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Costs and environmental effectiveness of options for reducing mercury emissions to air from small-scale combustion installations

Final report (Version 2)

AEA Technology / NILU-Polska

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Executive Summary

This study was initiated in response to Action 3 of the European Commission's Mercury Strategy (CEC 2005a) calling for further research into options to reduce mercury emission from small combustion installations. The Mercury Strategy has been developed to assess pathways of mercury into the environment, and means of controlling such releases, recognising the impacts mercury can have on human health and the environment in general.

A study on small combustion installations (SCIs) was specifically required, recognising SCIs as a significant, largely uncontrolled source of emissions. The key objectives were to:

- Assess the significance of SCIs as a source of mercury emissions now and in the future using an appropriate emission inventory and current energy use projections.
- Consider what options for the control of emissions are applicable to SCI's and which are the most cost-effective; options considered should include technical and preventative measures, and policy measures.
- Recommend cost effective actions that the Commission might take now to reduce mercury emission and research to facilitate future action.

Emission inventory

In the absence of a suitable emission inventory of mercury emissions from SCI sources, one was developed as part of this study. The primary purpose of developing an inventory was to identify the key sources on a country, sector, fuel, and technology basis, in order to provide a means for estimating mercury reduction potential. Due to the limited state of knowledge of mercury emissions (notably the lack of published emission factors and activity statistics), the resulting inventory, although providing comprehensive coverage across Europe, had a high relative uncertainty.

Inventory uncertainties were greatest regarding:

- Information on emission factors for biomass, as is data on consumption of biomass fuels.
- Understanding of mercury speciation, due to the number of different factors that affect the emission profile of SCIs, these include fuel type, other trace compounds in fuels, and appliance type.
- SCI industry fuel consumption, this is poorly reported internationally,
- Projections of solid fuel use in future years, due to uncertainty around switching to other fuels. A key factor is fuel prices and the future ability of populations to switch to other fuels.

Despite these uncertainties, the emission inventory compiled provides an adequate starting point for the investigation mercury emissions from SCI sources, and it provides a suitable basis for a cost-effectiveness analysis. The inventory estimates that SCI sources account for 16% of total European emissions. This compares to an estimation of 25% in earlier studies. Regardless of this difference and the apparently high level of uncertainty within the inventory, mercury emissions from SCIs remain a large component of the EU inventory, and a source for which controls may be available.

Emissions are highest in those countries that use a significant amount of coal, such as Poland and Germany. Countries that have high natural gas use or biomass use tend to have much lower emissions. The industry sector is the most significant of the SCI sectors in Europe, and in most countries. Projected emissions are estimated to be much lower in

future years – 2010 and 2020, driven by the large anticipated decreases in coal use in SCI sources. However, the assumption that coal use will decrease to such an extent in future year is problematic, given the issue of increasing gas and oil prices. National projections appear to be more cautious than the PRIMES-based projections used in this analysis, suggesting higher levels of coal use in future years.

Abatement options and policy measures

The emission inventory enabled:

a) The determination of the emission reduction potential of SCI sources by reviewing available abatement options and
b) A consideration of policy measures for the implementation of abatement options.

Abatement options (both technical and preventative) were reviewed, and assessed on the basis of cost-effectiveness. The most cost-effective options were preventative options (e.g. options prior to combustion to minimize emission) such as coal washing and fuel switching. Such options either require the use of a better quality, 'cleaner' fuel within the same fuel type, or the switching to an alternative fuel with lower emissions. Another preventative option highlighted was reduction in energy consumption through energy efficiency, leading to lower mercury emissions. This type of option was considered to be at no additional cost given that its introduction would not be based on action to reduce mercury emissions.

Limited technical abatement options (e.g. removal of mercury from flue gases after combustion) were identified specifically for SCIs, and those that were tended to be via abatement equipment that would normally be implemented for other pollutants, and which would have only indirect benefits for mercury emission reduction. In addition, as highlighted in the CAFE SCI study, few technical options exist for smaller installations (< 1 MW). Some R&D projects are being developed for smaller installations; a key recommendation from this study is to further promote and develop such R&D activities into specific abatement technologies applicable to smaller SCIs.

The review of policy measures suggests that there are no European wide policy measures that specifically address mercury emissions from SCI sources. The main existing policy measure concerned with reducing mercury concentrations in air is the Fourth Daughter Directive under the Air Quality Framework Directive, this has set ambient monitoring requirements for mercury but no air quality target limit. There are a number of other measures that could also lead to further mercury emission reductions:

- Revision of the IPPC / LCP Directives, resulting in the inclusion of a larger number of sub-50 MW plant
- Policy measures targeting energy efficiency, such as the Energy Performance of Buildings Directive (EPBD)
- Indirect benefits (reductions) through measures such as the EU ETS, or through the implementation of the Energy Using Products Directive (EuPD)

This review has also highlighted the types of national based measures that have been undertaken that may also have a role in reducing emissions of mercury, such as industrial regulation of sub-50 MW installations and measures relating to fuel quality.

Scenario analysis of options

To assess abatement options within a policy framework, we undertook an analysis to consider the reduction potential and costs associated with different policy scenarios. Scenarios considered included a baseline 'business as usual' scenario, a scenario (1) that determined the mercury emission reductions that might be anticipated from other air quality policies, specifically those considered under the Thematic Strategy on Air

Pollution, and finally a scenario (2) that assessed policy measures and abatement options targeted to meeting an overall mercury emissions reduction target.

The business-as-usual (BAU) scenario reflected the reductions in emissions forecast in the emission inventory, a total reduction of 50% of mercury emissions is estimated by 2020, based on the PRIMES assumptions about future coal use in the SCI sectors. The BAU scenario should be considered a 'best case' vis a vis the emissions forecasts by individual Member States, and given the uncertainty of future fuel prices, which could have significant impacts on demand.

The benefits resulting from scenario 1 were significant, a 26% maximum reduction relative to the baseline. This was based on further implementation of the EPBD (energy efficiency requirements across the residential sector building stock, not only the commercial sector) and inclusion of a significant number of sub-50 MW plant under an IPPC regime. Our analysis did not account for national action and therefore might over-estimate the reduction potential of these EU-wide measures. This analysis is somewhat speculative given that we do not know whether such proposals would be implemented; however, it does provide an indication of the potential mercury emission reduction benefits of measures targeted for different pollutants / policy areas.

We have assumed that this reduction is achieved at zero additional cost since the measures would be implemented primarily to control other pollutants. The analysis under this scenario does not include other indirect benefits that may have arisen from the cost-benefit analysis underpinning the Thematic Strategy. Such an analysis was considered but not undertaken due to limited data availability and resource constraints.

Under scenario 2, an emissions ceiling approach was simulated for the SCI source sector, based on achieving a 40% reduction in emissions (more than 4.7 t/a relative to the baseline); a cost curve analysis was then undertaken to consider how such a reduction might be met. Coal washing was found to be the most cost effective measure for achieving the required reduction but other measures in the mix of options included additional energy efficiency measures, fuel switching and some technical abatement options. The total cost of such a strategy was estimated to be around €110 million.

The policy options to implement the 40% reduction envisaged in Scenario 2 in are limited; an emissions ceiling approach would be problematic given the inventory uncertainties and the absence of a target value in the 4th Daughter Directive removes a potential driver for bringing about reductions. Consequently we suggest that the Commission considers policy measures that focus on regulating fuel quality. Improved emission characteristics for coal-based fuels may be achieved via fuel quality standards, that might be met by coal washing for example, or by restricting the use of certain types of coal products.

Based on the above analysis, and the preceding report sections, a number of recommendations were made.

Recommendations

Three sets of recommendations are made:

Recommendations applicable to all scenarios, irrespective of whether action is taken beyond that envisaged under the Baseline 'Business as Usual' scenario.

1. The UNECE LRTAP should be requested to amend the Guidelines for Estimating and Reporting Emission Data to include emissions from combustion units less than 50 MW. (N.B. The present EMEP / CORINAIR Inventory Reporting Guidelines

are due for review and revision by 2007 at the latest). The improved reporting would ideally allow the differentiation of fuel use statistics to distinguish coal and biomass.

2. Additional research should be undertaken to enable countries to report to the level of detail required in Recommendation 1 above. This would require the development of default emission factors for the newly proposed reporting categories and the development of speciation profiles.
3. Given that the performance of abatement options will depend on the chemical form of mercury to be captured and since there is at present no standardised method for the measurement of speciated mercury emissions (only total mercury emissions) it is recommended that a suitable standard method be developed.
4. Study is made available to the EMEP / EIONET Task Force on emission inventories and projections as a contribution to the improvement of currently available information on the emissions of mercury from SCI.

<u>Recommendations following from the scenario 1 and 2 analysis</u> e.g. action beyond that envisaged under the Baseline in scenarios 1 and 2.

5. Where appropriate, extant legal instruments regulating industrial emissions should be extended to cover industrial SCIs; opportunities may include reducing the reporting threshold of the IPPC Directive.
6. The benefits of reduced mercury emissions should be included when pollution abatement strategies are being considered for PM, SO_2, and NOx e.g. in the Thematic Strategy on Air Pollution.
7. Synergies with other initiatives, such as the Urban Thematic Strategy, should also be identified and developed.
8. Further consideration should be given to the potential role of 4th Daughter Directive for reducing mercury emissions in localities where they are significant. Mercury has no stipulated limit level under the Directive but there is an obligation on Member States to monitor and report ambient concentrations of mercury.

<u>Recommendations following from the scenario 2 analysis</u> e.g. action under scenario 2

10. Work should be undertaken to develop fuel quality standards for coal-based fuels that reflect the mercury reduction benefits that may be achieved via coal washing.
11. Further research needs to be carried out into the exchange of information on SCI abatement measures and the development of abatement techniques for the reduction of emissions from SCI’s, particularly those in the non-industrial sector.
12. Given the significant uncertainties identified by this study further work is needed to refine the cost curve used in scenario 2. It is recommended that where appropriate this work be integrated with ongoing research in this area (e.g. ESPREME).

Acknowledgements

The study team gratefully acknowledges the contribution of data from the EU funded ESPREME and MERCYMS projects. The following websites provide further information on these projects:

MERCYMS - http://www.cs.iia.cnr.it/MERCYMS/project.htm
ESPREME - http://espreme.ier.uni-stuttgart.de/

List of abbreviations

BAT	Best Available techniques
BREF	BAT references notes, used for operator / regulator guidance under IPPC
CAFE	Clean Air For Europe (programme)
CLRTAP	Convention on Long Range Transboundary Air Pollution
EMEP	Co-operative Programme for Monitoring and Evaluation of the Long-range Transmission of Air pollutants in Europe (under the CLRTAP)
EPBD	Energy Performance of Buildings Directive
EPER	European Pollutant Emission Register
ESP	Electro-static precipitator
ESPREME	Estimation of willingness-to-pay to reduce risks of exposure to heavy metals and cost-benefit analysis for reducing heavy metals occurrence in Europe (EC project under the 6th Framework Programme)
EU ETS	European Union Emissions Trading Scheme
EuPD	Energy Using Products Directive
FF	Fabric Filter
FGD	Flue gas desulphurisation
IPPC	Integrated Pollution Prevention and Control
MERCYMS	An integrated approach to assess the mercury cycle into the Mediterranean basin (EC project under the 5th Framework Programme)
PAC	Powdered Activated Carbon
RAINS	Regional Air Pollution Information and Simulation model
SCIs	Small Combustion Installations
TFEIP	Task Force on Emission Inventories and Projections (under the UNECE)
UNECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change
USEPA	United States Environmental Protection Agency

Country codes

There is scope for confusion in the national abbreviations as the following examples show: DE stands for Germany, not Denmark; ES stands for Spain, not Estonia; PL stands for Poland, not Portugal; SL stands for Slovenia and not Slovakia.

AT	Austria	HU	Hungary
BE	Belgium	IE	Ireland
BG	Bulgaria	IT	Italy
CH	Switzerland	LT	Lithuania
CZ	Czech Republic	LU	Luxembourg
DE	Germany	LV	Latvia
DK	Denmark	NL	The Netherlands
EE	Estonia	NO	Norway
ES	Spain	PL	Poland
FI	Finland	PT	Portugal
FR	France	RO	Romania
GB	Great Britain and Northern Ireland (otherwise referred to as the UK)	SE	Sweden
		SK	Slovakia
GR	Greece	SL	Slovenia

Contents

1 Introduction

This report is the final report under the *Service Contract on the cost and environmental effectiveness of reducing mercury emissions to air for small-scale combustion installations (EC ref. 070501/2004/393077/MAR/G2)*.

The primary objectives of this study were to develop emission estimates of mercury emissions from small combustion installations (SCI) across Europe, and to consider options for reducing emissions from these sources. The driver for this work was the formulation of a European Mercury Strategy, the scoping of which has identified SCIs as a significant source of mercury emissions. In addition, similar research has been completed under the Clean Air For Europe (CAFE) Programme, undertaken to formulate the Thematic Strategy on Air Pollution. This study provides a significant amount of the information for the basis of the analysis undertaken in this study.

The report structure is based on the following tasks:
- Compilation of an emissions inventory of mercury from SCI sources
- Assessment of abatement options and policy mechanisms for reducing emissions of mercury
- Cost-effective analysis of the above options, based on a set of scenarios
- Proposal of recommendations based on the study conclusions

The study conclusions and recommendations are intended to assist the Commission to formulate policy actions to address mercury emissions from SCIs.

2 Policy context

A Mercury Strategy has been proposed by the European Commission in response to an invitation by the Council to present '*a coherent strategy …with measures to protect human health and the environment from the release of mercury based on a life-cycle approach, taking into account production, use, waste treatment and emissions*'. The need for this strategy is that mercury and its compounds are toxic to humans, ecosystems and wildlife, and therefore their release into the environment is problematic.

Through work to develop the Mercury Strategy, small-scale installations (<50 MWth), or SCIs, have been identified as a significant source-pathway for mercury pollution, particularly those that use coal. Such conclusions are primarily based on Pacyna (2003), where mercury emissions from SCIs (burning coal) in the EU27 are estimated to account for approximately 25% of total EU emissions. An action has therefore been proposed in the Communication document COM (2005) 20 final 'Community Strategy concerning Mercury' to look at options for reducing mercury emissions from this source. Under Action 3 of the Strategy '*the Commission will undertake a study in 2005 of the options to abate mercury emissions from small scale coal combustion, to be considered alongside the broader CAFE assessment*'. The opportunity to undertake such a study was further enhanced by work already being undertaken within the CAFE programme.

There are six key objectives set out in the Mercury Strategy:

- Reducing mercury emissions;
- Reducing the entry into circulation of mercury in society by cutting supply and demand;
- Resolving the long-term fate of mercury surpluses and societal reservoirs (in products still in use or in storage);
- Protecting against mercury exposure;
- Improving understanding of the mercury problem and it solutions;
- Supporting and promoting international action on mercury.

This study is mainly in support of the first objective, with SCIs identified as a significant source sector. However, it also supports the last two objectives, (i) by helping to improve understanding of the problem of mercury emissions, and the potential solutions, through examining potential abatement options, and (ii) through consideration of international action, such as inventory development (under the CLRTAP) or policy responses through the Commission.

3 Study objectives

The overall objective of this study is to consider options for the reduction of mercury emissions from SCIs in view of the significance of these emissions, as categorised by country, sector, fuel or installation type.

Specifically, three specific study objectives have been formulated in view of this overall objective, namely:

1. ***Development of a Europe-wide emission inventory*** of mercury from SCI sources that provides adequate information to enable (a) consideration of the significance of SCI sources in Europe, (b) cost-effective analysis of abatement options and (c) consideration of appropriate policy responses.
2. ***Review and assessment of abatement options***, and their cost-effectiveness, in order to provide policy makers with the necessary information to enable the formulation of proportionate policy responses.
3. ***Proposal of recommendations for reducing mercury emissions*** in view of the objectives set out in the Mercury Strategy, and with consideration for other air quality based initiatives.

In addressing these objectives, we have structured the report as follows: Section 4 describes our approach to developing an emission inventory under objective 1. Sections 5 and 6 cover objective 2, providing information on abatement options for the reduction of mercury emissions and the policy mechanisms for introducing such abatement options. Cost-effectiveness analysis of potential options, to help develop recommendations, is described in section 7. Conclusions and recommendations are outlined in section 8. The report appendices provide additional detailed information relevant to the analysis in the main body of the report.

4 Developing estimates of mercury emissions from SCI sources

An emission inventory is fundamentally important to identify the amount of mercury emission from SCI sources, and what the key SCI sources of mercury are, on the basis of country, fuel type, installation type or sector. Without such information, it is not clear whether further action is necessary, and if deemed to be, which sources to specifically target.

No fit-for-purpose inventory currently exists that provides the necessary information at the European level on SCI sources, to enable an assessment of the problem of mercury emissions from SCIs, and the cost-effectiveness of potential abatement options. Therefore, an emissions inventory has been developed, using information from a range of different European inventory sources. This section of the report outlines our approach to the compilation of the SCI mercury inventory.

4.1 SCOPE OF THE INVENTORY

To meet the needs of the study, the scope of the inventory was defined as follows:

- All installations below 50 MWth (using a 4 sector categorisation - residential, industrial, commercial-institutional, and agriculture).[1]
- Timescale of 2000 to 2020 (NB. 2030 is not included due to lack of available projections data).
- Geographical scope of EU25, plus Switzerland, Norway, Bulgaria and Romania. Turkey has also been included in the scope of this study.
- Fuel-technology breakdown of estimates based on RAINS technology database
- Speciation of mercury emissions

This scope was proposed in order to enable a sufficiently detailed assessment of options for the reduction of mercury emissions from SCIs. The methodology to construct this inventory is similar to the approach used in the CAFE SCI study (AEA Technology 2004) and is presented in greater detail below.

The geographical scope of the inventory does not include Balkans countries - some of which may be future EU candidate countries and are significant solid fuel users. Nevertheless, limited resource was given to developing estimates; however, due to the absence of easily accessible data, it was not possible to derive emissions estimates.

Waste incineration has not been included in the scope of this study, as such installations are covered under the Waste Incineration Directive. Under this Directive, limits are specified for emissions of mercury.

4.2 APPROACH TO INVENTORY COMPILATION

Our approach to inventory compilation is described below, and split into the following sections:

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[1] 'Residential' includes all private households, whether they be single house dwelling or blocks of flat; 'Commercial-institutional' includes public buildings (hospitals, schools, libraries etc) while commercial is predominantly retails outlets. 'Agriculture' includes farm buildings and horticultural facilities. These three sectors will primarily use combustion appliances for space heating and hot water. 'Industry' includes many different industrial sectors, burning fuel for different processes, in addition to space heating.

- Development of **historic** emission inventory estimates for 2002, providing the baseline year on which to base projected estimates;
- **Projected** emission inventory estimates, for 2010 and 2020;
- **Speciation** profiles for mercury emission sources.

A stakeholder consultation process was also undertaken as part of this study, to ensure that the inventory reflected country-based knowledge concerning mercury emissions from SCIs. This is described at the end of this section.

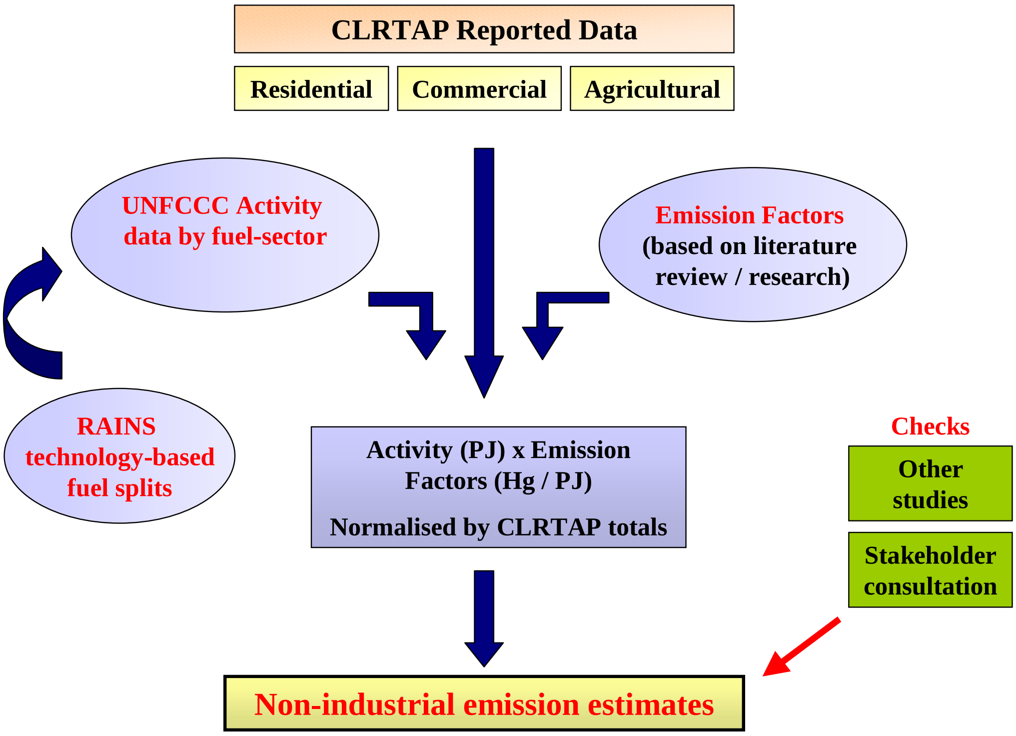
4.2.1 Historic inventory estimates

Inventory estimates were compiled for year 2002, using separate approaches for non-industrial and industrial sectors. Separate approaches were adopted due to the differing availability and resolution of the input data for these sectors.

Non-industrial estimates

Mercury emission estimates for non-industrial SCI sources (defined as installations in the commercial-institutional, residential and agricultural sectors) were derived through a process of disaggregating country reported totals, using a range of different datasets, as illustrated in Figure 4.1, and described below.

Figure 4.1 Basic approach to developing non-industrial SCI emission inventory



NB. All activity and emissions data used to compile the above inventory are based on inventory year 2002.

- Nationally reported data to the UNECE (under CLRTAP)[2] provided the official national reported data for this inventory – for residential, commercial-institutional and agricultural sectors. All of the disaggregated estimates within this inventory were normalised to these reported data. We considered it important to be consistent with official estimates where they were available; however, such estimates were not used in this inventory without further checking (through stakeholder consultation) to better understand how they were derived.
- These reported data were further disaggregated through the use of data from the following sources – (1) UNFCCC reported fuel use, and (2) RAINS technology database, which provide the activity data, and (3) literature review and research into emission factors.
- UNFCCC sourced fuel use data provided the breakdown by fuel type for the non-industrial sectors, into solid, gaseous, liquid and biomass fuels. This fuel split was further disaggregated into technology-specific sectors through the use of the RAINS technology database.[3]
- Emission factors were crucial in the inventory to be able to convert the above activity data into emission estimates (which were normalised to the CLRTAP estimates). They were identified via literature review and research, and compiled for specific fuel-technology sectors. This was the most significant task in compiling this inventory.
- Estimates were made for the different non-industrial sectors based on the activity values and emission factors. These estimates were normalised to sector total estimates reported by countries to the UNECE under CLRTAP.
- Iterative verification was undertaken with experts in the Member States via a questionnaire-based consultation.

Nationally reported emission totals for non-industrial sectors - 1A4a (commercial), 1A4bi (residential plant) and 1A4ci (stationary agriculture) - have been used as the basis for sector estimates. These national data were downloaded from WEBDAB,[4] and reviewed to assess where there were data gaps.

Reported data for year 2002 were used to ensure consistency with the fuel consumption data used, with data estimates from other studies e.g. Pacyna (2003), and because they were considered to be the most reliable, accurate and complete. Where data gaps exist for specific sectors within country submissions, they were 'gap-filled' on the basis of other available data. For example, in a given country, there may be 2002 estimates for residential and commercial sectors but not agriculture. However, in 2001, if data exists for all sectors, an estimate of agriculture emissions in 2002 can be estimated based on the proportion of emissions the agriculture sector represented in 2001. Where estimates were not available, they were derived through consultation with Member State experts.

Our understanding of country reported data has been checked through consultation with country experts. This was particularly important where reported estimates appeared unrealistic based on our understanding of country activity data and emission factors. In Table 4.1, the source of the data is described, whether it has been checked through consultation, what we consider to be the overall 'uncertainty' based on consultation, and the importance to the European estimates for non-industrial sectors.

Relative uncertainty is considered low where: CLRTAP data are available, data from MERCYMS / ESPREME are available, and validation through consultation has been

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[2] UNECE is the United Nations Economic Commission for Europe; CLRTAP is the Convention on Long Range Transboundary Air Pollution.

[3] The baseline (CP_CLE) November 2004 has been used in this inventory - http://www.iiasa.ac.at/web-apps/tap/RainsWeb/

[4] http://webdab.emep.int/

achieved; it is high where only data from MERCYMS / ESPREME are available. The consultation focused on countries where estimates were considered moderate to high, in terms of their contribution to overall European emissions. The majority of such countries have been successfully covered by this exercise. It is important to emphasise that a low 'relative uncertainty' does not necessarily reflect fewer uncertainties in the activity data or emission factors used to compile inventories; rather it reflects the level of checking against other country data sources.

Table 4.1 Source of inventory data, status of consultation and uncertainties

Country	CLRTAP 2002	MERCYMS & ESPREME Projects	Validated by consultation	Relative uncertainty	Importance (contribution to European totals)
Czech Republic	Yes	Yes	Yes	Low	High
France	Yes	Yes	Yes	Low	High
Italy	-	Yes	Yes	Low	High
Poland	Yes	Yes	Yes	Low	High
Spain	Yes	Yes	Yes	Low	High
United Kingdom	Yes	Yes	Yes	Low	High
Belgium	Yes	Yes	Yes	Low	Moderate
Germany	-	Yes	Yes	Low	Moderate
Ireland	Yes	Yes	Yes	Low	Moderate
Slovakia	Yes	Yes	Yes	Low	Moderate
Austria	Yes	Yes	Yes	Low	Low
Denmark	Yes	Yes	Yes	Low	Low
Finland	Yes	Yes	Yes	Low	Low
Hungary	Yes	Yes	Yes	Low	Low
Netherlands	Yes	Yes	Yes	Low	Low
Norway	Yes	Yes	Yes	Low	Low
Sweden	Yes	Yes	-	Low	Low
Bulgaria	Yes	Yes	-	Moderate	Moderate
Cyprus	Yes	Yes	-	Moderate	Low
Estonia	Yes	Yes	-	Moderate	Low
Finland	Yes	Yes	-	Moderate	Low
Latvia	Yes	Yes	-	Moderate	Low
Lithuania	Yes	Yes	-	Moderate	Low
Luxembourg	Yes	Yes	-	Moderate	Low
Portugal	Yes	Yes	-	Moderate	Low
Switzerland	Yes	Yes	-	Moderate	Low
Turkey	-	Yes	-	High	Moderate
Greece	-	Yes	-	High	Low
Slovenia	-	Yes	-	High	Low

Industrial estimates

National inventory classification does not enable the disaggregation of emissions (for any pollutants) into a '<50 MWth' category. Emissions are classified by sector type rather than size of installation. Industrial combustion installations below 50 MWth are included across most industry combustion sectors (as reported under the current NFR reporting format). Therefore, making estimates of industrial SCI emissions is very difficult, as was illustrated in the previous SCI study undertaken for the CAFE programme (AEA Technology 2004). An underlying reason for the absence of information is that fuel use statistics are not collected on the basis of the thermal size of the installation but usually on the basis of an economic sector breakdown.

Industrial estimates have been derived from work undertaken by the project team in the MERCYMS and ESPREME projects. These estimates include all combustion plant under 50 MW. In consultation with members of the MERCYMS / ESPREME team, our approach has been to derive the industrial sector emissions by subtracting the non-industrial estimates (made in this study) with these estimates for all sub-50 MW installations. The resulting industrial estimates are based predominantly on consumption of coal, while separate estimates for industrial emissions from liquid fuels are not available.

These estimates are much more uncertain than those for non-industrial sectors, particularly because we are deriving estimates on the basis of two different approaches. Such estimates need to be subject to further validation; however, few country specific datasets - only Poland and the UK - have been found on which to undertake such validation.

In both cases, comparison with national data has shown significant differences. UK emissions for industrial SCIs, derived on the basis of activity data for plant less than 50 MWth within different sectors of industry and using emission factors from the review, produced estimates that are 40% less than those proposed in this work; however, the estimated value is small – 0.297 tonnes - so the error expressed as a percentage may be high.

For Poland, official data on fuel consumption by combustion plants with capacities between 20 and 50 MW in the industrial sector (based on a study by Energsys (Tatarewicz 2005)) was considered. Again, the estimates were much lower than those estimated in this work, primarily due to the different assumptions concerning emission factors.

Based on this limited comparison with national datasets, the estimates in this study could be considered an over-estimate of emissions for industrial SCIs. However, as we only have data for two countries, no generalised conclusions should be drawn. The significant uncertainties associated with the industrial emissions estimates made in this study need to be recognised and action undertaken in the future to reduce them (as set out in the report recommendations). Despite the significant uncertainties, these data provide us with the only comprehensive dataset of industrial SCI emissions to be used in the cost-effectiveness analysis, and have therefore been included in this inventory.

4.2.2 Emission projections

Separate approaches were again used to estimate projected emissions for non-industrial and industrial SCIs. For **non-industrial sectors**, projections were developed on the basis of RAINS activity data for 2010 and 2020. The percentage change in fuel consumption for specific fuel-technology sectors between 2000 and 2010, and 2000 and 2020, was applied to the 2002 estimates to derive projected estimates.

In addition to the change in quantity of fuel, changes in the proportion of technology type used between years (within a specific technology-fuel category) was incorporated to reflect changes to types of technologies used e.g. for automatic solid fuel boilers, the percentage with a certain type of abatement may increase in later years.

For sub-50 MWth **industrial installations**, projection factors representing the change in fuel use between years are not available in the RAINS database (as installations are not classified on a size basis). Factors were therefore derived based on the change in fuel use data (for solid fuels) for two combustion sectors in the RAINS emission database – IN_BO (combustion in industrial boilers) and IN_OC (combustion in other industrial installations).

Although these sectors are not explicitly sub 50 MWth plant, they are considered to provide a good indication of the change in fuel use for industrial SCI sources. These derived factors are applied to the 2002 estimates in a similar way to that described for non-industrial sectors.

4.2.3 Mercury speciation

Speciation profiles have been developed in this study, to split totals mercury emissions into:

- Elementary form (elemental Mercury vapour Hg^0),
- Reactive gaseous form (Reactive Gaseous Mercury, RGM)
- Total particulate form (Total Particulate Mercury, TPM).

Profiles have been developed through literature review, expert knowledge and country-based consultation. None of the questionnaires responses used in the consultation exercise have provided any information on speciation, demonstrating the lack of information on this subject. In addition, limited literature data on speciation profiles from combustion of fossil fuels in SCIs is available. All literature data reviewed is based on understanding of mercury speciation from the combustion of coal and oil in large installations.

Uncertainties of speciation profiles result from the lack of experimental data for fossil fuel and biomass combustion in SCIs. In the absence of better data and for consistency with other inventory work we have adopted the quality rating of uncertainty estimation for emission inventories used by the UNECE Task Force on Emission Inventories and Projections (Pulles et al. 2001):

- C - an estimate based on a number of measurements made at a small number of representative facilities, or an engineering judgement based on a number of relevant facts
- D - an estimate based on single measurements, or an engineering calculation derived from a number of relevant facts.

For practical purposes it is important to recognise that other trace constituents in the fuel, particularly chlorine compounds, may influence the chemical form of the mercury emitted. The nature of the combustion appliance used and any associated abatement equipment will also have an effect. While there is a significant amount of literature in this area, particularly for large combustion plant installations, there is no clear consensus as to the impact of different trace compounds on mercury emissions, particularly from SCI sources.

To improve our understanding of mercury speciation and emission, it is necessary to carry out more research to investigate speciation profiles for different fuels used in a range of SCIs.

Table 4.2 Mercury emission factor speciation for different fuels

Fuel	**Installation**	**Hg^0 (gas)**	**Hg^{+2}**	**Hg (partic.); Hg^{PM}**	**Uncertainty**	**Ref.**
Hard Coal	Power plant	0.5	0.4	0.1	-	[1, 2]
	Residential	0.5	0.4	0.1	C	
	General	0.5	0.4	0.1	-	[3]
	Power plant	0.5	0.4	0.1	-	
	Power station stack monitoring	0.269	0.695	0.036	-	[4]
	Domestic coal burning	0.4	0.4	0.2	C	
	FBC [a)]	0.55-0.6	0.4	<0.05	-	[6]
	FBC [b)]	0.05 – 0.10	0.8	0.15 – 0.10	-	
	Research facility design to replicate typical power plant	0.2	0.8	-	-	[5]
	Stove	0.6		0.4	-	[7]
	Power plant	0.42	0.58	-	-	[8]
	Stove / Fireplaces	0.3	0.35	0.35	C	[9]
	Boiler manual fuelled - all SCI sectors	0.4	0.4	0.2	C	
	Boiler autom. (stoker) - all SCI sectors	0.5	0.4	0.1	C	
Brown coal	Power plant	0.61	0.39	~ 0.01	-	[8]
Biomass	Manual fuelled (stove boiler) - all SCI sectors	0.6	0.3	0.1	D	[9]
	Automatic fuelled- all SCI sectors	0.65	0.3	0.05	D	[9]
Liquid fuels	General for oil	0.5	0.4	0.1	-	[1, 2]
		0.5	0.4	0.1	-	[3]
		0.51	0.39	0.1	-	[4]
	SCIs (all sectors) Light fuel oil	0.75	0.2	0.05	C	[9]
	SCIs AFF, Com-Inst Heavy fuel oil	0.65	0.35	0.1	C	[9]
Natural gas	SCIs (all sectors)	0.8	0.15	0.05	C	[9]

NB. a) high content of volatile matter in coal (about 40%) of Cl; b) coal rich Cl (2304 ppm) content.
An uncertainty rating has not been given to non-SCI categories (as indicated by the dashes in the uncertainty column).

Table references:

1. Pacyna J.M., Munthe J., Summary of research of projects on mercury funded by EC DG Research, Workshop on Mercury Needs for further International Environmental Agreements, Brussels, March 29-30, 2004;
2. Pacyna E., Pacyna J.M., J. Pirrone N, European emissions of atmospheric mercury from anthropogenic sources in 1995"; Atmospheric Environment, June 2001, vol. 35, no. 17, pp. 2987-2996(10)
3. Senior C, Mercury Tutorial – Mercury Transformations"- Connie Senior (private presentation) Reaction Engineering International; The 29th International Technical Conference on Coal Utilization & Fuel Systems Clearwater, Florida April 18-22, 2004 (behalf of EPA)
4. UK National atmospheric Emission Inventory (supplied by Pye S, UK, July 2005)
5. Tan Y., Mortazavi R., Bob Dureau B., Mark A. Douglas M.A.; "An investigation of mercury distribution and speciation during coal combustion"; Fuel 83 (2004), pp. 2229–2236
6. Moritomi H., Fujiwara N.; Mercury emission from coal combustion in Japan"; Mercury Experts Conference 2; MEC2 – May 25, 2005 Ottava, Canada
7. Bartle K.D., Ściążko M., Kubica K., et al.; Clean Coal –Derived Solid Fuels for Domestic and power Plant Combustion; Report 1996, Contract Cipa-CT92-3009 1993-1996
8. Hlawiczka S., Fudala J.; "Distribution of Cd, Pb and Hg emissions among sectors of economy in Poland and the emission assessment for the years 1990-2000" in: Environmental Engineering Studies, Polish Research on the way to the EU; Kluwer Academic/Plenum Publishers, New York, 2003
9. Estimated under this project

4.2.4 Stakeholders consultation

Stakeholder consultation was an important part of the emission inventory task for the following reasons:

- To seek verification of the emission estimates made for non-industrial SCI in countries according to the method described above.
- To collect further data through which to make more robust estimates, focusing on the key emitting countries.
- To enable participation in this study by leading experts.

In addition, it was a useful means of collecting information on abatement options (although the focus of the consultation was on the emission inventory task).

The consultation exercise was focused on key countries where emissions were estimated to be significant, although questionnaires were distributed more broadly across countries covered by the inventory. The questionnaire was prepared to help gather country-based data (emission factors, activity data etc.) needed to ensure that the estimates made were robust, and to provide a degree of validation. The questionnaire focused on the following:

- Emission estimates (and projected if available);
- Activity (fuel use) data by sector;
- Emissions factor data by sector (and technology if available);
- Country specific information on speciation;
- The location of coal burning e.g. urban or rural; region of the country;
- Information on country-based strategies targeted at reducing mercury emissions.

The questionnaire was accompanied by the relevant country estimates of mercury emissions, developed in this study, with an indication of what we considered to be the largest SCI sources of emissions. This consultation built on the established network of contacts established under the CAFE SCI study.

Responses have been received from a range of stakeholders, and are summarised in Appendix 2. Any clarification of questionnaires received, or consultation due to a lack of response were undertaken by phone.

In summary, the stakeholder consultation enabled us to validate the assumptions that we have used in the inventory estimates, and ensure that the estimates made have broad agreement with in-country experts. It is clear from consultation that there is a lack of detailed data (by technology and fuel) on mercury emission from SCIs sources, except for selected countries e.g. Spain, Norway, UK, Romania, and that there are significant differences between emission factors used by different countries (see Annex 1, Table 14).

4.3 EMISSION FACTORS REVIEW

Fuel consumption estimates and mercury emission factors have been used to estimate emissions by sector, appliance, and fuel category. Fuel consumption estimates have been sourced from centralised European data sources. However, information on emission factors is not so readily available from centralised sources, and has therefore been a significant component of this emission inventory task.

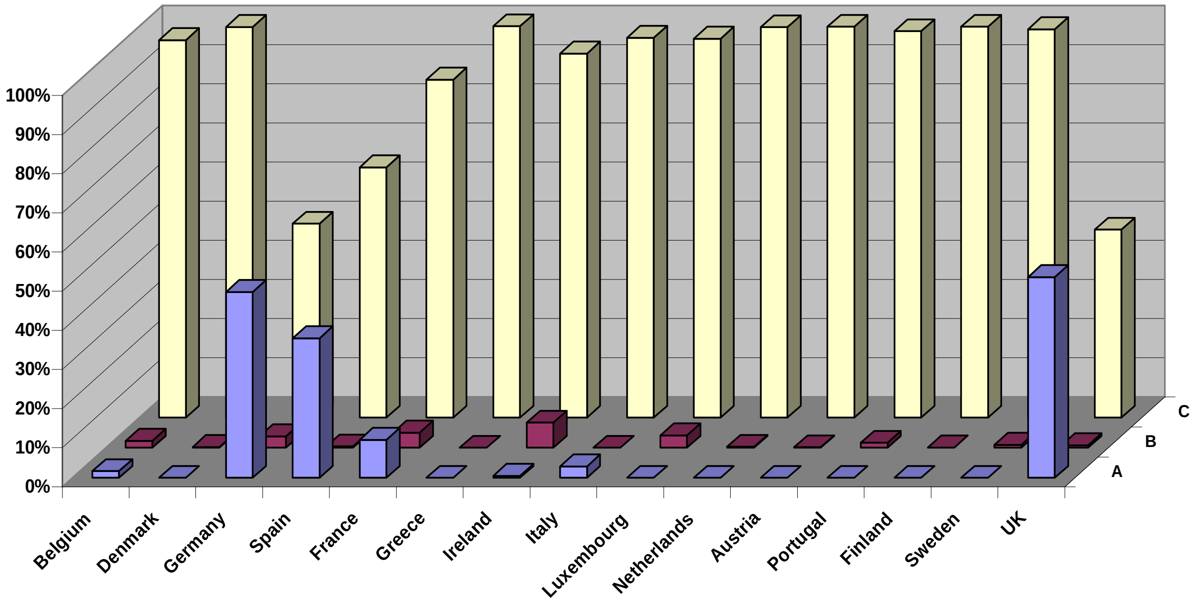
A review has been undertaken of emission factors, based on literature review, consultation with country-based inventory experts (see Table 14 in Appendix 1 for summary of emission factor information), in-house research, and on our understanding of mercury content in fuels, and the characteristics of combustion technologies. The understanding of mercury content of fuels is the key factor in determining emission factors, and provides the focus of this section of the report.

4.3.1 Mercury content of fuels

The mercury content of solid fuels and biomass fuels varies widely, in particular for coal, based on its origin (where it was extracted) and any processes it undergoes prior to sale on the market. In the literature, the mercury content of bituminous coal has a wide range, from 0.01 – 1.78 mg/kg.[5] Interestingly, older literature sources suggest higher contents of mercury in coal than more recently published sources. This is probably due to new analytical techniques and equipment that are currently applied for determination of mercury as well as the recent implementation of common pre-treatment (washing) of coal which lowers emission level.

The mercury content of coal varies, and depends on the origin of country and region. Statistics available for the EU15 group of countries show that the majority of coal used is imported from non-European countries, with only limited indigenous production, as illustrated in Figure 4.2. Figure 4.3 illustrates the mix of different coals imported into the countries for which data is available (European Commission 2004).

Figure 4.2 Supplies of coal in the EU countries in 2002 – indigenous coal production (A), receipts from other EU countries (B) and imports from non-EU countries (C)



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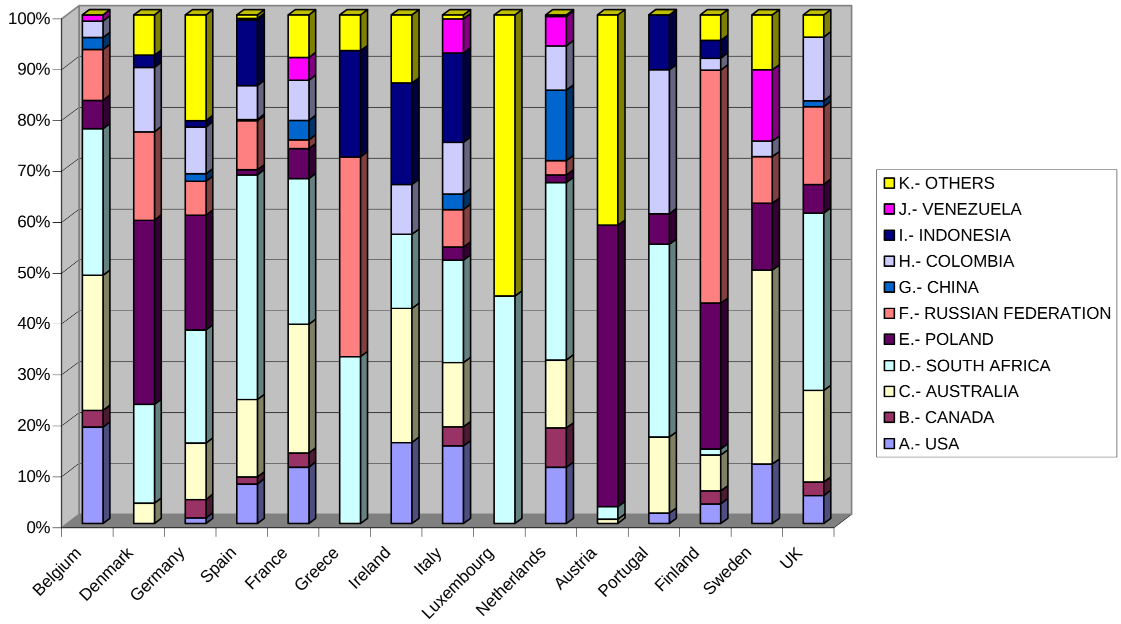
[5] See Tables 1–6 in Appendix 1 for further information.

Figure 4.3 Distribution of different countries imports of coal in the total import from non-EU countries for EU member states in 2002



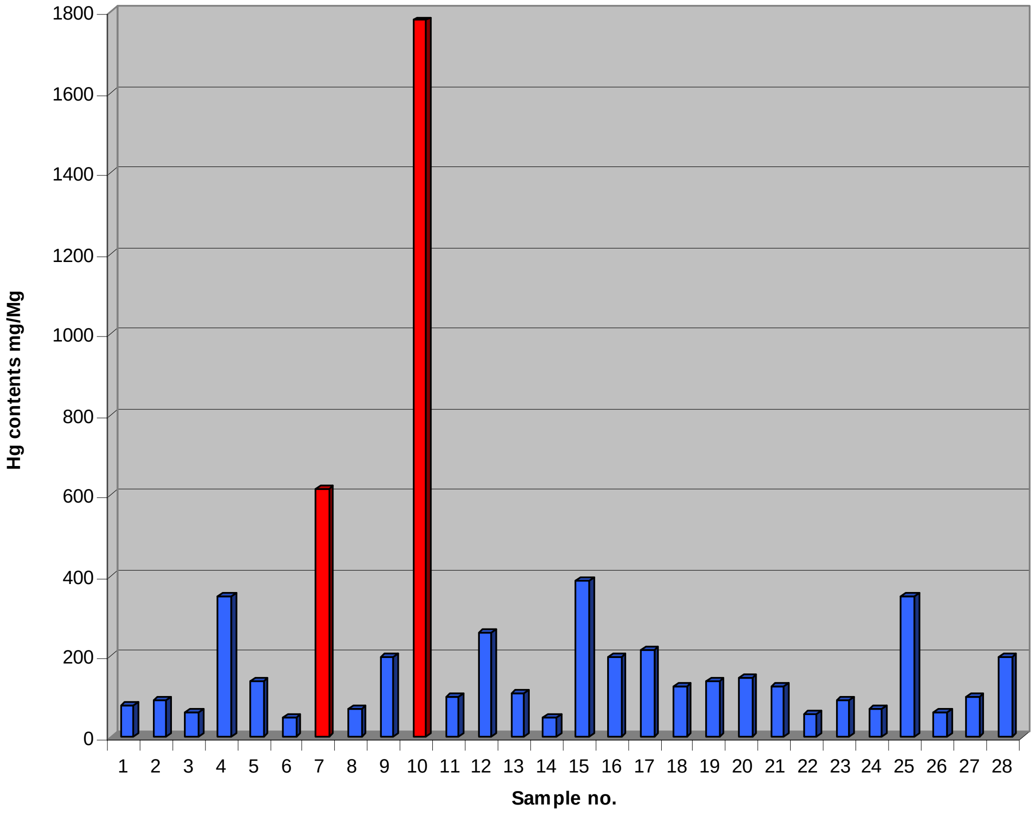
Significant country variation in imports and exports (as shown in the above figures) points to the need for country-specific emission factors. However, this is difficult for the following reasons:

- Data on imports and exports is not comprehensive for the whole of Europe;
- Even where data is available on imports, it is not clear which sectors use what type of coal;
- Mercury content of coal from a specific country can be highly variable;
- Information on country-specific factor is limited – see section 4.2.4 on stakeholder consultation.

An example of the significant variation in mercury content of coal can be illustrated using the example of Polish coal exports. The mercury content of coal exported to Denmark was 0.09 mg/kg on average, and for coal exported to Australia it ranged from 0.06 to 0.2 mg/kg (between 1992-2004). The content varies depending on the individual mines from which coal was extracted. This variation in mercury content of coal can also be observed for other exporting countries, such as USA, China, and South Africa.

The graph below illustrates the type of variation in measured mercury content of coal in Poland. Recent data on the mercury content illustrates less variation than previous measurements, with concentrations between 0.05-0.35 mg/kg, and most values below 0.2 mg/kg.

Figure 4.4 Mercury contents in the different samples of Polish coal (mg Hg/kg); red bars represent data reported before 1995 (from various emission factor review sources)



Data from EURELECTRIC (2004) also illustrates the significant diversity of mercury content of coal imported to UK, Netherlands, Austria, and Denmark from a range of exporting countries, and the subsequent differences between emission factors in different countries. Mercury concentrations in coal used in the Netherlands range from 0.05 to 0.35 mg/kg, with a weighted averaged concentration of 0.11 (based on 1999 data). Comparative results were also obtained in Denmark and Ireland.

Despite this recognition of differences between mercury content of coals used in different countries, it has not been possible to estimate country-specific emission factors for the reasons provided previously. No differentiation has therefore been made between countries included in the inventory – a single factor has been derived for all countries based on an extensive review of emission factors used across Europe.

Mercury contents for brown coal (lignite) are as diverse as those for bituminous coals, examples of which can be seen in Table 7 in Appendix 1. Mercury content in derived coals, such as smokeless solid fuels, tend to be 20-80% lower than in coal – for further detailed information see Tables 8-10 in Appendix 1. As for bituminous coal, it could be deemed better to have country specific emission factors e.g. for example, central European lignite fields have higher mercury contents than German lignite. Therefore, an averaged factor of 0.007 kg/TJ might overestimate emissions for certain countries.[6] This is clearly a limitation with the approach taken, for the reason outlined on the previous page.

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[6] Information based on personal communication with Thomas Schneider (DG TREN, 18/10/05)

There is very poor data on the mercury content of biomass (see Table 11 in Appendix 1 for further detail), and therefore the estimates of emission factors are very uncertain. Development of a better knowledge of heavy metal concentrations in biomass fuels is increasingly important, as the use of biomass is projected to increase in future years.

Mercury concentration in gas and petroleum is significantly lower than in coal and is usually in the range of 0.02 – 0.2 ppb (see Table 12 and 13 in Appendix 1) for natural gas and from 1.4-15 ppb for crude oil. Liquid fuel products differ significantly in terms of mercury content depending on the type of liquid fuel product.

4.3.2 Determination of inventory emission factors

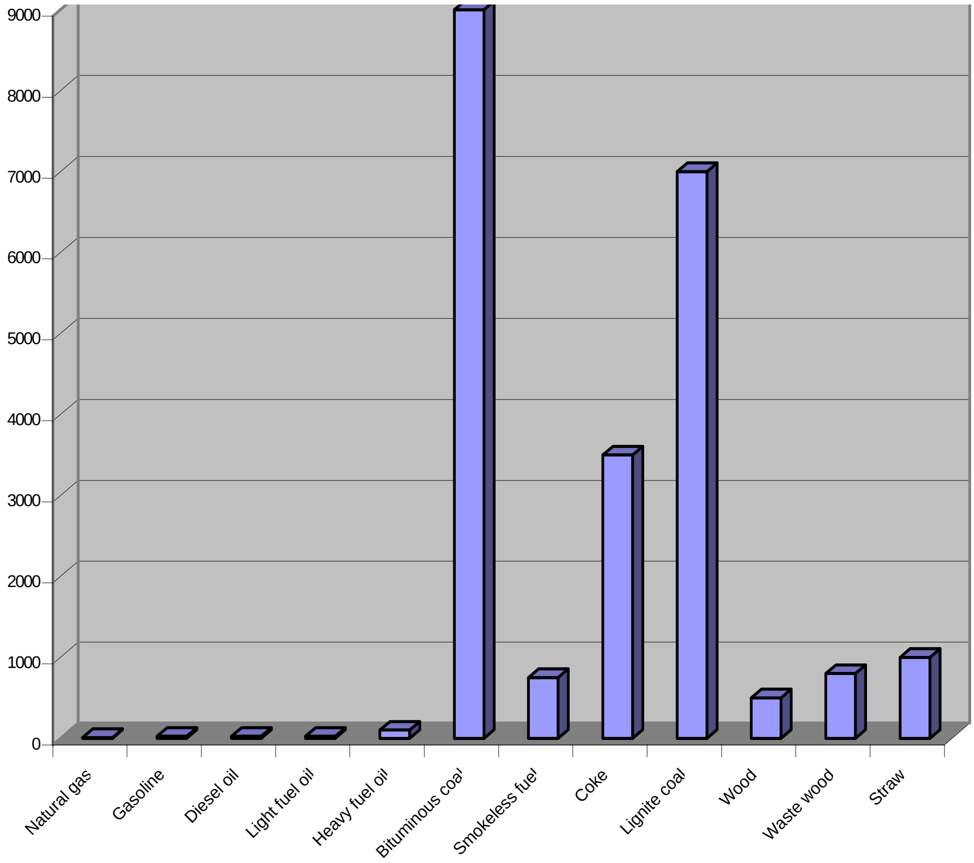
Based on our review of emission factors, we have taken an average factor from the observed emission factor ranges. These data are presented in Table 4.3 by fuel category. (NB. We have also included an uncertainty rating, which is described further in section 4.5).

Table 4.3 Review of range and estimated average mercury emission factor for different type of fuels (without abatement)

Fuel	Range (kg/TJ)		Average (kg/TJ)	Uncertainty
	Low	High		
Natural gas	0.0000006	0.00015	0.00001	C
Gasoline	0.0000050	0.00047	0.00003	C
Diesel oil	0.0000095	0.000071	0.000025	
Light fuel oil	0.0000024	0.00012	0.000025	
Heavy fuel oil	0.000006	0.015	0.0001	
Bituminous coal	0.00039	0.070	0.009	C
Smokeless fuel	0.00064	0.00099	0.00075	C
Coke	0.00060	0.015	0.0035	
Brown coal (Lignite)	0.005	0.13	0.007	C
Wood	0.00010	0.00188	0.0005	D
Waste wood	0.00025	0.0034	0.0008	
Straw	0.00007	0.0022	0.001	

As illustrated in Figure 4.5 below, estimated average emission factors of mercury for coal-based fuels are significant higher than for gas and liquid fuels.

Figure 4.5 Estimated average Hg emission factors for different types of fuel, mg/TJ



The finalised set of emission factors used in the non-industrial emission inventory is presented in Table 4.4. These take account of the combustion processes in different installations using both solid fuels and biomass.

Table 4.4 Mercury emission factors by sector-fuel-technology

ector	Fuel	Technology	Emission factors in kg/TJ
AFF	***Biomass***	Medium boilers (automatic) <50 MW using wood, waste, biomass	0.0008
		Medium boilers (manual) <1 MW using wood, waste, biomass	0.0006
		Single house boilers (automatic) <50 kW using wood, waste, biomass	0.00055
		Single house boilers (manual) <50 kW using wood, waste, biomass	0.0008
	Gaseous fuel	LPG	0
		Natural Gas	0.00001
	Liquid fuel	Diesel / Light fuel oil	0.000025
		Gasoline	0.00003
		Heavy fuel oil	0.0001
	Solid fuel	Medium boilers (automatic) <50 MW using brown coal	0.007
		Medium boilers (automatic) <50 MW using coke / briquettes	0.0035
		Medium boilers (automatic) <50 MW using hard coal	0.009
		Medium boilers (manual) <1 MW using brown coal	0.0055
		Medium boilers (manual) <1 MW using coke / briquettes	0.003
		Medium boilers (manual) <1 MW using hard coal	0.007
		Single house boilers (manual) <50 kW using brown coal	0.006
		Single house boilers (manual) <50 kW using coke / briquettes	0.0035
		Single house boilers (manual) <50 kW using hard coal	0.009
Commercial-Institutional	***Biomass***	Medium boilers (automatic) <50 MW using wood, waste, biomass	0.0008
		Medium boilers (manual) <1 MW using wood, waste, biomass	0.00055
	Gaseous fuel	LPG	0
		Natural Gas	0.00001
	Liquid fuel	Diesel / Light fuel oil	0.000025
		Gasoline	0.00003
		Heavy fuel oil	0.0001
	Solid fuel	Medium boilers (automatic) <50 MW using brown coal	0.007
		Medium boilers (automatic) <50 MW using coke / briquettes	0.0035
		Medium boilers (automatic) <50 MW using hard coal	0.009
		Medium boilers (manual) <1 MW using brown coal	0.006
		Medium boilers (manual) <1 MW using coke / briquettes	0.003
		Medium boilers (manual) <1 MW using hard coal	0.007
Residential	***Biomass***	Fireplaces using wood, waste, biomass	0.0004
		Single house boilers (automatic) <50 kW using wood, waste, biomass	0.00055
		Single house boilers (manual) <50 kW using wood, waste, biomass	0.0005
		Stoves using wood, waste, biomass	0.0004
	Gaseous fuel	LPG	0
		Natural Gas	0.00001
	Liquid fuel	Diesel / Light fuel oil	0.000025
		Gasoline	0.00003
		Heavy fuel oil	NA
	Solid fuel	Fireplaces	0.003
		Single house boilers (manual) <50 kW using brown coal	0.007
		Single house boilers (manual) <50 kW using coke / briquettes	0.003
		Single house boilers (manual) <50 kW using hard coal	0.006
		Stoves using brown coal	0.004
		Stoves using hard coal	0.006

4.4 INVENTORY ESTIMATES

Based on the described approach, historic and projected emissions estimates of mercury from SCI sources have been made, on a country basis and split into industrial and non-industrial sectors. These estimates provide the basis for the cost-effectiveness analysis described in section 7.

4.4.1 Historic inventory estimates

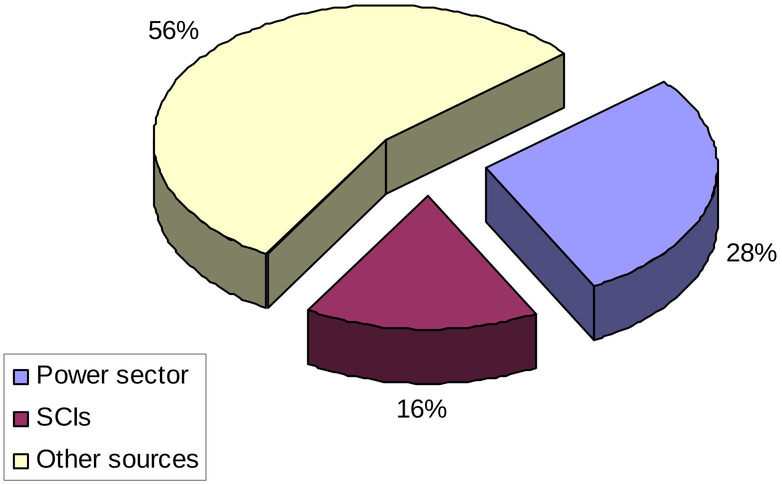
One of the objectives of the inventory task was to assess the significance of mercury emissions from SCI sources. In Figure 4.6, the contribution of SCIs to overall emissions is compared to the power sector, as a percentage of total European emissions. SCI sources are shown to account for approximately 16% of the total European mercury emissions. The percentage contribution was also considered for countries that are significant contributors to European emissions, and which have low relative uncertainty (based on the level of cross-checking with other sources). These countries include the top 6 countries in Table 4.1 (Czech Republic, Italy, Poland, UK, Spain and France). The data from these six countries shows a SCI contribution of 14%, a reduction of 2% from the estimate where all countries are included.

In the Mercury Strategy Extended Impact Assessment (CEC 2005), the overall contribution was considered to be higher than shown by the estimates in this inventory – with SCIs accounting for around 25% of total emissions. This is because those estimates sourced from work undertaken in the ESPREME / MERCYMS projects were based on a different estimation approach.

The ESPREME / MERCYMS approach made estimates based on PRIMES activity data, and emission factors derived on the basis of EMEP aggregate data on emissions and calculated for energy produced. (These factors can be found in Table 15 of Appendix 1). The factors used in this study are based on mercury contents in different fuels, and take into account sector differences and combustion technologies. The estimates based on this approach (in this study) produce much lower non-industrial estimates than those under the ESPREME / MERCYMS approach. We have used the industrial estimates from the ESPREME / MERCYMS work (but not the non-industrial part of the estimates) in the absence of other data.

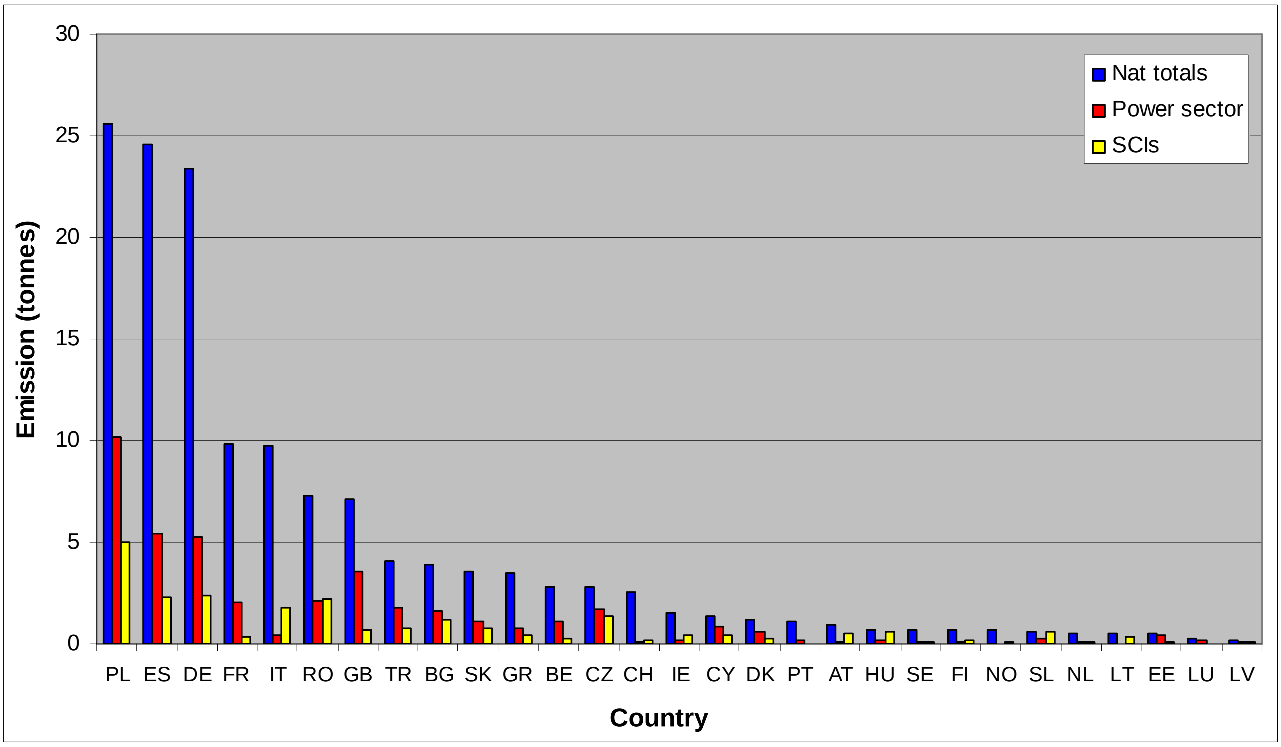
Both types of estimate indicate that SCIs are a significant source of European mercury emissions, and that consideration of abatement options and policy action is important. Given the level of uncertainty in the emission estimates, the differences in overall contribution to European emissions by SCI sources between the estimates made in this study and those in previous work may not be as significant as indicated by these percentage values.

Figure 4.6 Contribution of SCI sources to European mercury emissions (in 2002)



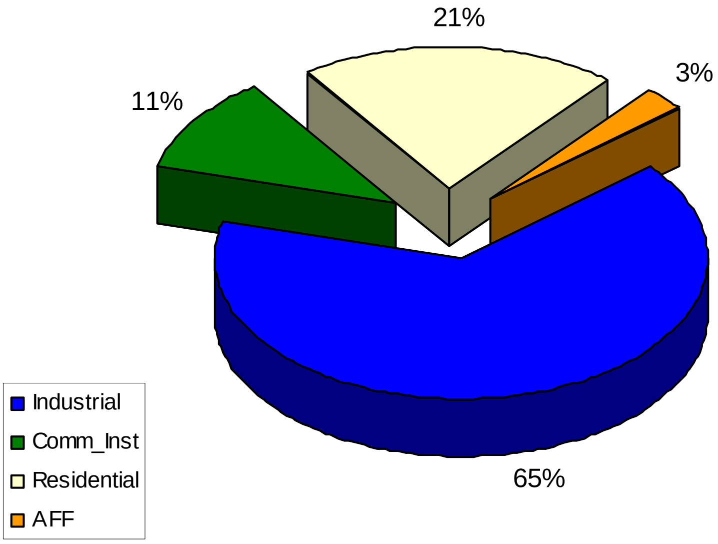
The contribution of SCI sources (both non-industrial and industrial) by country is shown in Figure 4.7, and illustrates the variation between different countries. For example, in the Czech Republic, it is clear that SCI sources account for a significant proportion of overall country emissions, while in France, they only represent a small proportion. The variation both in terms of the absolute mercury emissions and percentage contribution from SCIs may have implications for the type of action considered.

Figure 4.7 Estimates of mercury emissions (in 2002) from small combustion installations compared to national totals



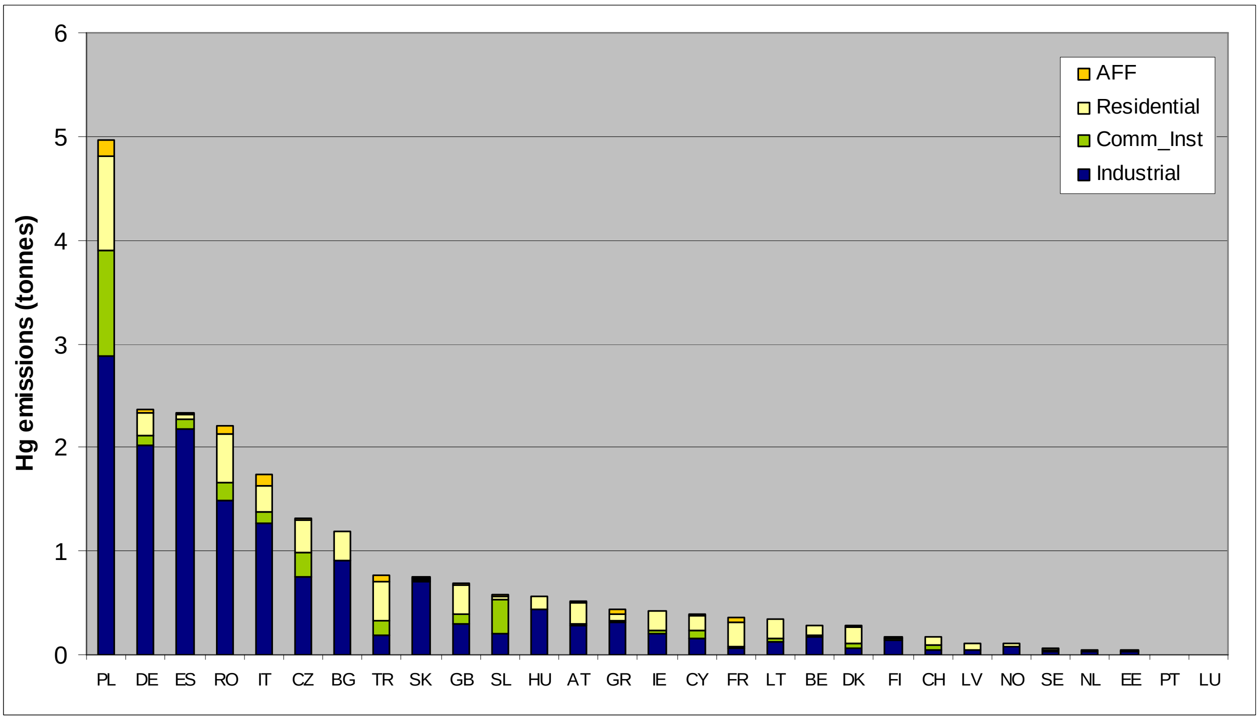
Emissions from SCI sources can be split into four main sectors, as shown in Figure 4.8. Over half of emissions are from the industrial sector, with just over 20% coming from the residential sector. The commercial-institutional sector accounts for approximately 11% of total emissions; the contribution from agricultural sector is small.

Figure 4.8 Percentage of European mercury emissions (in 2002) by SCI sector



Emissions from SCI source sectors are shown in Figure 4.9, disaggregated by country. The significant solid fuel users across Europe dominate the picture – primarily Poland but also Germany, Spain, Czech Republic Romania, Italy and the UK. Interestingly, the contribution to the overall SCI total is particularly significant in Poland, Czech Republic and Romania, indicating significant use of coal in the non-industrial sectors.

Figure 4.9 Emissions of mercury from SCI sources, disaggregated by sector (in 2002)



Countries with much higher biomass use such as the Scandinavian and Baltic countries have considerably lower emissions as might be expected. The actual emission estimates are shown below in Table 4.5.

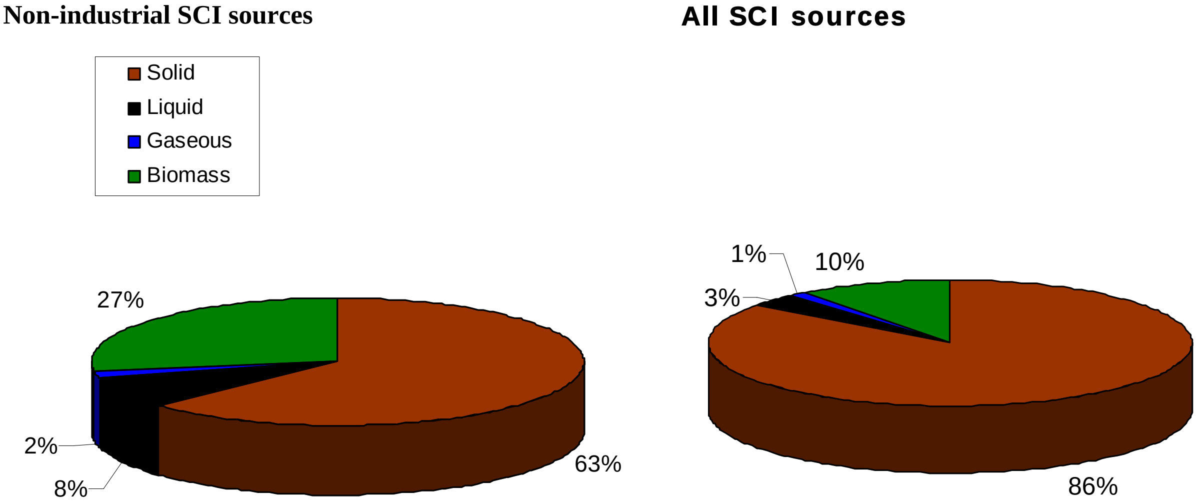
Table 4.5 Estimates of mercury emissions from SCIs sources in 2002

Country	**SCI emissions by sector (kg)**			
	Industrial	**Commercial – Institutional**	**Residential**	**Agricultural**
Poland	2880	1028	908	151
Germany	2025	89	218	27
Spain	2175	89	59	7
Romania	1485	170	483	70
Italy	1270	110	250	110
Czech Republic	750	234	316	17
Bulgaria	902	13	273	2
Turkey	188	136	386	56
Slovakia	709	5	29	2
United Kingdom	297	91	293	5
Slovenia	210	330	20	20
Hungary	444	2	124	0
Austria	285	9	204	12
Greece	315	10	60	60
Ireland	211	30	180	1
Cyprus	157	84	134	24
France	70	11	240	36
Lithuania	122	29	192	5
Belgium	171	10	100	4
Denmark	60	43	156	24
Finland	147	2	23	4
Switzerland	50	38	80	1
Latvia	52	0	63	0
Norway	72	13	24	2
Sweden	39	2	23	1
Netherlands	28	0	25	1
Estonia	35	1	10	1
Portugal	1	0	0	0
Luxemburg	0	0	0	0
Totals	15149	2579	4874	642

It is important to re-iterate the uncertainties surrounding the industrial estimates in particular (see end of section 4.2.1), and that such estimates only account for emissions from coal combustion. This is the most important fuel for mercury emissions. Emissions from liquid fuel and biomass in the industrial sector have not been quantified in the absence of any information and are considered much lower than those from coal.

A shown in Figure 4.10, the main fuels for which emissions are derived are coal-based fuels, over 80%, with biomass accounting for 10% of emissions. If industrial emissions are excluded, the proportion of emissions from biomass sources increases significantly, to 27%.

Figure 4.10 Proportion of mercury emissions from different SCI fuel sources (in 2002)

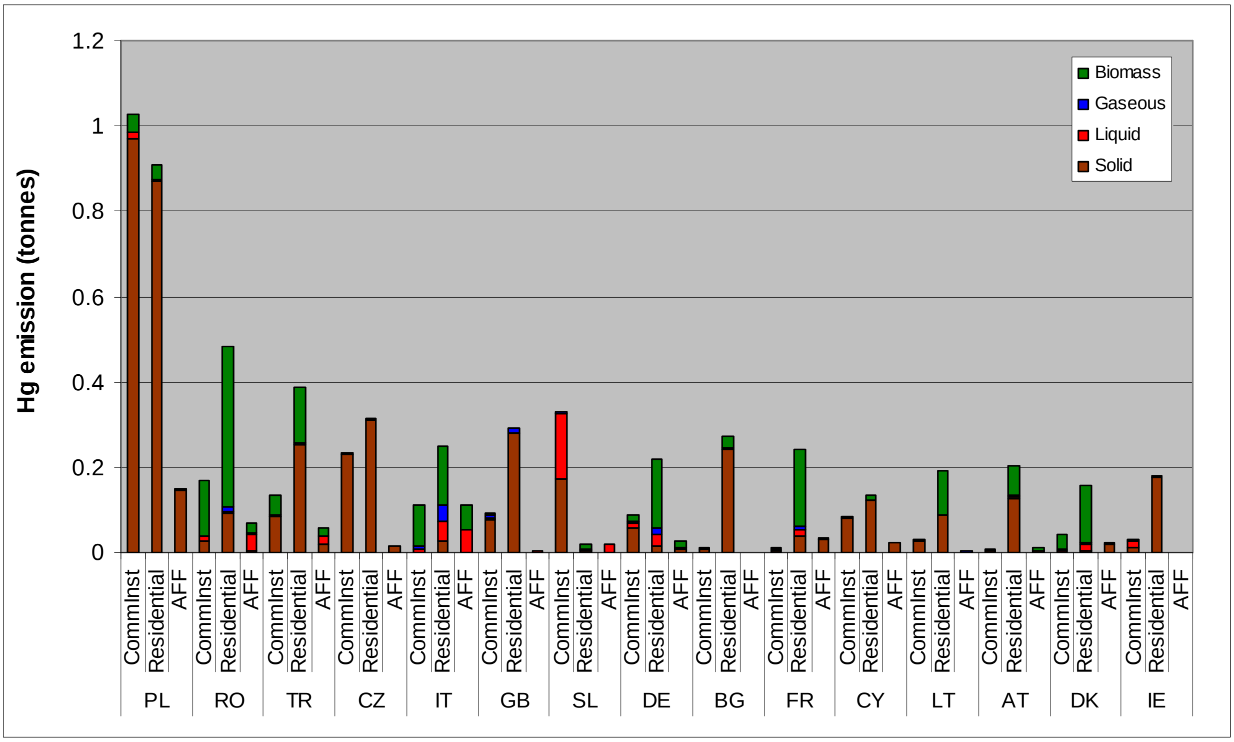


Non-industrial SCI sources

All SCI sources

Figure 4.11 shows the non-industrial sector emissions in more detail, focusing on those countries that contribute over 90% of total emission from non-industrial SCIs. The graph illustrates that the residential sector is the main contributor of emissions, although for some of the biggest emitting countries – Poland, Germany and Czech Republic – the commercial-institutional sector is also a major source. The major contribution by fuel type is from solid fuels, although biomass appears to be important in certain countries.

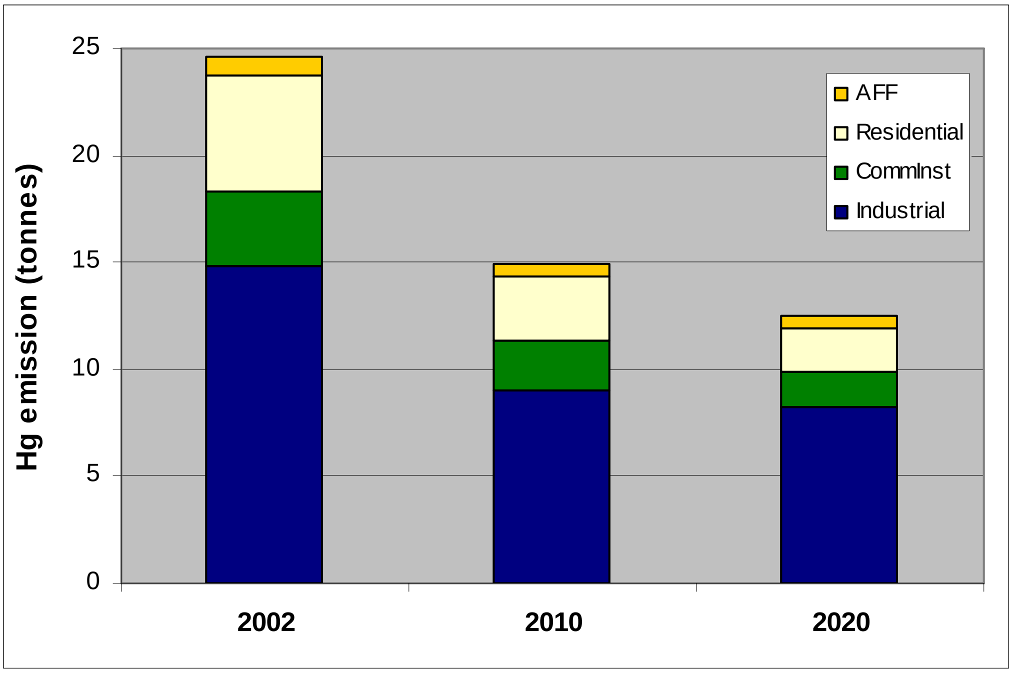
Figure 4.11 Emission estimates for non-industrial sectors in 2002, disaggregated by fuel type



4.4.2 Projections

Projections have been derived for both industrial and non-industrial sectors based on the approach described in section 4.2.2. Based on our estimates, mercury emissions will be reduced by 50% by 2020. This reduction is predominantly due to the switch away from coal-based fuels (as modelled in the energy projections) to alternatives such as oil and gas.

Figure 4.12 Emissions of mercury in Europe from SCIs (2002 – 2020)



The reduction in the contribution of solid fuels to mercury emissions can be seen in Figure 4.13, showing the change in non-industrial sectoral emissions in 2010 and 2020. Biomass is shown to become an increasingly significant source, in relative terms.

These projections are of course subject to significant uncertainties. Firstly, changes in fuel price might significantly reduce the projected decrease in the use of solid fuels. Secondly, estimates of emission factors for biomass are the most uncertain in the inventory; therefore, it may be that their future contribution is over- or underestimated. In addition, significant reductions across certain countries will also be contingent on increased wealth to be able to switch to other fuels.

The projected decrease for Europe by 2020 is clear from estimates shown in Figure 4.12. However, the projected decrease on a country-by-country basis differs, as illustrated in Figure 4.14. In terms of non-industrial emissions, the significant reductions in Poland and Germany are an important component of the projected reduction at the European level. In Romania, for example, the reduction is considerably less. From discussions with different stakeholders, there is contention concerning the rate of reduction in the use of solid fuels – such projections may be fairly optimistic for non-industrial sectors.

Figure 4.13 Projections of mercury emissions for non-industrial sectors, disaggregated by fuel type

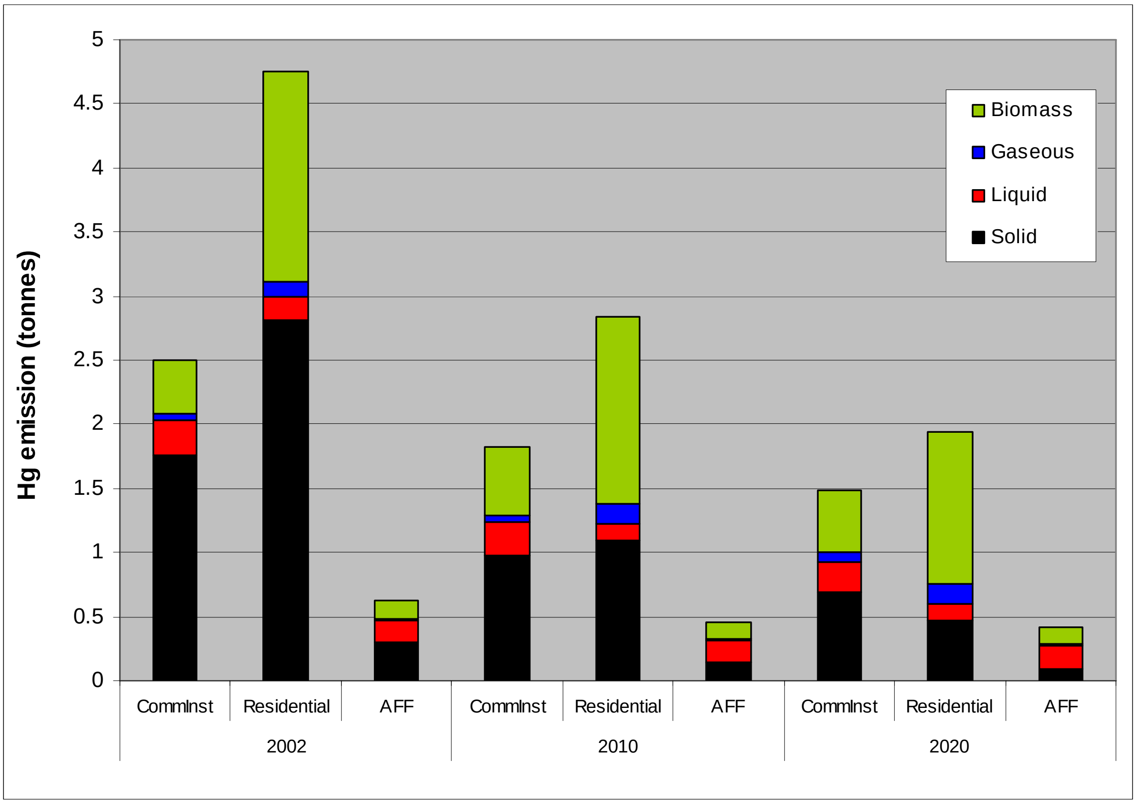
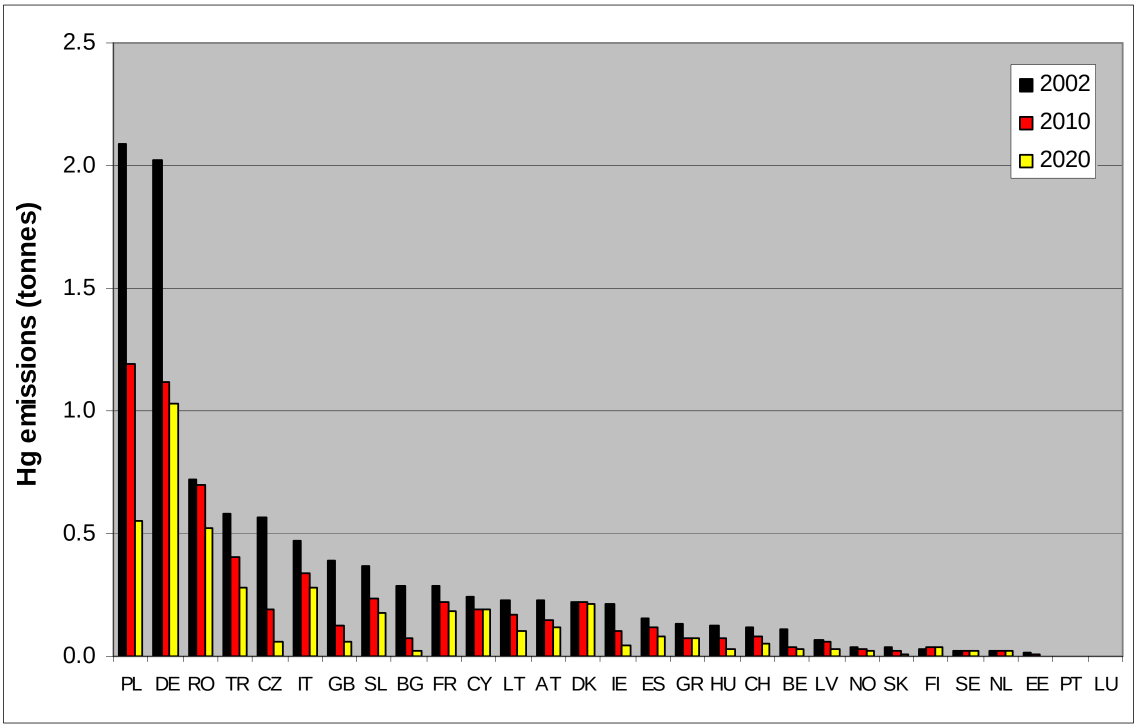
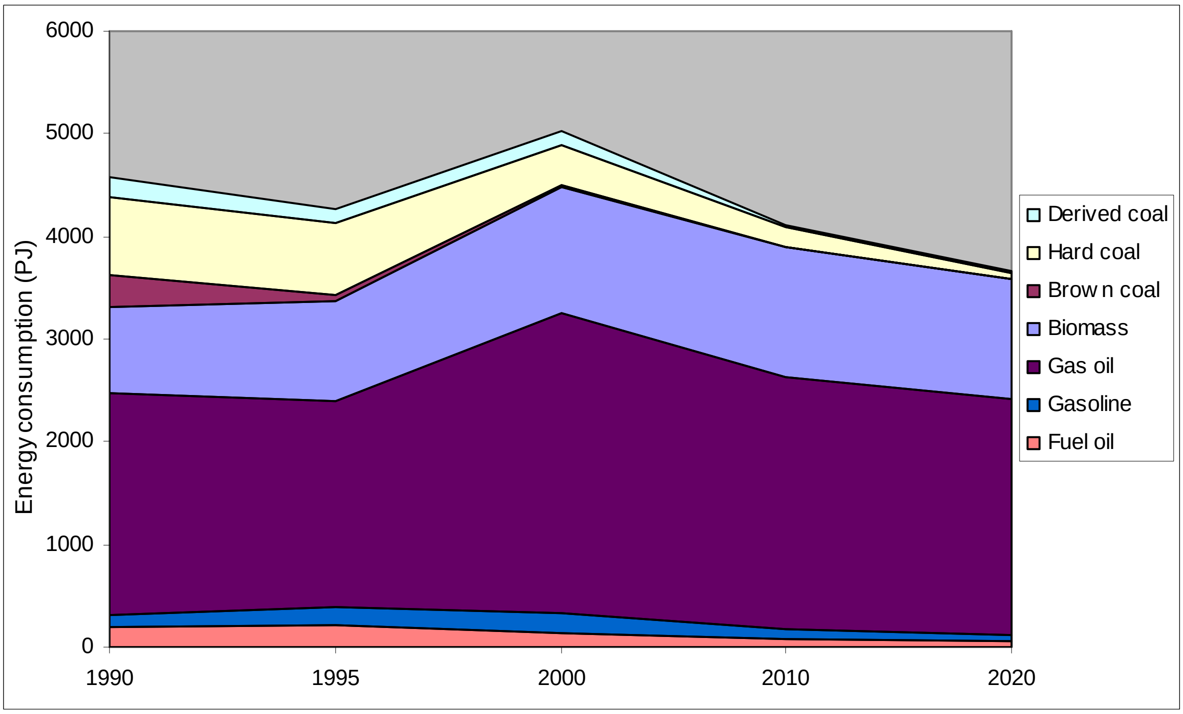


Figure 4.14 Projections of mercury emissions for non-industrial sectors by country



The decreases in solid fuel use are shown in Figure 4.15, illustrating the very low levels of hard coal use in 2020, and no brown coal use by 2020 in these sectors. The use of biomass increases steadily in comparison between 2000 and 2020.

Figure 4.15 Fuel use in residential-commercial sector in Europe (based on RAINS 'CP_CLE August 04'(Nov. 2004)))



NB. Gaseous fuels, excluded from the above graph account for 58% of consumption in 2000, and 70% in 2020/

Some country-based comparisons have been made between levels of solid fuel use in non-industrial sectors projected in the above scenario (CP_CLE Aug 04) (which has been used as the baseline scenario across analysis undertaken in the CAFE programme) and national projections (which exist for selected countries), also accessed from the RAINS model.[7] Unfortunately, there are no national projection datasets available for the two largest solid fuel users – Poland and Germany. As shown in Table 4.6 below, three countries where significant solid use occurs have been compared – in most instances, solid fuel use in the commercial-residential sector is higher in the national projections.

In particular, brown coal use is higher in national projections. In addition, all future projections of solid fuel use under national projections are higher – with the exception of hard coal use in the Czech Republic in 2010. What these selected data indicate is that there are considerable differences between country projections and those from the PRIMES model (used in RAINS), and that using national projections would show lower reductions in emissions of mercury from non-industrial sectors. Based on the country sample used, it could be suggested that the RAINS scenario provides a 'best case' baseline regarding solid fuel use in non-industrial sectors.

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[7] See http://www.iiasa.ac.at/web-apps/tap/RainsWeb/RainsServlet1. Scenarios selected for comparison were *CP_CLE Aug 04 (Nov 04)* and *NAT_CLE Aug 04 (Nov 04)*.

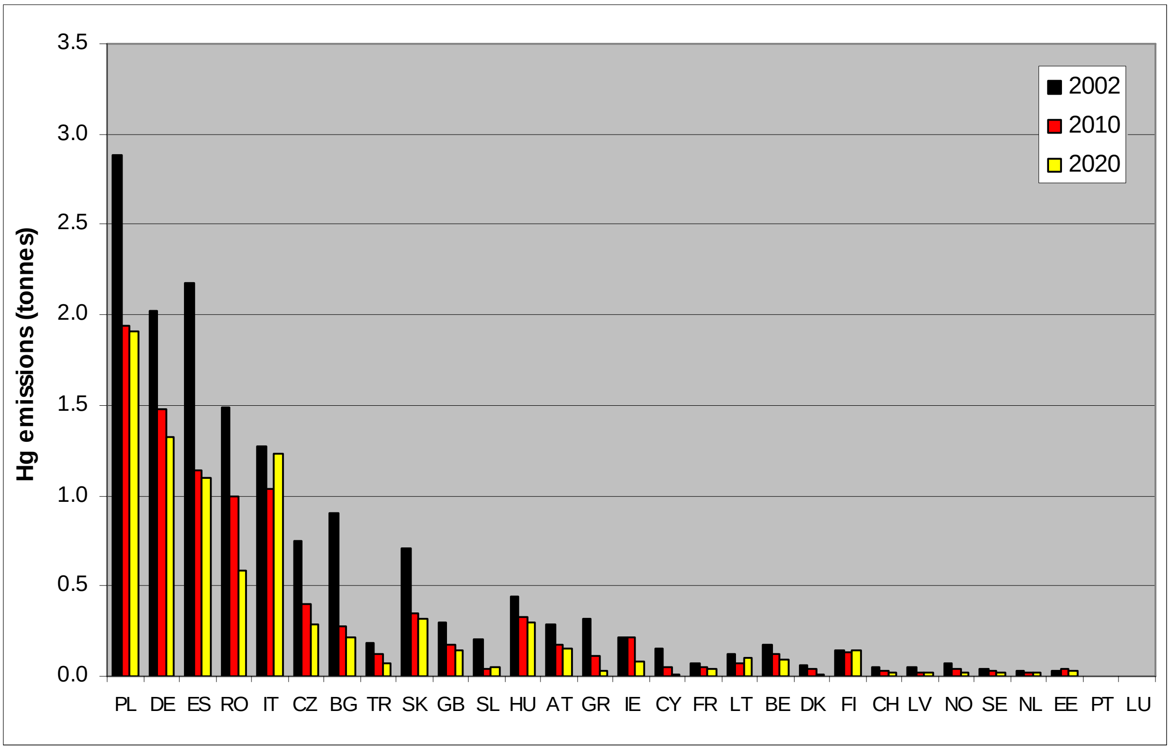
Table 4.6 Comparison of non-industrial solid fuel use in RAINS / PRIMES scenario and national projection scenario

Country	**Year**	**Hard coal**			**Brown coal**			**Derived coal**		
		RAINS (PJ)	National (PJ)	% change	RAINS (PJ)	National (PJ)	% change	RAINS (PJ)	National (PJ)	% change
Czech Republic	2000	46.05	9.74	373	0.04	32.22	-100	6.7	4.42	52
	2010	15.42	9.70	59	0.00	29.44	-100	2.08	3.97	-48
	2020	4.10	4.90	-16	0.00	7.03	-100	0.59	2.65	-78
Italy	2000	0.09	0.63	-86	0.00	0.63	-100	2.56	5.65	-55
	2010	0.03	0.88	-97	0.00	0.88	-100	0.20	7.91	-97
	2020	0.02	2.30	-99	0.00	2.30	-100	0.04	20.71	-100
UK	2000	54.87	66.90	-18	0.00	0.00	-	18.66	18.66	0
	2010	15.83	23.30	-32	0.00	0.00	-	0.78	5.40	-86
	2020	2.62	15.82	-83	0.00	0.00	-	0.09	2.71	-97

Projected estimates on a country-by-country basis for industrial SCIs are shown in Figure 4.16. The decrease in emissions is not as significant, in percentage terms, as that observed for non-industrial emissions, which means that in the future the industrial sector will make an increasing contribution to total SCI emissions.

The industrial inventory only reflects emissions of mercury from the use of solid fuels. As with the non-industrial sectors, the demand for solid fuels in future years is projected to decrease significantly.

Figure 4.16 Projection of industrial SCI emission (from solid fuels) for 2010 and 2020 in comparison to current emission inventory



4.5 EMISSION ESTIMATE UNCERTAINTY

An inventory is commonly compiled by multiplying an emission factor for each source sector by a matching activity factor. We have identified technical shortcomings with the emission factors that are currently used and incompleteness in the statistical information available on fuel consumption in small combustion installations. Indeed much of the data is best treated as qualitative or only semi-quantitative. Consequently we have insufficient published data (or data from unpublished work in progress) to estimate the numerical range of mercury emissions (i.e. the uncertainty) from the SCI sub-sectors.

Ideally inventory values should be quoted together with an indication of their uncertainty. Since numerical ranges convey a false sense of accuracy when calculated from very limited information we have, instead, listed the components that comprise the principal items of the uncertainty budget i.e. the terms that together influence the variability of the estimate of the real value. We have also commented on those items that we feel most determine the nature of the uncertainty and where further work is required to raise the quality of the inventory.

4.5.1 Emission factor uncertainty

Emission factor uncertainty, given the low rate of usage of abatement technologies for SCIs, is dominated by the variability of the mercury content in fuels. This is particularly so for solid coal-based fuels - as demonstrated earlier. Coal composition varies as a function of its source – both country of origin and mine of origin. The mercury content may be reduced by any coal cleaning / processing that is undertaken. In all cases the data relating to the coal composition is a function of the representativeness of the samples taken for analysis and the method of analysis.

Other terms in the uncertainty budget that are important are: the type, capacity, age, and abatement equipment fitted to an SCI appliance; mode of operation; and standard of maintenance. N.B. A single emission factor used to estimate emissions for a heterogeneous sector - such as single house boilers using coal from an undisclosed source - will not necessarily be able to reflect the variability of the emissions.

A further component contributing to uncertainty, in the case where emission factors have been derived by direct emission measurement, relates to how measurements were made, the effectiveness of instrument calibration, and the sampling frequency. Measurement taken from large-scale installations may not be representative of small combustion installations.

The chemical interaction of the various coal components can also be significant. In particular the interactions of mercury and chlorine compounds can influence the chemical speciation of emitted mercury and, depending on the mode of operation of the SCI plant, its emission.

Another issue influencing our views on the uncertainty of the SCI inventory has been the lack of information accompanying the emission factors published in literature; for example missing descriptions of various operational parameters, data on fuel, and the methodology used to measure concentration of pollutants in the flue gases as well as methodology for emission factor calculation.

In the absence of better data and for consistency with other inventory work we have, throughout, adopted the quality rating of uncertainty estimation for emission inventories used by the UNECE Task Force on Emission Inventories and Projections (Pulles et al. 2001).

Table 4.7, gives an estimate of the uncertainty of the default emission factors typically used for estimating mercury emissions. The range of potential error is considerable, particularly for biomass emission factors, which are considered much more uncertain than those for solid fuels.

Table 4.7 Uncertainties rating of mercury emission factors from small combustion installations (need to write '% range')

Fuel	Type of installations	Rating	Typical error (%)
Gas fuel		C	50 – 150
Liquid fuels		C	50 – 150
Coal fuels	Manual fuelled	C	50 – 150
	Automatic fuelled	C	50 – 150
Biomass	Manual fuelled	D	100 – 300
	Automatic fuelled	D	100 – 300

4.5.2 Activity factor uncertainty

The main uncertainty term affecting activity factors concern energy use statistics relate to the levels of biomass use, both historic and projected. Currently available estimates are significantly less certain than those for fossil fuel usage, in particularly where self-supply or direct purchases from local suppliers ('casual' markets) prevail. In addition, the specific quality of the biomass product is difficult to assess, particularly with regard to whether the product has been processed before sale.

Uncertainties relating to coal-based fuels are less but still exist with regard to the type of coal products used in certain sectors. In addition, uncertainty associated with data on the stock of technologies associated with the consumption of these fuels in the RAINS database is also high for certain countries, due to the lack of reporting of this type of data at a national level.

4.6 KEY INVENTORY FINDINGS AND RECOMMENDATIONS

There are a number of key conclusions that can be drawn from the inventory results. In view of these conclusions, recommendations can be proposed concerning the priority country-sectors-fuels-technologies for which policy options could be considered. A number of recommendations have also been proposed for improvements to data availability, and associated inventory research.

4.6.1 Inventory conclusions

The following conclusions can be drawn from the emission inventory estimates:

- **Emissions of mercury from SCI sources in Europe are significant**, accounting for approximately 16% of total mercury emissions in Europe (compared to the figure of 25% in the Mercury Strategy). Despite the observed difference between these estimates, it is clear that SCI sources are a significant source;
- **There is significant variation between countries** in terms of the contribution of SCIs to total mercury emissions;
- At a European level, **the industrial sector accounts for the largest contribution to SCI emissions** (65%), followed by the residential sector (21%). This pattern is observed in most countries although in certain countries e.g. Poland and Germany, the commercial-institutional sector accounts for a similar proportion as the residential sector;

- **Current emissions from non-industrial sources are highest in countries with significant coal use**, in particular Poland, and low in countries where the use of biomass (Baltic countries) or natural gas (Netherlands) predominates. In non-industrial sectors, coal-based fuels account for 63%; when all SCIs are considered, the percentage figure is 86%;
- **Projected emissions of mercury in Europe from SCIs are in excess of 12 tonnes lower in 2020 i.e. 50% of 2002 total**, with the largest relative reductions in non-industrial sectors (compared to the industrial sector);
- **These emission reductions are driven by significant reductions in the use of coal.** In the case of non-industrial sectors; by 2010 and 2020, biomass is the largest source of emissions in these sectors;
- **Significant reductions are seen across most European countries in mercury due to less coal use**, although the percentage decrease differs significantly e.g. the reductions observed for Poland in the non-industrial sectors are much more significant than those observed for Romania. There are significant uncertainties concerning the projected reductions in the use of solid fuels.

The above conclusions provide a reasonable representation of current and projected emissions of mercury from SCIs. However, when basing recommendations on these conclusions, the high uncertainties associated with estimates, as outlined in section 4.5, need to be considered. The uncertainties are primarily due to a lack of knowledge regarding emission factors, and lack of detailed energy consumption data, particularly in relation to variations in mercury content of fuels.

Recommendations for policy need to be considered in light of two key factors; firstly, the projected rate of decrease in the use of solid fuels is uncertain due to the different assumptions made in different projections data. This uncertainty is illustrated in the country comparison of national and RAINS projections. Secondly, industrial estimates are highly uncertain due to the lack of activity data on an installation capacity basis.

Despite the uncertainties, the inventory data is important for enabling cost-effective analysis of options for reducing emissions of mercury. It also indicates that SCI sources are significant, and that the consideration of options for reducing such emissions is sensible. In addition, it is clear that further work is needed in the area of mercury inventories – as illustrated by the recommendations made in the following section.

4.6.2 Recommendations for inventory improvement

There are a number of key recommendations that can be made for the improvement of mercury emission estimates. These concern both issues of inventory data reporting and recommendations for further research.

Inventory reporting

- There is a need to develop reporting of industry sector emissions by installation size if policy makers want to better understand the associated emission / air quality issues. Currently, data on such installations are not available, as energy consumption statistics tend to be reported on the basis of sector rather than plant size. This issue needs to be fed into European working groups, such as the Task Force on Emission Inventories and Projections (TFEIP), so that recommendations for revision to inventory reporting can be made.
- More information is needed from Member States concerning assumptions relating to activity data and mercury content of fuel, to ensure transparency of methods used for estimation, and to enable information sharing between Member States. Comprehensive information on projected fuel use is also important, and the assumptions behind such projections.

- Under CLRTAP reporting (or alternative mechanism if fuel quality directive established), there could be explicit guidance to provide mercury content information for coal used in different sectors. However, such a requirement would result in a significant increase in resource requirements, particularly given the current lack of information on basic coal use statistics (by type).
- Additional data collation on stock of technologies at a national level would improve confidence in estimates, particularly for non-industrial sectors. In addition, a review of the methodologies for collating statistics on quantity and type of biomass used is needed, again to improve confidence in such estimates.

Further research

Based on the experience of developing this inventory, we have highlighted some areas of research to improve understanding of emission factors and activity data.

- Development of country-specific profiles of the mercury content of fuels, particularly for solid coal-based fuels, but also for biomass, which is the least well understood. Given that biomass is an increasingly important fuel in the future means that additional work to understand emission factors associated with biomass burning should be a priority.
- Further research regarding the impact on emissions (and speciation) of different combustion installation
- Further research on the impact of trace compounds in coal on emissions of mercury, in particular chlorine
- Establishment of a measurement programme to derive emission factors and develop sampling techniques for SCIs, potentially based within the ongoing activities of the JRC relating to small combustion installations
- Development of European-wide statistics on biomass consumption to enable improved estimation of emissions. This is also of particular importance for estimation of PM emissions. This could be done through better communication with respective agencies to discuss ways of improving collection and reporting of biomass data.

5 Abatement options

Mercury emissions from SCI sources have been shown to account for a significant proportion of overall European emissions in the previous section. The objective of this section of the report is to assess emission control options that have the potential for reducing such emissions. Options include technical abatement technologies, and preventative options, which can be implemented through different policy initiatives. These options will be considered on the basis of their cost-effectiveness and applicability in terms of reducing emissions in priority sectors. The policy mechanisms through which such options could be introduced are considered in section 6.

This chapter of the report is split into three main sections:

- A description of the cost-effectiveness analysis is provided, including an outline of the assumptions made, uncertainties, and how data should be interpreted (section 5.1).
- Options that lead to the prevention of mercury emissions prior to combustion are known as preventative options, and are defined in section 5.2. Preventative options can be implemented across the broad range of SCIs included in this study, while technical abatement options are typically only applicable for larger installations.
- In section 5.3, technical abatement options are considered. These are options where mercury is removed from the exhaust flue gas of combustion installations.

The speciation of the mercury emission is a key factor in determining the likely effectiveness of a mercury abatement option. However, speciation of combustion mercury emissions is highly uncertain. Speciation has been discussed in section 4.2.3; the potential impacts of speciation on abatement technology are considered in this section of the report.

5.1 DEVELOPING COST-EFFECTIVENESS ANALYSIS

5.1.1 Cost data sources

The majority of cost data for the options analysed were provided by NILU-Polska from the ESPREME cost-effectiveness database. These comprise data describing the options and their capital and operating costs (where available). Data were also sourced from Pierce et al (2002). Expert judgement has been exercised when required to determine the size of installation to which each option can be applied. The assumptions made in the analysis are listed in the following section.

5.1.2 Assumptions in the cost-effectiveness analysis

The ESPREME database includes annualised investment and operating data (where available) based on lifetime costs for measures implemented from now onwards. We note that there are significant uncertainties in this dataset. For a 2020 implementation date it may be expected that investment may be put off for up to 10 years which is what we have assumed. We have calculated net present values and from them estimated annual costs based on 15 year lifetimes and the official discount rate of 4%. We then calculated the net present value were those annual costs deferred for up to 10 years. From this the annualised costs for the later implementation date were calculated.

Costs in the ESPREME database are described in units of cost per unit of energy consumed (€/MWh). We have therefore used the activity rates provided in the emissions inventory to calculate the total unit costs of installing an option.

5.1.3 Uncertainties

Clearly there are significant uncertainties attached to the analysis in this report. These are mainly due to the relative lack of robust data concerning the SCI sector. Hence, in some cases there are currently no known costs for certain options. Also, some costs have no variations to account for size. One would expect some abatement options to be more cost-effective at the larger installations (50 MW) than at the smaller ones.

There will be large site-by-site variation in the actual costs and effectiveness of any given option. These variations are necessarily omitted from this analysis looking at the effectiveness of options applied across Europe.

Finally we have had to apply our own judgement in deciding which options can be applied to certain sizes of installation. In this judgement we have assumed that the more costly options (essentially installing abatement equipment of any type) are only installed in SCI sources >1 MWth. Cheaper options or those that involve preventative measures (including fuel clean-up options) have been applied to all sources including the very small ones such an individual residential sources. Clearly there is uncertainty over the actual size threshold above which the option is viable and this will vary widely across the EU.

5.1.4 Interpreting the cost-effectiveness data

Values in this report are presented in units of €million / tonne of mercury abated relative to the 2010 baseline. For each option the value given is for the stand-alone implementation of that option. In any mercury reduction strategy then perhaps a number of the presented options would be taken-up. The marginal abatement effectiveness and mutual inclusivity of later options will be influenced by those options taken-up first. The analysis of the cost and effectiveness of an overall strategy will be discussed further in section 7, which includes some scenario analysis of options.

In this section, data are presented in tables under the following headings, described in Table 5.1 below.

Table 5.1 Presentation of technology cost data

Table heading	Description
Sector	Categorises options based on the following sector split - IND = industry, NI = non-industry
Fuel	Categorises options based on fuel - HC = hard coal, BC = brown coal, G = gas, B = biomass, L = liquid
Size	Categorises options based on installation size - M = medium (50-20 MWth), S = small (20-1 MWth), VS = very small (<1 MWth).
Option	Description of abatement option
Uptake by 2020 (%)	Considered to be the uptake of the option under the baseline 'business-as-usual' scenario. Significant uncertainties relate to this parameter, with 0% assumed in many cases in the absence of additional data.

Table heading	Description
Abatement efficiency (%)	Typical removal efficiency of a given option
Potential Hg abatement (t)	Total emissions abatement of a given option based on its potential implementation
Total cost (€mn)	The total cost related to the potential emissions abatement
C-E (€mn/t Hg abated)	The cost-effectiveness of a given option e.g. the cost per tonne abated

Below is an example of the calculation used to calculate the cost per tonne of mercury abated, which has been labelled 'C-E'.

Conventional Coal Washing applied to Small Industrial Plant using Hard Coal

Baseline mercury emission in 2020 = 4.998t
Estimated BAU take-up of coal washing by 2020 within the sub-sector = 70%
Incremental mercury abatement efficiency of the measure = 25%
Baseline energy consumption associated with the emissions in 2020 = 555 300 TJ
Estimated annualised capital cost of abatement (ESPREME data) = 0 €/MWh
Estimated annualised operating cost of abatement (ESPREME data) = 0.0147 €/MWh

Calculated incremental mercury abatement due to measure:
Baseline emission x remaining potential uptake of measure x abatement efficiency
4,998t x (100-70)% x 25% = 0.375t

Calculated incremental cost of abatement measure:
(operating + capital cost)/unit energy x energy consumed x unit energy conversion factor
(0+0.0147) x 555 300 / 3600 = 2.266 €mn

Calculated C-E of abatement measure:
Incremental cost / incremental mercury abatement
2.266 / 0.375 = 6,046 €mn/t

5.2 PREVENTATIVE MEASURES

Preventative measures are options that ensure that the release of mercury emissions are prevented prior to combustion processes. They are wide ranging, and can be implemented across a range of types of small combustion installation. This section describes each option in detail, and where relevant, outlines the cost-effectiveness data to be used in the subsequent scenario analysis.

5.2.1 Fuel Quality

Effective fuel quality management can have a significant impact on emissions of a range of pollutants including mercury.

Coal
The pre-treatment of coal and other solid fuels to improve fuel quality is a well-established preventative measure primarily used to raise calorific value (CV), by removing non-inherent ash and dirt, reduce sulphur, control physical size and moisture. Examples of fuel quality improvement include:

- *Pre-treatment of coal*, e.g. coal washing. Raw coal may contain up to 35% dirt; coal preparation by sizing and then washing with water will reduce the ash content often to around 7%, and can also reduce the sulphur content of the coal. The larger clean lumps of coal that are derived from coal preparation are commonly used for domestic and industrial processes, whilst the finer (sub-25mm) coal particles are processed and blended according to power station fuel requirements.
- *Pre-treatment of solid fuels to produce smokeless fuels*. For example, the carbonisation of coal will reduce the volatile content (typically from around 35% to around 2%) to produce "smokeless" fuels such as coke.
- *Modification of granular fuels through compacting* (briquetting, pelletising) to enable automated feed systems to be employed. The use of automated rather than manual fuel feed systems enables more control over combustion conditions, increasing combustion efficiency.
- *Reduction and homogenisation of moisture contents of fuels* (e.g. the development of consistent biomass pellets) to facilitate more stable combustion conditions, which can provide greater use of automatic systems and efficiency benefits.

It also important to note that the natural quality of fuels is a significant factor in terms of emissions, particularly for solid fuels which vary significantly in terms of energy, moisture, ash, and sulphur content.

In relation to mercury abatement, this section focuses on pre-treatment of coal, known as coal washing. Reducing the mercury content of coal can be done by the treatment (or washing) of coal after mining and before use, and can be categorised into the following three types – physical, chemical and biological.

The physical method of coal cleaning consists of mechanical separation of fuel components through processes of flotation and gravitational separation. This includes the removal of mineral matter and pyrite sulphur. It is assumed that most coal that is mined in Europe or imported will have some level of this conventional coal washing.

Under the chemical method, coal is subjected to chemical reactions with solutions of different compounds, mainly sodium and potassium based. These compounds effectively leach sulphur and mineral matter, more efficiently removing mercury bound with incombustible mineral matter but do not affecting the mercury bound to organic matter.

Emerging techniques of bio-chemical cleaning are presently in the R&D phase. Only this type of technique can remove the organically-bound mercury. Initial results are promising and may become an alternative to conventional physical methods. However, due to high costs, the use of such techniques, when available, may have slower uptake (Brown 1999).

Physical methods of coal pretreatment are being enhanced, particularly given the limitations of conventional cleaning methods. Enhanced treatments categorized as froth flotation columns, in combination with conventional cleaning, have been shown to remove 40-82% of mercury from the raw coal (Smit 1996). This method is used across Europe in some mining operations although data on the implementation of enhanced washing techniques is not readily available.

In summary, traditional methods may have a removal efficiency of between 20-30% while more advanced techniques can lead to 40-80% reduction efficiencies.[8] Much of the

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[8] U.S.-EPA Research and Development, Prepared by National Risk Management Research Laboratory, Control of mercury emissions from coal-fired electric utility boilers"; Office of Air Quality Planning and Standards

research on coal washing has been carried out on finer coal assortments, which tend to be used in larger industrial facilities. The conventional method of cleaning is less effective where coal fraction sizes are larger – in smaller stoves and boilers (e.g. found in the non-industrial sectors) the size of coal fraction tends to be higher.

The measures have been analysed for their mercury abatement cost-effectiveness. Table 5.2 summarises the estimated costs and effectiveness of these measures where they are available. The 'Conventional coal washing' option reflects the above physical method, while 'Enhanced coal washing' is the enhancement of physical methods through froth flotation.

We have assumed that most coal will have been washed using a conventional technique (70%) while enhanced coal washing will be less prevalent (30% uptake).[9] These uptake numbers are based on expert judgement. We have assumed that enhanced cleaning methods would not be applicable to solid fuel used in small installations as such installations would generally not be able to use coal that had been crushed into smaller fractions during the enhanced cleaning process. The costs of enhanced coal washing will be higher than conventional methods; in the absence of any cost data, these have assumed to be double the cost of conventional techniques.

Table 5.2 Summary of cost-effectiveness data for coal cleaning

Sector	Fuel	Size	Option	Uptake by 2020 (%)*	Abatement efficiency (%)	Potential Hg abatement (t)	Total cost (€mn)	C-E (€mn/t Hg abated)
IND	HC	M	Conventional coal washing	70	25	0.25	1.51	6.05
			Enhanced coal washing	30	65	1.52	3.02	1.99
		S	Conventional coal washing	70	25	0.37	2.27	6.05
			Enhanced coal washing	30	65	2.27	4.53	1.99
NI	HC	S	Conventional coal washing	70	25	0.03	0.07	2.30
			Enhanced coal washing	30	65	0.18	0.14	0.76

Notes: Sector: IND = industry, NI = non-industry; Fuel : HC = hard coal; Size : M = medium (50-20MWth), S = small (20-1MWth), VS = very small (<1MWth). 'C-E' is the cost-effectiveness of the option, based on the calculated costs per tonne of mercury abated.

Oil

A report on mercury in hydrocarbons for the USEPA indicates that mercury in crude oils is lower than coal but can vary widely. Various techniques are used to strip mercury from the refinery streams. Refined oil grades have low levels (generally less than 1 ppb) but mercury concentrations appear to be concentrated in products such as Naphtha, petroleum coke and, to a lesser extent, residual fuel oils. Petroleum coke has been used as a constituent in manufactured solid fuels.

Recovered oils resold for larger scale combustion use are likely to have had cleaning which may reduce their mercury content; however small-scale combustion of waste oil remains a potential emission source. Liquid biofuels are unlikely to have significant mercury emissions, and are not considered further in the cost-effectiveness analysis.

Gas

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[9] A 100% value would mean that the option had been fully implemented, and was reflected in the baseline inventory.

Many natural gas resources receive treatment to remove mercury before transmission to consumers. This is generally undertaken to avoid damage to processing and transport infrastructure rather than for mercury emission reasons. This pre-treatment is also likely to be necessary for gasification processes for example in clean coal technologies.

Fuel gases with potential for mercury emission include landfill gas and gasification of coal (including in-situ gasification). It is unlikely that coal gasification plant would be permitted without mercury treatment. Treatment of landfill gas for mercury is not usually undertaken and is used in SCIs for small-scale electricity generation. Gasification options are effectively fuel switching and are likely to require appliance replacement and transmission infrastructure (particularly if applied to residential SCIs).

None of the above options are highly relevant to SCI mercury abatement, and levels of mercury from gas use are low; therefore, these options are not considered further.

5.2.2 Fuel Switching

Where the use of a specific fuel type is identified as a significant polluting source, substitution to an alternative fuel with lower mercury content may lead to significant emission reductions.
Fuel switching may not necessarily require a change in appliance e.g. high mercury bituminous coal being replaced by a lower mercury coal or other solid fuel. However, fuel switching to a different type of fuel retaining the existing appliance is not likely to provide as much benefit as a new appliance designed for the replacement fuel.

Changing to natural gas or oil from solid fuel will incur significant capital costs due to appliance replacement. Fuel switching options are limited, in practice, by the availability and price of alternative fuels and associated combustion appliances.

A key example is the replacement of solid fuel appliances with natural gas based appliances. This has been an important trend across many Western European countries in the last 20 years following the establishment of extensive gas distribution networks. Such replacement of appliances and boilers is clearly limited by the availability (and price) of new technologies and suitable fuel distribution networks or market. Replacement of coal with refined natural gas can reduce potential mercury emissions by more than 99%; reductions of PM and SO_2 will be of similar magnitude. Where natural gas is not available, the use of liquid fuels or LPG could be potential options.

Fuel blending (for example coal with biomass or other low mercury coal) can also reduce mercury emissions. In addition, for low rank coal combustion plant, blending with a high rank coal is reported to provide improved performance of abatement measures for mercury. This may be of particular benefit to larger SCIs.

The measures described in the previous section have been analysed for their mercury abatement cost-effectiveness. Table 5.3 summarises the estimated costs and effectiveness of these measures where they are available.

It is clear from the inventory that a significant amount of switching away from solid fuels will be occurring up to 2010, and this has been modelled in the fuel consumption data used in the inventory. The uptake figures (in Table 5.3) are set as 0%, as these options refer to additional action beyond what is modelled in the inventory. 0% indicates no additional take-up by 2020 under a business-as-usual scenario. The fuel switching measures only apply to hard coal due to the absence of brown coal in the inventory in later years.

The benefits from such measures, in terms of mercury emission reduction, are considered further in section 7, where proposals are described for scenario analysis.

Table 5.3 Cost-effectiveness of fuel-switching options for mercury reduction

Sector	Size	Fuel	Option	Uptake by 2020 (%)	Abatement efficiency (%)	Potential Hg abatement (t)	Total cost (€mn)	C-E (€mn/t Hg abated)
IND	M	HC	Fuel switch: hard coal to oil	0	75	1.00	20.68	20.69
			Fuel switch: hard coal to gas	0	95	1.90	20.68	10.89
			Coal blending with low mercury coal	0	30	1.00	0.50	0.50
	S		Fuel switch: hard coal to oil	0	75	1.50	31.02	20.69
			Fuel switch: hard coal to gas	0	95	2.85	31.02	10.89
			Coal blending with low mercury coal	0	30	1.50	0.76	0.50
NI	S	HC	Fuel switch: hard coal to oil	0	75	0.12	0.93	7.86
			Fuel switch: hard coal to gas	0	95	0.23	0.93	4.14
			Coal blending with low mercury coal	0	30	0.12	0.02	0.19
	VS		Fuel switch: hard coal to oil	0	75	0.15	3.24	20.93
			Fuel switch: hard coal to gas	0	95	0.29	3.24	11.01
			Coal blending with low mercury coal	0	30	0.15	0.08	0.51

Notes: Sector: IND = industry, NI = non-industry; Fuel : HC = hard coal; Installation size M = medium (50-20MWth), S = small (20-1MWth), VS = very small (<1MWth). 'C-E' is the cost-effectiveness of the option, based on the calculated costs per tonne of mercury abated.

5.2.3 Replacement with more modern SCI appliances (including boilers)

An important measure, particularly for smaller SCIs, is the replacement of older appliances by more efficient or less polluting appliances that have improved combustion design and controls. Improved thermal efficiency reduces fuel consumption, which means less potential for mercury emission, providing potentially significant fuel cost savings and the associated benefit of reduced greenhouse gas emission per unit of heat recovered. Such combustion units commonly exhibit more complete combustion and lower emissions per unit of energy input. The replacement can also provide significant reductions in emissions of PM and other pollutants.

5.2.4 Retrofitting of improved combustion systems

Modifications to existing units can be made to improve appliance efficiency (less fuel use leading to lower mercury emission); for example, improving the control of fuel-air mixture, pre-heating combustion air, increasing turbulence in the combustion zone, or replacing grate or fuel feed designs with more efficient alternatives (e.g. the use of inserts to convert open fireplaces to more controllable semi-closed stoves). The retrofitting of improved control instrumentation and combustion management systems (such as lambda and temperature sensors) can significantly improve efficiency. This type of combustion control modification becomes increasingly viable in economic terms for all but the smallest SCI plant.

5.2.5 Best practice in SCI operation

For solid fuel and biomass appliances, emissions can be reduced through correct operation of an appliance, appropriate patterns of usage, and selection of compatible, properly specified fuel. These management techniques optimise the overall efficiency of the appliance and can improve fuel consumption. Costs and reduction efficiencies will be specific to the levels of best practise adopted. No specific options have been considered in the cost-effectiveness analysis.

5.2.6 Reducing the demand for energy

Emissions reductions can be achieved by reducing energy requirements, which may be achieved through improved maintenance of an appliance and associated equipment, reducing the need for heating through better insulation and other measures, and by installing appropriate sized appliances, according to the heating needs of a building. For example, measures such as improving insulation, glazing and door seals in a building can reduce heat demand. Similarly installation of more refined temperature control can reduce heat demand. Regular audits of energy use in industrial and larger facilities will identify heat losses.

The measures described in the previous sections have been analysed for their mercury abatement cost-effectiveness. The estimated costs and effectiveness of these measures, where available, are summarised in Table 5.4. This measure is a cost saving due to lower fuel use in the long term. The costs of insulation are unlikely to be attributable to a mercury reduction strategy in any case since they should occur under policy obligations to improve building energy efficiency.

Table 5.4 Cost-effectiveness of improvements to boiler efficiency

Sector	Size	Fuel	Option	Uptake by 2020 (%)	Abatement efficiency (%)	Potential Hg abatement (t)	Total cost (€mn)	C-E (€mn/t Hg abated)
IND	M	HC	Reduced fuel use through efficiency (e.g. insulation)	0	11	0.18	0	0.0
	S	HC				0.28	0	0.0
NI	S	B				0.03	0	0.0
		G				0.01	0	0.0
		HC				0.02	0	0.0
		L				0.02	0	0.0
	VS	B				0.07	0	0.0
		G				0.00	0	0.0
		HC				0.03	0	0.0
		L				0.01	0	0.0

Notes: IND = industry, NI = non-industry, HC = hard coal, BC = brown coal, G = gas, B = biomass, L = liquid, M = medium (50-20MWth), S = small (20-1MWth), VS = very small (<1MWth). 'C-E' is the cost-effectiveness of the option, based on the calculated costs per tonne of mercury abated.

The benefits from such measures, in terms of mercury emission reduction, are considered further in section 7, where proposals are described for scenario analysis. 0% uptake number does not reflect current uptake of energy efficiency measures in the emission inventory.

5.3 TECHNICAL ABATEMENT OPTIONS

Abatement controls may be fitted to combustion plant to remove mercury from flue exhaust gases. Some mercury abatement measures are associated with abatement measures for other pollutants (principally particulate and sulphur dioxide); in this section, these are referred to as 'indirect' options. There are also several techniques specifically for mercury abatement (referred to as 'direct' options). Note that, in general, abatement techniques have been designed / optimised for larger combustion processes, or process emissions with higher mercury concentrations than are generally found in combustion exhaust gases of SCIs. Therefore, most of the options listed are applicable to plant greater than 20 MW.

We first consider abatement options associated with control of other pollutants ('indirect' control), and then identify those options specifically for mercury abatement ('direct' control).

5.3.1 Indirect mercury abatement options

Particle Abatement and mercury control
Particulate control can help reduce mercury emissions; however as the bulk of mercury emitted is likely to be in the vapour (rather than particulate) phase, the scope for mercury control through particulate matter (PM) abatement measures is limited. Mercury removal efficiencies due to particulate abatement given in the literature are variable. The speciation data developed in this project suggests that there should be limited opportunity for mercury emission reduction by applying PM abatement but ESPREME and other sources indicate that mercury reduction can be substantial.

For larger commercial and institutional plant and industrial plant (1-50 MWth) the use of particulate abatement systems with solid and biomass fuels are prevalent. Table 5.5 provides a list of abatement technologies for particulates, indicating what the typical mercury reduction efficiencies are, based on existing literature (e.g. ESPREME, DTI 2003 / 2004, UN 2002).

Cyclone separators can typically achieve 75-85% (total) PM reduction efficiencies, a series of cyclones may be used to improve the PM capture efficiency to around 95%. No data have been obtained for the mercury-removal performance of cyclone devices. In the cost-effectiveness data collated under ESPREME mercury reduction for cyclones is not applied. This may or may not be reasonable[10], although it is unlikely that mercury removal efficiency is better than for other PM abatement devices cyclones can and are used in smaller plant and some reduction is probable; therefore, a range of 0-20% for mercury removal by cyclones has been applied.

Wet venturi-scrubbers inject water or other liquid media into the flue gases, where the PM is combined with the larger liquid droplets, which are then removed by a cyclone device. These devices have the advantage of cooling the exhaust gases, which could enhance mercury removal. In addition, chemical treatment of the liquid phase, for example for acid gas control, could provide further mercury reduction. Disadvantages include a high pressure drop and a liquid effluent. No data are available for coincidental mercury removal when they are used as PM abatement; however, if used as a Flue Gas Desulphurisation (FGD) system then mercury removal efficiency will be similar to wet FGD performance.

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[10] N.B. These devices are relatively low energy and remove the larger particle sizes whereas mercury will tend to be associated with the smaller particles that are captured less efficiently.

Table 5.5 Summary of mercury reductions associated with PM abatement measures

Abatement measure	Mercury control effectiveness	Comment
Cyclone / multicyclone	0-20%	No data, range is estimate based on other PM abatement and netcen expert judgment
Venturi scrubber	0-30%	No data, range is estimate based on other PM abatement and netcen expert judgement. ESPREME indicates <10% for venturi scrubber without additives and 50% if using chemical treatment
Electrostatic Precipitator (ESP)	0-82% (cold-side) 0-16% (hot-side)	Very variable range of capture efficiencies. US EPA found 36% for bituminous and 3% for sub-bituminous coal. UK data for large combustion plant indicate 50% retention for bituminous coal. ESPREME scenarios indicate range of 0-90%. US EPA found Hg removal efficiency of 42-83% on oil-fired boilers. Coldside refers to plant installed downstream of heat recovery equipment.
Fabric Filter	0-90%	USEPA found 80% for bituminous and 70% for sub-bituminous coals. Limited available data.
Enhanced ESP	0-50%	One test unit
Wet ESP	30%	From two pilot studies. ESPREME scenario of 98% when applied to oil-firing.
Combined ESP + fabric filter	34-87%	From 2 pilot facilities, higher figure may be from use of powder activated carbon

NB. Particulate removal efficiencies of different abatement equipment were discussed further in the previous report (AEA Technology 2004).

Electrostatic precipitators can achieve particulate removal efficiencies of between 99.5-99.9%. However, the costs of this technology are currently too high to be economically feasible for appliances less than 20 MWth.

Fabric filters achieve a very high particle removal efficiency of particulates of about 99.9%, but are limited in their range of application to SCIs. The use of fabric filters on combustion plant has tended to be on specific types of combustion process (for example biomass wastes requiring low PM emission). It is considered that the main reason that fabric filters are not used on conventional combustion plant is economic. They are also restricted to use in gas temperatures of (typically) below 200°C. Biomass combustion processes may use fabric filters but often also require use of cyclone upstream of the fabric filter as a pre-separator to remove burning particles to minimise the potential loss of fabric filter from fire.

A recent technology review for the UK Department of Trade and Industry (DTI 2004) suggests that on LCPs, fabric filters may offer enhanced mercury removal compared to electrostatic precipitators because there is more intimate contact between the flue gases and the particulate in a fabric filter. However, this may not be replicated for SCIs because most SCIs employ different combustion techniques, which are likely to result in differing speciation of mercury and, different physical and chemical composition of the fly ash.

The use of particulate abatement, where applicable, will also lead to reductions in other pollutants with a solid phase component (PAHs, dioxins and furans and other heavy metals). The above options are only likely to be considered where there are specific issues associated with emissions of PM; in such instances, multi-pollutant benefits can be realised. Consideration of action proposed under the CAFE programme is therefore important. For this study, it is also important to determine how far such abatement technologies have been implemented for larger SCIs.

Each of the measures described in the previous section have been analysed for their mercury abatement cost-effectiveness. Table 5.6 summarises the estimated costs and effectiveness of these measures where they are available.

Table 5.6 Cost effectiveness of selected particulate abatement options for mercury control

Sector	Fuel	Size	Option	Uptake by 2020 (%)	Abatement efficiency (%)	Potential Hg abatement (t)	Total cost (€mn)	C-E (€mn/t Hg abated)
IND	HC	M	Dry ESP	15	40	1.13	128	113
			Fabric filters medium	3	45	1.45	269	185
			Optimised fabric filters (coal)	3	90	3.17	407	129
			Retrofitted fabric filters	0	70	2.33	105	45
			Fluid-bed abatement + FF/ESP	2	85	2.78	820	296
			PAC + FF (coals)	0	98	3.27	484	148
		S	Dry ESP	15	40	1.70	192	113
			Fabric filters medium	3	45	2.18	403	185
			Optimised fabric filters (coal)	0	90	4.50	611	136
			Retrofitted fabric filters	0	70	3.50	158	45
			Venturii scrubber	0	30	1.50	789	526
			PAC + FF (coals)	0	98	4.90	726	148
NI	B	S	Dry ESP	30	40	0.16	47	305
			Abatement for biomass - upgrade to BAT through dry ESP	15	70	0.33	127	385
			Fabric filters medium	3	45	0.24	99	412
			Venturii scrubber	0	30	0.17	194	1173
	HC		Dry ESP	15	40	0.13	6	43
			Fabric filters medium	3	45	0.17	12	70
			Retrofitted fabric filters	0	70	0.28	5	17
			Venturii scrubber	0	30	0.12	24	200
			PAC + FF (coals)	0	98	0.39	22	56
	L		Dry ESP	0	40	0.16	828	5161
			Abatement for oil-fired plant - wet ESP	0	62	0.24	1335	5637
			Venturii scrubber	0	30	0.12	3411	29765

Notes: Sector: IND = industry, NI = non-industry; Fuel : HC = hard coal, BC = brown coal, G = gas, B = biomass, L = liquid; Installation size : M = medium (50-20MWth), S = small (20-1MWth), VS = very small (<1MWth); Option abatement technologies FF = fabric filters, ESP = electrostatic precipitators. 'C-E' is the cost-effectiveness of the option, based on the calculated costs per tonne of mercury abated.

SO_2 abatement and mercury

Wet SO_2 removal processes are reported to remove significant quantities of mercury from flue gases. These processes are primarily found on much larger combustion plant but smaller units are commonly fitted to incineration plant and to certain industrial processes, which can have similar flue gas flow rates to SCIs. Similar abatement technology is also found in many other small-scale process industries but for other pollutants. Acid gas abatement technology on incineration plant is generally either a semi-dry or dry process and consequently is likely to have different mercury abatement efficacy than the wet processes typically used on power stations.

Abatement measures for SO_2 are considered less practical for the smaller SCIs. Such measures are most practicable (in technical and economic terms) for large plant e.g. the use of flue gas desulphurisation (FGD) on power plant. However, small-scale wet FGD has been applied to boiler plant less than 50 MWth in other countries (for example China) although often these systems are comparatively simple with moderate SO_2 abatement efficiency.

Table 5.7 summarises the mercury abatement that is considered possible with typical FGD systems as applied to coal-fired utility boilers and other processes (DTI 2003 / 2004). There are some major variations in the published retention efficiencies for mercury from FGD plant. The main issues are that retention is primarily of reactive gaseous mercury (RGM - typically the inorganic $HgCl_2$ form) so if a process has a low proportion of RGM in the unabated emission then conventional FGD alone is unlikely to reduce emissions significantly. A variety of factors can affect mercury speciation from an SCI but data suggest that low rank (for example brown coal) and low chlorine coals are unlikely to achieve high mercury capture with FGD.

Table 5.7 Mercury removal by acid gas abatement technologies

Abatement measure	Mercury control effectiveness	Comment
Wet limestone scrubber	Up to approximately 70%	Up to 90% removal of RGM. No removal of elemental Hg – indeed potential re-release across scrubber. Effectiveness dependent on mix of mercury types at inlet to FGD and other factors such as chlorine content of coal and, coal rank (bituminous coals better than sub-bituminous or lignite). SCR can help increase removal efficiency (>80% for bituminous coals). Oxidising additives may also improve collection.
Dry and semi-dry scrubber with fabric filter	Up to approximately 70%	This is inconsistent with mercury capture efficiency of fabric filter PM abatement. Effectiveness dependent on mix of mercury types at inlet to FGD and other factors such as chlorine content, coal rank (bituminous coals better than sub-bituminous or lignite). Lime scrubbers show better mercury removal in pilot tests
Sea water scrubber	20%	Predicted at low-chlorine coal-fired boiler, no data

Mercury has been reportedly re-emitted from wet limestone FGD systems. This is based on determination of higher concentrations of elemental mercury at the FGD outlet compared to the inlet.

Wet limestone slurry FGD systems have a high recirculation rate and it has been suggested that RGM captured in the liquid phase can be converted to elemental mercury, which may be re-emitted.

There is research underway to develop flue gas treatment and FGD reagent additives, which increase the proportion of RGM to improve mercury capture and minimise subsequent transformation to elemental mercury in FGD plant. The waste incineration draft BREF reports that mercury removal of up to 85% can be achieved in wet scrubber systems used for SO_2 and HCl by addition of activated carbon and oxidising agents (hydrogen peroxide, chlorite ion). Further improvements are reported from injection of bromine into the furnace. There is evidence that SCR can improve mercury retention in FGD plant fitted to coal-fired utility boilers.

The use of FGD generally reduces emissions of PM and those pollutants with a particulate phase. In addition to SO_2 abatement, reduction in hydrogen chloride emission can be expected. However, there is an efficiency loss, wet plumes may require reheat to aid dispersion or appearance and, additional waste streams are generated.

The measures described in the previous section have been analysed for their mercury abatement cost-effectiveness. The following table summarises the estimated costs and effectiveness of these measures where they are available.

Table 5.8 Cost effectiveness of selected particulate abatement options for mercury control

Sector	Fuel	Size	Option	Uptake by 2020 (%)	Abatement efficiency (%)	Potential Hg abatement (t)	Total cost (€mn)	C-E (€mn/t Hg abated)
IND	HC	M	ESP+wet/dryFGD+PAC injection,	5	98	3.10	343	110
			wet FGD (state-of-the-art.)+ESP	4	70	2.24	688	307
			wet FGD + FF	0	70	2.33	493	211
			dFGD (state-of-the-art)	0	70	2.33	786	337
		S	ESP+wet/dryFGD+PAC injection, coal-fired SCIs	5	98	4.65	514	110
			Wet scrubbers, low tech	0	30	1.50	667	445
			wet FGD (state-of-the-art.)+ESP	4	70	3.36	1032	307
			wet FGD + FF	0	70	3.50	740	211
NI	B	S	Wet scrubbers, low tech	0	30	0.17	164	991
	HC		ESP+wet/dryFGD+PAC injection, coal-fired SCIs	5	98	0.37	15	42
			Wet scrubbers, low tech	0	30	0.12	20	169
			wet FGD (state-of-the-art.)+ESP	4	70	0.27	31	117
			wet FGD + FF	0	70	0.28	22	80
	L		Wet scrubbers, low tech	0	30	0.12	2881	25145
			wet FGD (state-of-the-art.)+ESP	35	70	0.10	4461	44917
			Dry FGD (state-of-the-art)	0	70	0.27	5096	19060

Notes: Sector : IND = industry, NI = non-industry; Fuel : HC = hard coal, B = brown coal, G = gas, B = biomass, L = liquid; Installation size : M = medium (50-20MWth), S = small (20-1MWth), VS = very small (<1MWth); Option abatement technology : FGD = flue gas desulphurisation, PAC = pulverised activated carbon, FF = fabric filters, ESP = electrostatic precipitators. 'C-E' is the cost-effectiveness of the option, based on the calculated costs per tonne of mercury abated.

NOx abatement and mercury abatement

Low NOx burners at pulverised fuel (PF) fired utility boilers have been suggested as providing indirect mercury reductions through increase in unburnt carbon in the fly ash. However it is unlikely that PF combustion is used in many SCIs.

Selective catalytic reduction (SCR) and selective non-catalytic reduction (SNCR) are post-combustion control techniques for NOx reduction. Research on utility boilers indicates that SCR can enhance the proportion of RGM and this can benefit subsequent removal of mercury in a downstream FGD unit. The effect is coal dependent with less benefit observed using sub-bituminous low chlorine coal.

Limited data are available on the impact of SNCR on mercury emissions but measurements on an SNCR plant with urea injection indicated no significant change in mercury collection across downstream ESPs (DTI 2003 / 2004).

No scenarios are proposed for mercury reduction using only NOx control technology and the ESPREME database does not include cost data for these technologies. Hence we do not present cost-effectiveness data for them in this report.

5.3.2 Direct mercury abatement options

This section describes those technologies that are used as abatement options specifically targeting mercury emissions.

Combustion processes
The available techniques for removal of mercury from combustion flue gases are restricted to a few well-established technologies. For example powdered activated carbon (PAC) injection with fabric filter collection is a proven technology used in incineration plants throughout the world; however these abatement techniques are typically installed on combustion units greater than 10 MWth, which is toward the larger SCI units.

Similar technology has been developed for application on utility boilers, cement works and, at a more relevant scale to SCIs, crematoria . For crematoria, heat recovery / heat removal plant are required to reduce exhaust temperatures to a level compatible with the carbon and filter. Crematoria are perhaps equivalent to a 600kW (thermal input) boiler. The PAC is usually injected as a carbon / lime or carbon / sodium bicarbonate mixture. Capital costs of this type of mercury abatement systems on crematoria are of the order of €390k-630k for 1-3 cremators respectively. The nominal additional cost of mercury abatement is €83 per cremation, which assuming a cremation period of 1 hour and 600kW input, is about €38/MWh.

The other main mercury abatement technology applied to crematoria is packed bed absorbers containing carbon and support media. A selenium-impregnated cartridge has been installed at one installation but this requires particulate abatement and heat recovery upstream of the collection media to precondition the flue gases to avoid blockage of the selenium cartridge. The cartridge is not intended as a particle removal device and has no capacity for removing accumulated particulate. A further comparatively low technology option for crematoria includes addition of a quantity of selenium placed in a container on the coffin lid prior to the cremation. Conflicting test results have been reported.

The emission concentration of mercury in combustion gases from fossil and other fuels are likely to be lower than for crematoria and incineration plant. Consequently, the potential abatement efficiency for SCIs may not be the same as reported as achievable for other processes. Table 5.9 provides a summary of mercury abatement technologies (DTI 2003 / 2004, UN 2002).

Table 5.9 Mercury abatement technologies (combustion gases)

Abatement technology	**Mercury control %**	**Comment**
Carbon injection + fabric filter	>85	As applied to incineration plant, 55-80% for coal. USEPA data 91.5 % average efficiency for MSW applying several technologies. >95% reported for cement kilns
Carbon bed filtration	>99	As applied to incineration plant
Selenium filter	>90	As reported for metallurgical applications

Condensing scrubbers are a potential but not widely regarded abatement option for incineration plant in the specific instance where a plant has a readily available cooling source (the example cited (European IPPC Bureau 2005) is a particularly cold (40 ºC) district heating water return, which is generally only encountered in colder climates). The application of the technique in other circumstances would require energy input to provide the cooling required. The temperature of the scrubber effluent is critical to ensure elemental mercury is condensed and does not pass through the scrubber to be released to air. To be effective for elemental Hg removal, scrubber outlet temperatures of below 40 °C may be required but it is also reported that temperatures as low as 5 °C are not adequate for mercury removal. This method is not considered as sufficient abatement for compliance with WID. This option is not one that we consider further but is mentioned here as part of this comprehensive review.

Process emission technologies
Most of these technologies for non-combustion process gases have been applied to metallurgical processes. Other reported applications include abatement of non-condensable gases from geothermal energy processes. Mercury concentrations in exhaust gases from such processes may be substantially higher than at SCIs. Also the mercury speciation is likely to be different from combustion flue gases of SCIs. For example some reported inlet concentrations are much higher than would be found for an SCI.

Selenium addition has been demonstrated to enhance mercury capture from crematoria and metallurgical processes. The measure involves adding selenium which, during combustion, reacts with mercury to form the stable compound mercury selenide; cooling the flue gases prior to particulate abatement may then be necessary. **Carbon bed filteration,** a fairly low technology devices can also be remove mercury effectively.

Other available technologies tend to be variations on these abatement technologies (DTI 2003 / 2004, UN 2002).

Table 5.10 Mercury abatement (process emissions)

Control technology	Mercury removal %	Comment
Selenium filter	>90	
Selenium scrubber	90-95	Efficiency data relates to high inlet concentration metallurgical processes. Residual outlet concentration is higher than typical coal combustion.
Carbon filter	90-95	
Odda chloride		No efficiency data. For high inlet concentration metallurgical process. Residual outlet concentration is higher than typical coal combustion.
Lead sulfide	90-99	Efficiency data for high inlet concentration. Residual outlet concentration is similar or higher than typical coal combustion.

It is unlikely that the Selenium scrubber, Odda chloride or lead sulfide processes could be applied to SCIs as they may not be suited to low concentration applications. In all instances there are potential additional wastes or effluents.

The abatement technologies for mercury are not considered to have a direct impact on other pollutants but some require treatment of exhaust gases to avoid contamination of absorbent or catalyst. Generally such pre-treatment will reduce particulate emissions and consequently emissions of those pollutants with a particulate phase will also be reduced. However, additional waste streams are generated.

The direct measures considered most appropriate technologies for SCIs are PAC injection coupled with fabric filter collection and, packed carbon absorber/carbon filter. The PAC injection option has been considered in Section 5.3.1. No cost data have been determined for carbon filter technology and consequently this option has not been developed further.

5.4 SUMMARY OF ABATEMENT OPTIONS

In this section, a range of abatement options has been reviewed, including preventative measures which are applicable to all SCIs, and flue gas abatement options, applicable only to the larger SCIs and often driven by need for abatement of other pollutants. For each option, the costs and reduction have been assessed where data is available, and the practicalities of implementation discussed.

Based on this review, the following conclusions can be drawn:

- **Options relating to efficiency improvements are the most cost-effective**, primarily because the costs are not associated with mercury reduction. Therefore, it is important to consider where other policy options related to energy efficiency have benefits for mercury reduction. Clearly, such options would not be implemented specifically for mercury emission reduction alone;

- **Fuel quality options are the next most cost-effective type of measure**, including coal washing / blending, and the use of lower mercury content coal. Such preventative measures are cost-effective due to low costs associated with washing / blending, or the low cost-differential between different types of coal. A major area of uncertainty is the current uptake of such measures, and the costs associated with the enhanced coal washing technique;
- The next most cost-effective option is another preventative option, **the switching away from coal to alternative fuels such as gas / oil.** Higher costs to the previous option will be incurred due to appliance replacement or retrofit;
- **Few flue gas abatement technologies exist specifically for mercury reduction**, and those that do are unlikely to be considered for SCIs. There are a number of options that might be considered for larger SCIs for other pollutants, such as PM and acidifying gases, which have significant benefits for the reduction of mercury emissions. These are considered the least cost-effective in the list of abatement options. Other areas of air quality policy will drive the implementation of these abatement techniques, and therefore co-ordination with such policy areas would be beneficial;

  There are some emerging technologies for SCIs being developed particularly aimed at reducing particulate matter from small combustion installations, for example the SCAPA R & D project under the European 5th Framework programme, established in response to particulate emission problems from SCIs (200 kW – 5 MW) in Eastern and Central Europe. Under this project, technologies should be ready for the market in the next 12 months. The benefits to mercury reduction and the costs of this technology are not yet known.[11] However, such technologies may be an important future abatement options in areas where coal use persists, and could lead to significant reductions in mercury as well as PM.

The above options are considered further within the framework of a scenario analysis (described in section 7), including the types of policy mechanisms that might be required for their implementation. There are considerable uncertainties associated with the cost data, and further research is required. It is recommended that the results from the ESPREME project, from where most of the data is sourced, be considered further when finalised data are available.

5.5 RECOMMENDATIONS

It is recommended that further research is carried out into the exchange of information on SCI abatement measures and the development of abatement techniques for the reduction of emissions from SCIs, particularly those in the non-industrial sector. Opportunities exist in the context of the UNECE LRTAP Task Force on Techno-economic Issues (EGTEI) and via the IPTS / JRC programme on emerging technologies. There could be further opportunities under the forthcoming 7th Framework Programme (2007 – 2013) to undertake further research in this area, particularly under the proposed *Environmental Technologies* sub-theme (CEC 2005b).

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[11] Personal communication, Tal Golesworthy, SCAPA project manager, October 2005

6 Policy measures for mercury emission reduction

Consideration of abatement options for reduction of emissions cannot be undertaken in isolation of policy mechanisms, which are necessary to drive the implementation of such options. This section assesses policy measures for the reduction of mercury emissions from SCIs by:

- Reviewing European and national measures currently implemented or proposed that could lead to reductions in emissions of mercury from SCIs.
- Considering additional policy options for further reducing emissions of mercury

Policy measures considered in the context of the CAFE SCI study (AEAT 2004) will also be considered to assess potential multi-pollutant benefits, and the potential synergies between the Thematic Strategy on Air Pollution and Mercury Strategy.

In the following section (7), a scenario analysis is undertaken to assess, on the basis of cost-effectiveness, potential policy options. Recommendations for types of action are made on the basis of the scenario analysis in section 8.

6.1 CURRENT MEASURES FOR TARGETING MERCURY EMISSION REDUCTION

There are a number of existing measures for the reduction of mercury emissions, and other measures which do not specifically target mercury emissions but which may lead to further reductions (through indirect benefits). This section identifies such measures, and considers the extent of emission reductions from SCI sources. This section considers four types of measure:

- European-based measures that have specific mercury reduction objectives
- Other international initiatives that also have specific mercury reduction objectives
- Other European-based measures that might have indirect benefits for mercury emission reduction
- National measures, implemented by individual countries

Note that only measures that may have some impact on reduction of emissions from SCIs are considered.

6.1.1 European measures

4th Daughter Directive under the Air Quality Framework Directive

Under Council Directive 96/62/EC of 27 September 1996 on ambient air quality assessment and management (CEU (1996a)), a Fourth Daughter Directive (CEC 2003) has entered into force. This covers the following pollutants - arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons (PAHs). The key objective of this Daughter Directive, similar to other Directives under the Framework, is to *define and establish objectives for ambient air quality in the Community designed to avoid, prevent and reduce harmful effects on human health and the environment as a whole* and *maintain ambient air quality where it is good, and improve it where it is not*.

A target value has not been proposed for mercury ambient concentrations; however, monitoring of ambient concentrations of total gaseous mercury is required, on the basis of one sampling point installed every 50,000 km² (Article 4).

This policy measure is focused on understanding the concentrations and fates of mercury in ambient air through monitoring. However, with no target values for mercury, it unlikely that additional measures to reduce concentrations further will result from such a Directive. Clearly, if ambient concentrations are considered to warrant a target value in future years, Member States could consider this.

Integrated Pollution Prevention and Control

The IPPC Directive (introduced in 1996) is concerned with minimising pollution from various point sources throughout the European Union (CEU 1996). Installations covered by Annex I of the Directive are required to obtain an authorisation (permit) from the authorities in the EU countries without which they are not allowed to operate. The permits must be based on the concept of Best Available Techniques (or BAT)[12]. The European IPPC Bureau co-ordinates the development and publication of BAT reference (BREF) documents to assist national regulators in determining BAT. In addition, emissions of different pollutants, where they exceed certain thresholds, need to be reported to the European Commission under the European Pollutant Emission Register (EPER).[13]

Heavy metals (to include mercury) and associated compounds are covered, although regulatory limits for such pollutants are less common across many installations than those for the main air quality pollutants. In relation to the type of installation, this Directive covers many different industries, many of which have thresholds to determine inclusion (often based on size of production). Combustion installations with a rated thermal input exceeding 50 MW are also covered. The Directive states that threshold values can be exceeded by a single operator carrying out several activities falling under the same subheading in the same installation or on the same site, where the capacities of such activities are added together. Smaller appliances can be included in IPPC if part of another IPPC activity or a combustion installation with a total capacity of over 50 MWth.

Crucially, it is the determination of what constitutes an installation or site by the regulator that is important in deciding whether a threshold has been exceeded. Under the Directive, an installation is defined as *a stationary technical unit where one or more activities listed in Annex I are carried out, and any other directly associated activities which have a technical connection with the activities carried out on that site and which could have an effect on emissions and pollution*.

The above two factors – the use of aggregated thresholds and incorporation of directly associated activities in the definition of an installation – means that a certain number of larger SCIs will be covered by this Directive. This may not mean they are subject to BAT but will certainly be regulated to some extent. Under the CAFE SCI study (AEAT 2004), an assessment was made (using data from the UK's EU ETS permitting database) of the number of combustion units above 20 MW that were regulated as Annex I activities in the Directive (referred to as Part A processes in the UK). 'Installation above 20 MW' in this instance means a single combustion unit above 20 MW rather than an aggregated capacity for a site (as stipulated under EU ETS regulations).

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[12] As stated under Article 2, 'best available techniques` shall mean the most effective and advanced stage in the development of activities and their methods of operation which indicate the practical suitability of particular techniques for providing in principle the basis for emission limit values designed to prevent and, where that is not practicable, generally to reduce emissions and the impact on the environment as a whole. Various considerations to be taken into accoutnare set out in Annex IV of the Directive.

[13] http://www.eper.cec.eu.int/. EPER was introduced through 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), 2000/479/EC

The study concluded that the majority (>90%) of such installations (single units above 20 MW) were regulated directly under the IPPC Directive as combustion installations[14] or as activities directly associated[15] with an IPPC regulated process (i.e. on the basis that they are located on the same site as a process listed under the Directive, e.g. pulp and paper production, and comprise part of the "installation").

This is important as it raises the question as to whether additional regulation is needed for installations with combustion units in the 20-50 MWth range if they are already effectively regulated under the IPPC Directive. There are some factors to consider:

- Although included as part of the installation, BAT requirements are unlikely to be applied rigorously to such combustion installation where they are not considered the key polluting sources.
- The UK example may not be reflected across other European countries; without further research, this is difficult to determine. Further information could be available through other registries / permit systems; however, the published NAPs do not provide this information on current regulatory status, and list installations on an aggregated basis e.g. it is difficult to determine whether a site is two 10 MW combustion units, or a single 20 MW unit.
- If associated with a regulatory regime, it may not be so costly to bring such installations into a new control regime.

6.1.2 Other international initiatives

1979 Convention on Long-range Transboundary Air Pollution (CLRTAP)

Introduced by the UNECE, this convention sets a framework for action to deal with issues of transboundary air pollution. The original convention has been extended through 8 different protocols, including the 1998 Aarhus Protocol on Heavy Metals (UNECE 2005). This protocol, which came into force in October 2003, targets three particularly harmful metals: cadmium, lead and mercury. In terms of basic obligations, Parties to the Convention must:

- Reduce total annual emissions of mercury into the atmosphere, compared to the reference year for the Party (1990, or an alternative year between 1985 and 1995 set when becoming a Party), through application of best available techniques, product control measures or other emission reduction strategies;
- Use best available techniques for stationary sources - for new plants within 2 years, for existing plants within 8 years. The standards for best available techniques are given as examples in Annex III to the Protocol, and include both cleaning technology and substitution of mercury based technology, for example in chlor-alkali plants;
- Ensure application of limit values to control emissions from major stationary sources, both new and existing.

Arctic Council Action Plan to Eliminate Pollution of the Arctic (ACAP)

Mercury is one of the priority pollutants that have been selected for action under ACAP, based on findings under the Arctic Monitoring and Assessment Programme (AMAP). In 2001, the project "Reduction of Atmospheric Mercury Releases from Arctic States" was launched.

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[14] Installations regulated under IPPC Directive can be regulated as combustion processes, if there total **aggregated** capacity is greater than 50 MW_{th}.

[15] Directly associated activities are those activities that have a technical connection with the activities carried out in the stationary technical unit and could have an effect on pollution. An example of a directly associated activity might be a gas-fired boiler that produces steam for a plant that produces in excess of 20 tonnes of paper per day. (The paper production plant would be regulated under the IPPC Directive (as set out in PPC Regulations in the UK)). This boiler would also be regulated as part of the installation, and have emission limits specified on the basis of Best Available Techniques (BAT).

The project's objective is to contribute to a reduction of mercury releases from the Arctic countries. This is being done through developing mercury release inventories and release reduction strategies (ACAP 2005).

6.1.3 Other European measures with potential indirect benefits for mercury reduction

A range of European measures could lead to indirect reductions in mercury emissions, all of which were reviewed in more detail as part of the CAFE SCI study (AEA Technology 2004). These are considered briefly in this section.

Energy efficiency measures
A new Directive on the energy performance of buildings (CEU 2002) has two main objectives - firstly, to improve energy performance of buildings within the EU, and secondly, to promote the convergence of building standards towards those in the EU that are most ambitious. The measures outlined in such a directive (including inspection and maintenance of boilers) could potentially lead to significant reductions in energy use. This will have indirect benefits of reducing mercury emissions associated with the energy saved. Further consideration is given to the impact of energy efficiency measures in the proposed scenario analysis – see section 7.

National Emissions Ceiling Directive
A key European Directive for reducing emissions of sulphur dioxide, nitrogen oxides, NMVOCs and NH_3 is the National Emission Ceilings Directive (CEU 2001), which sets limits on total emissions to be met in 2010. Under the emission ceiling approach, reductions can be met through measures implemented in any sector, including industry, residential and transport. Countries are likely to reduce emissions from sectors where the most significant gains can be made at least cost; this is probably going to be from larger industrial sectors where significant reductions may be achievable from few installations. Depending on the measures introduced, reductions in emissions of mercury may also be observed.

European Structural Funds
Structural Funds are a mechanism whereby the European Commission can grant supplementary financing for national and regional based projects, according to different objectives and criteria. Most funding is targeted at development and regeneration. However, where focused on improving energy infrastructure, or the promotion of alternative cleaner fuels, benefits could be seen for mercury emission reduction, particularly with a move away from coal.

European Emissions Trading Scheme (EU ETS)
The European Emissions Trading scheme, covering greenhouse gases, includes combustion installations above 20 MWth (on an aggregated basis). Efficiency improvements or switching to lower carbon fuels under this scheme, as installations look to reduce emissions of GHGs, could lead to reductions across many different pollutants, including mercury.

Energy Using Products Directive
The Framework Directive on Energy Using Products (EuP) Directive (CEU 2005) has been implemented to create a framework for addressing eco-design[16] requirements of energy-using products. A key objective is to improve environmental performance of these products and thereby protect the environment. A recent study known as MEEUP

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[16] Eco-design means the integration of environmental considerations (e.g. potential emissions released from product) at the product design phase.

(Methodology Study for Eco-design of Energy Using Products)[17] has developed a methodology for assessing which products should be subject to implementing provisions under the Directive. Under the Directive, products can be covered where they represent a significant sales volume (200,000 units per year), have a significant environmental impact, and where the EuP Directive offers significant cost-effective potential of reducing environmental impact.

At this stage, the specific products that will be subject the implementing provision are being reviewed. Based on communication with the European Commission, a preparatory study has already been launched for gas and oil appliances, while one will be launched in 2006 for solid fuels. For solid fuel appliances, emission limits for mercury, in addition to those for pollutants such as CO or PM, could be considered. However, the use of emission limits for mercury would require recognised measurement techniques for such appliances, and agreement on specific limits. Energy efficiency, which is likely to be an important criterion of eco-design requirements, could lead to indirect benefits for mercury emission reduction.

6.1.4 National measures

It is important to recognise that a number of different countries across Europe have national based legislation that is specifically aim at reducing levels of mercury emissions (or indirectly reduces emissions of mercury through action to reduce other pollutants).

Plant-based controls
Some countries in Europe have industry legislation for plant below 50 MW thermal capacity, in effect extending the type of control implemented under the Large Combustion Plant Directive, or IPPC Directive. France, Germany and Belgium have all adopted an emission limit values approach for regulating emissions from sub-50 MWth plant.

In France, all combustion installations with thermal capacities between 2 and 50 MWth are subject to specified emission limits, for NOx, SO_2, PM, CO and NMVOC. PAH and heavy metals are regulated for plant above 20 MWth. The Flemish government (in Belgium) has recently set limits for combustion plant less than 50 MWth, and classified limits based on date; before and after 31st December 2007. Limits have been set for installation between 300 kW and 5 MW, and for installation between 5 and 50 MWth. Limits also exist for liquid and gaseous fuels. Limits are for NOx, SO_2, PM, CO but not heavy metals. New member states, including the Czech Republic, Poland, Romania, Slovakia and Slovenia, have specified pollutant limits for new sub-50 MWth installations.

Certain European countries regulate small combustion plant on the basis of a BAT (Best Available Techniques) approach, including Finland, Denmark and the UK. In Finland, limits can apply to plant of 1 MWth, while in the UK, combustion installation greater than 20 MWth are included. In Table 6.1, a list of countries known to have sub-50 MW pollution control regimes is presented:

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[17] Eco-design of EuP Methdology project, http://www.eupproject.org/

Table 6.1 Countries with sub-50 MW pollution control regimes

Country	Control	Installation size (MW)
France	Limit value	2 - 50
Germany	Limit value	
Belgium (Flemish)	Limit value	0.3 – 50
Czech Republic	Limit value	0.2 – 50
Romania	Limit value	
Poland	Limit value	0.2 – 50
Slovenia	Limit value	1 – 50 (new plant)
Slovakia	Limit value	0.2 – 50 (new plant)
Denmark	BAT	
Finland	BAT	1 – 50
UK	BAT	20 – 50 (but also based on industry sector)

NB. This is not a complete list and is based on work undertaken by AEA Technology (2004) for the CAFE SCI study. The smallest installations will tend to be have 'light touch' regulation, such as self-certification through local authorities.

Few of these regimes seem to cover mercury emissions explicitly. However, the regulation of other pollutants is likely to have some indirect benefits, the extent to which will depend on the abatement options implemented. More information on these regulatory regimes can be found in the CAFE SCI study (AEA Technology 2004). Example limit values from that study are provided in Table 6.2 below.

Table 6.2 Summary of emission limits (mg/MJ) used for larger SCIs (>10 MW) across Europe

Fuel	NOx	SO_2	PM
Solid fuels	100 – 190 (140)	400 – 700 (500)	26 – 56 (36)
Fuel oil	80 – 150	500	15 – 40 (20)
Natural gas	18 – 50		
Biomass	90 – 130 (110)		15-50 (25)

Based on emission limits in France, UK, Finland and Denmark (average value in brackets).
NB. Solid fuels and biomass corrected to 6% 0_2 content before conversion to mg/MJ. Oil and gas corrected to 3% 0_2 content

Fuel / appliance controls

Measures have been introduced in certain countries across Europe, primarily at the local rather than national level, to control the use of solid fuels, and associated appliances. Two key examples are described in section 6.2.2 in the CAFE SCI report (AEA Technology 2004) – the use of smoke control areas in the UK, and the ban on the sale of bituminous coal in urban areas of the Republic of Ireland.

The UK Clean Air Act allows for the designation of smoke control areas (SCAs), usually in urban areas, in which restrictions are placed on the use of certain solid fuels in non-exempt appliances. Such a measure has led to significant reductions in the use of bituminous coal in urban areas, leading to reduction in associated pollutants, including PM, PAHs and mercury. The ban on the sale of bituminous coal also led to significant reductions in the use of this fuel in urban areas, leading to significant declines in PM and SO_2. Mercury reductions will also have been associated with this reduction in the use of solid fuels

Other local-based measures that have been used in different countries aimed at reducing the use of solid fuel, primarily in the residential sector, include appliance replacement schemes, either through state housing renovation, through the financial incentives provided by Government (e.g. grants), or through foreign technology investment and transfer e.g. investment in US technologies in Krakow, as described in Butcher (2001).

6.2 ADDITIONAL MEASURES FOR FURTHER REDUCING MERCURY EMISSIONS

Any additional policy measure for mercury emission reduction is likely to be split into small and large SCIs, and might take one or more of the strategies outlined below. In addition, some of these types of measure would not be driven by mercury reduction in isolation, as indicated by the *mercury driver* column.

Strategy area	Installation type	Example of policy type	Mercury driver?
Quality of fuel	All SCIs	Sulphur content of liquid fuels Directive / Fuel use restrictions	Yes
Quantity of fuel used	All SCIs	Energy efficiency policy	No – energy efficiency
Quality of appliance	Smaller SCIs	Product standards (e.g. EuP Directive) / Maintenance obligations	No – energy efficiency or other AQ pollutants
Requirement for flue gas abatement	Larger SCIs	IPPC / LCPD Directive	No – other air quality pollutants
Quality of ambient air	All SCIs	Air Quality Framework Directive	Yes

Of the above strategies, measures to regulate fuel quality and ambient air quality could be targeted directly at the issue of mercury emissions. The issue of ambient air quality is covered under the EU Framework Directive on Air Quality; however, no specific measures have yet been introduced that relate to fuel quality and mercury content of fuels. Such measures are considered in the next section of the report.

Both energy efficiency measures and the extension of industrial legislation to cover larger SCIs are being considered in other environment policy areas. The indirect mercury emission reduction associated with such policy areas is again considered in the next section.

Appliance quality, ensured through product standards, may have indirect benefits for the reduction of mercury emissions, through ensuring energy efficiency levels are met or by stipulating required limits for certain pollutants (to ensure combustion efficiency). However, product standards rarely have limits specifically for mercury, probably because the key driver of emission levels is the content in fuels rather than efficiency of combustion or specific abatement technologies. Therefore, this measure is not examined in greater detail.

7 Cost-effective analysis of mercury reduction scenarios

This section of the study integrates the information on emission estimates, abatement options and policy measures, through a cost-effectiveness analysis of a set of scenarios. The objective of the analysis is to explore the costs and emission reduction potential of policy measures (and associated abatement options) in order to propose a set of recommendations to the Commission concerning strategies for reducing mercury emissions from SCIs.

Action could be taken on the basis of the following scenarios:

1. **No additional action beyond current legislation (Baseline scenario[18]).** Such a decision would need to consider a) the significance of the problems of mercury emissions from SCIs (in Europe and individual countries), b) whether current action targeted at mercury emissions was sufficient and c) whether action to target other pollutants was already significantly reducing mercury emissions
2. **Take only those measures already proposed for future air quality policy (Scenario 1).** This strategy would involve identifying proposed policy action e.g. as part of the Thematic Strategy, that would further reduce mercury emissions. Based on the demonstrable benefits, further action may not be considered such a priority, or conversely, may be considered a high priority
3. **Introduce additional action for mercury emission reduction (Scenario 2).** Such a strategy might include a) extending the scope of existing industrial legislation to cover small combustion installations, b) introducing new legislation, or c) developing a voluntary based approach, whereby action is encouraged especially in those countries where emissions are significant.

The ‘no additional action’ scenario is fully reflected in the emission inventory projections (in section 4). The other two strategies are considered in this section, as scenario 1 and scenario 2.

Scenario 1 considers the indirect benefits of other air quality initiatives for mercury reduction. It analyses air quality measures that were considered in the CAFE SCI study (AEA Technology 2004), and mentioned in the Thematic Strategy on Air quality. Although the measures in this scenario were not explicitly included in the overall CAFE cost-benefit analysis (e.g. in the RAINS model assessments), they may be options that the Commission considers further as air quality policy in Europe is developed.

There is insufficient information to make an assessment of the impact on mercury emissions of the ambition levels set in the Thematic Strategy. Information from the RAINS model provides some aggregated data the implementation of certain technologies, which would have indirect benefits for mercury emission reduction. However, the aggregated nature of the data does not enable detailed analysis.

Scenario 2 considers additional measures directly targeted at mercury emission reduction. These measures will incur a cost, which is specifically attributable to mercury emission reductions, and therefore a cost-effectiveness analysis is required. A cost-curve approach has been used, to assess what are the most cost-effective options, and the mix of options that might be needed to meet a given policy target.

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[18] Often called the business-as-usual scenario.

7.1 BASELINE SCENARIO

The baseline scenario is reflected in the emission inventory described in section 4. It includes projected changes in the energy mix in 2010 and 2020, and the impact of current and proposed policies on the mix of technologies. A 50% reduction (based on 2002 levels) in mercury emissions is projected. This is driven by the phase out of coal in future years, particularly in the non-industrial sectors.

The percentage reduction under this scenario needs to be considered carefully, particularly in view of the uncertainties associated with the current inventory and the projections. The uncertainty in data projections is reflected in the differences between national projections and the PRIMES-based energy projections used in the CAFE assessments (using the RAINS model). Such differences are described in section 4.4.2, and show (for the sample of countries selected) that national projections estimate higher levels of solid fuel use in the SCI sector (which would lead to higher levels of mercury emissions). We make no suggestion as to which projection data is 'correct'; but we have used the PRIMES dataset due to its completeness and comparability across Europe, and for consistency with assessment in the CAFE programme. However, it illustrates the uncertainty in energy projections, particularly at the sub-sector level for solid fuels. Such differences are also highlighted through stakeholder consultation, where some experts have expressed surprise at the level of reduction in solid fuel use in future years.

It is clear from both PRIMES-based and national projections that the level of solid fuel use will decrease in future years. However, what appears to be the issue is the rate of decrease. This diversity of opinion derives from differences in assumptions made concerning the economic ability of countries to switch to other fuel types, the availability of alternative fuels, and the key factor of fuel prices. If gas and oil prices continue to rise significantly in future years the use in solid fuels may stabilise at current levels rather than decrease, particularly in areas where affordability is a significant issue.

7.2 SCENARIO 1: MEASURES ALREADY PROPOSED FOR FUTURE AIR QUALITY POLICY

7.2.1 Background and context

This scenario considers measures outlined in the Thematic Strategy on Air Pollution document that may have an impact on SCI sources. These measures were not included in the CAFE cost-benefit assessment but were assessed to some extent in the work on SCIs (AEAT 2004). At present there are no proposals within the Thematic Strategy that address mercury levels specifically but since mercury is present in combustion fuels and waste gases some of those instruments that aim to reduce the impacts of other pollutants (i.e. particulate matter, acid gases and carbon dioxide) would have a beneficial impact on mercury emissions.

Therefore, this scenario assesses the savings in mercury emissions that would accrue from the proposed instruments that focus on other combustion gases and which may form part of future European air quality policy as it continues to develop in coming years. The current draft communication from the Commission on the Strategy (CEC 2005b) states the following in relation to small combustion installations:

This increasingly important emissions source is not regulated at Community level. The Commission will examine whether the IPPC directive should be expanded to cover sources below 50 MWth.

Harmonised technical standards will also be developed for domestic combustion appliances and their fuels. If feasible, smaller residential and commercial buildings could be included in an extended directive on energy efficiency.

If the mercury emission reduction potential of such measures can be estimated, a clearer understanding of what further action is needed may result. This is based on the premise that these measures would be implemented in a future air quality policy programme.

7.2.2 Definition of the scenario

For the purpose of analysing the impact of this scenario on mercury emissions from SCIs we have assumed the following:

- The IPPC Directive would be extended to include all small combustion plant above 20 MWth and be fully implemented by 2020. These plant will be predominantly industrial sector plant, with a very limited number being public sector institutions.
- The Energy Performance of Buildings Directive (EPBD) would be extended to cover all houses and be fully implemented by 2020. This includes proposals for the improvement of building energy efficiency, and maintenance of heating systems.

This covers two of the three measures outlined in the Thematic Strategy. We have not considered the Energy Using Products Directive explicitly for various reasons; firstly, it is not clear what type of eco-design requirements would be included within any Daughter Directives for solid fuel appliances although this is currently being investigated; secondly, at this stage it is unclear whether mercury emission limits would be considered as eco-design requirements, and if they were, what the specified limit might be. One likely benefit of the Directive, if covering solid fuel appliances, would be from energy efficiency improvements; however, such benefits are reflected to a certain extent under the EBP Directive.

7.2.3 Sector and Country Impact Analysis

An extended IPPC Directive, as defined above, would primarily impact on SCIs in the industrial sector as plant size will generally be below the 20 MW threshold. We recognise that there will be some non-industrial plant that could exceed 20 MW; however, these are likely to be few in number, and in addition, we do not have the information to identify them.[19] Two options would be to define emission limit values for the affected plant or to define BAT for them. BAT would tend to vary in different Member States depending on local circumstances. The focus is likely to be on limiting the local environmental impacts of this plant (i.e. contributions to ambient levels mainly of NO2, SO2 and PM).

Based on data analysis in the CAFE SCI study (AEA Technology 2004), we assume that an extension of the IPPC Directive would cover 40% of industrial SCI emissions. Of these plant, we make the assumption that the majority will be subject to a BAT assessment, based on which 60-80% will have to implement some control. We do not assume 100% because some plant will already have such abatement equipment installed. What this analysis does not assume is the role of national regimes; for example, national legislation may be covering many such plants and enforcing strict pollution controls; therefore, we could be overestimating the potential emission reduction.

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[19] Many of the public sector buildings covered by the EU ETS in the UK are covered based on an **aggregated** capacity above 20 MW. Few such building have single boilers > 20 MW.

An extension of the EPB Directive would include all residential buildings under this regulation. A recent study (Ecofys 2004) estimated that under this scenario, European building stock CO_2 emissions could be 533Mt/a by 2015 rather than 596Mt/a under the current regulation. This would represent an 11% saving approximately equivalent to a reduction in energy use. For this analysis we have assumed that the extended Directive could be implemented and the energy savings be fully accrued by 2020 in 100% of non-industrial sources in the very small size range.

7.2.4 Quantified Analysis

Under this analysis we have considered two abatement technologies that could be implemented on the basis of BAT in the case of extending the IPPC Directive - fabric filters and electrostatic precipitators. They have been selected as technical measures that significantly abate PM and which are also the most cost-effective examples of such measures within each class. In the BREF note for large combustion plant, (European IPPC Bureau 2005a), these technologies are important means of meeting BAT requirements, particularly with regard to particulate matter. The BAT document also recognizes the importance of these techniques in reducing emissions of heavy metals (although it does stress the variability of emission reduction, particularly for mercury, as described earlier in this report).

In the case of extending the EPBD, we have assumed that 100% of non-industrial sources in the very small size range will achieve an 11% reduction in emissions equivalent to the energy savings. We assume that this would be achieved at a cost saving due to the efficiency gain.

It is noted that there is a considerable uncertainty associated with the values presented here. In large part they are due to uncertainties in the baseline emissions and cost-effectiveness data already discussed. They is also uncertainty over the actual effect of the described scenario since we do not have accurate figures available to define the baseline stock of SCIs that would be affected by the extended Directives.

The effects of the assumptions would be fully realised by 2020. Mercury abatement costs of this scenario are considered to be zero since these actions are taken to abate emissions of other pollutants. The mercury emissions abated due to the implementation of the two different technical measures due to the extension of the IPPC Directive, and the extension of the EPB Directive are tabulated below in Table 7.1.

Table 7.1 Emission reductions associated with measures outlined in the proposed Thematic Strategy on Air Pollution

Percentage of sector affected by the extension of IPPC Directive	Technical measure	Mercury emissions abated (t)
60%	Retrofit fabric filters	1.40
	ESP+FGD	1.08
80%	Retrofit fabric filters	1.87
	ESP+FGD	1.09
100%	Energy savings	0.054

Under this scenario mercury emissions are estimated to be 2.53 - 3.01 t/a less than the 2020 baseline (11.8t/a), which is equivalent to an approximate 21-26% reduction. Emissions reductions due to the extended EPBD are likely to be more evenly spread across the EU since it implies action in the whole housing stock regardless of fuel used.

7.2.5 Conclusions

The analysis illustrates the potential benefits to mercury emission reduction associated with the extension of these two Directives. These could be as much as 3.01 t/a equivalent to a 26% reduction from the baseline. These are considered to be at zero cost because they are associated with other air quality policy. Note that these estimates are very uncertain given that it is not clear how a BAT approach would be implemented across different countries, and because current national regimes have not been taken into account. Clearly, emission reductions will be contingent on the implementation of measures – therefore, further analysis will have to be undertaken to illustrate cost-effectiveness for other pollutants.

It is important to stress that this analysis does not reflect the potential mercury emission reduction of the wider proposals under the Thematic Strategy. In the cost-benefit analysis undertaken for the CAFE programme, ambition levels were set for various pollutants, and the necessary technologies to meet those levels were assessed, based on a cost-curve approach. The CAFE work did not reflect the SCI measures described in the Thematic Strategy. However, the introduction of a range of technologies – such as the introduction of new boilers in the residential sector, and fabric filters on larger commercial boilers is likely to have some impact on emission reduction. The impact on emissions for industrial SCIs is harder to determine, as industrial SCIs are not distinguishable in the RAINS model.

There are a number of implementation issues regarding the measures that specify extensions to Directives. Such issues relate to questions of feasibility, and the potential costs, which are not easily identified in standard cost-curve analysis. For the IPPC Directive extension, the following issues would need to be considered:

- **The extent to which industrial installations are already covered by national legislation.** If most countries have national legislation covering industrial installations there may be less requirement for a European-wide measure. However, there are also arguments for harmonising the approach taken across Europe for regulation of industrial sites – the experience of different national regimes could be useful in helping structure a European based measure.
- **The use of an ELV or BAT based approach.** This could be investigated further by reviewing national experience in the implementation of the different types of approach.
- **The thermal capacity range that would define inclusion of plant under a new measure.** If the threshold for coverage is set too low, too many installations may be included within the regulatory regime. This will have implications for identification of relevant plant, and costs of administration and enforcement.
- **The regulatory costs associated with such a measure would need to be considered further.** Enforcement and administration costs for the regulator may not differ significantly between a 40 MW_{th} plant and a 15 MW_{th} plant, although this will depend on whether a plant is already covered by the regulator i.e. through being directly associated with an IPPC regulated plant. If not covered, costs relative to emission reduction potential could be higher for smaller plant.
- **The compliance costs relative to the emission reduction potential.** Costs for larger plant (40 –50 MW_{th}) will probably not be significantly greater than for smaller plant (10 – 20 MW_{th}) e.g. the cost of a fabric filter does differ proportionately based on size of plant. However, the difference in emissions per plant could be significant, with smaller plants emitting much less; on this basis, the cost per tonne abated is likely to be much higher for smaller plant.

Similarly, there are issues that need to be considered further with regards to the extension of the EPB Directive. If this Directive was extended to cover residential buildings, how could it be enforced? The Directive includes the application of performance standards on new and existing buildings, a certification scheme for all buildings, and regular inspection and assessment of boilers / heating. To regulate private households through adhoc inspection and self-certification could be costly and problematic, both for households and the Government, and would need to be further investigated. Only including the rental sector and public housing could be more cost-effective.

7.3 SCENARIO 2: MERCURY SPECIFIC INSTRUMENTS

7.3.1 Background and context

Scenario 2 recognises that there is an agenda to specifically address and manage mercury emissions due to concerns over the health impact of exposure to levels of mercury released to and dispersed in the environment. Scenario 1 only demonstrated the limitations of achieving mercury abatement as a secondary benefit of managing the impacts of other pollutants.

For this scenario we assume that feasible measures to specifically abate mercury emissions would be applied in order of cost-effectiveness. The objective of such measures could be a European or national emissions ceiling. However, given the uncertainties associated with mercury inventories, the implementation of such a measure could be hugely problematic. Emission or ambient limit value approaches could also be envisaged that would also carry the obligation to reduce mercury emissions. Currently, under the 4th Daughter Directive (under the Framework Directive on Air Quality) an ambient limit value has not been proposed.

The analysis below is clearly not a full mercury abatement cost-curve since this study is only considering mercury emissions from SCI sources.

7.3.2 Definition of the scenario

For the purpose of illustration we have assumed a policy that requires mercury emissions to be reduced by 40% below the baseline by 2020. In emissions terms this would be a reduction (or a ceiling) of 4.7 t/a.

7.3.3 Sector and Country Impact Analysis

The most cost-effective measures are those delivering energy efficiency savings as these are assumed to be lifetime cost savings. We have assumed again that the EPBD would be extended to include all residential buildings within the regulation. This would represent an 11% CO_2 emissions saving approximately equivalent to a reduction in energy use. For this analysis we have assumed this level of efficiency gain for 100% non-industrial sources in the very small size range by 2020.

The next most cost-effective measures are those that comprise the pre-treatment of coals to either mix them or wash them to reduce their overall mercury content. An approach to this might be envisaged through the use of Council Directive 76/769/EEC of 27 July 1976 on the approximation of the laws, regulations and administrative provisions of the Member States relating to restrictions on the marketing and use of certain dangerous substances and preparations. Such a Directive might ban certain coal that exceeded a specified mercury content level.

An EU-wide standard of mercury content would oblige all coal suppliers / users to undertake coal washing prior to marketing of coal. Equally, a new instrument defining this fuel standard (similar to the Sulphur in Liquid Fuels Directive) could be envisaged that has the same effect. Such measures would require monitoring and reporting by manufacturers / distributors to the regulator to ensure that fuel quality standards were being met. This might include monitoring of the raw mined coal product, and the product post-washing.

The sale of low mercury content coal could also be promoted through the labelling of solid fuel products, providing consumers with environmental information that might effect purchasing decisions. An ecolabel could also be considered for low mercury coal products for which distributors would require a license. The effectiveness of labelling will be determined by the availability of low mercury coal on the market at competitive prices to higher mercury content coals.

We have made the following assumptions concerning coal washing – 70% of coal used across all sectors is subject to conventional coal washing (including imports) while 30% is subject to enhanced coal washing (across all sectors except for coal used in <1 MW installations).

Fuel switching from use of coal to gas or oil in non-industrial sectors is the next most cost-effective measure. An outright ban on the use of coals (similar to that adopted in Ireland) could achieve this switch; we highlight, however, that the switch comes with significant issues of energy security and supply infrastructure. The economic impact of the switch is expected to be greatest in countries where coal usage in this sector is above average while gas usage is below average. Impacts in other countries would be expected to be less due to either, more existing gas supply infrastructure or a large proportion of liquid fuel use by 2020. We have assumed that of the installations using coal in the non-industrial sector, 60% will have access to gas, while the other 40% who don’t have access can switch to oil.

What is clear in the energy forecasts in PRIMES (and national projections) is that switching to other fuels is already happening, leading to decreases in the amount of solid fuel used in non-industrial sectors. This measure would increase the rate of this switching. A sensitivity not considered in this analysis is the effect of different rates of switching, which could well be affected by future price changes in oil and gas; if the price of such fuels increase, the rate of switching is likely to be much lower.

Further measures to reduce mercury emissions include all of the technical abatement measures such as filtration of particulate matter or the removal of combustion gases. However, these are all less cost-effective than the switch to gas. Therefore, the measures would only be implemented once all other more cost-effective options had been used (as they are much further up the cost curve).

7.3.4 Quantified analysis

In this analysis, the effects of the assumptions are fully realised by 2020. The mercury emissions abated due to the cost-effective implementation of different technical measures to achieve a 40% reduction in mercury emissions (at least 4.7 t/a) are tabulated below.

Table 7.2 Emission reduction and costs associated with meeting a 50% reduction in mercury emissions by 2020

Sector	Size	Fuel	Measure	Incremental			Cumulative	
				Abatement (t)	Cost (€mn)	Abatement cost effectiveness (€mn/t)	Abatement (t)	Cost (€mn)
NI	VS	G	Reduced fuel use through efficiency (e.g. insulation)	0.00	0.00	0	0.00	0
		L		0.01	0.00	0	0.01	0
		B		0.07	0.00	0	0.08	0
		HC		0.03	0.00	0	0.11	0
NI	S	HC	Enhanced coal washing	0.14	0.13	0.3	0.25	0.1
I	M	HC		1.21	2.86	0.5	1.47	3
	S	HC		1.82	4.28	0.7	3.29	7.3
NI	VS	HC	Fuel switch from hard coal to gas	0.29	3.06	0.7	3.57	10.3
			Fuel switch from hard coal to oil	0.07	3.06	42.8	3.64	13.4
I	M	HC	Retrofitted fabric filters	1.19	99.26	121.6	4.82	112.6
		HC	ESP+FGD	0.69	323.70	993.9	5.52	436.3

Notes: Sector: IND = industry, NI = non-industry; Fuel : HC = hard coal, B = brown coal, G = gas, B = biomass, L = liquid; Installation size : M = medium (50-20MWth), S = small (20-1MWth), VS = very small (<1MWth); Option abatement technology : FGD = flue gas desulphurisation, ESP = electrostatic precipitators.

Figures in this table illustrate that energy savings might only achieve a 0.1 t/a emissions reduction by 2020. Enhanced coal washing is the single measure where most significant reductions can be seen – and at fairly low cost. The analysis shows that approximately 3 tonnes could be abated at a cost of just over €7 million. Two important issues need to be mentioned at this stage; firstly, the costs (sourced from the ESPREME project team) appear very low. It is clear that further work is needed to verify these data – this could happen as ESPREME outputs become finalised.

Secondly, further research is needed to better understand the current implementation of coal washing (both conventional and enhanced) across Europe, and its impact on different types of coal (e.g. its reduction efficiency). Despite the uncertainties in the data, coal washing is still an important option that should be explored further, given these initial indications of cost-effectiveness. Note that this analysis does not cover the potential costs of regulating fuel quality. This could include significant costs associated with monitoring and reporting mercury levels.

The next most cost-effective option is the switching from coal to gas, and coal to oil. The use of fabric filters on larger plant results in meeting the 40% reduction target, at a cost of €112 million. There is a significant increase in costs once preventative options have been fully implemented, and technical abatement options are used.

It is important to highlight that the coal washing measure is likely to create a new mercury waste stream (in solution) and one that would have to be accounted for in any overarching mercury reduction strategy.

7.3.5 Conclusions

There are a number of issues associated with the implementation of these options shown in Table 7.2.

1. The most cost-effective option - reduced fuel use through energy efficiency - is contingent on the introduction of energy efficiency based policy measures. In terms of overall emission reduction, the impact of this measure is small.
2. There may be some compatibility issues between coal washing, on one hand, and switching away from coal, on the other. If the Commission was to regulate the quality of hard coal going onto the market, could it then promote a shift away from this product? The main reason for considering both is that many consumers may not have access to gas or the economic ability to purchase what might be a higher priced alternative fuel.
3. Coal washing may be easier to implement given that much of the imported coal may have already undergone washing. Therefore, regulation may not impact on overseas producers. However, there may be competitiveness implications for European producers who have not needed to wash coal previously (or have only needed to pre-treat coal destined for certain sectors).
4. It is difficult to foresee how fuel switching could be implemented or encouraged directly by the European Commission. Measures to accelerate switching are usually undertaken at the local or sub-national level e.g. the Dublin ban on the sale of bituminous coal, or the implementation of smoke control areas in the UK. The primary mechanism for ensuring Member States do take action to reduce localised ‘hot spot’ pollution has been through the Air Quality Framework Directive. However, the Fourth Daughter Directive does not have a target value for mercury – therefore, this mechanism is unlikely to accelerate the implementation of measures that lead to further switching.

Although this is a useful review of the cost-effectiveness of measures, it does highlight the uncertainties in the data being used, both in terms of the costs and effectiveness of options. This is primarily due to a lack of data specifically relevant to SCIs, and illustrates the need for additional research, particularly where such data is needed to help formulate policy measures. However, it does provide a basis for discussion around different options, providing an indication of cost-effectiveness relative to alternative measures.

8 Conclusions and recommendations

This study has been produced in response to Action 3 of the Mercury Strategy (CEC 2005a) calling for further research into options to reduce mercury emission from small combustion installations. Our objectives have been:

- To develop a comprehensive emission inventory capable of providing information on the 'nature' and significance of mercury emissions from the SCI sector as a function of country, sector, fuel, and installation type;
- To make inventory projections to determine the likely future trend of emissions according to the CAFE Business as Usual scenario;
- To explore, using the inventory, where abatement measures (technical abatement or preventative measures) might reduce emissions and by how much.
- To order abatement measures, as a function of cost effectiveness, according to SCI sub-sector, fuel types or country;
- To identify indirect benefits to be anticipated from ongoing or proposed air quality initiatives;
- To propose policy opportunities to reduce emissions where these may be deemed cost-effective.

The key study conclusions are described below, and are followed by a set of proposed recommendations for consideration by the Commission.

8.1 STUDY CONCLUSIONS

Limited information has been published on mercury emissions from the SCI sector that is disaggregated to the level of country, sector, fuel, and installation type. In addition, there is limited data on emission factors (and to a lesser extent, activity data) that can be used to calculate emissions, a finding confirmed by a questionnaire-based survey of European inventory experts.

The inventory data that has been developed suggests a lower emission estimate for SCI sources than that given by other studies; 16% of the total European emission rather than 25% as given in the Mercury Strategy. Despite this apparently high level of uncertainty, on the balance of probability, mercury emissions from SCIs remain a large component of the EU inventory, and a source for which controls may be necessary. Should it be decided that administrative action to abate this source is desirable then action would be needed to improve the reporting of emissions. The most significant gaps in knowledge are country level activity data (fuel use) for industrial installations below 50 MW and biomass mercury emission factors. However, most data inputs into the inventory have high levels of uncertainty.

Mercury emissions are primarily driven by coal use, which is used much more in certain countries e.g. Poland and Germany are the two largest users. Countries which are dominated by gas or biomass use have much lower emissions. In future years, coal consumption is projected to decrease significantly in Europe as a whole but not equally in all countries. Projection factors are uncertain (as shown in section 4.4.2) and cannot accurately predict possible future changes in price of oil and gas that might influence the rate of decrease.

Consequently it is not clear, for the future, how fuels will redistribute between the various SCI sub-sectors, at a country specific level. In the absence of targeted abatement action mercury emissions from SCIs may continue to be significant where there continues to be a substantial use of solid fuel.

There are a variety of technical abatement options and policy measures that might be used to reduce mercury emissions and we have identified a sub-set that suit the range of size, fuel, application, and type of appliance comprising the SCI sector. We have found that there are few practical technical abatement options for SCIs. We included technical abatement options that could be applied to larger plant but which would normally be implemented, in the first instance, to abate other pollutants. Associated mercury reductions would therefore be considered to be a multi-pollutant benefit.

Because the content of mercury in fuels is more important than the type of equipment used, preventative measures are considered most cost-effective. Options that have been considered are energy efficiency measures (including energy conservation and district heating), improving fuel quality, or encouraging users of solid fuels to switch to oil or natural gas. Of these the most cost-effective are energy efficiency measures (at no additional cost), followed next by coal washing, and then switching from coal to natural gas / liquid fuels.

Given the lack of information on the mercury content of the coals available on the open market, their composition, and the variety of their country’s of origin, reducing mercury emissions via fuel switching, other than from coal to oil or gas (e.g. from a higher to a lower mercury content coal), is unlikely to be practical. Technical abatement options are the least cost-effective (and would only be considered for abatement of PM and acidifying gases or if mercury abatement needed to go well beyond a 40% reduction relative to the 2020 baseline). Our cost-effectiveness analysis is predominantly based on costs data from ESPREME (which is ongoing work); we note that there are significant gaps and uncertainties in this information.

In terms of policy mechanisms, there are no European wide measures that currently address mercury emissions from SCI sources. The Fourth Daughter Directive under the Air Quality Framework Directive has set ambient monitoring requirements but no air quality standard has be set that might otherwise have led to action at member state level to reduce emissions to air. There are, however, other Commission policy measures and examples of action at national level that have multi-pollutant benefits for mercury reduction.

To assess abatement options within a policy framework, we undertook an analysis to consider the reduction potential and costs associated with different policy scenarios. Scenarios included a baseline ‘business as usual’ scenario, scenario 1 - which determines the mercury emission reductions that can be anticipated from other air quality policies, specifically those considered under the Thematic Strategy on Air Pollution, and scenario 2 - policy measures / abatement options specifically targeting mercury emissions.

The projections according to the ‘Business as Usual’ assumptions of the CAFE programme are such that a reduction of up to 50% might be achieved. This 50% reduction is primarily due to the significant decline in the use of solid fuel in SCI sectors modelled in RAINS, projections of solid fuel use by Member States do not verify this trend in all cases. Another reason why the reduction should be viewed as a ‘best case’ estimate is because it is dependent on future fuel prices and the availability of alternative fuels. The benefits resulting from scenario 1 are sizeable (2.53 - 3.01 t/a), equating to up to 26% maximum reduction relative to the baseline.

This reduction is assumed to come at zero cost since the measures would be implemented to control other pollutants primarily. The significant uncertainty in this analysis is due to the following – 1) not fully understanding current implementation of abatement options in sub-50 MW plant, 2) not accounting for national regimes already in place, and 3) the differences in implementation of a BAT approach. The analysis under scenario 1 does not reflect other indirect benefits that may have arisen from the cost-benefit analysis underpinning the Thematic Strategy.

Scenario 2 results indicate that a 40% reduction in emissions (more than 4.7 t/a relative to the baseline) is possible primary through the full implementation of preventative measures (in the main coal washing), and the implementation of some less cost-effective technical abatement options. The total cost of such a strategy could be around €110 million. We note that there is significant uncertainty associated with this cost-effectiveness analysis that depends in the main on the current ESPREME database.

Developing the policy tool to implement a 40% reduction could be problematic. An emissions ceiling approach would be unworkable given the inventory uncertainties and the 4th Daughter Directive is not a strong driver given the absence of a target value.

The analysis of these three scenarios suggests a number of policy options and highlights a number of actions that either singly or in combination would lead to reductions in mercury emissions; recommendations are made accordingly.

8.2 RECOMMENDATIONS

Recommendations applicable to all scenarios

Irrespective of whether action is taken beyond that envisaged under the Baseline 'Business as Usual' scenario, it is recommended that:

1. The UNECE LRTAP is requested to amend the Guidelines for Estimating and Reporting Emission Data to include emissions from combustion units less than 50 MW. Emission data should be requested for the following sectors: - industrial, residential, commercial / institutional, and agriculture, disaggregated into the following thermal capacity categories - 0-5, 5-20, and 20-50 MW. The present EMEP / CORINAIR Inventory Reporting Guidelines are due for review and revision by 2007 at the latest.

2. Additional research to enable countries to report to the level of detail required in Recommendation 1 above. This would require the development of default emission factors for the newly proposed reporting categories and the development of speciation profiles. This would require monitoring emissions for a variety of commonly used solid fuels on typical combustion appliances. Research into biomass emission factors and activity data should be a priority. N.B This recommendation is also of relevance to the Thematic Strategy on Air Pollution, given the levels of PM emissions associated with biomass.

3. Given that the performance of abatement options will depend on the chemical form of mercury to be captured and since there is at present no standardised method for the measurement of speciated mercury emissions (only total mercury emissions) it is recommended that a suitable standard method be developed.

4. This study reviews recent work relevant to the development of mercury emission inventories. It is recommended that it is made available to the EMEP / EIONET Task Force on emission inventories and projections as a contribution to the improvement of currently available information on the emissions of mercury from SCI.

Recommendations following from the scenario 1 and 2 analysis

Should action be taken beyond that envisaged under the Baseline 'Business as Usual' scenario, i.e. the actions anticipated in scenarios 1 and 2, it is recommended that:

5. The industrial sector is the most significant contributor to SCI emissions both now and in the foreseeable future. The relative contribution from this sector is projected to increase although the emissions in absolute terms will decrease. Where appropriate, current legislative tools covering industrial emissions should be extended to cover industrial SCIs. Opportunities may include reducing the reporting threshold of the IPPC Directive.

6. The benefits of reduced mercury emissions should be included when pollution abatement strategies are being considered for PM, SO_2, and NOx e.g. Thematic Strategy on Air Pollution. In addition, measures implemented under Energy efficiency / climate change objectives, would be important to recognise, given that they could be considered to be low or no cost e.g. Energy Performance of Buildings Directive.

7. Synergies with other initiatives, such as the Urban Thematic Strategy, should also be identified and developed. The overall objective of the urban strategy is *to improve the environmental performance and quality of urban areas and to secure a healthy living environment for Europe's urban citizens* (CEC 2004). In the priority area of sustainable urban construction, there appear to be synergies between strategies on air pollution, climate change and mercury, given the focus on improving energy efficiency.

8. Further consideration should be given to the role of 4th Daughter Directive in reducing mercury emissions in localities where they are significant. Mercury has no stipulated limit level under the Directive but an obligation for monitoring. When this Directive is reviewed, it will be important to determine whether introducing a limit value could be a useful means of further reducing mercury emissions from SCIs. This measure could be an important mechanism for enabling the Commission to reduce emissions in those areas where this was necessary i.e. hotspots.

Recommendations following from the scenario 2 analysis

Should action be taken beyond that envisaged under the scenario 1, i.e. scenarios 2, it is recommended that:

9. Abatement measures should focus most on those countries with the highest mercury emissions from SCIs, often those with the greatest coal use. However, if measures are to be targeted at countries, means of assisting with technical and financial support should be considered.

10. Coal washing appears to be a very cost-effective option. This option should be investigated in greater detail and means of implementation examined, potentially through a measure regulating the quality of solid fuels. However, politically, this could be difficult given the significant reductions in solid fuel use anyway, and the perceived impacts on an industry that was in the process of restructuring.

11. It is recommended that further research is carried out into the exchange of information on SCI abatement measures and the development of abatement techniques for the reduction of emissions from SCI's, particularly those in the non-industrial sector. Opportunities exist in the context of the UNECE LRTAP Task

Force on Techno-economic Issues (EGTEI) and via the IPTS/JRC programme on emerging technologies.

12. Given the significant uncertainties identified by this study further work is needed to refine the cost curve used in scenario 2. It is recommended that where appropriate this work be integrated with ongoing research in this area (e.g. ESPREME).

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In addition to the references in this section, a comprehensive list of references used in the emission factor review is provided at the end of Appendix 1.

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Appendices

APPENDIX 1 DETAILED INFORMATION ON MERCURY CONTENT OF FUELS, AND EMISSION FACTORS

Table A1. Contents of mercury in world coal and relevant emission factors obtained by recalculation (N.B the Hg emission factor calculation assumes 24 GJ/t for hard coal and 95% emission during the combustion process)

No	Contents of Hg mg/ton	Emission factor mg/GJ	Origin of coal	Reference
1	50-500	1.98- 19.79	n.a.	[1]
2	30-300	1.19 – 11.88	n.a.	[2]
3	30-250	1.19 – 9.90	Australia	[3]
4	80	3.17	Australia	[4]
5	26-400	1.03 -15.83	Australia	[5]
6	160	6.33	Germany	[4]
7	160	6.33	Germany	[3]
8	700-1,400	27.71 – 55.42	Germany	[5]
9	27-110	1.07 – 4.35	Japan	[5]
10	20-560	0.79 – 22.17	New Zeeland	[5]
11	50	1.98	New Zeeland	[4]
12	80-615	3.17 – 24.34	Poland	[6]
13	90	3.56	Poland	[4]
14	60-200	2.38 – 7.92	Poland	[4]
15	350	13.85	Poland	[4]
16	140-1,780	5.54 – 70.46	Poland	[3]
17	50-70	1.98 – 2.77	Poland	[5]
18	200-700	7.92 - 27.71	UK	[5]
19	90-510	3.56 – 20.19	USA	[3]
20	140	5.54	USA	[4]
21	10-1,800	0.40 – 71.25	USA	[5]
22	60	2.38	Russia	[4]
23	74-180	2.93 – 7.13	Russia	[5]
24	40	1.58	Colombia	[3]
25	60	2.38	Colombia	[4]
26	150	5.94	China	[4]
27	100	3.96	Egypt	[4]
28	40	1.58	Indonesia	[4]
29	90	3.56	South Africa	[4]
30	140	5.54	Norway	[4]
31	80	3.17	Venezuela	[4]
32	200	11.1a)	Poland (sludge)	[2]
33	210	11.0b)	Poland (raw	[2]
34	100	4.5c)	Poland	[2]
36	100	5.8	Poland	[7]
38	260	10.3	Poland	[8]
38	110	4.32	Poland	[9]
39	50	1.98	Poland	[9]
40	390	15.43	Poland	[9]
41	200	11.1	Poland	[10]
42	10	0.39	Germany	[11]
43	70	2.77	Canada	[1]
44	60	2.38	Canada	[12]
45	100	4.5	Canada	[12]

46	<10-190	0.39-7.52	Australia, China, Indonesia	[13]
47	47[d]	1.86	Australia,	[13]
48	60– 140	2.38 – 5.54	Canada	[14]
49	80-200	3.17-7.92	USA	[15]
50	160 – 300	6.33-11.88	USA	[16]
51	214	8.47	Poland	[7]
51	127	5.03	Poland	[17]
51	140	5.54		
52	147	5.82		
53	126	4.99		
54	30-340	1.25-14.16	China	[18]
55	80-220	3.33-9.16	USA	[18]
56	65-68	2.57- 2.69	Canada	[19]
57	25[d]	1.04	Canada	[20]
58	80	3.17	Australia	[21]
59	90	3.56	South Africa	
60	390	14.70	Ukraine	
61	58	2.30	Poland	[22]
62	31	1.23	Colombia	
63	111	4.62	UK	[23]
64	130	1.78	South Africa	
65	140	5.83	Norway	
Range	**10 - 1,780**	**0.39 – 70.46**		
Average	**217**	**6.94**	-	-
Average after removal min. value <1 mg/GJ and max. value above 50 mg/GJ	**169.2**	**4.88**	-	-

[a] 18 GJ/t for hard coal was assumed
[b] 19 GJ/t for hard coal was assumed
[c] 22 GJ/t for hard coal was assumed
[d] Average value

Table A2. Evaluation of range and average mercury emission factor for hard coal from various countries (made on the basis of data collected in the Table A1 after removal min. value <1 mg/GJ and max. value above 50 mg/GJ)

No	Origin of coal	Range of emission factor of Hg mg/GJ		Average value of EF of Hg for each origin of coal (mg/GJ)
		from	to	
1	Australia	1.03	15.83	8.43
2	Canada	1.04	5.54	3.29
3	China	1.25	14.16	8.33
4	Colombia	1.23	2.38	1.81
6	Germany	6.33	27.71	17.02
7	Indonesia	1.58	7.52	5.34
8	Japan	1.07	4.35	2.71
9	New Zeeland	1.98	22.17	12.07
10	Norway	5.54	5.83	5.68
11	Poland	1.98	24.34	13.16
12	Russia	2.38	7.13	4.76
13	South Africa	3.08	5.42	4.25
14	Ukraine	14.70	14.70	14.70
15	UK	4.62	27.71	16.16
16	USA	3.33	20.19	11.76
17	Venezuela	3.17	3.33	3.25
18	Other	1.98	19.79	10.88

Table A3. Contents of mercury in coal originating from European countries and relevant emission factor obtained by recalculation (for recalculation of H_u, 24 GJ/t for hard coal was assumed and 0,95 as coefficient for emission mercury during combustion process)

No of coal consistent with table A1	Contents of Hg mg/kg	Emission factor mg/GJ	Origin of coal	Reference
1	0.05-0.5	1.98- 19.79	n.a.	[1]
2	0.03-0.3	1.19 – 11.88	n.a.	[2]
6	0.16	6.33	Germany	[4]
8	0.70-1.40	27.71 – 55.42	Germany	[3]
12	0.08-0.615	3.17 – 24.34	Poland	[1]
13	0.09	3.56	Poland	[4]
14	0,06-0,2	2.38 – 7.92	Poland	[4]
15	0.35	13.85	Poland	[4]
16	0.14-1.78	5.54 – 70.46	Poland	[3]
17	0.05-0.07	1.98 – 2.77	Poland	[3]
18	0.20-0.70	7.92 - 27.71	UK	[3]
22	0,06	2.38	Russia	[4]
23	0.074-0.18	2.93 – 7.13	Russia	[3]
30	0.14	5.54	Norway	[4]
32	0.20	11.1[a)]	Poland (sludge)	[2]
33	0.21	11.0[b)]	Poland (raw	[2]
34	0.10	4.5[c)]	Poland	[2]
36	0.10	5.8	Poland	[5]
38	0.26	10.3	Poland	[6]
38	0.11	4.32	Poland	[7]
39	0.05	1.98	Poland	[7]
40	0.39	15.43	Poland	[7]
41	0.20	11.1	Poland	[8]
42	0.01	0.39	Germany	[9]
51	0.214	8,47	Poland	[5]
51	0.127	5.03	Poland	[15]
51	0.140	5.54		
52	0.147	5.82		
53	0.126	4.99		
54	390	14.70	Ukraine	[19]
63	111	5.62	UK	[23]
65	140	5.83	Norway	
Range	**0.01 – 1.78**	**0.39 – 70.46**	-	
Average	**0.55**	**16.90**		
Average after removal min. value <1 mg/GJ and max. value above 50 mg/GJ	**0.211**	**5.35**		

[a)] for recalculation H_u of 18 GJ/t for hard coal was assumed
[b)] for recalculation H_u of 19 GJ/t for hard coal was assumed
[c)] for recalculation H_u of 22 GJ/t for hard coal was assumed
[d)] Average value

Table A4. Mercury concentrations in coal from China [18, 24]

No	Province	Concentration range, mg/kg	Average, mg/kg	Standard deviation
1	Heilongjiang	0.02-0.063	0.12	0.11
2	Jilin	0.08-1.59	0.33	0.28
3	Liaoning	0.02-1.15	0.30	0.24
4	Neimenggu	0.06-1.07	0.28	0.37
5	Beijing	0.23-0.54	0.34	0.09
6	Anhui	0.14-0.33	0.22	0.06
7	Jiangxi	0.08-0.26	0.16	0.07
8	Hebei	0.05-0.28	0.13	0.07
9	Shanxi	0.02-1.59	0.22	0.32
10	Shanxi	0.02-0.61	0.16	0.19
11	Shandong	0.07-0.30	0.17	0.07
12	Heinan	0.14-0.81	0.30	0.22
13	Sichuan	0.07-0.35	0.18	0.10
14	Xinjiang	0.02-0.05	0.03	0.01
	Range of average values		**0.03-0.34**	

Table A5. The mercury content of selected US coals [18]

Place	Average, (mg/kg)	Standard deviation	Minimum value (mg/kg)	Maximum value (mg/kg)	Number of samples
Appalachian	0.20	0.19	0.003	2.9	4399
Eastern Interior	0.10	0.07	0.007	0.4	301
Fort Union	0.13	0.12	0.007	1.2	.00
Green River	0.09	0.05	0.003	1.0	418
Hams Fork	0.09	0.004	0.02	0.6	29
Gulf Coast	0.22	0.19	0.01	1.0	142
Pennsylvania Anthracite	0.18	0.24	0.003	1.3	52
Powder River	0.10	0.09	0.003	1.4	616
Raton Mesa	0.09	0.10	0.01	0.5	40
San Juan River	0.08	0.11	0.003	0.9	194
South West Utah	0.10	0.09	0.01	0.5	42
Uinta	0.08	0.009	0.003	0.6	271
Western Interior	0.18	0.17	0.007	1.6	311
Wind River	0.18	0.19	0.007	0.8	42
Range of average value	**0.08-0.22**				

Table A6. Evaluation of range and average mercury emission factor for hard coal recently used in EC countries [23]

Country of origin	Number of samples	Mean of concentration (mg/kg)	Standard deviation
Bituminous steam coal as imported to Denmark			
Australia	23	0.05	0.02
Colombia	21	0.07	0.02
Poland	13	0.09	0.02
Russia	20	0.12	0.07
South Africa	52	0.13	0.07
United States	32	0.11	0.05
Bituminous steam coal as imported to UK (2002)			
Indonesia	2	0.025	0.007
Colombia	12	0.050	0.025
South Africa	19	0.074	0.046
United States (Eastern)	4	0.065	0.017
Australia	3	0.097	0.006
Poland	3	0.070	0.020
Russian	3	0.070	0.036
UK	120	0.111	0.057
Weighted average (2002)	**-**	**0.07**	**-**
Bituminous steam coal as imported to the Netherlands			
Australia	17	0.08	0.06
Colombia	7	0.06	0.03
China	2	0.15	-
Egypt	1	0.10	-
Germany (Ruhr area)	1	0.16	-
Indonesia	7	0.04	-
New Zeeland	1	0.05	-
Poland	10	0.35	0.55
Rusia (Kuzbas)	1	0.06	-
South Africa	12	0.09	0.02
Norway (Spitsbergen)	2	0.14	0.12
USA (Eastern)	15	0.14	0.12
Venezuela	2	0.08	-
Blend	36	0.09	0.07
Total	109	0.12	0.19
Weighted averaged in the Netherlands in 1999	**-**	**0.11**	**0.20**

Bituminous steam coal as imported to Ireland (2002)

Country of origin	Number of samples	Mean of concentration (mg/kg)	Analysis by
Colombia – Intercor El Cerrejon	1	0.050	KEMA
USA Consol (Bailey)	1	0.116	KEMA
Indonesia - Pinang	1	0.03	KEMA
South Africa	1	0.141	KEMA
Australia - Bengalla	1	0.03	SGS Australia Lab
Australia - Bengalla - NSW	1	0.063	KEMA Analysis
Australia – Queensland	1	0.02	CCI Australia
Australia – NSW Lemington	1	0.10	CCI Australia

Bituminous steam coal as imported to Austria (1992-2004)

Country of origin	Coal mine	Concentration Hg (mg/kg)
Poland	Rydultowy	0.06 – 0.1
Poland	Powstancow	0.06 – 0.2
Poland	Murcki	0.15
Poland	Debiensko	< 0.1
Poland	Bobrek	0.07
Scotland	Stewarton	0.05
China	Datong	0.08
Colombia	Cerrejon	0.05
Australia	South Blackwater	0.05
South Africa	Arthur Taylor	0.08

Arithmetic average all data and estimated EF of mercury (Hu of 24 GJ/ton was used)

Range mg Hg/kg	**0.02 – 0.350**
Range of mercury EF kg/PJ	**0.83 – 14.58**

Table A7. Contents of mercury in brown coal and relevant emission factor obtained by recalculation (for recalculation of H_u, 18 GJ/t was assumed and 0,95 as coefficient for emission mercury during combustion process)

Lp	Contents of Hg mg/kg	Emission factor mg/GJ	Origin of coal	Reference
1	0.14	7.8	Romania	[21]
2	0.14	7.8	Poland	[7]
3	0.19-0.25[a]	10.5-13.9	Czech	[25]
4	0.23	12.1		[26]
5	0.03	2.1		[26]
Range	0.14 – 0.25	2.1 – 13.9		
Average		7.0		

Table A8. A lost of mercury during coking and pyrolysis processes of coal [7]

Lp	Fuel	Contents of Hg mg/kg	Distribution of mercury, %	Emission factor of Hg, mg/GJ [1]
1	Hard coal	0.214	100	6.89
	Char from hard coal	0.012	6	0.37
2	Brown coal	0.14	100	7.4
	Char from brown coal	0.02	14	0.90
3	Blend coal (coking	0.099	100	3.50
	Coke	0.040	79	1.29

[1] Estimated on heating value of fuels and 0,95 as coefficient for emission mercury during combustion process.

Table A9. Contents of mercury in coal and solid derived fuels and emission factor of Hg – experimental data

Type of SCIs	Fuel	Contents of Hg mg/kg	Emission factor	Ref.
Stove	Hard coal	0.214	4.66 (7.25[a])	7
	Domestic coke	0.044	1.5	
	Smokeless fuel A [1]	0.030	0.99	
	Smokeless fuel B [2]	0.026	0.91	
	Smokeless fuel C [3]	0.018	0.64	
	Smokeless fuel C [4]	0.019	0.68	
	Domestic coke	0.037	1.3	27
	Hard coal	0.067	1.37[b] (2.27[a])	27
	Briquettes (hard coal+40%	0.370	2.27[b] (17.57[c])	
	Hard Coal	0.077	0.506[b] (2.62[d])	27
Boiler 25 kW (autom. stoker)	Hard Coal	0.067	0.195[b] (2.27[e])	
	Hard Coal	0.120	0.39[b] (5.1[f])	

[a] the data has received form recalculation of Hg content of fuel and H_u, 29.5 GJ/t that was used in the experiment (64.3% and 60.3%) of Hg content of fuel burned during combustion process)

[b] Hg associated with TSP

[c] the data has received form recalculation of Hg content of fuel and H_u, 20.5 GJ/t that was used in the experiment (13% of Hg content of fuel burned during combustion process)

[d] the data has received form recalculation of Hg content of fuel and H_u, 29.4 GJ/t that was used in the experiment (19.3% of Hg content of fuel burned during combustion process)

[e] the data has received form recalculation of Hg content of fuel and H_u, 29.5 GJ/t that was used in the experiment (8.6% of Hg content of fuel burned during combustion process)

[f] the data has received form recalculation of Hg content of fuel and H_u, 24.1 GJ/t that was used in the experiment (7.6 % of Hg content of fuel burned during combustion process)

Table A10. Distribution of Hg during the combustion of fuels in the CELUS stove [7]

Fuel	Content of mercury (mg/kg)	Bottom ash	Dust	Gas phase
		%		
Coal	0.214	35.5	25.5	40
Coke	0.044	3.3	18	78.7
Smokeless fuel A1)	0.030	6	23	67
Smokeless fuel B 2)	0.026	8	22	70
Smokeless fuel C 3)	0.018	8	25	63
Smokeless fuel D 4)	0.019	9	24	70
Coal	0.200	48	52 [8]	

1) smokeless fuel from hard coal without dolomite
2) smokeless fuel from hard coal with dolomite
3) smokeless fuel from brown coal without dolomite
4) smokeless fuel from brown coal with dolomite

Table A11. Contents of mercury and its emission factor for biomass fuels (for recalculation of H_u, 16 GJ/t and 0,95 as coefficient for emission mercury during combustion process was assumed)

Fuel	Contents of Hg mg/kg	Emission factor kg/TJ	Type of installation	Reference
Pine[a)]	0.0219-0.0437	0.0014-0.0027	ND	[28] [c)]
Oak[a)]	0.0713	0.0044	ND	
Beech[a)]	0.0524	0.0032	ND	
Fir, cedar[a)]	0.0542	0.0034	ND	
Mountain	0.0290	0.0018	ND	
Beech[b)]	0.0383	0.0024	ND	
Cedar[b)]	0.0587	0.0037	ND	
Fir[b)]	0.0301	0.0019	ND	
Pine[b)]	0.0139-0.0145	0.00087-	ND	
Bark	0.08-0.8	0.005 – 0.050	ND	[29] [1)]
Sawdust (pine)	0.021	0.0001	Boiler 30kWmanual fuelled	[30] [d)]
Lump wood	0.027	0.0012		[30] [d)]
Wheat straw	0.018	0.001		[30] [d)]
Rape straw	0.03	0.0007		[30] [d)]
Wood waste	-	0.000246	Boiler	[31]
Chip wood	0.053	0.006	Automatic Boiler 600kW	[32] [d) e)]
Wheat Straw	0.059	0.009		
Rape straw	0.03	0.007		
Wood bark	0.034	0.0034 [f)]	ND	[33]
Straw	0.031	0.002214 [g)]	ND	
Sewage sludge	2.77 (dry base)	0.277	Nd	[34]

ND non determined

[a)] waste wood

[b)] raw wood

[c)] for recalculation of H_u, 16 GJ/t was assumed

[d)] experimental data

[e)] after dedusting system

[f)] for recalculation of H_u, 10 GJ/t was assumed

[g)] for recalculation of H_u, 14 GJ/t was assumed

Table A12. Contents of mercury in gaseous and liquid fuels and emission factor obtained by recalculation (for recalculation of H_u, 42 GJ/t was assumed)

Fuel	Contents of Hg mg/ton	Emission factor mg/GJ	Origin of fuel	Reference
Liquid fuels				
Gasoline	0.22-1.43	0.005-0.034	USA	[35] (by Liang)
	0.72-3.2	0.017-0.076	USA	[35] (by Liang)
	Average value	**0.03**		
Diesel oil	0.4	0,0095	USA	[35] (by Liang)
	2.97	0,071	USA	[35] (by Liang)
Fuel oil (light)	0,59	0,014	USA	[36]
	1,32	0,031	USA	[35] (by Bloom)
	0,67	0,016		[37]
	<120[a]	0.029-0.031	USA	[38]
	<0.2[a]	0.0048	USA	[39]
	1[a]	0.024	USA	[40]
	1.32	0.031	USA	[41]
	Average value after removal values: <0.2,	**0.025**	-	-
Heavy fuel oil	0,27	0.006	USA	[37]
	0.4	0.095	USA	[41]
	0.67	0.016	USA	[41]
	50[b]	1.2	Belarus	[42]
	n.d.[d]	0.2-3.6	-	[43]
	Average value	**0.06**		
Kerosene	8-60	0.190-1.428	Asia	[35] (by Tao)
	3-40	0.071-0.952	USA	[35] (by Olsen)
	Average value	**0.66**		
Gaseous fuel				
Network natural gas	0.0014[c]	0.04	Belarus	[42]
	0.00002 -	0.0006-0.006	USA	[44]
	Average value	**0.01**		

[a] ppb; [b] residual, mazout; [c] mg/ m^3 (H_u of 40.1 MJ/m^3); [d] no data

Lp	**Total Hg (mg/ton)**	**Assessment emission factor (mg/GJ)**	**Origin**
1	<10	0.238	The Middle East
2	4.3	0.102	The Middle East
3	<10	0.238	Africa
4	1.7	0.040	Africa
5	<10	0.238	Asia
6	<15	0.357	South America
7	5.2	0.124	South America
8	<10	0.238	South America
9	5.0	0.119	North Sea
10	1.4	0.033	Mexico
11	<15	0.357	Canada
12	4.2	0.100	Libyan
13	<10	0.238	Asia
14	2.8	0.067	USA (California)
15	1.9	0.045	USA (California)
16	3.0	0.071	USA (California)
17	2.4	0.057	USA (California)
18	5.1	0.121	Libya
19	1.7	0.040	Libya
20	<5	<0.119	[6]
Range	**1.4 - 15**	**0.033 – 0.357** **(0.000033 – 0.000357)** **kg Hg/TJ**	-

Table A13. Content of mercury in crude oil [40]

Table A14. Emission factor of Hg to be used in emission inventory processes

Fuel	Technology	Original mercury Emission Factor	Emission Factor kg Hg/TJ	Ref.
EPA				
Heavy fuel oil – uncontrolled	-	4.23x10^{-4} lbs Hg/1000 gal oil	0.000024	45
Residual oil – uncontrolled	-	0.092 kg Hg/PJ	0.000092	
Wet wood – using PM controls	-	5.15x10^{-6} lbs Hg/ton wood	0.000194	
Residual oil	-	6.8 lb/10^{12} Btu	0.00002	
Destilate fuel oil		7.2 lb/10^{12} Btu	0.00003	
Poland				
Hard coal	Electricity production	-	0.008	46,47
Brown coal		-	0.005	
Brown coal	District heating	-	0.008	
Hard coal		-	0.005	
Hard coal	Commercial, institutional	-	0.008	
Brown coal		-	0.005	
Coke		-	0.0006	
Hard coal	Residential, agricultural, others	-	0.004	
Brown coal		-	0.005	
Coke		-	0.0006	
Australia				
Wood waste (C		2.58x10^{-6} kg Hg/t (10.5MJ/kg)	0.000246	48
Distillate Oil Fired (E	-	1.3 kg Hg/PJ	0.0013	
Fuel Oil Fired C	-	1.36x10^{-5}kg Hg/1000 L	0.00038	
Natural gas D		4.2x10^{-3}kg Hg/10^{6} m^{3}	0.000012	
Anthracite coal E	Stoker	4.4x10^{-5} – 8.52x10^{-5} kg Hg/t	0.002 – 0.004	
Lignite coal E	Stoker	9 kg Hg/PJ of energy produced	0.009	
Bituminous and sub-bituminous coal	Stoker, pulverized coal (dry bottom, wet bottom, cyclone furnace	6.9 kg Hg/PJ of energy produced	0.0069	
Norway				
Coal	Direct furnace	0.05 g Hg/ton (28.1 GJ/t)	0.0018	49
	Boiler	0.05 g Hg/ton (28.1 GJ/t)	0.0018	
	Stove	0.3 g Hg/ton (28.1 GJ/t)	0.0107	
Coke	Direct furnace	0.05 g Hg/ton (28.5 GJ/t)	0.00175	
	Boiler	0.05 g Hg/ton (28.5 GJ/t)	0.00175	
	Stove	0.3 g Hg/ton (28.5 GJ/t)	0.0105	
Charcoal	Stove	0.3 g Hg/ton (28.1 GJ/t)	0.0107	
Kerosene heating	Boiler	0.03 g Hg/ton (43.1 GJ/t)	0.000696	

	Stove	0.03 g Hg/ton (43.1 GJ/t)	0.000696	
Light fuel oil	Boiler	0.05 g Hg/ton (43.1 GJ/t)	0.00116	
	Stove	0.05 g Hg/ton (43.1 GJ/t)	0.00116	
Heavy distillate oil	Direct furnace	0.05 g Hg/ton (43.1 GJ/t)	0.00116	
	Boiler	0.05 g Hg/ton (43.1 GJ/t)	0.00116	
	Ship	0.05 g Hg/ton (43.1 GJ/t)	0.00116	
Heavy fuel oil (residual)	Direct furnace	0.2 g Hg/ton (43.1 GJ/t)	0.0046	
	Boiler	0.2 g Hg/ton (43.1 GJ/t)	0.0046	
	Ship	0.2 g Hg/ton (43.1 GJ/t)	0.0046	
Natural gas	Direct furnace, boiler, stove, ship	0.001 g Hg/1000 m^3 (40.1 GJ/1000 m^3	0.000025	
Fuel wood	Stove	0.0084 g Hg/ton (16.8	0.0005	
Special waste	Boiler	0.2 g Hg/ton		
	Ship	0.2 g Hg/ton		
Hungary				
Solid fuels		0.02142857 t Hg/PJ	0.02142857	51
Liquid fuels			ND	
Gaseous fuel		0.00015 t Hg/PJ	0.00015	
Spain				
Natural gas	All SCIs	0.1 mg Hg/GJ	0.0001	52
Residual oil	Residential; boiler <50MW	4.23 mg Hg/GJ	0.00423	
	Comm-Institut.; boiler <50MW, gas turbine, stationary engine	4.23 mg Hg/GJ	0.00423	
	AFF;boiler<50MW	4.23 mg Hg/GJ	0.00423	
Steam coal	Residential Comm-Institut; boiler <50MW	14.63 mg Hg/GJ	0.01463	
UK				
Anthracite	Domestic 1A4bi	0.00011 kg Hg/ton	0.00393 (Hu 28	53
Burning oil		0.0000001 kg Hg/ton	0.00000238	
Burning oil (P)		0.0000001 kg Hg/ton	0.00000238	
Coal		0.00011 kg Hg/ton	0.00458	
Coke		0.00011 kg Hg/ton	0.00372	
Fuel oil		0.0000234528 kg Hg/ton	0.000558	
Gas oil		0.000019936 kg Hg/ton	0.0004747	
SSF		0.00011 kg Hg/ton		
Wood		0.00003 kg Hg/ton	0.001875	
Derived fuels	Domestic house & garden 1A4bii	0.0000001 kg Hg/ton	0.00000357	
Coal	Agriculture 1A4ci	0.00045 kg Hg/ton	0.01875	
Coke		0.00045 kg Hg/ton	0.0152	
Fuel oil		0.0000234528 kg Hg/ton	0.000558	
Gas oil		0.000019936 kg Hg/ton	0.0004747	
Gas oil (Power unit)	Agric. 1A4cii	0.000019936 kg Hg/ton	0.0004747	
Gas oil	Fishing 1A4ciii	0.000019936 kg Hg/ton	0.0004747	
Fuel oil		0.0000234528 kg Hg/ton	0.000558	

Slovakia				
Brown coal [a)]	Commercial and institutional, agriculture	2.35 g Hg/ton	0.130	54
Hard coal [b)]		3.57 g Hg/ton	0.1488	
Residual fuel oil - heavy		0.2 g Hg/ton	0.00476	
Residual fuel oil - light		-		
Wood		0.2 g Hg/ton	0.0125	
Brown coal [a)]	Residential	2.35 g Hg/ton	0.130	
Hard coal [b)]		3.57 g Hg/ton	0.1488	
Residual fuel oil - heavy		-		
Residual fuel oil - light		-		
Wood		0.01286 g /t	0.000804	
"Small Combustion Installations"; Chapter for "Emission Inventory Guidebook"				
Coal	Stove	-	0.005	43
Coal briquettes		-	0.003	
Liquid fuels		-	0.0005	
Wood		-	0.0005	
Coal	Boiler <50kW	-	0.010	
Coal briquettes		-	0.007	
Liquid fuels		-	0.001	
Wood		-	0.002	
Coal	Boiler >50 kW$_{th}$ -to < 1 MWth	-	0.010	
Coal briquettes		-	0.007	
Liquid fuels		-	0.001	
Wood	Boiler >1 MW$_{th}$ to < 50 MWth	-	0.001	
Coal		-	0.01	
Liquid fuels		-	0.001	
Wood		-	0.0005	
Coal	Advanced stove	-	0.005	
	Manual boiler	-	0.005	
	Automatic boiler	-	0.005	
		-		
Wood	Advanced stove	-	0.0005	
	Pellet stove	-	0.0005	
	Manual boiler	-	0.001	
	Automatic boiler	-	0.0005	
Romania				
Lignite coal	Residential	0.004 kg/TJ	0.004	55
Bituminous coal		0.006 kg/TJ	0.006	
Wood		0.0004 kg/TJ	0.0004	
Natural gas		0.00004 kg/TJ	0.00004	
Lignite coal	Commercial/Institutional	0.0065 kg/TJ	0.0065	
Bituminous coal		0.0085 kg/TJ	0.0085	
Wood		0.00055 kg/TJ	0.00055	
Residual oil		0.0023 kg/TJ	0.0023	
Gasoline		0.00003 kg/Hg	0.00003	
Diesel/light fuel oil		0.000024 kg/TJ	0.000024	
Natural gas		0.00004 kg/TJ	0.00004	
Lignite coal	AFF	0.007 kg/TJ	0.007	
Coke		0.0035 kg/TJ	0.0035	
Wood		0.0008 kg/TJ	0.0008	
Gasoline		0.00003 kg/Hg	0.00003	
Diesel/light fuel oil		0.000024 kg/TJ	0.000024	
Natural gas		0.00004 kg/Hg	0.00004	

Italy				
Natural gas	All sectors	0.15 mg/GJ	0.00015	56
Gasoline		1 mg/GJ	0.001	
Gasoil		1 mg/GJ	0.001	
Oil		1 mg/GJ	0.001	
Wood		0.95 mg/GJ	0.00095	
Coal		10 mg/GJ	0.010	
Germany				
Coal	Residential	0.008 kg/TJ	0.008	58
Diesel/light fuel oil		0.0005 kg/TJ	0.0005	
Gaseous fuel		0.00005 kg/TJ	0.00005	
Diesel/light fuel oil	Commercial/Institutional	0.0005 kg/TJ	0.0005	
Heavy fuel oil		0.002 kg/TJ	0.002	
Diesel/light fuel oil	AFF	0.0005 kg/TJ	0.0005	
Heavy fuel oil		0.002 kg/TJ	0.002	
Residential				
Biomass	Boiler <50kW automatic	0.00055 kg/TJ	0.00055	57
	Boiler <50kW manual	0.0005 kg/TJ	0.0005	
	Stove	0.0004 kg/TJ	0.0004	
	Fireplace	0.0004 kg/TJ	0.0004	
Coke / briquettes	Boiler <50kW manual	0.003 kg/TJ	0.003	
Bituminous coal	Boiler <50kW automatic	0.0085 kg/TJ	0.0085	
	Boiler <50kW manual	0.008 kg/TJ	0.008	
	Stove	0.006 kg/TJ	0.006	
Lignite (brown) coal	Boiler <50kW automatic	0.0065 kg/TJ	0.0065	
	Boiler <50kW manual	0.006 kg/TJ	0.006	
	Stove	0.004 kg/TJ	0.004	
Liquid fuel	Heavy fuel oil	Na	NA	
	Diesel/light fuel oil	0.000024 kg/TJ	0.000024 kg/TJ	
	Gasoline	0.00003 kg/TJ	0.00003 kg/TJ	
Natural gas	Natural gas	0.00004 kg/TJ	0.00004	
Commercial and Institutional				
Biomass	Boiler <50 MW automatic	0.0055 kg/TJ	0.0055	57
	Boiler < 1MW manual	0.005 kg/TJ	0.005	
Coke / briquettes	Boiler <50 MW automatic	0.0035 kg/TJ	0.0035	
	Boiler < 1MW manual	0.003 kg/TJ	0.003	
Bituminous coal	Boiler <50 MW automatic	0.009 kg/TJ	0.009	

	Boiler < 1MW manual	0.0085 kg/TJ	0.0085	
	Boiler <1 MW manual	0.008 kg/TJ	0.008	
Lignite (brown) coal	Boiler <50 MW automatic	0.007 kg/TJ	0.007	
	Boiler < 1MW manual	0.0065 kg/TJ	0.0065	
	Boiler <1 MW manual	0.006 kg/TJ	0.006	
Liquid fuel	Heavy fuel oil	0.0023 kg/TJ	0.0023	
	Diesel/light fuel oil	0.000024 kg/TJ	0.000024	
	Gasoline	0.00003 kg/Hg	0.00003	
Agricultural Forestry Fishing				
Biomass	Boiler <50 MW automatic	0.0008 kg/TJ	0.0008	57
	Boiler < 1MW manual	0.0008 kg/TJ	0.0008	
	Boiler <1 MW manual	0.0006 kg/TJ	0.0006	
Coke / briquettes	Boiler <50 MW automatic	0.0035 kg/TJ	0.0035	
	Boiler < 1MW manual	0.003 kg/TJ	0.003	
Bituminous coal	Boiler <50 MW automatic	0.009 kg/TJ	0.009	
	Boiler < 1MW manual	0.0085 kg/TJ	0.0085	
	Boiler <1 MW manual	0.008 kg/TJ	0.008	
Lignite (brown) coal	Boiler <50 MW automatic	0.007 kg/TJ	0.007	
	Boiler < 1MW manual	0.0065 kg/TJ	0.0065	
	Boiler <1 MW manual	0.006 kg/TJ	0.006	
Liquid fuel	Heavy fuel oil	0.0023 kg/TJ	0.0023	
	Light fuel oil	0.000024 kg/TJ	0.000024	
Denmark				
Coal and coke/briquettes (stove, single automatic and manual boilers < 50MW	For all sectors	0.0017 kg/TJ	0.0017	59
Biomass (fireplaces, stove, single automatic and manual boilers <50MW		0.0068 kg/TJ	0.0068	
Diesel/light fuel oil		0,00117 kg/TJ	0,00117	
Heavy fuel oil		0,0043 kg/TJ	0,0043	

Czech Republic				
Brown coal	For all sectors	126,00 mg/t[a]	0.007	60
Hard coal		496,60 mg/t[c]	0.0215	
Coke		17,48 mg/t[d]	0.00065	
Biomass		0,000 mg/t	0.000	
Liquid fuel oil		336,00 mg/t[e]	0.008	
Netherlands				
Hard coal	Residential	-	0.000178	61
Wood/Waste		-	0.00242	
Liquid fuel oil		-	0.0000096	
Hard coal	AFF	-	0.000089	
Liquid fuel oil		-	0.0000766	
Heavy fuel oil		-	0.001121	
Hard coal	Commercial/Institutional	-	0.000107	
Liquid fuel oil		-	0.000119	
Austria				
Hard coal	For all sectors, combustion <50MW	10.71 kT/TJ	0.01071	62 - 64
Brown coal		9.17 kT/TJ	0.0917	
Coke		10.71 kT/TJ	0.01071	
Wood		2.00 kT/TJ	0.02	
Fuel oil extra light		0.01 kT/TJ	0.00001	
Fuel oil light		1.30 kT/TJ	0.00130	
Fuel oil medium		1.39 kT/TJ	0.00139	
Hard coal	Stoves, fireplaces, cooking	10.71 kT/TJ	0.01071	
Brown coal		9.17 kT/TJ	0.0917	
Coke		10.71 kT/TJ	0.01071	
Wood		4.00 kT/TJ	0.04	
Fuel oil extra light		0.01 kT/TJ	0.00001	
Fuel oil light		1.30 kT/TJ	0.00130	
Fuel oil medium		1.39 kT/TJ	0.00139	
Ireland				
Natural gas	Residential	-	0,00004	65
LPG		-	0,00004	
Gasoline		-	0,00003	
Diesel / Light fuel oil		-	0,000024	
Hard coal, single house boilers (manual) <50 kW		-	0.008	
Coke, briquettes, single house boilers (manual) <50 kW		-	0.003	
Biomass, single house boilers (manual) <50 kW using wood, waste, biomass		-	0.0004	
Natural gas	Commercial/Institutional	-	0,00004	
LPG		-	0,00004	
Gasoline		-	0,00003	
Diesel / Light fuel oil		-	0,000024	
Heavy fuel oil		-	0.0023	
Coke, briquettes, single house boilers (manual) <50 kW		-	0.003	
Diesel / Light fuel oil	AFF		0,000024	

Biomass, single house boilers (manual) <50 kW using wood, waste, biomass		-	0,0006	
Natural gas	Industrial	-	0,00004	
LPG		-	0,00004	
Gasoline		-	0,00003	
Diesel / Light fuel oil		-	0,000024	
Hard coal, single house boilers (manual) <50 kW		-	0.009	
Coke, briquettes, single house boilers (manual) <50 kW		-	0.0035	
Biomass, single house boilers (manual) <50 kW using wood, waste, biomass		-	0.00055	

a) for recalculation of $H_{u,}$ 18 GJ/t was assumed

b) for recalculation of $H_{u,}$ 24 GJ/t was assumed

c) for recalculation of $H_{u,}$ 24 GJ/t was assumed

d) for recalculation of $H_{u,}$ 42 GJ/t was assumed

Table A15. Average emission factors of mercury for Power Plants and District Heating conventional thermal electricity and heat generation (aggregate on coal and oil) that were elaborated under project Espreme/Mercyms [66]

Country	**Emission factor kg/TJ [a)]**								
	2005			**2010**			**2020**		
	1*)	**2**)**	**3***)**	**1*)**	**2**)**	**3***)**	**1*)**	**2**)**	**3***)**
Austria	0.006	0.006	0.005	0.005	0,005	0.004	0.004	0.004	0.004
Belarus	0.001	0.001	0.001	0.001	0,001	0.001	0.001	0.001	0.001
Belgium	0.006	0.006	0.006	0.006	0,005	0.004	0.006	0.004	0.004
Bulgaria	0.013	0.009	0.009	0.012	0,006	0.005	0.011	0.005	0.005
Czech Republic	0.001	0.001	0.001	0.001	0,001	0.001	0.001	0.001	0.001
Denmark	0.011	0.008	0.008	0.010	0,006	0.005	0.009	0.005	0.005
Estonia	0.010	0.008	0.008	0.010	0,007	0.005	0.009	0.005	0.005
Finland	0.002	0.002	0.001	0.001	0,001	0.001	0.001	0.001	0.001
France	0.021	0.014	0.009	0.016	0,006	0.005	0.010	0.005	0.005
Germany	0.005	0.005	0.004	0.005	0,005	0.004	0.005	0.004	0.004
Greece	0.008	0.006	0.006	0.006	0,005	0.004	0.005	0.004	0.004
Hungary	0.012	0.008	0.008	0.011	0,006	0.005	0.008	0.005	0.005
Ireland	0.026	0.015	0.009	0.026	0,006	0.005	0.022	0.005	0.005
Italy	0.007	0.007	0.006	0.006	0,005	0.004	0.006	0.004	0.004
Latvia	0.005	0.005	0.005	0.004	0,004	0.005	0.004	0.004	0.005
Lithuania	0.005	0.005	0.004	0.005	0,004	0.003	0.005	0.002	0.003
Luxembourg	0.005	0.001	0.005	0.005	0,005	0.004	0.004	0,004	0.004
The Netherlands	0.001	0.008	0.001	0.001	0,001	0.001	0.001	0,001	0.001
Norway	0.012	0.008	0.008	0.009	0,006	0.005	0.006	0,005	0.005
Poland	0.010	0.006	0.008	0.009	0,007	0.005	0.008	0.005	0.005
Portugal	0.008	0.011	0.006	0.007	0,005	0.004	0.005	0.004	0.004
Romania	0.015	0.002	0.009	0.014	0,007	0.005	0.013	0.005	0.005
Slovakia	0.002	0.008	0.002	0.002	0,002	0.002	0.002	0.002	0.002
Slovenia	0.011	0.008	0.008	0.010	0,006	0.005	0.008	0.005	0.005
Spain	0.013	0.001	0.008	0.012	0,006	0.005	0.010	0.005	0.005
Sweden	0.001	0.006	0.001	0.001	0,001	0.001	0.001	0.001	0.001
Switzerland	0.060	0.010	0.006	0.060	0,005	0.003	0.058	0.002	0.003
Turkey	0.008	0.008	0.007	0.007	0,006	0.005	0.006	0.004	0.005
United Kingdom	0.003	0.003	0.003	0.003	0,003	0.003	0.003	0.003	0.003
Europe	**0.008**	**0.007**	**0.006**	**0.008**	**0,006**	**0.004**	**0.007**	**0.005**	**0.004**

[a)] produced energy

1*) BAU Scenario ; business as usual; elaborated for 2000 with extrapolation to 2010 and 2020

2**) POT Scenario; with policy target in particular IPPC directive

3***) DEG Scenario; all available measures applied (technical implementation level and R&D level); maximum reduction regardless costs of reduction

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APPENDIX 2 STAKEHOLDER QUESTIONAIRE AND SUMMARY OF RESPONSES

Stakeholder Questionnaire

This questionnaire outlines the key issues / questions that we would like to consult on as part of the study "**Costs and Environmental Effectiveness of Reducing Mercury Emissions to Air from Small-Scale Combustion Installations (SCIs)**". It is split into two sections; the first section focuses on the country emissions data, while the second section focuses on options (measures/technologies) that have or could be introduced to reduce mercury emissions from SCIs.

Complete only those sections that you think are relevant based on field of expertise.

A. Emission Inventory

1. **Do you agree with the activity data by sector and mercury emission estimates and for each sector of SCIs, for historic (2000) and projected emission estimates (2010 and 2020)?**

YES – The emissions of mercury are compatible with national estimation in 2000

YES – The emissions of mercury projected for 2010 and 2020 are compatible with national scenarios

Please provide the comments:

NO – The emissions of mercury are not compatible with national estimation in 2000

Please provide details (why, which fuel activity data and/or which sectors are not correct, etc.):

NO - The emissions of mercury projected for 2010, 2020 and 2030 are not compatible with national scenarios

Please provide details:

2. For the sectors identified do you have (or know sources of) any data on the following that would help us develop a more robust assessment of mercury emission? Information may include:
   - Emission factors of total Hg, and its distributions on species:
     i. attached to particulate material (Hg PM)
     ii. unreactive gaseous elemental mercury (Hg0)
     iii. reactive gaseous mercury (includes both inorganic and organic forms normally in the Hg2+ oxidised form)
   - Statistics on fuel consumption by type
   - Data on types of appliance-fuel use
   - Knowledge of planned or existing changes in appliance (technology)-fuel use e.g. coal to gas, coal to biomass, coal to manufactured coal fuels (briquettes); open fires to closed appliances, manual fuelled boilers to new – automatic fuelled boilers
   - Knowledge of planned or existing changes in fuel activity use e.g. coal to biomass, coal to manufactured coal fuels (briquettes)
   - Other

B. Technologies and Measures

1. Do you have any knowledge or data sources of measures (including technologies) for your country or other member states relevant to reducing of mercury from SCIs? Measures could include those:

- **i. Currently in use (1990-present)**
- **ii. Proposed or planned (Present-2020)**
- **iii. Which could be potentially introduced or proposed (Present-2020)**

Could you provide details of:

- Costs
- Reduction efficiencies
- Sources of such data (e.g. other studies)
- Legal reference of measure(s)

▪ **Currently in use (1990-present)**

▪ **Proposed or planned (Present-2020)**

▪ **Potentially introduced or proposed (Present-2020)**

2. Do you think there is potential for action at the EU level that could help reduce mercury emissions from SCIs (e.g. subsidies, legislation)?

3. Are there any initiatives under the national air quality strategy that could have an impact in terms of reducing emissions of mercury from SCIs?

Summary of country responses to the stakeholder consultation

Country	Summary of response
Austria	Two answers were received from Austrian stakeholders. Austria's Hg emission data (by sectors) for 1985, 1990, and 1995 were provided. These data as well as emission factor data were used for verification of estimated mercury emission.
Belgium	One reply was received from a Belgian stakeholder. The Belgian emission data (by sectors) estimated in this study was close to the reported data in February 2005 for EMEP-CLRTAP. A conclusion of the exercise was that the majority of the combustion installations in the Commercial-institutional and AFF sectors are small in Belgium (certainly smaller than 50 MW).
Czech Republic	Detailed responses were received on emission estimates of mercury, activity of fuels and emission factor. Emission factors received can be found in Annex 1 Table 14. Information was received on emissions of mercury and fuel activity data were used for verification of mercury emission. It was noted that: - The emissions of mercury estimated in this project are compatible with national estimation in 2000 - The Czech Republic does not have projected Hg emission for years 2010,2020, 2030
Denmark	A response was received from the Ministry of the Environment, National Environmental Research Institute Department of Policy Analysis. Information on emission factors was provided. It was noted that: - The Danish inventory does not distinguish between plants > 50 MW and < 50 MW - Information provided on emissions of mercury from AFF, Comm.-Inst., and Residential sectors was used for verification of estimated mercury emission in this project - No projections have been developed for Danish Hg-emissions for 2010 and 2020 - No information is available concerning planned or existing changes in fuel activity use e.g. coal to biomass, coal to manufactured coal fuels (briquettes) - The Danish "Guidelines for air emission regulation" states the following "Coal, petcoke, and lignite should not be used in new plants with an input effect of less than 5 MW". This "Guidelines" contains the limit of mercury emission from heavy fuel installation capacity between 2MW and 50MW (0.1 mg/ normal m^3 dry flue gas at 10 percent O_2). In such situation the consumption of coal fuels will continuously decrease that it will influence on reduction of mercury emission.
France	A response was received from CITEPA, information on emission factors was provided that has been incorporated in the section of this report. It was shown that: - Mercury emissions from the combustion of natural gas are considered equal to zero, no matter what kind of combustion is concerned - The emission factor for wood is recent, sourced from a study made for the ADEME (the French agency for environment) two years ago; - France does not produce or consume any lignite coal (brown coal) or bituminous coal any more. It was concluded that the emissions provided are considerably under their estimation (273 kg in project estimation versus 800 kg for the whole combustion plants with a capacity under 50 MW in France in 2000). CITEPA does not make a distinction in this range of combustion installations so they are not able to provide this data. It was noted that France does not agree with the scenario used for the projections (Scenario: CP_CLE (IIASA) NOV_04). It was disclosed that the French agency ADEME launched a call for projects on the subject of measuring air pollutants for stationary sources. These air

	pollutants will include heavy metals; therefore the knowledge of mercury emissions will improve in France in coming years. No information was provided about any initiatives under the national air quality strategy that could have an impact in terms of reducing emissions of mercury from SCIs.
Germany	One reply was received from Germany stakeholders. They provided the Germany Hg emission data (by sectors) and prognosis for 2010 and 2020 estimated that were used for verification of estimates under this study. Emission factor for coal, and liquid fuels, used in SCI sectors, were also provided. It was noted that: - In Germany, coal consumption continues to decrease, while the consumption of natural gas and light fuel oil is rising - The use of coal in SCIs is declining and is supposed to become irrelevant within the next decades without further measures - Heavy fuel oil it is practically excluded from use in SCI < 50 MW with the entry into force of the "technical instruction air" in 2002.
Hungary	One response by the Hungary stakeholders was received. It was noted that: - Due to a lack of measurement data, emission factors from international literature are used in inventory estimates - In Hungary, the mercury emissions reduction is connected with the modification in structure of the fossil fuel consumption mainly and in less part with the ESP programme of the coal-fired; - Mercury reduction between 2010 and 2020 is connected with exchanging of solid fuel use by natural gas in residential and commercial and institutional sectors.
Ireland	The response came from Environmental Protection Agency. It provided the estimates of Hg Emissions from Commercial, Residential and Agriculture, and fuel activity data, EF of mercury split by sectors, fuels and technologies. These data were used for verification of mercury emission and projections estimated under this project. It was noted also that: emissions of mercury are very low priority in Ireland and are not part of normal inventory compilation. There is no data on national EF, projections or emission control options.
Italy	Two responses have been received from Italy consultees. The first was sent by the Italian regional agencies. It provided emission factors for mercury. It was noted that for natural gas Italian agency use a very old TNO emission factors that corresponds to the max EF of the UNECE Handbook for large combustion plants. Mercury emission inventory for SCIs in Italy were used to verify estimates made in this study. A second stakeholder has confirmed that information will be provided at later date.
Netherlands	A response came from The Netherlands Environmental Assessment Agency (The Dutch PRTR). It was noted that: - The mercury emissions for 2000 are (for each sector) approximately equal to the emissions in the Dutch PRTR database. In the Dutch PRTR, there is no distinction between SCI types - The total emission from SCI is very small. In the Netherlands, besides natural gas (mercury from combustion of natural gas is considered negligible and is not in the inventory), just a few fuels are used for combustion (for Residential: light fuel oil, hard coal and wood/waste, for Agriculture: light fuel oil, hard coal and heavy fuel oil and for Comm-Institut: light fuel oil, hard coal) - Calculations for all fuels, except wood/waste are done on the basis of a profile on co-emission with black carbon and PM_{10}. Emissions from wood/waste are calculated by activity data multiplied with an emission factor - The Netherlands has never submitted information on mercury projections - The projection is calculated (for both scenarios) with a yearly decrease of combustion in fireplaces (wood) of 1,1% (2001- 2010) and 1,2% (2011-2020). For the other fuels it is not expected that autonomous effects, e.g. changes in fuel activity, will occur in the

	projection period.
Norway	Emission factors of mercury split by fuel and technology as well as estimated mercury emission from SCIs sector were provided. It was noticed that it was not possible to estimate projected emissions for 2010 and 2020. The Norwegian Pollution Control Authority state that there are no current initiatives that have an impact on reducing emissions of mercury from SCI's.
Poland	Data on emission estimates of mercury, mercury emission speciation was received. This was split by size/capacity combustion installations were provided by national consultees. Power Plants, mining and research representative were involved in the process of consultation and data validation. It was noted that: - Poland adopted the National Strategy for Reduction of Heavy Metals in 2002 - Regional (voivod) and local (commune, gminas) programmes of "low level" emission reduction are directly connected with declining of coal use in residential sectors and are having significant affect on reduction of mercury emission.
Romania	One response by the Romania stakeholder was received. Emission factors, fuel activity data and estimates of mercury emissions were provided. Romanian statistics do not differentiate between light add heavy oil; the value is the total amount but the emission factor for light and heavy oil are diversified.
Slovakia	Some data on emission factors of mercury that are used in national inventory were provided in response. Some of these EFs are rather high compared to those used in this study (in particular for coal).
Spain	A response came from Ministry of Environment. Mercury emission factors were provided, and verification of mercury emission inventory and projections estimated under this project were delivered. It was noted that emission estimation for 2000 is very close to nationally reported estimates. Some differences were observed in the emission factors used in this study. Spain is aware of the revision (as of 14-10-2004) of the EFs in EMEP/CORINAIR chapter B-216 (SCI). They have asked if the EFs used in this project will be recommended by the TFEIP and proposed for the updating those referred in chapter B-216. There was no data provided for speciation of mercury emission. It was concluded that there is a lack of information to breakdown installation capacities into less than 1MW, between 1-20MW and neither between 20-50 MW nor to distinguish manual vs automatic. It was noted that the trend is to switch from coal to natural gas; coal represents in energy terms by 2000 less than 2% of fuel consumption.
United Kingdom	Detailed response regarding estimates for SCIs inventory, including emission estimates of mercury, mercury emission speciation as well as split by size of capacity for combustion installations.