**LETS** | LIFE Emissions Trading Scheme

# LETS Update: Working Groups A and B Report

With the contribution of the LIFE financial
instrument of the European Community

**The LETS Update project consists of five reports:**
The Decision Makers Summary
The Scoping Phase Report
The Sustainability Appraisal Report
Working Groups A and B Report
Working Group C Report


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## LETS Update Advisory Group

Matthias Duwe, Climate Action Network Europe
Christian Egenhofer, Centre for European Policy Studies (CEPS)
Michael Grubb, Carbon Trust
Madeleine Infeldt, European Commission (DG Environment)
Sébastien Merceron, Ministry for Ecology, France
Krzysztof Olendrzynski, Institute of Environmental Protection, Poland
Martina Priebe, International Emissions Trading Association (IETA)

## Additional members of the LETS Update Working Groups

## Working Group A (coal mining and chemicals)

Nick Campbell, Cefic
Chris McGlen, UK Coal
Martin Patel, University of Utrecht
Heinrich Steimann, Eurocoal (RAG, Germany)

## Working Group B (aluminium and refrigerants)

Nick Campbell, Cefic
Nick Cox, Earthcare Products Ltd.
Eirik Nordheim, EEA

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Dian Phylipsen (Project Manager)
Alyssa Gilbert
Claire Handley
Judith Bates
Gemma Reece
Meera Ghani Eneland

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A report produced for the LETS Update Partners
by AEA Technology Environment and Ecofys UK

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Environment Agency for England and Wales
Rio House
Waterside Drive
Aztec West
Almondsbury
Bristol
BS32 4UD

www.environment-agency.gov.uk

telephone: 08708 506506

AEA Technology Environment
The Gemini Building
Fermi Avenue
Harwell International Business Centre
Didcot
OX11 0QR

www.aeat-env.com

telephone: 0870 190 6487

facsimile: 0870 190 6318

AEA Technology Environment is a trading name of AEA Technology plc
AEA Technology is certificated to BS EN ISO9001:(1994)

Ecofys UK
78 Cannon St
London
EC4N 6NQ
United Kingdom

www.ecofys.co.uk

telephone: +44 (0)20 7618 6646

facsimile: +44 (0)20 7618 8001

email: info@ecofys.co.uk

# Contents

# Executive summary

## Background

In March 2005, the European Commission invited submissions for LIFE-Environment Preparatory Action Projects. The primary objective of the climate change theme was to provide background as well as the necessary data for an update to the Greenhouse Gas Emission Trading Directive (2003/87/EC). A secondary objective was an evaluation of the effects of the existing trading scheme. The Environment Agency for England and Wales led a successful project bid to undertake a technical assessment with the environmental protection agencies in Austria, (Umweltbundesamt), Denmark, (Miljostyrelsen/Danish Environment Protection Agency), Germany (Deutsche Emissionshandelstelle im Umweltbundesamt DEHSt) and Italy (Agenzia per la Protezione dell' Ambiente e per i Servizi Tecnici APAT) – the LETS Update project[1].

The LETS Update project has looked at the technical feasibility of expanding the European Union Emissions Trading Scheme (EU ETS) in future phases to cover additional sources of greenhouse gases (GHGs) and options for improving the design and harmonisation of the scheme. The project involved two phases. A Scoping Phase was undertaken to prioritise the areas of greatest importance for more detailed study. AEA Technology took the leading role in undertaking this assessment for the project partners. In the Main Phase of the work programme, three Working Groups, comprising of experts from the partner organisations and external bodies, oversaw the technical assessment. This work was undertaken for the project partners by a consortium led by Ecofys.

Working Groups A and B considered the feasibility of including additional sectors and gases in the scheme. DEHSt did not participate in either of these groups. Working Group C considered a number of issues relating to the design and harmonisation of the trading scheme as a whole. A Sustainability Appraisal was carried out on the conclusions of all three working groups. The outcomes of the project will be used primarily to contribute to the European Commission's review of the EU ETS during 2006.

Working Groups A and B were tasked with looking into the feasibility of inclusion of the most promising sectors and gases for expansion under the EU ETS, as selected in the Scoping Phase[2]. This report outlines the findings of Working Groups A and B and provides the relevant background data and possible route maps for inclusion for the recommended sectors. The in-depth analysis looked at the following sectors/gases:

- Chemicals – $CO_2$ and non $CO_2$
- Aluminium – $CO_2$ and non $CO_2$
- Coal-mine methane
- Refrigerants – HFCs.

The project is looking to draw conclusions on the potential for including these sectors and gases in Phase III of the EU ETS (commencing in 2013), and before, where considered appropriate.

The results of the Sustainability Appraisal[3] for the inclusion of each of the recommended sectors is summarised in the relevant chapters of this report. This appraisal was carried out at the macroeconomic level for $CO_2$ emissions from the non-ferrous metals (including aluminium) and the whole chemicals sector. A bottom-up methodology was used to assess the impacts on the non $CO_2$ sectors.

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1 The LETS project is funded by the EU LIFE Environment programme. Project number: LIFE05/ENV/UK/PREP/12.

2 (April 2006) 'LETS Update Scoping Phase Report', Environment Agency for England and Wales.

3 (April 2006) 'LETS Update Sustainability Appraisal Report', Environment Agency for England and Wales.

## Overall conclusions

Overall, LETS Update concludes that there is limited scope for modifying the current Directive to include additional sectors and gases in the scheme for practical reasons. Many sectors either consist of a large number of small emitters or their emissions are too uncertain. Other measures may be more appropriate for tackling emissions from these sectors.

However, the aluminium, coal mining and parts of the chemicals sector do provide some potential to expand the scope of the scheme. Inclusion of these sectors would see the scope of the EU ETS expand to cover approximately 300 new sites and increase the current $CO_2$ equivalent allowance for the EU25 by an estimated nine per cent.

## Chemicals

LETS Update concludes that several sub-sectors of the chemicals sector should be included in the EU ETS in the medium and longer term, both for carbon dioxide ($CO_2$) and nitrous oxide ($N_2O$). The sub-sectors were chosen for further investigation in the Scoping Phase of the project, these are: fertilisers and ammonia, and petrochemicals for $CO_2$, and adipic acid and nitric acid for $N_2O$.

The analysis has shown that these sectors together cover a large percentage of emissions in the chemicals sector, which is a large contributor to GHG emissions in the EU. Despite the degree of exposure to external competition, the environmental gains and the creation of a more level playing field with competing materials already covered by the EU ETS appear to outweigh the costs for the $CO_2$ emissions. For the $N_2O$ sub-sectors, there is a range of cost-effective abatement potentials and technologies currently available that make inclusion desirable from both the legislators and industry perspective.

The Sustainability Appraisal that followed the interim findings from this work confirmed the preliminary conclusion that it is feasible to include these sub-sectors of the chemical industry in the EU ETS.

For $CO_2$, a decision needs to be made as to whether the combustion emissions of these chemical sub-sectors should be included through an extension of the combustion definition or through explicit inclusion as Annex I sub-sectors. In this report it is proposed that the second approach is used, defining specific equipment to be included, in order to provide a level playing field between all operators in the EU.

The $N_2O$ emissions from the adipic acid and nitric acid sectors could be considered for inclusion as early as part way through the second phase, eg 2010 as many of the important elements of monitoring and reporting are already in place, and abatement technologies are ready to be used. Sector inclusion is recommended for Phase III or earlier if monitoring protocols could be agreed EU-wide. Some EU countries are considering opting-in these sectors in Phase II (2008–12). These installations are generally large point sources so no problems are foreseen in the use of the current Directive to include these sub-sectors.

The $CO_2$ sub-sectors are more complex with a high degree of integration within the petrochemicals sector, and between other downstream chemical plants. Therefore, more work would be needed on defining the boundaries of the sector for inclusion in Annex I, as well as on the definition of the process emissions for inclusion. It is therefore recommended that the sector be included in Phase III, from 2013. It might be possible to include one part of the chemicals sector, for example the crackers used in the manufacture of petrochemicals, earlier, as these individual pieces of equipment could be easily identified and monitored. The European Commission has indicated that Member States should include ethylene crackers in Phase II.

It is considered feasible to include $N_2O$ without including all $CO_2$ emissions – as would be the case for the time period between inclusion of $N_2O$ and the later inclusion of $CO_2$, because the emissions could be monitored separately and there are a clearly finite number of plants emitting $N_2O$ so the scope of inclusion could be easily delimited. Furthermore, as the adipic acid and nitric acid industries are interested in being included, this should make data collection and the administrative processes and procedures quite straightforward. France is already considering opting these emissions into the scheme, but all Member States would have to agree to overall inclusion.

# Aluminium

Working Group B reviewed the feasibility of expanding the EU ETS to cover $CO_2$ emissions and perfluorocarbons (PFC) emissions from the aluminium sector. It concluded that primary aluminium production should be included in the EU ETS with respect to its $CO_2$ emissions. The scale of emissions from the sector is significant enough to encourage the sector to incorporate the cost of carbon into their process, at least cost, through the EU ETS. In addition, aluminium competes with materials that are current (or planned) participants in the EU ETS. Inclusion of aluminium would create a more level playing field[4].

However, the aluminium sector is highly exposed to external competition and the possibilities to pass on costs to consumers may be limited. Although abatement opportunities and potential exists for $CO_2$ emissions, the costs are high and it would therefore be expected that, if included, aluminium installations would buy any further allowances on the market rather than making reductions in the installations themselves. The modelling work carried out during the Sustainability Appraisal assessed the economic impact of inclusion, using several indicators. On balance, the information from the model supported the inclusion of the sector, however, the limitations of the model means that further work is desirable before a decision on inclusion is taken.

Looking at other sectors in the EU, there are some other energy-intensive sectors in the EU ETS, such as the iron and steel sector, paper and glass for which the primary aluminium sector may be an important competitor at the level of products. Such sectors could argue that it is not equitable for them to be subject to this regulatory instrument and incur the associated costs while a competitor is not subject to them. A key issue is to understand the extent of this competition, and to work to ensure a level playing field between these sectors.

4 The European Aluminium Association (EAA) has indicated that in their view competition between aluminium and materials currently covered by the EU ETS is limited.

PFC emissions from the primary aluminium production sector should be included in the EU ETS only if $CO_2$ emissions are included in Phase III. The European aluminium industry is not in favour of inclusion under the EU ETS, but if $CO_2$ is included then they wish for PFCs to be included as well[5]. Inclusion of both GHGs would simplify emissions reporting and give flexibility to the approach for emission reductions. Taken in isolation, there is not a strong driving force to include PFCs from aluminium production in Phase III as the GHG emissions are smaller than for $CO_2$, there is limited abatement potential as over 90 per cent of plants will be Best Available Technology (BAT) by 2008 and the level playing field argument is not as strong for PFCs. However, limited abatement potential is not a valid reason to exclude PFCs and the European Aluminium Association (EAA) have commented that some marginal abatement of PFCs is possible above that achieved already.

The analysis in this report has focused on primary aluminium with limited analysis of secondary aluminium. There may be potential competition issues with primary aluminium, as well as other products already included such as paper, glass and steel. Potential competitions of secondary aluminium with materials already covered and consistency of approach to secondary materials (also included for, eg iron and steel) are reasons supporting the inclusion of both parts of the sector. Therefore, the recommendation in this report would be to include secondary aluminium where primary aluminium is included; however, this requires careful attention during the work towards inclusion.

Further studies on the effect of the EU ETS on electricity prices, and the competitiveness of the aluminium sector might be necessary before steps are taken to include the aluminium sector $CO_2$ emissions in the EU ETS. Information will also be needed on plant structure so that decisions can be taken about the boundaries relating to inclusion – in particular information about the level of integration between primary and secondary installations. Monitoring and reporting protocols need establishing too, but these are expected to be relatively straightforward.

## Coal-mine methane

LETS Update concludes that methane from active underground coal mines should be included in the EU ETS in Phase III. Opportunities for emission reductions exist that are relatively cost effective, there are a limited number of mines per Member State (each with high methane emissions) and mine specific emissions can be monitored with reasonably low uncertainty. The main challenges to sector inclusion are its exposure to international competition and the limited options for passing on costs to customers. A key step on the route map to inclusion will be developing an installation definition for the mine installation covering the key ventilation shafts and combustion equipment.

There are currently no EU-wide policies or measures to abate coal-mine methane and inclusion in the EU ETS would provide an incentive for abatement across all Member States. The recommendation is to only include active mine methane emissions at the start of Phase III. Emissions from abandoned mines are subject to very high uncertainty, data is not consistently available on a mine-by-mine basis and there is a question over abandoned mine ownership. For these reasons, abandoned mines are not recommended for inclusion in the early stages of Phase III, though this decision could be reviewed based on any experience gained from inclusion of active mine methane in the EU ETS.

[5] Personal Communication, Eirik Nordheim, European Aluminium Association (EAA), LETS Update meeting 14 December 2005.

# Refrigeration

LETS Update concludes that the stationary refrigeration sector (excluding the air-conditioning and mobile air-conditioning sectors) should not be considered at this time for inclusion in the EU ETS in Phase III. The sector will already be subject to a range of mandatory emission control measures as a result of the forthcoming EU Regulation on fluorinated gases, which appears to be a more practical and cost-effective approach to reducing refrigerant emissions.

This study recommends that the suitability of the sector for inclusion is re-evaluated after the Commission's first review of the fluorinated gases Regulation (to be performed not later than four years following entry into force of the Regulation). The stationary refrigeration sector has many thousands of operators across Europe, with each installation emitting a significantly lower level of GHGs than current installations under the EU ETS. This would have implications in terms of the resourcing of the allocation process and monitoring and verification requirements by Member States.

As full inclusion of refrigeration under the EU ETS was not recommended Working Group B assessed other policy alternatives. Domestic offset projects were discussed as a voluntary option for the refrigeration sector. For example supermarket chains could bundle several sites together to give a higher combined emissions reduction which could qualify for carbon credits. However, this option is uncertain because of the unclear future status of domestic offsets under the scheme in general. A major barrier to this approach for tackling refrigeration lies in the political sensitivity of granting carbon credits to projects that would already be mandatory in some Member States, such as Denmark and Austria, who have pending F-gas bans. Therefore domestic action to reduce F-gas emissions from supermarkets would not be additional in some Member States.

# Scheme administration

It should be noted that the expansion of the EU ETS system, considering all of the sectors above, will add administrative burden to national governments and at the EU level as a whole. This should be understood as part of the policy costs in implementing the EU ETS. However, alternative low-carbon policies are also likely to involve similar levels of administrative burden, so this should not be an argument against inclusion. Furthermore, the additional burden to governments of adding on sectors is likely to be smaller than from setting up a new policy altogether.

# 1 Introduction

The EU ETS has been operating for a year. At this point there is a need to look critically at the system with a view to improving and developing the scheme for the longer term. The European Commission will be undertaking a review and, if necessary, presenting legislative proposals for an update of the scheme during 2006[6]. The environmental protection agencies for England and Wales, Austria, Denmark, Germany and Italy have carried out the LETS Update project under the EU LIFE Environment Programme to help inform the Commission's review of the scheme.

The LETS Update project consists of a Scoping Phase, which identified and prioritised key issues for more detailed study during the Main Phase of the work programme. This included a comprehensive review of available information on Phase I of the EU ETS and preparations by Member States for Phase II and a criteria-based evaluation of a wide range of sectors currently not covered by the scheme to assess their suitability for inclusion in a future phase.

The Steering and Advisory Groups[7] selected the issues for further study in the Main Phase of the work programme, according to where the LETS Update project could provide the greatest contribution and bearing in mind other work being undertaken by Working Group 3 of the Climate Change Committee[8] and the Climate Strategies Network[9].

Three Working Groups carried out the Main Phase of the LETS Update work programme. Working Group A considered the feasibility of including $CO_2$ and non $CO_2$ emissions from chemical production (ammonia, fertilisers, petrochemicals and adipic and nitric acid) and methane ($CH_4$) from active coal mines. Working Group B considered the feasibility of including $CO_2$ and PFC emissions from aluminium production and HFCs used in refrigeration. This report presents the findings of Working Groups A and B, including a summary of the relevant results from the Sustainability Appraisal. Working Group C considered a number of design and harmonisation issues, including the transparency of the preparation and assessment of National Allocation Plans, the interactions between the EU ETS and other EU policies and the potential for using domestic offset programmes.

6 Article 30 of the EU Emissions Trading Directive (2003/87/EC ) requires the Commission to present a report to the European Parliament 30 June 2006.

7 See Acknowledgments for a list of people who have supported the LETS Update project.

8 Working Group 3 is coordinated by the European Commission and is made up of representatives of the EU25 Member States.

9 The Climate Strategies Network, represented by Michael Grubb on the project's Advisory Group, has undertaken studies on allocation issues for Phase II.

Each group consisted of representatives from the partner organisations[10] and additional members invited to join the groups due to specialist knowledge in a relevant area[11]. The Working Groups steered the technical work, which was undertaken by the contractors, Ecofys and AEA Technology.

The Scoping Phase for the LETS Update project identified which sectors, gases and harmonisation issues should be investigated in greater depth during the main phase of the project.

Working Groups A and B have looked into the feasibility of including the most promising sectors in the EU ETS, as selected in the Scoping Phase. This report presents the findings of that work, which includes in-depth analysis for the following sectors/gases:

- Chemicals – $CO_2$ and non $CO_2$
- Aluminium – $CO_2$ and non $CO_2$
- Coal-mine methane
- Refrigerants – Hydro-Fluro-Carbons (HFCs).

10 DESHt was a member of Working Group C only.

11 See Acknowledgments for members of the Working Groups.

# 2 Methodology

This section describes the overall approach used to assess the feasibility of including the sectors and gases in Phase III of the EU ETS.

Emissions data was collected from a variety of statistical databases. Information on the structure and size of installations was gathered from industry organisations. This information was used to assess key countries for each sector and gas where they are responsible for at least 70 per cent of total EU25 greenhouse gas emissions for the given sector/gas combination. The choice of key countries was refined to ensure that, where relevant, there was sufficient coverage of new and old Member States, bearing in mind the predicted patterns of growth in the EU.

The emissions data and sector structure was analysed to highlight key factors relevant to the decision to include the sector. These factors were as follows:

- Overall emissions, and an estimate of emissions as a percentage of total EU25 emissions
- Key emitting countries
- Feasibility issues:
  - The need for de minimus threshold
  - The need to alter the definition of an installation in the Directive
  - Monitoring and reporting requirements
  - Level of transaction costs
  - Competition issues (intra-EU and exposure to extra-EU)
  - Timeframe for inclusion.
- Other legislation that influences emissions
- Available abatement technologies and future potential for abatement.

The findings for each of these areas is summarised in a summary table that includes an overall decision of whether to include the sector, or not. Further detail on the data used in the assessments is available in the annexes of this report.

For sectors where the initial decision was that the sector was suitable for inclusion, a Sustainability Appraisal was carried out[12]. This used the General Equilibrium Model for Energy-Economy-Environment (GEM-E3), a general equilibrium model of the economy to look at the economic impacts on the sector and the overall economy of inclusion in the EU ETS. The modelling was undertaken by the E3M Lab of the Institute of Communication and Computer Systems (ICCS) of the National Technical University of Athens (NTUA). For the chemicals sub-sectors, which are $N_2O$ emitters, and coal mines, this was complemented by a more bottom-up economic analysis. The results of the sustainability analysis were then fed back into the Working Group A and B assessment, and are taken into account in the overall conclusions presented in this report. The results of the economic modelling were important to the final conclusions of the Working Groups, particularly for the aluminium and chemicals sectors where competitiveness is a major issue.

12 (April 2006) 'LETS Update Sustainability Appraisal Report', Environment Agency for England and Wales.

For each sector and gas a decision was made about whether the EU ETS is the best instrument to achieve emission reductions. The decision of whether or not to include the sector was based on balancing the different elements of the summary table against each other, and considering the other legislative options available at present. The main driver for inclusion was often environmental gain and/or achieving a level playing field between current participants and candidate sectors.

For some sectors, the potential emissions saving that would be achieved by inclusion in the EU ETS was apparently small. In order to understand whether a sector should still be recommended for inclusion, an approximate estimate of this coverage was compared to those for existing EU ETS sectors.

The key conflict encountered during the decision-making process was the conflict between competition with countries outside of the EU25 and the scope of emissions coverage. Data on the exposure of sectors to external competition has been gathered from Eurostat and is described in the analysis. This data provides estimates for the degree of exposure for each sector. However, this information cannot directly assess the impact that the EU ETS will have on competitiveness.

Where a sector was found to be suitable for inclusion in the EU ETS, a route map was devised to show the preparation that will be necessary to achieve implementation in time for Phase III.

These route maps set out the key steps that should be taken in the areas of:

- data collection and analysis
- legislative changes
- competition studies
- monitoring and reporting provisions
- administration
- communication with the sector.

Where sectors have not been recommended for inclusion, some direction has been given on alternative approaches to working towards a low-carbon future.

# 3 Chemicals sector

## 3.1 Overall findings

This report recommends the inclusion of several sub-sectors of the chemicals sector in the EU ETS in the medium and longer term both for $CO_2$ and $N_2O$. The sub-sectors analysed were selected in the project's Scoping Phase[13], and were: fertilisers and ammonia, and petrochemicals for $CO_2$, and adipic acid and nitric acid for $N_2O$.

A decision needs to be made as to whether these chemical sub-sectors should be included through an extension of the combustion definition or as an explicit extension to the list of sub-sectors in Annex I to the Directive. LETS Update proposes that the second approach is used in order to provide a level playing field between all EU operators. However, rather than including the sector as a whole, a specific set of installations and processes has been identified that would limit potential difficulties related to, eg system boundaries, monitoring and competitiveness.

The analysis has shown that the sub-sectors together cover about two-thirds of the emissions from the chemicals sector, which is a large contributor to greenhouse gas emissions in the EU. $CO_2$ emissions from the sector can be up to eight to nine per cent of total $CO_2$ emissions in individual Member States. The chemical sector, especially the organic chemicals sector, does appear to be more exposed to competition from outside of the EU. However, the sector's share of total emissions and the potential for competition between materials produced by the chemicals sector and sectors already covered by the EU ETS would suggest inclusion of the sector to be appropriate. For the $N_2O$ sub-sectors, there are a range of cost-effective abatement potentials and technologies currently available that make inclusion desirable from both the legislators, and industry perspective.

The Sustainability Appraisal that followed the interim findings from this working group confirmed the preliminary conclusion that it is feasible to include these sub-sectors of the chemical industry in the EU ETS (see Section 3.4 of this report[14]).

The adipic acid and nitric acid sectors could be considered for inclusion as early as part way through the second phase, eg 2010, as many of the important elements of monitoring and reporting are already in place and abatement technologies are ready to be used. Some EU countries are considering opting-in these sectors in Phase II (2008–12). The installations in these sectors are generally large point sources so no problems are foreseen in the use of the current Directive to include these sub-sectors.

The inclusion of the $CO_2$ sub-sectors is more complex as there is a high degree of integration within the petrochemicals sector, between ethylene crackers and other downstream chemical plant. More work will be needed to define the boundaries of the sector for inclusion in Annex I to the Directive, as well as on the definition of process emissions. It is recommended that the sector be included in Phase III, from 2013. However, it would not be unfeasible to consider inclusion at an earlier stage. The Guidance Document from the European Commission[15] released in December 2005 on Phase II of the EU ETS states that Member States should include ethylene crackers in Phase II.

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13 (April 2006) 'LETS Update Scoping Phase Report', Environment Agency for England and Wales.

14 (April 2006) 'LETS Update Sustainability Appraisal Report', Environment Agency for England and Wales.

15 Communication from the Commission COM (2005) 703 final 'Further Guidance on Allocation Plans for the 2008–12 Trading Period of the EU ETS'.

It is considered feasible to include $N_2O$ without including all of $CO_2$ emissions – as would be the case if $CO_2$ were not included until Phase III but $N_2O$ were included part way through Phase II. The emissions could be monitored separately and there are a clear and finite number of plants emitting $N_2O$ so the scope of inclusion could be easily delineated. Furthermore, the adipic acid and nitric acid industries are interested in being included, which should make data collection and the administrative processes and procedures quite straightforward.

The following sections provide information on these decisions in more detail for $CO_2$ and non $CO_2$ separately.

## 3.2 Carbon dioxide – recommendation

### Table 1 | Summary for $CO_2$ from petrochemicals and fertilisers and ammonia sectors

| **Sector** | **Chemicals** – petrochemicals and fertilisers and ammonia – carbon dioxide |
|---|---|
| Recommendation | Include. |
| Overall emissions | 177 $MtCO_2$ EU25. |
| Emissions as a percentage of EU25 total $CO_2$ (as from scoping phase) | Fertilisers and ammonia 0.2% coming from combustion, 0.4% from process emissions; Petrochemicals 0.9% from combustion but not significant process emissions. |
| Key emitting countries | Belgium, France, Germany, Netherlands, UK. |
| Feasibility issues | • De minimus – not needed.<br>• Definition of installation – insufficient.<br>• Monitoring and reporting – high integration level of plants is an issue, along with the treatment of $CO_2$ sold within chemical industry or to other sectors.<br>• Transaction costs – low to medium due to variety of plant size, in these sub-sectors mostly larger plants therefore lower costs.<br>• Competitiveness – issues already exist intra-EU due to uneven treatment in Phase I, organic chemicals in particular are highly exposed to extra-EU competition.<br>• Timeframe – easily ready for inclusion during Phase III (2013 onwards), some elements could be pushed forwards. |
| Other legislation present/planned | Integrated Pollution Prevention and Control (IPPC) and Large Combustion Plant (LCP) Directives cover these installations, some also covered currently by industry voluntary agreements that pre-date the EU ETS. |
| Abatement technology | Readily available technology at reasonable costs. |
| Potential for abatement | 21% direct emissions in petrochemicals, 23% in ammonia & fertilisers but requiring large capital investments. |

The overall recommendation is to include the chemicals sub-sectors of petrochemicals, and ammonia and fertilisers for $CO_2$ emissions in the EU ETS. These sub-sectors are responsible for a significant level of $CO_2$ emissions that are comparable to sectors already included in the EU ETS. There are abatement technologies available for these sub-sectors at reasonable costs. The potential to abate carbon amounts to slightly over 20 per cent of direct emissions in both sub-sectors. However, large-scale capital investments would be required in the fertiliser and ammonia sub-sector. However, it has significant emissions, which favours its inclusion. It would be expected that these sectors would buy additional allowances from sectors where emissions savings can be made at a lower cost.

The chemicals sector as a whole, but particularly the organic sector, seems to be more exposed to international competition with countries outside the EU than some of the other sectors currently included in the EU ETS. As a result, inclusion in the EU ETS could be damaging to the sector's profitability. This was investigated in the economic modelling in the Sustainability Appraisal, which indicated that value added in the chemicals sector as a whole could drop by 0.7 to 1.7 per cent depending on the stringency post-Kyoto targets for emissions reductions (see Section 3.4). These results suggest that while there may be some adverse impacts on the chemicals sector they are not so significant as to rule out inclusion in the EU ETS.

Other factors to be considered in the decision on inclusion in future phases are the potential competition distortions caused by the exclusion of the chemicals industry from Phase I of the EU ETS. In addition, the current differences in the definition of combustion installation between Member States in this sector affect the current coverage of installations. It is considered important to ensure that there is a level playing field within the EU ETS and this is most easily done through the inclusion of the sector as a whole.

The sector will be covered by the IPPC and LCP Directives, but their effect as a driver of emission reductions is expected to be limited. Part of the sector is currently covered by voluntary agreements in some countries. The inclusion in voluntary agreements of the chemicals sector is likely to be similar to the coverage by voluntary agreements of some of the participants in Phase I of the EU ETS. Voluntary agreements, although favoured by industry for $CO_2$ emissions reductions, do not allow interaction with other sectors or gases where emissions reductions might be possible at lower costs. Furthermore, voluntary agreements do not provide the same level of certainty that the environmental targets will be reached as a cap and trade system does.

Given the sector structure, the EU ETS seems an appropriate policy instrument to address emission reductions in the chemicals sector in an integrated way. The route map in Section 3.2.1 outlines further work that is necessary in preparation for the inclusion of the sector. In particular, a decision has to be made about how the sector should be included. The recommendation in this report is to include chemicals as an Annex I sector, either as a whole or by the identification of specific equipment. The alternative is to include petrochemicals through the use of the broad definition of combustion installations across all Member States. Annex A provides a detailed overview of the different options and the advantages and disadvantages of each for both the petrochemicals, and ammonia and fertilisers sub-sectors.

### 3.2.1 Route map for inclusion

The route map below highlights some areas where further work will need to be done to facilitate the inclusion of the sector in the EU ETS. The individual areas are discussed in the following sections.

**Table 2 | Route map for inclusion of $CO_2$ from the petrochemicals and fertilisers & ammonia sectors in the EU ETS**

| Time | 2008 | 2009 | 2010 | 2011 | 2012 | Start Phase III 2013 |
|---|---|---|---|---|---|---|
| **Data collection** | Collect data for historical emissions approach OR Collect data on plant integration to inform sector boundaries | Develop benchmarking approach by subsector – many needed | | | | |
| **Legislative process** | Define process emissions for this sector | Alter Annex 1 to cover sector by naming the sub sectors OR harmonisation of the combustion definition across member states | | | | |
| **Competition** | Carry out further analysis of competition with those outside EU25 | | | | | |
| **Monitoring and reporting** | Modify monitoring and reporting guidelines to cover chemical processes and take into account $CO_2$ transfer as a feedstock | | Ensuring monitoring protocols are in place | | | |
| **Administration** | | | | Include in NAPs | | |
| **Communication** | Communication with CEFIC, EFMA and national sectoral bodies on sector boundaries, thresholds and definition issues | | Communication on allocation methodology | | | |

Note:
CEFIC = European Chemical Industry Council
EFMA = European Fertilizer Manufacturers Association

### 3.2.2 Data

Overall $CO_2$ emissions from the chemicals sector as a whole stood at 177 $MtCO_2$ in 2003 in the EU25. Within this the two sub-sectors responsible for the largest portion of $CO_2$ emissions are the petrochemicals sector (largely ethylene production) and the ammonia and fertilisers sector, which together account for about two-thirds of the total emissions of the sector.

It is important to note that certain parts of the ammonia and petrochemicals sectors are already included in the first phase of the EU ETS in some Member States, which is currently causing market distortions across the EU (see Section 3.2.4 for more detail). As an indicative figure, extension of the petrochemicals sector to include all $CO_2$ emissions is estimated to provide an additional 4 $MtCO_2$ coverage (compared with the current allocation for the UK chemical industry as a whole in Phase I of 6.5 $MtCO_2$). Inclusion of ammonia and fertilisers would add another 2–3 Mt to this. In the Netherlands, both ethylene crackers and ammonia plants were originally included in the NAP, later an opt-out was requested because many of their competitors in other countries were not included. As a result, in the Netherlands the share of emissions for these plants covered by the EU ETS dropped from 100 per cent to about 25–30 per cent.

Germany, the Netherlands, France, Belgium and the UK are the five Member States with the highest $CO_2$ emissions from these two sub-sectors of the chemicals industry. These five countries are responsible for more than 70 per cent of EU25 $CO_2$ emissions from petrochemicals and more than 80 per cent of $CO_2$ emissions from ammonia and fertilisers.

The International Fertilizer Development Center (IFDC) publishes lists of specific sub-sector chemical plants worldwide, including ammonia, urea and ethylene plants. The data included in this list is largely in the form of production and capacity data. Production and capacity data from 2001 were used to estimate $CO_2$ emissions from the ammonia and ethylene (petrochemicals) plants in the five Member States with the highest emissions share of the chemicals sector: Belgium, France, Germany, the Netherlands, and the UK. This data was then used to assess the average size and distribution of the major EU ammonia and ethylene plants. Figures 1 and 2 in Annex A show the distribution of ammonia and petrochemical plants in the five key Member States.

In general, plants in both the ammonia and fertilisers and petrochemicals sub-sectors are large. There are no plants that would fall below the common definition of a small installation within the EU ETS, ie less than 10 kt $CO_2$/yr or 25 kt $CO_2$/yr. Around two-thirds (76 per cent) of ammonia plants in the five Member States studied in detail emit between 100–1000 kt $CO_2$/yr. Ethylene plants are, on average, even larger, with just under half (46 per cent) in the five key Member States emitting more than 1000 kt $CO_2$/yr.

The majority of plants in the petrochemicals sector are fully integrated petrochemical facilities[16], although there are exceptions. The level of integration causes issues that would have to be resolved, particularly regarding the monitoring, reporting and verification of emissions. The definition of installation boundaries would also be an important issue to consider and to ensure that any definition used to delineate the sector in Annex I is consistent with definitions currently recognised in the sector, to avoid regulatory complexity and potential market distortions caused by Member States interpreting definitions in different ways.

[16] Meaning that the major source, ethylene crackers, are not only integrated with separation processes to separate ethylene from the other products of the crackers (propylene, butene, aromatics fraction, hydrogen, methane, heavy fuel residues), but with other installations that further separate or process these intermediate products.

Further information is needed on the extent to which $CO_2$ is transferred as a feedstock between installations. This is considered an issue in the fertiliser and ammonia sector and this information is needed to determine whether or not the definition has to be devised to take this into account.

The specific data needs for expansion to the chemicals sector to enable allocation will depend on the allocation methodologies chosen by Member States in future phases. If a grandfathering approach were chosen, ideally at least three years of historic emissions data would be preferable to enable Member States to take an average figure (as most have chosen to do in their Phase I allocation methodology).

If a benchmarking approach were chosen, benchmarks would need to be developed for the various sub-sectors. For the chemical industry as a whole, this may require a significant amount of work due to the large number of potential products and the high degree of integration within the sector. However, for ethylene crackers and ammonia plants, benchmarking approaches are more feasible and have been used before[17]. The appropriate level of aggregation for chemicals benchmarks would have to be carefully considered to ensure that the benchmarks developed are relevant and at a suitable level of aggregation for the installations covered.

### 3.2.3 Legislative processes

Including the chemicals sector in the EU ETS would be quite straightforward from the legislative perspective. Installations are generally medium to large point sources and would therefore fit the current definitions for installations in the Directive and preclude the need for a de minimus rule.

As illustrated in the route map, inclusion will require careful consideration of the following issues:

- Drawing up the sectoral boundary – petrochemical installations are complex and mostly integrated with downstream processes
- Ensuring that $CO_2$ is carefully accounted for – in ammonia production, as well as other chemical process, it is quite common for carbon or hydrogen from the fuels to end up in the materials or for $CO_2$ to be captured and transferred to other users. This issue needs to be assessed and then dealt with appropriately in the Directive.

Most importantly a choice needs to be made about *how* the sector is included in Annex I to the Directive. There are three choices:

- Include the sector explicitly by naming the relevant chemical sub-sector and determining a threshold for inclusion.
- Including the sector by explicitly specifying which types of installations are to be included.
- Including crackers and processes driven by steam, ie non-combustion processes, through the harmonisation of the combustion definition at the broad level across Member States.

The advantage of including the sub-sector explicitly in Annex I is that this enables a threshold to be set that ensures broad inclusion of medium to large sized plants, avoiding the confusion related to the use of different definitions of combustion installations. Including the sector by specifying installation types could avoid the inclusion of the parts of the chemicals sector that have lower emissions and are made up of many smaller installations, ie general chemicals and pharmaceuticals.

[17] Although some confidentiality issues may be attached to using them. Dian Phylipsen (2005), 'Recommendations on the use of benchmarking in the UK allocation in Phase II of the EU', Report for the UK Department of Trade and Industry, Confidential.

Alternately, using the combustion installation definition as a threshold would exclude smaller installations, but would require agreement to harmonise the definition at the EU level, which could be more challenging than reaching agreement about the inclusion of the chemicals sector as a whole. The greatest disadvantage of this approach is that it would not cover plants that are just under the combustion threshold, and therefore could cause competition distortions between plants within the EU (see Table 22, Annex A for the advantages and disadvantages of the different approaches to inclusion).

### 3.2.4 Competition

There are two areas of concern in relation to competition for the chemical sector and the EU ETS.

First, there are competition distortions already apparent in the chemicals sector due to the varied coverage of the EU ETS across Member States. As a result, there are comparable plants within the same sector that are not covered by the scheme in Phase I. In countries where the broad definition of combustion installation has been applied, eg the Netherlands, crackers in the petrochemical sector have been covered. In the UK, Germany and France only emissions from boilers and Combined Heat and Power (CHP) within the petrochemicals sector are covered, crackers have explicitly been excluded. In Belgium, the key petrochemicals installation is included, but it is not clear from the installation list whether this includes the combustion only, or also includes the cracker. As a result of this discrepancy, the Dutch installations affected have sought and been awarded opt-outs from the first phase of the scheme. The Directive, however, does not allow opt-outs in Phase II. These discrepancies could be removed by including crackers explicitly in the scheme, or by ensuring that all countries use the broad interpretation of combustion installation.

The second area of concern is the high degree of exposure of the chemicals sector to competition from outside the EU25 compared to sectors already covered by the EU ETS[18]. According to the International Energy Agency (IEA)[19], the chemical industry as a whole is not that different from other industries, but statistics suggest that for sub-sectors such as the organic chemicals this may not be the case. Looking more closely at the UK, one of the key countries, an assessment of UK trade flows[20] prepared in the run up to the first phase of the EU ETS shows 39 per cent of the exports of organic chemicals, 31 per cent of inorganic chemicals' exports and 18 per cent of fertilisers and nitrogenous compound are exported to non-EU countries, demonstrating a relatively high degree of exposure of the sector.

Considering that the sector accounts for a large volume of emissions, that there is sufficient room for abatement, and the absence of a level playing field with sectors already covered by the EU ETS, inclusion of the sector would be preferable. The modelling exercise carried out using the GEM-E3 model as part of the Sustainability Appraisal (Section 3.4) indicated that there may be some adverse impacts on the chemicals sector upon inclusion in the EU ETS, but they are not so significant as to rule out inclusion. However the results are only indicative as due to the sectoral disaggregation available within the model, they are for the chemicals sector as a whole rather than the sub-sectors identified as potentially suitable for inclusion (petrochemicals, fertilisers, ammonia and nitric and adipic acid production). It would therefore be useful to carry out a further examination of economic impacts on the sector before a final decision is made on inclusion using either modelling techniques capable of more detailed sub-sectoral modelling, or a bottom-up approach. This is shown in the route map.

18 Eurostat data: www.eu.int/comm/eurostat/

19 IEA information paper, J Reinaud, 'Industrial Competitiveness Under The European Union Emissions Trading Scheme', IEA, Paris, 2005.

20 'Competitiveness, Trade and Regional Implications of EU Emissions Trading Scheme', UK Department of Trade and Industry, no date given. web address: www.dti.gov.uk/energy/sepn/euetsimplications.pdf

### 3.2.5 Abatement technologies

For both petrochemicals and ammonia production, the potential for emissions abatement is slightly above 20 per cent of total direct emissions. For ammonia manufacture, savings are generally associated with significant process changes, which, whilst often assessed to be cost effective, require large levels of capital investment. The adoption of these technologies is therefore limited by structural and re-organisational changes within the industry. The potential for savings is therefore generally considered to be low, despite low abatement costs when each technology is considered on its own.

### 3.2.6 Monitoring and reporting

In order to include the $CO_2$ element of the chemicals sector, work will need to be carried out to develop appropriate monitoring and reporting protocols. Although these are likely to be possible to develop, these sectors involve a high degree of integration so a mass-balance approach may need to be developed. This is, however, not different from the approaches currently used in the iron and steel sector or the refineries sector under the EU ETS. Special attention should be paid to use of fuels for feedstock purposes (carbon or hydrogen that end up as part of the material) and the capture and storage or transfer of $CO_2$.

Work should begin on monitoring and reporting early on, in order to ensure that protocols and methods are in place in time for the start of Phase III.

### 3.2.7 Administration

The major administrative requirement for the inclusion of the chemicals sub-sectors would be the preparation of a monitoring and reporting protocol. Sector and installation definitions within the chemicals sector are complex so this process may require more time than for other sectors. Formal definitions of the sectors and sub-sectors used in the ETS would need to be developed and ideally aligned with IPPC guidelines to avoid legislative complexity. However, chemicals plants are already regulated under IPPC and so there should be certain emissions monitoring systems already in place. Formal EU ETS data collection from installations in time for the development of the Phase III NAP (or earlier for certain sections) would still be required.

The administrative burden on individual companies or Member States should not be disproportionate compared to the existing scheme. The coverage of some parts of the sector in Phase I may in fact mean that expansion to the remainder of the sector would remove some of the regulatory complication. In general chemicals installations are large installations so the administrative burden should be low to medium.

### 3.2.8 Communication

Communication with CEFIC, EFMA, and national sector bodies (for example Association of Chemical Industries in the Netherlands (VNCI) and Chemicals Industry Association (CIA) in the UK) would be required for successful inclusion of these sectors. The input from these sector bodies on the sector definitions and installation boundaries would be particularly valuable, even more so if it were decided that a benchmarking methodology should be used.

## 3.3 Non $CO_2$ greenhouse gases – recommendation

### Table 3 | Summary for $N_2O$ from adipic and nitric acid production

| Sector | $N_2O$ from chemicals sector |
|---|---|
| Recommendation | Include. |
| Overall emissions | 53.5 Mt $CO_2$ eq (in 2003). |
| Emissions as a percentage of EU25 total GHG | 1.1% |
| Key emitting countries | France, Italy, Germany, Netherlands, Poland, Belgium, UK. |
| Feasibility issues | • De minimus – not needed: typical installation emission are at least 50 kt $CO_2$ eq per year.<br>• Definition of installation – sufficient: well defined point sources.<br>• Monitoring and reporting – technically feasible.<br>• Transaction costs – low – medium: new monitoring equipment required for many plants.<br>• Competitiveness – fertiliser industry under pressure from imports but low cost of abatement technology means inclusion should not cause problems.<br>• Timeframe – Phase III; national opt ins being proposed for Phase II. |
| Other legislation present/planned | Medium, attention paid to this gas in legislation (IPPC draft BREF note and national pollution control legislation). |
| Abatement technology | Available at low cost (1–5 €/t $CO_2$ eq ) in pilot/pre-commercial phase. |
| Potential for abatement | Significant. |

$N_2O$ emissions in the chemicals sector arise mainly from adipic and nitric acid production with smaller emissions from glyoxylic acid and carpolactum production. LETS Update concludes that nitric and adipic acid production should be included in Phase III of the EU ETS. Many of the steps necessary for inclusion are already in place so that consideration could also be given to including them in Phase II if work on a monitoring and reporting protocol and an allocation methodology could be completed in time. As no international measurement standard for $N_2O$ would be available in time for the start of Phase II, the monitoring protocol would have to be supported by national standards or codes of best practice for measurement.

Adipic and nitric acid production plants are well defined, point sources and monitoring of emissions to acceptable standards is technically feasible. All but one of the adipic acid plants in the EU has already installed abatement equipment, but inclusion in the EU ETS could provide an incentive to maximise the abatement efficiency and time that the abatement plant is operational. Abatement techniques are available to reduce emissions from nitric acid plants significantly at a low cost, meaning that impacts on the competitiveness of the fertiliser industry should be minimised. France is planning to opt-in some installations of the $N_2O$ sectors (nitric, glyoxylic and adipic acids), and EFMA is keen for nitric acid production to be included in Phase II. Adipic and nitric acid plants in non Annex 1 countries are being considered for Clean Development Mechanism (CDM) projects[21].

The main alternative to inclusion in the EU ETS would be regulation of emissions under pollution control legislation. All[22] of the production processes are covered by IPPC and existing installations must therefore have an IPPC permit by 30 October 2007. For nitric acid production the relevant (draft) advisory Best Available Technology Reference document (BREF)[22] specifies what constitutes best available techniques and sets a Best Available Technology (BAT) level for $N_2O$ emissions for new plants. The inclusion of a level for existing plants is currently under discussion. Adipic acid plants are not specifically discussed in the BREF note.

Member States may also be setting limits for $N_2O$ emissions under national pollution legislation. For example, Germany has a proposal for existing nitric acid plants to meet a relatively stringent limit requiring the use of abatement techniques by 2010. Existing reductions in emissions from adipic acid plants have typically been achieved through voluntary agreement with the industry or through national pollution control legislation. Installation of abatement equipment at the only plant with unabated emissions in Italy is planned for before 2008.

While emissions from nitric acid plants will be tackled under IPPC, it is likely that the financial incentives available to manufacturers from inclusion in the EU ETS would lead to earlier installation of abatement equipment, thus reducing emissions earlier. There would also be an incentive to seek to achieve the greatest reductions possible, rather than the minimum to ensure compliance with limits set in IPPC permits, which, depending on how stringent the BAT limit set, could deliver additional reductions compared to an IPPC only approach.

21 An example of a Joint Implementation (JI) project is nitrous oxide reduction at Agropolychim's fertiliser plant in Bulgaria. Examples of CDM projects include nitrous oxide reduction at an adipic acid plant in Korea and at fertiliser plants in Egypt.

22 'Integrated Pollution Prevention and Control'. Draft Reference Document on Best Available Techniques in the Large Volume Inorganic Chemicals, Ammonia, Acids and Fertilisers Industries. March 2004. European Commission Directorate General JRC.

### 3.3.1 Route map for inclusion

**Table 4 | Route map for inclusion of $N_2O$ from adipic and nitric acid production in the EU ETS**

| Time | 2008 | 2009 | 2010 | 2011 | 2012 | Start Phase III 2013 |
|---|---|---|---|---|---|---|
| **Data collection** | Collate available emissions monitoring data | Consider approaches to allocation | | | | |
| **Legislative process** | Agree definitions of plant to be included | | | | | |
| **Competition** | | | | | | |
| **Monitoring and reporting** | Develop EU monitoring protocol<br>Encourage development of ISO/CEN standard | | Review feasibility of monitoring | All plant to begin continuous monitoring | | |
| **Administration** | Learn from experience of UK ETS and any national opt-ins in Phase II | | Include in NAP | | | |
| **Communication** | Ongoing dialogue with EFMA and adipic acid manufacturers | | | | | |

Note:
ISO = International Standards Organisation
CEN = European Committee for Standardisation

### 3.3.2 Data

Information is publicly available on $N_2O$ emissions at the national level from production of nitric and adipic acid and other sources (production of glyoxylic acid and carpolactum). Information from Member States' inventory reports indicates that data on emissions factors for individual installations are generally collected and then combined with information on production rates to produce the national estimate. Emissions factors are typically either a default emission factor based on the type of plant technology or plant-specific emissions factors based on sample measurements. Only a few plants currently use continuous monitoring to determine emissions. The uncertainty in most of the emissions estimates is therefore relatively high.

There are fewer than 100 nitric acid production plants in the EU25. As the main use of nitric acid is for fertiliser manufacture, many plants are owned by fertiliser manufacturers and may be part of a larger fertiliser manufacturing facility; a list of plants is held by EFMA. EFMA also hold a list of emissions factors estimated by individual installations.

There are five adipic acid plants in the EU: one in France, one in Italy, one in the UK, and two in Germany.

The number of carpolactum and glyoxylic plants is unknown but is thought from existing information to be small. Emissions from these two types of plant are less well characterised than for nitric and adipic acid manufacture.

### 3.3.3 Legislative processes

There are no key legislative issues to address; definition of the plant should be straightforward as the products are well defined. No de minimus rule should be needed; on the basis of the available information all installations are estimated to produce at least 100 kt $CO_2$eq per year.

### 3.3.4 Competition

The European fertiliser industry is currently under some pressure from imports from countries with cheaper energy prices than in the EU. However, the low cost of abatement compared with the current prices for carbon suggest that inclusion of $N_2O$ emissions in the scheme would not have any impacts on the competitiveness of the EU industry. This was confirmed by the bottom-up assessment carried out as part of the Sustainability Appraisal (Section 3.4) which suggests that the nitric acid sector would not reap financial benefits from participation in the EU ETS, but that impacts are not significant in the short or long term.

### 3.3.5 Abatement technologies

For adipic acid plant, either catalytic decomposition, or thermal destruction (combustion of the off-gases in the presence of methane) can be used; these systems have efficiency of between 95 and 99 per cent. Costs are typically less than 1 €/t $CO_2$. These systems were installed in France, the UK and Germany between 1994 and 1998[23].

For nitric acid plant, there are a number of technologies that could be retro-fitted to existing plant, developed either by manufacturers themselves or contractors. These are summarised in Table 24, Annex B and are based on using catalysts to decompose the $N_2O$. The suitability of the various technologies depends on the design of the plant. The costs of these technologies are reported to be in the range of 1–5 € /t $CO_2$eq, and typically they reduce $N_2O$ emissions by 60 to 80 per cent. Some of these technologies have been installed in plant within the EU, so that experience is being gained in their operation, but their use is not currently widespread. Techniques also exist for new plants[24], and typically have costs in the same range.

23 J de Beer, D Phylipsen, and J Bates, 2001. 'Economic Evaluation of Carbon Dioxide and Nitrous Oxide Emission', contribution to a study for DG Env; www.europa.eu.int/comm/environment/enveco/climate_change/industry.pdf

24 A new plant under construction in Hungary will have abatement equipment incorporated, but a plant which has recently come on stream in the Czech Republic does not.

### 3.3.6 Monitoring and reporting

Inclusion in the EU ETS would require development of a monitoring and reporting protocol. (Draft) protocols and monitoring methodologies that could form a useful input into this areas follows:

- EFMA have commissioned the development of a draft annex on monitoring and reporting for nitric acid production[25].
- France has developed good practice guides (published by the French Standards Agency AFNOR) for quantifying $N_2O$ emissions from nitric acid, adipic acid and glyoxalic acid manufacture[26].
- Approved baseline and monitoring methodology for abatement at adipic acid plants for CDM projects[27].

The EFMA commissioned report on the draft monitoring and reporting annex suggests that continuous monitoring of $N_2O$ emissions using infrared techniques will be required, and that this should achieve an uncertainty of ±5 per cent. Only a few plants in Europe currently have continuous monitoring systems; installation of the system will thus be a cost, but should not be prohibitive. The French protocols were drawn up specifically for the French situation and, as they stand, are not generic enough to be adopted across the EU. Protocols for adipic and nitric acid production were developed under the UK ETS, but were based on the use of default emissions factors, an approach which probably has too high a level of uncertainty to form the basis for monitoring and reporting guidelines for the EU ETS.

There are currently no ISO or CEN standards on $N_2O$ measurements. An ISO standard is being developed and a draft will possibly be available for public consultation by 2006, a full standard could thus, in principle, be available by 2007/8. A German standard was published in 2005 on automatic continuous measurement of $N_2O$ emissions based on non-dispersive infrared absorption principles[28].

### 3.3.7 Administration

The key administrative requirements are preparation of a monitoring and reporting protocol, and collation of emissions data for development of allocation methodologies. Nitric and adipic acid manufacturers are already regulated under pollution control legislation so should have systems of monitoring and reporting in place.

25 A Wartmann and J Harnisch, 2005. 'A Framework for the Monitoring and Reporting of $N_2O$ Emissions from Nitric Acid Production in the EU Emissions Trading Scheme', final report prepared by Ecofys on behalf of EFMA.

26 BP X 30-330, Protocol for quantification of nitrous oxide emissions in the manufacture of adipic acid; BP X 30-331 Protocol for quantification of nitrous oxide emissions in the manufacture of nitric acid; BP X 30-332 Protocol for quantification of nitrous oxide emissions in the manufacture of glyoxal and glyoxalic acid (www.boutique.afnor.fr/).

27 Approved monitoring methodology AM0021, Monitoring Methodology for decomposition of $N_2O$ from existing adipic acid production plants, cdm.unfccc.int/UserManagement/FileStorage/CDMWF_AM_802035877

28 German Verein Deutscher Ingenieuner (VDI) Guideline VDI 2469: 'Gaseous emission measurement – Measurement of nitrous oxide, Part 2: Automatic infrared spectrometric method' (25 February 2005).

### 3.3.8 Communication

EFMA (who represent nitric acid producers) was contacted during the course of the study. They are keen for nitric acid manufacture to be included in Phase II of the scheme[29], and are taking an active role in debate on this issue.

## 3.4 Sustainability Appraisal summary

Based on the initial findings of Working Groups A and B, $CO_2$ emissions from the fertiliser, ammonia and petrochemicals sectors and $N_2O$ emissions from the nitric acid and adipic acid sectors were recommended for inclusion. A Sustainability Appraisal of these conclusions was undertaken to assess the social, environmental and economic impacts of inclusion. An initial screening of potential impacts identified that the main impacts requiring further assessment were economic and these were assessed using a a top-down, macroeconomic modelling approach and for the nitric and adipic acid sectors a bottom-up, sectorally based approach.

Macroeconomic effects, impacts on competitiveness, employment and energy use were modelled using GEM-E3. A baseline scenario assuming continuation of the EU ETS in its current form was compared against scenarios which assumed expansion of the EU ETS to include the chemicals sector. The scenarios were evaluated for both a 'low' and 'high' post-Kyoto target, of a 15 per cent and 30 per cent reduction in GHG emissions by 2020 from 1990 levels.

The bottom-up economic assessment used marginal cost curves and an illustrative carbon price for the EU ETS (of 10 €/t $CO_2$) to examine the impacts on the sectors. This bottom-up assessment was conducted by Metroeconomica.

The modelling represents a 'worst case' appraisal of the impacts of moving into the EU ETS in the sense that if the sector remains outside the EU ETS, emissions are unlikely to be allowed to be totally unconstrained, as they would be the target of other policies and measures.

The results from the modelling (described below) can only be taken as indicative of the impact of including the chemicals sector in the EU ETS:

- The results are for the chemicals sector as a whole rather than the sub-sectors identified as potentially suitable for inclusion by this study (petrochemicals, fertilisers, ammonia and nitric and adipic acid production). It was not possible to subdivide the chemicals sector within the GEM-E3 model. The sub-sectors identified are significant emitters of $CO_2$, and are estimated to account for almost 60 per cent of combustion and process related $CO_2$ emissions from the sector[30].
- In the current EU ETS + chemicals scenario, the model assumes that all non $CO_2$ GHGs from the chemicals sector are included in the EU ETS, rather than just $N_2O$ as considered in the study. Again, this is a limitation of the way the model can be set up.
- Some combustion plants within the chemicals sector are already included within the EU ETS; it was not possible to reflect this in the 'current EU ETS' scenario.

[29] EFMA, 2005. The position of EFMA on $N_2O$ emissions from nitric acid plants, 30 March 2005.

[30] (April 2006) 'LETS Update Scoping Phase Report', Environment Agency for England and Wales.

The GEM-E3 model results suggest that on inclusion in the EU ETS, demand for chemical sector products will fall slightly, leading to a reduction in production, and a moderate fall in value added (of 0.7 and 1.7 per cent for low and high post-Kyoto target scenarios, respectively). Exports fall more significantly (by six per cent under a high post-Kyoto target). These results suggest that while there may be some adverse impacts on the chemicals sector upon inclusion in the EU ETS, they are not so significant as to rule out inclusion. It would, however, be useful to carry out a further examination of economic impacts on the sector before a final decision is made on inclusion using either modelling techniques capable of more detailed subsectoral modelling, or a bottom-up approach.

When moving from the scenario of ‘current EU ETS sector’ to ‘current EU ETS + chemicals’ trading, $CO_2$ emissions from the chemicals sector fall by five per cent and $N_2O$ emissions by nine per cent for under a low EU post-Kyoto target. Under a high post-Kyoto target emission reductions are approximately doubled. In real terms $CO_2$ emissions are significantly higher than $N_2O$ emissions and the cost of abating these emissions will dominate the economic impacts on the sector.

Inclusion of $N_2O$ emissions from nitric and adipic acid production was also examined using a bottom-up approach which considered the two production sectors individually. While adipic acid manufacturers have already installed abatement equipment, its operation could potentially be improved to reduce emissions further, and the assessment shows that the sector could benefit economically from participation in the EU ETS. Their marginal abatement costs are very low (yet positive), so that at an illustrative equilibrium allowance price of 10 €/t$CO_2$eq, producers accrue a significant amount of revenue from selling surplus allowances to offset any abatement costs. International exposure (both for adipic acid production and production of the intermediate product nylon 6-6) is relatively low. The amount of allowance revenue generated will depend on the allocation of allowances, and producers would be expected to abate emissions up to the maximum technical potential.

The bottom-up assessment suggests that the nitric acid sector would not reap financial benefits from participation in the EU ETS, but that impacts are not significant. Revenue from selling surplus allowances is not sufficient to offset total abatement costs; it only reduces the cost of meeting the sector’s target. Despite the presence of significant total fixed abatement costs, inclusion in the EU ETS is not forecast to have a significant impact in the long run. As with adipic acid, international exposure of the sector for both the initial product (nitric acid) and main final product (nitrogenous fertiliser) is relatively low.

On the basis of this bottom-up modelling, we would recommend that $N_2O$ from nitric and adipic acids are considered for inclusion in the EU ETS as the economic impacts are not significant for either sector. In both cases, care would need to be taken in the allocation of allowances, due to the low marginal costs of abatement and significant reductions from ‘business as usual’ emissions which are available.

# 4 Aluminium

## 4.1 Overall findings

The aluminium sector is very electricity intensive and therefore is indirectly affected by the EU ETS due to higher electricity prices caused by the inclusion of the power sector in the scheme. Only one aluminium plant is covered directly by the scheme due to on-site generation falling within the Directive's 20MW thermal combustion threshold. Working Group B considered the feasibility of expanding the scheme to include some of the process emissions from primary aluminium processes.

The overall findings of the Working Group suggest that $CO_2$ emissions from primary aluminium production should be included in Phase III of the EU ETS. The findings also suggest that PFC emissions from the primary aluminium production sector should only be included in the EU ETS if $CO_2$ emissions are included. The analysis in this report has focused on primary aluminium production. Limited consideration has been given to secondary production, which has potential competition issues with primary aluminium, as well as other products already included in the EU ETS, such as paper, glass and steel. Therefore, the preliminary recommendation in this report would be to include secondary aluminium where primary aluminium is also included. However, this aspect would require careful attention during the work towards inclusion.

$CO_2$ emissions from the aluminium sector are significant. For example, $CO_2$ emissions from the primary aluminium process (due to the reduction of the carbon electrodes) in the UK, is three times the EU ETS coverage of the UK ceramics industry (minus bricks). The scale of emissions is significant enough to encourage the sector to incorporate the cost of carbon into their process, at least cost, through the EU ETS.

However, the aluminium sector is highly exposed to external competition and the industry claims that it cannot pass on its costs to consumers. Although abatement opportunities and potential exists, the costs of abatement are high and so it would therefore be expected that, if included, aluminium installations would buy allowances on the market rather than making their own reductions. As a result, the modelling work carried out during the Sustainability Appraisal section of this project has been important in making the final decision as to whether or not the environmental gain of including these emissions in the scheme is outweighed by the economic risk to the aluminium sector in terms of both profit and jobs.

Looking at other sectors in the EU, there are some other energy-intensive sectors in the EU ETS, such as the iron and steel sector, paper and glass for which the primary aluminium sector may be an important competitor at the level of products. Such sectors could argue that it is not equitable for them to be subject to this regulatory instrument and incur associated costs while a competitor is not subject to them. A key issue is to understand the extent of this competition, and to work to ensure a level playing field for these sectors.

PFC emissions from the primary aluminium production sector should be included in the EU ETS only if $CO_2$ emissions are included in Phase III. The European aluminium industry represented by the EAA is not in favour of inclusion under the EU ETS, but if $CO_2$ is included then they wish for PFCs to be included as well[31]. Inclusion of both GHGs would simplify emissions reporting and give flexibility to the approach for achieving emission reductions.

31 Personal Communication, Eirik Nordheim, European Aluminium Association (EAA), LETS Update meeting 14 December 2005.

Taken in isolation, there is not a strong driving force to include PFCs from aluminium production in Phase III as the level of emissions is smaller than for $CO_2$ and there is limited abatement potential as over 90 per cent of plants will be BAT by 2008. However, limited abatement potential is not a valid reason to exclude PFCs and the EAA comment that some marginal abatement of PFCs is possible above that achieved already on BAT plants.

Note that although explicit inclusion is not recommended here, operators may prefer coverage of all GHGs where this offers additional flexibility in meeting allocations, though no direct requests for this approach have been made at the European level.

## 4.2 Carbon dioxide – recommendation

### Table 5 | Summary for $CO_2$ from aluminium sector

| Sector | Primary aluminium – carbon dioxide |
|---|---|
| Recommendation | Include. |
| Overall emissions | 8Mt for Aluminium as a whole, approx. 1/6th process emissions. |
| Emissions as a percentage of EU25 total $CO_2$ | 0.1% from combustion, 0.1% from process. |
| Key emitting countries | Germany, France, UK, Spain and the Netherlands. |
| Feasibility issues | Benchmarking may be feasible, as the product portfolio is relatively uniform. Limited work done on this sector in this regard so far:<br>• De minimus: not needed, most installations are large or medium sized.<br>• Definition of installation: no change to definition needed.<br>• Monitoring and reporting: Straightforward for process emissions as directly related to anode consumption.<br>• Transaction costs: Few large installations, therefore considered low. Industry claims that costs are higher than other sectors as they cannot pass on rise in electricity prices on to the consumers.<br>• Competitiveness: highly exposed to extra-EU and inter-MS competition. |
| Other legislation present/planned | Currently negotiated agreements at national level, existed in some Member States (MSs) prior to the EU ETS. |
| Abatement technology | Many for end-use energy, but relate to electricity use. Some available for process emissions but high cost. |
| Potential for abatement | 7.5%, but at high cost. |

From a feasibility perspective, the inclusion of the aluminium sector would be quite straightforward as the sector is made up of relatively few, large installations.

The analysis in this report has focused on primary aluminium. However, there are potential competition issues between primary and secondary aluminium, as well as with other products already included such as paper, glass and steel. Secondary aluminium production takes place at different sites from primary aluminium production and for certain applications either primary or secondary aluminium can be used. According to the industry, this does not, however, lead to competition between primary and secondary aluminium. At this moment it is not clear whether secondary aluminium competes with, eg secondary steel, which is currently covered by the EU ETS. For reasons of consistency of approach and to make sure no competitiveness issues arise, including secondary aluminium production may be advisable.

### 4.2.1 Other approaches

The main alternative to the EU ETS in terms of encouraging the aluminium sector to embrace low-carbon technologies, are voluntary agreements. This is industry's preferred approach to making emissions reductions as it enables them to participate more actively in target-setting than in a cap and trade scenario. Furthermore, voluntary agreements often involve production-related targets, which industry feels is easier to plan for. However, this approach can result in less ambitious environmental targets than under a trading approach. In addition, the outcome is less certain and it does not help to provide a price signal for carbon.

## 4.2.2 Route map for inclusion

The route map below highlights some areas where further work will need to be undertaken to facilitate the inclusion of the sector in the EU ETS.

### Table 6 | Route map for inclusion of $CO_2$ from aluminium in the EU ETS

| Time | 2008 | 2009 | 2010 | 2011 | 2012 | Start Phase III 2013 |
|---|---|---|---|---|---|---|
| **Data collection** | Collect data for historical emissions approach OR | Develop benchmarking approach | | | | |
| **Legislative process** | Define process emissions for this sector | Alter Annex I to cover sector | | | | |
| **Competition** | Review Phase I – real effects of electricity price increases on sector | Carry out detailed analysis of competition with those outside EU25 and with products in EU ETS already | | | | |
| **Monitoring and reporting** | | Modify monitoring and reporting guidelines to cover carbon anodes | Ensuring monitoring protocols are in place | | | |
| **Administration** | | | | Include in NAPs | | |
| **Communication** | Communication with EAA and national sectoral bodies on competition and definition issues | | Communication on allocation methodology | | | |

## 4.2.3 Data

The data sets on various installation size, technology and production capacity have been obtained from the EAA. They mainly focus on Germany, Spain, the UK and the Netherlands. The data shows capacities from the years 1998 and 2005 to allow for comparison.

The carbon emissions factor of 470 kt carbon per Mt aluminium was calculated by taking an average of emissions from two processes currently used in the UK (ie Söderberg and pre-bake) taken from the UK GHG inventory. As an initial assessment, the average UK emissions factor was applied across the board to all key countries to estimate $CO_2$ emissions by multiplying by the sector outputs for 2005. This data also gives us an indication of the size distribution of various installations across Europe.

In general, the plants in Europe are fairly large in size (ie production capacity of 150 kt/yr), but compared to other smelters outside the EU these would be considered small. All future installations will therefore be of capacity 250 Mt/yr or more in order to remain competitive on the global market.

The emissions from these plants are mainly process emissions, which are emitted from the carbon anode during the production of aluminium (see Annex D). These emissions account for one-sixth of the total emissions from the aluminium sector. In order to make a better assessment of the industry's actual emissions a more precise definition of process emissions would be required.

Most of the plants buy grid electricity from designated suppliers. Industries in this sector mainly rely on long-term contracts with suppliers that run over a period of five to ten years and in some cases even longer. There are two plants covered by the EU ETS – the Alcan-owned coal-fired plant in the UK, whose onsite generation capacity is covered through the combustion installation category, and one hydro power plant in the UK. Some other installations may buy electricity from a separate entity within their own company but this is usually subject to competitive pricing. This information is commercially sensitive; therefore a more detailed breakdown is not available at present. It would be important to understand the extent to which long-term contracts are used in order to understand the full impact of the EU ETS on the aluminium sector.

Aluminium companies are generally quite integrated, operating smelters, extrusion and rolling. Integrated companies make up 85 per cent of primary production, 80 per cent of rolled production and 40 per cent of extrusion. However, this type of company will be less numerous in the future. Now 50 per cent of the extrusion market consists of independent roller and extrusion companies.

The refining and re-melting of aluminium come under secondary production. Information on whether or not primary and secondary aluminium production takes place at different locations seems to be contradictory between different sources. More data may be required on the level of integration of various plants to get a better understanding of the sector if it were to be included in the EU ETS. This data will be important in determining the level to which some or all secondary processes must also be included in the EU ETS along with primary aluminium production. Alternatively, the definition used in Annex I to the Directive could be altered to cover parts of the rolling and extrusion, or restricted only to process emissions. It is through looking precisely at the degree of integration of individual plants that these decisions can be made.

A benchmarking approach might be feasible as the product portfolio is quite uniform but this would have to be developed.

More analysis is needed to determine how much the rise in electricity prices would affect this sector. According to the industry it is not able to pass on these price effects to the consumers as aluminium prices are set on the world market.

### 4.2.4 Legislative processes

The inclusion of aluminium as an Annex I sector should be relatively straightforward from a legal perspective. Consideration will need to be made of the following factors:

- The boundaries of the sector with respect to alumina, primary and secondary production and anode production
- The threshold for inclusion in terms of throughput
- The definition of process emissions to encourage harmonised treatment across Member States.

It should be relatively straightforward to come up with such definitions and delineate individual installations.

Table 26 in Annex C shows the pros and cons of four different options for inclusion of the aluminium sector in the EU ETS: aluminium smelters only, smelters plus attached processes, including all primary and secondary aluminium production, or by ensuring a broad definition of combustion installation is used in all Member States.

As discussed in Section 4.2 it would be advisable to include both primary and secondary aluminium production for reasons of consistency of approach and to make sure no competitiveness issues arise. The major disadvantage of this, however, is the current lack of data availability for secondary aluminium production.

### 4.2.5 Competition

This section considers competition in the aluminium sector with respect to different European installations in the sector, installations in other sectors, and competition from outside the EU.

As with the chemicals sector, there is some distortion of competition within the current EU ETS because of the definition of combustion installation in the NAPs. These differences have led to a degree of inconsistency between the inclusion of calciners, which have been included in Ireland, for example, but not in countries where the medium definition of combustion installation was used (France, Spain, and the UK). The explicit inclusion of the aluminium sector would be one way to ensure a consistent approach between countries.

Looking at other sectors in the EU, there are some other energy-intensive sectors in the EU ETS, such as the iron and steel, paper, and glass sectors for which the primary aluminium sector may be an important competitor at the level of products. Such sectors could argue that it is not equitable for them to be subject to this regulatory instrument and incur the associated costs while a competitor is not subject to them. A key issue is to understand the extent of this competition, and to work to ensure a level playing field between these sectors.

To a certain extent the aluminium industry is already subject to costs associated with the EU ETS, through the increase in electricity prices. An analysis undertaken by Oxera on behalf of the Carbon Trust[32] shows that for the primary aluminium sector in the UK, based on the assumption of 90 per cent pass through of costs by generators, sector profitability is reduced significantly on inclusion for electricity only. Such effects are not identified for other energy-intensive industries. The report also suggests that the inclusion of the aluminium sector in the EU ETS would not help, as the problem is

[32] Carbon Trust (2005), 'The European Emissions Trading Scheme: Implications for Industrial Competitiveness'.

driven by increases in electricity prices and the limited potential for abatement within the sector, ie windfall gains would be unlikely. However, the Carbon Trust report does not take into account the likelihood of new sources of low-carbon electricity coming on stream, the degree to which installations benefit from dedicated contracts, nor whether or not smelters buy electricity from the grid or have their own generation. It is important to remember that this assessment relates only to the electricity price effect, and not to greater coverage of the sector in the scheme.

### Table 7 | National emission factors for electricity production

| Country | $CO_2$ emission factor electricity (g/kWh) |
|---|---|
| Austria | 176 |
| France | 47 |
| Germany | 524 |
| Italy | 485 |
| Netherlands | 547 |
| Norway | 0 |
| Spain | 343 |
| UK | 430 |

Source: CAIT[33]

The Carbon Trust analysis is carried out for the UK, and so does not reflect the different carbon intensities that the electricity grid can have on electricity prices. Often, aluminium production plants are found in countries with low carbon intensities, such as France and Norway. Table 7 shows emission factors for different countries.

It must be noted that these are national average values and grids are inter-connected. It does, however, provide an indication of the differentiation of fuel mix in the electricity sector in different countries to illustrate potential availability of lower carbon, lower cost electricity for large industrial consumers. Even aside from the carbon price signal, large customers with long-term contracts have often in the past been able to negotiate electricity or gas prices that are substantially below the average market price.

The actual effect of increased electricity prices on profitability may be lower than currently estimated in some studies[34] as these studies do not account for captive generation capacity based on low-carbon technologies. A large part of the industry has long-term contracts at fixed, relatively low prices with electricity suppliers (often based on hydro power, nuclear power or lignite). According to the IEA these types of contracts are very competitive, with suppliers more likely to pass on real cost (ie cost of abatement measures or purchases of allowances) rather than full opportunity cost (total value of allowances, even if largely allocated for free). This effect would partially shield the industry from the current high levels for electricity prices.

33 World Resources Institute (WRI's) Climate Analysis and Indicators Tool: cait.wri.org/

34 Eg Carbon Trust (2005), 'The European Emissions Trading Scheme: Implications for Industrial Competitiveness'; J Reinaud, (2005), 'Industrial Competitiveness under the European Emissions Trading Scheme', IEA Information Paper.

According to data from the EAA, electricity suppliers pass through 30–70 per cent of the opportunity cost from the EU ETS in their power prices, resulting for the aluminium sector in a six to eight per cent increase compared to the price set at the London Metal Exchange (LME). Note that prices on the LME are very volatile. Two years ago the price was about 1300 €/t, while currently aluminium trades at around 1900 €/t. This is a large market fluctuation compared to the predicted price increase due to the EU ETS.

About half of the long-term electricity supply contracts will expire before 2010. According to industry, prices in new contracts will not depend on the carbon intensity of the electricity and industry claim that new long-term contracts with power companies at acceptable prices have not been possible to achieve so far. Unfortunately, current and future prices offered in such bilateral and often captive contracts are not available for this analysis.

Looking outside the EU25, the aluminium sector is highly exposed to international competition[35]. The UK's assessment of export flows in the run-up to the first phase estimates that 32 per cent of total exports in the aluminium sector are being made to non-EU countries, which is a high degree of exposure. The ability to pass on the cost of carbon to the customer is more limited in such a case. As a result, inclusion in the EU ETS would disadvantage the sector considerably.

Inclusion in the scheme will not have a direct bearing on the competitive issues associated with electricity prices, as these will exist whether the sector is in or outside of the scheme. However, it will add additional costs relating to meeting allocation caps, and the costs associated with administration, and monitoring, reporting and verification. The potential to abate and associated costs of abatement will be key factors in how the sector meets these costs.

The GEM-E3 model was used to examine the macroeconomic effects of expanding the EU ETS to the aluminium industry as part of the Sustainability Appraisal. The findings for the aluminium industry are summarised here in Section 4.4.

From the route map in Section 4.2.2 it is clear that further work would need to be done in the run-up to the inclusion of the aluminium sector to make a more detailed assessment of the:

- extent of current agreements with electricity suppliers, and therefore the real level of exposure to increased electricity prices
- true effect that increased electricity prices, as a result of the first phase of the EU ETS, has had on the sector
- extent of international competition and growth of the sector, in the future under a business-as-usual scenario
- extent of competition with products from included sectors, ie steel, paper and glass. EAA has indicated that in their view competition between aluminium and materials currently covered by the EU ETS is limited.

It is likely that the inclusion of aluminium will remain contentious on cost grounds, making these supporting studies a very important part of the route map.

35 Eurostat data: www.eu.int/comm/eurostat/

### 4.2.6 Abatement technology

Most of the opportunities for energy end-use reductions in primary aluminium smelting are associated with electricity demand reductions. There is therefore little or no opportunity for direct emissions savings from energy end-use.

In this analysis we consider therefore the potential for the reduction of process $CO_2$ emissions, which are associated with the consumption of the carbon anodes during manufacture.

The Genesis database[36] identifies emission abatement technologies and has been used to assess the cost of climate targets and emission trading in the EU for the European Commission. Results suggest that there is a savings potential of approximately 7.5 per cent of total process emissions; however, the costs of abatement are high.

The relatively high cost of abatement means that it is likely that, if included in the scheme, aluminium installations would buy extra allowances on the open market at lower cost than abatement. Therefore a genuine assessment of the potential costs and effects on competitiveness is needed. The Sustainability Appraisal (Section 4.4) was unable to do this fully as it was not possible to model the aluminum sector separately, only the larger 'non-ferrous' sector. As aluminium production is more energy intensive than other non-ferrous metal production, this is a very coarse approximation and is a serious limitation of the modelling work carried out. It is recommended that further modelling work, using a sectoral model of the aluminium industry or a more bottom-up economic modelling approach is carried out to gain a better indication of the magnitude of impacts on the aluminium sector before making a decision on whether the aluminium sector should be included in the EU ETS.

### 4.2.7 Monitoring and reporting

Monitoring protocols need to be developed in a timely fashion, but these are likely to be quite straightforward as $CO_2$ emissions will be directly linked to the degradation of the carbon anode. The levels of uncertainty with respect to these emissions are likely to be very low.

### 4.2.8 Administration

The administration costs associated with the inclusion of the aluminium sector are expected to be quite low. As mentioned above, in the monitoring section, some protocols would have to be developed and then documented. This documentation would have to be harmonised across the EU to in order for the costs to remain minimal. Other than that, as there is no de minimus clause, other administrative costs would be quite low. This is because the structure of the installations is fairly similar and the majority of the plant sizes range from medium to large.

### 4.2.9 Communication

Communication to the EAA and other national sector bodies on issues such as the clarification of definitions for various process emissions and the effects of intra-EU and extra-EU competition on the sector after its inclusion in the EU ETS. The reporting and monitoring methodologies would also have to be communicated to the sector.

36 The Energy End-Use Simulation Model (ENUSIM) database deals mainly with end-use energy opportunities and is therefore not appropriate for this analysis.

## 4.3 PFCs – recommendation

**Table 8 | Summary for PFC emissions from aluminium sector**

| | |
|---|---|
| Primary aluminium production, PFC emissions | Include only if aluminium $CO_2$ included. |
| Overall emissions | 4.23 Mt $CO_2$ eq. |
| Emissions as a percentage of EU25 total GHG | 0.09% (65% of EU25 PFC emissions). |
| Key emitting countries | Netherlands, France, Germany, UK, Spain. |
| Feasibility issues | If $CO_2$ included under ETS, industry in favour allow abatement flexibility:<br>• De minimus – not required as large point sources.<br>• Definition of installation – sufficient with single identified source on site.<br>• Monitoring and reporting – robust reporting across all EU25 countries at plant level, however, need to ensure consistent approach to estimation across sector.<br>• Transaction costs – dependent on need to invest in more advanced measurement approach.<br>• Competitiveness – vulnerable to competition impacts 1) sector in very competitive global industry; 2) other competitors within EU25, eg iron and steel included in scheme; it could be deemed inequitable that aluminium is currently excluded.<br>• Timeframe – realistic for inclusion in Phase 3. |
| Other legislation present/planned | PFC emissions covered under IPPC, which covers all EU25 smelters. Voluntary agreements with government (covering PFC emissions) in France, Germany and the UK. Strong voluntary initiative by sector in monitoring PFC emissions, identifying best practice and benchmarking. |
| Abatement technology | Available but already implemented across sector. |
| Potential for abatement | Limited due to significant gains during 1990s. Potential could be significantly increased through development and commercialisation of more advanced cell technology. |

The overall recommendation is that PFC emissions from the primary aluminium production sector should only be included in the EU ETS if $CO_2$ emissions are included in Phase III. The European aluminium industry is not in favour of its inclusion under the EU ETS, but if $CO_2$ is included then they wish PFCs to be included as well[37]. Inclusion of both GHGs would simplify emissions reporting and give flexibility to the approach for emission reductions.

Taken in isolation, there is not a strong driving force to include PFCs from aluminium production in Phase III as the GHG emissions are smaller than for $CO_2$ and there is limited abatement potential as over 90 per cent of plants will be BAT by 2008. However, limited abatement potential is not a valid reason to exclude PFCs and the EAA comment that some marginal abatement of PFCs is possible above that achieved already on BAT plants.

The aluminium sector has achieved significant reductions in PFC emissions across the EU25 in the last 15 years; hence a benchmarking approach to allowance allocation is recommended to account for early action.

Our preliminary recommendation to include both $CO_2$ and PFCs was subject to the results of the Sustainability Appraisal because the primary aluminium sector could be vulnerable to competitive pressures particularly because of its reliance on electricity supplies. The sector is also exposed because it is unable to easily pass through any additional costs incurred (due to the price of aluminium being set globally), and because non-EU smelters could gain competitive advantage by not being subject to the same regulatory costs. The results of the Sustainability Appraisal, however, supported our initial conclusions that the primary aluminium sector would be a suitable candidate for inclusion in the EU ETS (see Section 4.4).

In the previous section, it has been argued that the inclusion of $CO_2$ process emissions from this sector is necessary because close competitors are subject to caps on $CO_2$ emissions under the EU ETS, while the primary aluminium sector is currently not. This argument is less relevant to PFCs as this GHG is not covered under the EU ETS for other competitor sectors. However, we recommend inclusion of both gases because operators prefer coverage of all GHGs where this offers additional flexibility in meeting allocations.

We conclude that there are no significant feasibility issues that would preclude the emissions of PFCs from primary aluminium sector entering the EU ETS. The sector comprises of 25 large sites, which account for a significant proportion of total EU25 PFC emissions. Significant experience of reporting of PFC emissions exists, based on internationally recognised approaches, within the sector and to outside bodies (national regulators under IPPC, the Commission under the European Pollutant Emission Register (EPER), and to national inventories under the United Nations Framework Convention on Climate Change (UNFCCC)). Comprehensive historic data should be available to assist development of the emissions baseline needed for allocation purposes.

[37] Personal Communication, Eirik Nordheim, EAA, LETS Update meeting 14 December 2005.

A comprehensive list of issues for and against the inclusion of PFC emissions is provided in Table 9.

**Table 9 | Pros and cons for the inclusion of PFC emissions from aluminium production in the EU ETS**

| Reasons against PFC inclusion |
|---|
| Limited abatement potential across sector – by 2008 over 90% sector BAT. |
| Driver to reduce emissions – PFCs indicate production process problems. |
| Competitive global market. |
| Significant reliance on electricity could result in exposure to future price rises. |
| PFC emissions 0.09% of EU25 GHG emissions. |
| Direct regulation (IPPC) Industry voluntary initiatives. |

| Reasons for PFC inclusion |
|---|
| Rival products already under scheme for $CO_2$. |
| If $CO_2$ included European industry wants PFCs included as well to simplify reporting and increase carbon abatement flexibility. |
| EAA consider similar if not greater abatement potential for PFCs compared to $CO_2$. |
| Ongoing research and development (R&D) into alternatives could lead to a breakthrough enabling emission reductions eg anode cell research (USA & EU). |
| Established systems of emissions reporting. |
| Internationally agreed approaches to estimation and protocols for measurement. |
| Largest source of PFC emissions in the EU25 from 25 large sized plant. |

### 4.3.1 Other approaches

There are a number of other approaches currently implemented across the EU25 that have a role in the reducing of PFC emissions from this sector. These are listed in Table 10.

**Table 10 | Other approaches to reducing aluminium PFC emissions in the EU25**

| Approach | Description |
|---|---|
| Direct regulation under the IPPC Directive | Regime stipulates restrictions on the release of different pollutants, and the reporting of pollutants on an annual basis subject to threshold limits. A BREF has been published for the non-ferrous metal industry,[38] in which the BAT for reducing PFC emissions are described. The use of centre worked prebaked cells with automatic point feeding of alumina is considered BAT for primary aluminium producers. This technology produces the lowest levels of PFC emissions due to the much lower frequency of anode effects. Over 90% of EU25 production capacity in 2008 will be from smelters with point feeding technology, the majority using centre worked prebaked cells.[39] |
| Voluntary or negotiated agreements | In some EU25 countries, agreements have been made between the government and aluminium sector. Within the EU25, France, Germany and the UK all have agreements under which they are required to reduce PFC emissions. In the UK, the agreements are negotiated within the framework of the Climate Change Levy (CCL). Targets are set every two years for GHGs; if operators meet the targets, they receive an 80% rebate on the CCL.[40] |
| Industry Initiatives | Global initiative, co-ordinated by the International Aluminium Institute (IAI)[41], where surveys are undertaken of PFC emissions from individual smelters and used in benchmarking reports to promote further reductions. An IAI voluntary objective is to reduce PFC emissions by 80% per tonne of aluminium produced by 2010, relative to a 1990 baseline.[42] |

38 European Commission (2001), Integrated Pollution Prevention and Control (IPPC) – 'Reference Document on Best Available Techniques in the Non Ferrous Metals Industries', Published by the European IPPC Bureau at the Institute for Prospective Technologies (IPTS), December 2001.

39 EAA (2005), Personal communication with the European Aluminium Association (Brussels), November 2005.

40 CCL information on the Defra website, www.defra.gov.uk/environment/ccl/intro.htm (accessed November 2005).

41 IAI (2002), Perfluorocarbon Emissions Reduction Programme 1990–2000, International Aluminium Institute, London and IAI (2005), Report on the Aluminium Industry's global perfluorocarbon gas emissions reduction programme – results of the 2003 anode effect survey, 28 January 2005, London.

42 IAI website, www.world-aluminium.org/iai/publications/sustainable.html (accessed November 2005).

### 4.3.2 Route map for inclusion

PFC emissions from primary aluminium production have been recommended for inclusion in the EU ETS only if $CO_2$ is recommended for inclusion. The following route map outlines some of the issues that would need to be considered prior to joining the scheme. It would also be important to monitor the emergence of new technologies that enable further PFC emission reductions, beyond what is currently feasible.

The different issues in the above route map are considered in more detail in the sections below. The majority relate to the assessment of data availability, and current approaches to monitoring and reporting of PFCs, two significant issues that would need to be addressed prior to sector inclusion.

**Table 11 | Route map for inclusion of PFCs from aluminium in the EU ETS**

| | Route map: PFC emissions from primary aluminium smelters | | | | | Start Phase III |
|---|---|---|---|---|---|---|
| **Time** | **2008** | **2009** | **2010** | **2011** | **2012** | **2013** |
| **Data collection** | Establish sources of data, and estimation techniques | Review data availability and quality for baseline assessment/benchmarking | | | | |
| **Legislative process** | Review any potential issues relating to installation definition | Alter Annex I to cover PFCs from Al sector | | | | |
| **Competition** | Competition issues – 1) assess competitive pressures facing industry; 2) assess inter-sector competition, eg with iron and steel sectors | | | | | |
| **Monitoring and reporting** | Review of current approaches to M&R | Development of draft guidance based on established approaches (eg IPCC) | Roll out of EC M&R guidance | | | |
| **Administration** | | | | Inclusion in Phase III NAP | | |
| **Communication** | Sector consultation about current reporting mechanisms | Consultation in developing monitoring / reporting protocols | | | | |

### 4.3.3 Sector overview

Issues relating to sector structure are important to consider when assessing the inclusion of the primary aluminium smelting sector. Production of primary aluminium is located at 25 smelters in 12 countries across the EU25, the largest country producers being Germany, France, the Netherlands, Italy and the UK. The two main operators are Alcoa and Alcan (who now also own the smelters formerly owned by Pechiney), who operate half of the smelters in the EU25, particularly in Italy, Spain, UK and France. A list of smelters in the EU25, including the operating company, is provided in Table 29 in Annex D.

PFC emissions are not emitted during normal smelting operating conditions, but are produced during brief upset conditions known as 'anode effects' Such conditions occur when the level of alumina in the cell drops too low and the electrolytic bath itself begins to undergo electrolysis. Table 30 in Annex D provides an overview of emissions of PFCs from the sector. Emissions from aluminium smelters account for 65 per cent of EU25 PFC emissions, or 0.08 per cent of total GHG emissions. These emissions are likely to remain at similar levels over the next ten years, with new production capacity unlikely to increase[43]. Current capacity stands at over 3 Mt of aluminium per year. Based on known closures in the next five years, and in the absence of new build, this could drop to 2.7 Mt.[44]

### 4.3.4 Data

Sector allocations under the EU ETS for this sector could either be calculated on the basis of a benchmarking approach or grandfathering using historic emissions data. A benchmarking approach is likely to be output-based, using factors such as tonnes of PFCs per tonne of aluminium produced for different smelter technologies. A benchmarking approach could be developed on the basis of BAT, which would incentivise all operators to move to BAT (most of which have) and improve operational processes to what is considered best practice. Emission factors for use in benchmarking exist and are used in current emission estimation approaches.

The use of historic emission data is another approach to allocation[45]. Based on current data reporting, it would be possible to develop estimates between 2008 and 2011 (for Phase III), based on robust estimation techniques which include smelter-specific parameters. Historic data is currently available by site through reporting under IPPC, both to the national regulator and to the Commission under EPER[46], much of this information provides the basis for national reporting under the UNFCCC. Annual emission reporting under EPER is on a two to three year basis, based on a reporting threshold for PFC emissions of 100kg/year, which most smelters exceed.

43 EAA (2005), Personal communication with the European Aluminium Association (Brussels), November 2005.

44 Primary production data from the RAINS model indicates that production rises from current levels of 2.7 Mt, to 2.8 in 2010, and 3.6 Mt in 2020. This suggests that capacity would need to increase to meet such levels of production (see IIASA (2004), The Extension of the RAINS Model to Greenhouse Gases, IIASA Interim Report IR-04-015, April 2004).

45 Grandfathering emissions based on historic data, however, may mean that plants yet to implement BAT could delay technology improvement till after allocation, and make windfall gains by converting afterwards. This is likely to only be the case for a couple of smelters.

46 European Commission (2000), Commission decision of 17 July 2000 on the implementation of a European pollutant emission register (EPER) according to Article 15 of Council Directive 96/61/EC concerning integrated pollution prevention and control (IPPC), Official Journal of the European Union (28/07/2000). EPER (European Pollutant Emission Register) website, www.eper.cec.eu.int/eper/, (accessed November 2005). The current EPER (for 2001) does not include the 10 New Member States, who will report for the second reporting year of 2004.

In addition to the official reporting mechanisms, the aluminium industry has developed its own internal reporting system under which individual plant submit PFC emissions data on an annual basis. In summary, there are good data reporting systems in place across Europe, through national reporting under the UNFCCC, under EPER obligations, and internally by the industry sector.

Data availability should enable both a benchmarking or historic emission approach to be developed. Irrespective of the approach adopted, it will be important to develop co-operation with the relevant sector bodies to improve understanding of industry reporting and benchmarking, and to identify the type of approach to emission estimation used on a site-by-site basis. Issues of data quality, eg measurement methodologies used, are addressed in Section 4.3.8.

### 4.3.5 Legislative processes

Defining an installation for this sector when considering PFC emissions should not be too problematic given that emissions only arise from a specific part of the site, namely the pot shed, where the anode cells are located. This question may require more consideration if process $CO_2$ emissions are also included. Where a site has a combustion facility for electricity generation above 20 MW, this facility will already be included under Phase I. Though the EAA reports that there are only two plants in the EU which have their own on-site generation, the rest have contracts with power suppliers.

There is unlikely to be a need for a de minimus rule, given that all primary aluminium production sites are reasonably large producers of aluminium (> 40kt aluminium per year), and because there are only 25 currently in existence.

### 4.3.6 Competition issues

Exposure to external competition is considered for the sector as a whole in Section 4.2.5 above.

### 4.3.7 Abatement technologies

There are three main types of smelter in the EU25 currently operating:

- Centre Worked Pre-bake (CWPB, or PFPB if they have point feeder technology)
- Side Worked Pre-bake technology (SWPB)
- Vertical Stud Söderberg (VSS). Two plants in Spain are currently being upgraded to use point feeder technology.

The main abatement technology identified for this sector in the literature is the conversion to PFPB technology, or the retrofitting of point feeder controls in smelters. By 2008, all smelters except four VSS plants will be PFPB plants, while two of the VSS plants will have had point feeder controls retro-fitted. More information on these different technologies can be found in Annex D.

No recent analysis of reduction potential exists, based on the current knowledge of European smelter technologies, and associated emissions. Using a very simplistic analysis based on two VSS smelters retrofitting point feeder technology, two VSS converting to PFPB, and operational improvements being made across smelters to further reduce PFCs, a reduction potential of 17 per cent could be achieved; however, 12 per cent of this would be across the four VSS plants.

This is based on an 86 per cent removal efficiency from converting VSS to PFPB (€48/t $CO_2$ eq[47]), and 26 per cent removal efficiency from retrofitting VSS (-0.3/t $CO_2$ eq).[48] In the absence of any other information, we have assumed a maximum feasible five per cent removal efficiency through operational improvements.

The most promising future abatement technology is the inert anode cells, replacing carbon anodes. Such cells would eliminate emissions of PFCs (and $CO_2$ from the electrolysis process), and would be used in combination with wetted cathode technology[49]. The wetted cathode (currently at the test stage) is considered feasible, and would lead to a significant reduction in electricity requirements, if used in conjunction with a drained cathode. Much of the work is being funded by the US Department of Energy, Office of Industrial Technologies. Many technical challenges are still to be overcome in the development of an inert anode, in particular selecting a viable inert material, and therefore commercialisation of a viable design is considered to be approximately ten years away.[50]

### 4.3.8 Monitoring and reporting

Current sectors included in the EU ETS are subject to reporting and monitoring guidelines, set out in the European Commission decision document of 29 January 2004[51]. Such guidelines set out how an operator is to monitor and report emissions to the competent authority, providing the relevant information to enable subsequent verification.

In the section on 'Data', the current reporting of emissions data by this sector has been described. Estimates are made based on a range of tier approaches outlined in IPCC guidance,[52] and further described in Annex D. Based on the current EU ETS reporting guidelines, it is probable that the IPCC approach would be considered as the basis for the guidelines, as it is an internationally agreed approach that is used across the industry.

47 Please note that this is a relatively conservative estimate of the costs and that significantly higher costs have also been quoted.

48 J Harnisch and C Hendriks (2000), 'Economic Evaluation of Emission Reductions of HFCs, PFCs and $SF_6$ in Europe', on behalf of the European Commission, 25 April 2000.

49 The Aluminium Association (2003), Aluminium Industry Technology Roadmap, Published February 2003, Washington D.C. Also Aluminium Association (1998), Inert Anode Roadmap, February 1998.

50 US Climate Change Technology Program (2003), Technology Options for the Near and Long Term, November 2003.

51 European Commission (2004), Commission decision of 29 January 2004 establishing guidelines for the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council, Official Journal of the European Union (26 February 2004).

52 IPPC (2000), 'Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories', Edited by J Penman, D Kruger, I Galbally, T Hiraishi, B Nyenzi, S Emmanul, L Buendia, R Hoppaus, T Martinsen, J Meijer, K Miwa and K Tanabe, IPCC National Greenhouse Gas Inventories Programme, Published for the IPCC by the Institute for Global Environmental Strategies, Japan.

Monitoring and reporting guidelines will need to specify the necessary tier approach that site operators will be required to use. Under the EU ETS, this requirement is outlined in Section 4.2.2.1.4 of the guidelines.[53] Operators are required to use the most accurate methodology unless *it is shown to the satisfaction of the competent authority that the highest tier approach is technically not feasible or will lead to unreasonably high costs*. It is likely that Tier 3b would be the preferred method of choice, with Tier 2 as the next most preferred. Tier 3a is likely to be deemed too expensive while Tier 1 is too simplistic. Current practice is the use of Tier 2, with some operators using Tier 3b.[54]

A key issue for the competent authority and operator will be the verification of emission estimate parameters, in particular the amount of aluminium produced, and the anode effect in minutes per cell day. Both parameters are used in Tiers 2 and 3b. In addition, for Tier 3b, the slope coefficient (defining the relationship between anode effect and emissions) or the over-voltage coefficient (which defines the extra cell voltage caused by anode effects averaged over a 24-hour period) are additional parameters. Defaults are used in Tier 2. Robust systems for measuring and recording these parameters will need to be in place to enable verification.

Based on the development of current approaches to emission estimation, it should not be problematic to develop guidelines under the EU ETS for this sector. An internationally recognised approach (from the IPCC) has been established, with additional guidance on estimation for site operators from the Greenhouse Gas Protocol Initiative.[55] A protocol exists for the measurement of PFCs, in particular the measurement of the site-specific parameters required for Tier 3b,[56] and is recognised across the industry having been incorporated into the Aluminium Sector Greenhouse Gas Protocol.[57]

### 4.3.9 Administration

The inclusion of the primary aluminium sector would result in a range of associated costs, both for the European Commission, national authorities and industry. Such administrative costs would need to be considered when assessing inclusion into the scheme.

There are two types of cost:

- Administrative costs of the scheme
- Resource costs of meeting scheme requirements.

Administrative costs to the schemes competent authorities will include the determination of credit allocation, and requirements for permitting and registration. Administrative costs borne by industry will include payment of fees (permit, scheme subsistence and verification). These may be reduced due to the small number of operators, and co-operation through strong trade association bodies.

53 European Commission (2004), Commission decision of 29 January 2004 establishing guidelines for the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council, Official Journal of the European Union (26 February 2004).

54 EAA (2005), Personal communication with the European Aluminium Association (Brussels), November 2005.

55 GHG Protocol Initiative (2005), Calculating Direct GHG Emissions from Primary Aluminium Metal Production – a guide to calculation worksheets, www.ghgprotocol.org/

56 J Marks, R Kantamaneni, D Pape and S Rand (2003), *Protocol for Measurement of Tetrafluoromethane and Hexafluoroethane from Primary Aluminium Production*, Published in Light Metals 2003. Funded by US EPA Climate Protection Partnerships Division. (Published in greater detail in May 2003 by US EPA and IAI as document EPA 43-R-03-006).

57 IAI (2003), The Aluminium Sector Greenhouse Gas Protocol, International Aluminium Institute, May 2003.

The sector will also have other costs, which will be incurred through preparation for participating in the scheme. These might include:

- the purchase of PFC measurement equipment, particularly if operators need to move to a higher estimation tier, eg Tier 2 to 3b
- installation of software for recording the different parameters on which anode effect frequency and duration are recorded
- training cell operators to effectively manage a monitoring and reporting system.

Implementation of management systems to ensure a systematic approach to monitoring and reporting may also be an additional cost, which could be marginal if necessary systems are already in place.

### 4.3.10 Communication

The EAA recently published a position statement on the EU ETS in the second phase and beyond.[58] They state that other mechanisms may be more appropriate for regulating GHGs, such as voluntary agreements.

If the aluminium sector is included in a future phase of the EU ETS, there will be a need for good communication with industry, who have been heavily involved in developing monitoring and reporting protocols, and who have long established reporting mechanisms within industry. Such co-operation should help in establishing sector guidance, and developing the approach to allocation.

## 4.4 Sustainability Appraisal summary

The aluminium sector is very electricity intensive and therefore is already indirectly affected by the EU ETS through the effect that the inclusion of the power supply sector has on electricity prices. LETS Update looked at the impacts that the expansion of the EU ETS to include $CO_2$ and PFC emissions from the primary aluminium industry in Phase III would have on the sector using GEM-E3[59].

Previous work on the impact of the EU ETS on the aluminium sector has looked at indirect effects from higher electricity prices rather than the direct effects of sector inclusion. This found that compared to energy-intensive sectors such as cement and steel which are already in the EU ETS, the aluminium sector was the most likely to experience the greatest financial impact; even though the impact of the EU ETS was limited to indirect costs only. The aluminium sector is significantly more open to international competition (as measured by the Organisation for Economy, Cooperation and Development (OECD) openness ratio) than other sectors such as the iron and steel sectors which are already in the EU ETS, and this threat of international competition limits the pass through of costs by smelters. Any increased production costs caused by the EU ETS are thus likely to be absorbed, lowering operating margins. The concerns identified in these studies were reiterated by the sector during stakeholder consultation.

58 EAA (2005b), European Aluminium Association position on EU Emission Trading Scheme – Second Phase and Post-2012, 26 October 2005.

59 (April 2006) 'LETS Update Sustainability Appraisal Report', Environment Agency for England and Wales.

The GEM-E3 model used to examine the macroeconomic effects of expanding the ETS for this Sustainability Appraisal does not allow the aluminium industry to be modelled as a separate sector as disaggregated international trade statistics are not available. The greatest level of disaggregation which can be achieved is the 'non-ferrous' metals sector. The aluminium sector accounts for almost a fifth of non-ferrous metals production (by volume), about a third of direct (process and combustion) $CO_2$ emissions and about 50 per cent of end use energy demand within the sector (including electricity use)[60]. It is significantly more energy intensive than other parts of the non-ferrous sector. The use of the non-ferrous sector to represent the aluminium sector in the analysis is thus a very coarse approximation and is a serious limitation of the modelling work carried out.

The GEM-E3 model was used to compare macroeconomic indicators for the chemicals sector under two scenarios:

- Current ETS – there is no expansion of the ETS, ie the ETS applies only to sectors currently (in Phase I) in the ETS and only to $CO_2$ emissions from those sectors. A reduction is required in emissions from the ETS sectors. The only constraint placed on emissions from the aluminium sector is that they may not rise above those in the reference base case where no emissions targets are set post-Kyoto.
- Current ETS + non-ferrous – the ETS is expanded to include the non-ferrous metals sector.

The modelling represents a 'worst case' appraisal of the impacts on the non-ferrous metals sector of inclusion in the ETS in the sense that if it remains outside the ETS, emissions are unlikely to be allowed to be totally unconstrained, as they would be the target of other policies and measures.

The GEM-E3 model results show that inclusion of the non-ferrous metals sector in the ETS leads to reduced demand for non-ferrous metals (as a result of higher prices) which leads to a small (less than one per cent) reduction in production levels and in value added for the sector, even under a high post-Kyoto target. Work during the development of the model scenarios suggested that the results are quite sensitive to the stringency of the EU post-Kyoto target compared to other Annex B country targets, and the level that both these countries and the EU use the Kyoto mechanisms (JI and CDM). This is to be expected given the relatively high exposure to international competitiveness of these sectors.

Sectoral emission reductions are significantly higher than those forecast if the sector remains outside the EU ETS. However, the reductions forecast for PFC emissions seem high given the proposed adoption of BAT in a 'business as usual' future, suggesting that this business as usual development is not taken into account in the reference baseline for the model.

For the non-ferrous sector as a whole the small adverse impacts on the sector on inclusion in the EU ETS do not appear so significant as to warrant not considering inclusion. However, it is not possible to say by how much the results at the sub-sector level of primary aluminium production would vary from these 'average' results for the sector as a whole, given the more energy-intensive nature of aluminium production compared to other non-ferrous metals. A better indication of the magnitude of impacts on the aluminium sector could be gained through using a sectoral model of the aluminium industry[61], or using a more bottom-up economic modelling approach. Further analysis of this kind is needed before making a decision on whether the aluminium sector should be included in the EU ETS.

60 PRIMES data for 2000 and (April 2006) 'LETS Update Scoping Phase Report', Environment Agency for England and Wales.

61 It might be necessary to develop such a model; ideally it would need to model the industry globally.

# 5 Deep-mine methane

## 5.1 Overall findings

Methane from active mines is recommended for inclusion in Phase III with the caveat of it being possible to agree an acceptable allowance allocation methodology and if issues related to safety regulations in Germany and the UK can be overcome. Relatively cost-effective abatement opportunities already exist for the sector. There are a limited number of mines per Member State, each with high methane emissions and mine-specific emissions can be monitored with reasonably low uncertainty. The main challenges for the inclusion of the sector are the sector's exposure to international competition and the limited options for passing on costs to customers, the projected decline of the European coal industry, safety issues and the development of an acceptable installation definition. However, as there are currently no EU-wide measures to abate coal-mine methane, the inclusion of this sector in the EU ETS would incentivise emission reductions across all Member States.

Our initial recommendation is to only include active mine methane emissions at the start of Phase III. Emissions from abandoned mines are subject to high uncertainty, data is not consistently available on a mine-by-mine basis and there is a question over abandoned mine ownership. A decision on the inclusion of abandoned mines could be reviewed some years after the inclusion of active mines.

The results from GEM-E3 modelling undertaken as part of the Sustainability Appraisal indicate that the coal sector could benefit from coal-mine methane inclusion in the EU ETS. This is in agreement with the results from the bottom-up modelling.

## 5.2 Methane – recommendation

**Table 12 | Summary for coal-mine methane**

| **Sector** | **Methane from active underground coal mines** |
|---|---|
| Sector and Recommendation | Include. |
| Overall emissions | 33Mt $CO_2$ eq from coal mining in the EU25 in 2003. |
| Emissions as a percentage of EU25 total GHG (as from scoping phase) | 0.7%. |
| Key emitting countries | Poland, Germany, UK, Czech Republic. |
| Feasibility issues | • De minimus – not needed.<br>• Definition of installation – not under IPPC. Mine definition is a key challenge to inclusion.<br>• Monitoring and reporting – UK, Poland & Germany already report on mine specific methane emissions to the inventory or are currently gathering mine specific data.<br>• Transaction costs – large emissions from a single mine result in low costs/t $CO_2$ eq.<br>• Competitiveness – Coal price fixed internationally and so difficult to pass on costs to consumers. Strong competition from outside EU from cheaper coal imports.<br>• Timeframe – Active mines realistic for inclusion in 2013. |
| Other legislation present/planned | No EU-wide legislation. Electricity from coal-mine methane (CMM) exempt from UK CC levy, exempt from excise tax in Poland and given generous feed-in tariffs in Germany. UK ETS. |
| Abatement technology | Readily available for high concentration methane streams. Dilute methane abatement catalysts still under development. |
| Potential for abatement | 30% methane abated in key countries, further abatement potential in all MS. |

Methane from active underground coal mines should be included in the EU ETS as it is a significant source, making up 87 per cent of the 33 Mt $CO_2$ eq from mining in the EU25. These emissions are distributed across a small number of mines with good abatement potential. Average mine emissions are 600 kt $CO_2$ eq, which can be considered a large source and makes transaction costs worthwhile. Abatement options for the sector are available and cost effective, and in some cases profitable. Nevertheless, the economic impacts of including active coal mines in the EU ETS would need to be closely monitored to avoid accelerated mine closures and job losses as the sector is exposed to tough international competition.

Key challenges for the inclusion of the sector include bringing all Member States up to comparable levels of monitoring as some countries do not collect mine-specific data and uncertainty levels vary. As the sector does not fall under IPPC, an installation definition would need to be developed, as would an agreed monitoring protocol.

## 5.2.1 Other approaches

The overall aim of including CCM in the EU ETS is to reduce methane emissions using a cost-effective approach. There are no EU-wide initiatives to promote CMM abatement and technology collaborations have limited coverage, for example, the UK and Italy are the only EU partners in 'Methane to Markets'[62] which promotes methane utilisation. There is a need to create an EU-wide incentive to capture CCM as currently Member States have very different approaches to the sector with some countries, such as Germany, providing more favourable economic incentives.

**Table 13 | Other incentives for coal-mine methane capture in the key emitting countries**

| Country | Legislation addressing CMM |
|---|---|
| UK | • CMM from active mines in UK emissions trading scheme.<br>• CMM exempt from the Climate Change Levy.<br>• Coal Authority responsible for safety for abandoned mine methane.<br>• Coal Authority competitive grants scheme for abandoned mine CMM projects. |
| Germany | 'Feed in tariffs' for electricity generated from CMM. |
| Poland | Exemption from excise tax on electricity production from hard coal-bed methane. |
| Czech Republic | CMM utilisation supported through direct government funding and favourable leasing policy[63]. |

In the UK, CMM is not covered by the renewables obligation as it is not classified as a truly renewable energy source. CMM is eligible for 'feed in tariffs' in Germany where electricity generated from active and abandoned mines receives a fixed favourable electricity price, higher than that for standard wholesale electricity. These electricity costs are passed onto consumers preventing a breach of state aid rules. CMM is not classed as a renewable fuel in Germany, but the environmental benefits were considered high enough to justify the high feed in tariffs[64].

In addition to active mines, there is a need to consider methane from abandoned mines as currently operational mines will continue to close and they have their highest emissions in the initial years after closure. The suggestion to exclude abandoned mines from the EU ETS should be reviewed after several years of experience with including active mine emissions.

62 The Methane to Markets Partnership is an international initiative that advances cost-effective, near-term methane recovery and use as a clean energy source. www.methanetomarkets.org

63 US EPA, Coalbed Methane Outreach Program www.epa.gov/cmop/intl/czech.html 2005.

64 DTI, 'Methane from Abandoned Coal Mines – a Solution for Controlling Emissions', March 2004.

## 5.2.2 Route map for inclusion

Key milestones are outlined below for the inclusion of methane from active underground mines in the EU ETS.

### Table 14 | Route map for inclusion of coal-mine methane in the EU ETS

| Time | 2008 | 2009 | 2010 | 2011 | 2012 | Start Phase III 2013 |
|---|---|---|---|---|---|---|
| **Data collection** | GE & PL to consolidate mine specific data collection<br>CZ to initiate data collection in its three mines | | Develop allowance methodology. Establish baseline data for eg grandfathering of allowances. | | | |
| **Legislative process** | Agree definition of mine installation, eg active shafts | Address safety constraints on new methane combustion plant | | | | |
| **Competition** | Monitor coal prices as lower coal price would accelerate mine closures<br>Map plans for mine rationalisation (eg closures in PO, GE, UK) | | | | | |
| **Monitoring and reporting** | Agree EU monitoring protocol for CMM from active mines | Mine-specific emissions monitored through regular spot measurements with uncertainty, eg below 10% from 2006–2009. Annual audit to verify data. | | | | |
| **Administration** | Learn from administrative process involved in UK ETS participation | | | Submission of NAP | | |
| **Communication** | Disseminate lessons learnt from UK ETS inclusion | Communication with competent authorities & EURACOAL, key countries, Methane to Markets | | | | |

As methane emissions per tonne of coal mined vary depending on the geology of the area and the level of seam gas already drained, the most realistic approach to allowance allocation is through grandfathering. A key part of the route map involves setting and implementing emissions monitoring procedures to produce a reliable emissions data series for a period of four years prior to submission of the Phase III NAP.

### 5.2.3 Data

If allowances are allocated by a grandfathering approach a reliable emissions baseline must be recorded for each individual mine that is to be included in the EU ETS. Data collection of monitored emissions from mines already takes place for the UK and data collection levels are under improvement in Germany and Poland, but no reports of mine-specific data collection in the Czech Republic have been found. In some Member States, rapid action would need to be taken to initiate detailed emissions monitoring activities at active mines in order to generate four years of baseline data before the NAPs are submitted in 2010/11 for Phase III.

The key countries chosen for more detailed assessment for the coal mining sector were Poland, Germany, the UK and the Czech Republic as they account for almost 90 per cent of EU25 emissions from active underground mines. Availability of data on a mine-by-mine basis is summarised in the table below. The most accurate level of emissions reporting under IPCC (Tier 3) is recommended were mines to be included in the EU ETS. Currently only the UK reports coal mine emission in its national greenhouse gas inventory at this level.

Our contact, Krzysztof Kstańczyk, at Poland's Central Mining Institute[65] is in favour of including active coal mines in the EU ETS. However, he does not think that grandfathering is a suitable allocation approach as a mine can move from very low to high methane emissions over a short period when a new methane-rich seam is tapped. This could be overcome by pooling the carbon allowances for a number of mines and the 'winners and losers' would cancel out in terms of overall methane emission changes during the year. The German Coal Association[66] also has concerns over grandfathering due to increases in emissions associated with tapping a new seam, but each Member State would be able develop its own chosen allocation approach.

Benchmarking would not be a suitable approach for allocation, as production of coal cannot be used as a guide to methane emissions because methane emitted per tonne of coal mined fluctuates depending on the geological conditions.

**Table 15 | Mine specific data availability for both active and abandoned underground mines**

| Country | Methane emissions data for specific active mines available? | Methane emissions data for specific abandoned mines across MS? |
|---|---|---|
| Czech Republic | Not submitted to national inventory. | No – not included in GHG inventory. |
| Germany | Underway – gathering data from operators etc (Tier 2). | No – but total emissions in inventory (150% uncertainty in EF). |
| Poland | Underway – report on methodology for specific mines. | No – not included in GHG inventory. |
| UK | Yes – from mine operator (Tier 3). | No – methane reserves calculated for all UK coal fields and EF applied. |

65 Personal Communication, Krzysztof Kstańczyk, Department Of Energy Saving And Air Protection, Poland's Central Mining Institute, December 2005.

66 GVSt German Coal Association, personal communication, February 2005.

Data quality on emissions from UK active mines is to a good standard and is measured based on the Tier 3 methodology in the IPCC guidelines. UK COAL supply figures for emissions of methane on a mine-by-mine basis to the national emissions inventory. The company holds data going back to 1995 and covers around 90 per cent of deep mine production. Based on UK COAL's monitoring regime, their spot measurements of ventilation gas have a +/- ten per cent uncertainty and spot measurements for drainage gas have an uncertainty of up to +/- five per cent. Their monitoring data is audited once a year. Methane combusted in the gas engines and flares is monitored using flow meters in order to calculate the fraction of the total utilised. The biggest source of fluctuation in methane emissions is due to barometric pressure: when pressure drops rapidly, large releases of methane can occur. Averaging annual emissions over a three-year period will help to even out pressure shifts.

Germany is improving its monitoring of methane emissions through an ongoing government-funded research project[67] which is developing data sources, deriving national emission factors, carrying out calculations and determining uncertainties. The available and relevant data from operators, associations and the licensing and monitoring authorities of the Länder is being compiled. The German mining company RAG[68] highlighted that the fluctuations in methane emissions means that a mine emission factor cannot be calculated. This could be overcome by taking a baseline based over several years of monitoring emissions, as was done for the UK ETS. RAG also has concerns that current equipment for monitoring the dilute amounts of methane in the ventilated air is not sufficiently accurate for inclusion in the EU ETS. However, monitoring accuracy can be expected to improve in the years up to 2013. For a single longwall operation, the IPCC's 2006 draft guidelines report that with weekly monitoring of ventilation air emissions, the accuracy of annual emission figures will probably be +/- five per cent[69].

Germany reports emission figures for methane based on the Tier 2 level methodology in the IPCC Guidance 2000, using a methane emission factor from a project published in 1993: reporting would need to be improved to a Tier 3 level before German mines could be included in Phase III of the EU ETS. A by-country comparison of specific emission factors used for underground coal mining shows a broad range. Germany's emission factor[70] falls in the lower part of the range, comparable to that of the Czech Republic. Poland's emission factor is even lower and lies outside the IPCC's recommended range.

Poland has recently produced a report covering mine-specific emissions data and has mine-specific records of methane emissions and capture back to 1988.

It is unclear whether the methane emissions from Czech mines are available on a mine-specific basis. The National Inventory Report for the Czech Republic reports that emissions are calculated based on a national emission factor for deep mining.

Abandoned mine methane emissions are only included in the inventories of the UK and Germany. The uncertainty level for the German emission factor for abandoned mines approaches 150 per cent. The UK has derived abandoned mine emission estimates for the years 1990 to 2004 using a relationship between emissions and the quantity of the underlying methane gas within the

67 'Methane Emissions from Coal Mining' – Ongoing research project (FKZ 203 41 253/05).

68 RAG Position paper on including coal-mine methane from active underground mines the EU ETS, January 2006.

69 Draft 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

70 Germany, National Inventory Report, 2005.

abandoned mine, based on a recent study funded by Defra[71]. The lack of mine-specific data, high uncertainty and complete omission of abandoned mines from the majority of national inventories present significant data challenges for including abandoned mine methane in the EU ETS.

### 5.2.4 Legislative processes

The installation definition of a mine presents a challenge as coal mines are not covered by IPPC. It is recommended that a mine installation definition would be based on the methane emissions from active mine shafts only. This would include all methane emitted through the active shaft – even though some methane may be from abandoned mine tunnels, it is impossible to trace the exact source of the methane.

Basing an installation definition around the active mine shaft is preferable to trying to set a mine boundary as some mining areas can stretch for 100km$^2$ and other mines are linked through shafts to other deep mines. In addition, abandoned mines can be located above the active deep mine and abandoned mine emissions can seep into the active mine shaft. In Poland, methane in several abandoned mines is drained through an underground drainage system to a neighbouring mine and special treatment may be needed to define 'active mine emissions' in this case[72].

A de minimus threshold is not needed as average mine emissions are around 600 kt $CO_2$ eq per year.

### 5.2.5 Competition

The coal sector is particularly exposed to competition as EU producers must compete against more cheaply produced foreign imports. Economic impacts due to the inclusion of the coal sector in the EU ETS must be carefully considered and monitored over time as the price of coal, though currently favourable, may drop and additional costs could accelerate mine closures.

Coal producers have very little flexibility to pass on costs to customers as they are exposed to international competition and the price of coal is effectively set by the international market. Coal mined in the EU faces competition against supplies from South Africa, Russia, Colombia, Kazakhstan, Indonesia and Australia[73]. Only supplies of coal from Poland to the EU rivalled the tonnage of imports from these countries. Although some cost savings are made in the shorter transport distances afforded by local coal production, EU coal production costs remain far higher than costs for foreign competitors.

The Czech Republic and UK coal industries are privatised and receive very limited subsidies from their respective governments. In contrast, the German coal industry still receives large subsidies, as the cost of producing the coal is several times higher than the market price. In 2003, the German Government approved a financial framework for further support of the hard-coal sector for reducing from 26 million tonnes in 2005 to 16 million tonnes in 2012[74]. The Polish coal industry has been restructured over the last ten years resulting in many mine closures. Rationalisation of the industry is likely to continue.

71 Kershaw (2005), 'Development of a Methodology for Estimating Methane Emissions from Abandoned Coal Mines in the UK', White Young Green report to Defra, 2005.

72 Jan Kwarcinski, State Geological Institute, Personal Communication November 2005.

73 IEA Statistics, IEA Coal Information 2005.

74 BMWA, 2003: Bundesministerium für Wirtschaft und Arbeit. Entscheidung der Bundesregierung zur Förderung des Steinkohlebergbaus von 2006–2012. Pressemitteilung vom 11.11.2003. Internetseite URL: www.bmwa.bund.de/Navigation/Presse/pressemitteilungen,did=27282.html

### 5.2.6 Abatement technologies

Widely used options for abating coal-mine methane include methane-powered generators, flares and gas turbine combined cycle generators with large gas flows (eg 18MW generator). Conventional energy generation technologies require a relatively high concentration of methane and mainly use seam gas methane pulled directly off the coal seam. However, the majority of methane occurs in a dilute form in the ventilation shaft air that is difficult to utilise and is vented. For example, UK COAL reports that in 2004 66 per cent of methane produced was in the general body of air and only 35 per cent captured. Of the amount captured, 37 per cent was utilised.

For certain mines, where methane concentrations are very low, it becomes difficult to abate emissions in a safe and economic manner. Methane concentrations in ventilation air normally range from about 0.2 per cent to one per cent. It may not be possible to abate methane in the ventilated air that is emitted in the active shaft air streams in some countries when concentrations are particularly low. However, new technologies are under development that would facilitate abatement and inclusion of CMM in the EU ETS could accelerate their deployment. This would have a significant impact on reducing methane released to air as the majority of methane is emitted in the ventilation air compared to seam gas. Megtec[75] have installed the first commercial methane oxidation and heat recovery system for capturing dilute ventilation air methane. Above methane concentrations of 0.3 per cent the system can produce energy. Regenerative heating, where exhaust gases heat the incoming shaft air, enables 98 per cent combustion of methane. However, capital costs for installing these new technologies are high. A 6MW Australian project will cost over US$14 million and will abate 4.4 Mt $CO_2$ eq between the years 2008 and 2012[76]. German mines normally have ventilation air methane concentrations below 0.3 per cent so it would be difficult to generate energy using Megtec's system, though Megtec can abate methane emissions at 0.2 per cent and as low as 0.1 per cent in a variant system[77]. Natural Resources Canada (CANMET) are working with industry to develop technology to abate dilute methane gas, but their catalytic system is not commercially available yet.

Any new technology such as dilute methane abatement catalysts could take over two years to be approved by the mining authorities within the UK and Germany. This is due to strict health and safety regulations imposed on mining activities. As methane is explosive in air between concentrations of five and 15 per cent per volume it has been treated as a potential safety hazard for underground mining. The feasibility of the sector inclusion given these constraints needs to be reviewed before coal-mine methane could be included in Phase III. Consultation with mining authorities and mining companies would be needed to clarify these issues. It should be noted that the UK successfully reduced methane emissions under the UK ETS in spite of the safety constraints they operate under.

Flaring methane is a common control measure for more concentrated methane emissions and costs approximately 5 €/t $CO_2$ eq[78]. Flaring allows high combustion efficiencies, resulting in close to 100 per cent abatement if the gas is concentrated. The gas in ventilation air is too dilute to be flared.

75 Megtec Systems www.megtec.com

76 Coalbed Methane outreach Program 'BHP Billiton to Install World's First Commercial VAM Oxidation Project' website August 2005 www.epa.gov/cmop/vam/highlights.html

77 Personal communication 205, Megtec, Systems AB, Sweden, R&D Manager.

78 EMF, Methane and Nitrous Oxide Marginal Abement Cost Curves www.epa.gov/outreach/appendices.html

The most cost-effective measures for coal-mine methane abatement is to fit a reciprocal gas engine, and costs range from 5 €/t $CO_2$ eq to an income of 5 €/t $CO_2$ eq[79]. The costs are offset by the energy generated by the gas engine and a higher gas price means lower net marginal abatement cost. Abatement costs will be lower in the new Member States as labour prices are lower and this would outweigh the slightly lower gas prices in Eastern Europe.

### 5.2.7 Monitoring and reporting

A monitoring protocol and guidelines would need to be developed and agreed at the EU level. This section discusses existing coal-mine methane monitoring methodologies that could act as the basis for a protocol. Agreeing a protocol would need to be a rapid process to enable the development of baselines using data from 2006 to 2009. If data is available, a historic baseline from 2000 to 2004 may be more appropriate as this would account for Member States who took early action to abate emissions. Using a baseline to 2009 could provide a disincentive to coal producers to install abatement technology until after the baseline period has passed.

The data section above gave an overview of the level of monitoring and reporting currently undertaken in the key countries, with the UK having the highest level of monitoring in place and Germany and Poland fast approaching this level. The Polish Environment Ministry has recently produced a report[80], which presents a new method of evaluating emissions of methane from hard-coal mining. Consistent with IPCC classification, the new method of monitoring allows methane emissions for individual mines to be calculated.

Verification of emissions would be important to ensure that the integrity of the existing trading scheme was not damaged. As average emissions are as high as 600 kt $CO_2$ eq per mine, and there are very few small mines in operation, the highest level (Tier 3) of monitoring would be recommended for the vast majority of sites.

### 5.2.8 Administration

The key administrative task would be to develop an EU monitoring protocol for coal-mine methane from active mines. There are significant resources available to act as a basis for this protocol:

- The 2006 IPCC Guidelines[81]
- The UK COAL protocol for the measurement of methane emissions from working coal mines[82], developed under the UK ETS
- Baseline methodology for coal-mine methane CDM projects (UNFCCC 2006)[83].

79 AEAT (1998). 'Options to Reduce Methane Emissions'. A Report produced for DGXI, AEA Technology Environment.

80 'The Real Emission of Methane to the Atmosphere Generated by Hard Coal Exploitation' or 'Ocena rzeczywistej emisji metanu do atmosfery spowodowanej eksploatacja wegla kamiennego', Polish Environment Ministry.

81 Draft 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

82 Defra 2003, 'Guidelines for the Measurement and Reporting of Emissions by Direct Participants in the UK Emissions Trading Scheme'.

83 UNFCCC 2005, 'Consolidated Baseline Methodology for Coal Bed Methane and Coal-mine Methane Capture and Use for Power (Electrical or Motive) and Heat and/or Destruction by Flaring 28' November 2005 cdm.unfccc.int/EB/Meetings/022/eb22_repan10.pdf

The CDM guidance cites five additional published baseline methodologies for active coal-mine methane with authors ranging from IT Power to the Prototype Carbon Fund (PCF). Abandoned mines are currently excluded from guidance on CDM projects.

The administration burden will vary between Member States depending on the current level of emissions monitoring and reporting that takes place. The UK already has a system of mine-specific monitoring, reporting and verification in place and so the additional administrative costs will be relatively low.

Poland has 33 mines and all but one are state owned. The government will have a significant administration cost to set up mine-specific monitoring to the standard needed for EU ETS participation. The Czech Republic has only three mines, all privately owned, and so administration costs will be limited. Germany is currently gathering mine-specific monitoring data from operators.

### 5.2.9 Communication

Communication between Member States, through EU bodies and international technology collaborations will help to disseminate best practice and cost-effective solutions to methane capture and utilisation. This would reduce competitiveness impacts for vulnerable mines covered by the EU ETS. Parties to work with would include the competent authorities, EURACOAL, the IEA, key coal producing countries and ‘Methane to Markets’. In addition, the lessons learnt from CMM inclusion under the UK ETS should be shared with other Member States. Private sector coal-mine methane energy generation companies should be kept informed. The IEA, UK COAL, EURACOAL, UNECE, RAG, the German Coal Association, Polish State Geological Unit and Alkane Energy were contacted during the LETS project.

Communication with stakeholders during the project has revealed a number of challenges that would need to be overcome if CMM were to be included in Phase III. Specific issues are highlighted on a Member State basis in the box below. Member States are concerned about the allowance allocation methodology and about safety and regulatory constraints. These issues are included in the route map.

## Feedback from Member States on inclusion of mine methane under Phase III

**Poland**[84]

- Poland's Central Mining Institute (CMI) was in favour of the inclusion of coal-mine methane under the EU ETS in some form as Poland has significant methane abatement options.
- Poland has concerns about the allowance allocation methodology, as grandfathering would not account for unpredictable fluctuations in methane when drilling into a new seam. We comment that pooling allowances for a number of mines should even out fluctuations.
- Safety regulations are not a major barrier in Poland to methane combustion installations such as CHP plant using methane pumped from seam.
- Some safety concerns concerning the combustion of ventilation shaft methane.

**Germany**[85]

- RAG in Germany was, on balance, not in favour of inclusion in Phase III due to safety constraints on methane combustion.
- Methane combustion plants are approved by the mining authority and thus the decision on methane combustion plant installations lies outside the control of the mining companies.
- The mining authority can instruct German mines to carry out safety actions that lead to unpredicted amounts of methane being vented to the air.
- Inclusion in the EU ETS would collide with the German financial support for power generated by coal-mine methane from active and abandoned mines[86].

**UK**[87]

- UK COAL would be in favour of inclusion in the EU ETS if safety constraints could be overcome and if any grandfathering baseline took account of early action. We have added these issues to the route map.
- Safety legislation restricts methane combustion below concentrations levels of 27%. Below 27% flares and engines must be turned off. Flaring approvals can take up to eight months to obtain.

Alkane Energy[88] was consulted under the study as they generate energy from abandoned mine methane sites. The company is in favour of including abandoned mine methane in the EU ETS in Phase III.

84 Personal Communication, Krzysztof Kstańczyk, Department Of Energy Saving And Air Protection, Poland's Central Mining Institute, December 2005.

85 Personal Communication, Heinrich Steimann, RAG Aktiengesellschaft, Germany, December 2005.

86 RAG Position paper on including coal-mine methane from active underground mines in the EU ETS, January 2006.

87 Personal Communication, Chris McGlen, UK COAL, November 2005.

88 Personal Communication, Bill Tonks, Alkane Energy, January 2005.

## 5.3 Sustainability Appraisal summary

Methane emissions from active coal mines accounted for 0.7 per cent of EU25 total greenhouse gas emissions in 2003. In Europe, four countries dominate coal production and collectively account for about 94 per cent of total production: the UK, the Czech Republic, Germany and Poland.

The results of both the GEM-E3 modelling and the bottom-up assessment indicate that the coal sector would benefit from inclusion of coal-mine methane in the EU ETS. The sector has low (or even negative) abatement costs, due to the value of electricity generated from recovered methane, and significant reductions in emissions are possible. The GEM-E3 modelling scenarios indicate that the coal sector undertakes significant abatement and becomes a net seller of permits. This highlights the need to take care in setting the allocation for this sector to ensure that it does not experience windfall gains and flood the market with allowances. The GEM-E3 model forecasts increases in production (and value added) as the financial benefits of inclusion are used by the sector to reduce the price of coal, which results in increased demand. This could help ameliorate the significant shrinkage in coal production which is expected in the future.

A similar picture emerges from a bottom-up economic assessment. Sector expansion is predicted because the negative variable costs of abatement provide producers with the opportunity to reduce price, with the result that output increases. The bottom-up assessment also suggests that the coal sector in Poland and the Czech Republic could benefit more than the UK and German industry due to lower abatement costs. This could put the UK and German coal industry under greater competitive pressure from Polish and Czech imported coal. In the analysis undertaken, there are no adverse impacts on domestic production from inclusion in the ETS, because of the possibility of reducing prices. However, if inclusion were to lead to any increase in production costs, then this could not be passed on as the price of coal as it is set internationally.

Although the modelling points to the benefits of including CMM in the EU ETS, there are significant barriers. Safety concerns have been raised by all the major producers in Europe as combustion plant approval is in the hands of the mining authorities. In addition, Germany's 'feed-in tariff' legislation is not compatible with plants included in the EU ETS.

Overall, the Sustainability Appraisal leads to the recommendation that CMM should be included in the EU ETS with the caveat that safety concerns are addressed. Based on the modelling results, the low abatement costs within the sector mean that the economic impacts of inclusion could be positive, so the position of EU coal on the international market should not be jeopardised.

Further work that could be usefully undertaken before inclusion is a review of feasible abatement opportunities and an update of the marginal costs abatement curves for the sector. This would help to provide a sound basis for setting allocations for the sector. Consideration of the coal industry restructuring is also needed as the sector will shrink significantly in the EU in the next ten years.

# 6 Refrigeration gases

## 6.1 Overall findings

The overall conclusion for the stationary refrigeration sector (which excludes the air-conditioning and mobile air-conditioning sectors) is that it should not be considered at this time for inclusion in an expanded EU ETS. The main reason for this recommendation is that the sector will be subject to a range of mandatory emission control measures as a result of the proposed (and forthcoming) EU regulation on fluorinated gases (F-gas)[89]. The regulation will help to reduce leakage rates from HFC refrigerant systems but will have a lesser effect on encouraging the up-take of alternative refrigerants. It is recommended that the suitability of inclusion of this sector in the EU ETS is reviewed once the impact of the F-gas regulation has been assessed (no later than four years after entry into force). If the sector were included in the EU ETS it could act as an incentive to move towards alternative refrigerants.

The stationary refrigeration sector has a large number (many thousands) of operators across Europe, with each installation emitting a significantly lower level of greenhouse gases than current installations under the EU ETS. This will have implications for resourcing the allocation process and monitoring and verification by Member States.

89 European Commission (2004). Proposal for a regulation of the European Parliament and of the Council on certain fluorinated gases. Text of the proposed regulation as agreed at the meeting of the Council (Environment) on 14 October 2004. Regulation Interinstitutional file 2003/0189 COD.

## 6.2 HFCs and PFCs – recommendation

### Table 16 | Summary for HFCs and PFCs from refrigeration sector

| Sector | Refrigeration – HFCs & PFCs |
|---|---|
| Recommendation | Do not include. |
| Overall emissions | 29.8Mt $CO_2$ eq from refrigeration & air conditioning (RAC) in the EU15. |
| Emissions as a percentage of EU15 total GHG | RAC F-gas emissions are 0.7% of total EU15 GHG. |
| Key emitting countries | France, Germany, UK and Italy. |
| Feasibility issues | • De minimus – The thousands of small plants in stationary commercial refrigeration are a reason for exclusion. If included, a threshold would be needed based on refrigerant charge.<br>• Definition of installation – Emissions are very low per installation.<br>• Monitoring and reporting – Major barrier as virtually no installation specific leakage data.<br>• Transaction costs – High costs relative to the emission savings available per site.<br>• Competitiveness – For supermarkets, costs could be passed on to the consumers.<br>• Timeframe – Review decision to exclude after F-gas Regulation impact is known. |
| Other legislation present/planned | Proposed F-gas regulation would have major effect on sector emissions. |
| Abatement technology | Available – better F-gas containment or alternative refrigerant. |
| Potential for abatement | Containment of HFCs could improve abatement across the sector but the abatement potential from alternative refrigerants such as $CO_2$ and ammonia is unknown and could be restricted due to safety concerns/technology availability. |

Key reasons for excluding the sector from the EU ETS are the small plant size and the low F-gas emissions per plant, limited data availability and the difficulties associated with defining an installation. Thousands of installations in each Member State would need to be included in the scheme in order to make an impact on emissions from this sector, but this would massively increase costs for the competent authorities.

Despite concluding that the sector is not suitable for inclusion in the EU ETS, this chapter nevertheless addresses the feasibility issues for inclusion. This highlights the potential challenges that would need to be addressed if the sector were to be included at a later stage.

First, a de minimus threshold would need to be set based on the combined refrigerant charge size of the refrigeration systems at a particular site or installation. This would help to rule out thousands of very small commercial refrigeration plants for which inclusion would be a burden. It is likely that, for the majority of installations, transaction costs will be high relative to the emission savings per site.

Competitiveness impacts were not seen to be a barrier to inclusion for larger participants such as supermarkets. Increased costs from meeting an emissions cap could be passed onto consumers through a negligible increase in food prices and the sector is not significantly affected by competition from outside Europe.

## 6.3 Other approaches

Since the refrigeration sector structure is not very amenable to inclusion under the EU ETS, other policy approaches are particularly important. This section discusses the proposed F-gas regulation that is expected to reduce refrigerant leakage levels, other measures in place in specific Member States and an upstream approach for inclusion in the EU ETS. One policy option to encourage a switch to non F-gas refrigerants would be to allow a group of refrigeration system replacements to be classed as a domestic offset project. This is also discussed further in this section.

The main legislation measure affecting this sector is the forthcoming F-gas regulation. The proposed Regulation is anticipated to impact on this sector by introducing mandatory emission control measures. The actual extent to which emissions will be reduced is the subject of debate by industry and non-governmental organisations (NGOs). The Regulation, as presently drafted, is based on a strategy of F-gas containment. It requires, amongst other measures, a requirement to inspect certain equipment types containing fluorinated gases (including refrigeration and air-conditioning equipment); installation of leakage detection systems for applications containing large amounts of fluorinated gases; records to be kept of fluorinated gases installed, added and recovered; recovery of fluorinated gases at end of life and training and certification of handlers of fluorinated gases.

It is anticipated that the Regulation will lead to a better state of knowledge concerning the use and leakage of fluorinated gases in this sector. Under the current requirements of Article 9 of the proposed F-gas regulation, the Commission is obliged to publish a report reviewing the experience of the application of the Regulation not later than four years after its entry into force. As part of the review, the effectiveness of the Regulation in terms of its impact on emissions will be assessed, and additional applications where the use of F-gases might be scheduled for future elimination will be identified (including those from the refrigeration sector).

An important consideration for this sector is the potential for double counting of emission reductions. It is important that any future emission reductions that occur as a result of the mandatory emission control requirements specified in the Regulation are not also made available for inclusion in any future trading scheme.

Beyond the F-gas regulation there may be additional price-based mechanisms through which use and leakage of fluorinated gases may be reduced. For example, a deposit scheme where the deposit is returned upon receipt of recovered refrigerant could be introduced, or Global Warming Potential (GWP) taxation where the tax would be proportional to the global warming potential of a refrigerant and the tax refunded upon receipt of recovered refrigerant.

Some EU countries already have other national legislation in place that places controls on the use and/or handling of fluorinated gases. For example, since March 2001 Denmark has had a tax on all F-gases except sulphurhexafluoride ($SF_6$) of around €40/kg. In the Netherlands the STEK system has been in place since the early 1990s, which involves requirements such as the registration of equipment of over 500 watts compressor power input, auditing of companies, monitoring of refrigerant use and training for personnel. A study by ENVIROS[90] contacted national governments in the EU15 to assess what national legislation was already in place concerning the control of F-gases. The results of this consultation are presented in Annex F.

A different approach to abating refrigerant HFC emissions would be to take an up stream approach to allowance allocation under the EU ETS. Manufacturers of HFC and PFC refrigerants would be set an allowance for the sale of the F-gases and they would have to buy more credits in order to sell refrigerants above their allowance levels. LETS Update concludes that this is not the best way to encourage abatement in this sector. A tax would achieve a similar result in a more straightforward and cost-effective manner. In addition, the manufacturers of F-gases are not in control of how the gas is used and once it is sold the purchaser could allow significant leakage to the atmosphere through careless handling.

### 6.3.1 Domestic offset projects

A decision has not been taken on whether domestic offset projects will permitted in the EU ETS, though they are mentioned as an option under the Linking Directive. However, here we consider the potential use of domestic offsets by supermarket chains for large-scale F-gas emission reduction projects.

A domestic offset project is where an approved emissions reduction project in the EU25 would gain carbon credits that could be sold into the EU ETS. The domestic offset process could work in a number of ways, and the steps involved could include:

- development and approval of a monitoring protocol
- evaluation of a potential domestic offset project, eg bundle a number of large refrigeration systems at a number of stores
- submission of project proposals for approval with projected baseline emissions and reductions predicted over business as usual baseline
- initiation of emissions reduction project if approved
- monitoring, reporting and verification of emissions reductions
- company obtaining carbon credits for emissions reduction
- carbon value attached to credits and company sells carbon credits into the EU ETS.

Companies with extensive refrigeration systems such as supermarket chains could potentially apply for offset projects such as the conversion of a number of large refrigeration systems from F-gas to a zero or low global warming potential refrigerant. One supermarket chain interviewed for LETS Update reported that supermarkets are likely to be in favour of applying for domestic offset projects. Refrigerant replacement for a number of systems would cost millions[91], leading to massive impacts to store profits. Income from carbon credits would be needed to encourage investment. Domestic offsets could help soften the impact if governments impose F-gas taxes at some stage.

90 Enviros (2003). Assessment of the costs and implications for emissions of potential regulatory frameworks for reducing emissions of HFCs, PFCs & $SF_6$. EC002 5008.

91 Personal Communication, Sainsburys, December 2005.

There are a number of significant barriers to refrigeration offset projects. First, there is a high level of uncertainty on whether domestic offset projects would be allowed to receive credits under the EU ETS. Industry is very sceptical and it would be difficult to convince EU companies to rely on them as an option. Second, political or legal challenges could be made by companies in Member States that have already been forced to phase out F-gas use because of national policies. Finally, there is some industry concern that if life cycle carbon emissions are considered in domestic offset projects, then carbon savings from refrigerant replacement would be counteracted to some degree by the embodied energy required to produce the new plant hardware.

## 6.4 Feasibility issues

Our recommendation for refrigeration is that it should not be considered at this time for inclusion into an expanded EU ETS and so it was not appropriate to develop a route map for inclusion for the sector. Nevertheless, we have provided an overview of feasibility issues that would need to be considered if the sector were to be included in the EU ETS.

### 6.4.1 Data

A major feasibility challenge to including refrigeration is the low level of GHG emissions per refrigeration installation. An initial estimate of leakage from refrigeration installations (supermarket and industrial) was compiled for a generic 'average' and 'maximum' size of facility (Table 17). This analysis shows that emissions from an individual site/facility are significantly below the generic threshold of 5 kt $CO_2$ eq/year that LETS Update considered reasonable for inclusion in a future trading system. Even the estimated emissions from the largest industrial system lie just below 1 kt $CO_2$ eq. Average supermarket systems emit about 0.2 kt $CO_2$ eq, which is around a factor of 25 smaller than the 5 kt $CO_2$ eq suggested threshold.

**Table 17 | Generic estimate of annual F-gas leakage from supermarket and cold storage systems for average and 'maximum' scale facilities**

| | Supermarket systems DX system | | Industrial cold storage DX system warehouses | |
|---|---|---|---|---|
| | average | maximum | average | maximum |
| Typical charge size (kg) | 1000 | 1800 | 4000 | 6000 |
| GWP refrigerant blend[92] | 2435 | 2435 | 1991 | 1991 |
| Annual 2010 leakage estimate (%)[92] | 10 | 10 | 8 | 8 |
| Annual leakage (kt $CO_2$ eq) | 0.24 | 0.44 | 0.64 | 0.96 |

92 AEAT (2004). Emissions and projections of HFCs, PFCs and $SF_6$ for the UK and Constituent Countries. Second edition. Report produced for the Department for Environment, Food and Rural Affairs.

In efforts to establish an estimate of emissions and numbers of refrigeration installations across Europe, project partners were contacted for information. Unfortunately, as already noted, there is a lack of information in many countries concerning the size of the refrigeration market and so no firm data on the number of refrigeration installations by Member States was obtained, except for the UK, which is shown below. In the UK alone there are over half a million integral retail display cabinets and nearly 200,000 walk-in cold stores.

### Table 18 | Estimate of UK stock of refrigerant equipment

| Equipment type | 2004 UK Stock[93] |
|---|---|
| Packaged liquid chillers (process cooling) | 20,000 |
| Integral retail display cabinets | 586,766 |
| Remote retail display cabinets | 227,240 |
| Commercial service cabinets | 422,219 |
| Cellar cooling equipment | 81,931 |
| Ice making machines | 127,664 |
| Walk-in cold rooms | 197,068 |
| Refrigerated vending machines | 45,000 |
| Miscellaneous | 100,000 |
| **Totals for refrigeration** | **1,807,888** |

An attempt at estimating the abatement potential for the refrigeration sector has not been performed. The main reason for this is that the impact of the proposed F-gas regulation is not yet known, so it is not clear as to what scope there is for further reductions in emissions.

## 6.4.2 Legislation

Due to the wide variety of stationary refrigeration application sizes (ranging from small chillers containing a few hundred grams of refrigerant to large industrial cooling installations containing thousands of tonnes of refrigerant fluid), it is recommended that a minimum installation size be specified were the sector to be included in the EU ETS. The most effective method of applying a threshold for participation may be on the size of refrigerant charge, eg those refrigeration applications containing 300 kg or more of fluorinated gases.

93 MTP (2005). Personal comm UK Market Transformation Programme.

Single refrigeration installations could be defined on the basis of charge size. Annual emissions from even very large systems are likely to be less than 1 kt $CO_2$ eq, so to make involvement in a trading scheme practical and balance the costs of participation against potential emission savings, ‘bundling’ of installations may be needed to allow participation in the market.

## 6.4.3 Competition

No significant competition barriers have been identified as the businesses using larger refrigeration plants are not significantly exposed to international competition. Larger companies such as the supermarket chains should be able to pass on costs to consumers if the sector was included under the EU ETS.

The setting of baselines and the allocation of allowances will be important to ensure certain participants do not benefit unduly from changes that may have occurred anyway under their BaU plans (eg equipment upgrades/replacement, introduction of alternative refrigerant etc).

## 6.4.4 Abatement technologies

Techniques for fluorinated gas emission reductions can be categorised into four general approaches[94]:

- Improved containment of fluorinated gases during the life cycle of equipment (manufacture, use and decommissioning)
- Use of alternative fluids with a zero/low GWP
- Use of not-in-kind (NIK) technologies
- Process modifications to avoid by-product formation or emission (not of relevance for the refrigeration sector).

There is a range of potential abatement strategies of relevance to the refrigeration sector. For existing systems containing HFCs, such strategies are generally focussed on a strategy of containment, ie reducing the leakage from equipment through the improved design, servicing and maintenance of such systems. This can lead to both higher energy efficiencies and lower operating emissions for many systems.

Other abatement strategies are based on the use of alternative refrigerants/technologies, such as ammonia, hydrocarbons, and $CO_2$. However, in some sub-sectors their uptake has been limited by safety concerns and performance issues, such as energy efficiency, compared with the continuing use of fluorocarbons. There are also a variety of other refrigeration technologies that are currently in the research and development phase and which potentially may be brought to a wide-scale market by 2013 or later. These include absorption cycle cooling with combined heat and power and specialised refrigeration cycles such as Stirling and Ericsson Cycle technology. It is important to note that not all technologies are considered suitable for use in large-scale refrigeration applications.

## 6.4.5 Monitoring and reporting

There are a very large number of stationary refrigeration units across the EU. The main challenges in terms of monitoring and reporting include ensuring a robust verification of emissions despite the present lack of leakage data at an installation/site level, coupled with the very large number of refrigeration operators in the sector across Europe.

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94 ECCP (2001). European Climate Change Programme. Long Report. WG5 Industry. June 2001.

There is typically a very high level of uncertainty in estimating emissions from this sector at a national level. Operating leakage is a main source of emissions, yet different types (and ages) of equipment can have very different leakage rates. For commercial equipment, the servicing regime can also directly affect the amount of fluid leaked. Equipment typically contains different blends of HFCs/PFCs, with each blend having a different global warming potential value. At a site/facility level, sales data for refrigerant fluid (together with other parameters) can be used to calculate emissions from equipment. Various emissions monitoring protocols for the sector have previously been developed in Europe and other countries.[95, 96, 97] Such initiatives could be potentially used as the basis for a European monitoring protocol.

In many European countries, refrigeration installations are not licensed by environmental regulators (eg under IPPC). In these cases, infrastructure for monitoring and verifying emissions would need to be put in place. With the large number of possible participants across Europe, this does have resource implications for Member States.

### 6.4.6 Administration

As described above, an administration infrastructure for monitoring and verifying emissions would need to be put in place in most countries. A suitable de minimus threshold for participation in any scheme will of course help limit the extent of any additional infrastructure and resources required by Member States for administering the scheme for the refrigeration sector. The administrative requirements may represent a significant burden to small operators if they are included in the scheme. Existing monitoring protocols (see Section 6.4.5) could be used as a basis for a European protocol to help reduce administrative costs.

Since there are a very large number (many thousands) of refrigerant operators across the EU, transaction costs could be high relative to the emission savings per site. There would need to be a balance between operational costs due to inclusion in the EU ETS against potential emission savings. Similarly, the introduction of the sector into EU ETS may involve high transaction costs for Member States that will have to issue allowances and collect from the many operators.

### 6.4.7 Communication

As previously described in other sections, refrigerant operators are presently not licensed by environmental regulators in many countries. Therefore it is likely that there are relatively poor channels of official communication with the sector. Trade associations that represent their member companies are one of the primary communication mechanisms between Government and industry operators.

95 WRI (2005) *Calculating HFC and PFC Emissions from the Manufacturing, Installation, Operation and Disposal of Refrigeration and Air-conditioning Equipment* (Version 1.0) *GHG Protocol HFC Tool (Version 1.0)*. World Resources Institute and the World Business Council for Sustainable Development.

96 US EPA (2004) Direct HFC and PFC Emissions from Use of Refrigeration and Air Conditioning Equipment October 2004. Climate Leaders Greenhouse Gas Inventory Protocol.

97 EFTC (2003) Protocol for the Measurement of HFC and PFC Greenhouse Gas Emissions from Refrigeration and Air Conditioning prepared at the request of the European Fluorocarbons Technical Committee. July 2003.

# Annex A

## Chemicals $CO_2$ data

### Ammonia and fertilisers

The International Fertilizer Development Center publishes a list of all ammonia ($NH_3$) and urea plants worldwide. The data included in this list is largely in the form of production and capacity data. We used 2001 production and capacity data to estimate $CO_2$ emissions from the ammonia and ethylene plants in the five Member States with the highest emissions share of the chemicals sector: Belgium, France, Germany, the Netherlands, and the UK. This data was then used to assess the average size and distribution of chemicals plants across the EU. The tables and figures below show the distribution of ammonia and petrochemical plants in the five key Member States. Note that some of the IFDC data contains anomalies due to $CO_2$ being sold into other processes; this is an issue that would have to be carefully considered when writing guidelines for inclusion of many areas of the chemicals sector.

Ammonia:

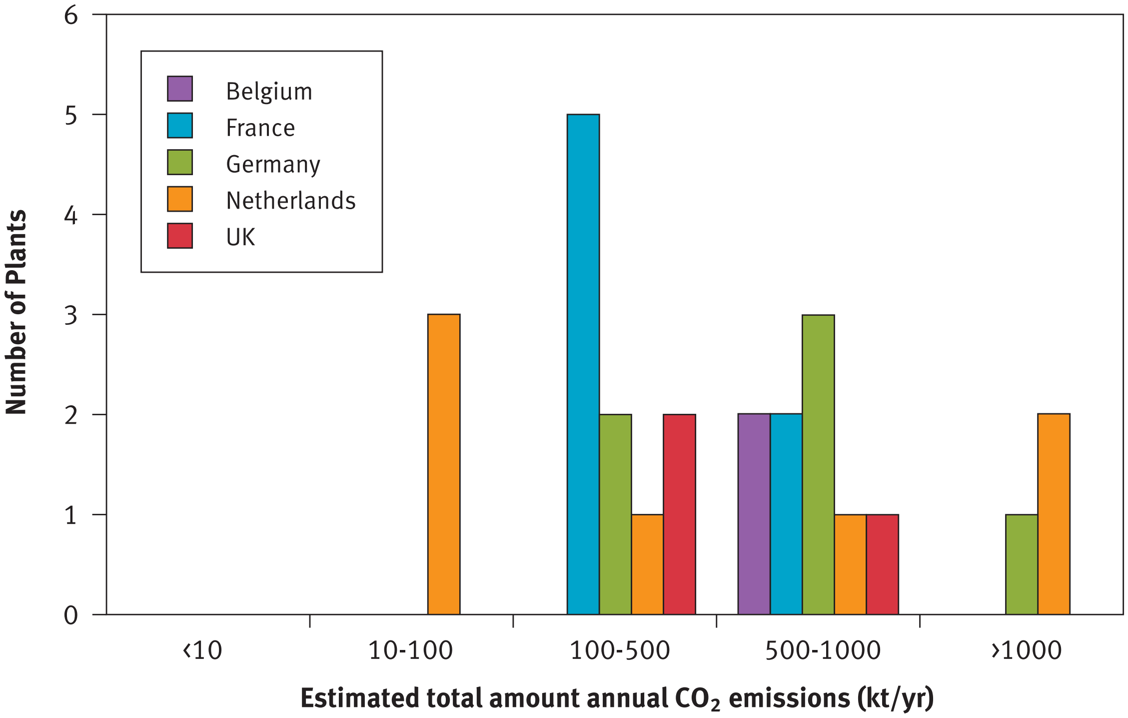
- Two lines of data for every ammonia plant – pure $CO_2$ emitted and $CO_2$ from flue gases
- Where available, reported $CO_2$ emissions from plant are included in the table
- Reported emissions are often quite different to estimated emissions – often because the estimate takes into account $CO_2$ produced but not emitted because it has been used for urea production (urea production also included in database), but not always
- Note that in many cases the pure $CO_2$ stream would be sold and used elsewhere
- Several ammonia plants have closed in recent years, due partly in many cases to rising gas prices.

**Table 19 | Distribution of ammonia plants by emissions in Belgium, France, Germany, the Netherlands and the UK**

| Number of ammonia plants in key Member States | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Annual $CO_2$ emissions (kt/yr)** | **Overall** | **Belgium** | **France** | **Germany** | **Nether-lands** | **UK** | **Overall percentage** |
| ‹10 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| 10–100 | 3 | 0 | 0 | 0 | 3 | 0 | 12% |
| 100–500 | 10 | 0 | 5 | 2 | 1 | 2 | 40% |
| 500–1,000 | 9 | 2 | 2 | 3 | 1 | 1 | 36% |
| ›1,000 | 3 | 0 | 0 | 1 | 2 | 0 | 12% |
| **Total** | **25** | **2** | **7** | **6** | **7** | **3** | |

Source: adapted from IFDC data

**Figure 1 | Distribution of ammonia plants by emissions in Belgium, France, Germany, the Netherlands and the UK**




Source: adapted from IFDC data

**Table 20 | Pros and cons of five different options for inclusion of $CO_2$ from ammonia plants**

| Options for inclusion of $CO_2$ from ammonia and fertilisers | | | | |
|---|---|---|---|---|
| **$NH_3$ Only** | **$NH_3$ + attached** | **$NH_3$ + N fertilisers** | **$NH_3$ + all fertilisers** | **Combustion installations** |
| **Pros** | **Pros** | **Pros** | **Pros** | **Pros** |
| Covers process emissions. | Covers process emissions Integrated plant. | Covers more emissions Covers process emissions Integrated plant. | One stakeholder Level playing field for fertilisers Covers process emissions. | No change to Directive (change definition of combustion installation). |
| **Cons** | **Cons** | **Cons** | **Cons** | **Cons** |
| Integrated plant Excludes other fertilisers – potential competition issues. | Excludes other fertilisers – potential competition issues. | Excludes other fertilisers. | Potassium/ phosphorus (K/P) fertiliser plants relatively small. | Excludes process emissions. |

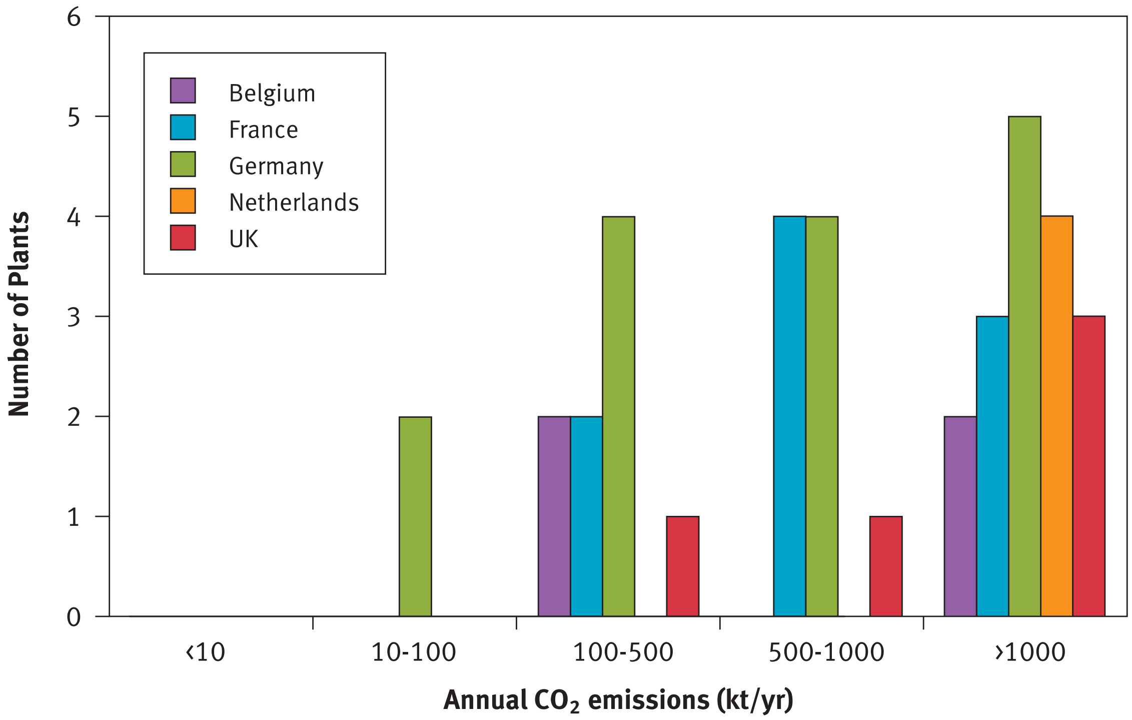
## Petrochemicals

**Table 21 | Distribution of ethylene plants by emissions in Belgium, France, Germany, the Netherlands and the UK**

| Number of ethylene plants in key Member States | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Annual $CO_2$ emissions (kt/yr)** | **Overall** | **Belgium** | **France** | **Germany** | **Nether-lands** | **UK** | **Overall percentage** |
| ‹10 | 0 | 0 | 0 | 0 | 0 | 0 | 0% |
| 10–100 | 2 | 0 | 0 | 2 | 0 | 0 | 5% |
| 100–500 | 9 | 2 | 2 | 4 | 0 | 1 | 24% |
| 500–1,000 | 9 | 0 | 4 | 4 | 0 | 1 | 24% |
| ›1,000 | 17 | 2 | 3 | 5 | 4 | 3 | 46% |
| **Total** | **37** | **4** | **9** | **15** | **4** | **5** | |

Source: adapted from IFDC data

**Figure 2 | Distribution of ethylene plants by emissions in Belgium, France, Germany, the Netherlands and the UK**




Source: adapted from IFDC data

**Table 22 | Pros and cons of four different options for inclusion of $CO_2$ from the petrochemical industry**

| Options for inclusion of $CO_2$ from petrochemicals | | | |
|---|---|---|---|
| **Cracker only** | **Cracker + attached + BTX** | **All petrochemicals** | **Combustion installations** |
| **Pros** | **Pros** | **Pros** | **Pros** |
| Single unit<br>Main source of emissions from petrochemical site. | Integration of site<br>All Benzene, Toluene and Xylene (BTX) units included. | Covers more emissions. | No change to Directive (change definition of combustion installation). |
| **Cons** | **Cons** | **Cons** | **Cons** |
| Integration of site<br>Separate BTX units not included<br>Monitoring issues. | More units included. | Less data available<br>Larger number smaller plants<br>Benchmarking becomes difficult. | Monitoring issues<br>More, smaller plants. |

# Annex B

## Chemicals sector ($N_2O$)

### Emissions by source and Member State

Table 23 shows $N_2O$ emissions from production of adipic and nitric acid for the Member States for 2002. The category ‘other’ is carpolactum production and gloxylic acid production.

Table 24 shows abatement technologies for nitric acid plant. Not all technologies are suitable for all types of plant; type of plant (for example high or low pressure, and temperature of tail gases are some of the factors determining the suitability of the technologies. In addition to this non-selective catalytic reduction, used primarily to reduce oxides of nitrogen (NOx) emissions, it also reduces $N_2O$ emissions.

## Table 23 | $N_2O$ emissions from the production of adipic and nitric acid for MS

| | Adipic acid production | | | | Nitric acid production | | | | Other | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Production kt | EF kg $N_2O$/T acid | Emissions kt $N_2O$ | Emissions kt $CO_2$ eq | Production kt | EF kg $N_2O$/T acid | Emissions kt $N_2O$ | Emissions kt $CO_2$ eq | Emissions kt $N_2O$ | Emissions kt $CO_2$ eq | Emissions kt $N_2O$ | Emissions kt $CO_2$ eq |
| Austria | | | | | 522 | 4.98 | 2.6 | 807 | | | 2.6 | 807 |
| Belgium | | | | | 1,674 | 7.54 | 12.6 | 3,912 | 0.93 | 287 | 13.5 | 4,199 |
| Cyprus | | | | | | | | | | | | |
| Czech Republic | | | | | 437 | 6.57 | 2.9 | 891 | 0.27 | 84 | 3.1 | 974 |
| Denmark | | | | | 334 | 7.48 | 2.5 | 774 | | | 2.5 | 774 |
| Estonia | | | | | | | | | | | | |
| Finland | | | | | 448 | 9.44 | 4.2 | 1,310 | | | 4.2 | 1,310 |
| France | | | 12.8 | 3,979 | 2,436 | 5.83 | 14.2 | 4,403 | 2.08 | 646 | 29.1 | 9,028 |
| Germany | | | 9.9 | 3,074 | 2,350 | 5.50 | 12.9 | 4,007 | | | 22.8 | 7,081 |
| Greece | | | | | 406 | 4.50 | 1.8 | 566 | | | 1.8 | 566 |
| Hungary | | | | | | | 2.7 | 846 | | | 2.7 | 846 |
| Ireland | | | | | 130 | 7.25 | 0.9 | 292 | | | 0.9 | 292 |
| Italy | 74 | 300 | 22.2 | 6,882 | 492 | 3.83 | 1.9 | 585 | | | 24.1 | 7,467 |
| Latvia | | | | | | | | | | | | |
| Lithuania | | | | | 288 | 10.00 | 2.9 | 892 | | | 2.9 | 892 |
| Malta | | | | | | | | | | | | |
| Netherlands | | | | | | | 17.7 | 5,498 | 2.451 | 760 | 20.2 | 6,258 |
| Portugal | | | | | 253 | 7.52 | 1.9 | 590 | | 0.006 | 1.9 | 590 |

**Table 23 |** **$N_2O$ emissions from the production of adipic and nitric acid for MS** (continued)

| | Adipic acid production | | | | Nitric acid production | | | | Other | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Production kt | EF kg $N_2O$/T acid | Emissions kt $N_2O$ | Emissions kt $CO_2$ eq | Production kt | EF kg $N_2O$/T acid | Emissions kt $N_2O$ | Emissions kt $CO_2$ eq | Emissions kt $N_2O$ | Emissions kt $CO_2$ eq | Emissions kt $N_2O$ | Emissions kt $CO_2$ eq |
| Spain | | | | | 896 | 7.0 | 6.3 | 1,945 | | | 6.3 | 1,945 |
| Sweden | | | | | 263 | 5.41 | 1.4 | 441 | 0.05 | 15 | 1.5 | 455 |
| United Kingdom | 192 | 10.99 | 2.1 | 656 | 1,566 | 4.95 | 7.8 | 2,405 | | | 9.9 | 3,061 |
| Poland* | | | | | 2,060 | 6.44 | 13.3 | 4,112 | | | 13.3 | 4,112 |
| Slovakia | | | | | 464 | 1.44 | 0.7 | 207 | | | 0.7 | 207 |
| Slovenia | | | | | | | | | | | | |
| **Total** | | | **47.1** | **14,591** | | | **111** | **34,483** | **6** | **1,791** | **1,64.1** | **5,0865** |

*Data is for 2001
Source: Locator database, 2004 inventory submissions; data for 2002 unless indicated.

## Table 24 | Abatement technologies for nitric acid plant

| Stage in production process | Technology | Cost | Abatement efficiency | Demonstrated |
|---|---|---|---|---|
| **First** (catalytic oxidisation of ammonia) | Alternative oxidation catalysts. | US$1.5 to 2M. | 80–90% | Incitec, Australia Former CIS. |
| **Second** (process gas stream up to absorption tower treatment) | Homogenous decomposition through increased residence time (Norsk Hydro patent). | 5% increase in investment costs. | 70% | More applicable for new plants. |
| | High temperature catalytic decomposition (Norsk Hydro and BASF have patents). | 0.3 to 0.5€/t $CO_2$ eq. | 80–90% | Installed at BASF plant in Germany (1), Belgium (2) and proposed for installation in the Netherlands. |
| **Third** (between absorption tower and expansion turbine) (can also be applied downstream of expander) | Low temperature catalytic decomposition. | 0.5 to 1€/t$CO_2$ eq 1–2 €/t $HNO_3$. | 70–90% | Laboratory scale and pilot tests only. |
| | Selective Catalytic Reduction (SCR) with hydrocarbons. | 1.5 to 3€/t. | 80–90% in laboratory. | Laboratory scale tests only. |
| | Uhde process. | Capital cost 1.7M €. | Up to 99% in commercial plant. | Installed at Agolonz Melamine International plant. |

Source: Derived from Integrated Pollution Prevention and Control. Draft Reference Document on Best Available Techniques in the Large Volume Inorganic Chemicals, Ammonia, Acids and Fertilisers Industries. Draft March 2004. European Commission Directorate General JRC.

# Annex C

## Aluminium $CO_2$ data

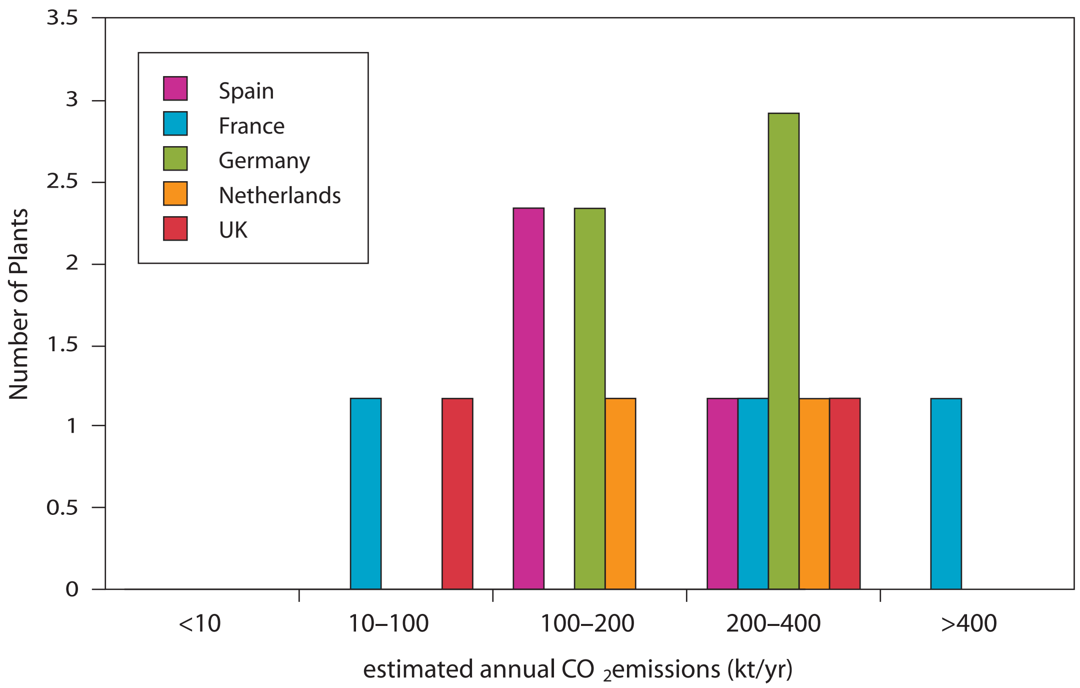
The data sets were obtained from the EAA. The $CO_2$ emission factors were calculated by taking UK carbon emissions from 2001 averaged out for Söderberg and Prebaked technologies and applied across the board for all the key EU countries to get a rough estimate of $CO_2$ emissions from various installations. This also gives an indication of installation size.

**Table 25 |** **$CO_2$ emissions from aluminium plant in France, Germany, the Netherlands, Spain and the UK**

| Country | Site | | Technology 1998 | Production kt/yr 1998 | Technology 2005 | Capacity kt/yr 2005 | ktC/Mt(Al) av.emission factor with Söderberg & Prebake tech | Tonnes C 2005 | kt of $CO_2$ 2005 | Emissions kt $CO_2$ eq |
|---|---|---|---|---|---|---|---|---|---|---|
| France | Auzat | Alcan Primary | SWPB | 45 | | 0 | 470 | 0 | 0 | 34.3 |
| France | Graveline | Alcan Primary | PFPB | 220 | PFPB | 256 | 470 | 120,320 | 441.17 | |
| France | Lannemezan | Alcan Primary | SWPB | 45 | SWPB | 50 | 470 | 23,500 | 86.17 | 84.7 |
| France | St. Jean | Alcan Primary | PFPB | 125 | PFPB | 137 | 470 | 64,390 | 236.10 | 12.6 |
| Total | | | | 390 | | 443 | | 208,210 | 763.44 | 131.6 |
| Germany | Hamburg | HAW | PFPB | 120 | PFPB | 134 | 470 | 62,980 | 230.93 | 6.91 |
| Germany | Voerde | Corus Aluminium | PFPB | 82 | PFPB | 90 | 470 | 42,300 | 155.10 | NE |
| Germany | Essen | Trimet | PFPB | 126 | PFPB | 157 | 470 | 73,790 | 270.56 | NE |
| Germany | Norf | Hydro Aluminium | PFPB | 210 | PFPB | 222 | 470 | 104,340 | 382.58 | 18.1 |
| Germany | Stade | Hydro Aluminium | SWPB | 70 | SWPB | 70 | 470 | 32,900 | 120.63 | 9.9 |
| Total | | | | 608 | | 673 | | 316,310 | 1159.80 | 34.91 |
| Netherlands | Delfzijl | Corus Aluminium | PFPB | 98 | PFPB | 110 | 470 | 51,700 | 189.57 | NE |
| Netherlands | Vlissingen | Alcan Primary | SWPB | 175 | PFPB | 224 | 470 | 105,280 | 386.03 | NE |
| Total | | | | 273 | | 334 | | 473,290 | 1735.40 | |
| Spain | La Coruna | Alcoa Spain | VSS | 82 | | 89 | 470 | 41,830 | 153.38 | 10.1 |
| Spain | San Ciprian | Alcoa Spain | PF/SWPB | 197 | PFPB | 220 | 470 | 103,400 | 379.13 | 8.13 |
| Spain | Aviles | Alcoa Spain | VSS | 82 | | 86 | 470 | 40,420 | 148.21 | 9.81 |
| Total | | | | 361 | | 395 | | 185,650 | 680.72 | 28.04 |
| UK | Holyhead | Anglesey Alu | PFPB | 135 | PFPB | 145 | 470 | 68,150 | 249.88 | 1.4 |
| UK | Kinlochleven | British Alcan | VSS | 8 | | 0 | 470 | 0 | 0 | 0 |
| UK | Fort William | Alcan Primary | PFPB | 38 | PFPB | 40 | 470 | 18,800 | 68.93 | 0.687 |
| UK | Lynemouth | Alcan Primary | PFPB | 70 | PFPB | 170 | 470 | 79,900 | 292.97 | 6.82 |
| Total | | | | 251 | | 355 | | 166,850 | 611.78 | 8.9 |

Source: European Aluminium Association (2005)

**Figure 3 | Estimated annual $CO_2$ emissions from installations across key EU countries.** Emissions and production capacity give a rough estimate of the size of installations




Source: European Aluminium Association (2005)

**Table 26 | Pros and cons of four different options for inclusion of $CO_2$ from the aluminium industry**

| Options for inclusion of $CO_2$ from aluminium sector | | | |
|---|---|---|---|
| **Al smelters only** | **Al + attached processes** | **Primary and secondary production** | **Combustion installations** |
| **Pros** | **Pros** | **Pros** | **Pros** |
| Covers process emissions. | Will cover all installations in primary. | Covers all emissions No discrimination between primary and secondary. | No change to Directive (change definition of combustion installation). |
| **Cons** | **Cons** | **Cons** | **Cons** |
| Discrimination between Söderberg vs Pre-bake Discrimination between primary and secondary. | Discrimination between primary and secondary Discrimination stand-alone processes. | Secondary less data available secondary plants smaller, large number. | Excludes process emissions. |

# Annex D

## Aluminium PFCs

This annex provides additional information relating to the primary aluminium sector including:

- an overview of the key issues relating to inclusion of the sector in the EU ETS
- description of the production process and smelting technologies
- data on plant technology and emissions across the EU25
- information on the Intergovernmental Panel on Climate Change (IPCC) approach to emission estimation.

### The primary aluminium production process and smelting technologies

The primary production process involves the processing of alumina, refined from aluminium ore, into aluminium. The basis of the production process is dissolving alumina in an electrolytic bath through electrolysis to produce molten aluminium. Alumina is dissolved in an electrolytic bath of molten cryolite within a large carbon or graphite lined steel container known as a pot (or a cell). A typical aluminium smelter consists of around 300 pots. An electric current is passed through the electrolyte at low voltage, but very high current, typically 150,000 amperes. The electric current flows between a carbon anode (positive), made of petroleum coke and pitch, and a cathode (negative), formed by the thick carbon or graphite lining of the pot. Between the anode and the cathode is a space filled by electrolyte. This mixture must be heated to about 980°C, at which point it melts and the refined alumina is added, this then dissolves in the molten electrolyte.

Molten aluminium is deposited at the bottom of the pot and is siphoned off periodically, taken to a holding furnace, often but not always blended to an alloy specification, cleaned and then generally cast. This process is very energy intensive, requiring large amounts of electricity to produce the required heat to form aluminium. On average, around the world, it takes some 15.7 kWh of electricity to produce one kilogram of aluminium from alumina[98]. Electricity supply will either be from autogeneration or from grid supplies, often on the basis of long-term contract with generation companies.

There are three main types of smelter in the EU25 currently operating:

- CWPB, or PFPB if they have point feeder technology
- SWPB
- VSS. Two plants in Spain are currently being upgraded to use point feeder technology.

Söderberg and Pre-bake technology differ based on the type of anode cell used. A Söderberg cell uses a continuous anode which is delivered to the pot in the form of a paste, and which bakes in the cell itself. Pre-bake technology uses multiple anodes in each cell, which are pre-baked in a separate facility and attached to ‘rods’ that suspend the anodes in the cell.

98 International Aluminium Institute website, www.world-aluminium.org/, (accessed November 2005).

In the literature on abatement technologies[99, 100, 101], the move to centre-worked pre-bake cell technology with point feeding techniques has been recognised as the main way to reduce anode effects, and as a result, PFC emissions. This is reflected in the emission factors shown below. Point feeder technology essentially allows greater control over the alumina feed process, ensuring that levels of alumina within the anode cells does not drop to a level whereby 'anode effects' occur (and PFC emissions result). These plants will also tend to have computer controls to optimise cell performance through monitoring parameters associated with anode effects. Smaller abatement potential is possible through improving cell operator training and establishing improved production processes to reduce the duration of anode effects when they occur.

The majority of European smelters now use CWPB technology, which have either been built or retrofitted with the modern point feeder technology (approximately 85 per cent of capacity). By 2008, almost all smelters will be operating with point feeder technology (approximately 90 per cent of capacity), including VSS plants retrofitted with point feeder process controls. Due to the technological changes across the sector, a 73 per cent reduction can be seen since 1990 in the EU15 group, based on total emissions of 13 Mt $CO_2$ eq in 1990.[102]

Smelter technology emission factors, based on the basic Tier 1 approach, provide an indication of the level of emissions associated with different types of technology.

**Table 27 | Default $CF_4$ emission factors by technology type from the GHG protocol initiative**

| Technology | Specific emissions (kg $CF_4$/t Al) Years 1990–1993 | Years 1998–2000 |
|---|---|---|
| Center Work Pre-bake | 0.4 | 0.2 |
| Point Fed Pre-bake | 0.3 | 0.08 |
| Side Work Pre-bake | 1.4 | 1.4 |
| Vertical Stud Söderberg | 0.6 | 0.4 |
| Horizontal Stud Söderberg | 0.7 | 0.6 |

Source: GHG Protocol Initiative, Calculating Direct GHG Emissions from Primary Aluminium Metal Production – Guide to calculation worksheets.

99 US EPA (2001), US High GWP Gas Emissions 1990–2010: Inventories, Projections, and Opportunities for Reductions, Report No. EPA 000-F-97-000, June 2001.

100 J Harsnich, I Wing, H Jacoby and R Prinn (1998), *Primary Aluminium Production: Climate Policy, Emissions and Costs*, Report 44 under MIT Joint Programme on the Science and Policy of Global Change.

101 J Harnisch and C Hendriks (2000), *Economic Evaluation of Emission Reductions of HFCs, PFCs and $SF_6$ in Europe*, on behalf of the European Commission, 25 April 2000.

102 J Harnisch and R Gluckman (2001), Final report on the European Climate Change Working Group Industry – Work Item Fluorinated Gases, Prepared on behalf of the European Commission, June 18 2001.

## Table 28 | IPCC emission factors (currently being updated)

| Technology type | Kilograms $CF_4$ per tonne of aluminium produced (production weighted average) |
|---|---|
| CWPB | 0.31 |
| PFPB | |
| SWPB | 1.7 |
| VSS | 0.61 |
| HSS | 0.6 |

Source: IPPC (2000), Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories.

## Table 29 | Primary aluminium smelters in the EU25

| Country | Site | Owner | Technology 1998 | Production 1998 (kt/yr) | Technology 2005 | Capacity 2005 (kt/y) | Comments |
|---|---|---|---|---|---|---|---|
| France | Auzat | Alcan Primary | SWPB | 45 | | 0 | Closed |
| France | Graveline | Alcan Primary | PFPB | 220 | PFPB | 256 | |
| France | Lannemezan | Alcan Primary | SWPB | 45 | SWPB | 50 | Closing before 2008 |
| France | St. Jean | Alcan Primary | PFPB | 125 | PFPB | 137 | |
| Germany | Hamburg | HAW | PFPB | 120 | PFPB | 134 | Closing end 2005 |
| Germany | Voerde | Corus Aluminium | PFPB | 82 | PFPB | 90 | |
| Germany | Essen | Trimet | PFPB | 126 | PFPB | 157 | |
| Germany | Norf | Hydro Aluminium | PFPB | 213 | PFPB | 222 | |
| Germany | Stade | Hydro Aluminium | SWPB | 70 | SWPB | 70 | Closing end 2005 |
| Greece | St. Nicolas | Aluminium de Greece | PFPB | 146 | PFPB | 166 | |
| Hungary | Inota | Inota AlumiumKft | VSS | 34 | VSS | 35 | Closing end 2006 |
| Italy | Fusina | Alcoa Italy | PFPB | 43 | PFPB | 44 | |
| Italy | Porto Vesme | Alcoa Italy | PFPB | 145 | PFPB | 153 | |
| Netherlands | Delfzijl | Corus Aluminium | PFPB | 93 | PFPB | 110 | |
| Netherlands | Vlissingen | Alcan Primary | SWPB | 175 | PFPB | 224 | |
| Poland | Konin | Impex Metal | VSS | 53 | VSS | 55 | |
| Slovakia | Ziar | Slovalco | PFPB | 117 | PFPB | 155 | |
| Slovenia | Kidriãevo | Talum Kidricevo | SWPB/ PFPB | 32/39 | PFPB | 117 | |
| Spain | La Coruna | Alcoa Spain | VSS | 82 | VSS | 89 | Upgrade to PFVSS started |
| Spain | San Ciprian | Alcoa Spain | PFPB/ SWPB | 30/166 | PFPB | 220 | |
| Spain | Aviles | Alcoa Spain | VSS | 82 | VSS | 86 | Upgrade to PFVSS started |
| Sweden | Sundsvall | Glencore | VSS/ PFPB | 71/25 | VSS/PFPB | 75/22 | |
| UK | Holyhead | Anglesey Alu | PFPB | 135 | PFPB | 145 | |
| UK | Kinlochleven | British Alcan | VSS | 8 | | 0 | Closed |
| UK | Fort William | Alcan Primary | PFPB | 38 | PFPB | 40 | |
| UK | Lynemouth | Alcan Primary | PFPB | 82 | PFPB | 170 | |

Source: European Aluminium Association (2005).

## Table 30 | Emissions of PFCs in the EU25 for Member States in 2002

| Country | Site | Total emissions ($Kt\ CO_2\ eq$)[103] | Plant emissions (t PFCs)[104] |
|---|---|---|---|
| Netherlands | Delfzijl | 1,249 | NR |
| | Vlissingen | | NR |
| France | Graveline | 973 | NR |
| | Lannemezan | | 84.7 |
| | St. Jean | | 12.6 |
| Germany | Hamburg | 431 | 6.9 |
| | Voerde | | NR |
| | Essen | | NR |
| | Norf | | 9.9 |
| | Stade | | 18.1 |
| Sweden | Sundsvall | 283 | 38.3 |
| Poland | Konin | 266 | – |
| UK | Holyhead | 209 | 1.4 |
| | Fort William | | 0.7 |
| | Lynemouth | | 6.8 |
| Hungary | Inota | 202 | – |
| Italy | Fusina | 199 | 7.8 |
| | Porto Vesme | | 26.5 |
| Spain | La Coruna | 199 | 10.1 |
| | San Ciprian | | 8.1 |
| | Aviles | | 9.8 |
| Slovenia | Kidriãevo | 116 | – |
| Greece | St. Nicolas | 88 | 11.9 |
| Slovakia | Ziar | 11 | – |
| Total | | 4,226 | – |

103 Reporting under UNFCCC for 2002 (submitted in 2005).

104 EPER reporting of 2001 estimates. NR signifies 'not reported' while a dash indicates not included under 2001 EPER submission.

## IPCC guidance on approaches to emission estimation

The IPCC recommends three different tiers of method for estimation of PFC emissions from primary aluminium smelters:[105]

### Tier 3a

**Continuous emission monitoring** is considered to be the most accurate means of determining emissions under IPCC guidelines. However, due to associated costs of this methodology, its implementation is not considered necessary for good practice. There is associated guidance on direct measurement techniques for PFCs in the IPCC guidance document, and in a protocol funded by the US EPA[106].

### Tier 3b

**Smelter-specific relationship between emissions and operating parameters based on field measurements** uses actual emissions measurements to establish a smelter-specific relationship between operating parameters and emissions. Operating parameters include frequency and duration of anode effects or Anode Effect Overvoltage. Two types of estimation process can be used:

- A slope method, whereby the linear relationship between anode effects and measurements is established
- Overvoltage method, which is a measurement of extra cell voltage due to anode effects.

### Tier 2

**Smelter-specific relationship between emissions and operating parameters based on default technology-based slope and overvoltage coefficients** which is the same method as for Tier 3b except that default coefficients are used rather than smelter-specific ones. Smelter-specific information used will include information on the duration/frequency of anode effects and production levels – but not the relationship to emissions (which will be based on default factors).

### Tier 1

**Production-based emission factors** method uses default emission factors applied to production statistics.

105 New guidance is currently being drafted by the IPCC for publication in 2006.

106 J Marks, R Kantamaneni, D Pape and S Rand (2003), *Protocol for Measurement of Tetrafluoromethane and Hexafluoroethane from Primary Aluminium Production*, Published in Light Metals 2003. Funded by US EPA Climate Protection Partnerships Division. (Published in greater detail in May 2003 by US EPA and IAI as document EPA 43-R-03-006).

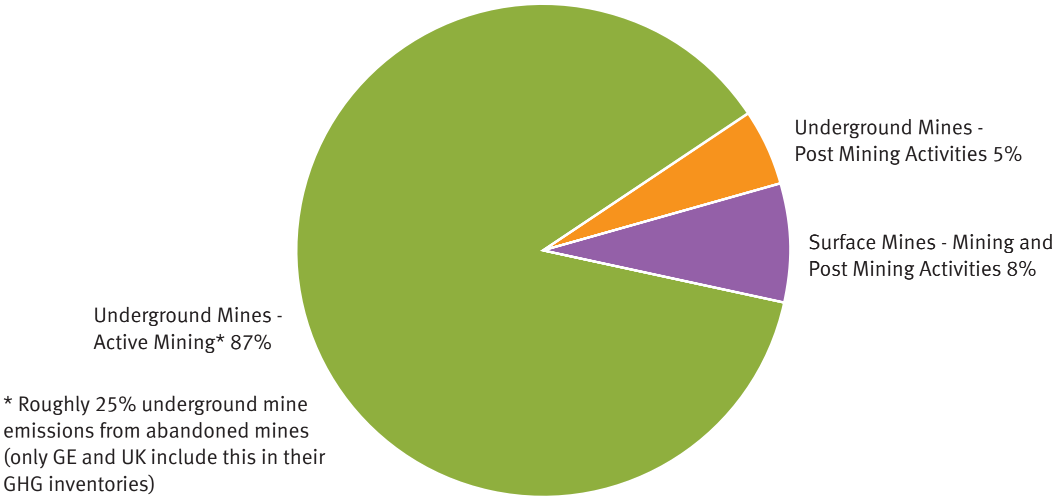
# Annex E

## Coal-mine methane

### Share of emissions from mining sub-sectors

About 25 per cent of emissions from underground mines are from abandoned mines though many Member States do not include them in their greenhouse gas inventories. Our initial recommendation for coal-mine methane is to only include active mine methane emissions at the start of Phase III and leave out abandoned mine methane as emissions are subject to very high uncertainty, data is not available on a mine-by-mine basis and there is a question over abandoned mine ownership. Based on the success of inclusion of methane from active mines in Phase III this recommendation could be reviewed. Surface mines are excluded from the EU ETS as they are responsible for a small proportion of total emissions and it is not possible to effectively recover the methane.

**Figure 4 | Emissions from underground mines, surface mines, post mining activities and the approximate proportion from abandoned underground mines**




### Industry structure

Table 31 summarises the industry structure for the underground coal mining sectors in the UK, Germany, Poland and the Czech Republic. Poland has the largest number of mines and would see the largest impact on transaction costs across its mining sector. Most countries have planned to shrink their coal production by closing unprofitable mines. Germany and Poland have high levels of state subsidy, whereas the UK and Czech Republic have privatised the industry and have little or no state subsidy. The proportion of methane emissions recovered from active mines is fairly similar across Member States, if the values reported in the inventory are correct – data is not available to verify this and countries such as Germany may actually have higher levels of recover. As only about 30 per cent of methane is recovered, there is significant potential for further abatement.

**Table 31 | Industry structure for the four countries with the largest methane emissions from active underground mines**

| 2003 data | UK | Germany | Poland | Czech Rep |
|---|---|---|---|---|
| Hard coal production from underground mines | 17 Mt | 26 Mt | 103 Mt | 14 Mt |
| Number of active mines (GHG Inventory 2005) | Eight large active underground mines. | 10 underground hard coal mines[107]. | 33[108]. | 3 mines |
| Future plans | Two mines to be mothballed. UK COAL have coal resources in 3+ mines operate to 2020 if economic conditions viable. | Reduce production from 26 million tonnes in 2005 to 16 million tonnes in 2012[109]. | New restructuring and rationalisation program about to be announced. Poland predicts output around 80–100Mt coal per year for the next decade. | |
| Coal production per mine | 2–3Mt | 2–3Mt | 2–4Mt | 4–5 Mt |
| Methane emitted per tonne coal (kg/t underground mines) | 12.3 overall<br><br>Deep mine 9.1. | 12.0 | 4.8 | 12.3 |
| Net methane emissions from active U/G mines (kt) | 204 | 310 | 489 | 167 |
| Average methane emissions per mine (kt) – *rough estimate* | 17[110] | 31 | 15 | 56 |
| % mine methane currently utilised/flared | 25% | 35% | 33% | 32% |
| Abandoned mines covered in GHG inventory? | Yes | Yes | No (TBC) | No (TBC) |

107 Chris McGlen, UK COAL, Personal Communication, November 2005.

108 Jan Kwarcinski, Poland's State Geological Institute, Personal Communication, November 2005.

109 Megtec Systems www.megtec.com

110 Chris McGlen, UK COAL, Personal Communication, November 2005.

**Table 31 | Industry structure for the four countries with the largest methane emissions from active underground mines** (continued)

| 2003 data | UK | Germany | Poland | Czech Rep |
|---|---|---|---|---|
| Annual methane emissions from abandoned mines (kt) | 53.6 (emissions almost halved from 1993–2003). | 87 | Not given | Not given |
| % of CMM from abandoned mine | 26% | 28% | Not given | Not given |
| Other measures addressing CMM | UK ETS. Methane to markets technology co-operation initiative. | Feed-in tariffs. | Exemption from excise tax on electricity production from hard coalbed methane. | |
| Industry structure | Operates without significant state support. Seven mines owned by UK COAL and one mine owned by Tower Collieries. | Heavily subsidised by state support. Plans for sector reduction from 26 Mt coal produced in 2005 to 16 Mt in 2012[111]. | Subsidised by the state. Significant decline in hard coal mining over the last ten years. | Operates without significant state support. OKD is major hard coal producer, along with OMD[112]. |
| Methane abatement | See methane to markets study. | Some methane is suctioned off directly from seams and ancillary rocks and used, primarily as pit gas. | 18 out of 33 mines with methane drainage and recovery systems. | Two out of three mines with methane drainage and recovery systems. |

Source: 2003 data, reported in 2005 in the CRF tables submitted to the UNFCCC. www./unfccc.int/national_reports

111 Megtec Systems www.megtec.com

112 Brian Ricketts, Energy Analyst – Coal, IEA, Personal Communication, November 2005

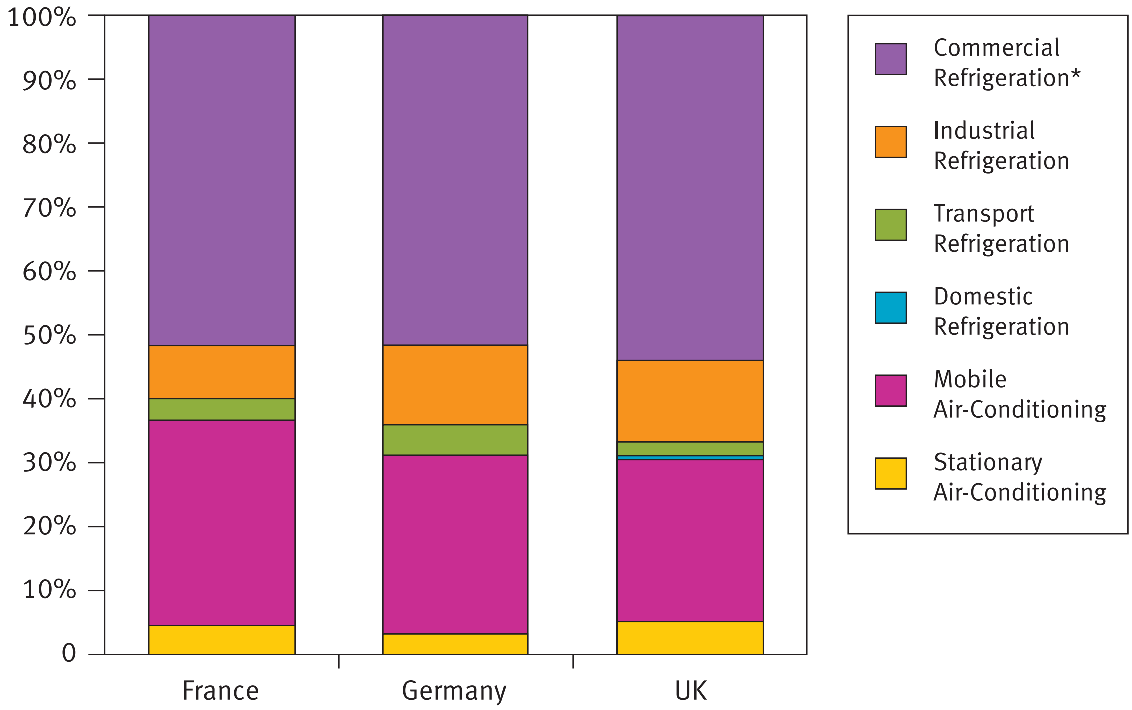
# Annex F

## Refrigeration (HFCs and PFCs)

### Distribution of emissions across the sector

The share of HFC and PFC emissions from the refrigeration and air-conditioning sectors is shown in the chart below for France, Germany and the UK. These three Member States account for 62 per cent of the EU15 emissions from this sector.

Figure 5 | **Share of F-gas emissions by refrigeration and air conditioning sub-sector**




### Number of plants

In efforts to establish an estimate of refrigeration installations across Europe, project partners were contacted for information. Unfortunately as already noted, there is a lack of information in many countries concerning the size of the refrigeration market and so no firm data on the number of refrigeration installations by Member State was obtained, except for the UK which is shown below. The hundreds of thousands of refrigeration systems in place in the UK demonstrate the vast administrative challenge that would be faced if the sector were to be included in the EU ETS.

## Table 32 | Estimate of UK stock of refrigerant equipment

| Equipment type | 2004 UK stock |
|---|---|
| Packaged liquid chillers (process cooling) | 20,000 |
| Integral retail display cabinets | 586,766 |
| Remote retail display cabinets | 227,240 |
| Commercial service cabinets | 422,219 |
| Cellar cooling equipment | 81,931 |
| Ice-making machines | 127,664 |
| Walk-in cold rooms | 197,068 |
| Refrigerated vending machines | 45,000 |
| Miscellaneous | 100,000 |
| **Totals for refrigeration** | **1,807,888** |

Source: MTP (2005). Personal comm UK Market Transformation Programme.

## Alternative approaches

As the structure of the refrigeration sector is not suitable for inclusion in the EU ETS, it was deemed important to examine other approaches to reduce F-gas emissions. The proposed F-gas regulation will play a major role in reducing refrigerant leakage and this is addressed in the main report.

Austria, Denmark and Luxembourg have all implemented legislation to phase out F-gases. The UK, France, Germany and Italy have not announced major changes to their F-gas policies in the last couple of years, though limited updated information is available and is included below. A key source for some of the policies below is the Enviros report *Assessment of the costs & implication on emissions of potential regulatory frameworks for reducing emissions of HFCs, PFCs & $SF_6$*, (Enviros 2003) though this has been updated wherever possible. The countries covered below are either major emitters of HFCs from refrigeration or Member States which have taken a strong alternative policy approach to F-gas reductions.

## Other measures to address refrigeration and F-gas emissions in the EU

**Austria** Austria has a general ban on HFCs to be implemented in 2008. The Austrian Ordinance came into force in 2002 and applies to HFCs, PFCs and $SF_6$. F-gas use in refrigeration systems, foams, aerosols and other projects is banned for HFCs and PFCs, with specific deadlines varying between 2003 and 2008. A ban on $SF_6$ use in magnesium production and filling of tyres was put in place in 2003[113].

**Denmark's F-gas ban** Denmark's F-gas legislation order stipulates a ban on the import, sale and use of new products containing hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphurhexafluoride ($SF_6$), after 1 January 2006. Some exemptions are made but the ban applies to both new and recovered F-gases[114].

While the general ban date is 2006 for F-gas use in new products and equipment, some phase-outs will be earlier and others later. For large coolers, for example, the deadline will be 2007. Some applications, such as air conditioning in cars, are excluded altogether.

A blanket ban on PFCs in new products was in place from 2002, with the ban for $SF_6$ use in products coming into force in 2003. The sale and use of new products containing HFCs is to be banned in 2007 for refrigeration plant, heat pumps, air conditioning plant and dehumidifiers with charges at or above 10kg.

The majority of F-gases for industrial use are not covered by the ban, where 'industrial use' is defined as use of the specified gas in the production of a product in which the greenhouse gas is not present in the final product. However, certain industrial uses are still covered by the ban including $SF_6$ use in metal foundries and refrigerants containing PFCs and polyeurethane foam production.

**Denmark's F-gas tax** The Danish tax on industrial greenhouse gases HFCs, PFCs and $SF_6$ entered into force in 2001[115]. The amount of the tax is based on the various substances' global warming potential. The tax amounts to about €40 per kg of the net weight of the gas. The maximum tax of this magnitude was considered necessary to reduce unnecessary use of certain F-gases and to encourage installation of the currently more expensive refrigeration plant based on natural refrigerants. If a mixture is comprised of several F-gases, the tax is calculated as the sum of the taxes on each individual substance. The individual taxes were revised slightly in 2004 to incorporate the new GWP from the UNFCCC report. Since 1950 Denmark has had a minimum requirement for education authorisation and control for people working with refrigerants.

113 F-gases in Austria, Electronic Industries Alliance Regulatory Tracking Tool, 2004. www.eiatrack.org/s/1303&kw=

114 Ministry of the Environment, Danish Environmental Protection Agency, translation LK August 2002. Statutory Order no. 552 of 2 July 2002 Regulating Certain Industrial Greenhouse Gases. In pursuance of sections 30, 45(1), 59(4), and 60 of Act on Chemical Substances and Products, cf. Consolidated Act no. 21 of January 16, 1996, as last amended by Act no. 424 of June 10, 1997, and Act no. 256 of April 12, 2000.

115 Text translated by David Barry, November 2000. Act No. 49 (as put before Parliament): Bill proposing an Act amending the Act on taxes on certain chlorofluorocarbons and halons (CFC tax). Tax on the Industrial Greenhouse Gases HFCs, PFCs and $SF_6$. Put before Parliament on 11 October 2000 by the Minister for Taxation.

**France** Two regulations have been in place since 1992 for refrigeration equipment containing over 2kg of refrigerant. The first concerning the qualifications necessary to handle fluids – personnel are registered by local authorities – and the second governing the recovery and handling of equipment. In 1998 a health and safety regulation was introduced including minimum requirements for equipment and an annual obligation to detect leakages and repair any that are found. A new national programme was approved in 2000, intended to be active by the end of 2002. This contains two levels of regulations, one which extends regulations to all amounts of refrigeration fluid charge (with more detailed requirements for systems over 3kg) and one concerning qualifications, control, leakages and recovery in mobile air-conditioning. It also includes measures to forbid the sale of fluids to those without minimum qualifications[116].

**Germany** A regulation from 1991, dealing with halons and CFCs (Article 8), prohibits the escape of these gases during operation, maintenance or at end of life and includes obligations for recovery and specifies relevant expertise and technical equipment for those handling gases. The German Federal Ministry for Economy and Technology and the Federal Ministry for Environment discussed a proposal at the end of 2002, which is likely to amend existing regulations to include HFCs and also the possibility of further adapting regulations to include PFCs and $SF_6$. Some technical requirements may also be included plus further regulations on the competence of personnel. Problems with this previous article have been that the Federal Landau does not have the personnel to control its implementation, plus the regulations are unclear on requirements for owners of equipment[117].

**Italy** In their submission to the greenhouse gas monitoring mechanism 2005, Italy outlined an option for abatement of fluorinated gases which involves the reduction of HFC leaks from mobile air-conditioners, reduction of $SF_6$ leaks from electrical equipment, abatement devices and low GWP substances in the production of semi-conductors[118]. It is not yet approved as it is one of a suite of additional measures which the government may choose to implement if required.

**Luxembourg** Luxembourg was the first EU nation to prohibit the use of synthetic refrigerants[119].

**Netherlands** Since 1991 the STEK organisation has administrated the certification of refrigerant engineers, it also registers companies and equipment. Legislation, with specific penalties, was also introduced detailing maximum leakage rates, the use of certified installers, preventative maintenance measures, technical requirements (RLK) and use of logbooks to record any handling, this legislation is enforced by a government inspectorate[120].

Under STEK, HFC users and suppliers in the Netherlands are licensed and have to report on use and emissions, including leaks. Potential emissions reductions brought about by the STEK system are hard to identify with great clarity. The Institute for European Environmental Policy (IEEP) reported that more detailed study of STEK-sponsored research indicates that HFC leak rates could be double the reported figure of 4.8 per cent – depending on how the data are interpreted. Comparing end-user leakage data with sales figures from HFC distributors shows potential leak rates of anywhere

116 Enviros (2003). Assessment of the costs and implications for emissions of potential regulatory frameworks for reducing emissions of HFCs, PFCs & $SF_6$. EC002 5008.

117 Enviros (2003). Assessment of the costs and implications for emissions of potential regulatory frameworks for reducing emissions of HFCs, PFCs & $SF_6$. EC002 5008.

118 Policies and Measures Dossier, Italian Submission to the GHG Monitoring Mechanism 2005.

119 Nick Cox Personal Communication, Response to Chapter 6, Refrigerants, LETS Update Working Group B Interim Report. 14 December 2005.

120 Enviros (2003). Assessment of the costs and implications for emissions of potential regulatory frameworks for reducing emissions of HFCs, PFCs & $SF_6$. EC002 5008.

from 6.9 per cent to 12.7 per cent annually. The IEEP comment that, as was reported by STEK itself, there was likely to be a bias towards non-reporting of high emissions by companies worried about measures that they may face in future to reduce emissions; secondly, when looking at countries with very similar leakage reduction efforts, like Sweden, reported emissions rates are significantly higher[121].

**Sweden** Sweden allows a maximum of 200kg of HFC per site, which should enable Sweden to achieve its goal of stabilising F-gas emissions at 2000 levels by 2010. The Swedish EPA recommends additional measures for aluminium manufacture and stationary refrigeration and air-conditioning equipment which are not covered by EU regulations.[122]

**UK** In the UK Climate Change Programme (UKCCP), the Government set out the four key elements of its position on the future of HFCs:

- HFCs should only be used where other safe, technically feasible, cost-effective and more environmentally acceptable alternatives do not exist.
- HFCs are not sustainable in the long term – the Government believes that continued technological developments will mean that HFCs may eventually be able to be replaced in applications where they are used.
- HFC emission reduction strategies should not undermine commitments to phase out ozone-depleting substances under the Montreal Protocol.
- HFC emissions will not be allowed to rise unchecked.

The UK reaffirmed its views on 6 October 2004 when the Environment Minister announced stricter purchasing and estate management targets to ensure that government departments do not use HFCs where safe, cost-effective and feasible alternatives are available.

121 'Is STEK as Good as Reported? Uncertainties in the Concept Underlying the Proposed European Regulation on Fluorinated Gases', 14 June 2005, Institute for European Environmental Policy (IEEP).

122 Nick Cox Personal Communication, Response to Chapter 6, Refrigerants, 'LETS Update Working Group B Interim Report'. 14 December 2005.

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