmental monitoring.

APPROVED

The standard IPCC GWPs for each HFC and PFC will be used when reporting CO<sub>2</sub> equivalence.

Quality Control and Quality Assurance Systems in accordance with *2000 IPCC Good Practice Guidance* will be applied to ensure transparency, consistency, comparability, completeness and confidence.

An approved accreditation body will verify all source emissions and their measurement protocols to the same standard that was applied during the baseline verification in July 2002. We are duty bound to ensure that all relevant information is declared to the verification body.

**SUMMARY OF METHODOLOGIES****METHOD 1 – EMISSIONS FROM CONTINUOUS OPERATION**

This method depends on the continuous measurement and daily summation of flow. The quantity emitted to atmosphere is the mathematical product of the total daily flow, the volumetric composition of the component and its density. The annual emission is the sum of the daily emissions.

## Equation 1

1.1.1.1.3.1 Emission of Component = Summed (daily flow x component composition x density of component)

$$E_i = \sum_n f \cdot C_i \cdot d_i$$

Where:

$E_i$  is the annual mass emission of component  $i$  in vent stream,

$f$  is the totalised daily volumetric flow,

$d_i$  is the density of component  $i$

$C_i$  is the volumetric concentration (vol/vol) of component  $i$  and

$n$  is the number of days per year (normally measurements are made every day; exceptionally if there are problems with flow measurement procedures based on analysis of historical data may be used to provide estimates)

Volumetric concentration will be determined to a minimum frequency of once a month.

The most recent concentration measurement will be applied to the volumetric flow to calculate the daily emission.

Daily emissions, in kilogrammes, should be rounded down for baseline determination and rounded up for annual reporting.

Total annual emissions should be rounded down to the nearest 0.1 tonne of gas for baseline reporting and rounded up for annual reporting.

There will be an uncertainty in the measurement of the component in the stream as a consequence of uncertainties in measured concentration, flowrate and density. The combined uncertainty for the stream is given by Equation 2.

## Equation 2

Uncertainty in Emission of Component = 2 x Square root of [Square of Concentration Measurement Error + Square of Flowrate Measurement Error + Square of Uncertainty of Density]

$$U_i = 2 \times \sqrt{(ME_{Ci}^2 + ME_f^2 + U_{di}^2)}$$

Where:

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$U_{i}$  and  $U_{di}$  are percentage uncertainties of component  $i$  in, respectively, the emission and the density of the emission stream.

$ME_{Ci}$  is the measurement error (instrumental and sampling errors) in the concentration of component  $i$ , expressed as coefficient of variation, and  $ME_f$  is the instrumental measurement error in the flow, expressed as coefficient of variation.

The factor of 2 is introduced to convert uncertainties measured by the coefficient of variation (the standard deviation divided by the mean expressed as a percentage) to the 95% confidence interval.

**1.1.2.1 Method 2 – Emissions from the transfer of products**

Method 2 deals with special cases of emissions, due to release of a specific volume or mass as a result of a particular procedure.  $R_Z$  is the specific quantity of each release event and  $C_{Z,i}$  is the concentration of the component and  $n$  represents the annual number of events. Otherwise, transfer emissions are treated in the same way as more continuous sources.

<p>Equation 3 for emission events</p> <p>Emission of Component = Mass Fraction of Component x Mass released per release event summed over the number of release events</p> $E_{Z,i} = (C_{Z,i} \cdot R_Z)_1 + (C_{Z,i} \cdot R_Z)_2 + (C_{Z,i} \cdot R_Z)_3 + \dots$
--

Where:

- $E_{Z,i}$  is the annual emission of component  $i$
- $R_Z$  is the measured mass release per release event
- $C_{Z,i}$  is the concentration of the component and
- $n$  is the number of operations which result in a release event

There will be an uncertainty in the measurement of the emission of the component as a consequence of uncertainties in measured mass release and the composition of the component. The combined uncertainty for the stream is given by Equation 4.

<p>Equation 4</p> <p>Uncertainty in Emission of Component = 2 x Square root of [Square of Mass Measurement Error + Square of Component Concentration Error]</p> $U_{Fi} = 2x \sqrt{(ME_{Ci}^2 + ME_R^2 + ME_n^2)}$
--

Where:

- $U_{Ei}$  is the uncertainty in the emission of component  $i$  from the specific source.
- $ME_{Ci}$  is the measurement error (instrumental and sampling errors) in the concentration of component  $i$ , expressed as coefficient of variation,
- and  $ME_R$  is the error in the measurement of mass release, expressed as coefficient of variation.  $ME_n$  is the uncertainty in the estimation of the number of release events.

The factor of 2 is introduced to convert uncertainties measured by the coefficient of variation (the standard deviation divided by the mean expressed as a percentage) to the 95% confidence interval.

**METHOD 3 – EMISSIONS FROM THE USE OF PRODUCT IN WHICH HFC IS A  
contaminant (impurity component)**

This method estimates the typical losses based on the measurement of flows and compositions and then applies these average losses across the number of batches produced each year.

Equation 5 - for losses of HFC as an impurity during use

Emission component = Estimated emission of component *i* each batch x number of batches manufactured each year

1.1.2.1.1

1.1.2.1.2 Where:

$E_i$  is the estimated annual emission of the impurity component

$E_{p,i}$  is the estimated emission per batch of impurity *i*, calculated from typical losses established by past measurements on typical batch emissions established using equation 6.

*N* is the number of batches per annum containing this component

Equation 6 – determination of typical losses of impurity during batch manufacture

1.1.1.1.3 Estimated emission of = sum of (flowrate of emission stream during Impurity per batch various stages of manufacture x composition of impurity at each stage) / number of batches during which composition is measured

$$E_{pi} = \sum_N \{ (f_1 \cdot C_i)_1 + (f_2 \cdot C_i)_2 + \dots (f_n \cdot C_i)_n \} / N$$

Where:

$f_1, f_2 \dots f_n$  are the measured flowrates of the stream containing impurity component *i*, during the different stages of manufacture

$C_i$  is the concentration of the impurity component *i* for each stage

*n* is the number of stages of manufacture for which measurements of flowrate and concentration during the manufacturing stages and

*N* is in this case the number of batches, over which measurements were taken.

Uncertainty of the estimate is expressed as a coefficient of variation (%). It is calculated by the root-squared sum of the individual uncertainties in measured flowrates and concentrations as these are used to establish typical losses from a batch manufacture.

## Equation 7

Uncertainty in emission = 2 x Square Root of [Square of Uncertainty of flowrate of impurity component + Square of the Uncertainty in impurity composition]

$$U_E = 2 \times \sqrt{(U_f^2 + U_C^2)}$$

Where:

$U_E$ ,  $U_f$  and  $U_C$  are the uncertainties in the total estimate, volumetric flowrate and component concentration.

The factor of 2 is introduced to convert uncertainties measured by the coefficient of variation (the standard deviation divided by the mean expressed as a percentage) to the 95% confidence interval.

**Method 4 – Emissions of HFC 23 from Aqueous Hydrochloric Acid in which it is dissolved**

The quantified daily production of the aqueous by-product is summed to obtain the annual production and this is multiplied by the average concentration of HFC 23 in the by-product to determine the total annual emission.

1.1.1.1.2.4.1.1.1 Equation 8

Emission of HFC 23 from Aqueous Stream = Quantity of Aqueous Hydrochloric Acid x the Concentration of HFC 23 in the Aqueous Acid

$$E_z = S_z \cdot C_z$$

Where:

$E_z$  is the annual emission of HFC 23 in the Aqueous Hydrochloric acid.

$S_z$  is the annual production of the Aqueous Hydrochloric acid.

$C_z$  is the average concentration of HFC 23 in the Aqueous Hydrochloric acid as a result of periodic monitoring.

The uncertainty of the method is expressed as a coefficient of variation (%). It is calculated as the standard deviation divided by the mean expressed as a percentage over the samples taken of measured production quantities and measured concentrations. The concentration error is itself a product of sampling errors and analytical errors.

## Equation 9

Uncertainty in emission = Square Root of [Square of Uncertainty of flowrate of impurity component + Square of the Uncertainty in impurity composition]

$$U_z = \sqrt{(ME_{S_z}^2 + ME_{C_z}^2)}$$

Where:

$U_Z$  is the overall uncertainty in emission of HFC 23 from Aqueous Hydrochloric acid.

$ME_{S_z}$  is the error in the measurement of the production of Aqueous Hydrochloric acid.

$ME_{C_z}$  is the error in the measurement of the concentration of HFC 23 in Aqueous Hydrochloric acid.

Uncertainty in the determination of total emission from all sources of HFC23 dissolved in aqueous hydrochloric acid is the root square of the combined uncertainty of all of the emissions considered.

Equation 10

1.1.1.1.1.1 Total uncertainty = 2 x Square root of [Sum of the Squares of all individual  
1.1.1.1.2 Uncertainties]

$$U_{E,i} = 2 \times \sqrt{(\sum U_{Z,i}^2)}$$

The factor of 2 is introduced to convert uncertainties measured by the coefficient of variation (the standard deviation divided by the mean expressed as a percentage) to the 95% confidence interval.

### 1.1.2.2 Method 5 – Emissions of HFCs from gaseous effluent destruction

**Method 5** is based on the continuous measurement of HFC 23 from the HCFC 22 manufacturing process passing into the gaseous effluent abatement system (thermal oxidiser) and the destruction efficiency of this device based on commissioning trials to give the emission at the exit of the thermal oxidiser.

Equation 11

1.1.1.1.2.1 Emission of Component = Inefficiency measure x Totalised daily flow x  
component composition x density of component

$$E_j = (100-e)/100 \cdot \sum_n f \cdot C_i \cdot d_i$$

Where:

$E_j$  is the annual mass emission of component  $i$  in vent stream,

$f$  is the totalised daily volumetric flow to destruction process,

$d_i$  is the density of component  $i$

$C_i$  is the volumetric concentration of component  $i$

$n$  is the number of days per year (normally measurements are made every day; exceptionally if there are problems with flow measurement procedures based on analysis of historical data may be used to provide estimates)

$e$  is the % of material removed by the destruction process and  $100-e/100$  is the inefficiency measure

There will be an uncertainty in the measurement of the component in the stream as a consequence of uncertainties in destruction efficiency, measured concentration, flowrate and density. The combined uncertainty for the stream is given by Equation 12.

## Equation 12

Uncertainty in Emission of Component = 2 x Square root of [Square of destruction efficiency error + Square of Concentration Measurement Error + Square of Flowrate Measurement Error + Square of Uncertainty of Density]

$$U_i = 2 \times \sqrt{(ME_{de}^2 + ME_{Ci}^2 + ME_f^2 + U_{di}^2)}$$

Where:

$U_j$  and  $U_{di}$  are uncertainties of component  $i$  in, respectively, the emission and the density of the emission stream.

$ME_{de}$  is the destruction efficiency error.

$ME_{Ci}$  is the measurement error (instrumental and sampling errors) in the concentration of component  $i$ , expressed as coefficient of variation,

and  $ME_f$  is the instrumental measurement error in the flow, expressed as coefficient of variation.

The factor of 2 is introduced to convert uncertainties measured by the coefficient of variation (the standard deviation divided by the mean expressed as a percentage) to the 95% confidence interval.

### 1.1.2.3 Method 6 – Emissions of Carbon dioxide from gaseous effluent destruction

**Method 6** establishes the carbon dioxide emissions from the gaseous effluent abatement system (thermal oxidiser). It is based on the continuous monitoring of all carbon containing gases and their compositions entering the abatement system (both effluents and natural gas used for combustion).

## Equation 13

1.1.1.1.2.4 Emission of Carbon dioxide from continuous inputs = Sum for all continuous gas streams (Gas stream volumetric gas entered x volumetric concentration of carbon containing molecule x density x no carbon atoms x ratio of molecular mass for CO<sub>2</sub>/molecular mass of carbon containing molecule)

$$E_{CO_2C} = \sum_s \sum_n f \cdot C_j \cdot d_j \cdot m_j \cdot RMM_{CO_2} / RMM_j$$

Where:

$E_{CO_2C}$  is the annual mass emission of carbon dioxide in the vent stream of the thermal oxidiser from continuous inputs,

$f$  is the total daily volumetric flow of the stream to destruction process,

$d_j$  is the density of component  $j$  in the stream entering the oxidiser

$C_j$  is the volumetric concentration in the stream of component  $j$

$n$  is the number of days of operation per year (normally measurements are made every day; exceptionally if there are problems with flow measurement procedures based on analysis of historical data may be used to provide estimates)

$m_j$  is the number of carbon atoms in each molecule

$s$  is the number of continuous streams entering the destruction process

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$RMM_{CO_2}$  is the relative molecular mass of carbon dioxide.

$RMM_j$  is the relative molecular mass of the carbon containing gas stream.

There will be an uncertainty in the measurement of the carbon dioxide in the stream as a consequence of uncertainties in measured concentration, flowrate and density. The combined uncertainty for the stream is given by Equation 14.

Equation 14

Uncertainty in Emission of carbon dioxide from continuous inputs = Square root of [Square of Concentration Measurement Error + Square of Flowrate Measurement Error + Square of Uncertainty of Density]

$$U_j = 2 \times \sqrt{(ME_{de}^2 + ME_{Cj}^2 + U_{dj}^2 + ME_f^2)}$$

Where:

$U_j$  and  $U_{dj}$  are uncertainties of component  $j$  in, respectively, the emission and the density of the emission stream.

$ME_{Cj}$  is the measurement error (instrumental and sampling errors) in the concentration of component  $j$ , expressed as coefficient of variation,

and  $ME_f$  is the instrumental measurement error in the flow, expressed as coefficient of variation and

$ME_{de}$  is the measurement error in the establishment of the vent gas density.

Equation 15

1.1.1.1.2.3 Emission of Carbon dioxide from batch inputs = Carbon emission per batch x ratio of molecular mass of CO2/carbon x number of batches per year

$$E_{CO_2B} = E_c \cdot RMM_{CO_2} / RMM_c \cdot N$$

$E_{CO_2B}$  is the annual mass emission of carbon dioxide in vent stream from batch inputs,

$RMM_c$  is the relative molecular mass of carbon.

$N$  is the number of batches processed through the destruction process per annum.

$E_c$  is the average carbon content of the gases placed into the destruction process (from plant trials)

There will be an uncertainty in the measurement of the carbon dioxide in the stream as a consequence of uncertainties in the number of batches processed in a year and the carbon emission per batch. The combined uncertainty for the stream is given by Equation 16.

Equation 16

Uncertainty in Emission of carbon dioxide from batch inputs = 2 x Square root of [Square of error in number of batches processed + Square of carbon emission per batch.]

$$U_j = 2 \times \sqrt{(ME_N^2 + ME_C^2)}$$

The factor of 2 is introduced to convert uncertainties measured by the coefficient of variation (the standard deviation divided by the mean expressed as a percentage) to the 95% confidence interval.

$ME_N$  is the error in number of batches per year and  $ME_C$  is the error in the measure of carbon emission per batch

Equation 17

1.1.1.1.2.2 Annual Emission of Carbon dioxide from thermal oxidiser = Emission of Carbon dioxide from continuous inputs + Emission of Carbon dioxide from batch inputs

$$E_{CO2} = E_{CO2C} + E_{CO2B}$$

**TOTAL EMISSIONS AND UNCERTAINTIES**

1.1.2.3.1 13. Applying methods 1 to 6 will give N determinations ( $1 \leq n \leq N$ ) of gaseous emissions components  $e_n$  each with uncertainty  $u_n$  and global warming potential  $G_n$ . Total emissions will be given by  $E_T$  where

1.1.2.3.2

1.1.2.3.3  $E_T = \sum G_n e_n$  and the sum runs from  $n = 1$  to  $N$ .

If all these determinations were independent statistically, the total uncertainty in  $E_T$  would be given by

1.1.2.3.4

1.1.2.3.5  $U_T = (1/E_T) \sqrt{(\sum (G_n \cdot e_n \cdot u_n)^2)}$  where the sum would again run from  $1=1$  to  $N$ .

However where a particular method has been applied to give determinations on more than one component simultaneously, the determinations will not be independent for that group of components. These groups of correlated measurements should first be combined using global warming potentials before making the determination of  $U_T$  using the equation above. The uncertainty of such a correlated group will be the same as the uncertainty of any component within the group. The groupings do not of course affect the total emissions estimate  $E_T$  in any way; they are simply necessary for the correct application of the error propagation equation where some of the data are correlated. The summation in the equation for  $U_T$  will then be over 1 to  $M$ , where  $M < N$ , since some of the components will have been pre-combined.

**3.8 ESTIMATION OF HFC-23 EMISSIONS FROM HCFC-22 MANUFACTURE****3.8.1 Methodological issues**

Trifluoromethane (HFC-23 or CHF<sub>3</sub>) is generated as a by-product during the manufacture of chlorodifluoromethane (HCFC-22 or CHClF<sub>2</sub>)<sup>44</sup> and emitted through the plant condenser vent. There are a small number of HCFC-22 production plants globally and thus a discreet number of point sources of HFC-23 emissions.

**CHOICE OF METHOD**

The choice of *good practice* method will depend on national circumstances. The *IPCC Guidelines* (Vol. 3, Section 2.16.1, By-product Emissions) present two broad approaches to estimating HFC-23 emissions from HCFC-22 plants. The Tier 2 method is based on measurement of the concentration and flow-rate from the condenser vent at individual plants. The product of HFC-23 concentration multiplied by the volumetric flow-rate gives the mass rate of HFC-23 emissions. The Tier 1 method is relatively simple, involving the application of a default emissions factor to the quantity of HCFC-22 produced. This method can be applied at the plant level or the national level. In cases where there are Tier 2 data available for some plants, the Tier 1 method can be applied to the remainder to ensure complete coverage. Regardless of the method, emissions abated should be subtracted from the gross estimate to determine net emissions. It is *good practice* to use the Tier 2 method if possible. Direct measurement is significantly more accurate than Tier 1 because it reflects the conditions specific to each manufacturing facility. In most cases, the data necessary to prepare Tier 2 estimates should be available because facilities operating to good business practice perform regular or periodic sampling of the final process vent or within the process itself as part of routine operations. For facilities using abatement techniques such as HFC-23 destruction, verification of the abatement efficiency is also done routinely. The Tier 1 method should be used only in rare cases where plant-specific data are unavailable.

**CHOICE OF EMISSION FACTORS**

There are several measurement options within the Tier 2 method relating to the location and frequency of the sampling. In general, direct measurement of the emissions of HFC-23 provides the highest accuracy. Continuous or frequent measurement of parameters within the production process area itself is almost as accurate. In both cases, the frequency of measurement must be high enough to represent the variability in the process (e.g. across the life of the catalyst). Issues related to measurement frequency are summarised in Box 3.5, Plant Measurement Frequency. General advice on sampling and representativeness is provided in Chapter 8, Quality Assurance and Quality Control (see *Appendix 2*). In cases where plant-specific measurements or sampling are not available and Tier 1 methods are used, the default emission factor of 4% (tonnes of HFC-23 produced per tonne of HCFC-22 manufactured) presented in the *IPCC Guidelines* should be used, assuming no abatement methods.

**BOX 3.5: PLANT MEASUREMENT FREQUENCY**

The accuracy and precision of the estimates of annual HFC-23 emissions are directly correlated with the number of samples and the frequency of sample collection. Since production processes are not completely static, the greater the process variability, the more frequently plants need to measure. As a general rule, sampling and analysis should be repeated whenever a plant makes any significant process changes. Before choosing a sampling frequency, the plant should set a goal for accuracy and use statistical tools to determine the sample size necessary to achieve the goal. For example, a study of HCFC-22 producers indicates that sampling once per day is

<sup>44</sup> HCFC-22 is used as a refrigerant in several different applications, as a blend component in foam blowing, and as a chemical feedstock for manufacturing synthetic polymers.

## APPROVED

sufficient to achieve an extremely accurate annual estimate. This accuracy goal should then be revised, if necessary, to take into account the available resources.

RTI, Cadmus, 'Performance Standards for Determining Emissions of HFC-23 from the Production of HCFC-22', draft final report prepared for USEPA, February 1998.

### CHOICE OF ACTIVITY DATA

When using the Tier 1 method, production data should be obtained directly from producers. There are several ways producers may determine their production levels, including shipment weights and measuring volume-times-density, using flow meters. These data should account for all HCFC-22 production for the year, whether for sale or for use internally as feedstock, and the plant should describe how the HCFC-22 production rate is determined.

### COMPLETENESS

Review of plant data indicates that at properly run manufacturing facilities, fugitive emissions of HFC-23 (e.g. from valves, water scrubbers, and caustic washes) are insignificant (RTI, 1996). If information is available that indicates fugitive emissions are significant, they should be reported and well documented.

### DEVELOPING A CONSISTENT TIME SERIES

Emission of HFC-23 from HCFC-22 production should be estimated using the same method for the entire time series. If data for any years in the time series are unavailable for the Tier 2 method, these gaps should be filled according to the guidance in *Appendix 3*.

### UNCERTAINTY ASSESSMENT

The Tier 2 method is significantly more accurate than the Tier 1 default method. Regular Tier 2 sampling of the vent stream can achieve an accuracy of 1-2% at a 95% confidence level in HFC-23 emissions.

#### 3.8.2 Reporting and documentation

It is *good practice* to document and archive all information required to produce the emissions inventory estimates as outlined in *Appendix 2*, Section 8.10.1, Internal Documentation and Archiving.

Some examples of specific documentation and reporting relevant to this source category are provided below:

To provide for completely transparent reporting, emissions of HFC-23 from HCFC-22 production should be reported as a separate item, rather than included with other HFC emissions.

Documentation should also include:

- (i) Methodological description;
- (ii) Number of HCFC-22 plants;
- (iii) HCFC-22 production (if multiple producers);
- (iv) Presence of abatement technology;
- (v) Emission factors.

#### 3.8.3 Inventory quality assurance/quality control (QA/QC)

Quality control checks as outlined in Chapter 8, Section 8.7, Source Category-specific QC Procedures (Tier 2)(see *Appendix 2*), and quality assurance procedures are applicable. In addition to the guidance in *Appendix 2*, specific procedures of relevance to this sub-source category are outlined below:

##### Direct emission measurement check

Verification should confirm that internationally recognised, standard methods were used for plant measurements. If the measurement practices fail this criterion, then the use of these emissions data

#### APPROVED

should be carefully evaluated. It is also possible that, where a high standard of measurement and QA/QC is in place at sites, the uncertainty of the emissions estimates may be revised downwards. Each plant's QA/QC process should be evaluated to assess if the number of samples and the frequency of sample collection is appropriate given the variability in the process itself. Where possible, all measured and calculated data should be verified by comparison with other systems of measurement or calculation. For example, emissions measurement within the process itself can be verified periodically with measurement of the vent stream. Inventory agencies should verify abatement system utilisation and efficiency.

**8.7 SOURCE CATEGORY-SPECIFIC QC PROCEDURES (TIER 2)**

In contrast to general inventory QC techniques, source category-specific QC procedures are directed at specific types of data used in the methods for individual source categories and require knowledge of the emission source category, the types of data available and the parameters associated with emissions.

It is important to note that Tier 2 source category-specific QC activities are in addition to the general QC conducted as part of Tier 1 (i.e. include QC checks listed in Table 8.1). The source category-specific measures are applied on a case-by-case basis focusing on *key source categories* (see Chapter 7, Methodological Choice and Recalculation) and on source categories where significant methodological and data revisions have taken place. It is *good practice* that inventory agencies applying higher tier methods in compiling national inventories utilise Tier 2 QC procedures. Specific applications of source category-specific Tier 2 QC procedures are provided in the energy, agriculture, industrial processes and waste chapters of this report (Chapters 2 to 5).

Source category-specific QC activities include the following:

- . Emission data QC;
- . Activity data QC;
- . QC of uncertainty estimates.

The first two activities relate to the types of data used to prepare the emissions estimates for a given source category. QC of uncertainty estimates covers activities associated with determining uncertainties in emissions estimates (for more information on the determination of these uncertainties, see Chapter 6, Quantifying Uncertainties in Practice).

The actual QC procedures that need to be implemented by the inventory agency will depend on the method used to estimate the emissions for a given source category. If estimates are developed by outside agencies, the inventory agency may, upon review, reference the QC activities of the outside agency as part of the QA/QC plan. There is no need to duplicate QC activities if the inventory agency is satisfied that the QC activities performed by the outside agency meet the minimum requirements of the QA/QC plan.

**8.7.1.3 DIRECT EMISSION MEASUREMENTS**

Emissions from a source category may be estimated using direct measurements in the following ways:

- . Sample emissions measurements from a facility may be used to develop a representative emission factor for that individual site, or for the entire category (i.e. for development of a national level emission factor);

- . Continuous emissions monitoring (CEM) data may be used to compile an annual estimate of emissions for a particular process. In theory, CEM can provide a complete set of quantified emissions data across the inventory period for an individual facility process, and does not have to be correlated back to a process parameter or input variable like an emission factor.

Regardless of how direct measurement data are being used, the inventory agency should review the processes and check the measurements as part of the QC activities. Use of standard measurement methods improves the consistency of resulting data and knowledge of the statistical properties of the data. If standard reference methods for measuring specific greenhouse gas emissions (and removals) are available, inventory agencies should encourage plants to use these. If specific standard methods are not available, the inventory agency should confirm whether nationally or internationally recognised standard methods such as ISO 10012 are used for measurements and whether the measurement equipment is calibrated and maintained properly.

For example, ISO has published standards that specify procedures to quantify some of the performance characteristics of all air quality measurement methods such as bias, calibration, instability, lower detection limits, sensitivity, and upper limits of measurement (ISO, 1994). While these standards are not associated with a reference method for a specific greenhouse gas source category, they have direct application to QC activities associated with estimations based on measured emission values.

Where direct measurement data from individual sites are in question, discussions with site managers can be useful to encourage improvement of the QA/QC practices at the sites. Also, supplementary QC

activities are encouraged for bottom-up methods based on site-specific emission factors where significant uncertainty remains in the estimates. Site-specific factors can be compared between sites and also to IPCC or national level defaults. Significant differences between sites or between a particular site and the IPCC defaults should elicit further review and checks on calculations. Large differences should be explained and documented.

#### **8.7.1.4 EMISSION COMPARISONS**

It is standard QC practice to compare emissions from each source category with emissions previously provided from the same source category or against historical trends and reference calculations as described below. The objective of these comparisons (often referred to as ‘reality checks’) is to ensure that the emission values are not wildly improbable or that they fall within a range that is considered reasonable. If the estimates seem unreasonable, emission checks can lead to a re-evaluation of emission factors and activity data before the inventory process has advanced to its final stages.

The first step of an emissions comparison is a consistency and completeness check using available historical inventory data for multiple years. The emission levels of most source categories do not abruptly change from year to year, as changes in both activity data and emission factors are generally gradual. In most circumstances, the change in emissions will be less than 10% per year. Thus, significant changes in emissions from previous years may indicate possible input or calculation errors. After calculating differences, the larger percentage differences (in any direction) should be flagged, by visual inspection of the list, by visual inspection of the graphical presentation of differences (e.g. in a spreadsheet) or by using a dedicated software programme that puts flags and rankings in the list of differences.

It is *good practice* to also check the annual increase or decrease of changes in emissions levels in significant sub-source categories of some source categories. Sub-source categories may show greater percentage changes than the aggregated source categories. For example, total emissions from petrol cars are not likely to change substantially on an annual basis, but emissions from sub-source categories, such as catalyst-equipped petrol cars, may show substantial changes if the market share is not in equilibrium or if the technology is changing and rapidly being adopted in the marketplace.

It is *good practice* to check the emissions estimates for all source categories or sub-source categories that show greater than 10% change in a year compared to the previous year’s inventory. Source categories and sub-source categories should be ranked according to the percentage difference in emissions from the previous year. Supplementary emission comparisons can also be performed, if appropriate, including order-of-magnitude checks and reference calculations.

### **8.7.2 Activity data QC**

The estimation methods for many source categories rely on the use of activity data and associated input variables that are not directly prepared by the inventory agency. Activity data is normally collated at a national level using secondary data sources or from site-specific data prepared by site or plant personnel from their own measurements. Inventory agencies should take into account the practical considerations discussed above when determining the level of QC activities to undertake.

#### **8.7.2.2 SITE-SPECIFIC ACTIVITY DATA**

Some methods rely on the use of site-specific activity data used in conjunction with IPCC default or country-specific emission factors. Site or plant personnel typically prepare these estimates of activity, often for purposes other than as inputs to emissions inventories. QC checks should focus on inconsistencies between sites to establish whether these reflect errors, different measurement techniques, or real differences in emissions, operating conditions or technology.

A variety of QC checks can be used to identify errors in site-level activity data. The inventory agency should establish whether recognised national or international standards were used in measuring activity data at the individual sites. If measurements were made according to recognised national or international standards and a QA/QC process is in place, the inventory agency should satisfy itself that the QA/QC process at the site is acceptable under the inventory QA/QC plan and at least includes Tier 1 activities. Acceptable QC procedures in use at the site may be directly referenced. If the measurements were not made using standard methods and QA/QC is not of an acceptable standard, then the use of these activity data should be carefully evaluated, uncertainty estimates reconsidered,

and qualifications documented. Comparisons of activity data from different reference sources may also be used to expand the activity data QC. For example, in estimating PFC emissions from primary aluminium smelting, many inventory agencies use smelter-specific activity data to prepare the inventory estimates. A QC check of the aggregated activity data from all aluminium smelters can be made against national production statistics for the industry. Also, production data can be compared across different sites, possibly with adjustments made for plant capacities, to evaluate the reasonableness of the production data. Similar comparisons of activity data can be made for other manufacturing-based source categories where there are published data on national production. If outliers are identified, they should be investigated to determine if the difference can be explained by the unique characteristics of the site or there is an error in the reported activity.

### 8.7.3 QC of uncertainty estimates

It is *good practice* for QC procedures to be applied to the uncertainty estimations to confirm that calculations are correct and that there is sufficient documentation to duplicate them. The assumptions on which uncertainty estimations have been based should be documented for each source category. Calculations of source category-specific and aggregated uncertainty estimates should be checked and any errors addressed. For uncertainty estimates involving expert judgement, the qualifications of experts should also be checked and documented, as should the process of eliciting expert judgement, including information on the data considered, literature references, assumptions made and scenarios considered.

## 8.8 QA PROCEDURES

*Good practice* for QA procedures requires an objective review to assess the quality of the inventory, and also to identify areas where improvements could be made. The inventory may be reviewed as a whole or in parts. QA procedures are utilised in addition to the Tier 1 and Tier 2 QC. The objective in QA implementation is to involve reviewers that can conduct an unbiased review of the inventory. It is *good practice* to use QA reviewers that have not been involved in preparing the inventory. Preferably these reviewers would be independent experts from other agencies or a national or international expert or group not closely connected with national inventory compilation. Where third party reviewers outside the inventory agency are not available, staff from another part of the inventory agency not involved in the portion of the inventory being reviewed can also fulfil QA roles.

It is *good practice* for inventory agencies to conduct a basic expert peer review (Tier 1 QA) prior to inventory submission in order to identify potential problems and make corrections where possible. It is also *good practice* to apply this review to all source categories in the inventory. However, this will not always be practical due to timing and resource constraints. *Key source categories* should be given priority as well as source categories where significant changes in methods or data have been made. Inventory agencies may also choose to perform more extensive peer reviews or audits or both as additional (Tier 2) QA procedures within the available resources.

### 1.1.2.3.5.1.1.1 AUDITS

For the purpose of *good practice* in inventory preparation, audits may be used to evaluate how effectively the inventory agency complies with the minimum QC specifications outlined in the QC plan. It is important that the auditor be independent of the inventory agency as much as possible so as to be able to provide an objective assessment of the processes and data evaluated. Audits may be conducted during the preparation of an inventory, following inventory preparation, or on a previous inventory. Audits are especially useful when new emission estimation methods are adopted, or when there are substantial changes to existing methods. It is desirable for the inventory agency to develop a schedule of audits at strategic points in the inventory development. For example, audits related to initial data collection, measurement work, transcription, calculation and documentation may be conducted. Audits can be used to verify that the QC steps identified in Table 8.1 have been implemented and that source category-specific QC procedures have been implemented according to the QC plan.

### 8.10.1 Internal documentation and archiving

As part of general QC procedures, it is *good practice* to document and archive all information required to produce the national emissions inventory estimates. This includes:

- . Assumptions and criteria for selection of activity data and emission factors;
- . Emission factors used, including references to the IPCC document for default factors or to published references or other documentation for emission factors used in higher tier methods;
- . Activity data or sufficient information to enable activity data to be traced to the referenced source;
- . Information on the uncertainty associated with activity data and emission factors;
- . Rationale for choice of methods;
- . Methods used, including those used to estimate uncertainty;
- . Changes in data inputs or methods from previous years;
- . Identification of individuals providing expert judgement for uncertainty estimates and their qualifications to do so;
- . Details of electronic databases or software used in production of the inventory, including versions, operating manuals, hardware requirements and any other information required to enable their later use;
- . Worksheets and interim calculations for source category estimates and aggregated estimates and any re-calculations of previous estimates;
- . Final inventory report and any analysis of trends from previous years;
- . QA/QC plans and outcomes of QA/QC procedures.

It is *good practice* for inventory agencies to maintain this documentation for every annual inventory produced and to provide it for review. It is *good practice* to maintain and archive this documentation in such a way that every inventory estimate can be fully documented and reproduced if necessary. Inventory agencies should ensure that records are unambiguous; for example, a reference to 'IPCC default factor' is not sufficient. A full reference to the particular document (e.g. *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*) is necessary in order to identify the source of the emission factor because there may have been several updates of default factors as new information has become available.

Records of QA/QC procedures are important information to enable continuous improvement to inventory estimates. It is *good practice* for records of QA/QC activities to include the checks/audits/reviews that were performed, when they were performed, who performed them, and corrections and modifications to the inventory resulting from the QA/QC activit

## Protocol C10: Measurement of N<sub>2</sub>O, CH<sub>4</sub> and CO<sub>2</sub> from the manufacture of Nylon

The methodology for this protocol is based on the reporting protocols provided by DuPont ('Reporting of Greenhouse Gas Emissions for the UK Emissions Trading Scheme'), who are the sole Nylon manufacturer within the UK. *Caveat:* Note that the methodology presented here is only applicable to the Nylon and downstream manufacturing processes (KA Process, Nitric Acid Process and Adipic Acid Process) of DuPont. Emission factors and other aspects of the methodology, including the source lists, cannot simply be applied to plants which are not operated by DuPont. Other plant operators involved in the production of Nylon and/or its precursors (adipic acid, nitric acid) are required to submit their own protocols for approval by DEFRA.

The DuPont reporting protocols are based on:

- a. *Environmental Reporting Guidelines for company reporting greenhouse gas emissions – DETR June 1999*
- b. *IPCC, Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, Geneva*
- c. *Framework for the UK Emissions Trading Scheme – UKETS(01)-01 – August 2001.*
- d. *Guidelines for the Measurement and Reporting of Emissions in the UK Emissions Trading Scheme – UKETS(01)-05*
- e. *The GHG Protocol Initiative - WRI.WBCSD Adipic Acid and Nitric Acid Production GHG Measurement and Reporting Collaboration peer review - World Business Council for Sustainable Development, Switzerland.*
- f. *KA Environmental Dossier – NW/KA/ENV/001. DuPont Internal Document.*
- g. *Nitric Acid Environmental Dossier – NW/NA/ENV/001. DuPont Internal Document.*
- h. *AA2 Environmental Dossier – NW/NA/ENV/001. DuPont Internal Document.*
- i. *Reporting of Greenhouse Gas Emissions for the UK Emissions Trading Scheme – WSP1110C. DuPont Internal Document.*

Process greenhouse gas emissions from the Nylon manufacturing process occur from point sources from the KA Process, the Nitric Acid Process and the Adipic Acid Process. Emissions from transport, imported energy use (steam and electricity) and from direct energy use are not included in this procedure nor are emissions from the Thermex Heater Furnaces on the Nylon Polymer Plant, since these are used for energy only. Imports of electricity from the public supply network are calculated according to DEFRA Protocol A2.

Three of the basket of six GHGs subject to the UK Emissions Trading Scheme are emitted from the Nylon manufacturing process. The gases emitted from the respective individual processes/plants are listed below:

Nitric Acid Plant	Nitrous Oxide (N <sub>2</sub> O)
KA Plant	Carbon Dioxide and Methane
Adipic Acid Plant	Carbon Dioxide and Nitrous Oxide (N <sub>2</sub> O)

Determination of emissions from the three plants is outlined below.

**Nitrous oxide emissions from the Nitric Acid Plant**

This protocol is based on the IPPC good practice guidance. Note that this protocol has been specifically designed for the DuPont Nitric Acid Plant and may apply to nitric acid plants of other operators. Nitric acid manufacturers other than DuPont are required to submit their own protocols for approval by DEFRA.

Source

Nitrous oxide is the only greenhouse gas produced in the Nitric Acid (NA) process. The Nitric Acid 2 & 3 Off-Gas Stack (common) vent is the only emission source for this gas. 'Lean Gas' (gas that has been through the absorption section and so has a lower concentration of NO<sub>2</sub>) is treated to abate NO<sub>x</sub> in a reactor, using ammonia and vanadium pentoxide catalyst. The gases leaving the abatement reactor are sent to atmosphere via a concrete stack, which is common to both Nitric 2 & 3 areas.

Measurement

The Nylon Site operates a computer system of process and laboratory data access and storage. Each measurement is allocated an identifying tag (eg. instrument number) which is used to access data on that particular measurement. Access to this system is a key element in the calculation of emissions of nitrous oxide from the plant.

The amount of nitrous oxide in the combined off-gases is not measured directly, but is calculated based on the production rate of 100% Nitric Acid, from both Nitric 2 & 3 areas. The flows are continuously measured by on-line instruments and are available via the computer system of process and laboratory data access and storage. These measurements are the basic data from which the quantities of nitrous oxide emitted from the NA stack source are calculated. The N<sub>2</sub>O emission factor for the Nitric Acid Plants is 8.3Kg N<sub>2</sub>O per te nitric acid produced. This factor will be used unless or until the process is changed. If the process is changed, the factor will be formally reassessed. Again, note that this factor only applies to the DuPont Nitric Acid plant.

Calculation Procedure

Inputs from the computer system of process and laboratory data access and storage:

<b><i>Parameters measured</i></b>
Tes/day of 100% Nitric Acid produced from Nitric 2
Tes/day of 100% Nitric Acid produced from Nitric 3
<b><i>Manual inputs</i></b>
Ratio of mass of nitrous oxide level in the off-gas : mass 100% nitric acid produced. This ratio is 8. 3Kg N <sub>2</sub> O per te nitric acid produced.

These data are used to calculate the quantities of nitrous oxide emitted from the stack as follows:

Quantity of nitrous oxide from each stack = Ratio of mass of N <sub>2</sub> O per te 100% Nitric Acid x Mass flow of 100% NA from both NA2 & 3 plants
---

The calculations are performed in a spreadsheet which has been formatted with the approved methods. This includes an emission factor derived in Ref 1, which is within the range as quoted in Ref 3 – 5.

References and Approved Calculations

1. DuPont internal calculation 'NA & AA2 greenhouse gas emissions'.

## APPROVED

2. Application for Registration under IPC for:- A process to manufacture Nylon Polymer.
3. 'Reduction of Nitrous Oxide Emissions from Nitric Acid Plants', by M Schwefer, R Maurer & M Groves, Krupp Uhde GmbH, Germany, March 2000.
4. 'Catalytic Reduction in Nitric Acid Plants of N<sub>2</sub>O from Adipic Acid', by G Kuhn, V Schumacher & E Wagner, BASF, Germany, October 2999.
5. 'Developing N<sub>2</sub>O Abatement Technology for the Nitric Acid Industry', by J S Choe, P J Cook, F P Petrocelli, Air Products & Chemicals Inc, Allentown, PA, October 1993.

### **Emission from the KA (SDC) plant**

The KA plant is unique within the UK. Where appropriate the methodology listed below is based upon the relevant parts of the IPPC guidance (Ref. 1)

#### Source

Carbon dioxide and methane are the only greenhouse gases produced in the KA process. Carbon monoxide, cyclohexane and other hydrocarbons, which are also produced in the process, have the potential to produce carbon dioxide in the COGA off gas abatement process.

The following vents are emission sources for these gases:

<i>Source</i>	<i>Emission</i>
A2 High Pressure (HP) Absorber Off Gas	CO <sub>2</sub> , CH <sub>4</sub> , VOCs (cyclohexane and other hydrocarbons, CO
A3 Low Pressure (LP) Absorber Off Gas	CO <sub>2</sub> , CH <sub>4</sub> , VOCs (cyclohexane and other hydrocarbons, CO
No10 Mother Liquor and Slurry Tank Vent Condenser	CO <sub>2</sub> , CH <sub>4</sub>
No8 Crystalliser Pre-flash Drum Condenser	CO <sub>2</sub> , CH <sub>4</sub>

#### High Pressure Absorber Off Gas

##### Measurement

The Nylon site operates the Info Plus 21(IP21) computer system of process and laboratory data access and storage. Each measurement is allocated an identifying tag (e.g. instrument number) which is used to access data on that particular measurement. Access to this system is a key element in the calculation of emissions of greenhouse gases from the HP and LP Absorbers.

The HP Absorber processes the off gases from the oxidation trains to recover cyclohexane and the treated gases are normally passed to COGA to abate residual VOC's by oxidation, producing carbon dioxide. If COGA is not available the off gases are vented directly to atmosphere.

##### *Measurement of carbon dioxide and carbon dioxide equivalent*

The concentrations of carbon monoxide and carbon dioxide, in the off gas from each oxidation train, are measured by on line instruments. These instruments are calibrated twice weekly with a standard gas mixture. The total air rate to each oxidation train is available as the sum of individual flows to each of four oxidisers, which are continuously measured on line. These measurements which are available on IP21 are the basic data from which the quantities of carbon oxides emitted by each oxidation train are measured.

The rate of combined oxidation off gases fed to the HP Absorber is continuously measured on line and the levels of cyclohexane and other hydrocarbons in HP Absorber off gas are measured daily by laboratory analysis. These measurements which are available on IP 21 are used to calculate the quantities of cyclohexane and other hydrocarbons emitted from the HP Absorber.

##### *Measurement of methane*

APPROVED

The concentration of methane in HP Absorber off gas is not routinely measured. The concentration is assumed based on previous measurements for registration of the KA plant under IPC. The assumed level of methane, the gas feed-rate to the HP Absorber and COGA off line time, which are continuously measured on line, and available on IP 21, are used to estimate the quantity of methane emitted to atmosphere from the HP Absorber. During the period when the HP Absorber is on line to COGA methane is not separately accounted as it is part of the measured total of other hydrocarbons which are converted to carbon dioxide.

Calculation Procedure

*Carbon dioxide*

The carbon dioxide equivalent of HP Absorber off gas passed to COGA is calculated as the sum of the following elements:

$\text{CO}_2 \text{ equivalent of HP Absorber off gas (passed to COGA)} = \text{quantity of CO}_2 \text{ emitted by both oxidation trains} + \text{CO}_2 \text{ equivalent of carbon monoxide emitted from both oxidation trains} + \text{CO}_2 \text{ equivalent of cyclohexane and other hydrocarbons (OHC's) emitted from the HP Absorber}$
--

*Methane*

<b>Parameters measured (Inputs from IP 21)</b>
mg/m3 of cyclohexane in HP off gas
mg/m3 of other hydrocarbons in HP off gas
klb/h air to north train
klb/h air to south train
klb/h gas feed to HP absorber
vol % carbon monoxide in north train off gas
vol % carbon dioxide in north train off gas
vol % carbon monoxide in south train off gas
vol % carbon dioxide in south train off gas
KA to COGA shift time
<b>Manual inputs</b>
Assumed methane level in HP Absorber off gas vol %.

This data and the manual input are used to automatically calculate the quantities of carbon dioxide, carbon monoxide cyclohexane, other hydrocarbons and methane emitted from the HP absorber.

The carbon dioxide equivalent of the HP off gas feed to COGA is calculated as follows:

$\text{CO}_2 \text{ equivalent of the HP off gas feed to COGA} = \text{COGA occupation \%} \times \{ \text{Mass of CO}_2 \text{ generated} + \text{Mass of carbon monoxide generated} \times 44/28 + \text{Mass of cyclohexane generated} \times 6 \times 44/84 + \{ \text{Mass of other hydrocarbons generated} \times 44 \times 0.07(\text{Carbon number/Mol wt}) \}^1$
---

<sup>1</sup>see Appendix 1 for carbon number and molecular weight

Calculation Procedure when HP Absorber Off Gas is vented to atmosphere:

$\text{CO}_2 \text{ equivalent of the HP off gas feed to COGA} = \text{COGA off line time \%} \times \text{Mass of carbon dioxide generated COGA} + \text{off line time \%} \times \text{Mass of methane generated}$
--

LP Absorber Off Gas

The LP Absorber processes off gases to recover cyclohexane from the following plant items:

Flash Column, Deperoxidiser, No.5 Column, and No.6 Column. The treated off gas from the LP Absorber combined with No.4 Column off gas is currently vented to atmosphere. It is intended that the combined off gases will be passed to COGA for abatement of VOC's but this has not yet been established.

Measurement*Measurement of carbon dioxide and carbon dioxide equivalent*

During 1998 and 1999 the concentrations of carbon dioxide and carbon monoxide in the combined off gases were measured weekly by laboratory analysis. Subsequently this analysis was discontinued and typical concentrations based on previous analysis are used. The gas feed rate to the LP Absorber which is continuously measured by an on line instrument is available on IP 21. These measurements are the basic data from which the quantities of carbon oxides emitted from this source are calculated.

The concentrations of cyclohexane and other hydrocarbons in the combined off gases measured daily (Monday-Friday) by laboratory analysis are available on IP21. These and the feed rate to the LP Absorber are used to calculate the quantities of cyclohexane and other hydrocarbons emitted from this source.

*Measurement of Methane*

The concentration of methane in LP Absorber off gas is not routinely measured, the concentration is assumed based on previous measurements for registration of the KA plant under IPC. The assumed level of methane and the gas feed-rate to the LP Absorber, which is continuously measured on line, and available on IP 21, are used to estimate the quantity of methane emitted from the LP Absorber. During the period when the LP Absorber is on line to COGA methane is not separately accounted as it is part of the measured total of other hydrocarbons which are converted to carbon dioxide.

Calculation Procedure

<b><i>Parameters measured (Inputs from IP 21)</i></b>
mg/m3 of cyclohexane in LP off gas
mg/m3 of other hydrocarbons in LP off gas
lb/h gas feed to LP Absorber
Time sending to COGA hrs/shift
<b><i>Manual inputs</i></b>
Levels of carbon monoxide and carbon dioxide in LP Absorber off gas (vol%)
Assumed methane level in LP Absorber off gas vol %

This data and the manual inputs are used to automatically calculate the quantities of carbon dioxide, carbon monoxide, cyclohexane, other hydrocarbons and methane emitted from the LP absorber.

The carbon dioxide equivalent of the LP off gas feed to COGA is calculated as follows:

$$\text{CO}_2 \text{ equivalent of the LP off gas feed to COGA} = \text{COGA occupation \%} \times \{ \text{Mass of CO}_2 \text{ generated} + \text{Mass of carbon monoxide generated} \times 44/28 + \text{Mass of cyclohexane generated} \times 6 \times 44/84 + \{ \text{Mass of other hydrocarbons generated} \times 44 \times 0.07(\text{Carbon number/Mol wt}) \}^1$$

<sup>1</sup>see Appendix 1 for carbon number and molecular weight

Calculation Procedure when LP Absorber Off Gas is vented to atmosphere

$$\text{CO}_2 \text{ equivalent of the LP off gas feed to COGA} = \text{COGA off line time \%} \times \text{Mass of carbon dioxide generated} + \text{COGA off line time \%} \times \text{Mass of methane generated}$$

### **Mother Liquor/Slurry Tank Vent Condenser**

The Mother Liquor and Slurry tanks are low pressure, storage tanks, which vent directly to atmosphere via a common vent condenser.

#### Measurement

##### *Measurement of carbon dioxide and methane*

The concentrations of methane and carbon dioxide in the gases vented to atmosphere from these storage tanks and the vent gas rate are not routinely measured. Values are assumed based on previous measurements made for registration of the KA plant under IPC.

#### Calculation Procedure

Emission rates (tes) are calculated for each component as:

$$\text{tes} = \text{Vol\% component} \times \text{Mol Wt}/22.4 \times \text{vent exhaust rate (m}^3/\text{h)} \times \text{emission period (hrs)}$$

### **Crystalliser Pre-flash Drum Condenser**

The Crystalliser Pre-flash Drum recovers cyclohexane from hydrolysis separator oil layer by steam stripping and condensation with the exhaust gases passing directly to atmosphere.

#### Measurement

##### *Measurement of carbon dioxide and methane*

The concentrations of methane and carbon dioxide in the gases vented to atmosphere from the Crystalliser Pre-Flash Drum Condenser and the exhaust rate are not routinely measured. Values are assumed based on previous measurements made for registration of the KA plant under IPC.

#### Calculation Procedure

Emission rates (tes) are calculated for each component as:

$$\text{tes} = \text{Vol\% component} \times \text{Mol Wt}/22.4 \times \text{vent exhaust rate (m}^3/\text{h)} \times \text{emission period (hrs)}$$

### **References and Approved Calculations**

## APPROVED

- 6.6 IPPC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, IPPC, 2001
- 6.7 Application for Registration under IPC for:- A process to manufacture Nylon Polymer
- 6.8 P6040 Adipic Acid IPC Application: No2 KA Plant Release Data: Supporting Calculations
- 6.9 P5769/25 HP Absorber VOC losses to Atmosphere
- 6.10 DP 74/19 Convert HP Absorber CO and CO<sub>2</sub> emissions to kg/s
- 6.11 DP74/21 LP Absorber Quantification of Environmental Impact
- 6.12 DP 74/26 LP Absorber KO Pot: Estimate Total Flow for Environmental Impact
- 6.13 W/KA/9.2 Laboratory method for the determination of cyclohexane and other hydrocarbons in plant off gas

### **Emission from the Adipic Acid Plant**

Note that this protocol has been specifically designed for the DuPont Adipic Acid Plant and may apply to adipic acid plants of other operators. Adipic acid manufacturers other than DuPont are required to submit their own protocols for approval by DEFRA.

Carbon dioxide, CO<sub>2</sub> and nitrous oxide N<sub>2</sub>O are the only greenhouse gases produced in the Adipic Acid (AA2) process. Carbon monoxide, CO, which is also produced in the process is oxidised to CO<sub>2</sub> in the COGA (Common Off-Gas Abatement) unit.

The following vents are the only emission sources for these gases:

- Adipic Acids 2 Absorber Off-gas Stack
- COGA stack

This protocol is based on the IPPC Good Practice Guidance.

### **Adipic Acids 2 Absorber Off Gas**

#### **Measurement**

The Nylon site operates the Info Plus 21 (IP21) computer system of process and laboratory data access and storage.

The Absorption section of the AA2 plant processes the nitrous gas from the reaction section and converts it into nitric acid for re-use. Nitrous gas from the tanks and other vessels on the Crude and Purge sections are also processed through absorption. The non-recoverable gases; nitrous oxide and carbon dioxide, are normally passed to COGA where the nitrous oxide is destroyed via reaction with fuel and via thermal oxidation. If COGA is not available the off-gases are vented directly to atmosphere, via the local plant stack.

#### ***Measurement of carbon dioxide and carbon dioxide equivalent***

The concentrations of carbon dioxide, in the Absorber Off-gas Stack is determined by calculation of N<sub>2</sub>O released, reference section 5.9.2.2.

#### ***Measurement of nitrous oxide***

The concentration of nitrous oxide in the Absorber off gas to stack is calculated based upon the production rate of Adipic Acid, available on IP21, which is continuously measured.

The spreadsheet also calculates the time that the AA2 OG is not sent to COGA, but released to atmosphere via the local stack. This is calculated based on two parameters: KA feed rate to reaction and AA2 OG flow rate to COGA, available on IP21, which is continuously measured.

Calculation Procedure

<b><i>Parameters measured (Inputs from IP 21)</i></b>
AA2 production rate (te/h)
KA feed rate (te/h)
AA2 OG feed rate to COGA (Nm <sup>3</sup> /h)
<b><i>Manual inputs</i></b>
Mass ratio of CO <sub>2</sub> : N <sub>2</sub> O
Mass ratio of N <sub>2</sub> O : AA2 production rate

The carbon dioxide content in the absorption off gas to COGA is calculated as follows:

$$\text{CO}_2 \text{ released (te/h)} = \text{N}_2\text{O released (te/h)} * 0.24$$

The N<sub>2</sub>O content in the absorption off-gas is calculated as follows:

$$\text{N}_2\text{O released (te/h)} = 0.3 * \text{AA Production rate (te/h)}$$

Time OG is diverted to local stack. This is determined in the spreadsheet by the following two parameters:

- i. KA feed rate to the reactors  
Without KA feed to the reactors AA is not being produced, therefore no emission of GHGs.
- ii. AA2 OG flow rate to COGA  
If KA is on (parameter 1), then OG containing GHG emissions will be released to either COGA or local stack.  
The AA2 OG flow rate is measured at the inlet to COGA, therefore if this value indicates low low (which signifies 0 flow) and KA feed is on-line, the AA2 OG has been sent to local stack.

If COGA is not available the AA2 OG flow will register low as OG will be diverted to local stack.

**COGA Emissions**

The COGA unit uses thermal oxidation technology to treat off-gases that are generated from the Nylon processes and is located in the Acids area. The process streams that are supplied to COGA are generated by KA, Adipic Acid and HMD. These off-gases were previously discharged to stack.

If COGA is not available the off-gases are vented directly to atmosphere via the respective plant stacks.

The emission point of the off-gases, ie. COGA or local stack is determined by calculation.

Measurement*Measurement of Carbon Dioxide*

## APPROVED

The concentration of carbon dioxide in the flue gas exit COGA is measured by on-line instruments & is available on IP21. The analysers are regularly calibrated.

### *Measurement of Nitrous Oxide*

The concentration of nitrous oxide in the flue gas exit COGA is measured by on-line instruments and is available on IP21. The analysers are regularly calibrated.

### Calculation Procedure

<b><i>Parameters measured (Inputs from IP 21)</i></b>
Flue Gas N <sub>2</sub> O Content
Flue Gas CO <sub>2</sub> Content
AA2 OG feed rate to COGA (Nm <sup>3</sup> /h)
<b><i>Other parameters measured</i></b>
The CO <sub>2</sub> content in the absorption off-gas is determined direct from the OLA
The N <sub>2</sub> O content in the absorption off-gas is determined direct from the OLA

### References and Approved Calculations

1. DuPont internal calculation 'DP180:NA & AA2 greenhouse gas emissions'.
2. Application for Registration under IPC for:- A process to manufacture Nylon Polymer

### **Uncertainty estimates**

These are based on expert judgement.

<b>EMISSION</b>	<b>SOURCE</b>	<b>UNCERTAINTY</b>
CARBON DIOXIDE	AA2 Absorber Off-gas via Plant Stack	± 10%
NITROUS OXIDE	AA2 Absorber Off-gas via Plant Stack	± 10%
CARBON DIOXIDE	AA2 Absorber Off-gas via COGA	± 10%
NITROUS OXIDE	AA2 Absorber Off-gas via COGA	± 10%

**Appendix 1**HP ABSORBER OFF GAS: COMPOSITION OF OTHER HYDROCARBONS  
REF IPC APPLICATION

<b>Component</b>	<b>Mol W t</b>	<b>Vol %</b>	<b>normalised</b>	<b>carbon No</b>	
Methane	16	0.03	0.058731402	1	
Ethylene	28	0.0123	0.024079875	2	
Ethane	30	0.1235	0.241777604	2	
Propane	44	0.105	0.205559906	3	
Butane	58	0.21	0.411119812	4	
Pentane	72	0.03	0.058731402	5	
total		0.5108	1		C No/MW
Average	45.986			3.145262	0.068

LP ABSORBER OFF GAS: COMPOSITION OF OTHER HYDROCARBONS  
REF IPC APPLICATION

<b>Component</b>	<b>Mol W t</b>	<b>Vol %</b>	<b>normalised</b>	<b>carbon No</b>	
Methane	16	0.126	0.095310136	1	
Ethylene	28	0.069	0.052193646	2	
Ethane	30	0.068	0.051437216	2	
Propane	44	0.179	0.135400908	3	
Butane	58	0.69	0.52193646	4	
Pentane	72	0.19	0.143721634	5	
total		1.322	1		C No/MW
Average	51.107			3.515129	0.069