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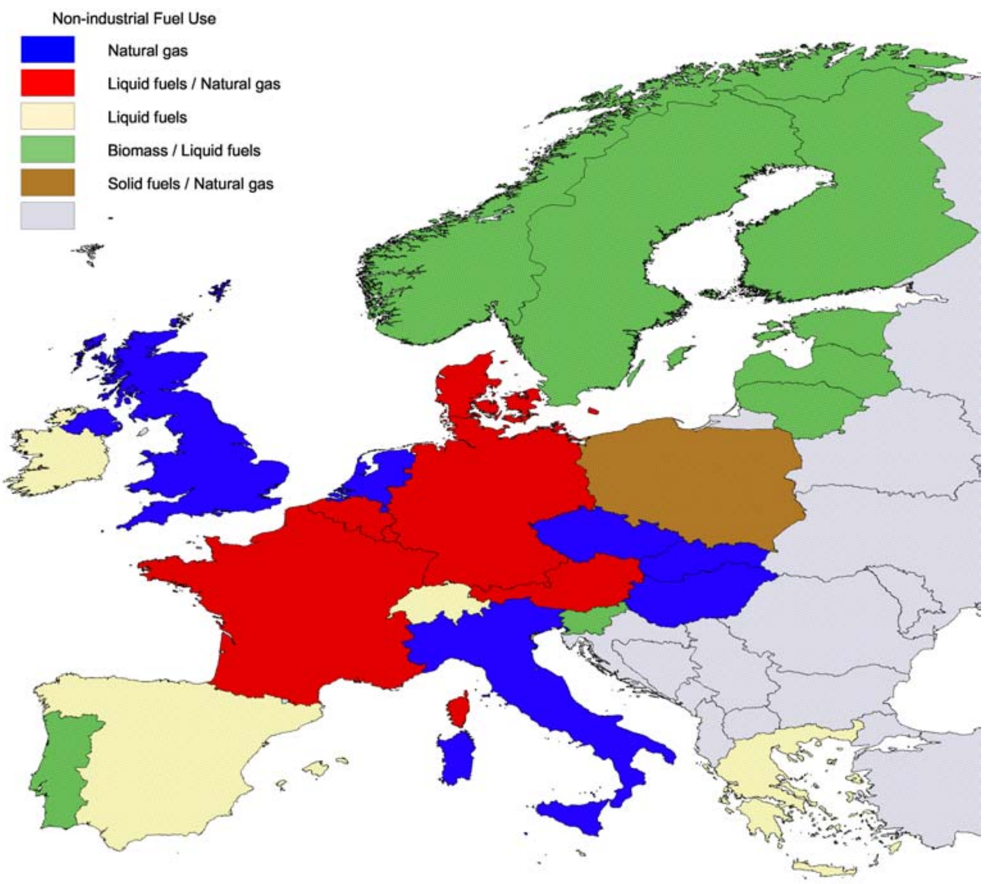
Costs and environmental effectiveness of options for reducing air pollution from small-scale combustion installations

Final Report for European Commission DG Environment



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Costs and environmental effectiveness of options for reducing air pollution from small-scale combustion installations

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AEA Technology Environment
BLDG 154 Harwell Business Centre
Harwell, OXON OX11 0QJ
United Kingdom
Telephone +44 (0) 870 190 6554
Facsimile +44 (0) 870 190 6327
Email: stephen.pye@aeat.co.uk

AEA Technology Environment is a business division of AEA Technology plc

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	Name	Signature	Date
Authors	Steve Pye Glen Thistlethwaite Martin Adams Mike Woodfield Justin Goodwin Dan Forster Mike Holland (EMRC)		
Reviewed by	Mike Woodfield		
Approved by	Mike Woodfield		

Executive Summary

The CAFE programme of the European Commission has been set up to develop the Thematic Strategy on Air Pollution under the 6th Environmental Action Programme. Under this programme, different policy options are being considered to address a range of current air pollution problems. Small combustion installations (SCIs) are considered to be a significant source of a range of pollutants, the most important of which is particulate matter (PM) due to the scale of emissions and associated health impacts. This study was undertaken to:

- Assess the significance of emissions of different pollutants from SCIs
- Characterise the type of SCIs, and associated fuels used, across Europe
- Identify the range of different options for reducing emissions
- Propose a range of feasible and cost-effective measures for consideration in the Thematic Strategy

In the absence of existing inventories, emission estimates were derived for both non-industrial and industrial SCIs. The data highlighted the following key issues:

- The high level of PM and NMVOC emissions from the residential sector due to consumption of biomass and solid fuels.
- The contribution from industrial SCIs to emissions of NOx, PM and SO_2.
- The high level of emissions of NOx from non-industrial SCIs, due to the consumption of natural gas, and to a lesser extent, liquid fuels.

These issues provide the focus for identifying potential policy options and technical measures. A major complexity arises because of the heterogeneity of SCIs and associated fuel use across Europe, and the very different characteristics of sectors that use SCIs. A large number of policy options were identified, most of which have been assessed in this study, while a limited number were rejected for reasons including limitation of application across Europe. A full synopsis of the findings of this study are given in Section 1, the evidence is given in Sections 2 – 7. In summary, the principle policy options assessed and recommendations are:

Introduction of product standards within a regulatory framework
European standards for non-industrial SCIs could be introduced within the framework of the proposed Energy Using Products Directive, and other New Approach Directives, as a means of ensuring minimum emissions from stoves and boilers. These product standards can have a significant impact in reducing emissions, and are considered particularly important for the reduction of PM related biomass emissions.

Promotion of local-based measures targeting urban pollution
The Air Quality Framework Directive provides the policy mechanism for identifying and ensuring that localised pollution exceedances are targeted. As reporting under the Directive by Member States evolves, our understanding of the need for additional measures will become clearer. Measures could include the promotion of ‘successful’ cost-effective measures for implementation by Member States under the Air Quality Framework Directive, or additional EU action e.g. restriction of the use of certain solid fuel products in urban areas.

Additional fuel quality requirements for products sold in the EU

The introduction of tighter limits on sulphur content of liquid fuels could lead to additional reductions in PM emissions, in addition to SO_2 reductions, although further research is needed to assess such impacts. New legislation on sulphur content of solid fuels may be considered less of a priority due to the projected reductions in the use of these fuels. Restrictions on biomass fuels are not considered (in the context of European policy) due to potential conflicts with Climate policy objectives although it is clear that wood fuel products have significantly lower associated PM emissions than conventional wood fuel.

Introduction of specified emission limits for larger SCIs

Emission limits for sub-50 MW_{th} installations could be considered, through extension of the IPPC or LCP Directives, or through a new Directive. Another alternative is the introduction of an emissions trading scheme, using the platform set by the EU ETS. However, the scope of existing regulation e.g. the IPPC Directive is considered to have significant coverage across the 20 – 50 MW_{th} range, and the estimated small contribution to overall European emissions questions the need for additional policy action.

Use of Structural Funds for Air Quality projects

The current structure of these funds means that they have not been used significantly in the past for projects relating to local air quality. Such funds could be further considered and restructured to enable financing of projects that require significant capital investment, and which can be very effective at improving poor urban air quality.

Development of energy efficiency measures in line with air quality objectives

Many energy efficiency measures are currently targeted at non-industrial sectors, and are therefore particularly relevant for SCIs. The recent Energy Performance of Buildings Directive has two proposals that could result in significant benefits for air quality pollutant emission reductions – improved building insulation and inspection / maintenance schemes. Further amendments to this Directive could also result in additional emission reductions.

SCIs are an important emission source, particularly of PM, and will continue to be so in future years. Therefore, options to target such emissions will need to be considered in the context of the Thematic Strategy, and developed based on the findings and recommendations made in this study.

Le programme CAFE de la Commission Européenne fut mis en place afin de developer la Stratégie Thématique pour la Pollution de l'Air dans le cadre du 6ème Programme d'Action Environnemental. Dans ce programme, différentes options sont considérées pour addresser une gamme de problèmes liés à la pollution de l'air. Les Petites Installations de Combustion (PIC) sont considérées comme étant une source significative d'une gamme de polluants dont le plus important est la Matière Particulaire (MP) dû à l'échelle des émissions et aux effets sur la santé. Cette étude fut entreprise afin de:

- Déterminer l'étendue des émissions des différents polluants provenant des PIC
- Caractériser les types de PIC ainsi que les carburants utilisés à travers l'Europe
- Identifier les différentes options pour réduire les émissions
- Proposer une gamme de mesures réalisables et d'un coût raisonnable pour considération dans la Stratégie Thématique

En l'absence d'un inventaire répondant aux critères de cette étude, des estimations sur les émissions provenant des PIC non-industriels et industriels furent dérivés à partir de plusieurs inventaires pré-existants. L'analyse des données a mis en évidence les points clés suivants:

- Les hauts niveaux d'émission de MP et de Composés Organiques Volatiles autres que le Méthane provenant du secteur non-industriel dûs à la consommation de biomasse et de carburants solides..
- La contribution de manière significative aux émissions de NOx, MP et SO_2 des PIC industriels
- Les hauts niveaux d'émission de NO_x provenant des PIC non-industriels, dûs à la consommation de gaz naturel.

Ces points clés permettent l'identification des potentielles options politiques et des solutions techniques. Une complexité majeure découle de l'hétérogénéïté des types de PIC et des carburants utilisés à travers l'Europe, ainsi que des très différentes caractéristiques des secteurs utilisant des PIC. Un grand nombre d'options politiques furent identifiées, dont un certain nombre furent rejetées pour des raisons telles que les limitations d'application à travers l'Europe. Les options politiques présentées dans cette étude sont concentrées sur les points suivants:

- Limites d'émission sur l'appareillage
- Obligations sur l'inspection et la maintenance
- Limites spécifiques pour les installations
- Mesures locales
- Restrictions sur la qualité du carburant
- Fonds structurels
- Mesures sur l'utilisation efficace de l'énergie

L'analyse démontre que les émissions provenant des PIC pourraient être réduites de manière significative et que certaines des mesures identifiées qui pourraient être appropriées à une application à travers l'Europe semblent être économiquement efficaces. Le secteur des PIC mérite donc d'être considéré pour un abattement futur dans le cadre de la Stratégie Thématique sur la Pollution de l'Air.

Das CAFE Programm der Europäischen Kommission wurde geschaffen, um die Thematische Strategie zur Bekämpfung der Luftverschmutzung im sechsten Umwelt-aktionsprogramm zu entwickeln. In diesem Programm sind die verschiedenen politischen Massnahmen zur Bekämpfung von gegenwärtigen Luftverschmutzungs-problemen beschrieben. Kleinfeuerungsanlagen sind eine bedeutende Quelle für eine Reihe von Luftschadstoffen, wobei Feststoffteilchen (Staub) als der wichtigste Schadstoff aufgrund des Emissionsausmasses und den damit verbundenen Aus-wirkungen auf die Gesundheit angesehen werden. Diese Studie wurde ausgeführt um:

die Bedeutung der Emissionen von verschiedenen Luftschadstoffen zu bewerten.
die Kategorien der Kleinfeuerungsanlagen mit den entsprechenden Brennstoffen europaweit einzuordnen.
verschiedene Massnahmen zur Verringerung von Emissionen zu bestimmen.
eine Reihe von durchführbaren und kostengünstigen Massnahmen für die Thematische Strategie vorzuschlagen.

Emissionswerte für industrielle und nicht-industrielle Kleinfeuerungsanlagen wurden, wenn keine Kataster existierten, geschätzt. Die Daten zeigten folgende Schwerpunkte:

Die hohen Werte der Feststoffteilchen und NMVOC Emissionen in privaten Einrichtungen werden der Verwendung von Biomassebrennstoffen zugeschrieben.
Kleinfeuerungsanlagen tragen zu den Emissionen von NOx, Feststoffteilchen und SO_2 bei.
Die hohen NOx Emissionen von nicht-industriellen Kleinfeuerungsanlagen werden verursacht durch die Nutzung von Erdgas und, zu einem geringeren Mass, auch durch flüssige Brennstoffe.

Mögliche Rechtsvorschriften und technische Massnahmen wurden hinsichtlich dieser aufgeführten Schwerpunkte untersucht. Die Verschiedenartigkeit der Kleinfeuerungs-anlagen und Brennstoffe, die in Europa genutzt werden, sowie die sehr verschiedene Charakteristik der Bereiche in denen diese Anlagen eingesetzt werden, bereitet grosse Schwierigkeiten. Eine Anzahl von möglichen Rechtsvorschriften und Massnahmen wurde identifiziert, von denen die meisten in dieser Studie geprüft wurden, wobei aber auch einige zurückgewiesen wurden, u.a. wegen Beschränkungen in der europa-weiten Anwendung. Ein Überblick der Ergebnisse dieser Studie wird in Kapitel 1 gegeben, Nachweismaterial wird aufgeführt in Kapitel 2-7. Die prinzipiellen Möglichkeiten für Rechtsvorschriften und Regelwerke wurden geprüft und die Empfehlungen sind wie folgt:

Einführung von Produktstandards mit Hilfe von Rahmengesetzgebung
Europäische Standards für nicht-industrielle Kleinfeuerungsanlagen könnten mit Hilfe der Rahmengesetzgebung der vorgeschlagenen Richtlinie für die Anforderungen an die umweltgerechte Gestaltung energiebetriebener Produkte, und weiteren Richtlinien zu neuen Verfahrensweisen, eingeführt werden. Dies könnte zum Beispiel eingesetzt werden, um die Emissionen der Öfen und Kessel auf ein Minimum zu halten. Diese Produktstandards können einen erheblichen Einfluss auf die Verringerung der Emissionen haben, und daher sind sie als besonders wichtig zur Verringerung der Feststoffteilchen erachtet.

Förderung der örtlichen Messungen von städtischen Luftverschmutzungen
Die Richtlinie über die Beurteilung und die Kontrolle der Luftqualität stellt die rechtlichen Regelwerke zur Verfügung, so dass sichergestellt ist dass die Überschreitungen der lokalen

Luftverschmutzung gemessen und bearbeitet werden. Die zukünftige Berichterstattung der Mitgliedstaaten im Zusammenhang mit dieser Richtlinie wird zu einem verbesserten Verständnis für notwendige zusätzliche Massnahmen führen. Die möglichen Optionen könnten zum Beispiel die Förderung zur Anwendung von „erfolgreichen" kostensparenden Massnahmen von Mitgliedstaaten im Rahmen dieser Richtlinie beinhalten. Weitere Optionen sind zusätzliche EU Aktionen, z.B. die Beschränkung im Verbrauch von bestimmten festen Brennstoffen in städtischen Gebieten.

Strengere Begrenzung der Inhaltstoffe in Brennstoffprodukten zum Verkauf in der EU
Die Einführung von niedrigeren Grenzwerten für den Gehalt von Schwefel könnte zu einer zusätzlichen Verringerung der Emissionen von Feststoffteilchen führen, im Zusatz zur SO_2 Reduzierung. Es ist jedoch weitere Forschung notwendig, um diese Einflüsse beurteilen zu können. Neue Gesetzesvorschriften für Schwefelgehalte in festen Brennstoffen könnten mit geringerer Dringlichkeit betrachtet werden, da bereits geplante Reduzierungen im Brennstoffverbrauch berücksichtigt werden. Beschränkungen für Biomassebrennstoffen ist nicht berücksichtigt wegen dem potentiellen Konflikt mit den Zielen der Klimavorschrift, obwohl es offensichtlich ist, dass Holzbrennstoffprodukte deutlich niedrigere Emissionen an Feststoffteilchen hat als konventionelle Holzbrennstoffe.

Einführung von festgelegten Emissionsgrenzwerten für grössere Kleinfeuerungs-anlagen
Emissionsgrenzwerte für Anlagen kleiner als 50 MW_{th} könnten durch die Erweiterung der IPPC oder LPC Richtlinien, oder auch durch neue Richtlinien, in Betracht gezogen werden. Eine weitere Alternative ist die Einführung des Emissionshandels-system, basierend auf dem System der EU ETS. Allerdings wird angenommen, dass die bereits bestehenden Richtlinien, wie z.B. die IPPC Richtlinie, die 20-50 MW_{th} Anlagen im erheblichen Umfang abdecken werden. Daher ist es fraglich, ob zusätzliche Regelungen notwendig sind, wenn man den geschätzt geringen Beitrag dieser Anlagen zu den Emissionen in Europa insgesamt betrachtet.

Einsatz von strukturbedingten Finanzmitteln für Luftreinhaltungsprojekte
Die gegenwärtige Struktur der Finanzmittel bedeutet, dass diese bisher nicht in bedeutendem Ausmasse für lokale Luftreinhaltungsprojekte verwendet wurden. Solche Finanzmittel könnten daher mehr berücksichtigt (und umstrukturiert) werden, um die Finanzierung von Projekten zu ermöglichen, welche ein erhebliches Investitionkapital benötigen aber auch sehr effektiv in der Verbesserung der schlechten städtischen Luftqualität wären.

Entwicklung von Energiesparmassnahmen im Zusammenhang mit Luftrein-haltungszielen
Viele der Energiesparmassnahmen sind gegenwärtig auf nicht-industrielle Branchen gerichtet und sind daher besonders relevant für Kleinfeuerungsanlagen. Die neue Richtlinie zur Gesamtenergieeffizienz von Gebäuden hat zwei Vorschläge, die von erheblichen Nutzen für die Verringerung der Emissionen von Luftverschmutzungs-schadstoffen sein könnten – verbesserte Gebäudeisolierung und Inspektions-/Instand-haltungssysteme. Weitere Verbesserungen zu dieser Richtlinie könnten ebenfalls zu zusätzlichen Emissionsreduzierungen führen.

Kleinfeuerungsanlagen sind massgebliche Emissionsquellen, insbesondere für Feststoffteilchen, welches auch in zukünftigen Jahren fortbestehen wird. Aus diesem Grund sollten Möglichkeiten, die diese Emissionen erfassen besonders im Zusammen-hang mit der thematischen Strategie berücksichtigt und entwickelt werden, basierend auf den Ergebnissen und Empfehlungen hergeleitet in dieser Studie.

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Abbreviations

AFF_	Agriculture, Forestry and Fishing sectors
APHEIS	Air Pollution and Health: A European Information System Programme
BAT	Best Available Techniques
B(a)P	Benzo(a)pyrene
CAFE	The Clean Air For Europe Programme of European Commission DG Environment
CHP	Combined Heat and Power
CLRTAP	Convention on Long Range Transboundary Air Pollution
Comm_Institut_	Commercial and institutional sectors
CORINAIR	Co-ordinated Information on the Environment in the European Community - AIR
CPD	Construction Products Directive
EEA	European Environment Agency
EC DG ENV	European Commission Directorate General for Environment
EGTEI	Expert Group on Techno-Economic Issues
ELVs	Emission Limit Values
EPBD	Energy Performance of Buildings Directive
EPER	European Pollutant Emission Register
ERDF	European Regional Development Fund
ETC-ACC	European Topic Centre on Air Emissions and Climate Change
EU15	The European Union Member States Prior to May 1st 2004 (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the UK)
EU25	The current 25 Member States of the European Union (as EU15, with Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia and Slovenia)
(EU) ETS	(European Union) Emissions Trading Scheme
EuPD	Energy Using Products Directive
GHGs	Greenhouse gases
IIASA	International Institute for Applied Systems Analysis
IPCC	Inter-governmental Panel on Climate Change
IPPC	Integrated Pollution Prevention and Control
JRC	Joint Research Centre
LCPD	Large Combustion Plant Directive
LPG	Liquefied petroleum gas
MW_{th}	Mega-Watt thermal capacity
NAEI	National Atmospheric Emissions Inventory (UK)
NAP	National Allocation Plans (submitted to the EC under the EU ETS Directive)
NECD	National Emission Ceilings Directive
NH_3	Ammonia
NIHE	Northern Ireland Housing Executive
NMVOCs	Non-Methane Volatile Organic Compounds
NOx	Oxides of nitrogen (NO and NO_2)
OGC	Organically bound carbon

PAHs	Poly Aromatic Hydrocarbons
PICs	Products of Incomplete Combustion (particulate, CO, NMVOC and PAH)
PM, PM_{10}, $PM_{2.5}$	Particulate Matter, with diameter less than 10 microns (PM_{10}), with diameter less than 2.5 microns ($PM_{2.5}$)
PPC	Pollution Prevention and Control
RAINS	Regional Air Pollution Information and Simulation Model
SCAs	Smoke Control Areas
SCIs	Small-scale combustion installations ($<50MW_{th}$)
SCPs	Small-scale combustion plant (an alternative term for SCIs)
SNAP	Selected Nomenclature for Atmospheric Pollutants
SO_2	Sulphur dioxide
SSF	Solid Smokeless Fuel
TFEIP	Task Force on Emission Inventories and Projections
UNECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change

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

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1 Report Summary

1.1 REPORT STRUCTURE

This report has been structured with Section 1 as the *Report Summary*, and Sections 2 to 7 providing the study evidence and analysis. The *Report Summary* provides an overview of the main study conclusions, drawing from the evidence and analysis provided in the main body of the report (Sections 2 and 7). This report structure has been used to enable access to the key conclusions of the study, and where required, the detailed evidence and analysis that supports these conclusions.

1.2 INTRODUCTION TO THE STUDY

Background to this Report

One of the seven Thematic Strategies in the framework of the 6th Environmental Action Programme will focus on air pollution. The Clean Air for Europe Programme (CAFE) has been launched by the Commission in order to gather together the relevant scientific information to support the Air Pollution Thematic Strategy. Under the CAFE programme, small-scale combustion installations (SCIs, also known as small combustion plant or SCPs) have been identified as an emission source for which options for emission reduction may need to be considered.

SCIs are defined as combustion units of less than 50 MW thermal capacity (50 MW_{th}). They include a significant range of appliances, including those used in the residential sector (e.g. fireplaces, stoves, boilers) and large industrial units; they utilise a wide range of fuels including various types of solid fuels and biomass, natural gas and liquid fuels. SCIs are found across many different sectors including industrial, residential, commercial, agricultural and public administration or institutional (which includes government buildings, hospitals, universities etc.).

SCIs are an important source of air pollution as they are often concentrated in populated areas and emit pollutants close to ground level. Other characteristics include low efficiency of many devices (though not all), and poor maintenance. Operational lifetimes are frequently long, typically in excess of 15 years and often much longer, with the effect that improved appliance standards may take a long time to have a significant effect without intervention of some form.

Although measures are applied in a number of countries to control SCI emissions, there is currently no pan-European action to target emissions from SCIs. This study aims to assess the types of measures that could be used to reduce emissions, and whether they are cost-effective (i.e. that they can achieve emission reductions at lowest cost relative).

Objectives and scope of study

The key objectives of this study are:

- To understand the key emission issues relating to SCI sources
- To identify potential measures for the reduction of emissions

- To assess the feasibility of the implementation of these measures at the European level
- To describe the cost-effectiveness of such measures

The findings of this study should provide the European Commission with the basis for starting to assess the need for European level action, and to develop a strategy for emission control.

The years 2000-2020 provide the timeframe for analysis of future technology options and implementation of policy measures. The geographical extent for this work covers all countries involved in the CAFE programme (EU 25 plus Switzerland, Norway, Bulgaria and Romania), with options considered at both European and national levels.

The analysis covers the following air pollutants:
- Ammonia (NH_3)
- Sulphur dioxide (SO_2)
- Nitrogen Oxides (NOx)
- Carbon monoxide (CO)
- Particulate Matter (TSP, PM_{10}, $PM_{2.5}$)
- Non-methane volatile organic compounds (NMVOCs)

The analysis also investigates the indirect benefits of measures on other pollutants, specifically greenhouse gas emissions that contribute to the overall cost-effectiveness. In addition to greenhouse gases, emissions of dioxins, PAHs and certain heavy metals may also be affected by specific measures considered in this study. While a detailed analysis of such indirect benefits has not been undertaken, this study has sought to provide an understanding of where such indirect benefits may occur.

Methodology overview
There are five key methodological stages in this study, as outlined below:

1. *Quantify emissions* – To develop a strategy for targeting emissions from SCIs, it is imperative that emission contributions from different sectors and installations are well understood.
2. *List options for reducing emissions* – In this stage, different policies and potential options for reducing emissions from small combustion installations are identified, particularly for those emission issues highlighted in the first stage.
3. *Collect information on options* –. Once listed, the next stage reviews information (both qualitative and quantitative) on options.
4. *Prioritise options* – Based on the key issues highlighted, and the information on measures reviewed, options for reduction of emissions from SCIs need to be prioritised. This is done on the basis of cost-effectiveness information combined with other factors including:
    - Key emission issues identified
    - Scale of implementation
    - Political acceptability
    - Social impacts

5. *Assessment of specific policy options* – The final stage undertakes a more detailed assessment of selected policy options, which involves analysis of cost-effectiveness, and assessment of factors that will determine feasibility / appropriateness.

Stakeholder consultation
Consultation with national experts has been an important part of the study methodology and has been used for two purposes. Firstly, in quantifying the emissions from SCIs, it is important that national experts are able to state whether they consider inventory estimates made 'broadly correct' so as to provide some level of verification. Secondly, national experts understand the national situation, and are in a good position to comment on proposed policy options and feasibility of technical measures.

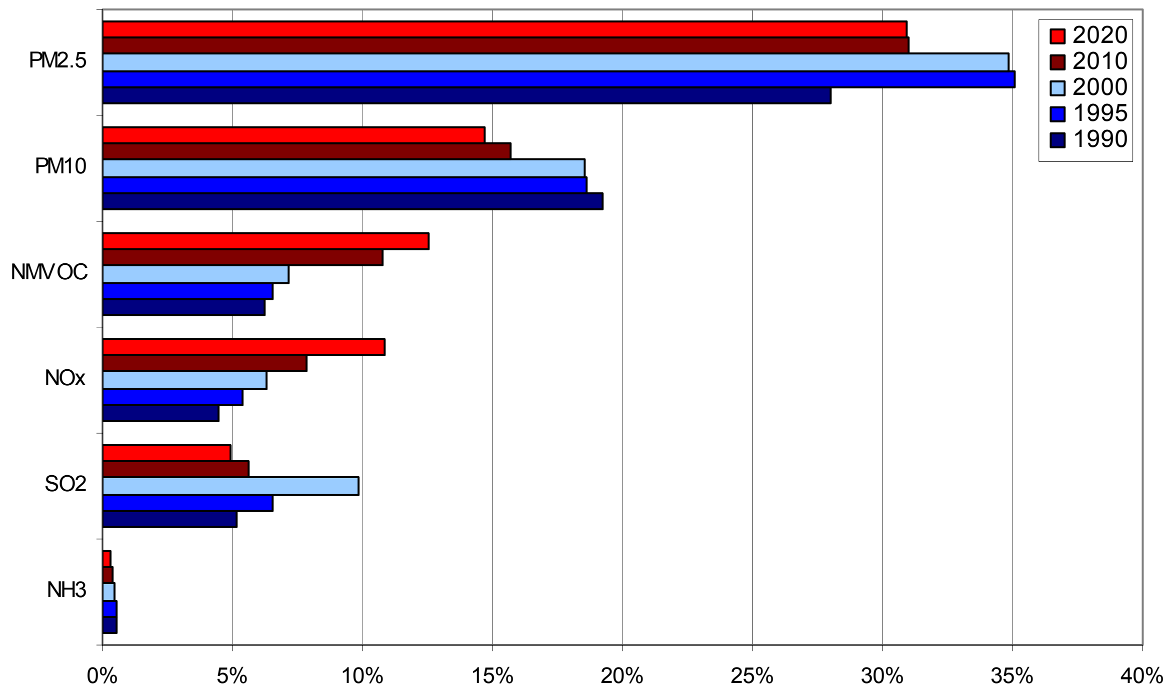
1.3 AN EMISSION INVENTORY FOR SMALL COMBUSTION INSTALLATIONS IN EUROPE

A key task for this study was to analyse existing emission inventories of SCIs. However, no previously reported inventory provides a sufficient level of detail at the European scale to properly assess emissions from SCIs. Therefore, the technical assessment reported here starts with the construction of an inventory of emissions from SCIs disaggregated to specific fuels, technologies and sectors by country. The main role of this inventory is to provide guidance on priorities for action. Specifically, the inventory helps to:

- Identify the priority sources, fuels and technologies that contribute significantly to current and projected emissions, and for which measures and technologies could most effectively be applied;
- Identify countries and SCI sub-sectors where emission reductions have successfully been achieved;
- Provide the baseline data from which costs and benefits (in terms of emission reduction) for measures can be calculated.

To build the inventory, data are drawn from various sources, including submissions to IPCC/UNFCCC, UNECE/CLRTAP, the European Commission with regard to the NECD and LCPD, data from the RAINS model, EPER, and national inventories. Due to differences in data availability, two separate inventories have been derived; one for non-industrial emissions and another for industrial SCI emissions. Figure 1.1 provides an overview of the proportion of total European emissions from non-industrial SCI sources, highlighting the significant contribution to PM_{10} and $PM_{2.5}$.

Figure 1.1 Emissions from non-industrial SCIs (as a percentage of total European emissions)



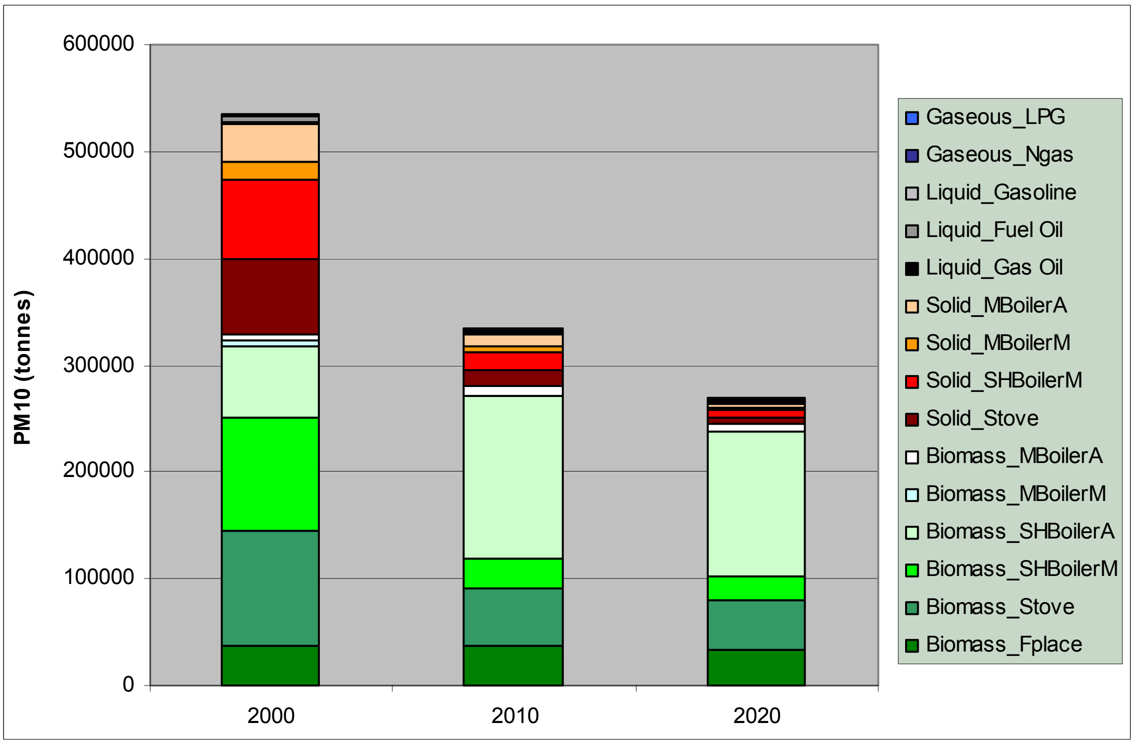
NB. The above comparison is based on derived inventory emission estimates as a percentage of CLRTAP reported totals. The exception is non-industrial SCI emission total for $PM_{2.5}$, which is a percentage of RAINS emission totals. This is probably why the proportion of $PM_{2.5}$ emissions is much higher than PM_{10}. For example, if the RAINS PM_{10} total has been used, the contribution would have been nearer 25%.

The key findings from the non-industrial inventory include:

- Emissions from non-industrial SCIs make a significant contribution to the European PM emission totals in 2000.
- Emissions of PM are predominantly from residential biomass and solid fuel burning in 2000, with a significant decrease projected in future years from solid fuels but not biomass. NMVOC emissions show a similar pattern.
- Emissions of NMVOC, SO_2, and NOx from non-industrial SCIs contribute approximately 6-10% of national emission totals.
- NOx emissions from non-industrial SCIs are predominantly due to commercial and residential natural gas use. Emissions are not projected to decrease significantly in future years and may become an increasing proportion of total controllable NOx emissions in urban areas.

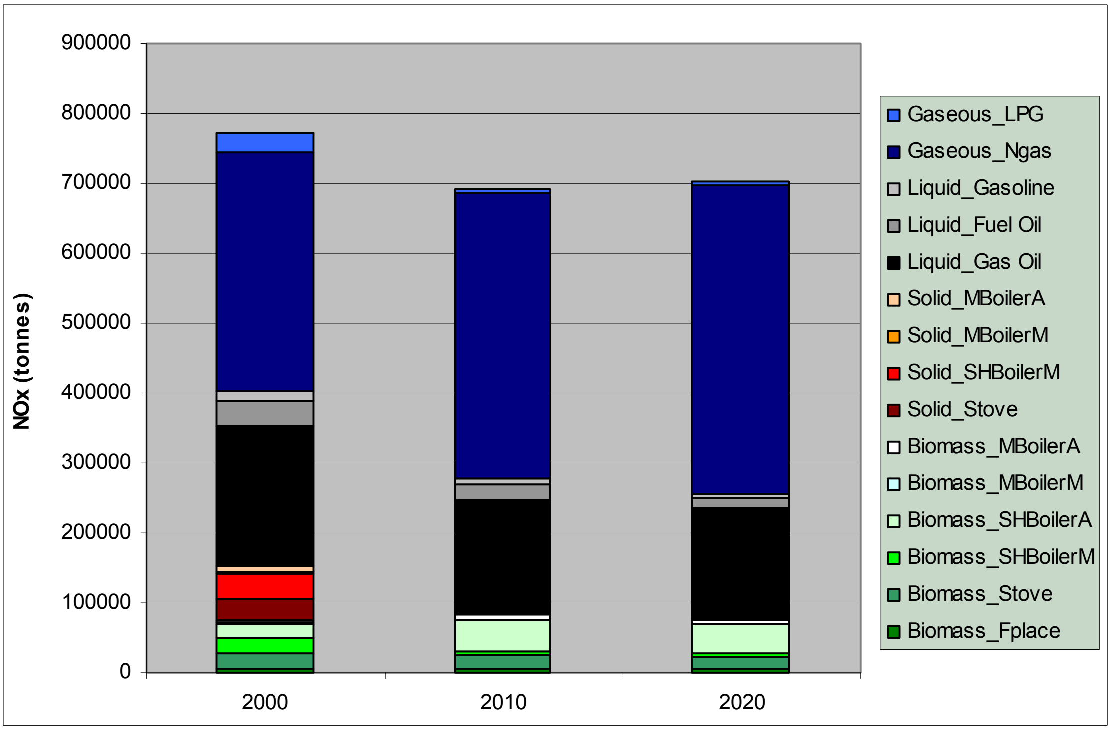
The following graphs show the above information (for PM_{10}, NOx, SO_2 and NMVOCs) from Figure 1.1 in greater detail, broken down by fuel and technology type, for 2000, 2010 and 2020. The non-industrial SCI emission inventory for PM_{10} (which shows a similar trend for $PM_{2.5}$) highlights the decrease in emissions from 2000 to 2020, predominantly due to the decline in the use of solid fuel. This source, however, remains significant due to the continued use of biomass. Emissions from this source are projected to decline overall due in main to the increased use of automatic feed boilers.

Figure 1.2 PM_{10} emissions from non-industrial sources by fuel-technology



NB. In the legend, 'Mboiler' refers to medium sized boiler (50 kW – 1 MW manual; 1-50 MW automatic), while 'SHBoiler' refers to single house boiler (0-50 kW). 'A' at the end of the label means 'automatic feed', while 'M' means 'manual feed'.

Figure 1.3 NOx emissions from non-industrial sources by fuel-technology

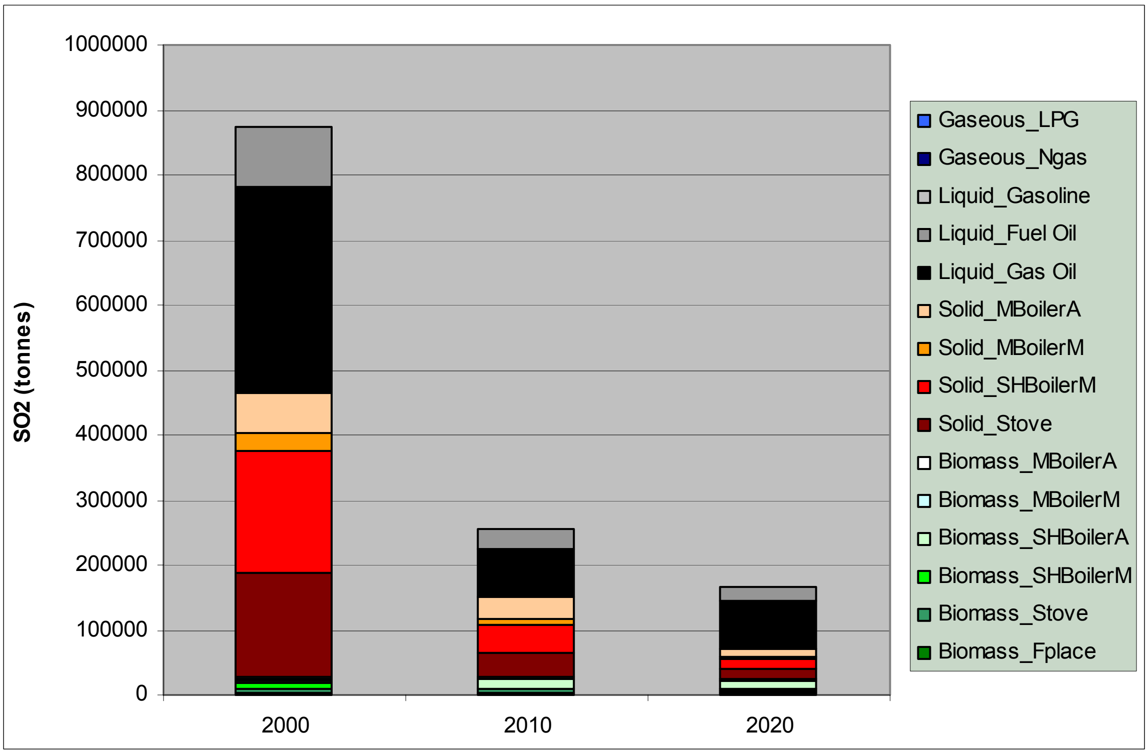


NB. In the legend, 'Mboiler' refers to medium sized boiler (50 kW – 1 MW manual; 1-50 MW automatic), while 'SHBoiler' refers to single house boiler (0-50 kW). 'A' at the end of the label means 'automatic feed', while 'M' means 'manual feed'.

NOx emissions from non-industrial sources are predominantly due to the use of oil and natural gas, as shown in Figure 1.3. The increasing use of natural gas in these sectors (as illustrated in Figure 1.7) and continued use of liquid fuels at 2000 levels in future years results in emissions of NOx remaining at consistent levels. Biomass contributes to total emissions at a consistent level across the time series, while solid fuels only make a limited contribution to the total in 2000.

The significant decrease in SO_2 emissions over the time series is dramatically reflected in Figure 1.4, and is primarily due to the significant decline in the use of solid fuels, and the lower sulphur content liquid fuels used in future years.

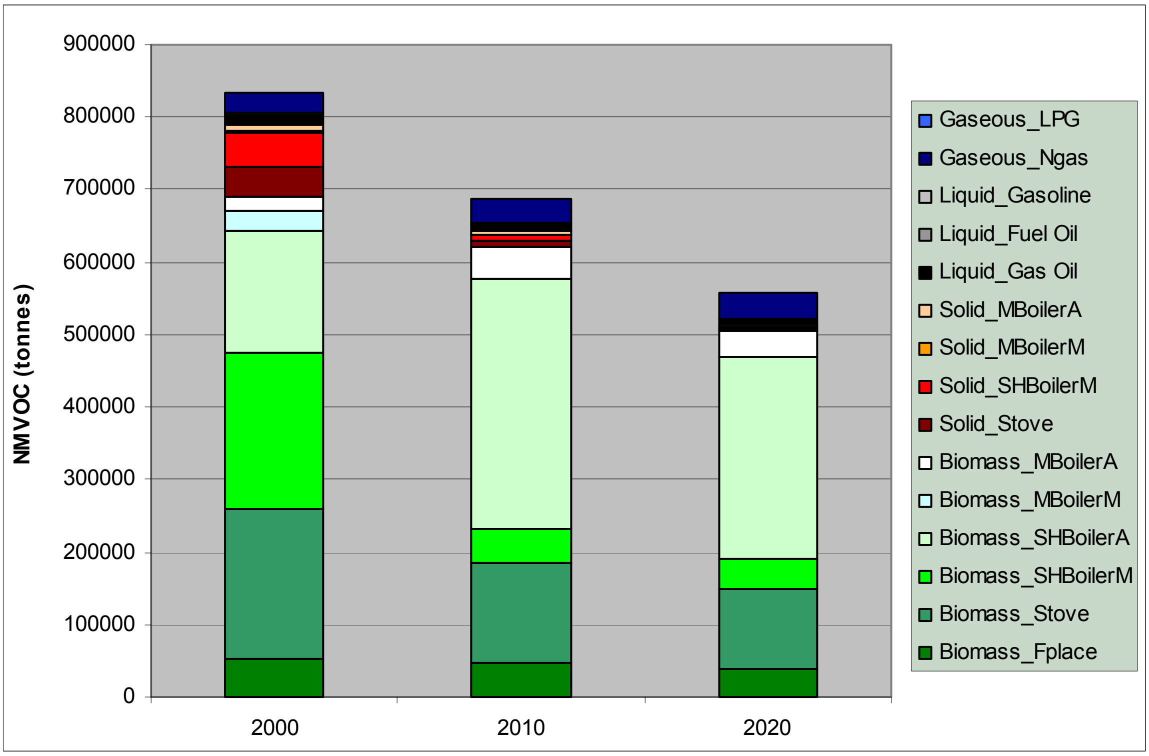
Figure 1.4 SO_2 emissions from non-industrial sources by fuel-technology



NB. In the legend, 'Mboiler' refers to medium sized boiler (50 kW – 1 MW manual; 1-50 MW automatic), while 'SHBoiler' refers to single house boiler (0-50 kW). 'A' at the end of the label means 'automatic feed', while 'M' means 'manual feed'.

NMVOC emissions from combustion sources in non-industrial sectors are primarily a result of the use of biomass, as reflected in Figure 1.5. Therefore, limited reductions are seen in emissions associated with this source. The most significant reduction comes from the reduction in the use of solid fuels.

Figure 1.5 NMVOC emissions from non-industrial sources by fuel-technology

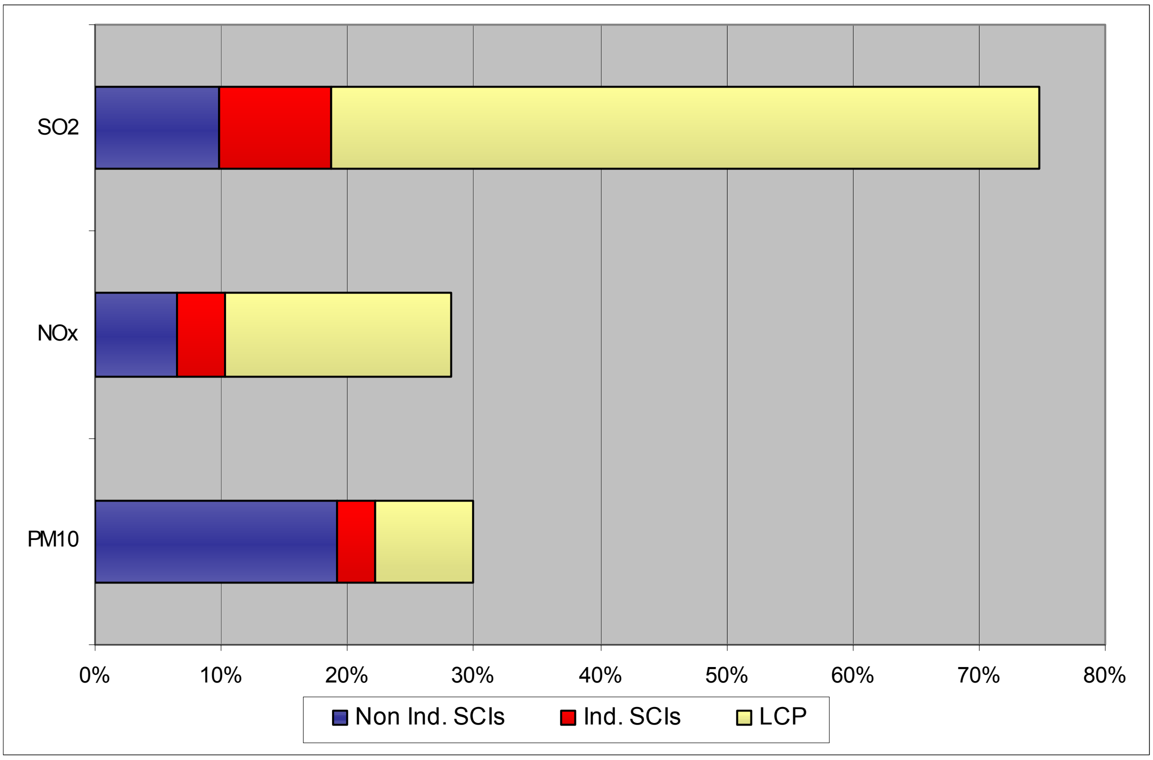


NB. In the legend, 'Mboiler' refers to medium sized boiler (50 kW – 1 MW manual; 1-50 MW automatic), while 'SHBoiler' refers to single house boiler (0-50 kW). 'A' at the end of the label means 'automatic feed', while 'M' means 'manual feed'.

Overall, industrial SCIs do not contribute significantly to total European emissions, although out of the three pollutants considered in estimates, SO_2 contributes approximately 8%, with a contribution of approximately 3% of total emissions for PM_{10} and NOx (as illustrated in Figure 1.6). When considered just in terms of industrial combustion emissions, industrial SCIs contribute approximately 18% to PM and 12% to SO_2 and NOx. Country specific data illustrates that in certain countries, this percentage value is much higher.

Unfortunately, the absence of projected emissions does not enable us to assess whether these contributions increase – this proportion could increase if the majority of these plant are unregulated and further reductions occur from larger regulated plant. Significant levels of uncertainty associated with these estimates, due to data limitations, and a simplistic inventory methodological approach.

Figure 1.6 Comparison of industrial SCI emissions with non-industrial SCI and LCP emissions (as percentage of European total)



Three priority issues have been identified, based on the inventory estimates, which future policy action may need to address, and include:

- PM and NMVOC emissions from residential burning of biomass and solid fuel
- Industrial-based SCI emissions of SO_2, NO_x and PM
- NO_x emissions from non-industrial consumption of gas and liquid fuels

PM emissions should be considered for the following reasons:

- They contribute significantly to overall European emissions, and in most countries to national emissions of PM
- They are known to have significant health impacts, particularly if sources (such as those in the residential sector) are concentrated in urban areas with large populations
- Emissions of PM from biomass use are not projected to decrease significantly
- Targeting emissions from biomass will have significant benefits for reducing NMVOC, and other emissions such as PAHs.

The issues relating to biomass and solid fuels differ significantly. Biomass consumption is likely to increase over the next 20 years, as countries look for opportunities to reduce emission of CO_2 through their climate change programmes. The focus needs to be on ensuring a high uptake of low emitting technologies, and the removal of older high emitting technologies, rather than removal of this type of fuel altogether. For solid fuels, current projections show significant decreases in solid fuel consumption. Options need to focus on ensuring a quicker uptake of cleaner fuels, and where solid fuel use persists (particularly for backup use), cleaner solid fuels and improved appliances.

The problem of PM emissions in future years is strongly driven by the projected consumption in biomass, which unlike solid fuels, does not decrease. Development of policy action relating to this issue will need to consider the inherent uncertainties, both in the emission factors and consumption data. Fuel consumption is difficult to estimate due to the nature of wood burning, which can be occasional, and may involve the use of 'private sale or gathered' wood, rather than marketed biomass products. Emission factors vary significantly depending on the characteristics of wood used in emissions testing. The other key issue is whether these emissions will actually have a significant impact, particularly if most use of biomass is in rural areas, away from large populations.

Industrial emissions are much more uncertain than non-industrial emissions, due to issues of data availability. However, options should still be considered for the following reasons:

- Industrial SCIs are an important source of industrial combustion emissions in many countries
- Many of these installations may be unregulated, and therefore, potential emission reductions may be significant

NOx emissions from non-industrial SCIs are considered a problematic issue, due to limited reductions in projected estimates by 2010 and 2020, and increasing contribution to overall urban emission levels. SCIs will tend to be located in urban areas (as that is where natural gas networks tend to be located), and may become an increasingly important source with greater controls of urban road transport. However, it is also important to note that natural gas, the main source of NOx, is an important alternative cleaner fuel to other solid and liquid fuels and therefore may be less of a priority than the other two key issues.

SO_2 emissions from non-industrial SCIs are perceived as a lesser priority due to significant reductions that will occur by 2010 in the baseline emission projections. However, measures are considered in this study that reduce SO_2 emissions, and have additional benefits for other pollutants. NH_3 is not considered further due to the fact that SCI sources contribute very little to overall emissions.

This inventory provides a useful guide to what some of the main pollutants, sectors and fuels are, in terms of absolute emissions. However, its primary limitation is that it does not provide the spatial dimension of the inventory, e.g. where emission sources are located in relation to population. A higher level of emissions in rural areas may be a lower priority than low emissions in urban areas (where health impacts could be more significant due to higher population densities). This issue is considered further in section 7.3.2.

For further information, see **Section 3 Emissions from small combustion installations in Europe**.

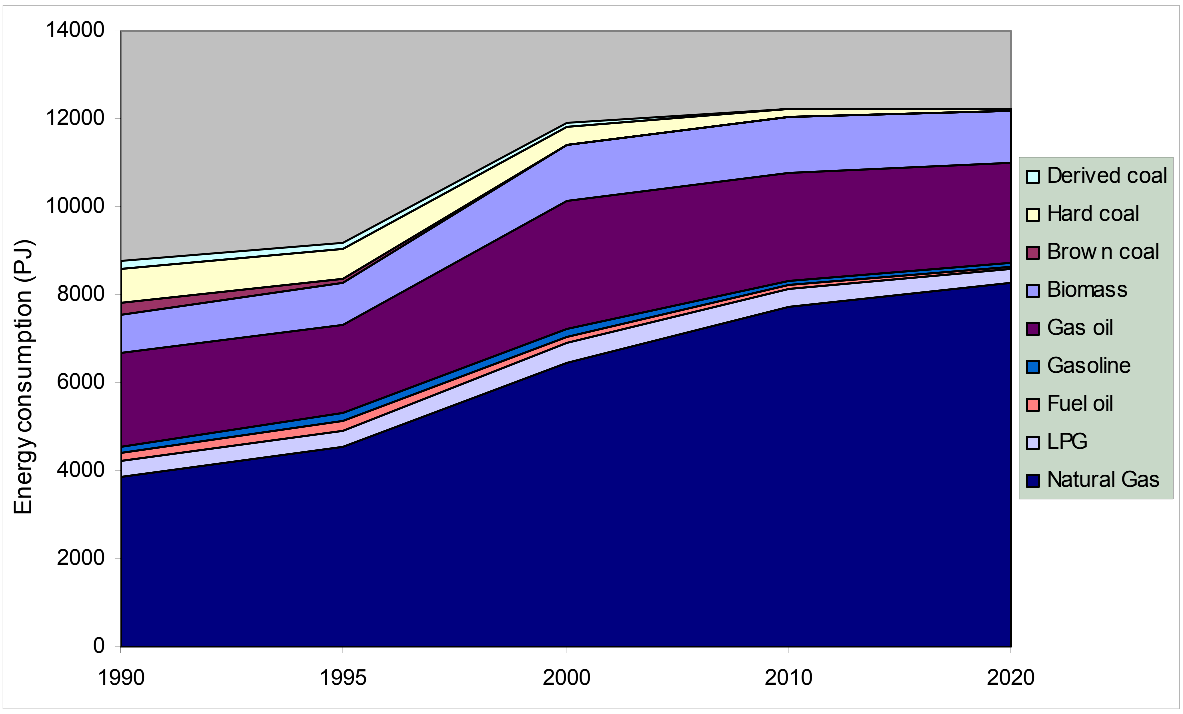
1.4 COUNTRY FUEL-TECHNOLOGY PROFILES ACROSS EUROPE

The applicability of technical measures and appropriateness of policy options is dictated by the types of fuels and technologies being used across Europe. This is particularly the case with non-industrial SCIs, where very different energy markets can be seen across Europe, both in terms of the type and quality of fuels being used, and the type of technologies employed (in terms of age, combustion process, efficiency etc.).

An overview of fuel consumption trends in the key non-industrial sectors in Europe is provided in Figure 1.7. There are four key trends that can be identified:

- Natural gas consumption increases significantly up to 2020.
- Solid fuel consumption rapidly decreases, with only very small quantities being used by 2020.
- The consumption of biomass remains at the same level between 2000 and 2020.
- Oil continues to be a significant fuel in future years, providing 20% of total energy for non-industrial sectors in 2020.

Figure 1.7 Energy consumption trends in non-industrial sectors for Europe



Source: RAINS web data for the commercial-residential sectors. Agricultural energy consumption from stationary sources has not been considered (and is not so significant).

In terms of emission trends observed in the previous section, these data demonstrate why the emissions associated with solid fuels decrease significantly (PM, SO_2), while emissions of NOx from natural gas use, and emissions associated with biomass do not show significant reductions in future years. SO_2 from oil decreases significantly in future years (despite consumption levels in 2020 similar to those in 2000) due to the impact of the sulphur content legislation.

To develop a better understanding of the structure of fuel market profiles across Europe, countries can be categorised into the following groupings:

- Significant natural gas markets
- Significant biomass markets
- Significant liquid fuel markets
- Significant solid fuel markets

These groupings help to provide a better understanding of emissions data, and a first indication of where policy action and / or technical measures may be most applicable, most effective or have the best and worst cost-effectiveness. Figure 1.8 illustrates on a map of Europe how countries have been grouped according to the dominant fuels used in the non-industrial sectors. This reflects dominant fuels used; for example, a country such as Italy uses significant amounts of liquid fuels.

Figure 1.8 Overview of the dominant non-industrial fuels used across Europe

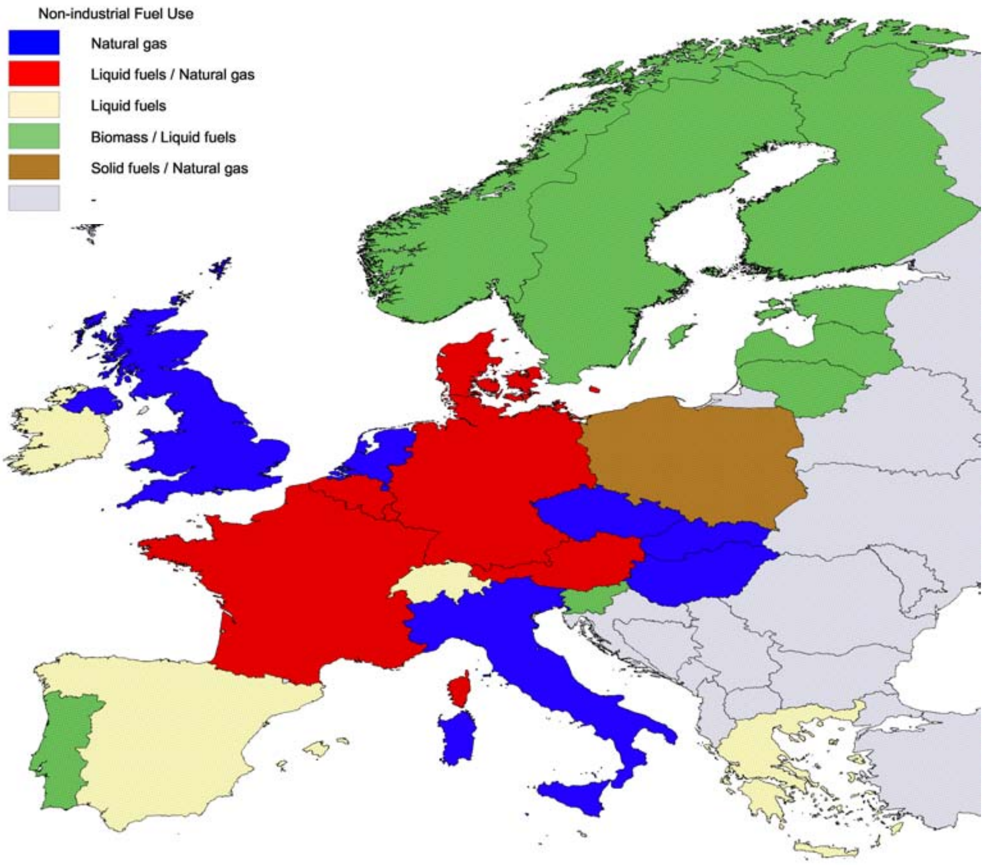


Table 1.1 provides additional detail on fuel use profile in the non-industrial sectors and illustrates the significant variation between countries that will need to be considered when deriving relevant policy action. The three key groupings include gas, liquid fuels, gas / liquid fuels, and biomass / liquid fuels, with significant exceptions such as solid fuel consumption in Poland.

Table 1.1 Overview of country groupings based on non-industrial fuel profile

Country	Gas use	Liquid fuel use	Biomass use	Solid fuel use	District heating levels*	Groupings
Netherlands	>90%				L	Gas
UK	>80%				L	Gas
Slovakia	>80%				H	Gas
Hungary	>80%				M	Gas
Italy	>70%				L	Gas
Czech Republic	>60%			>20%	H	Gas, Solid fuel
Belgium	>50%	>30%			L	Gas, Liquid
Germany	>50%	>25%			M	Gas, Liquid
France	>40%	>30%	20%		L	Gas, Liquid, Biomass
Austria	>30%	>30%			M	Liquid, Gas
Denmark	>30%	>40%			H	Liquid, Gas
Luxembourg	>40%	>50%			L	Liquid, Gas
Greece		>75%			L	Liquid
Switzerland	>25%	>70%			L	Liquid
Ireland	>20%	>55%			L	Liquid
Spain	>20%	>40%			L	Liquid
Sweden		>60%	>30%		H	Liquid, Biomass
Finland		>50%	>40%		H	Liquid, Biomass
Slovenia		>45%	>30%		H	Liquid, Biomass
Portugal		>35%	>45%		L	Biomass, Liquid
Norway		>45%	>50%		L	Biomass, Liquid
Estonia		>30%	>45%		H	Biomass
Lithuania	>25%		>60%		H	Biomass
Latvia			>60%		H	Biomass
Poland	>25%			>35%	H	Solid fuel, Gas

* District heating levels are ranked high (H), medium (M) and low (L).

District heating is also an important method of heating provision in many countries across Europe. It primarily involves the provision of heating from a central plant, and reduces the need for individual homes or buildings to have their own heating unit. This has important implications for emission control, as emissions are easier to control from central plant rather than many diffuse sources.

Across this broad range of fuel use (and associated SCIs), different technical measures are going to be more cost-effective for some countries than others. Countries that already have significant investment in pipeline infrastructure for gas or district heating will be able to consider further expansion as a more realistic option than countries without such infrastructure in place.

This section provides the context to both provide a better understanding of the emissions data, and to consider appropriate technical measures and policies. For further information, see **Section 4 Country fuel-technology profiles across Europe**.

1.5 REVIEW OF TECHNICAL MEASURES APPLICABLE TO SCIs

Technical measures are the means by which emission reductions can be realised, and range from the replacement of an old appliance with a modern appliance to use of a less polluting fuel. Based on the findings of Section 3, particular attention is given to technical measures for reduction of PM and NMVOC from solid fuel and biomass burning in non-industrial SCIs, predominantly in the residential sector.

There are two main types of abatement measures to address emissions from SCIs; firstly, by avoiding formation of emissions (preventative measures) and secondly, by removal of pollutants from exhaust gases (abatement measures). Abatement measures have traditionally been less applicable to smaller scale installations (less than 1 MW_{th}) due to lower cost-effectiveness, and are predominantly used for larger installations.

For smaller SCIs, preventative measures are the main technical means through which to reduce emissions, with abatement measures either not cost-effective or not applicable to the smaller SCI market. This section covers the following broad technical measures:

- Appliance replacement (including the use of new modern technologies)
- Fuel quality
- Prospective emerging technologies
- Other technical measures

Table 1.2 Consideration of types of technical measures (and potential costs)

Type of fuel	Technical measures	Cost
Biomass (where PM / NMVOCs are key emissions)	Fuel switching (within biomass to pellets) Switching to new fuel-based appliance (gas) Add on technologies (catalysts, insets, accumulator tanks) Behavioural change (to improve operation)	High (due to costs of new appliance) High Medium Low
Solid fuels (where PM / NMVOCs are key emissions)	**Same as for biomass.** Switch to less polluting solid fuel Coal cleaning	 Low Very high
Gas (where NO_x is the main issue)	Switching to more energy-efficient boiler Other energy efficiency measures (better boiler sizing, improved insulation)	High Medium
Oil (for PM / NO_x and SO_2 emissions)	Switching to more energy-efficient boiler Other energy efficiency measures (better boiler sizing, improved insulation)	High Medium
All	Prospective / emerging technologies – fuel cells, renewables etc.	Potentially high

Based on the review of the available data, Table 1.2 outlines the applicability and a broad indication of potential cost of technical measures, and their relevance to the key emission issues. Costs of these measures will vary greatly depending on the specific country, investment issues (new central heating or just new boiler), the specific type of technology, and relative fuel costs. The effectiveness of the measure will also be dependent on the pollutant in question, and the characteristics of the measure.

For non-industrial emissions of NO_x from natural gas consumption, potential reductions for these smaller units will mainly be realised through energy efficiency measures. This may be problematic when defining policy options as energy efficiency measures tend to be driven by climate change policies. Relevant energy efficiency measures are described further in section 6.2.8.

For further information, see Section 5 **Review of technical measures applicable to SCIs**.

1.6 POLICY MEASURES TO REDUCE EMISSIONS FROM SCIS IN MEMBER STATES

Section 6 explores the measures applicable to the SCI relevant sectors, by installation size, for the emission issues highlighted in section 1.3 above. An overview is provided of the characteristics of each of the measures that may be suitable at EU level and their current use by Member States. In addition to measures targeted specifically at the local and regional air pollutants that are the drivers for this study, climate change policy measures are considered which may have benefits in terms of emissions abatement across the board.

Measures that have been considered include: traditional industrial regulation, flexible mechanisms with a national scope, targeting larger installations, local based approaches such as information campaigns, appliances replacement, and fuel bans. This evidence informs the in-depth analysis of measures considered suitable for EU application (Section 7) concerning their implementation, and potential costs and effectiveness.

Table 1.3 illustrates the variety of the measures considered, comments on the nature of the impact they would have and gives an indication (based on the current experience of Member States) of their likely acceptability as a pan European measure. Product standards and fuel quality regulations bearing directly on consumers have been demonstrated by a number of Member States to have a beneficial impact; energy efficiency measures have proved successful at sector level; financial mechanisms, taxes, and site-specific regulations also have attractions. Local based mechanism, while addressing particular problems are more difficult to implement; clearly very different policy options will be required for targeting the different emission problems identified.

For further information, see **Section 6 Policy measures to reduce emissions from small-scale combustion installations**.

Table 1.3 Types of measure considered for abatement of emissions from SCIs

Type of measure	Specific measure	Direct impact	Accept-ability
Product standards	Product standards (and ecolabels) and associated emission limits (voluntary and obligatory)	Increased development / manufacture of certain products to specified standards (product standards) and increased uptake of certain products by consumers on the basis of environmental criteria (Ecolabels)	**H**
Local-based measures	Area product / appliance ban	Reduction in use of specific fuel products / appliances in designated area	**M**
	Other measures e.g. reactive measures, appliance replacement, information campaigns	Reduction in emissions from various action taken through these measures	**M**
Fuel quality restrictions	Fuel quality restrictions, bans and voluntary agreements	Reduced or no sale of certain fuel products, based on fuel quality indicators	**H**
Site –specific restrictions	Emissions limit value or BAT approach	Emissions controlled by permitting in line with concentration limits	**H**
	Emission trading	Reduction in emissions encouraged through designating pollution as a commodity	**M**
Emission ceiling	Emission ceilings approach	Emission reductions through the setting of national emission limits	**H**
Environmental taxes	Emission taxes	Incentive not to emit on the basis that emissions can be taxed	**M**
	Fuel taxes	Incentive to reduce fuel consumption or consider alternative due to increased price	**H**
Financial mechanisms	Appliance subsidies / grants	Increase use of specific less polluting appliance(s) due to increased consumer demand	
	Fuel subsidies	Increase use of selected less polluting fuel(s) due to increased consumer expenditure	
	Structural funds	European funding of projects seeking to reduce emissions or that have associated benefits	**H**
Energy efficiency programmes / policies	Boiler efficiency standards	Reduced fuel use due to more efficient boilers / appliances	**H**
	Building standards	Improved insulation leading to lower energy demand	**H**
	Appliance inspection / maintenance obligations	Improved performance (efficiency / combustion) of appliances due to regular inspection / maintenance	**H**
	Grants, loans and subsidies	Increased consumer demand for more efficient appliances	**H**
	Energy taxes	Increase price of energy products to encourage lower consumption levels	**H**
	Promotion of renewable technologies	Increase take-up of renewables, thereby replacing other more polluting technologies	**M**
	Information campaigns	Helping reduce emissions by changing consumer behaviour through information e.g. on boiler operation or purchasing	**H**

1.7 ANALYSIS OF EUROPEAN POLICY OPTIONS

A series of recommendations can be made from this study concerning policy options, to be considered in the context of the Thematic Strategy on Air Pollution. These recommendations are made based on our understanding of the emissions problems related to SCIs, the technical measures and policy mechanisms available to address such problems, and analyses of the cost-effectiveness, which in some cases, can be further developed in the framework of the RAINS model.

A series of policy scenarios, drawn from a range of potential policy options, were developed in consultation with the Commission and have been considered within this study analysis; these are listed in Table 1.4, with additional comment concerning the sector-emission problem they are most relevant to.

Table 1.4 Policy scenarios considered in SCI emission reduction analysis

Policy option areas (report section)	**Key emission issue(s)**
Introduction of obligatory product standards for appliances below 300 kW (1.7.1)	PM / NMVOC and NOx emissions from non-industrial sources
Promotion of local-based measures, particularly in PM urban 'hotspots' (1.7.2)	PM / NMVOC emissions from non-industrial sources
Stricter or new fuel quality criteria for certain fuel products (1.7.3)	PM / SO_2 from solid fuels across all sectors
Introduction of specified emission limits to larger installation (< 50 MW) (1.7.4)	Emissions from industrial / large institutional sites
Increased use of Structural Funds to increase access to cleaner fuels e.g. energy network expansion, funding for cleaner technologies (1.7.5)	PM / NMVOC emissions from non-industrial sources
Development of energy-efficiency measures to further benefit air quality policy e.g. Energy Performance of Buildings Directive (1.7.6)	NO_x from gas (non-industrial); other pollutants in the non-industrial sectors

The range of different measures illustrates the wide scope of this project in terms of:

- *Pollutant* – the SCI inventory developed as part of this study draws attention to the significant, SCI contribution to the overall EU PM emission. However, other air quality pollutants (covered by the CAFE programme) also need to be considered.
- *Sector* – the capacity range of 0 – 50 MW_{th} includes a variety of sectors, for which some measures applicable to SCIs are appropriate while others are not.
- *Installation size* – this study includes a wide range of installation type, including the relatively small number of medium to large industrial combustion plant to the large number of very small residential fireplaces; measures therefore have to relate to a given size of installation.
- *Country* – due to the very different energy profiles of different countries (see section 4), measures need to be carefully considered in order to meet the needs of Member States.

In conclusion, policy options need to consider pollutant, sector, installation and country. Due to the large number of possible combinations of these parameters, a selection of the most promising options has been considered.

For each of these scenarios, analysis was undertaken to address overall impact (in emission reduction terms) of the options, and cost-effectiveness, as required before such an option is considered further – see Section 7 'Options and Recommendations for European Policy.' This analysis is important in helping define what might be important for inclusion in the Thematic Strategy, and direction for further scenario analysis in the RAINS model.

1.7.1 Introduction of obligatory product standards

The primary objective of product standards is to ensure that products entering the market meet certain quality criteria, including environmental criteria, the most important of which in the context of this study is the use of emission limits. Such criteria would ensure that new appliances being bought to replace older appliances (through 'natural' replacement) met minimum emission standards. This type of mechanism is likely to cover smaller capacity SCIs (< 300 kW), which are primarily used for hot water and space heating in non-industrial sectors.

There are two mechanisms that could be used to further promote the use of product standards in a regulatory framework:

- The proposed Framework Directive on Energy Using Products (EuP): boilers and stoves could be included based on the proposed scope of the EuP. Emission limits could be proposed as part of the product criteria to ensure compliance under the Directive.
- Under the New Approach Directives (which is an approach that the proposed EuP Directive will follow), certain harmonised CEN standards can be used to meet the requirements of certain Directives, regarding different products e.g. the use of EN 13229 (Inset appliances including open fires fired by solid fuels) and EN 13240 (Room heaters fired by solid fuel) under the Construction Products Directive. In other words, CEN standards provide one of the vehicles for compliance under the Directive.

Our analysis assessed the impact of emission limits for TSP from biomass and solid fuels, and NOx from gaseous and liquid fuels for a range of appliance types based on European and national standards. Limits were compared to those used in the RAINS model, which enabled an assessment to be made of the impact in terms of emission reductions. The cost of the measure was the difference in price between the purchase of an appliance that meets the limits set out in the standard, and one that does not (net of any savings in fuel costs as a result of purchasing a more efficient appliance).

Based on this analysis, the introduction of product standards (under a regulatory framework) across the EU would lead to significant emissions reduction. This is particularly important given the significant emissions of PM from biomass in future years, particularly as it is promoted as a carbon-neutral fuel - with few other mechanisms available at European scale to reduce such emissions, standards for appliances are an important option. In addition, the potential for further NOx reductions is also important, given that the non-industrial contribution is likely to increase in future years.

The most promising mechanism for the introduction of product standards under a regulatory framework is the EuP Directive. The advantages of using this mechanism is that its proposed scope potentially covers all smaller SCIs; furthermore, it is at a proposal stage which provides policymakers the opportunity to incorporate objectives relating to SCIs. Two potentially significant difficulties arise from the use of this mechanism. Firstly, emission limits need to be carefully defined due to potential conflicts with national regulation. If a product standard is proposed in the framework of a European Directive, this will supersede national based regulations (unless special provisions are made). Therefore, manufacturers may be able to design a product to meet criteria (such as emission limits) specified by the Directive, which is less stringent than national regulations. Under a voluntary standard, deviations would avoid this problem; however, deviations would not be recognised in the context of a regulatory framework. The EuP Directive may offer the flexibility to avoid this problem, by allowing other means of meeting product criteria; however, at the present time this is not clear.

As second issue is that many standards, including those issued by CEN (excluding EN 303-5) do not stipulate PM emission limits, due to lack of agreement on testing methods. It is not clear how far other limits provide a good proxy for PM; as this is considered a priority pollutant, further work may be needed to establish this proxy relationship, and develop testing methods that provide consensus across Member States.

Based on our analysis, key recommendations are listed below. A full description of the proposed scenario, and analysis results is provided in section 7.3.1.

Key recommendations

- Further exploration of the potential of the proposed Framework Directive on Energy Using Products as a means for introducing emission limit criteria in product design.
- Undertake further discussions with CEN concerning the development of standards that reflect the needs of EU policy e.g. the use of PM emission limits in standards for stoves. The CEN programme being developed under a mandate from the Commission in support of the EuP Directive may provide a good opportunity.
- Promote the development and inclusion of PM limits in stove and boiler product standards and / or research how well other pollutants are represented by CO limits.
- Further assessment of the cost-effectiveness of this option in the framework of the RAINS model, to confirm and strengthen findings of this study.

1.7.2 Promotion of local-based measures

In some countries, there are significant local, urban air quality problems associated with PM emissions from solid fuels and biomass, predominantly due to consumption of these fuels in the residential sector. While there is a lack of centralised European data, the inventory developed as part of this study in conjunction with literature based sources provides indicative evidence of such problems and where they exist.

This study indicates that such local-based urban air quality problems are best tackled through the use of local-based measures, as these measures can be structured and introduced according to the local situation. A broad national or European-based measure may not be able to do this in such a cost-effective manner. What is needed are national or European mechanisms that ensure local-based measures are introduced if required; mechanisms at the European level have been introduced that provide the regulatory framework without prescribing the specific action to be taken. The National Emission Ceiling Directive is one such example but the most important in terms of local air quality is the Air Quality Framework Directive.

The Air Quality Framework Directive should remain the main mechanism through which action is instigated to target pollution exceedances in different urban areas. It is difficult to ascertain exactly how this mechanism is working with regards to reduction in air pollution associated with SCIs, due to the absence of country reporting on the implementation of local measures to deal with SCI emission sources; such reporting should be undertaken in future years based on Commission proposals.

A number of countries across Europe are considered to have pollution problems associated with solid fuel and biomass burning. These include some of the Eastern European new Member States, notably Poland but other solid fuel using countries such as the Czech Republic and Slovakia. In Western Europe, countries such as the UK still have localised problems, particularly in Northern Ireland, where significant action has been taken to identify and tackle pollution problems associated with residential coal burning. Germany and Ireland, who have also used significant amount of solid fuel in the past may also have localised problems. Accession countries or Bulgaria and Romania, are also thought to have significant local air pollution associated with coal burning in residential sectors – based on literature review, limited information is available for these countries.

The other main source of local air pollution is biomass, particularly in Baltic countries. Many Scandinavian countries are undertaking research programmes to assess the problems of PM associated with biomass, which is used in many urban areas. For other Baltic countries, problems associated with biomass are less well known. In France, the largest user in Europe, little biomass appears to be used in the main cities. However, it is unclear as to whether it is used significantly in smaller cities and towns, or predominantly in rural areas.

The Commission may need to ensure that adequate action is taken under the Air Quality Framework Directive. A clearer understanding of the potential problem and action taken should be available under Directive reporting – based on this, consideration can be given to this, and the need for additional measures. Two examples have been highlighted of successful measures to reduce emissions from SCI sources. These include the use of smoke control areas in Belfast (and Northern Ireland) and the ban on coal in Dublin. Both measures illustrate cost-effective ways of reducing pollution from solid fuels, and may be examples that the Commission can propose in providing advice to countries with similar problems.

If the problem of PM emissions from coal burning is found to be extensive, based on reporting under the Air Quality Directive, the Commission could propose further action, perhaps restricting the use of certain solid fuels in urban areas with a population of over 250,000. Such a measure is likely to only be considered if this was a widespread problem – based on the evidence in this study, it is considered that this is not the case, with the problems relating to solid fuel burning specific to certain European countries, and decreasing in line with projected solid fuel use. However, it is proposed that the extent of solid fuel burning is re-considered in future months based on reporting under the Air Quality Framework Directive and any findings that might come out of research undertaken for the Mercury

Strategy. Local action relating to biomass is likely to be undertaken at the national and local levels.

The following recommendations can be made on the basis of the study findings, while greater detail of the analysis and types of measures can be found in section 7.3.2.

Key recommendations

- Ensure full reporting by Member States under the Air Quality Framework Directive to assess the types of actions being undertaken to reduce emissions for SCIs in non-attainment areas.
- Identify and propose the use of local measures in the Thematic Strategy, as a cost-effective means of reducing emissions associated with SCI use in urban areas (based on the case study evidence presented in this study, and analysis undertaken).
- Consideration for further measures would need to be based on stronger evidence of the persistence of solid fuel use in urban areas in future years. This study only provides part of this picture.
- Local based measures considered in this section are all represented in the RAINS model to some extent. Further analysis would be difficult in the framework of the RAINS model, as sub-national spatial resolutions cannot be modelled.

1.7.3 Introduction of new or stricter fuel product quality restrictions

The lifetime of installations can be considerable, meaning that polluting installations may not be replaced for many years. Therefore, an important issue to consider is how the quality of fuel used in SCIs can be improved in order to reduce emissions without appliance replacement. The objective of the analysis in this study was to assess the impact of improved fuel product quality on emissions from SCI's, primarily in the non-industrial sectors. Four types of individual measures were considered, including:

- More stringent sulphur content of oil limits, beyond those stipulated in the Sulphur Content of Liquid Fuels Directive, with potential additional benefits for reducing PM.
- Introduction of sulphur content of solid fuels restrictions, using a similar policy mechanism to that for liquid fuels
- Increased use of pellets in the residential sector, although the policy mechanism to consider at the European level to introduce this is unclear.
- Use of less polluting solid fuels (in terms of PM) e.g. use of smokeless solid fuels instead of bituminous coal – covered in the section on local-based measures.

More stringent sulphur content limits would not only reduce SO_2 emissions but could have the additional benefit of reducing secondary PM emissions. With the use of solid fuel projected to decrease significantly and natural gas to increase, it is probable that liquid fuels will become a more significant SCI contributor to urban PM emissions. The Thematic Strategy might usefully re-assess the case for more stringent sulphur limits on liquid fuels for this sector. It should be noted, however, that the evidence of reduced PM from lower sulphur liquid fuels used in the non-residential sector is unclear, and the benefits of going beyond the 0.1% limit post 2008 (as set in the Sulphur Content of Liquid Fuels Directive) are not fully known (although some evidence is provided in this study). Further work would be needed to quantify such benefits before further consideration is given to more stringent limits e.g. in line with road vehicles for example.

The emission inventory indicates a general decline in the use of solid fuels, and therefore associated SO_2 emissions. Based on this trend, introducing additional regulation for the sulphur content of solid fuel may not be a priority, and has significant associated difficulties. Additional benefits for the reduction of other pollutants are not deemed to be significant, plus the priority for air quality may be the removal of such fuels due to associated PM emissions, not improvements to fuel quality.

Analysis undertaken indicates significant reductions of PM are possible with the introduction of pellet fuels as an alternative to wood in the non-industrial sectors. However, it is difficult to envisage a policy mechanism at the European level that stipulated the type of wood products to use, particularly as this has implications for the type of appliance used. Member States will need to put measures in place to promote the use of pellet-based fuels, whilst ensuring it makes economic sense for consumers in order that the objectives of Climate policy are not hindered.

The following recommendations can be made on the basis of the study findings, while greater detail of the analysis and types of measures can be found in section 7.3.3.

Key recommendations

- Highlight in the Thematic Strategy the importance of improved fuel quality for reducing emissions from SCI (particularly in the non-industrial sectors), particularly due to long lifetimes of appliances, making ‘natural’ replacement a slow process.
- Further explore the potential of introducing more stringent sulphur content limits in the Sulphur Content of Liquid Fuels Directive, particularly in terms of associated PM reductions (primary and secondary). This consideration is important given the potential increased importance of liquid fuels as a source of future PM urban emissions.
- Consider this measure further in the framework of the RAINS model. A potential approach for RAINS is described in more detail in section 7.3.3.3.

1.7.4 Installation specific limits for larger plant (less than 50 MW)

Larger industrial plant (>50 MW_{th}) have traditionally been the focus of European and national legislation, with no European-based measure explicitly targeting larger installations in the sub 50 MW_{th} capacity range (although some of these installations will be covered by existing European legislation); unless national legislation covers such installations, there may be significant sized combustion plant that are currently unregulated.

The objectives of this analysis were to:

- Determine the need for additional legislation specifically for installations below 50 MW_{th} based on the quantity of emission (of NOx, SO_2 and PM) from these sources and the scope of existing legislation.
- Dependent on conclusions concerning the need for additional legislation, assess different policy options that could be considered for reducing emissions from larger

installations (below 50 MW_{th}), and recommend the extent of coverage (in terms of thermal capacity) of such measures.

(Note that the focus of this measure would be on site-specific emission limits, and therefore applies to larger plant. Other measures outlined in this analysis deal with smaller types of installation used predominantly in the commercial / residential sectors).

Emissions inventory data indicates that in terms of overall emissions, industrial[1] SCIs do not contribute significantly to overall European emissions. However, on a country-by-country basis and depending on the pollutant in question, this source can be more significant. The emission inventory data, on which such assumptions are made, is much more uncertain than for the non-industrial estimates, and therefore caution is needed when considering further policy action.

We believe that the coverage of existing legislation (at both a national and European level) is significant. Country-based data indicates that the IPPC Directive may have significant coverage of installations in the 20-50 MW_{th} capacity range, which are the key installation that would likely to be considered under any new proposals. Such combustion installation will either be regulated as 'directly associated activities' (i.e. they provide energy to a regulated IPPC process) or as combustion processes where two or more single units have an aggregated capacity greater than 50 MW_{th}.

In addition, the EU Emissions Trading Scheme will cover all sites with aggregated capacities above 20 MW_{th}. This will result in many sites being subject to site-specific regulation for the first time, and will include single combustion units less than 20 MW_{th} (as threshold is based on aggregated capacity). Although this scheme is dealing specifically with GHGs, it is probable that reducing GHGs will have some indirect benefits for air quality pollutant emission reduction. Coverage of SCIs is also increased by many countries across Europe have introduced national legislation for sub-50 MW_{th} installations.

On the basis of our understanding of the contribution of industrial SCIs to overall European emissions, and the scope of existing legislation, it may be that a new legislative instrument or extension of existing legislation to increase coverage of industrial SCIs is not necessary. However, such conclusions, particularly concerning the contribution to overall emissions, are uncertain; therefore, the type of measure available to the Commission if action was deemed necessary have been considered.

A new Directive or extension of LCPD could be considered, that introduced emission limits for all installations down to 1 MW_{th}, based on limits considered under existing national legislation (based on existing BAT guidance and proposed emission limits in use across Europe). Such a measure would need to consider 'light touch' regulatory approach for sites less than 15-20 MW_{th}, due to the number of sites that would be covered by such thresholds. As in France, the emphasis could be on self-regulation and intermittent reporting to local authorities. Sites between 20 – 50 MW_{th} could be regulated as under the IPPC or LCPD Directives, for the following reasons:

- 20 – 50 MW_{th} installations are far less numerous than smaller sites

[1] This analysis also applies to large institutional plant – however, most of the larger plant within the scope of this study will be industrial; hence the focus on industrial emissions.

- The emission contribution per site (and potential for reduction) may justify the costs of this type of regulation.
- They have been comprehensively identified under the EU ETS, and in many countries under national-based legislation.
- The infrastructure for regulation of these installations may already be in place, if indeed the scope of the IPPC Directive is as far reaching as thought.

Another interesting option might be the consideration of NOx or SO_2 emissions trading, although this may only be feasible for installations with an aggregated capacity of 20 MW_{th}, as trading often requires an understanding of site-specific emissions contribution. This could be based on the EU ETS trading platform that has been established, where sites for inclusion have already been identified – the model for such a scheme may be that being developed in the Netherlands, where NOx emissions trading scheme is proposed for introduction alongside the EU ETS in January 2005.

In conclusion, better data is needed on which to justify any further action, and on which to assess the impacts of different options. However, if action is considered necessary, the Commission could consider closely national based measures, which provide experience of implementation, and the technical background to emission limits.

The following recommendations can be made on the basis of the study findings, while greater detail of the analysis and types of measures can be found in section 7.3.4.

Key recommendations

- In view of the emission contribution of industrial SCIs, and the potential scope of existing measures, it is possible that additional site-specific regulation may not be required for large SCI plant (>1 MW_{th}); however, such conclusions have strong caveats attached due to data uncertainty.
- Ensure improved inventory reporting for small industrial combustion installations to better meet the needs of European policy makers.
- Consider further the potential for emissions trading, which could 'piggy-back' off the EU ETS platform, and cover all installations with an aggregated capacity over 20 MW_{th} (aggregated) up to LCP. This may also be a useful mechanism for countries to meet NECD targets.
- Further analysis could be undertaken by the RAINS model, in particular to model the effect of plant in the 20-50 MW_{th} range being included under the IPPC Directive. The possible approach is set out in section 7.3.4.5.

1.7.5 Increased use of European Structural Funds in reducing SCI emissions

The Structural and Cohesion Funds are significant sources of European central financing for Member States, primarily structured to further regional development, and enhance economic and social cohesion across Europe. The analysis undertaken in the Study had two primary objectives:

- To better understand the how such funds work, their allocation, and the role of the Commission in determining this allocation.
- To illustrate how such funds could be used to reduce emissions (particularly PM) from SCIs (where urban air quality issues arise), and how they might be restructured to provide funding opportunities for air quality issues in Member States.

To date, few projects have been undertaken that directly relate to the reduction of emissions from SCIs. This reflects that the priorities of these funds are driven by other objectives. Within the scope of Structural Funds programme, environmental considerations are included as a fundamental aspect of sustainable development. However, such considerations are usually a theme within funding programmes, rather than the driving objective for selection of projects.

If restructured, these central funds could provide financing that would enable the introduction of measures in local areas that had specific air quality problems due to SCI emission sources (particularly in the residential / commercial sectors). (This funding could be important for some of the measures discussed in the 'local-based measures' analysis).

In particular, the type of pr0ject that could benefit most are those that require significant levels of capital investment. These types of project include:

- *Technology improvement projects* - Replacement of older technologies with lower emitting technologies in urban areas (across all sectors), where contribution to urban air quality problems is significant.
- *Infrastructure development projects* - Extend existing energy networks to areas that currently do not have district heating or natural gas provision.

These measures are illustrated in a case study on Krakow, where funding was provided that enabled significant reductions in urban pollution levels (through removal of the key polluting sources).

The following recommendations can be made on the basis of the study findings, while greater detail of the analysis and types of measures can be found in section 7.3.5.

Key recommendations include:

- The Thematic Strategy might usefully reflect the importance of available funding to assist countries (particularly new Member States and Candidate countries) in dealing with local and regional air quality problems associated with emissions from SCIs, and the effectiveness of such funding in achieving emission reductions.
- Further consideration of the possibilities for ensuring Structural and Cohesion Funds provide financial assistance to tackle SCI air quality related issues. This study has determined that there are a number of countries that still have significant local air quality problems due to emissions from SCI sources, who could benefit from such investment.
- Increase awareness of the potential for using Structural Funds, as currently structured, to further prioritise environmental objectives in national fuding programmes.
- Broaden scope of the Cohesion Fund, which specifically relates to environmental and transport infrastructure to include energy infrastructure.

1.7.6 Development of energy-efficiency measures to further benefit air quality policy

Many of the measures highlighted in this study that relate to SCIs, particularly those in non-industrial sectors, have been driven by Climate policy, and energy efficiency objectives. The Energy Performance of Buildings Directive (EPBD) is a key example, with the main objective of reducing energy demand of buildings through measures such as improved insulation and boiler maintenance. This Directive comes into force in 2006.

This study has assessed the potential reduction in energy use associated with such measures, and the potential benefits for air quality emission reduction. Some consideration has also been made regarding how such measures could be structured to increase benefits both for air quality policy objectives, and those associated with climate change / energy policy.

Our analysis has indicated that 2-3% annual reductions (on average as this will depend on the type of appliance-fuel) can be made in energy consumption through regular inspection and maintenance, leading to some emission reductions. In addition to energy savings, there are also likely to be direct emission reductions from boilers (decoupled from energy savings), particularly those that are not performing at an optimal level – some evidence exists for the impact on PM emissions from oil boilers – however, for other pollutants and fuels, limited information is available. Overall, we believe that the benefits of inspection and maintenance are less than might be expected due to the significant number of schemes already in place across Europe, and servicing of boilers under the initiative of home and business owners.

Analysis based on work undertaken by Ecofys indicates significant technical potential for energy savings in the European building stock, potential that will also be targeted by the EPBD. Significant energy savings can be made through improved insulation, the predominant factor in energy performance of buildings, which lead to the reduction of carbon dioxide and other combustion related pollutants. Based on other studies, the payback period on the costs of insulation is considered to be short.

The following recommendations can be made on the basis of the study findings, while greater detail of the analysis and types of measures can be found in section 7.3.6.

Key recommendations include:

- Highlight the benefits of action in the climate policy area across Europe, in particular the EPBD, but through other Directives such as that relating to the Energy efficiency of boilers.
- Further research to be undertaken on the direct benefits of maintenance for air pollutant reduction, not only those derived from energy savings.
- Consideration of future changes to the EPBD, to broaden the scope of types (based on size) of the buildings and installations covered.

2 Background and Methods

2.1 BACKGROUND TO THIS REPORT

One of the seven Thematic Strategies in the framework of the 6^{th} Environmental Action Programme will focus on air pollution. The Clean Air for Europe Programme (CAFE) has been launched by the Commission in order to gather together the relevant scientific information to support the Air Pollution Thematic Strategy. One of the main activities of the CAFE programme is to assess the environmental and economic impact of existing air quality policies as well as to identify possible new policies that will deliver environmental improvement while limiting as much as possible economic cost.

Under the CAFE programme, small-scale combustion installations (SCIs, also known as small combustion plant or SCPs) have been identified as an emission source for which options for emission reduction may need to be considered in order to address a number of social and environmental issues, or which the following are particularly important[2]:

- Effects of particles, NOx and photochemical oxidants on health.
- Effects of acidifying and nutrifying pollutants, and photochemical oxidants on ecosystems.
- Effects of air pollution on materials, particularly those used that form much of our cultural heritage.

SCIs are defined as combustion units of less than 50 MW thermal capacity (50 MW_{th}). They include the following types of unit:

- Fireplaces (<15 kW)
- Household stoves (<15 kW)
- Household boilers (15 – 150 kW)
- Medium sized residential and commercial boilers (150 kW – 5 MW)
- Larger institutional / industrial boilers (5 – 50 MW)

They utilise a wide variety of fuels:

- Brown coal
- Hard (or black) coal
- Coke and SSF (Solid Smokeless Fuel)
- Oil
- Petroleum
- Liquefied petroleum gas (LPG)
- Natural gas
- Biomass (chiefly wood)
- Peat

[2] More detail on impacts and the way in which they are being assessed under the CAFE programme are provided through a separate contract on cost-benefit analysis, details of which are available at http://www.europa.eu.int/comm/environment/air/cafe/activities/cba.htm

SCIs are an important source of air pollution as they are often concentrated in populated areas and emit pollutants close to ground level. Other characteristics include low efficiency of many devices (though not all) and poor maintenance. Operational lifetimes are frequently long, typically in excess of 15 years and often much longer, with the effect that improved appliance standards will take a long time to have a significant effect without intervention of some form.

Although measures are applied in a number of countries to control SCI emissions, there is currently no European action specifically targeting SCIs. This study aims to assess the types of measures that could be used to reduce emissions, and whether they are cost-effective (i.e. that they can achieve emission reductions at lower cost than other sectors – expressed as a cost per tonne of pollutant abated). Through this, the project contributes to the development of strategies for the reduction of emissions, which will feed into the Thematic Strategy.

2.2 OBJECTIVES AND SCOPE OF STUDY

This study was developed with the following objectives:

- To understand the key emission issues relating to SCI sources
- To identify potential measures for the reduction of emissions
- To assess the feasibility of the implementation of these measures at the European level
- To describe the cost-effectiveness of such measures

The findings of this study should contribute significantly to the Commission's assessment of the need for European level action, and help to develop a strategy for emission control of SCI sources.

SCIs are found across many different sectors including industrial, residential, commercial, agricultural and public administration (including government buildings, hospitals, universities etc.). All of the sectors were considered during this work, although a technology review for the industrial sector was not undertaken as this was being covered under another programme of work.

The years 2000-2020 provide the timeframe for analysis of future technology options and implementation of policy measures. The geographical extent for this work covers all countries involved in the CAFE programme (EU 25 plus Switzerland, Norway, Bulgaria and Romania), with options considered at both European and national levels. No data are provided for Malta or Cyprus in this report because of a lack of source information and the high uncertainty associated with any attempt to extrapolate data from other countries to these island states. It is, however, felt that emissions from SCIs in Malta and Cyprus could be locally important and so should be systematically assessed in the near future. Bulgaria and Romania are covered to some extent in this study, although their associated inventory data is less detailed.

The analysis covers the following air pollutants:

- Ammonia (NH_3)
- Sulphur dioxide (SO_2)
- Nitrogen Oxides (NOx)
- Carbon monoxide (CO)

- Particulate Matter (TSP, PM_{10}, $PM_{2.5}$)
- Non-methane volatile organic compounds (NMVOCs)

Data for particulate matter presented in this report concern only ‘primary particles’ – particles that are emitted direct into the atmosphere from anthropogenic actions (here, combustion). Total anthropogenic particle loading in the atmosphere also includes ‘secondary particles’, formed through chemical reaction of pollutants such as SO_2 and VOCs. Formation of these secondary particles is accounted for in the CAFE process through use of the EMEP dispersion models. CO estimates have not been made due to lack of inventory information. NMVOCs are considered to provide a reasonable proxy for CO.

The analysis also investigates the indirect benefits of measures on other pollutants, specifically greenhouse gas emissions which add to overall cost-effectiveness. In addition to greenhouse gases, emissions of dioxins, PAHs and certain heavy metals may also be affected by specific measures considered in this study. While a detailed analysis of such indirect benefits has not been performed, this study has sought to provide an understanding of where such indirect benefits may occur.

2.3 METHODOLOGY OVERVIEW

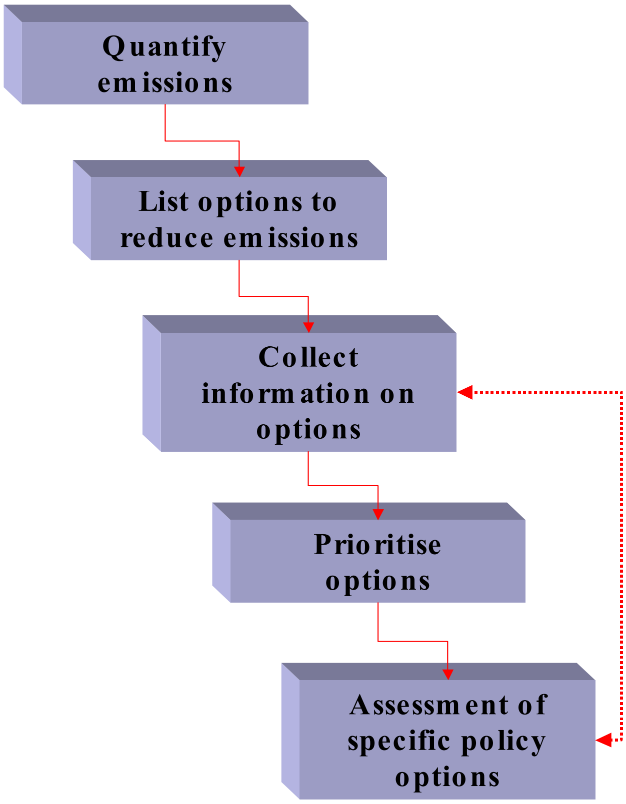
There are five key methodological stages in this study, as illustrated in Figure 2.1, and discussed below.

1. **Quantify emissions** – To develop a strategy for targeting emissions from SCIs, it is imperative that emission contributions from different sectors and installations are better understood. Such an understanding includes identification of countries that are the most significant emitters, key pollutants for targeting under the Thematic Strategy, etc.

2. **List options for reducing emissions** – In this stage, different policies and potential options for reducing emissions from small combustion installations are identified, particularly for those emission issues highlighted in the first stage. Options include both policy measures, and technical and non-technical measures. Policies, through the establishment of objectives, are the driver for the introduction of technical and non-technical measures. Technical measures include improvements to appliances, the use of additional abatement equipment or the use of cleaner fuels. Non-technical measures include changing consumer preferences through marketing more efficient options or promoting behavioural change (e.g. through the regular maintenance of appliances).

3. **Collect information on options** –. Once options have been listed, the next stage reviews information (both qualitative and quantitative) on options. This provides information on how measures work, and experience of previous implementation. It also provides data on costs and reduction potential of measures. It is important to note that this stage has also been revisited as part of the assessment of specific policy options.

Figure 2.1 Methodological overview of study



4. **Prioritise options** – Based on the key issues highlighted, and the information on measures reviewed, options for reduction of emissions from SCIs are prioritised. This is done on the basis of cost-effectiveness information and other factors including:
   - Key emission issues identified
   - Scale of implementation
   - Political acceptability
   - Social impacts

   Options have been prioritised on the basis of findings in earlier drafts of this report and through consultation with the Commission (and other stakeholders).

5. **Assessment of specific policy options** – The final stage undertakes a more detailed assessment of selected policy options (as identified in section 7). This involves analysis of cost-effectiveness, and assessment of factors that will determine the feasibility / appropriateness of a given option.

Stakeholder consultation has also been an important component of the methodology, and is discussed in further detail in the next section.

2.4 STAKEHOLDER CONSULTATION

A stakeholder consultation exercise was carried out for the following reasons:

- To provide limited verification of the emission inventory data, and to obtain any additional information on which to improve the inventory estimates
- To understand the types of control measures and technologies implemented across Europe to address emissions from SCIs
- To engage expert opinion on the types of measures that could be introduced in the future based on their understanding of country situations.

Stakeholders were sent an email questionnaire (see Appendix 3) with a copy of draft material produced under the contract, with follow-up by phone where clarification was needed or where no response was gained. Responses received from countries / institutes have been summarised briefly in Table 2.1.

The respondents who commented on the inventory data appear to have been broadly satisfied that the emission estimates, at a minimum, provided an indication of what the priority sectors were. Where significant differences were observed by respondents, changes were made to the study estimates if data were subsequently provided (e.g. Switzerland and France).

Table 2.1 Responses received from the stakeholder consultation exercise

Country /Institute	Issues	Additional data provided
Belgium (Flanders) 3 responses		• National law on emission limits for certain SCIs • Emissions and technological data • Views on possible EU policies on SCIs • Information on EU inspection / maintenance programmes
Czech Republic 2 reponses		• Industrial (incl. installation numbers) and household emissions data • Twinning programme report by Brandt (2004)
France 1 response	• Use of RAINS data prior to completion of bilaterals • Emissions from plant <1 MW_{th} • Small differences on emission estimates	• Emission limit regulations in France for combustion plant >2, <50 MW_{th} • Data on emission estimates, industry installations and residential wood burning
Germany 1 response	• Some differences between national estimates and project estimates for emissions, particularly for NMVOCs from residential biomass, and NOx and SO_2 from residential liquid fuels	• Studies by Pfeifer (2000) and Struschka (2003) • Various other data
Ireland 1 response		• Irish energy data • Specific measures banning solid fuel burning
Italy 2 responses	• Slight underestimation of residential gas and biomass PM emissions • Emissions from the commercial-institutional sector in relation to biomass burning	• Emission factors • Regional activity data • Paper on control of PM emissions from small wood fired furnaces (Schmatloch 2002) • Views on strategy regarding wood consumption and climate change policy • Effect of banning fuel oil burning by SCIs in large towns
Netherlands 2 response	• PM emissions from agriculture	• JRC workshop on emissions from small and medium scale combustion • Data on industrial installations from national inventory
Poland 1 response		• Detailed response on emissions, technologies and regulation in Poland • Data on urban air quality levels from SCIs
Switzerland 2 responses	• Differences between emission estimates of this study and Swiss sources	• UNFCCC emissions data • Nussbaumer (2003) paper on biomass combustion technologies
Sweden 2 responses		• Trends data on use of different fuels • Emission factors for small domestic wood burning (www.itm.su.se/bhm/) • Data on technologies and control measures
UK 4 responses		• Detailed data on industrial installation breakdown (from NAEI / Environment Agency) • Information regarding Structural Funds process • Information on product standards / emission limits
JRC	• Consistency in use of emission factors across pollutants for Commercial-Institutional wood burning • Czech SO_2 estimates for Commercial-Institutional solid fuel burning • Possible inclusion of off-road emissions for diesel/light fuel oil use • Penetration of automatic wood technologies for single house boilers	

NB. The above table also summarises some of the other data received even if not received as a result of the initial consultation exercise.

3 Emissions from small combustion installations in Europe

3.1 INTRODUCTION

Emissions from small combustion installations (SCIs) are considered an important source of emissions across Europe. However, no inventory was available at the start of this work programme that had specifically assessed emissions from SCIs across Europe. Inventories provide an understanding of the emissions problem, and enable policy makers to prioritise where they focus resources and target measures. It is very difficult to formulate policy with confidence when there is limited understanding of the emission sectors for which action is being considered.

An important part of this work has therefore been to construct an inventory, disaggregated to specific fuels, technologies and sectors by country. The main role of the inventory in the context of this study is primarily to provide guidance on what the priorities for action should be. Specifically, the inventory helps to:

- Identify the priority sources, fuels and technologies that contribute significantly to current and projected emissions, and for which measures and technologies could most effectively be applied;
- Identify countries and SCI sub-sectors where emission reductions have successfully been achieved;
- Provide the baseline data from which costs and benefits (in terms of emission reduction) for measures can be calculated.

This section of the report focuses on how the inventory was constructed, associated data limitations, and key findings based on the emission estimates.

3.2 OVERVIEW OF EUROPEAN EMISSION INVENTORY ACTIVITY

The main reporting bodies to which country-based estimates are submitted are:

- Intergovernmental Panel on Climate Change (IPCC) under the United Nations Framework Convention on Climate Change (UNFCCC)
- United Nations Economic Commission for Europe (UNECE) under the Convention on Long Range Transboundary Air Pollution (CLRTAP)
- European Commission under the National Emission Ceilings Directive (NECD)

Most of these inventory data sources provide at least one component of the detail required in the SCI inventory but none provide a complete set. Therefore, derived inventories have been constructed, which aim to provide the level of disaggregation necessary to achieve the objectives of this study. These are described in the following section (3.3).

3.3 A DERIVED SCI EMISSION INVENTORY

Due to differing issues of data availability, two separate emission inventories have been developed to assess emissions from SCIs – an emission inventory of non-industrial SCIs and one of industrial SCIs.

The emission inventory for non-industrial SCIs has been developed using existing data from a range of different inventories, including the RAINS model emissions database, UNFCCC country submissions, and CLRTAP submissions. The inventory has been constructed on the basis of the following parameters (to enable further analysis):

- Country
- Pollutant (currently including SO_2, NOx, NMVOC, PM_{10}, $PM_{2.5}$, and NH_3)
- Inventory year (1990, 1995, 2000, 2010 and 2020)
- SCI sub-sector (residential, agriculture, commercial and institutional)
- Technology by MW_{th} (e.g. stove, fireplace, heating boiler)
- Fuel (coal, coke/briquettes, liquid fuels, oil, natural gas, biomass, peat)

CO is covered by the scope of this study but no estimates have been included in this report. Estimates have not been made for two reasons – firstly, there are no data from the RAINS model from which to derive sector specific splits, and secondly, NMVOC combustion emissions can be used as a reasonable proxy for CO.

The derived estimates for industry SCIs are based on data from current reported national estimates, using the previous CORINAIR reporting splits. In the course of determining the methodology to use, estimates were also derived using EPER reported data and RAINS emission estimates. Both of these datasets have also been used to compare against the estimates based on CORINAIR data.

The detail and completeness of the derived SCI emissions inventories has largely been dictated by the availability of data. A limited consultation process has been undertaken with experts to provide additional verification to the non-industrial SCI inventory.

3.3.1 An 'idealised' inventory

Table 3.1 illustrates an 'idealised' inventory for this work, that would provide the appropriate level of detail with regard to sector, technology and fuel split (all by country) for the purposes of the this study analysis. Additional detail on the type of fuel (e.g. solid fuels split by type and quality) would also be useful in order to consider options relating to fuel quality and type.

Figure 3.1 An 'idealised' SCI inventory (by country and pollutant)

Sector	Technology	Fuel	Emission, tonnes/ year			
			1995	2000	2010	2020
Residential	Fireplaces					
Residential	Stoves					
Residential	Central Heating Boiler 100 - 1000kW					
Residential	Central Heating Boiler 50 - 100kW					
Residential	Central Heating Boiler 20 - 50kW					
Residential	Central Heating Boiler 10 - 20kW					
Residential	Central Heating Boiler 5 - 10kW					
Residential	Central Heating Boiler <5kW					
Agriculture	Boiler 1 – 5MW					
Agriculture	Boiler 1000 – 10,000kW					
Agriculture	Boiler 50 - 1000kW					
Agriculture	Boiler 20 - 50kW					
Agriculture	Boiler 10 - 20kW					
Commercial / Institutional	Boiler 5 – 20 MW					
Commercial / Institutional	Boiler 1 – 5MW					
Commercial / Institutional	Boiler 1000 – 10,000kW					
Commercial / Institutional	Boiler 50 - 1000kW					
Commercial / Institutional	Boiler 20 - 50kW					
Commercial / Institutional	Boiler 10 - 20kW					
Industrial	Boiler 20 – 50 MW					
Industrial	Boiler 5 – 20 MW					
Industrial	Boiler 1 – 5MW					
Industrial	Boiler 1000 – 10,000kW					
Industrial	Boiler 50 - 1000kW					

NB. Fuels would be reported separately and include, biomass, and solid, liquid and gaseous fuels.

This level of detail has largely been realised for non-industrial SCI emission estimates, but not for industry based estimates.

3.3.2 Emission inventory construction – non-industrial SCIs

3.3.2.1 Data sources

A variety of inventory data sources were used in the compilation of the non-industrial SCI emission inventory, and are summarised in Table 3.1. Reported emissions and activity data have been used as the basis of the inventory, supplemented by RAINS estimates to add extra detail regarding technologies used.

- *UNFCCC* data were used as the primary source of activity data, as it was considered important to use a robust reported dataset as the basis of the inventory. It is the only reported source that provides types of fuel consumption, disaggregated into residential, commercial-institutional and agricultural sectors.
- *RAINS* emissions database provided an understanding of the split between technologies for different fuels and across relevant sectors. It also provided the information on emission projections, which are very difficult to source from country reported data. This helps to ensure consistency with the modelling being carried out using the RAINS model under the CAFE programme.

- *CLRTAP*[3] data provided reported aggregated estimates of emissions, to which the detailed estimates were fixed.

Table 3.1 Data sources used in the non-industrial SCI emission inventory compilation

Data source	Sector	Technology	Fuel	Pollutants	Countries	Years used
UNFCCC (2002 national submissions)	Residential, Commercial & Institutional, Agriculture, Forestry and Fishing (AFF); UNFCCC CRF	None	Yes (Liquid fuels, solid fuels, gaseous fuels, biomass)		All countries that fill in detailed CRF tables	1990, 1995, 2000
CLRTAP (2003 national submissions)	Residential, Commercial & Institutional, Agriculture; WEBDAB & ETC-ACC database	None	None	PM_{10}, $PM_{2.5}$, CO, NOx, SO_2, NH_3, NMVOC	All countries that report in NFR format	1990, 1995, 2000
RAINS	Residential + Commercial (DOM); RAINS WEB[4]	Boiler (by size), stove, fire-place	Yes (Gasoline, diesel/light fuel oil, heavy fuel oil, brown coal, hard coal, coke/briquettes, natural gas, LPG, wood waste & biomass	PM_{10}, $PM_{2.5}$, NOx, SO_2, NH_3, NMVOC	All (excluding Liechtenstein, Iceland, Bulgaria, and Romania)	1990, 1995, 2000, 2010, 2020

3.3.2.2 Activity data

Activity fuel use data for each country for the years 1990, 1995 and 2000 was based on official reported data to UNFCCC under sectors 1A4a (commercial and institutional), 1A4b (residential) and 1A4c (agriculture/forestry/fishing) for the 2002 reporting year. Where countries had not reported a complete time series, or had not reported data for one or more of the required years, a gap-filling process was used. The process used is the same as that used by the European Topic Centre on Air and Climate Change (ETC-ACC) to compile air emissions data.

Where countries reported no data to UNFCCC, (and where gap-filling was subsequently not possible), an estimate of fuel use within each country was derived based on the sum of activity values for the respective country region (countries were categorised into EU/Western Europe or AC/Eastern Europe regions) which was subsequently split on the basis of population. The fuel estimates for each of the sectors 1A4a, 1A4b and 1A4c (each of which is split into the UNFCCC classifications: liquid fuels, solid fuels, gaseous fuel and biomass) were further disaggregated into the RAINS technology and fuel activity codes (using the ratio of the individual RAINS sector activity to the sum of RAINS activity that corresponded to the relevant UNFCCC Classification).

[3] CLRTAP data is used rather than data reported under the NECD because (1) more countries are included (not just EU15) (2) both UNECE and NECD reporting is to be in the new NFR format and should be virtually identical, and (3) the UNECE reporting deadline is later than NECD, ensuring countries have an opportunity to correct their earlier submissions if necessary.

[4] RAINS data was obtained from the publicly accessible web-module, using the scenario CP_CLE (Climate policy scenario; Control strategy: Current legislation). This scenario was chosen as it represents current legislation controls plus the impact of the emissions trading scheme under the EU ETS, which is currently being implemented. The use of this scenario as opposed to BL_CLE (RAINS scenario illustrating current legislation only) is considered to make limited difference to the disaggregation profile.

An example of the approach was to take the UNFCCC ‘Liquid fuels’ category and split it into the RAINS categories of gasoline, medium distillates and heavy fuel oil on the basis of the relative activities for each of these sectors predicted within RAINS. Table 3.2 illustrates the relevant fuel and technology codes in RAINS used in this inventory.

Table 3.2 RAINS technology and fuel codes used in compiling inventory activity statistics

Abbreviation	Description
DOM-GSL	Gasoline
DOM-MD	Diesel / Light fuel oil
DOM-HF	Heavy fuel oil
DOM_MB_A-BC	Medium boilers (automatic) <50 MW using brown coal
DOM_MB_M-BC	Medium boilers (manual) <1 MW using brown coal
DOM_SHB_M-BC	Single house boilers (manual) <50 kW using brown coal
DOM_STOVE-BC	Stoves using brown coal
DOM_MB_A-HC	Medium boilers (automatic) <50 MW using hard coal
DOM_MB_M-HC	Medium boilers (manual) <1 MW using hard coal
DOM_SHB_M-HC	Single house boilers (manual) <50 kW using hard coal
DOM_STOVE-HC	Stoves using hard coal
DOM_MB_A-DC	Medium boilers (automatic) <50 MW using coke / briquettes
DOM_MB_M-DC	Medium boilers (manual) <1 MW using coke / briquettes
DOM_SHB_M-DC	Single house boilers (manual) <50 kW using coke / briquettes
DOM-GAS	Natural Gas
DOM-LPG	LPG
DOM_FPLACE-OS	Fireplaces using wood, waste, biomass
DOM_MB_A-OS	Medium boilers (automatic) <50 MW using wood, waste, biomass
DOM_MB_M-OS	Medium boilers (manual) <1 MW using wood, waste, biomass
DOM_SHB_A-OS	Single house boilers (automatic) <50 kW using wood, waste, biomass
DOM_SHB_M-OS	Single house boilers (manual) <50 kW using wood, waste, biomass
DOM_STOVE-OS	Stoves using wood, waste, biomass

NB. The above category DOM applies to residential and commercial / institutional sectors, and has also been used in agricultural SCI estimates.

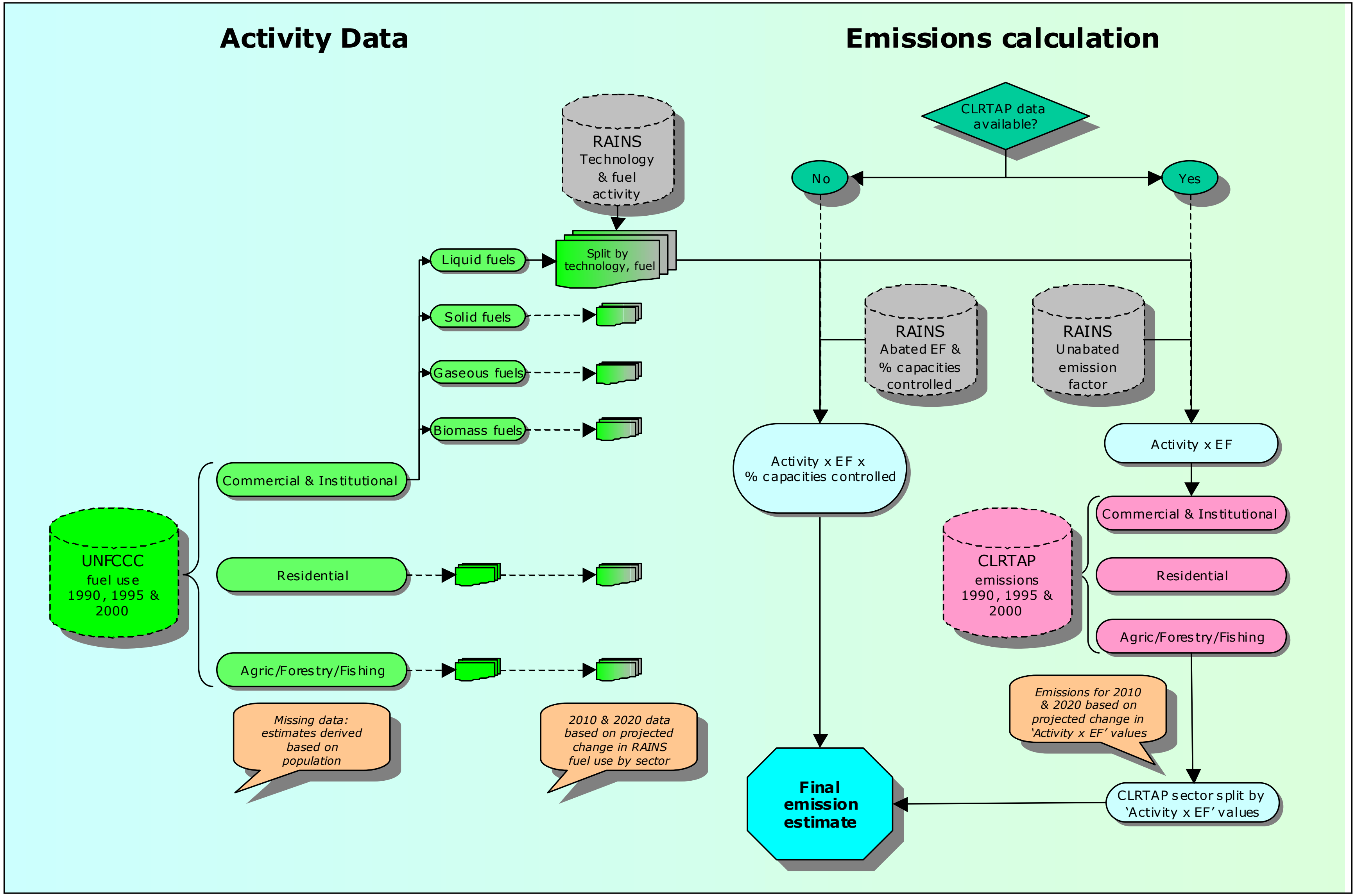
3.3.2.3 Emission data estimates

Non-industrial emissions of the pollutants SO_2, NOx, NMVOC, PM_{10} / $PM_{2.5}$ and NH_3 were calculated using one of two methods, depending on whether countries had reported emissions of air pollutants to UNECE-CLRTAP for the sectors 1A4a (Commercial / Institutional), 1A4bi (Residential plants) and 1A4ci Stationary (AFF). Both methodologies are illustrated in Figure 3.2.

Where countries had reported emissions to CLRTAP, an estimated emission for each pollutant/RAINS fuel code sector for the years 1990, 1995 and 2000 was made by multiplying the respective activity data (derived as described above) by the ‘RAINS unabated emission factor’ for the respective year/pollutant /sector combination. These estimated emissions were subsequently used to disaggregate the CLRTAP reported emission value and hence derive the final emission estimate for 1990-2000.

Emissions for 2010 and 2020 were calculated from emissions for 2000 using the percentage change for these years predicted by the ‘RAINS unabated (and abated) emission factor multiplied by activity’ estimates. Both unabated and abated projection factors were considered to better understand the effect of assumptions on control strategies in the RAINS model.

Figure 3.2 Illustration of methodology and data-flows used in compiling the SCI emission inventory



For countries that did not report emission data in the required sectors to CLRTAP, an alternative approach was used. In these instances, final emission estimates were calculated by multiplying the activity data (derived as described above) by the 'RAINS abated emission factor' and by the RAINS '% capacities controlled' value. Projected data were also derived on the basis of unabated and abated projection factors, for the reason previously stated.

In many instances there were discontinuities in the RAINS output, for example, where a given pollutant/sector combination was reported in the years 1990 and in 2000 but not in 1995. In these cases the gap-filling interpolation routine described in the preceding section was used to complete the time series for emissions.

Importantly, some limited verification of the estimates was provided through consultation with national experts. This was necessary due to some of the uncertainties surrounding emission estimates for SCIs, particularly regarding RAINS data that had not been rigorously discussed with country experts.[5] It is noted, however, that this is not a stringent validation exercise. Such an exercise is deemed unnecessary as the inventory is designed primarily to be a tool for identification of key emission issues, and to highlight the need for action to reduce emissions.

3.3.3 Emission inventory construction – industrial SCIs

Construction of a detailed industrial SCI inventory is made difficult by the lack of available data on reported emissions from industrial installations below a 50 MW_{th} capacity. In the course of this study, three separate estimation methodologies were investigated in an attempt to generate a robust and comparable set of industrial SCI emission estimates for European countries, each of which is described below. Further details on selected country-specific industrial inventories can be found in section 3.5.2.

3.3.3.1 CORINAIR-based estimates

Under the CLRTAP reporting framework, different types of reporting formats have been used over the past 15 years. An earlier reporting format was CORINAIR 90, which stipulated that emissions were to be reported on the basis of power range e.g. 0-50 MW_{th} (sub-category of SNAP3 level). The CORINAIR 90 database from 1994 is the main source of data, which provides estimates of emissions data for a range of European countries to the detailed SNAP3 level. Other more recent reporting formats e.g. NFR01 and NFR02 do not provide such disaggregated information. Importantly, there is presently no requirement or mechanism for such emissions data to be reported.

NOx and SO_2 estimates of industrial SCIs were therefore constructed using the ratio of emissions from < 50 MW_{th} installations applied to year 2000 emissions from CLRTAP (2003 data submission). Specifically, 1990 emissions from the following SNAP3 sectors from CORINAIR 90 were used:

- 01_01_03 (public power and cogeneration - combustion plants < 50 MW)

[5] IIASA has undertaken bilateral discussions with national experts to derive a consistent baseline under the CAFE programme. The RAINS emissions data used in this study was that published just before the completion of these bilaterals. Based on discussion with IIASA, it is felt that the estimates used in this study would not have changed considerably as a result of the bilaterals that were yet to take place.

- 01_02_03 (district heating - combustion plants < 50 MW)
- 03_01_03 (industrial combustion - plants < 50 MW)

The percentage of emissions from these sectors relative to the 1990 national totals was calculated for each country/pollutant combination, and these splits applied to the officially reported CLRTAP national totals for the year 2000. PM_{10} estimates are not available in CORINAIR 90 – initially it was assumed that the respective emissions ratio for this pollutant were the same as those determined for SO_2 but this significantly overestimated emissions based on country specific data (France and UK). PM_{10} estimates for Western Europe have therefore been made on the basis of an average SCI estimated percentage of 13.9% (from UK and France) of total reported industrial combustion emissions, while for Eastern Europe, estimates have been made using a Czech Republic derived estimate of 29% of industrial combustion emissions.

There are both advantages and disadvantages inherent in this approach. Firstly, as previously mentioned this data source allows emissions to be split by combustion process size i.e. into SCI categories (< 50 MW_{th}). However, the main disadvantage of using these data is that significant changes that have occurred in combustion plant emissions over the past 10 years; therefore, the ratio of emissions from such sources in 1990 relative to the national total is unlikely to be the same as in 2000. However, the estimates derived using this approach appear to be significantly closer to the actual reported values for SO_2, and NO_x than the other approaches described below, based on checking against country reported data. Another disadvantage is that no projected emissions can be estimated, as estimates are derived on the basis of historic data.

A full set of industrial SCI estimates using the CORINAIR data are provided in section 3.5. For the reasons described above, these emission estimates are subject to significant uncertainties, and should therefore be used with care. **The estimates as described above are being used in this study**, not the estimates described in the following sections, which use alternative approaches.

3.3.3.2 RAINS-based estimates

Emission estimates for industrial SCIs were also made using a combination of RAINS model data, and CLRTAP industrial combustion emission estimates. The RAINS estimates represent emissions from combustion plant above 50 MW_{th}, which were subtracted from reported totals for industrial combustion emissions, to provide an estimate of industrial SCIs.

The RAINS model does not have a sector for large combustion plants, only a sector called ‘Public Power’ (PP) sector, which also includes district heating plants and industrial power plants. This sector is thought to have some plants below 50MW_{th}, which are expected to be a small fraction of the total.

These RAINS based estimates were considered to be quite consistent with country reported data, and were checked accordingly. Their use in estimating industrial SCIs was considered advantageous because a consistent set of data for all countries was provided for the three key industrial pollutants – SO_2, NO_x and PM_{10}.

However, comparison of these estimates with actual values for industrial SCI emissions obtained for selected countries shows large discrepancies between the estimated and actual values. Although the RAINS estimates for LCP in most instances agreed very well with actual reported LCP data from Member States where this was available (see Table 3.6), the industry SCI emissions calculated by difference (using the CLRTAP total energy emissions) appeared overestimated. One reason for this is likely to be that the LCP reported values (and those obtained from RAINS) do not capture all combustion sources > 50 MW_{th}, e.g. while boiler facilities are included in LCP estimates, large furnaces and gas turbines may not be. Therefore, subtraction of LCP data from the total CLRTAP energy-related emissions does not provide industrial SCI emissions alone, but also includes additional larger emission sources that are not included in the LCP returns. In contrast, results using the CORINAIR 90 approach outlined above provided emission estimates much closer to the actual values.

3.3.3.3 EPER-based estimates

EPER (the European Pollutant Emissions Register) reported data were also considered, to derive industrial SCI estimates. These data were used to estimate LCP (large combustion plant) emission totals. Industrial SCI estimates were derived in the same way as above, by taking the difference between EPER estimates and emission estimates of total industrial combustion reported to CLRTAP, and were deemed problematic for the same reasons as described above.

3.4 EMISSION ESTIMATES – NON-INDUSTRIAL SCIS

In this section, an overview of emission estimates from non-industrial SCIs is provided, both at the European level, and then in detail by pollutant and sector at the national level.

3.4.1 European emission estimates

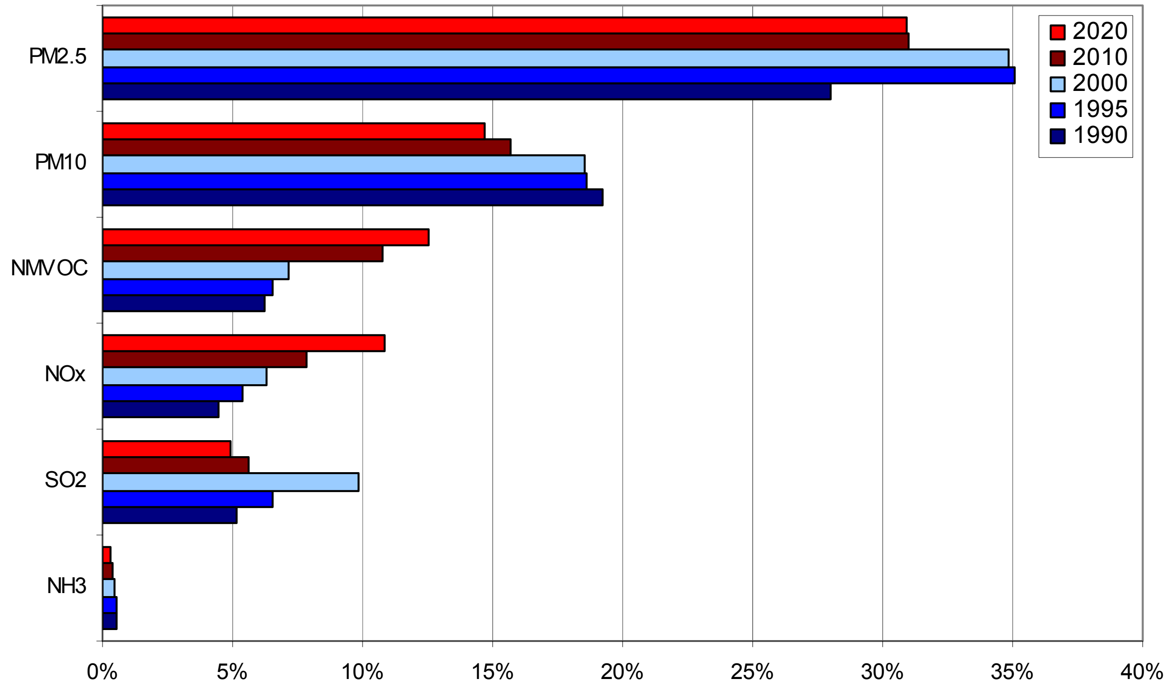
Figure 3.3 below illustrates the percentage of total European emissions from non-industrial SCIs, between 1990 and 2020. PM_{10} emissions from non-industrial SCIs are significant in 2000 (around 18% of the European total) but decline gradually to under 15% by 2020. The decline in absolute emissions between 2000 and 2020 is by about 50%, primarily due to the significant decline in solid fuel use. The most significant contribution by non-industrial sources is to $PM_{2.5}$, accounting for approximately 35% of total European emissions in 2000, declining to just over 30% in 2020; however, this is using a European total derived from the RAINS emissions database, rather than CLRTAP reported emissions (which have been used for the other pollutants). A very significant contribution is also made to PM_{10}, accounting for almost 20% of total European emissions.

Emissions of NOx and NMVOCs increase in terms of contribution to total emissions up to 2020. As shown in section 4.2, the increasing consumption of gas is increasing emissions contribution of NOx from the non-industrial sectors from approximately 6% in 2000 to 11% in 2020. NMVOC emissions are also increasing (from approximately 7% in 2000 to 14% in 2002), due to no significant decreases in biomass consumption, and greater relative reductions in other sectors. In summary, the contribution from both these pollutants appears to double, although in absolute terms, non-industrial emissions of NOx are reduced by 9% in 2020, relative to 2000 levels, and by just over 30% for NMVOCs.

SO_2 emissions show an increase contribution up to 2000, followed by a decreasing contribution to 2020. Checked against the RAINS inventory, this trend seems unusual, at least between 1990 and 2000. The RAINS inventory shows a decreasing trend, from 10% in 1990 to 8% in 2000, while the SCI inventory shows an increasing contribution. However, both inventories indicate a falling contribution up to 2020, illustrating the lower sulphur content of fuels being used in future years, and significant decline in solid fuel consumption.

For most of the pollutants, non-industrial SCI sources make a significant contribution to European emission totals in 2000 and 2020, except for SO2 emissions, which appear to halve. The exception is ammonia, with SCI emissions accounting for less than 1% of total emissions, with an even lower contribution in future years. Due to lack of data, estimates of CO have not been made (but are thought to be similar to the trends observed for NMVOCs).

Figure 3.3 Percentage of total European emissions from non-industrial SCIs

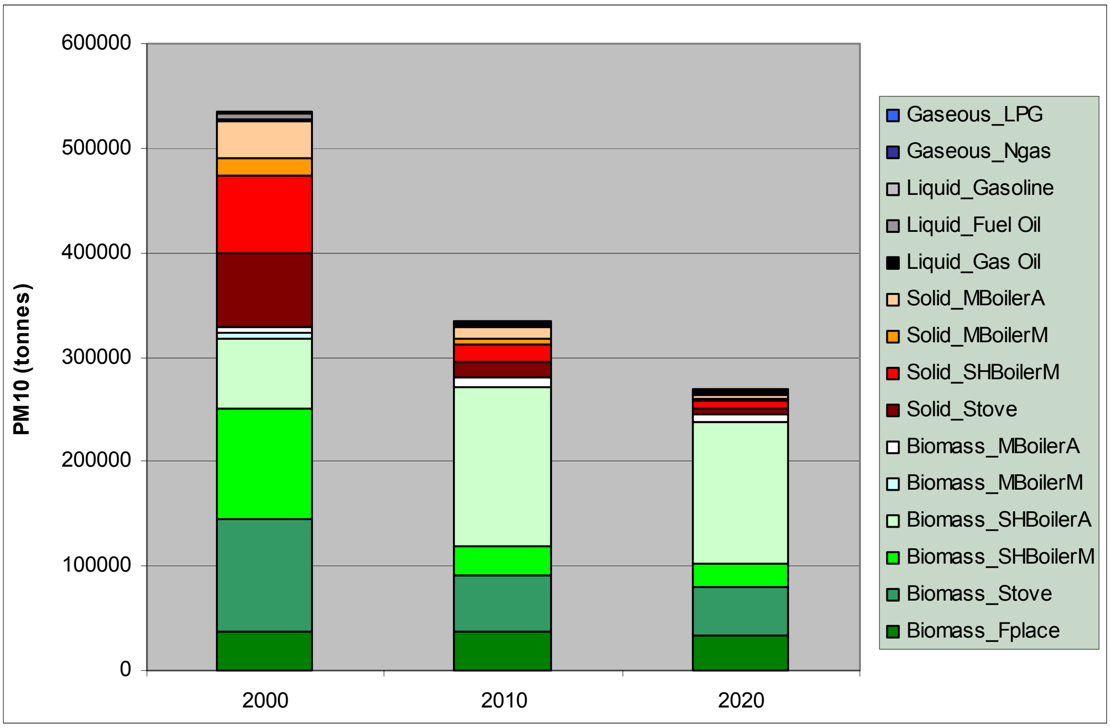


NB. Above comparison based on derived inventory emission estimates as a percentage of CLRTAP reported totals. The exception is $PM_{2.5}$ non-industrial SCI emission contribution, which is a percentage of RAINS emission totals. This may be the explanation as to why the proportion of $PM_{2.5}$ emissions is much higher than PM_{10}. If the RAINS PM_{10} total has been used, the contribution would have been nearer 25%.

The following graphs show the above information (for PM_{10}, NOx, SO_2 and NMVOCs) in greater detail, broken down by fuel and technology type, for 2000, 2010 and 2020. Appendix 1.1 also provides additional detail on what the main contributing sectors are to overall non-industrial SCI totals, and highlights sector values where they contribute greater than 3% of the total.

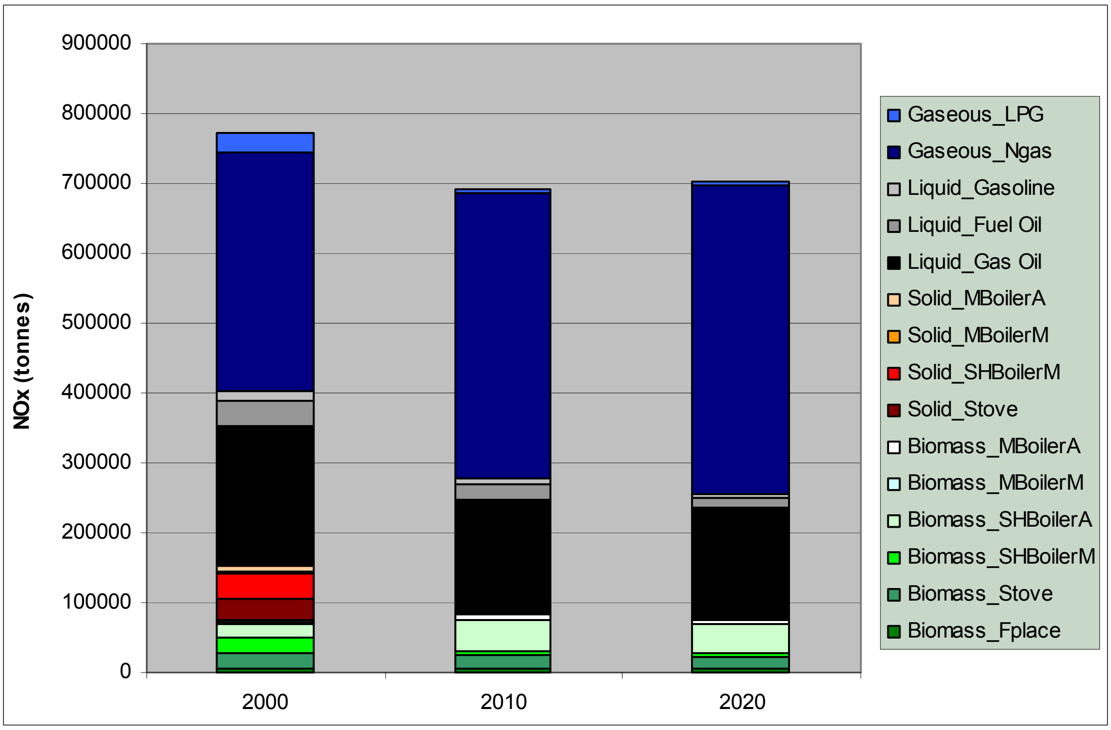
The non-industrial SCI emission inventory for PM_{10} (which shows a similar trend for $PM_{2.5}$) highlights the decrease in emissions from 2000 to 2020, predominantly due to the decline in the use of solid fuel. This source, however, remains significant due to the continued use of biomass. Emissions from this source are projected to decline overall due in main to the increased use of automatic feed boilers.

Figure 3.4 PM_{10} emissions from non-industrial sources by fuel-technology



NB. In the legend, ‘Mboiler’ refers to medium sized boiler (50 kW – 1 MW manual; 1-50 MW automatic), while ‘SHBoiler’ refers to single house boiler (0-50 kW). ‘A’ at the end of the label means ‘automatic feed’, while ‘M’ means ‘manual feed’.

Figure 3.5 NOx emissions from non-industrial sources by fuel-technology

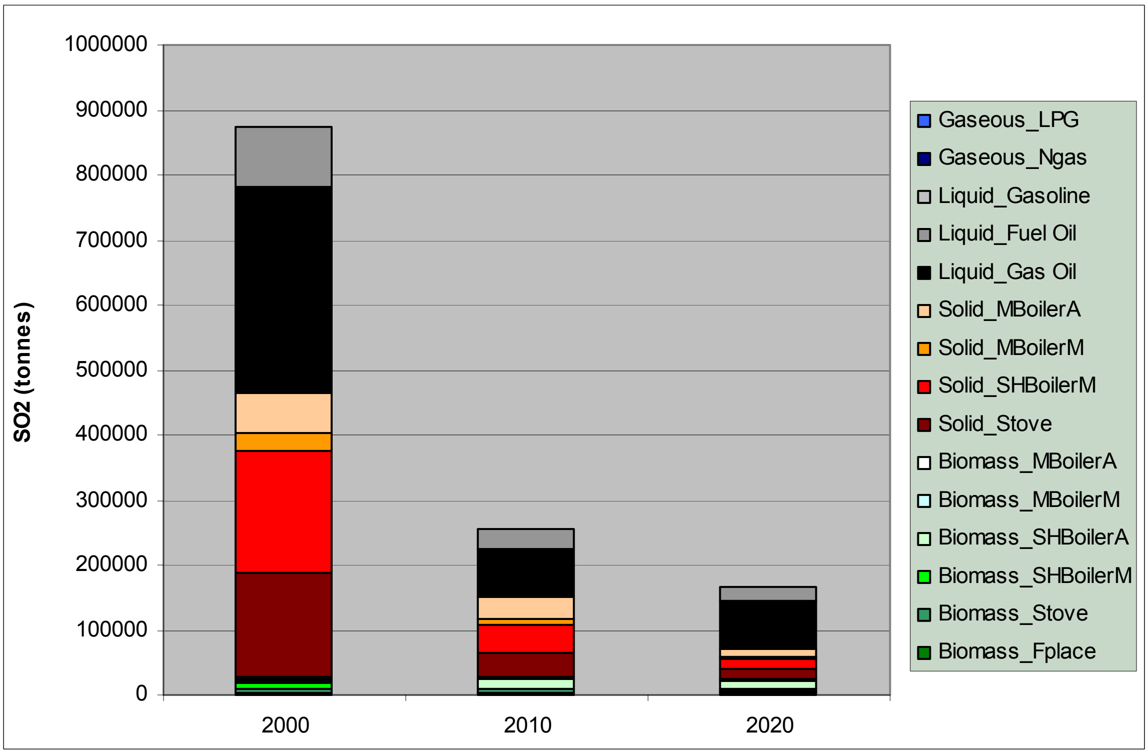


NB. In the legend, ‘Mboiler’ refers to medium sized boiler (50 kW – 1 MW manual; 1-50 MW automatic), while ‘SHBoiler’ refers to single house boiler (0-50 kW). ‘A’ at the end of the label means ‘automatic feed’, while ‘M’ means ‘manual feed’.

A shown in Figure 3.5, NOx emissions from non-industrial sources are predominantly due to the use of oil and natural gas. The increasing use of natural gas in these sectors (as illustrated in Figure 4.2) and continued use of liquid fuels at 2000 levels in future years results in emissions of NOx remaining at consistent levels. Biomass contributes to total emissions at a consistent level across the time series, while solid fuels only make a limited contribution to the total in 2000.

The significant decrease in SO_2 emissions over the time series is dramatically reflected in Figure 3.6, and is primarily due to the significant decline in the use of solid fuels, and the lower sulphur content fuels used in future years.

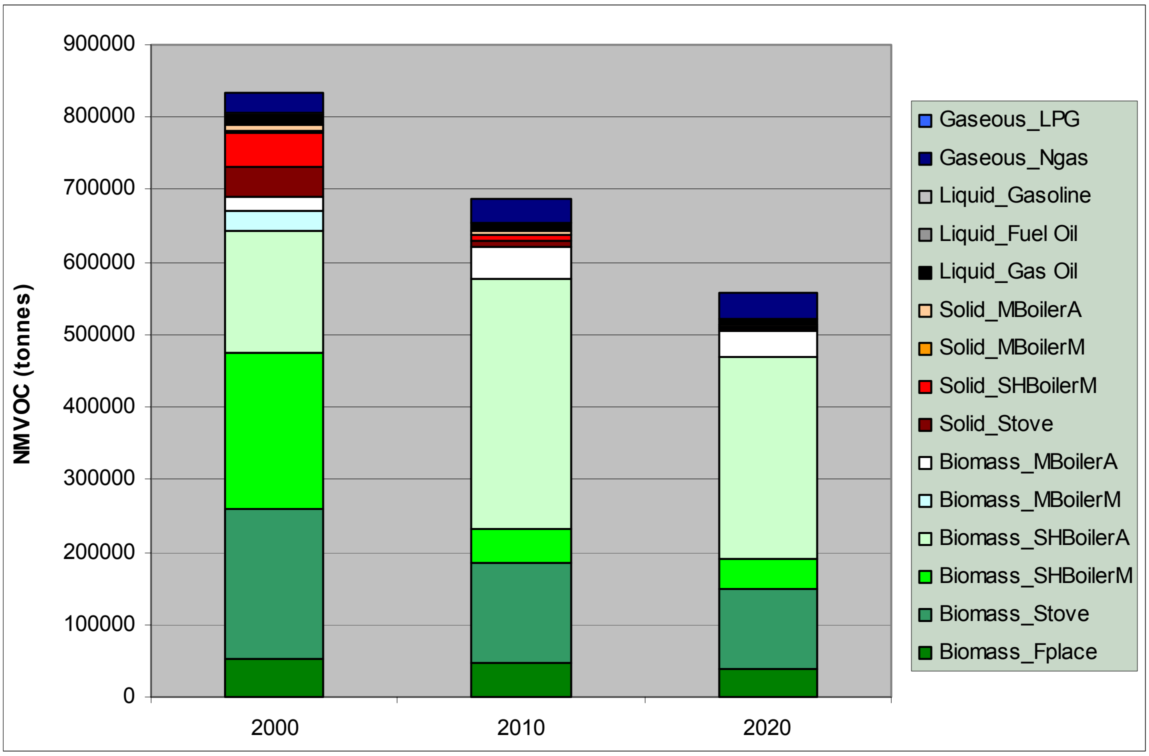
Figure 3.6 SO_2 emissions from non-industrial sources by fuel-technology



NB. In the legend, 'Mboiler' refers to medium sized boiler (50 kW – 1 MW manual; 1-50 MW automatic), while 'SHBoiler' refers to single house boiler (0-50 kW). 'A' at the end of the label means 'automatic feed', while 'M' means 'manual feed'.

NMVOC emissions from combustion sources in non-industrial sectors are primarily a result of the use of biomass, as reflected in Figure 3.7. Therefore, limited reductions are seen in emissions associated with this source. The most significant reduction comes from the reduction in the use of solid fuels.

Figure 3.7 NMVOC emissions from non-industrial sources by fuel-technology



NB. In the legend, 'Mboiler' refers to medium sized boiler (50 kW – 1 MW manual; 1-50 MW automatic), while 'SHBoiler' refers to single house boiler (0-50 kW). 'A' at the end of the label means 'automatic feed', while 'M' means 'manual feed'.

3.4.2 Country-based emission estimates

This section assesses emission estimates for each pollutant individually, identifying contribution to total European emissions by country, and determining what the key sectors (and fuels) are within individual countries. NH_3 has not been assessed on an individual basis due to the very small contribution from non-industrial SCIs to overall European emissions.

3.4.2.1 Current and projected emissions of particulate matter (PM_{10} and $PM_{2.5}$)

Historic Emissions

In terms of contribution to European totals, $PM_{2.5}$ and PM_{10} are the most important pollutants from non-industrial SCIs, with emission contribution estimated at approximately 35% and 19% in 2000 (see Figure 3.3). Based on size of contribution, and as a priority pollutant of concern due to associated health impacts, it is clear that PM emissions from non-industrial SCIs may need to be a priority for potential action. In addition, PM emissions from non-industrial SCIs may be emitted in areas of higher population density, leading to even greater health impacts.

The main contribution to European SCI emissions of PM_{10} and $PM_{2.5}$ is from residential burning of solid fuels and biomass (see Figure 3.8, which also reflects the trend for PM_{10}), with Poland and France as the most significant contributors to overall emissions. The Nordic countries are also significant emitters of PM from biomass combustion (again in the residential sector). Apart from Poland, the UK and Czech Republic are the other two countries where emissions from solid fuel combustion are most significant.

There are two distinct country groupings that can be identified here – countries where emissions from biomass predominate and those where emissions from solid fuels predominate, as shown in Figure 3.9 by the light and dark blues. The contribution to national emission totals can be seen in Appendix 1.2; within many countries, non-industrial SCIs make a considerable contribution to national emissions of PM, although this contribution appears to have generally reduced between 1990 and 2000.

Projected Emissions
Figure 3.10 (which includes control technologies) shows the general decrease in emissions of PM_{10}, particularly due to the use of less solid fuels (especially in Poland), and through increased use of improved, more efficient SCIs, particularly those burning biomass. Note that for year 2000, all emissions sum to 100%. In 2020, the emission estimates account for 55.4 % of the 2000 Europe estimate, as shown by the reductions in Figure 3.10. Nearly 30% of the overall change is a function of what happens in Poland, and so assumptions for Poland are critical to the trends analysis.

Figure 3.11 demonstrates the impact of control options, as modelled in RAINS, illustrating the difference between 2010 estimates where both controls and no controls have been assumed, and the percentage difference between the two types of estimate. The 2010 abated estimate is 63% of the 2000 total, while the unabated estimate is 71% of the total. Unabated emissions shows emission estimates based on no controls, illustrating the effect of change in energy consumption, while the second, abated emissions, illustrates the reduction due to modelled control strategies. It is necessary to understand the control strategies currently modelled in the projections, in order to determine the implementation of additional measures.

Summary
In terms of contribution to European emissions, SCIs are an important source of PM, although decrease significantly in future years due to the decrease in solid fuel use. The main non-industrial sector source in 2000 is residential from consumption of solid fuels and biomass. Biomass remains a particularly important source of emissions in future years, with significant reductions in emissions from solid fuels observed, particularly between 2000 and 2010. Emission totals for 2000-2020 are provided in Table 3.3 below.

There are two key issues that need particular consideration for this PM inventory. Firstly, emissions of PM are often localised, leading to significant impacts in specific areas. This inventory data does not provide an understanding of regional and local distribution, as it is not a spatial emissions inventory. This is important when we consider that certain pollutants, in particular PMs, are likely to be targeted on the basis of their health impacts. An example might be that PM emission sources in one country are primarily located in rural areas but in another country in urban areas. Therefore, priorities and action taken at the national level might be very different between countries. A spatial understanding of emissions from biomass and solid fuels (which drive PM emissions) is provided in section 7.3.2 of this report, the assessment of local measures as a policy option. Secondly, projected emissions of PM are still high in future years due to biomass consumption – emission factors and activity statistics on which estimates are based are highly uncertain, and therefore such estimates need to be considered with strong caveats attached.

Figure 3.8 $PM_{2.5}$ emissions (2000) from non-industrial SCIs by country as % of total EU emissions

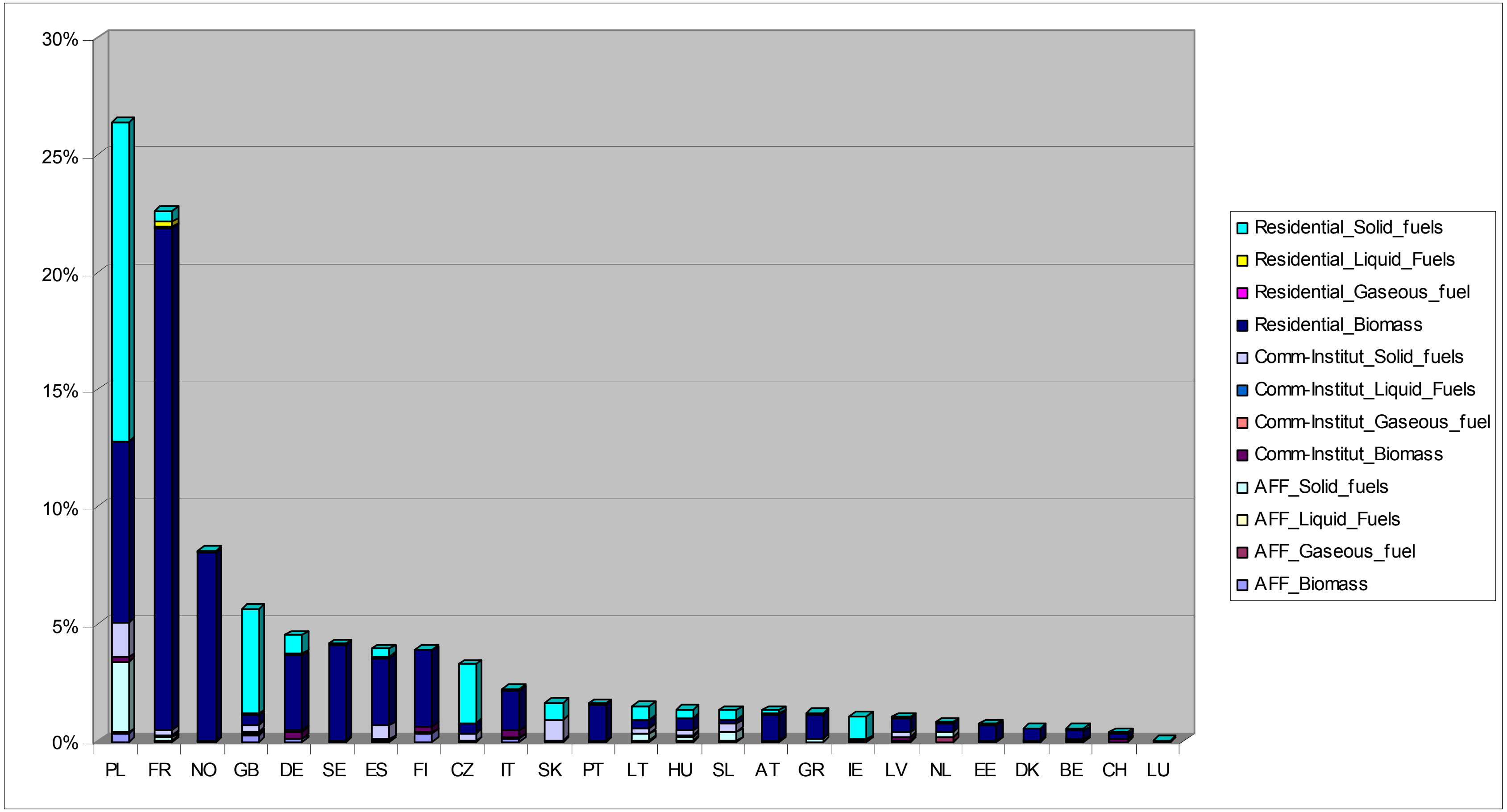


Figure 3.9 Percentage contribution of PM emissions (2000) from non-industrial SCI

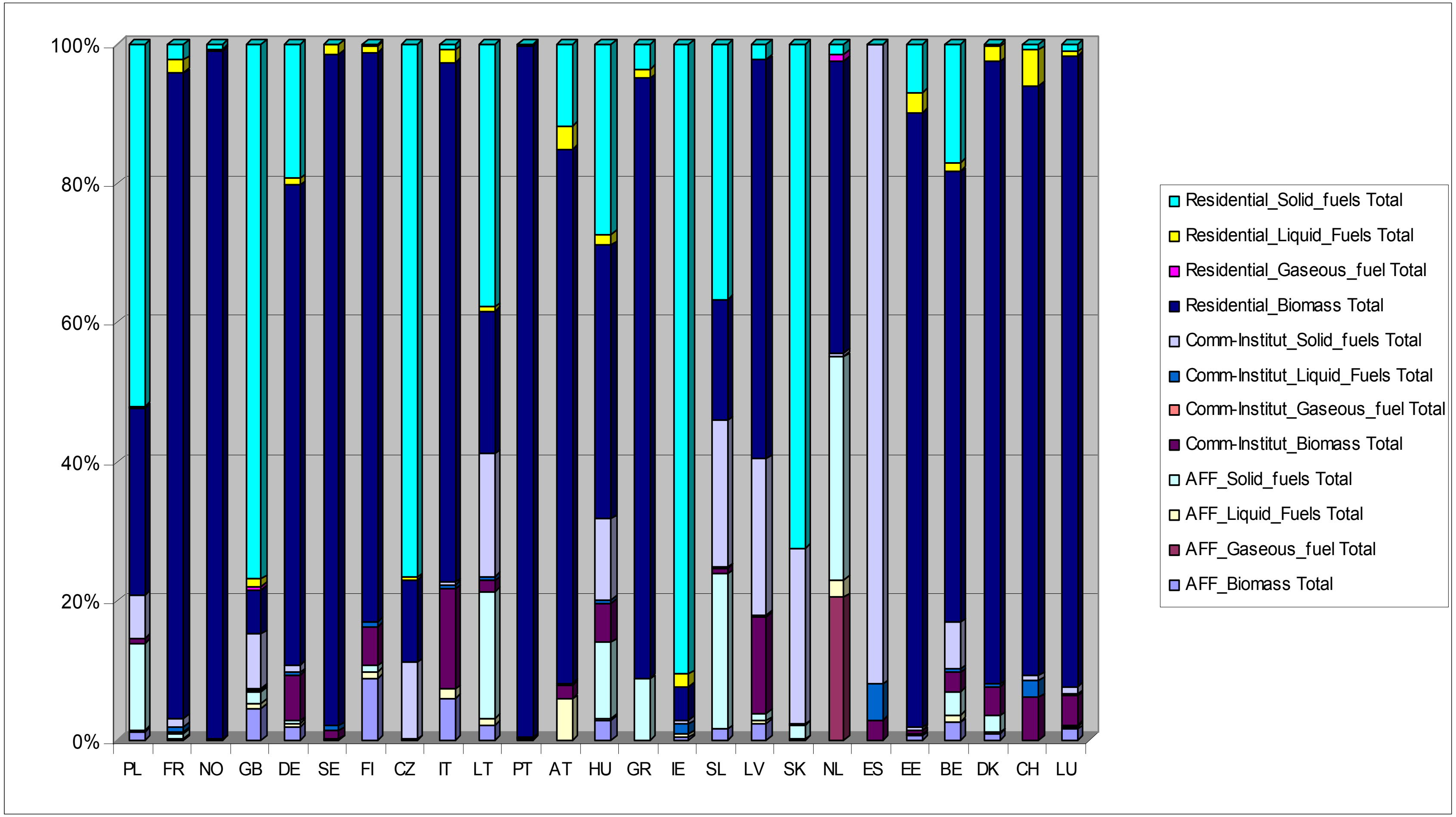


Figure 3.10 PM_{10} emissions (2000-2020) from non-industrial SCIs by country as % of total EU emissions

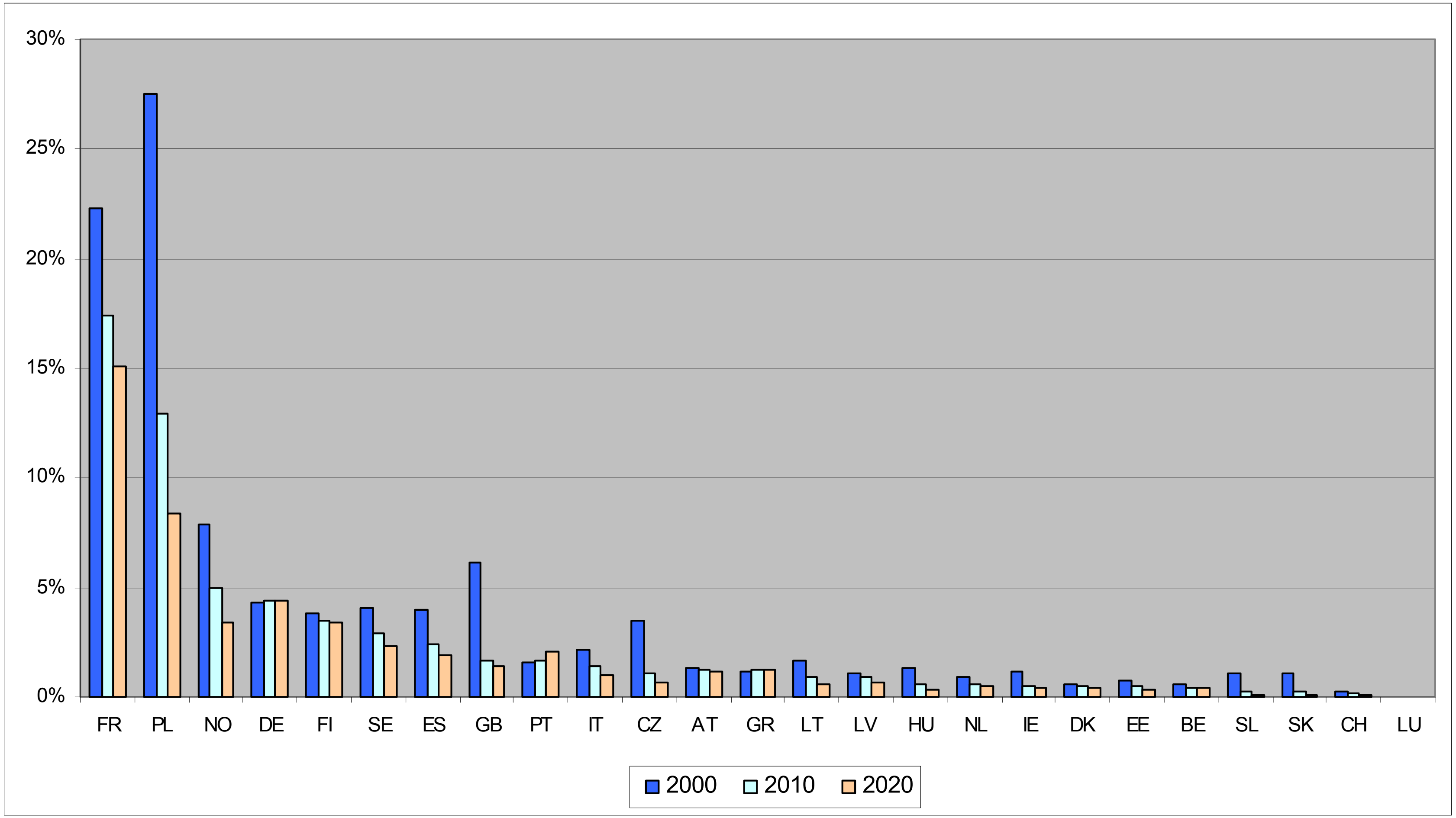
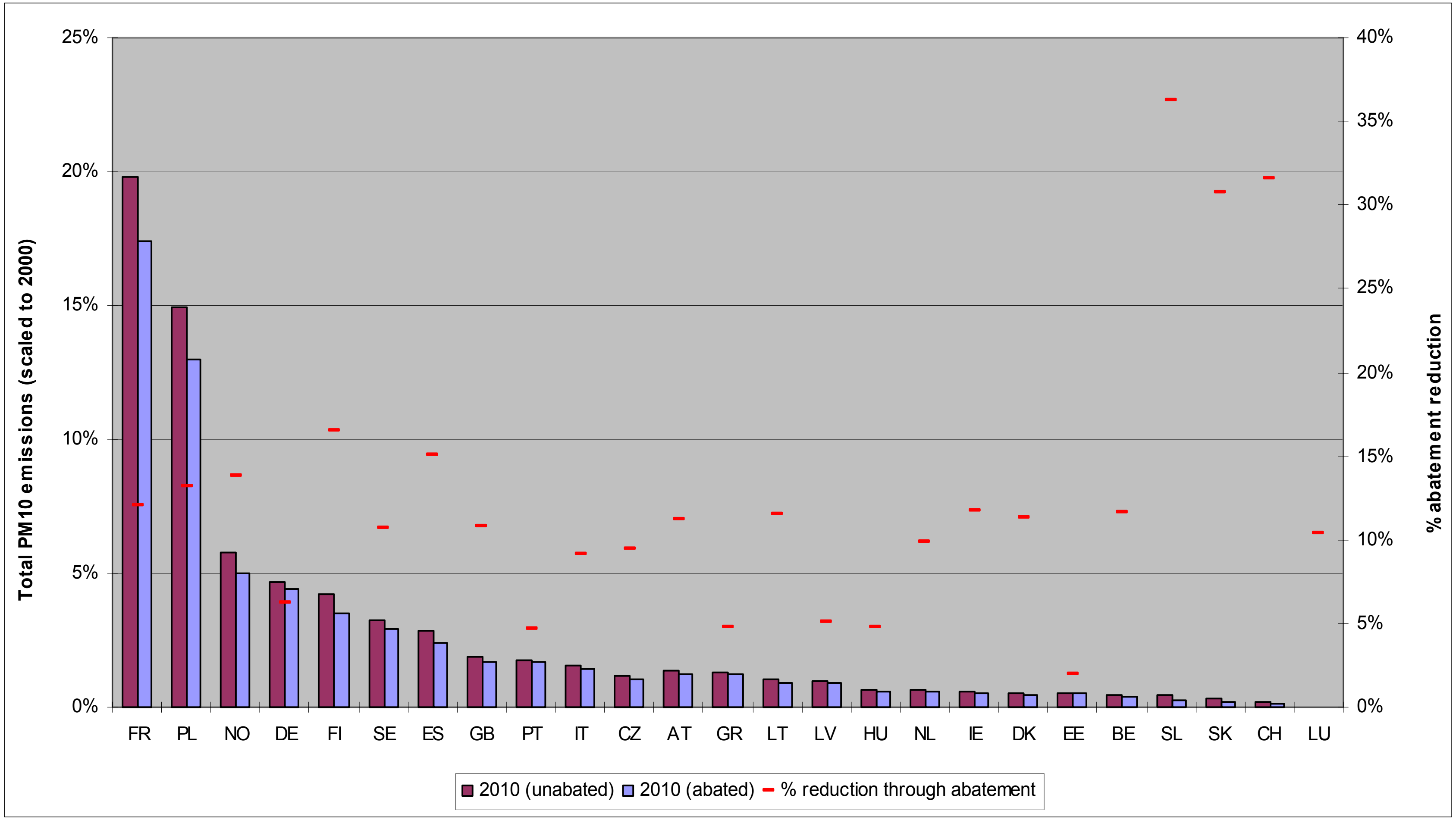


Figure 3.11 PM_{10} emissions (2010) from non-industrial SCIs – abatement measures as % of total EU emissions



3.4.2.2 Current and projected emissions of NOx

Historic Emissions

Emissions of NOx from non-industrial SCIs (in 2000) are dominated by the use of natural gas primarily across residential and commercial-industrial sectors, as shown in Appendix 1.3. A significant proportion of emissions is also from liquid fuels. The most significant contributors to the European totals are the Western European countries, with large and / or high-density populations, all of which have mature gas distribution networks. Such countries include France, Germany, UK, Italy and Netherlands. In Poland, however, a significant amount of NOx emissions are due to consumption of solid fuels in the residential sector (in addition to significant emissions from natural gas).

In Appendix 1.3, an overview of sectoral contribution of emissions to country totals is provided. It is clear that the mix of fuels and sectors that give rise to NOx emissions vary much more significantly than for PM. Gaseous and liquid fuel consumption in the residential sector appears to predominate, with the commercial-institutional sector important in some countries. An obvious and interesting exception is the significant emission contribution from the agricultural sector in Netherlands, probably due to the energy used by the horticultural industry.

Projected Emissions

Appendix 1.4 shows projected emissions of NOx in 2010 and 2020. The percentage figures have been scaled to 2000 estimates; 2020 estimates sum to 86.4% of the 2000 emission total. The contribution from gaseous fuels remains the most significant source, with little variation between years (in terms of country totals), followed by liquid fuels. Emissions from solid fuels account for a very small proportion of overall emissions in future years.

It is important to note that unlike emissions of other pollutants, emissions of NOx are not projected to decrease significantly from non-industrial sources in future years. This highlights the increasing demand for natural gas as an alternative source of heating, particularly in the residential sector, and the continued use of gas oil as a significant energy source. The demand for gas will increase particularly in countries where solid fuel use has decreased, and in countries which have growing markets and developing networks.

3.4.2.3 Current and projected emissions of SO_2

Historic Emissions

As shown by the SO_2 graph in Appendix 1.3, Poland clearly dominates European non-industrial SCI emissions of SO_2, accounting for approximately 40% of the total. This is primarily due to the large quantities of solid fuel used, particularly in the residential sector. Commercial-institutional sector consumption of solid fuel and oil also accounts for a significant proportion of Polish emissions.

Other countries where non-industrial emissions represent a significant proportion of the European total include Germany, France, Spain and Italy. SO_2 emissions primarily arise from the consumption of oil in the residential and commercial-institutional sectors. Other countries that are significant emitters of SO_2 from solid fuel consumption in the residential sector include the UK, Czech Republic, Hungary, Ireland and Slovakia.

Projected emissions
Annual emissions of SO_2 are projected to decrease significantly in 2010 and 2020 (see Appendix 1.4 and Figure 3.6) relative to 2000 levels, with 2010 emissions estimated at approximately 30% of the 2000 total, and 2020 emissions at 20%. This is largely due to the reduction in solid fuel consumption and the increased use of lower sulphur content liquid fuels.

3.4.2.4 Current and projected emissions of NMVOCs

Historic Emissions
Appendix 1.3 shows that non-industrial SCI emissions of NMVOCs are dominated by the residential combustion of biomass. The most significant emitters are those countries where non-industrial biomass consumption is significant such as France, Germany, Poland and Sweden. A significant fraction of the emissions in Poland comes from solid fuel burning in the residential sector.

Projected Emissions
Appendix 1.4 shows that annual emissions of NMVOCs are projected to be lower in future years; in 2010, they represent 82% of the 2000 emission, a figure that drops to 66% by 2020. The main reductions are due to lower levels of solid fuel consumption. NMVOC emissions from non-industrial small-scale combustion installations remain significant as a contributor to overall totals in future years because they are driven by biomass consumption (particularly in the residential sector).

Table 3.3 Total emissions of NOx, SO_2 and NMVOCs from non-industrial SCIs (tonnes)

Country	PM_{10}			NOx			SO_2			NMVOC		
	2000	**2010**	**2020**	**2000**	**2010**	**2020**	**2000**	**2010**	**2020**	**2000**	**2010**	**2020**
AT	7294	6459	6103	15584	14205	12979	10132	1929	1535	26694	20477	16600
BE	2947	2176	2023	23314	22884	22650	31415	6149	5126	14327	12669	10703
CH	1502*	765	372	17019*	14251	12176	6236*	4223	2545	5419*	4909	3469
CZ	18523	5639	3413	19879	13057	12703	51165	10444	3370	15681	8962	6505
DE	23288	23511	23562	117921	116671	117918	89775	25975	23798	130092	155722	152121
DK	2915	2600	2439	7430	6054	5792	3260	683	555	12420	11394	10043
EE	3902	2745	1868	2580	2238	1652	3530	1884	1080	6660	4793	3100
ES	21238	12981	10418	30032	30202	30265	41481	10649	8660	39568	22575	17499
FI	20454	18803	18194	8645	7993	7518	3713	1573	1363	29635	30579	25434
FR	110183*	93358	80641	96893*	89311	86145	77461*	16106	13352	190281*	156000	113779
GB	32743	9061	7496	103689	99188	98352	61848	13523	8313	35867	15533	14318
GR	6132	6684	6547	8565	7142	7054	13053	4280	4070	16252	20567	18821
HU	7184	3170	1960	13192	13299	13185	29396	6816	3720	10992	7201	4954
IE	6111	2759	2103	9732	9847	9675	19559	8638	6070	5536	6005	5266
IT	11581	7673	5540	68143	70390	70241	34633	10559	8461	38575	25892	15795
LT	8743	4991	3257	4914	5727	6746	20647	10584	6234	8494	5871	4323
LU	203	106	93	605	674	661	274	130	114	559	321	254
LV	5771	5041	3445	2807	2970	2420	2606	1494	837	12453	12498	8503
NL	4699	3051	2770	62867	65172	65283	2623	897	853	16759	14386	13148
NO	42123	26785	18271	2283	838	572	1130	239	162	7998	4813	2811
PL	147398	69433	45026	117222	84758	103661	342800	115426	63304	113841	79722	56859
PT	8217	9097	11157	22833	5507	6802	9110	16	20	20600	19655	22488
SE	21686	15515	12531	6406	4900	4144	4035	1283	1050	72804	48468	32238
SK	5551	1113	270	6965	5301	5115	15250	1943	422	2899	981	519
SL	5886	1471	660	3695	776	693	7713	898	411	1305	498	254
Total	**535565**	**334987**	**270159**	**773414**	**693355**	**704402**	**873033**	**256341**	**165425**	**835596**	**690491**	**559804**

NB. Projected emissions include control technologies, as modelled in RAINS.

* Data provided by country expert.

3.4.2.5 Greenhouse gas emission estimates

For inventory completeness, estimates have also been made of CO_2 emissions from non-industrial SCIs, and are presented in Table 3.4 below.

Table 3.4 Total emissions of CO_2 from non-industrial SCIs (tonnes)

Country	2000	2010	2020
AT	12826	11460	10292
BE	13793	13566	13449
CH	15590	13531	11553
CZ	14342	10720	9710
DE	110843	103586	104330
DK	6942	5273	5037
EE	997	1009	862
ES	33491	39800	40914
FI	5365	4277	4017
FR	91062	87501	85258
GB	107452	103966	102062
GR	8061	5786	5730
HU	12533	13077	13289
IE	9600	9451	9378
IT	67236	70739	71587
LT	3978	5136	6582
LU	599	685	674
LV	833	977	890
NL	30713	32170	32280
NO	3034	2800	2214
PL	41804	37329	42461
PT	5040	5302	7156
SE	7064	5299	4593
SK	5558	4517	4128
SL	2277	1911	1780
Total	**611031**	**589867**	**590225**

NB. Projected emissions include control technologies, as modelled in RAINS.

3.4.3 Comparison of non-industrial estimates with RAINS estimates

As outlined in section 3.3.2, the non-industrial estimates are based primarily on UNFCCC reported activity data, and CLRTAP reported data, while RAINS data have been used to try and understand the technology profiles. Therefore, there are some differences between the estimates used in this study, and the estimates taken from the RAINS model emission database. These differences are outlined below in Figure 3.12.

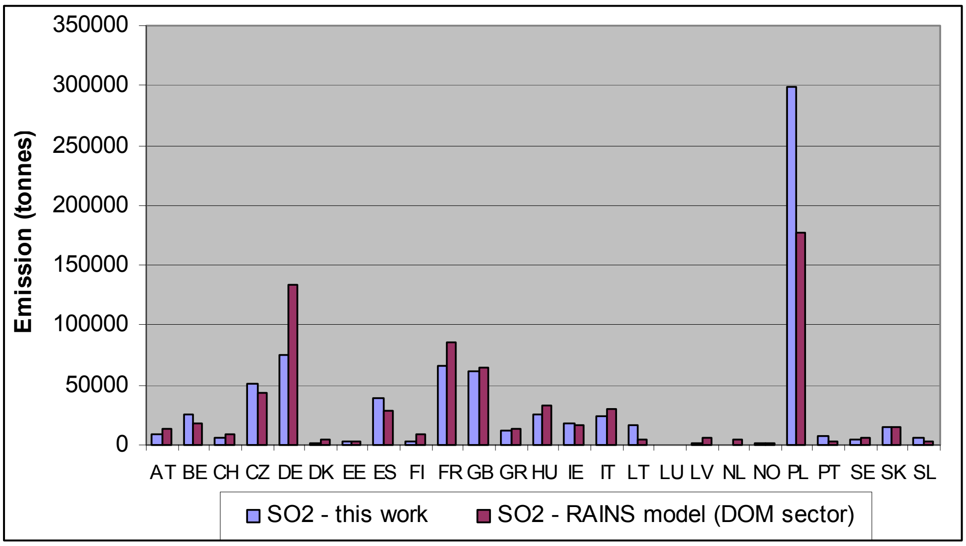
The study estimate (for commercial and residential) has been compared to the most recent CLRTAP reported estimate, original RAINS emission estimate, and updated RAINS baseline estimate. RAINS emission values have changed quite significantly in some cases, and are generally closer to study estimates, with some remaining differences. Most CLRTAP values have remained similar.

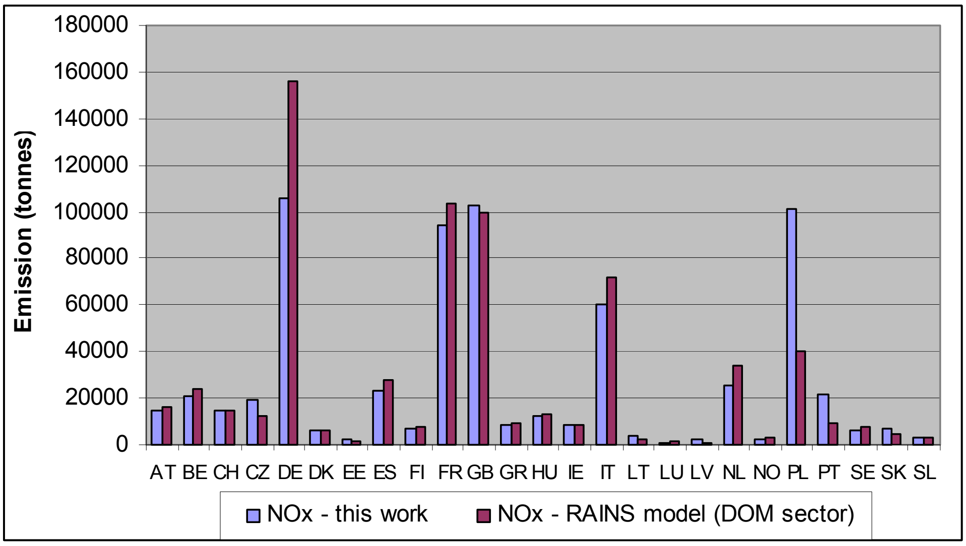
Table 3.5 Observed differences between emissions from RAINS DOM sector to estimates from this work

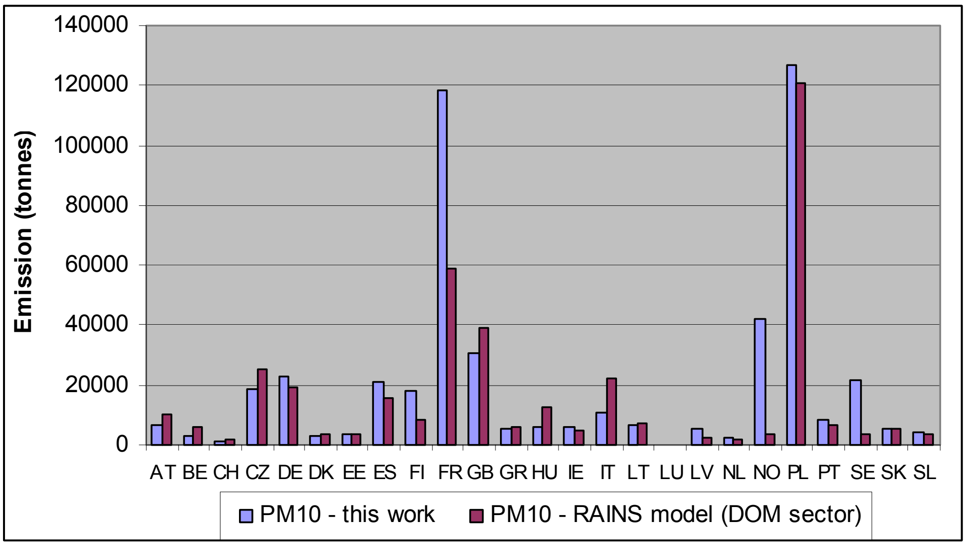
Poll	Country	Study estimate (t)*	CLRTAP 2004 (t)	Original RAINS 'DOM' (t)	Updated RAINS 'DOM' (t)	Comment
SO_2	Germany	74419	90416	133687	101054	No CLRTAP data available in 2003 (SNAP only). Germany increased emission estimate for this sector in 2004 compared with 2004. The updated RAINS model estimate is lower than the original estimate and is now closer to the original estimate from this work
	Poland	299400*	299400 (2001 value)	177224	180032	2000 value gap-filled from reported 2001 value. Both updated values (CLRTAP and RAINS model) largely similar to previous values. The reason for the discrepancy between the country CLRTAP estimate and the RAINS model value is not clear.
NOx	Germany	105918	107716	156369	108446	No CLRTAP data available in 2003 (SNAP only). The original estimate for NOx from this work is very close to the value reported by Germany to CLRTAP in 2004 (a CLRTAP value was not available in 2003 as Germany reported at SNAP1 level only). The updated RAINS model estimate is significantly lower than the previous estimate, and close to the value estimated in this work.
	Poland	101410*	101410 (2001 value)	40308	54952	2000 value gap-filled from CLRTAP reported 2001 value. Reported values divided by 1000 – error in reporting. The updated RAINS model estimate has increased compared with the previous baseline, but is still significantly different to the value reported by Poland for 2001 (in lieu of reported data, the value in 2000 was assumed to be the same).
PM_{10}	France	118219*	109486	58910	158486	The updated RAINS model estimate has increased significantly compared with the previous RAINS baseline estimate. The updated RAINS estimate is now significantly larger than the value reported by France to CLRTAP.
	Norway	42115*	42614	3560	11860	The updated RAINS model estimate has increased compared with the previous baseline estimate. Now closer to the estimate from this work, but still a relatively large difference compared with the value reported by the country to CLRTAP.
	Sweden	21663*	22043	3762	12775	The updated RAINS model estimate has increased compared with the previous baseline estimate. Now closer to the estimate from this work, but still a relatively large difference compared with the value reported by the country to CLRTAP.

* Scaled to 2003 CLRTAP data where this was available

Figure 3.12 Comparison of emissions from RAINS DOM sector to the Residential and commercial sectors (combined) from this work for a) SO_2, b) NOx and c) PM_{10}







3.5 EMISSION ESTIMATES – INDUSTRIAL SCIS

3.5.1 European overview

The emission estimates for industrial SCIs are presented below in Table 3.6. They have been calculated based on the ratio of emissions from industry SCI sources <50 MW_{th} as reported in CORINAIR 90 and subsequently applied to data from CLRTAP for year 2000 as described in section 3.3.3.

Table 3.6 Industrial SCI estimates for 2000

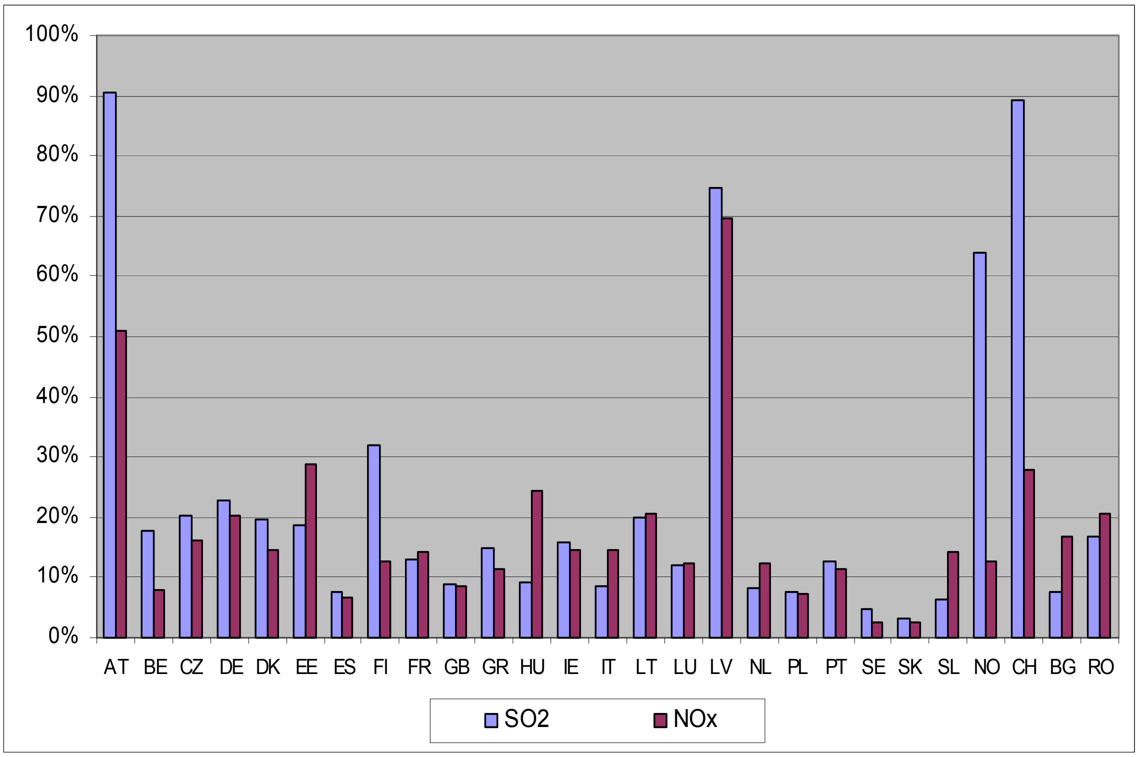
Country	SO_2 (kt)		NOx (kt)		PM_{10} (kt)	
	CLRTAP	SCIs	CLRTAP	SCIs	CLRTAP	SCIs
Austria	16.3	14.8	41.4	21.0	7.5	1.05
Belgium	111.1	19.7	117.5	9.5	7.8	1.09
Denmark	20.2	4.0	76.3	11.2	2.6	0.37
Finland	55.6	17.8	69.2	8.7	10.6	1.47
France	446.7	88.0 (58)	312.3	33.8 (44.7)	33.5	4.65 (4.3)
Germany	464.0	105.1	439.0	88.6	119.2	16.57
Greece	420.0	62.8	115.0	13.2	14.0	1.95
Ireland	104.7	16.6	53.2	7.8	5.8	0.80
Italy	580.0	50.0	307.0	44.5	48.7	6.77
Luxembourg	1.4	0.2	7.0	0.9	0.4	0.06
Netherlands	57.2	4.7	97.7	12.0	4.6	0.64
Portugal	235.2	29.4	115.3	13.3	6.1	0.85
Spain	1357.2	103.0	549.0	36.2	30.7	4.27
Sweden	33.6	1.6	67.5	1.7	9.9	1.37
UK	1049.1	91.7	659.0	52.1 (56.6)	50.2	6.98 (7.51)
Czech Rep.	199.8	1.6 (40.3)	140.6	1.0 (22.6)	7.2	2.1 (2.1)
Estonia	91.3	17.0	15.5	4.4	25.1	7.33
Hungary	429.8	39.7	49.4	12.0	NA	NA
Latvia	12.3	9.2	10.8	7.5	3.4	0.99
Lithuania	32.8	6.5	15.2	3.1	7.5	2.19
Poland	1134.0	86.3	410.0	30.4	64.1	18.69
Slovakia	106.7	3.4	60.4	1.6	14.3	4.17
Slovenia	90.5	5.8	18.4	2.6	6.6	1.93
Norway	4.3	2.7	46.5	5.9	1.3	0.18
Switzerland	4.9	4.3	10.7	2.9	0.7	0.09
Total	**7059**	**825 (11.7%)**	**3804**	**448 (11.8%)**	**482**	**87 (18%)**
Bulgaria	907.9	68.5	68.8	11.6	62.7	18.29
Romania	710	119.6	136	27.9	108.8	31.73

NB. SCI column refers to SCI estimates made for industrial SCIs in this study. CLRTAP column is all industrial combustion emissions, as reported to the UN ECE.
Actual industry SCI emissions for France, Czech Republic and UK are shown in brackets together with the CORINAIR-based industry SCI emission estimates – the Czech estimates for NOx and SO_2 are clearly erroneous.

The bracketed percentage figures in the totals row provide an indication of the proportion of industrial combustion emissions that are from industrial SCI sources. For NOx and SO_2, approximately 12% is from industrial SCI sources, while the figure for PM_{10} is 18%.

Country specific percentages are shown in Figure 3.13. Contribution to industrial combustion emission totals seems to vary significantly between different countries, although the majority of countries have a percentage contribution of less than 20% (as indicated by the European average of 12% shown in Table 3.6). Austria, Latvia, Norway and Switzerland show very high contributions from industrial SCIs, particularly of SO_2, while Slovakia and Sweden show a very low contribution. These high values need to be viewed with care, as they look significantly different to the other estimates (and are potentially erroneous). PM_{10} has not been included in the above graph as estimates are based on a constant percentage contribution of industrial SCIs to total industrial emissions of 13.9% for Western Europe (based on UK and French data), and 29% for new Member States (based on Czech Republic data).

Figure 3.13 Percentage contribution of industrial SCIs to total industrial combustion emissions for SO_2 and NOx

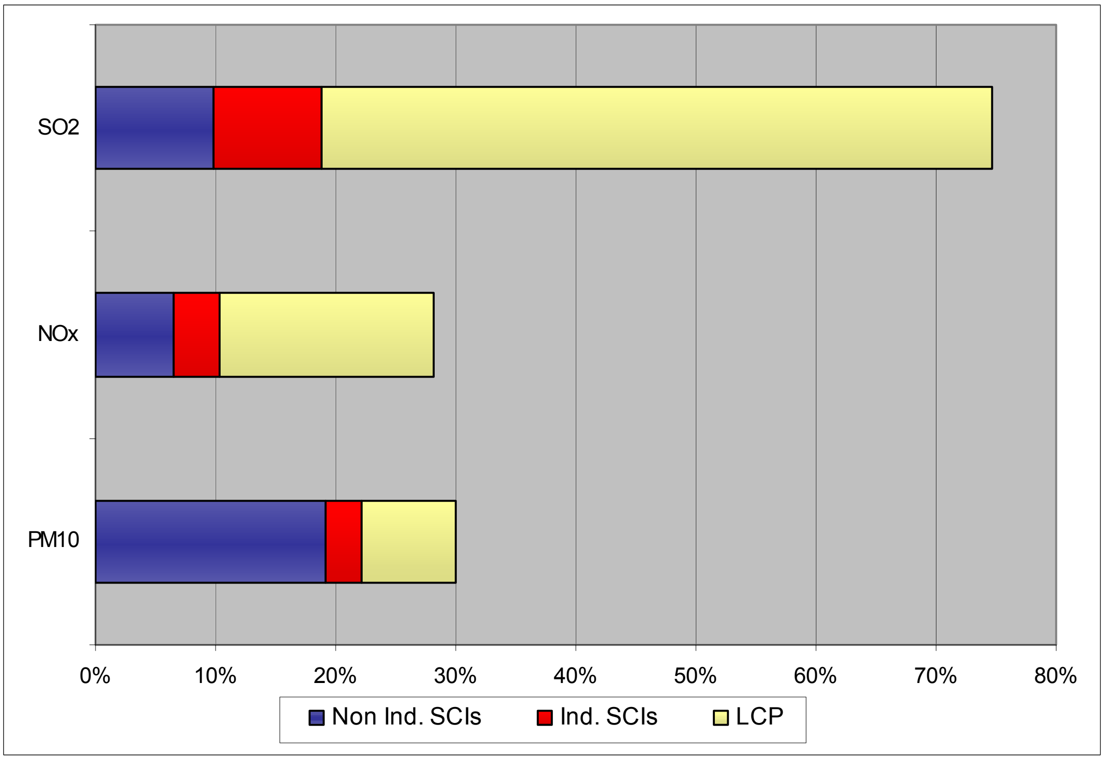


NB. Actual reported estimates for Czech Republic, UK and France have been used in data.

The significance of industrial SCI relative to European total emissions is provided in Figure 3.14, where estimates are plotted as percentage of total European emissions, and compared with non-industrial SCIs and large combustion plant emissions. SO_2 emissions are dominated by large combustion plant, although industrial SCIs contribute a significant percentage (approximately 9%). For NOx, the contribution is again largest from LCPs (large combustion plant) with a relatively small overall contribution of 3.5% arising from industrial SCIs.

PM_{10} has the smallest contribution to European emissions, of approximately 3%. This compares to the LCP contribution of approximately 8%, and a non-industrial SCI estimate of almost 19%. This PM_{10} figure is very uncertain, and is estimated by apportioning emissions to industrial SCIs on the basis of data from 3 countries. Previously, PM_{10} estimates were derived on the basis of methods described in sections 3.3.3.2 and 3.3.3.3, and were significantly overestimated when compared to national reported data.

Figure 3.14 Comparison of industrial SCI emissions with non-industrial SCI and LCP emissions (as percentage of European total)



NB. Graph does not contain industry figures for Romania and Bulgaria as estimates for LCP and non-industrial SCIs have not been estimated. Actual reported estimates for Czech Republic, UK and France have been used in data

Overall, industrial SCIs do not contribute significantly to total European emissions, although out of the three pollutants included, SO_2 contributes approximately 8%. When considered just in terms of industrial combustion emissions, PM contributes approximately 18% and SO_2 and NOx 12%. Unfortunately, the absence of projected emissions does not enable us to assess whether these contributions increase – proportions could increase if further reductions are seen from larger regulated plant.

3.5.2 Country-specific industry data

Emission estimates (in the previous section) have not been further disaggregated by thermal capacities below 50 MW_{th}, but are reported as total emissions. In order to better understand the industry SCI totals, data have been provided from three different countries to illustrate numbers of plant in a given capacity range, and the contribution to emissions of each capacity range. These data are country-specific, and reflect country-specific situations e.g. significant use of gaseous fuels in the Netherlands. How much they reflect the situation in other countries is difficult to determine. Ideally, it would be useful to get this breakdown for all countries across Europe, so that a comprehensive assessment could be made of emission contribution from different capacity size ranges. However, very few countries construct this type of detailed inventory.

The three countries for which data are available include:

- Netherlands
- UK

- Czech Republic

3.5.2.1 Netherlands

The Netherlands has a detailed emission inventory which provides emissions data on an installation basis.[6] The dataset includes institutional installations although the majority are industrial. Data are available from 1990 – 1998, with approximately 80% coverage prior to 1995, declining to approximately 50% due to the new reporting regime for individual companies.

Data are representative of a gas dominated economy, with far fewer oil and solid fuel based installations. Only boilers using natural gas have been included in Table 3.7 below, as accompanying NOx estimate are available. Other types of boilers (solid and liquid fuel) are not considered due to lack of emissions data.

Table 3.7 Dutch emission inventory of industrial boilers using natural gas (1995)

Capacity range (MW_{th})	Number of boilers	NOx emissions (tonnes)	Average emission per boiler (tonnes)
0-20	390	1,229	3.2
20-50	50	912	18.2
>50	50	6,990	139.8

NB. 1998 data, although less complete, indicates a comparable profile.

These data indicates that for natural gas boilers using NOx, up to 30% of NOx emissions is emitted from boilers with less than 50 MW_{th}. There are significantly lower average emissions from installation in the smaller capacity range.

3.5.2.2 UK

Emissions contribution by plant capacity range for the UK is based on national inventory data. A 'combustion calculator' has been developed, which provides an indication of emissions from combustion units in different sectors, on the basis of fuel and thermal capacity of unit.[7] The data does not include power production (although does include industry autogeneration), refineries, cement or lime sectors. Furnaces and gas turbines have not been included in the data presented here.

Table 3.8 provides emissions data for PM_{10}. The percentage contribution of emissions is uniform over the inventory size bands. To compare to the Dutch data, it is useful to assess contribution in the same bands – on this basis, approximately 72% of these emissions are from sources with a thermal capacity less than 20 MW_{th}, with the main fuel sources being coal.

[6] Emissions inventory data provided by TNO (compiled on behalf of the Ministry of Environment of the Netherlands).
[7] The combustion calculator is currently being developed as part of ongoing work; the numbers included in this report are not currently published.

Table 3.8 PM_{10} emissions from industrial combustion sources in the UK (<50 MW_{th})

Size range	Burning oil	Coal	Coke	Fuel oil	Gas	Gas oil	Total	%
<2MW	0.21	1.12	0.00	0.13	0.06	0.52	2.04	27
2-5MW	0.15	0.57	0.00	0.08	0.17	0.33	1.3	17
5-20MW	0.00	1.44	0.02	0.12	0.35	0.17	2.1	28
20-50MW	0.00	1.02	0.24	0.39	0.17	0.28	2.1	28
Total	0.36	4.15	0.26	0.72	0.75	1.3	7.54	
%	5	55	3	10	10	17		100

NB. Data includes a small contribution from public service / institutional installations.

For NOx (in Table 3.9) the most significant emission contribution is from the larger installations within the 0 – 50 MW_{th} range. Installations less than 20 MW_{th} contribute approximately 59%. This is a similar profile to that observed in the Dutch example (57%).

Table 3.9 NO_x emissions from industrial combustion sources in the UK (<50 MW_{th})

Size range	Burning oil	Coal	Coke	Fuel oil	Gas	Gas oil	Total	%
<2MW	1.15	0.51	0.00	0.30	1.67	1.17	4.8	8
2-5MW	1.42	0.30	0.00	0.27	3.86	1.74	7.59	13
5-20MW	0.04	0.86	0.02	0.47	18.59	1.32	21.3	38
20-50MW	0.00	2.34	0.73	0.55	17.34	1.99	22.95	41
Total	2.61	4.01	0.75	1.59	41.46	6.22	56.64	
%	5	7	1	3	73	11		100

NB. Data includes a small contribution from public service / institutional installations.

The combustion calculator does not provide data on number of installation by plant. However, the EU ETS data provides some useful numbers on installation that have applied or are eligible, and includes all installation over 20 MW_{th}, and some below 20 MW_{th} that are eligible on the basis of an aggregated thermal capacity of 20 MW_{th}. The figure is approximately 840 for England and Wales (including 130 LCP plant), and nearer 1200 for the UK. These data are considered further for analysis in section 7.3.4.

3.5.2.3 Czech Republic

More detailed data from the Czech Republic emissions inventory has been presented in Table 3.10. This data reinforces the observed profile in the previous inventory data, with significant contribution to PM and NMVOC emissions from the residential sectors (with a similar profile for CO). The data also shows the significant contribution of emissions of NOx and SO_2 from large installations but also from households. Medium sized sources (as defined here) have much lower contributions. The extra large sources have been used to represent industry SCIs (although some institutional sources may be included). These data are difficult to compare to the Dutch and UK data because of the capacity bands used.

Table 3.10 Czech Republic emission inventory data (2001 / 2002) for sources < 50 MW_{th}

Description of plant site	REZZO level	No. of sources	No. of boilers	Emission estimates (tonnes / year)				
				PM	SO_2	NOx	CO	VOC
Extra large and large sources (>5 MW)	1	1,816	5,721 boilers (4,462 gaseous, 431 liquid)	2,090	40,267	22,635	5,425	2,132
Medium size sources (200 kW - 5 MW)	2	20,000	28,000 boilers (21,500 gaseous, 1,500 liquid)	3,102	7,227	4,648	10,135	2,168
Household (<200 kW)	3			30,844	32,565	13,619	104,467	102,953

Source: Machalek (2004); All data is for year 2002 except for REZZO 2 which is for year 2001

There are a considerable number of medium sized sources in the Czech Republic – over 28,000 boilers at 20,000 sites. This illustrates the potential difficulties of extending site-specific legislation to this size range of boiler.

3.5.2.4 France

Although no official statistics on installation numbers, CITEPA (2004) have estimated that there are approximately 1000 installations in the 20 – 50 MW_{th} range (valid for 2000-2002), while LCP number 278. Estimation of installations <20 MW_{th} is not possible on the basis of available data. Only in urban areas (>250,000 persons), a 2003 study estimated over 31,000 installations in the 0.4 – 2 MW_{th} range across a range of sectors (industry, commercial, residential).

Data was also compiled from the EU ETS for many countries, based on their national allocation plans (NAPs). Few conclusions however can be drawn from this data with regards to numbers of installations, because this data include LCP sites, installation in the 20 – 50 MW_{th} range, and many installations below 20 MW_{th}, that will be permitted on the basis of aggregated capacities (e.g. a number of units aggregated exceed 20 MW_{th}). The NAPs also include sites that will not be eligible on the basis of thermal capacity but as industrial processes.

There are significant difficulties with trying to draw out the main trends from three different country-based datasets, all of which have very different fuel profiles (e.g. Netherlands dominated by gas; more solid fuel consumption in Czech Republic). However, there are some tentative conclusions that can be made, which could be followed up in more detail under future work:

- Numbers of installations increase significantly below 50 MW_{th}. From the Czech Republic data, it is difficult to get a good understanding of the industry bands due to the aggregation between 5 – 50 MW.
- Below 50 MW_{th}, PM emissions are more significant from the smaller sized installations, while NOx and SO_2 are more significant from larger installation. This trend is also observed in the emissions data, when comparing large combustion plant and combustion plant below 50 MW_{th} for these pollutants.

3.6 CONCLUSIONS

The inventory estimates provide a useful understanding of what the key issues are with regard to emissions from SCIs, and help define the priorities for this study in terms of what types of policy action are needed. This review also highlights some important issues with regards to data availability and uncertainties of estimates.

3.6.1 Key inventory findings

A number of key issues have been highlighted, which provide the focus for determining future policy action (as discussed in section 7). For non-industrial SCI emissions, the key issues are listed below:

PM

- PMs from non-industrial SCIs appear to account for a significant proportion of overall European PM emissions in 2000. For NOx, SO_2 and NMVOCs, the proportion is lower but still important.
- The main contribution to overall European PM emissions from SCIs is biomass combustion (France, Poland, Baltic countries) and solid fuel use (Poland, UK, Czech Republic).
- The sectoral contribution to national totals of PM is dominated by use of solid fuels / biomass in the residential sector. Projected emissions show the diminishing contribution from solid fuels (although this source may continue to be important in specific regions or localities) but significant emissions from biomass.

NOx

- European NOx emissions are dominated by natural gas use, primarily in Western Europe, where a mature gas distribution network has been established. The emission is primarily from residential consumption although other sectors are important in different countries. Liquid fuels also contribute significantly to the emission total.
- Projected emissions of NOx from SCIs are estimated to remain at similar levels in future years, primarily due to increased gas demand, and continuing consumption of oil in future years.

SO_2

- European SO_2 emissions are dominated by Poland, due to the very high levels of coal consumption. Emissions also arise from the consumption of liquid and solid fuels across Europe, with levels clearly dependent on the sulphur content of such fuels. Projected emissions decrease significantly, due to the reduction in solid fuel use, and the impact of increased uptake of lower sulphur content liquid fuels.

NMVOCs

- Emissions of NMVOCs are driven primarily by the use of biomass, with a significant contribution from solid fuels. Significant emitters include France, Germany, Poland and Sweden, with the key sector being residential. Emissions of NMVOCs are projected to decrease but not to the same extent as PM, as the level of biomass consumption remains at similar levels up to 2020.

Using previous estimation methodologies, industrial-based SCI emission estimates were thought to be more significant. The current estimates indicate that for PM_{10} and NOx, industrial SCIs contribute over 3% of total emissions, while for SO_2, the contribution is about 8%. For many countries across Europe, emissions from industrial SCIs account for a significant proportion of total industrial emissions, the average being 12% for NOx and SO_2, and 18% for PM. There are however significant levels of uncertainty associated with these estimate, due to data limitations, and a simplistic inventory methodological approach.

3.6.2 Potential study priorities

Three key issues can be proposed that could shape future policy action, based on the inventory findings listed above, namely:

- PM and NMVOC emissions from residential burning of biomass and solid fuel
- Industrial-based SCI emissions of SO_2, NOx and PM (although current estimates are lower)
- NOx emissions from non-industrial consumption of gas and liquid fuels

PM emissions in particular should be considered for the following reasons:

- They contribute significantly to overall European emissions, and in most countries to national emissions of PM
- They are known to have significant health impacts, particularly if sources (such as those in the residential sector) are concentrated in urban areas with large populations
- Projected emissions of PM from these sectors do not decrease significantly from biomass, the demand for which may increase due to climate change based policies aimed at encouraging biomass consumption
- Targeting emissions from biomass will have significant benefits for reducing NMVOC, and other emissions such as PAHs.

The issues relating to biomass and solid fuels differ significantly. Biomass consumption is likely to increase over the next 20 years, as countries look for opportunities to reduce emission of CO_2 through their climate change programmes. The focus needs to be on ensuring uptake of low emitting technologies, and the removal of older high emitting technologies, rather than removal of this type of fuel altogether. For solid fuels, current projections estimate significant decreases in solid fuel consumption. Options need to focus on ensuring a quicker uptake of cleaner fuels, and where solid fuel use persists (particularly for backup use), cleaner solid fuels and improved appliances.

The priority of PM emissions as a problem in future years is strongly driven by the projected emissions from biomass. When policy measures are considered for this issue, it will be important to consider the inherent uncertainties, both for the emission factors and consumption data. Fuel consumption is difficult to estimate due to the nature of wood burning, which can be occasional, and may involve the use of ‘private sale or gathered’ wood, rather than marketed biomass products. Emission factors vary significantly depending on the characteristics of wood used in emissions testing.

Industrial emissions are much more uncertain due to the lack of available data. However, options may need to be considered for the following reasons:

- They are the source of a significant proportion of industrial emissions in many countries
- Many of these installations may be unregulated, and therefore, potential emission reductions may be significant

NOx emissions from non-industrial SCIs could be considered a problematic issue, due to limited reductions in projected estimates by 2010 and 2020, and increasing contribution to overall emission levels. SCIs will tend to be located in urban areas (as that is where natural gas networks tend to be located), and may become an increasingly important source with greater controls of urban road transport. However, it is also important to note that natural gas, the main source of NOx, is an important alternative cleaner fuel to other solid and liquid fuels and therefore may be less of a priority than the other two key issues. SO_2 emissions from non-industrial SCIs are perceived as a lesser priority due to significant reductions that will occur by 2010 in the baseline emission projections.

This inventory provides a useful guide to what some of the main pollutants, sectors and fuels are, in terms of absolute emissions. However, its primary limitation is that it does not provide the spatial dimension of the inventory, e.g. where emission sources are located in relation to population. A higher level of emissions in rural areas may be a lower priority than low emissions in urban areas (where health impacts could be more significant due to higher population densities). This issue is considered further in section 7.3.2.

3.6.3 Inventory development recommendations

There are significant uncertainties in the derived SCI inventory, and as a result, the following recommendations have been made:

- Countries improve completeness of reporting to CLRTAP, EPER and UNFCCC for relevant sectors.
- This includes an increased level of disaggregation of data, so that boiler sizes are distinguished. It is important to note, however, that such information is generally unavailable for most countries.
- There is a need for improved reporting of PM size classification, though the difficulties for countries from having to do this should be recognised.
- Improved reporting of projections for 2010 and 2020 would also be useful, along with documentation.
- All countries need to use the most up-to-date CLRTAP reporting format, noting that this will be reviewed periodically.
- Industrial emissions data need to distinguish installations with a thermal capacity of <50 MW and >50 MW. Additional improvements would also see the $<50\ MW_{th}$ band disaggregated further.

Inventory review and assessment is ongoing through work at the European level undertaken by ETC-ACC, and driven through exercises such as the bilateral discussions between the RAINS team and Member States (as part of CAFE programme). The above recommendations should feed into these ongoing programmes of work.

3.6.4 Uncertainties

A detailed uncertainty assessment of emission data has not been undertaken. This is because the inventory was originally perceived as an 'indicator' of potential emission issues, not a detailed and rigorous bottom-up inventory. Further detailed data for countries and sectors of particular interest have been considered on the basis of the policy measures for which further analysis is being undertaken. It is probable that there are some significant uncertainties in the data – therefore, non-industrial estimates were sent out to country experts to provide an indication as to whether the data seemed broadly correct. A summary of responses can be found in section 2.4. Most of the national stakeholders stated that the estimates appeared broadly correct.

Estimating emissions of PM in inventories, particularly specific fractions, is still very uncertain. This is particularly the case for different types of solid fuels and biomass, where specific characteristics of the fuel largely determine the subsequent level of emissions. Other parameters that need to be accounted for in emission estimates include the use of a wide range of appliances, and the behaviour of the consumers (fuel storage, appliance operation, primary / secondary fuel).

Another specific area of uncertainty is in the industry estimates, due to the use of older data to determine the split of plant under 50 MW_{th}, and estimates from three countries to estimate PM_{10}. An important recommendation for inventory improvement has been made, for countries to report the emissions from <50 MW_{th} installations (as was the case in earlier inventory formats) to enable policy makers to better understand this sectors' contribution.

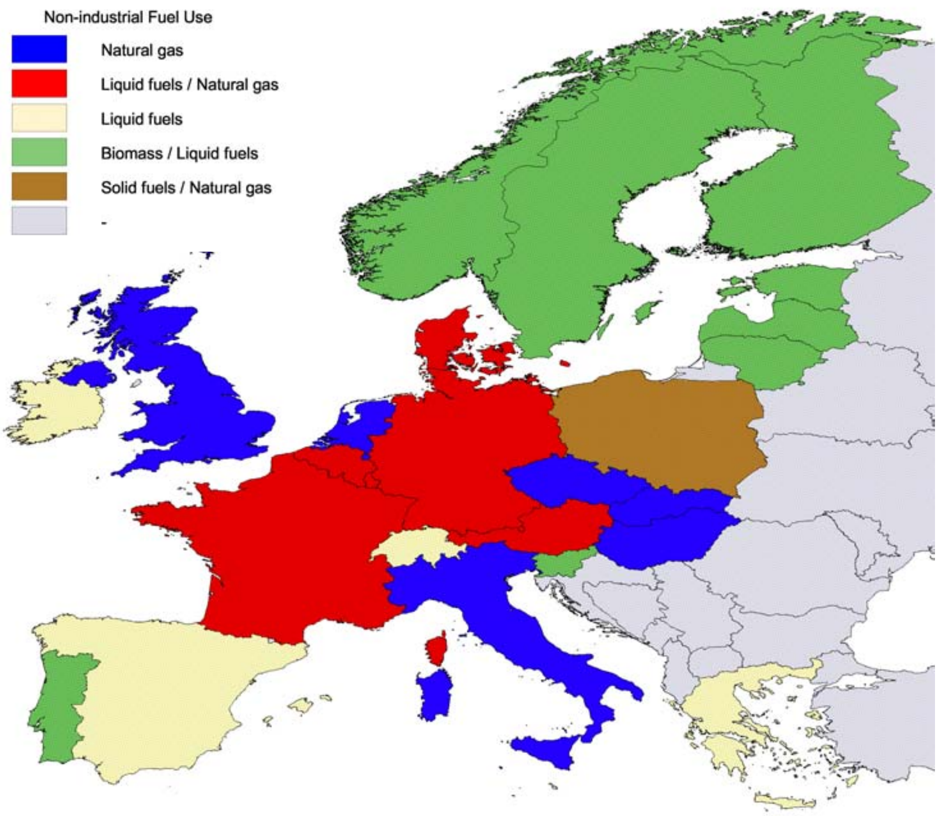
4 Country fuel-technology profiles across Europe

4.1 INTRODUCTION

The applicability of technical measures and appropriateness of policy options is dictated by the types of fuels and technologies being used across Europe. This is particularly the case for non-industrial SCIs, where very different energy markets can be seen across Europe. These differences are due to the type and quality of fuels being used, and technologies employed (in terms of age, combustion process, efficiency etc.).

The focus of this section is to provide a clearer understanding of the profile of technology- and fuel use within Europe for non-industrial SCIs[8], grouping countries together on the basis of the profiles generated. This will help in the considering the extent to which policy options will be effective across Europe. In addition, a broad overview of fuel consumption trends for non-industrial sectors in Europe is also considered. This reflects the importance of understanding future trends in consumption, so that this can be reflected in policy-making decisions.

Figure 4.1 Dominant fuels used across Europe in non-industrial sectors (as % of national rather than European energy consumption)



[8] This section focuses on the residential and commercial sectors. Agricultural energy consumption from stationary sources has not been considered in detail as it is not considered significant across most countries. Industrial fuel profiles have not been developed for two reasons; firstly, the data are not available for the 0-50 MWth range, and secondly, energy profiles are likely to be more homogeneous.

Dominant fuel use by country can be seen in Figure 4.1, based primarily on fuel use data from the UNFCCC and RAINS emissions database. Within these countries, significant variation occurs in terms of the type of SCI technologies used. Some countries have more than one significant fuel being used e.g. commonality between significant biomass consumers and the liquid fuel dominated market.

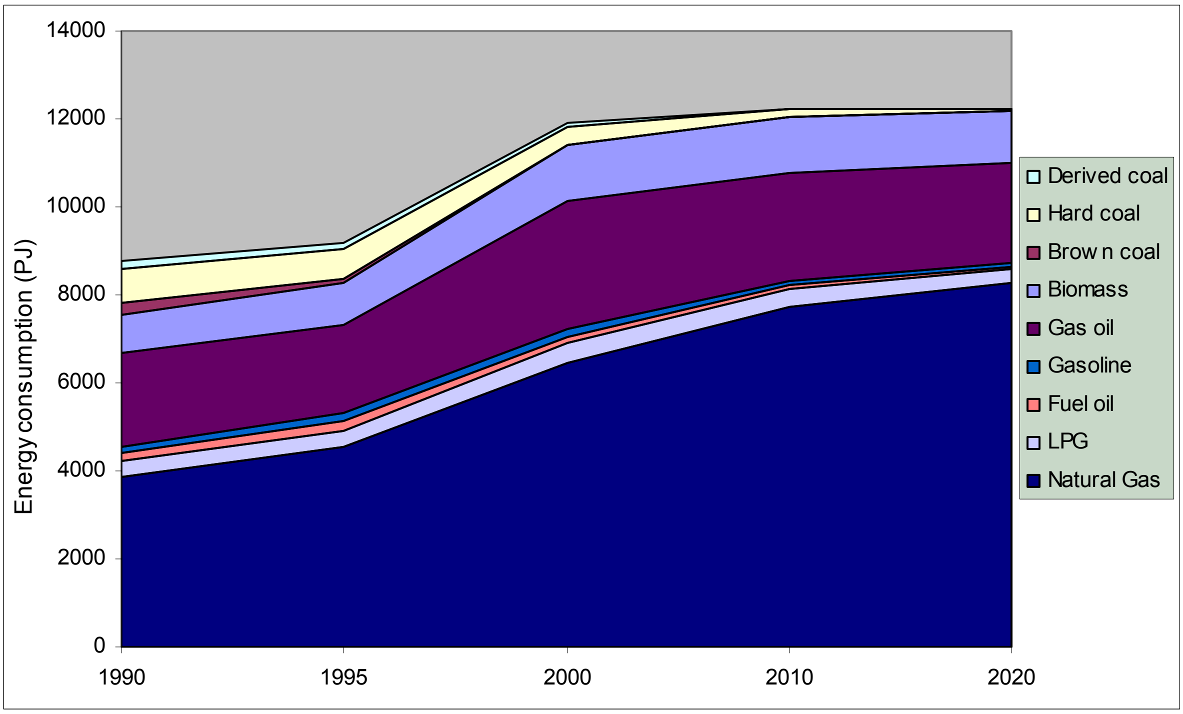
The energy data used in this section relates to all non-industrial sectors (residential, commercial and agricultural) although the residential sector is generally the most significant sector, and dictates the trends observed in this section. Percentage energy consumption data used in this section is relative to total direct consumption, and therefore does not include consumption of district heating or electricity. Data on district heating in this section is only relevant to the residential sector.

4.2 EUROPEAN TREND IN NON-INDUSTRIAL FUEL CONSUMPTION

There are four key trends that can be identified from Figure 4.2 below, which provides an overview of fuel consumption in Europe for the key non-industrial sectors:

- Natural gas consumption increases significantly up to 2020.
- Solid fuel consumption rapidly decreases, with only very small quantities being used by 2020.
- The consumption of biomass remains at the same level between 2000 and 2020.
- Oil continues to be significant fuel in future years, providing 20% of total energy for non-industrial sectors in 2020.

Figure 4.2 Energy consumption trends in non-industrial sectors for Europe



Source: RAINS web data for the commercial-residential sectors. Agricultural energy consumption from stationary sources has not been considered (and is not so significant).

In terms of trends observed in section 3, these data demonstrate why the emissions associated with solid fuels decrease significantly (PM, SO_2), while emissions of NOx from natural gas use, and emissions associated with biomass do not show significant reductions in future years. SO_2 from oil decreases significantly in future years (despite consumption levels in 2020 similar to those in 2000) due to the impact of the sulphur content legislation.

4.3 SIGNIFICANT NATURAL GAS MARKETS

Assessing the extent of natural gas use across Europe is important for the following reasons:

- Natural gas is considered an important alternative to other more polluting fuels, and therefore knowledge of natural gas penetration is important when considering options for emission reduction
- As a fuel that is predominantly used in urban areas, NO_x emissions from natural gas use may become increasingly important as a source of urban air quality, particularly as the contribution of road transport sector decreases.

Table 4.1 Countries with significant natural gas markets (for non-industrial sectors)

Country	% of direct energy consumption met by gaseous fuels	Other fuels used by non-industrial sectors	Use of district heating (in residential sector)
Netherlands	>90%		Approximately 3% of residential heating demand is met by district heating
UK	>80%	UK solid fuel use accounts for over 13% of the total European consumption	Approximately 1% of residential heating demand met by district heating
Slovakia	>80%	Solid fuel account for over 15% of direct energy consumption	A significant proportion of Slovakia residential energy demand is met by district heating (40%)
Hungary	>80%	Biomass and solid fuels together account for over 10% of non-industrial sectors consumption	20% of the residential sector demand is met by district heating
Italy	>70%	Over 15% of energy consumption is from liquid fuels, with between 5-10% biomass consumption	Approximately 1% of residential households are connected to district heating
Cyprus	>70%	Most other energy demand is met through liquid fuels.	
Czech Republic	>60%	Solid fuels account for over 25% of energy consumption (and over 10% of total European solid fuel use in non-industrial sectors).	Over 40% of Czech Republic residential energy demand is met by district heating
Germany	>50%	Over 30% of energy consumption is from liquid fuels.	In absolute terms, Germany produces the most district heating in Europe, supplying heat to meet 10% of residential market demand
Belgium	>50%	Natural gas consumption is nearly matched by consumption of liquid fuels (oil), which accounts for over 45%.	
France	45-50%	Biomass use is significant, accounting for 18% of energy consumption nationally, and approximately 25% of European biomass consumption.	Approximately 5% of households connected to district heating

Source: Energy percentage figures are based on direct energy consumption, and therefore do not include district heating. Energy consumption data is sourced primarily from UNFCCC reported data but also from RAINS database. District heating information is from EC (2002b) and Euroheat (2003).

In Western Europe, the non-industrial markets most dominated by natural gas are the Netherlands and the UK; 90% of Netherlands' direct energy demand[9] is met by natural gas. Both countries have low relative consumption levels of other fuels. Other Western European countries where gas use dominates include Italy, Germany, Belgium and France. Germany, Belgium and France are also significant consumers of liquid fuels (which account for over 30% of energy consumption for non-industrial SCIs). France is unique in this grouping with very high levels of biomass use (accounting for over 25% of non-industrial European biomass use). The energy consumption characteristics of these countries are outlined in Table 4.1 above.

District heating levels (in terms of residential market) tend to be low for these Western European countries, with Germany having the highest rate (10% of residential demand), with district heating infrastructure predominantly located in the east of the country.

Of the new Member States, the Czech Republic, Hungary and Slovakia all have very high gas consumption levels. All three, but in particular the Czech Republic, also have significant levels of solid fuel consumption, illustrating the potential for localised air quality problems (in urban areas) due to solid fuel burning. In Slovakia, most family houses use natural gas, with up to 57% of communities connected to the gas distribution network. Both Slovakia and the Czech Republic have very high levels of district heating, with 40% of residential demand being met in this way, while the figure for Hungary is closer to 20% (Euroheat 2003). Where significant district heating infrastructure exists, the potential for extending the network could be considered as an option to provide communities with an alternative, less polluting form of heating.

To assess the potential for reducing energy consumption (and emissions), it is important to identify the penetration of different types of gas appliance (although these data are not commonly available across Europe). The Netherlands has the highest penetration of highly efficient condensing boilers, which account for 36% of installed systems. For France and Germany, condensing boilers have market shares of 6.7% and 5.5% respectively, while in the UK (1.4%) and Italy (0.4%), penetration is much lower (EC 2002b).

Understanding the future growth of the gas markets is important in policy terms, so that strategies can be developed to take this into account. For EU15 Member States, an overview of future trends in natural gas consumption in the residential market is outlined in Table 4.2. All of the countries in this country grouping are considered as having mature markets, with steady growth rates (1-5%). Northern Ireland in the UK is the exception, with a new market projected to grow significantly following connection of the province to the UK and Irish gas infrastructure. This has been particularly important for providing Northern Ireland with alternatives to oil and in particular, solid fuels.

Natural gas is an important fuel for the non-industrial markets, particularly as a cleaner fuel with very low emissions of PM. However, its use as an alternative fuel will be dependent on where gas infrastructure is located. Non-urbanised areas are less likely to be supplied with gas (for economic reasons) so other options may need to account for geographical variation.

[9] Direct energy demand means energy supplied to a sector as a fuel (e.g. natural gas direct to a household) rather than energy derived from natural gas and supplied through district heating).

As the demand for gas in these sectors does increase, a potential problem of increased NOx emissions in urban areas from gas is likely to become more apparent.

Table 4.2 Future trends of natural gas consumption in EU15

Country (s)	Future market development	Projected growth rate
Finland, Sweden	Both have frozen markets. Only limited growth in line with changes in urban areas.	Lowest
Denmark	Growth is expected to be greater than in Sweden and Finland but still not significant. The growth rate will probably be similar to that in mature markets.	
Austria, Belgium, France, Germany, Italy, Netherlands, UK (excl. Northern Ireland)	This group of countries have mature gas markets, with growth rates of between 1-5%. Out of this group, Germany has seen the highest rate of growth in recent years.	
Greece, Portugal	Significant growth predicted for the future in these countries although this will be dependent on infrastructure build.	
Spain, Ireland, UK (Northern Ireland)	Significant growth predicted to continue in these countries with many households yet to be connected	Highest

Source: Griffin and Fawcett (2000)

4.4 SIGNIFICANT BIOMASS MARKETS

As illustrated in section 3 on emission inventories, biomass use is a significant source of emissions of PM and NMVOCs. Additional information on the use of biomass is therefore particularly important, in order to identify the key countries that use biomass, and assess the types of SCI technologies and fuel products used. Another important issue is determining where biomass is consumed, relative to populated areas. This is considered further in the section 7.3.2 on analysis of local measures.

The most significant users of biomass in the residential and commercial sectors are situated in the north of Europe; in Scandinavia (Norway, Finland and Sweden) and the Baltic countries of Estonia, Latvia and Lithuania. The countries in this grouping (shown below in Table 4.3) are not necessarily dominated by biomass use but are significant users. France is also a significant user of biomass in the European context (over 25% of European non-industrial consumption), and is therefore also included in this grouping. According to CITEPA (2004), out of 13.1 million 'main' homes, 5.9 million consume wood.

In Scandinavian countries, the non-industrial markets is also characterised by significant levels of oil consumption, significant penetration of district heating (although not in Norway where electricity use is high) and low levels of direct household natural gas use.[10] Similarly, in the Baltic countries, district heating is also a significant method of heating. The prominence of district heating in these Northern European countries is probably indicative of the longer, colder winters, and the need for continuous heating, making the initial investment costs of expensive infrastructure justifiable.

[10] Many district heating plants use natural gas.

Table 4.3 Countries with significant biomass markets (for non-industrial sectors)

Country	% of direct energy consumption met by biomass fuels	Other significant fuels used by non-industrial sectors	Use of district heating (in residential sector)
Lithuania	>60%	Gas consumption is reasonably significant, accounting for over 20% of energy consumption.	Accounts for approximately 40% of residential market energy demand*
Latvia	>60%	Gas consumption is reasonably significant, accounting for over 20% of energy consumption.	Accounts for approximately 70% of residential market energy demand
Estonia	>50%	Consumption of liquid fuels in non-industrial sectors is significant at approximately 30%.	Accounts for approximately 30-40% of residential market energy demand
Norway	>50%	Over 45% of energy consumption is from liquid fuels, showing a very similar pattern to Finland and Sweden.	The main difference to Finland and Sweden is the small share of district heating (<10%)
Portugal	>45%	A significant amount of energy consumption (nearly 40%) is from liquid fuels. Natural gas only entered the market in 1997, with approximately 2-3% of households connected in 2000. The percentage of connections is expected to rise to 10% by 2010 (Griffin 2000).	No data but likely to be negligible (as Southern European country).
Finland	>40%	Liquid fuels account for the largest share of energy consumption (>50%).	Accounts for approximately 50% of residential market demand
Sweden	>30%	Liquid fuels account for the largest share of energy consumption (>60%).	Accounts for just under 40% of residential market demand
Slovenia	>30%	Liquid fuels account for the largest share of energy consumption (>45%).	
France	>15%	Accounting for up to 25% of European biomass use in these sectors. Significant gas consumer (45 – 50%)	

Source: Energy percentage figures are based on direct energy consumption, and therefore do not include district heating. Energy consumption data sourced primarily from UNFCCC reported data but also from RAINS database. District heating information is from EC (2002b) and Euroheat (2003).
* District Heating takes approximately 60% market share of the total Lithuanian heat market, covering up to 90% of the heat demand in big cities and about 40% in rural areas. Heating plants are predominantly fueled by natural gas and fuel oil.

The percentage consumption of biomass (as outlined in the above table) or solid fuels may not entirely mirror emissions data based on this pattern of fuel use for several reasons, including:

- Differences in technologies used (particularly old and new equipment, and penetration of district heating systems)
- Differences in fuel quality (e.g., for biomass, type of wood used, condition of wood)

These factors are compacted through comparison across different types of fuel.

A key factor in understanding emissions from biomass use is knowledge of the type of fuel and appliance used. However, understanding this is difficult for a variety of reasons, including:

- Wood consumption statistics usually only take account of official sales, and not harvesting for personal use
- Condition of fuel has a significant influence on PM emissions e.g. moisture content
- Behaviour of appliance operator e.g. wood used as back-up fuel, number of times fire started etc.

Sternhufvud (2004) provides a good overview (in Table 4.4) of the types of wood burning appliances used in Scandinavia. A significant proportion of wood is used in stoves, particularly in Norway and Finland, many of which are older conventional types. This indicates that significant quantities of biomass are being consumed for back-up heating (and saunas) and therefore on a non-continuous (or intermittent) basis. Based on these factors; it is not surprising that significant levels of emissions are experienced by this sector.

Table 4.4 Use of wood burning appliances in the residential sector in Scandinavian countries (as a percentage of fuel burned)

Country	Conventional stoves (%)	Conventional boilers (%)	Modern low emitting boiler / stove (%)
Denmark	35	50	12
Finland	70	10	20
Norway	85	5	7
Sweden	35	49	16

Source: Sternhufvud (2004)

Scandinavian countries have the most comprehensive information on biomass use, with limited information from the Baltic countries.

- In Norway, 57% of households have stoves installed, most of which are conventional. Pellet boilers and stoves are not very common (Sternhufvud 2004). Pellet production is, however, significant, with most being exported to countries such as Sweden rather than used domestically (UMBERA 2000). In general, biomass boilers are not common, with few households using biomass as the main heating source.
- Most biomass use in Sweden is concentrated in the residential sector (mainly firewood) and district heating / public power, which uses mainly wood chips and pellets. In the residential sector, there are approximately 170,000 older boilers and 100,000 newer boilers, with less than 15% meeting current Swedish environmental standards (Sternhufvud 2004). Older boilers are being replaced at a rate of 15-20,000 per year, and there is also significant uptake of accumulator tanks (with an estimated 10,000 tanks per year). There are also over 1.1 million smaller fireplaces and stoves in use ((Sternhufvud 2004).
- In Finland, most non-centrally heated households use firewood in stoves, and much additional heating involves the use of firewood, again in stoves. Finland is also a significant user of peat. In Finland's submitted plan under the NECD (Finnish Ministry of Environment 2002)), it is estimated that there are about 2.2 million fireplaces plus about 1.5 million wood-fired saunas (many household saunas) and boilers. In 2000, it was estimated that wood burning fires and stoves caused 40% of all national PM_{10} emissions, half of all $PM_{2.5}$, and almost one fifth of NMVOC

emissions. Therefore, the use of wood is highly significant for air emissions. Few households (10%) use wood for primary heating although consume about 65% of all wood fuel (Sternhufvud 2004).

- In the residential sector in Denmark, there are about 300,000 stoves installed, and 90,000 small-scale boilers, mostly using wood. 60,000 of these boilers are conventional boilers, with the remainder modern boilers, of which 20,000 are pellet fuel based (Sternhufvud 2004). Unlike other Scandinavian countries, the use of natural gas in Denmark is significant, with approximately 12% of households directly connected to the natural gas grid and a further 27% of households receive heating from district heating plants that are fuelled by natural gas. It is unlikely that the natural gas network for domestic customers will be extended much further. In terms of boiler technologies, the proportion of condensing boiler is anticipated to rise to 35% by 2005 (Griffin and Fawcett 2000). The level of district heating in Denmark is also very high compared to other countries - the Danish government is aiming to get the number of households supplied by district heating up to 60% by 2005 (Griffin and Fawcett 2000).

It is important to note that biomass is becoming increasingly important as a fuel in national climate change programmes. Options to reduce emissions from biomass use will need to focus on the technologies that burn biomass, rather than on levels of biomass consumption. Options might include appliance replacement of older technologies, and increased use of pellet fuels.

4.5 SIGNIFICANT LIQUID FUEL MARKETS

The third country grouping represents countries whose residential-commercial fuel market is dominated by the use of oil. This is the largest group, and also includes a number of countries that were included in the gas and biomass grouping, as shown in the table below.

A feature of this group is that apart from Scandinavian countries and Denmark, levels of district heating are very low. In all of these countries, gas use is also a significant fuel except for Scandinavian countries (excl. Denmark) and Greece, where only 0.1% of households use natural gas. In Greece, the domestic network is confined to Athens, and is based on the old town gas network. Gas networks in other populated areas (Thessaloniki and Thessalia) are planned – if these were constructed, potentially 50% of the population would have access to natural gas (EC 2002b).

In Ireland, another significant consumer of oil, the domestic gas market has expanded rapidly over the past 15 years – 27% of households are now thought to use natural gas for space and / or water heating (Griffin 2000). This increase has significantly reduced the amount of coal consumed in the residential sector. The switch to natural gas has also been sped up due to the introduction of coal bans in specific urban areas (see section 6.2.2.1 for further information).

Table 4.5 Countries with significant liquid fuel markets (for non-industrial sectors)

Country	% of direct energy consumption met by liquid fuels	Other significant fuels used by non-industrial sectors	Use of district heating (in residential sector)
Greece	>75%	Greece has a significant amount of biomass use, at over 20%	No data but thought to be low as a Southern European country
Switzerland	>70%	The majority (25%) of the non-liquid fuel consumption is met by gas.	
Sweden	>60%	Significant biomass user – see Table 4.3	
Luxembourg	>55%	40% of energy consumption is met by gas	
Ireland	>55%	In terms of energy consumption, over 20% is met by gas, while over 15% of consumption is met by solid fuels. Natural gas is rapidly replacing other fuels, particularly solid fuels.	No data but thought to be low.
Finland	>50%	Significant biomass user – see Table 4.3	
Norway	>45%	Significant biomass user – see Table 4.3	
Belgium	>45%	Significant gas user – see Table 4.1	
Slovenia	>45%	Significant biomass user – see Table 4.3	
Spain	>40%	Other fuels used include biomass (15%); and natural gas (approximately 30%)	No data but thought to be low as a Southern European country.
Denmark	>40%	Similarly to Spain, other fuels used include biomass (15%); and natural gas (approximately 40%)	Almost 50% share of residential energy demand
Portugal	>40%	Significant biomass user – see Table 4.3	No data but thought to be low as a Southern European country.
Austria	>30%	Austria also uses just under 30% biomass, and over 30% gas.	District heating provided to just under 20% of households

Source: Energy percentage figures are based on direct energy consumption, and therefore do not include district heating. Energy consumption data sourced primarily from UNFCCC reported data but also from RAINS database. District heating information is from EC (2002b) and Euroheat (2003).

An important consideration with the future consumption of oil is the price, which has been very high in recent months. If prices remain high, a fuel switching trend could begin without the introduction of additional measures. Obviously the type of fuel considered for switching will be dependent on availability.

4.6 SIGNIFICANT SOLID FOSSIL FUEL MARKETS

An important country not included in the above groupings is Poland. This is because Poland's energy market is uniquely characterised by very high consumption of coal, with over 40% of non-industrial consumption from solid fuels, supplemented by around 20% biomass and 30% gas. Poland's use of solid fuels accounts for over 30% of the European total. However, this is changing with decreasing consumption of solid fuels, and a move toward other alternative heating sources. The other major users of solid fuels in Europe are Romania (15%), UK (13%) and Czech Republic (10%) - see Table 4.6 for an indication of solid fuel consumption as a percentage of country demand.

Table 4.6 Consumption of solid fuel as percentage of total non-industrial demand

Country	% of direct energy consumption met by solid fuels
Poland	>40%
Czech Republic	>25%
Romania	>25%
Slovakia	>15%
Ireland	>15%

Source: Energy percentage figures are based on direct energy consumption, and therefore do not include district heating. Energy consumption data sourced primarily from UNFCCC reported data but also from RAINS database. Hungary, Latvia, Lithuania and the UK all have 5% (or more) of national non-industrial demand being met by solid fuels.

In most Western European countries, solid fuel use in the residential (and commercial-institutional sector) has decreased significantly over the past 25 years, particularly in the UK, Ireland and Germany where it was traditionally most used. In the UK, solid fuel use in the residential sector is still a significant fuel in specific regions, such as parts of Northern Ireland, North England and Wales. The persistence of solid fuel use in localised areas (not reflected in national trends) is particularly important, and is not effectively identified in many studies. It is an important issue in the implementation of measures, and the difficulties of formulating European policy to tackle localised pollution problems.

It is clear from the data that the levels of solid fuel use are going to decrease significantly in future years. In view of this trend, policy options to tackle emissions from solid fuels should focus on speeding up the transition to other cleaner fuels, and ensuring that use of solid fuels does not persist in and cause pollution problems in localised areas.

4.7 DISTRICT HEATING

District heating is important to recognise in the context of this study as an existing means of heating in many countries, particularly for the residential sector, and as a potential alternative to other types of fuel combustion. The introduction of district heating may be limited (due to the high investment costs) to where infrastructure is already in place or to where demand for heating is continuous.

District heating involves the production of heat at a centralised plant for distribution to other buildings e.g. residential houses or blocks of flats. Therefore, buildings do not have their own independent primary heating system. CHP (combined heat and power) can also be the basis of a district heating scheme, where a centralised plant produces power e.g. for industrial processes, but also supplies useful heat to activities on the same site and surrounding premises. On average, in EU15 countries, 67% of district heating is produced from CHP plant, while in new Member States, the average is approximately 52% (Euroheat 2003). Across many countries, the use of CHP in district heating is being encouraged through different policy mechanisms. Table 4.7 shows the significant amount of district heating generated from CHP systems in Scandinavian countries.

Table 4.7 Residential heating systems using district heating in Scandinavian countries (% of total households)

Type of dwelling	Sweden	Finland	Denmark
District Heating	41	48.1	54.5
(% from CHP)	(30)	(80)	(70)

Source: EC (2002b)

For Europe as a whole, the heating needs of 100 million people are met through district heating (Euroheat 2003). As mentioned previously, the use of district heating is particularly high in Scandinavian countries (excluding Norway) compared to the rest of Western Europe, and is also a significant source of heating in many of the recently acceded Eastern European countries. The primary driver for this is thought to be climatic conditions, which mean a greater need for continuous heating, which helps justify the much higher initial investment costs for such systems (EC 2002b). The main costs come from the need to install piping to transport the heat to the end users.

Fuels used in district heating vary, with coal predominating across Europe, followed by natural gas, and then other fuels such as biomass (particularly in Scandinavia). One of the key advantages of district heating is that emissions and energy efficiency are controlled for a single installation, rather than across a significant number of small, dispersed sources. Abatement technologies may also be considered for larger plant, which might not be economically viable for much smaller household units. Another advantage is that such an installation can be located just outside of a residential areas with high population densities, although not too far from supply area given the costs of pipework, and heat losses during transmission.

According to Euroheat (2003), the main competitor for district heating schemes is individual gas heating. The stability of the position of district heating could be threatened if consumers decide to switch to gas on the basis of price. Consumer disconnection from the district heating network could compromise the sustainability of the district heating supply, as the cost efficiency depends heavily on high heat consumer density. Any reduction in the market may also undermine the potential for Combined Heat and Power (CHP) production, which is an important element for obtaining environmental goals in the energy sector. These issues will need careful consideration if district heating (and CHP) is to remain an important heating option, both for air quality and climate change policy.

4.8 SUMMARY

The fuel-technology profiles are very different across Europe, and within different country regions. However, countries have been grouped into broad categories based on their fuel market characteristics (for non-industrial sectors). Groupings provide an understanding of where different options may be appropriate, both in terms of technical measures and policy options that may be considered.

Table 4.8 provides an overview of the data presented in this section. In terms of the non-industrial sectors, a range of options will need to be considered to reduce emissions from a range of different fuels. In considering a range of options in subsequent sections of this report, these differences are recognised and highlighted.

Table 4.8 Summary of fuel use characteristics across Europe for non-industrial SCIs

Country	Gas use	Liquid fuel use	Biomass use	Solid fuel use	District heating levels*	Groupings
Netherlands	>90%				L	Gas
UK	>80%				L	Gas
Slovakia	>80%				H	Gas
Hungary	>80%				M	Gas
Italy	>70%				L	Gas
Czech Republic	>60%			>20%	H	Gas, Solid fuel
Belgium	>50%	>30%			L	Gas, Liquid
Germany	>50%	>25%			M	Gas, Liquid
France	>40%	>30%	20%		L	Gas, Liquid, Biomass
Austria	>30%	>30%			M	Liquid, Gas
Denmark	>30%	>40%			H	Liquid, Gas
Luxembourg	>40%	>50%			L	Liquid, Gas
Greece		>75%			L	Liquid
Switzerland	>25%	>70%			L	Liquid
Ireland	>20%	>55%			L	Liquid
Spain	>20%	>40%			L	Liquid
Sweden		>60%	>30%		H	Liquid, Biomass
Finland		>50%	>40%		H	Liquid, Biomass
Slovenia		>45%	>30%		H	Liquid, Biomass
Portugal		>35%	>45%		L	Biomass, Liquid
Norway		>45%	>50%		L	Biomass, Liquid
Estonia		>30%	>45%		H	Biomass
Lithuania	>25%		>60%		H	Biomass
Latvia			>60%		H	Biomass
Poland	>25%			>35%	H	Solid fuel, Gas

* District heating levels are ranked high (H), medium (M) and low (L).

5 Review of technical measures applicable to SCIs

5.1 INTRODUCTION

The focus of this section is to assess technical measures that could be implemented to reduce emissions from SCIs, particularly smaller SCIs in non-industrial sectors.[11]. Technical measures are the means by which emission reductions can be realised, and range from the replacement of an old appliance with a modern appliance to use of a less polluting fuel. Based on the emission issues highlighted in section 3, particular attention is given to technical measures for reduction of PM and NMVOC from solid fuel and biomass burning in the residential sector.

Part of the scope of this study is to assess what new and emerging technologies (appliances, abatement equipment etc) may exist that could lead to significant emission reductions. In this context, existing technologies are those currently on the marketplace, and being taken up within a country. An 'existing' technology may also be considered a newer technology in countries were uptake has been limited e.g. this terminology is country-specific. Emerging or new technologies include state-of-the-art new appliances, new abatement technologies, and novel technologies that exist but that are not currently viable in economic terms.

A significant amount of literature has been reviewed regarding the design, costs and effectiveness of technical measures. In particular, we acknowledge the significant use of materials from the following sources:

- UNECE Emission Inventory Guidebook – Small Combustion Installations Chapter (Draft 2.0), Kubica et al, EC JRC (December 2003). Main source of text regarding technology descriptions provided within the main report, and significant source of default emission factors.
- European Bioenergy Networks (EUBIONET), a key source for literature pertaining to fuel costs, biomass use and renewable energy sources.
- Solid Fuel Combustion in Small Appliances, EGTEI (October 2003)
- Combustion and Industry Expert Panel Workshop on: Emissions from Small and Medium Combustion Plants, Dilara et al, EC JRC (April 2002)
- Final Summary – Emissions from Residential Fuel Combustion, USEPA EIIP (September 2002)
- Labelling and other Measures for Heating Systems in Dwellings, EC SAVE II ACTION (January 2002)

5.2 TECHNICAL MEASURES FOR EMISSION REDUCTIONS

SCIs use a wide variety of fuels and combustion technologies, from simple, traditional systems to modern installations with advanced combustion controls. This range can be observed across all sectors, and leads to differing levels of emission depending on fuel type, combustion appliance, operational practices and maintenance.

[11] An assessment of new and emerging industrial-based technologies is currently the focus of other research being carried out within the CAFE research programme. http://www.europa.eu.int/comm/environment/air/cafe/activities/emerging_technologies.htm

There are two main types of technical measure to address emissions from SCIs; firstly, by avoiding formation of emissions (preventative measures) and secondly, by removal of pollutants from exhaust gases (abatement measures). Abatement measures have traditionally been less applicable to smaller scale installations (less than 1 MW_{th}) due to lower cost-effectiveness, and are generally used for larger installations (also considered in the scope of this study). The primary focus of this section is therefore based on preventative measures.

5.2.1 Preventative measures

Fuel Quality
Effective fuel quality management can have a significant impact on emissions of a range of pollutants. The pre-treatment of fuels to improve fuel quality is a well-established preventative measure, and a good example is the use of lower sulphur coal or liquid fuels. Examples of fuel quality improvement, which are considered in more detail in section 5.3.2, 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 steady combustion conditions to be maintained, increasing combustion efficiency and reducing emissions.
- *Reduction and homogenisation of moisture contents of fuels* (e.g. the development of consistent biomass pellets) to facilitate more stable combustion conditions.

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.

Fuel Switching
Where the use of a specific fuel is identified as a significant polluting source, substitution with an alternative fuel may lead to significant emission reductions. The use of an alternative fuel will not necessarily require a change in appliance e.g. bituminous coal being replaced by a less polluting solid fuel. However, fuel switching 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.

Retrofitting of improved combustion systems
Physical modifications to existing units can be made to improve combustion properties by, 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 combustion performance (and improve efficiency). This type of combustion design modification becomes increasingly viable in economic terms for larger SCI plant.

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. Such combustion units commonly exhibit more complete combustion and lower emissions per unit of energy input, leading to significant reductions in emissions of PICs and other pollutants. Improved thermal efficiency also reduces fuel consumption, providing potentially significant fuel cost savings, with the associated benefit of reduced greenhouse gas emission per unit of heat recovered.

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 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.

The RAINS model includes a range of control options regarding replacement of appliances. The removal efficiencies are shown below in Table 5.1.

Table 5.1 Appliance replacement measures modelled by RAINS (in PM module)

Control technologies	Removal efficiency (%)
New domestic wood stoves (non-catalytic)	63
New domestic wood stoves (catalytic)	65
New domestic coal stoves (stage 1)	30
New domestic coal stoves (stage 2)	50
New domestic coal boilers	40
New medium sized pellet / wood chip boilers (automatic)	89

Source: RAINS module (http://www.iiasa.ac.at/web-apps/tap/RainsWeb/) – Accessed 05/2004

Best practice in SCI operation
For solid fuel and biomass appliances, emissions can be significantly reduced through correct operation of an appliance, appropriate patterns of usage, and selection of compatible, properly stored fuel. Poor operation practises can lead to significant increases in emissions, particularly PM.

Reducing the demand for energy
Emissions reductions can be achieved by reducing energy requirements, either through proper maintenance of an appliance, reducing the need for heating through better insulation, and by installing appropriate sized appliances in building, according to the heating needs of a building.

5.2.2 Abatement measures

Abatement controls may be fitted to combustion plant to remove pollutants from flue exhaust gases, primarily PM and NOx. Such controls are not typically applied to smaller SCIs in the residential sector, as they are not economically viable and in certain cases not technically viable.

Particle Abatement
For larger commercial and institutional plant (usually above 1 MW_{th}) and industrial plant (1-50 MW_{th}) the use of particulate abatement systems are prevalent and include:

- *Cyclone separators,* which can typically achieve 75-85% reduction efficiencies through trapping fine particles. These may suffer from build-up of tar residues that condense within the apparatus over time. Where practicable, a series of cyclones may be used to improve the capture efficiency to around 95%.
- *Fabric filters* achieve a very high particle removal efficiency of about 99.9%, but are limited in their range of application to SCIs (appropriate for larger plant above 5 MW_{th}) due to their high pressure drop across the fabric barrier.[12] Due to very low flue gas flow rates associated with smaller units, fabric filters are not usually appropriate. They are also restricted to use in gas flow temperatures of (typically) below 200°C, much higher than smaller SCI units.
- *Electrostatic precipitators* can achieve particulate removal efficiencies of between 99.5-99.9% and have a low pressure drop. However, the costs of this technology are currently too high to be economically feasible within small or medium-sized combustion plant.

The use of particulate abatement, where applicable, will also lead to reductions in pollutants linked to PM, including PAHs, dioxins and furans and heavy metals. Removal efficiencies of different abatement equipment, primarily for larger plant, are provided in Table 5.2, based on data provided in the RAINS model.

Table 5.2 Secondary technical measures modelled by RAINS (in PM module)

Control technologies	Removal efficiency (%)
Fireplaces, non-catalytic insert	44
Cyclone for medium solid fuel boilers	50
Cyclone for medium biomass boilers	35
Baghouse for medium solid fuel boilers	99.45
Baghouse for medium biomass boilers	99.12

Source: RAINS module (http://www.iiasa.ac.at/web-apps/tap/RainsWeb/) – Accessed 05/2004

Oxidation Catalysts
Significant developments are evident in the design and use of catalysts in flue gas exhausts to reduce PICs (and specifically VOCs), and many modern solid fuel stove designs now incorporate such units to improve combustion efficiency and reduce pollutant emissions. These catalysts usually comprise a cellular or honeycomb structure that is coated with small amounts of catalyst materials (usually rhodium or platinum) which promote more complete oxidation of flue gases.

The efficiency of pollutant oxidation on passing through the catalyst is dependent on factors such as: the catalyst material, active surface area, and the conditions of flue gas flow such as temperature, flow path, residence time, homogeneity, pollutant constituents. Given regular cleaning and inspection, catalysts can remain effective for a lifetime of about 10,000 hours.

[12] SCIs have low flue gas flow rates as they rely on natural draft, not being forced through (using controls) at high pressure as in industrial. Due to significant build up of particles on a fabric filter, this is likely to get blocked up, the pressure drop across the unit will become significant (as flue gases are not being forced out) and hence flue gases will back-up and enter the dwelling.

Studies have shown the effectiveness of catalysts to vary considerably; typical reduction efficiencies from wood stoves have been determined as 70-90% (for CO) and 43-80% (for PAHs).

NOx Abatement
There is a more limited range of suitable abatement measures for NOx, in particular selective and non-selective catalytic reduction, which are predominantly used in the industrial sector. Due to the scope of this report, there is limited focus on these abatement technologies. No specific secondary abatement measures for NO_x in smaller plant are considered in this study in detail.

SO_2 Abatement
Abatement measures for SO_2 are less practical for SCIs. Such measures are most practicable (in technical and economic terms) for large plant e.g. the use of flue gas desulphurisation on power plant. The main measure for SO_2 emission reduction in the SCI sector is through the use of lower sulphur fuels.

Emerging abatement technologies
There are a number of abatement technologies that are emerging as potentially effective and economic for larger combustion plant (Table 5.3), driven by policy development to minimise emissions from waste incineration and power plant. A number of these technologies may become applicable to the larger-scale SCIs over the next twenty years.

Table 5.3 Emerging abatement technologies for larger combustion plant

Technology	Fuel	Description	Effectiveness	Stage of Development
Integrated Gasification Combined Cycle	Coal	Fuel reacted with steam and oxygen at high temp and pressure to produce a combustible gas mixture that can be cleaned and used in combined cycle gas burner.	SO_2 may be reduced by up to 45%, with reductions also achievable for PM and metals	Under development
Limestone Injection Multistaged Burner	Coal	Limestone injected through staged low-NOx burners. Moderate levels of SO_2 emission control by injecting sorbent at certain stages.	NO_X reduced by 40-50%, SO_2 reduced by 65-70%	Demonstrated
Limestone Injection Dry Scrubbing	Coal	Limestone is first injected into furnace, with resulting excess calcined lime CaO used as dry scrubbing reagent	SO_2 reduced by 65-70%	Demonstrated
Oxygen enhanced low-NO_X technology	Coal	Local injection of small amounts of oxygen in specific locations in the coal boiler can be used to reduce the formation of fuel-NO_X	NOx reduced by 50-80%, depending on burner design and over fire air	Demonstrated
Catalytic combustion	Gas	Fuel is combusted without flame and at a lower peak of temperature, reducing NOx formation	Small reductions in NOx	Pilot scale
Microturbines	Gas	A compact turbine generator that delivers local power supply	Provides energy efficiency savings due to direct supply of power	Limited commercial success
Diesel Particulate Filters, Catalysis	All	The application of technologies designed for use on vehicle emissions to SCIs is under research	Potential to reduce PM and NOx emissions	Under development

5.3 DETAILED ASSESSMENT OF TECHNICAL MEASURES

For smaller SCIs, preventative measures are the primary technical means through which to reduce emissions, with abatement measures either not cost-effective or not applicable to the smaller SCI market. Consequently, the focus of a more detailed assessment is on the use of preventative technical measures, with consideration of abatement measures where applicable. This section covers the following broad technical measures:

- Appliance replacement (including the use of new modern technologies)
- Fuel quality
- Prospective emerging technologies
- Other technical measures

5.3.1 Appliance replacement

One of the main technical measures for reducing emissions from existing SCIs is to replace current SCIs with more advanced and lower emitting technologies. This might involve changing to an SCI that uses a different type of fuel (which would be termed ‘fuel switching’) or upgrade to a more advanced appliance that uses the same fuel (termed ‘appliance improvement’). Using a cleaner fuel of the same group (e.g. switching from coal to smokeless solid fuel) is considered in the fuel quality section (section 5.3.2).

This section considers different types of SCI technology, assessing the difference in emissions for SCIs grouped on the basis of the type of fuel that they use. For solid fuels and biomass, a wide range of combustion designs, and capacities exist. Solid fuel systems are predominantly grate firing; though fluidised bed combustion technology is becoming more common in medium and large-scale boilers, that are used in the institutional-commercial sectors, and in district heating plant using solid biomass. The technologies for liquid and gaseous fuels have a narrower range of design and fuel specifications, although a similarly broad range of capacity. For residential and commercial / institutional boilers, SCI designs are normally simple, robust (and therefore long-lived), and not dissimilar to those used for production of thermal energy in industrial installations.

5.3.1.1 Solid fuel SCI Technologies

There are many different types of solid fuel appliances using solid fuels, the range of which considered in this study are listed in Table 5.4.

Table 5.4 Generic solid fuel SCI appliance and boiler technologies

Boiler / Appliance type	Sector
Fireplaces	Residential
Stoves	Residential
Boilers (single residence <50 kW)	Residential / Commercial
Medium sized boilers (50kW – 1 MW)	Institutional / Industrial / Agricultural
Large boilers (1-50MW)	Institutional / Industrial

These technologies use a range of solid fuels including sub-bituminous and bituminous coal, anthracite, coke, petroleum coke, smokeless solid fuels, coal briquettes, and peat briquettes. The emissions associated with these different types of fuel are considered further in 5.3.2. Not all solid fuels are appropriate for use in all stoves and fireplaces; for example, some stoves are designed to use petroleum-based fuels such as petroleum coke, which burns at much higher temperatures than other solid fuels (and is often used in blend with other solid fuels, such as anthracite, to improve combustion).

Fireplaces
Solid fuelled fireplaces are typically fixed grate combustion appliances where the user manually feeds solid fuel into the appliance. The types of fuels used in such appliances include coal, coke, smokeless solid fuels, and coal briquettes. Fireplaces are typically used for supplemental heating in residential dwellings, and may be of three broad designs:

- *Open fireplaces*, which are simple designs typified by a basic combustion chamber directly connected to a chimney, with large openings to the fire bed.
- *Partly closed fireplaces*, which are commonly masonry fireplaces that have been fitted with louvers and glass doors to reduce the intake of combustion air to the appliance.
- *Closed fireplaces*, which are equipped with front doors and a degree of combustion control through adjustable combustion air inlet vents. These units commonly exhibit primary and secondary combustion chambers.

Open fireplaces have very low energy efficiencies (typically 10%), with very poor combustion leading to high emissions of particulate, CO, NMVOC and PAHs. Improved efficiencies (to 50%) and combustion can be achieved by retrofitting to a partly closed fireplace, or by replacement with a closed fireplace or stove. Inserts can also be fitted which are essentially metal plates that heat up and improve heating efficiencies.

Due to the manual feed into a fireplace, emission levels are very dependent on the operating behaviour of users. If they do not maintain the fireplace e.g. leave ash build up preventing ventilation into the fireplace, or use intermittently, constantly starting up a fire (which can lead to high levels of particulates), emission levels may be much higher than if operated properly. Emissions will also be dependent on the types of fuel used, and the proper maintenance of the burn.

Importantly fireplaces (and stoves) are often maintained for aesthetic reasons, or for back-up heating and therefore not used as a primary, regular means of heating. A switch from coal to an alternative fuel such as gas central heating does not necessarily mean the removal of a fireplace. It is therefore very difficult to accurately estimate emissions from this type of SCI, particularly as it is so dependent on user behaviour (e.g. frequency of use, choice of fuels, appliance operation).

Solid fuel stoves
Similar to fireplaces, stoves are basic manually fed appliances that can use a range of solid fuels including: coal (anthracite, hard coal, brown coal), smokeless solid fuels, and coal briquettes (technologies for wood and other biomass fuels are discussed below). Variations in combustion design (e.g. grate design) and fuel use lead to a range of thermal efficiencies and emission characteristics. Stoves typically exhibit more complete combustion than fireplaces but lower thermal efficiencies than boilers and larger units. Stoves usually have some crude form of combustion control (adjustable combustion air inlet valves).

Older solid fuel stove combustion chamber design is likely to be the simple *up-draught* design (under fire, down-burning combustion), and is similar to a closed fireplace. It exhibits higher emissions, particularly of PICs (and lower efficiencies of 40-50%) than the *downdraught* (up-burning combustion) design, which is used in more modern stoves. This incorporates features such as pre-heating of inlet air and secondary combustion chambers to ensure more complete combustion, higher thermal efficiency and lower emissions.

Types of modern stoves

- *Advanced radiating stoves* incorporate a secondary combustion chamber, secondary air combustion inlets and pre-heating of secondary combustion air by heat exchange with hot flue gases. These design improvements lead to improved thermal efficiencies of around 55-75% and reduced PIC emissions in comparison to conventional stoves.
- *Heat storing, heat accumulating stoves* vary in their design on a regional basis, although are generally made of bricks, stones and ceramic. They typically produce relatively low emissions of pollutants compared with radiating stove designs achieve thermal efficiencies of 60-80%.
- *Catalytic combustor stoves* are equipped with a catalyst to clean flue gases and reduce PIC emissions. The catalyst also ensures more complete oxidation of fuels, providing an increase in energy efficiency. Catalytic combustors are not common for coal stoves, but are more evident within wood-stoves designs in some regions.

An emerging abatement measure, not currently viable for stoves as an add-on technology but as a built-in technology, is the reduction of emissions from stoves by using a catalyst in the flue. Some existing appliances will be designed such that they have a flue into which a catalyst can be added without impairing the flow of effluent gases, and (if near enough to the combustion zone) will be able to be operated at a sufficiently high temperature to ensure that the catalyst surfaces are able to reduce emissions, without the need for a supplementary fuel to heat up the catalyst. Many others e.g. open fireplaces with unlined brick flues, will not be suitable for fitting catalysts, as they can not operate at a sufficiently high temperature, and poor combustion which emits high levels of tars and benzoles will clog up the catalyst very quickly. Also if the flue is not lined properly and the catalyst adds significant resistance to effluent gas flow, flue gases may be forced out of alternative routes e.g. seep through the walls rather than out of flue exit.

With catalysts, there are two key aspects – (1) can the catalyst be operated at a high enough temperature to be effective? and (2) is the existing combustion complete enough such that a retrofitted catalyst will not get blocked by condensing tars combining with benzoles? Newer cast-iron solid fuel stoves have catalysts built into the outlet of a secondary combustion zone. As an add-on abatement technology (rather than built in), this is probably viable for larger units (>200kW).

Boilers (<50 kW) – Single Residence

Single residence boilers typically have a capacity of 10-50kW. The choice of fuel is usually determined by regional availability and cost. Similar to solid-fuel stoves, there are both over-feed and under-feed designs of combustion grate, which provide a range of thermal efficiencies and PIC emissions. Both types of boiler design can use all types of solid fuels except pellets, wood chips and fine-grained coal.

Conventional (over-fire) boilers are widely used in residential heating due to their simple operation and low investment cost. The simple combustion design commonly uses natural draught supply of combustion air with fuel periodically fed to the top of the fuel bed on the combustion grate. These features lead to low efficiency combustion (typically 50-65% depending on design) with significant emissions of PICs, especially when these boilers are "choked" through operation at low load. There are a number of modern types of boiler technology that can be used as replacement technologies, leading to emission reductions.

Types of modern small boiler, and their advantages over conventional over-fire boilers

- *Conventional under-fire boilers* - two-stage combustion chamber provides more stable combustion, due to continuous gravity feed of fuel onto the fire bed. These features result in higher thermal efficiency (60-70%) and lower emissions of PICs in comparison to over-fire boilers.
- *Advanced under-fire coal boilers* are similar in grate design and combustion technique to traditional under-fire boilers, but the more advanced designs also incorporate fan-assisted supply of combustion air. Closer control over the fuel/air mix and the use of more modern combustion control systems enables thermal efficiencies of up to 70-80%.
- *Stoker coal burners* are typically fuelled using coal with low ash content and of specific grain sizes that can be automatically fed into to a retort by a screw conveyor. When combined with good combustion controls and supply of combustion air, these units can achieve efficiencies of over 80%, and they also have the advantage of being able to operate at high efficiency over a broad load range. The high-temperature, high-efficiency combustion that can be achieved leads to low emissions of PICs compared to conventional designs, although NOx emissions tend to be higher due to the higher combustion temperature.

Boilers (large scale <50 MW)

Boilers of this range of thermal capacity may be used in blocks of flats, district heating systems, and all non-residential sectors. Different types of combustion grate designs are used in these larger boilers, with fixed bed combustion technology the most prevalent technology and some fluidised bed designs used for some biomass-fuelled plant. Fuel-feed design can have a significant impact on emission characteristics.

Similar to the smaller boiler range, manual feed boilers may be either under-fire or over-fire combustion designs, although the larger plant will tend to have better combustion air controls and are more likely to be fitted with secondary emission control measures (e.g. particulate abatement). For under-feed boiler, emissions of PICs (i.e. CO, NMVOC, TSP and PAH) are typically quite high, and thermal efficiencies range from 60- 80%. Emissions of PICs are lower in over-fire boilers due to the more complete combustion from this design

As well as replacement with better, more modern designs, as shown in the box below, abatement options are more economically viable, and include bag filters, ESPs, cyclones, wet scrubbers or urea-injection systems.

For the technologies described in this section, more detailed data on emission factors and costs can be found in Appendix 4. Due to uncertainties, a range of values has been provided where appropriate.

Types of modern larger boilers as potential replacement of conventional technologies

- *Automatic feed boilers* in which the fuel feedstock must be of a standard, homogenous quality. Due to the capability of maintaining a more stable combustion process (compared to the more cyclical batch-feeding type of combustion typical of manually-fed units) these plant usually exhibit more closely controlled combustion that is more efficient and less polluting. In addition, where commercially viable, larger plant may well be suitable for the application of secondary abatement equipment.
- *Moving bed combustion units* are classified by the method of fuel feeding to the grate (i.e. spreader stokers, overfeed or underfeed stokers). Fuels used are typically fine granules of coal or fine wood chips/sawdust (or co-combustion of coal and biomass fuels), and combustion temperatures are high (1000 - 1300°C). These plant are commonly used for district heating systems.
- *Advanced boiler technologies* (e.g. over-fire burning, stoker boilers, underfeed rotating grate) may be used for coal or biomass combustion. Similar to an underfeed stoker, low-ash fuel (wood chips, sawdust, pellets, coal up to 30 mm) is fed to the combustion chamber using a screw conveyor.
- *Fluidised bed combustion* can be used to burn poor quality, ash-rich coal, and is also used for co-combustion of coal and biomass or coal and waste fuels. There are only few medium size installations of this type in operation.

5.3.1.2 Biomass SCI Technologies

Biomass is widely used in SCIs in across Europe, notably in Northern European countries. As seen from the emissions data, a significant amount of PM and NMVOC emissions arise from biomass burning. This is particularly the case for smaller appliances where incomplete combustion is commonplace. A range of different biomass technologies are used in SCIs, many of which are similar to the technology designs used for burning solid fuel. Appliance replacement of older SCI designs with more modern combustion units (which are designed to be more fuel-efficient and less polluting) is a particularly important technical measure to consider, due the difficulties listed below of switching to other types of fuel:

- The increasingly important role played by biomass in climate change policy, with switching to biomass actively encouraged due to being considered carbon neutral (and therefore not contributing to GHG emissions across the fuel cycle).
- Biomass may be the preferred fuel in a region due to historical or cultural reasons
- Significant local reliance on biomass – some regions of the EU are dominated by biomass burning, and an established market for biomass has been developed
- Limited availability of appropriate alternatives and / or cost-competitive fuels
- Lack of a developed market for supply, maintenance and installation of alternative combustion technologies
- Biomass SCIs are commonly regarded as a positive aesthetic feature within a dwelling

Biomass is generally burned on the same type of appliances used for solid fuel, a summary of which is given in Table 5.5 below.

Table 5.5 Generic biomass SCI appliance and boiler technologies

Boiler / Appliance type	Sector
Fireplaces	Residential
Stoves	Residential
Boilers (single residence <50 kW)	Residential / Commercial
Medium sized boilers (50 kW – 1 MW)	Institutional / Industrial / Agricultural
Large boilers (1-50 MW)	Institutional / Industrial

Fireplaces and stoves[13]

The range of combustion unit designs for biomass-fired fireplaces and stove replacement are the same as for solid fuels, with the addition of the biomass-specific radiating stove design, using pellets, which can be considered as an existing abatement option for biomass SCIs. *Pellet stoves* are designed to allow automatic feeding of pelletised solid fuels (usually wood-pellets) from a small fuel storage hopper. These designs of stove typically incorporate a fan and electronic control system for supply of the combustion air, leading to high thermal efficiency (80-90%) and low emissions of CO, NMVOC, PM and PAH.

Boilers (<50 kW) – Single residence

Many of the designs of boilers described in the solid fuels section at the residential scale are also applicable to biomass. Existing biomass boilers tends to be conventional over-fire boilers, which are used in residential heating due to their simple operation and low investment cost. The simple combustion design commonly uses natural draught supply of combustion air with fuel periodically fed to the top of the fuel bed on the combustion grate. These features lead to low efficiency combustion (typically 50-65% depending on design) with significant emissions of PICs. There are a number of modern design biomass boilers, as shown in the box below, which could be considered as replacement options for older, conventional designs.

Modern biomass boiler designs

- Downdraught wood boilers have been designed to improve combustion of lump wood fuel supplies. A 2-stage combustion chamber is used, whereby fuel is partly devolatised in the first chamber, with a secondary chamber for oxidation of combustible gases. Flue gases are forced to flow down through holes in a ceramic grate and are burned at high temperature within the secondary combustion chamber. This design significantly improves the completion of the combustion process, increasing thermal efficiency and reducing emissions.
- *Modern wood pellet boilers* are designed to enable a fully automated feeding system, close control over supply of combustion air, fuel-air mix and the use of primary and secondary combustion chambers. The pellets are introduced from a storage hopper into the fuel bed using a by screw conveyor. These boilers can achieve high thermal efficiencies of over 80% and their emissions are comparable to those of liquid fuel boilers. The use of wood pellets is further considered in section 5.3.2.

[13] The use of fireplaces and stoves is uncertain with potentially only occasional use or support to the main heating systems during winter months. Understanding the stock of such appliances can also be difficult, as numbers of secondary heating appliances are often not quantified.

As well as replacement options, an abatement measure for conventional wood boilers is the fitting of an accumulator tank, which can significantly reduce emissions by enabling more efficient firing. An accumulator tank is a tank of water that can accumulate at least the heat equal to a full loading of fuel. This allows the boiler to operate at its nominal output instead of part load. Operating at part load reduces air supply to the combustion chamber, leading to 'choking' and high emissions of PICs.

Boilers (large scale <50 MW)
Larger biomass combustion systems show more variety and can be classified into three broad categories (IEA 2004): Fixed bed combustion, fluidised bed combustion, and dust combustion. In addition biomass *gasification systems* have been developed. The emission abatement options for larger biomass-fired boilers are as described for the larger solid fuel boilers.

Specific technical measures and their associated reduction efficiencies for small-scale boilers are outlined below in Table 5.6. Emission factor and cost data has been collated for generic types of the technologies listed, and can be found in Appendix 4.

Table 5.6 Selected technical Measures for PM reduction from conventional biomass boilers

Measure	Reduction efficiency	Description of measure
Accumulator tank	70%	Installation of tank on boilers
Fuel switch – pellets	50-90%	Pellet boilers tend to have lower emissions and higher heating efficiencies
Pellet burner	50-90%	Installation on existing boiler
Catalyst for wood burner	30%	Also reduces Co and VOC

Source: Sternhufvud (2004)

5.3.1.3 Gaseous fuel SCI Technologies:

Natural gas (and to a lesser extent liquefied petroleum gas (LPG)) has increasingly been seen as an important fuel for many sectors due to being a 'cleaner', lower cost fuel, with lower emissions of a range of pollutants. To a certain extent, natural gas is regarded as an alternative less polluting fuel, and therefore the basis of the fuel switching technical measure. However, NOx emissions from non-industrial SCI sources are becoming increasingly important. The main technical measure for reducing NOx emissions will be through energy efficiency measures, as discussed in Section 6.2.8.

The main barrier to the use of natural gas is it availability via a distribution network. The costs of extending the network are not considered in this study, as they will only be an option so far as infrastructure development allows. Another barrier could be the initial capital investment costs for gas boilers and central heating systems.

The range of gas appliances in the residential sector is much smaller than for biomass or solid fuels and are outlined in Table 5.7. UK-sourced figures are provided to give a broad indication of the fuel use across different device types within SCI sectors.

Table 5.7 Generic gas-fired SCI appliance and boiler technologies

Boiler / Appliance type	Sector
Fireplaces / Stoves	Residential
Boilers (single residence <50 kW)	Residential / Commercial
Medium sized boilers (50 kW – 1 MW)	Institutional / Industrial / Agricultural
Large boilers (1-50 MW)	Institutional / Industrial

Fireplaces / Stoves
Gas fireplaces (also classified as room heaters) tend to be of simple design, using valves for adjustment of fuel/air ratio and commonly using non-premixing burners. Compared to more complex gas burning devices (boilers etc) the temperature and efficiency of combustion in gas fireplaces is lower, leading to lower NOx emissions but higher emissions of CO_2, CO and NMVOC.

Boilers (<50 kW) – Single Residence
Gas boilers in this capacity range are typically water-tube low temperature boilers with an open gas combustion chamber heating water to below 100°C, made of cast iron or steel. They are used primarily for domestic central heating systems, providing hot water and heat, and they fall into two main categories: standard and condensing boilers.

Standard boilers have a maximum thermal efficiency of around 80%. Flue gases are discharged at a temperature above 200°C and the inlet/return water temperature is normally above 60°C. The combustion design is very simple, using an open combustion chamber with controls that allow good fuel/air mix and combustion air supply. Although more efficient than stoves and fireplaces, these units typically exhibit higher emissions of CO and VOC in comparison to larger boilers. More modern units may also use low-NOx burner technologies. *Condensing boilers* use a closed combustion chamber, recovering some of the latent heat from flue gases to reap thermal efficiencies of more than 90%. At optimum performance, water vapour is condensed from the flue gases, which then have a temperature below 60°C at the chimney inlet.

Boilers (50 kW-50 MW)
Larger gas boilers include a range of different designs, with different features with respect to:

- Burner configuration
- Construction materials
- The medium used for transferring heat (hot water, steam)
- Power/capacity
- Water temperature in the boiler (low temperature ≤100°C; medium-temperature 100-115°C; high-temperature >115°C)
- Heat transfer method (water-tube, fire-tube)
- Arrangement of the heat transfer surfaces

Smaller units up to around 1.5 MW may be constructed of cast iron, and these units are commonly used to raise low-pressure water or steam. Such units may be used within small residential district heating systems or in the commercial –institutional sector. Larger boilers up to 50 MW are constructed of steel and may incorporate a range of designs, as described below:

Water-tube boilers – Within a steel water jacket, water-tubes are welded across the flow of hot exhaust gases downstream from the combustion zone (water flows inside, exhaust gases outside).

Fire-tube boilers – Combustion gases are passed down a central smoke tube surrounded by the boiler water reservoir. Most frequently designed as a cylindrical structure.

Condensing boilers – As with the residential designs of condensing boilers, the latent heat of the water vapour in the flue gases are partly utilised through condensation in the heat exchanger, increasing the thermal efficiency of the system, often to achieve greater than 90% efficiency.

Where economically feasible, the use of abatement plant such as urea-injection systems to reduce NOx can be considered. Emerging abatement measures to reduce emissions from large boilers include catalytic combustion, and increase use of microturbines for local power supplies.

The primary mechanism to achieve emission reductions from gas-fired SCIs (excluding larger industrial plant) is to improve the thermal efficiency of SCI designs (wider energy efficiency measures are discussed in Section 6.2.8). The replacement of existing biomass and solid fuel SCIs by the installation of gas-fired alternatives is a key technical option in the reduction of PM and NMVOC from the SCI sector as a whole. Costs and emissions data for generic gas-fired technologies are listed in Appendix 4. Costs of large plant have not been considered as these are highly variable and will depend on a large number of factors. Larger installations are more likely to fit secondary abatement equipment than make large investment in new plant.

5.3.1.4 Liquid fuel SCI Technologies

Liquid fuels are widely used across Europe and in all sectors. The main liquid fuel used in smaller SCIs is gas (or diesel) oil, while medium or larger plants tend to use gas or fuel oil. Similarly to gas-based SCIs, there are few types of oil-based appliances; these are outlined in Table 5.8.

Table 5.8 Generic oil-fired SCI appliance and boiler technologies

Boiler / Appliance type	Sector
Stoves	Residential
Boilers (single residence <50 kW)	Residential / Commercial
Medium sized boilers (50 kW – 1 MW)	Institutional / Industrial / Agricultural
Large boilers (1-50 MW)	Institutional / Industrial

Stoves

Simple liquid fuel stoves use evaporation systems for preparation of fuel/air mixture and use valves for fuel/air ratio adjustment to control the combustion. The temperature and efficiency of combustion in oil stoves is lower than for boilers, and hence NOx emissions are lower in comparison. The design and construction materials for oil stoves is less diverse than for solid fuel stoves - they are made of steel and prefabricated, often with a “coal-effect” appearance for aesthetic reasons. Existing abatement options for oil-fired stoves are limited, with the use of cleaner fuels (e.g. low-sulphur oil) or switching to gas being the main options.

Boilers (<50 kW)
Oil-fired boilers in this capacity range are typically water-tube low temperature boilers with an open oil combustion chamber heating water to below 100°C, made of cast iron or steel. They are used primarily for domestic central heating systems, providing hot water and heat, and as with gas-fired domestic boilers they fall into two main categories: standard and condensing boilers.

- *Standard boilers* have a maximum thermal efficiency of around 80%. The combustion design is very simple, using an open combustion chamber with controls that allow good fuel/air mix and combustion air supply. 3
- *Condensing boilers* use a closed combustion chamber, recovering some of the latent heat from flue gases to reap thermal efficiencies of more than 90%. At optimum performance, water vapour is condensed from the flue gases, which then have a temperature below 60°C at the chimney inlet.

Boilers (50 kW-50 MW_{th})
The range of boiler types in this size category for liquid fuels is similar to those described for larger gas boilers, and there is frequently scope for firing a range of fuels depending on fuel availability and process stage. For example, many larger plant may utilise fuel oil firing during start-up or as a standby fuel where an interruptible gas supply is the main fuel source. In the commercial and institutional sector, gas oil-fired units up to $5MW_{th}$ are evident, whilst larger plant typically use fuel oil as a standby fuel option.

Primary emission reduction measures include the use of low-sulphur oils. For larger plant, there is more scope for application of abatement equipment, such as wet scrubbers to remove acid gases or urea-injection to reduce NOx. Where particulate emissions are a concern, bag filters, cyclones or ESPs may be used. In general, however, the primary mechanisms for emission reduction from oil-fired SCIs is the application of the more energy-efficient condensing boiler technology

5.3.2 Fuel type and quality

Controlling fuel quality or using cleaner types of fuel are important technical measures for reducing emissions from SCIs, particularly as secondary abatement equipment is not usually technically or economically appropriate for small plant, and costs of boiler / appliance replacement may be significant. A potential advantage is that a better fuel can be considered without replacement of appliance, making costs potentially lower than appliance replacement. This section focuses predominantly on solid fuels and biomass, with less variability in the fuel quality of gaseous and liquid fuels, the exception being sulphur content of liquid fuels.

5.3.2.1 Types of fuel

There is a wide variation in the types of fuels available for use in SCIs, particularly for solid fuels and biomass.

Solid fuels (coal)
The different types of coal are listed in Table 5.9 below. Coals can be ranked (high to low) according to a range of characteristics, anthracite being the highest and lignite the lowest ranked.

Table 5.9 Types of coal

Fuel type	Characteristics
Anthracite	Hard, black smokeless coal, with high calorific value, carbon content but low volatile matter (5%), and low ash content. Normally more suited to use in closed appliances / commercial heating boilers rather than open fires due to being difficult to light. Or blended with other fuels (e.g. petcoke) to make lighting easier.
Bituminous coal	Hard (black) coal. Not smokeless, with much higher levels of volatile matter (35%)
Sub-bituminous coal	Brown, softer coal, with lower ranked characteristics than bituminous coal
Lignite	Soft, brown coal, with much higher levels of volatile matter, and lower carbon content and calorific value. Will burn easier than hard coals due to the higher volatile matter content.

Biomass

The most commonly used wood fuels are logs and wood chips. However, in recent years the use of wood pellets has increased. Pellets provide more controlled combustion and thus lower emissions. They are widely used within Scandinavia (particularly Sweden and Denmark) and Austria, but not within the rest of Europe. The driving forces behind the spread of pellet fuels in Scandinavia and Austria were the introduction of carbon taxes and the provision of Government incentives and subsidies to promote 'carbon neutral' fuels.

Pellets are milled, dried, and extruded to form a low moisture (10%), consistent fuel that is somewhat easier to handle and store, and produces less ash on combustion. Pellets can be made from waste wood, sawdust, recycled pallets or specially grown crops like willow coppice or straw.

Pellets are generally used in 4 types of heating system which include:

- Small pellet stoves (6-10 kW)
- Small pellet boilers (7 – 20 kW)
- Medium sized pellet boilers (20 – 50 kW)
- Large-scale district heating (mainly found in Sweden)

Liquid fuels

In terms of fuel quality, liquid fuels will vary predominantly on the basis of sulphur content.

5.3.2.2 Natural fuel quality

Solid fuels (non-manufactured) have various natural characteristics that will have an impact on emission levels. Coal deposits that are sub-bituminous will tend to have higher natural sulphur content than hard coal or anthracite. For biomass, emission levels will be more a factor of how fuel has been stored, seasoned and sized.

Coal-based fuels can be classified either as low or high rank coal based on natural characteristics. Low rank coals have low carbon (and energy) contents and high ash content, and include sub-bituminous coal, brown coal and lignite. Daly (1996) states that these coals (including brown coals and lignite) have ash contents up to 30%, variable moisture content (average 30%) and low heating values. High rank coals tend to have higher carbon content and lower ash content, and include hard or bituminous coal. The highest ranked coal is anthracite (CARNOT 2001). Hard coals and anthracite in Europe also tend to have lower moisture and sulphur contents (Daly 1996).

In general terms, anthracite tends to be used in the domestic sector, with lower quality coals being used in power generation (where abatement technologies can better control emissions e.g. FGD on power plant). This sectoral use does differ depending on the country in question, particularly due to the availability of coals, which will depend on indigenous coal deposits, and extent of imports / exports. Bulgaria, Czech Republic and Hungary have predominantly low rank coals. Poland has large reserves of hard coal, with some significant deposits of low rank coals (Daly 1996).

5.3.2.3 Technical measures for improving fuel quality

The impact of potential fuel quality based measures will be dictated to some extent by the natural characteristics of fuel, as summarised above. This section considers what fuel quality based measures could be considered, which could help reduce emissions from SCIs. Options described in this section include:

- Coal Cleaning
- Smokeless Solid Fuel Manufacture
- Processing fuels to include drying and pelletising / briquetting to ensure a homogeneous fuel feedstock that can be used in an automatic feed design
- Sulphur reduction in liquid fuels

A significant amount of literature has been reviewed regarding the design, costs and effectiveness of these technical measures, in particular:

- *Technology Status Review: Monitoring & Control of Trace Elements* Project Report R249, UK Clean Coal Technology Programme (DTI, 2003)
- *Technology Status Report: Coal Preparation* Status Report 015, UK Clean Coal Technology Programme (DTI, 2001)
- *BS EN 303-5:1999: Heating Boilers for Solid Fuels, hand and auto-fired, nominal heat capacity of up to 300kW* (BSi, 1999)
- *Review of the Worldwide Status of Coal Preparation Technology* UK Clean Coal Technology Programme Report No R199, by RJB Mining for DTI (DTI, 2000)
- *A Profitable Process for Production of a Stable High-BTU Fuel from Powder River Basin Coal* (US Dept of Energy, 1993)
- *Scoping Study for the Transfer of Clean Coal Technology in the Domestic and Small Industrial Markets*, Clean Coal Technology Programme Report R094 (DTI, 1997)

Coal Cleaning

This is a mature technology that is used widely to process mined coal (mainly for use in power generation) to meet specifications of sulphur and mineral (ash) content. Coal preparation and cleaning has four main benefits:

- Reduction in ash content of coal
- Reduction in sulphur content of coal
- More consistent composition
- Increased heating value

Some trace elements in coal are mineral associated, such as Zn, As, Cd, Hg and Pb, and are all reported to associate with pyrites or accessory sulphide minerals. Reduction in ash content (and hence in mineral content) through coal cleaning therefore makes it a good option for removal of trace elements (some of which – such as mercury – are difficult to abate from flue gases).

The quality of the source coal can have a significant effect on the effectiveness of coal cleaning. For example, lower rank coals with more finely disseminated mineral matter are more difficult to clean, with trace elements like mercury organically associated and therefore not released by grinding. The washing effectiveness of lower rank coals can also be inhibited by their tendency to oxidise and their wetting characteristics.

Pre-treatment of coal for use in the residential and small commercial sectors is mostly restricted to very basic size classification followed by limited crushing and separation of lump coal. This is primarily because small fractions can often not be used in associated appliances. The more advanced pre-treatment options are limited for use in coal fuel destined for use in power stations.

This assessment of coal cleaning for use in SCIs has been split into two sections, one focusing on residential and small commercial SCIs and the other on larger SCIs.

1. Coal cleaning for residential and small commercial SCIs

Initially, coal can be crushed and screened to separate coal by fragment size. Subsequent treatment of “large coal” (nominally >25mm, which is the fraction that may be used for burning on less sophisticated grates such as those that dominate in the domestic and small commercial sectors) is usually restricted to limited washing and removal of non-carbonaceous ash content by separation processes. The key point here is that cleaning of coal may be significantly restricted by the need to ensure that the fuel is a specific size. For advanced cleaning, coal has to be broken up into significantly smaller sizes (which cannot be used on basic fixed grate appliances).

This basic coal cleaning for products destined for the market will have some impact on subsequent levels of emission, to an extent dependent on the natural characteristics of the coal. Estimated reductions of approximately 10-15% of TSP and SO_2 due to coal cleaning are thought possible, while reductions in mercury and other heavy metals will probably only result from advanced cleaning. It is considered unlikely that this coal cleaning measure would be specifically carried out to produce cleaner coal for the non-industrial sector. Coal cleaning is probably not economic unless driven by the demands of much larger industries.

2. Coal cleaning for larger SCIs

For coal-fired plant of greater thermal capacities than domestic and small commercial, there is a greater range of coal cleaning technologies that can be considered because the coal feedstock is typically much smaller in size. Grinding to smaller fragment sizes enable much more effective separation of coal and mineral matter. Table 5.10 below illustrates different stages of the coal cleaning process, starting with basic cleaning up to more advanced techniques. Cleaning of coal used in the residential sector takes place up to about stage 2.

Table 5.10 Stages of coal cleaning process

	Stage of process	Scope	Recovery of coal mass (%)
1	Crushing & screening	Crush to a given top-size, possibly with screening into specified size ranges	95-100
2	Coarse coal wash only	Material > 10mm is washed, fines that by-pass the process are added to the washed product	80-95
3	Coarse & intermediate sizes washed	All material >0.5mm is washed (possibly by different processes). Fines may be added to product or discarded.	60-90
4	All sizes separated	Plant must have several circuits where appropriate sizes are separated – larger sizes by density difference, smaller sizes by surface properties.	60-80
5	Coal pre-crushed to increase mineral matter liberation	All of the feed coal is crushed to very small pieces size and washed. Often called "Advanced Coal cleaning"	20-50

Source: DTI Clean Coal Technology Programme Project Report R249 (2003)

Based on advanced coal cleaning processes, a 50% reduction in sulphur emissions (best-case scenario) can be realised, with between 10 – 50% (mean 21%) mercury removal. Coal preparation and cleaning is a significant additional cost to the cost per tonne of mined coal. A recent survey of the UK coal cleaning industry (which is regarded as one of the most cost-efficient industry of its type in Europe) suggested that the average coal preparation operational costs are currently around £0.80 / tonne coal (DTI 2000). This cost is probably for the type of coal cleaning only considered for use in very large industrial installation.

Smokeless solid fuels

There are several types of smokeless solid fuel – including natural and man-made – and several associated manufacturing / processing approaches.

- *Natural smokeless solid fuels (e.g. anthracite)*

Fuel may be processed (sizing, washing) into user-friendly lumps of fuel, whilst the fines (anthracite duff) can be processed together with a binder to produce briquettes suitable for use in SCIs (i.e. useable in a range of different grate-designs, including fixed-grate stoves and fireplaces, or auto-fed from a hopper in a larger unit). Such fuels are naturally low in volatiles and hence are "smokeless" on combustion, although they can be more difficult to light.

A range of briquetting processes can be used – some requiring heat-treatment, others relying on a chemical binder for the fines. Typically the processing required is minimal and the process is quite cost-effective when compared to the more involved chemical treatment processes required to produce manufactured smokeless solid fuels where volatiles need to be driven off and captured. The applicability of such processes is limited by the availability of smokeless solid fuel resources such as anthracite.

- *Manufactured smokeless solid fuels (coal-based)*

These fuels may be manufactured by thermal processing of bituminous coal feedstock in the absence of oxygen. The carbonisation process drives off volatile content from the coal, and if applied thoroughly to a batch of coal will produce coke – a smokeless fuel with very low volatile content which is quite difficult to light. More commonly in some European markets, the carbonisation process is stopped before the coal is reduced to coke, to produce a solid fuel "semi-coke" which still has sufficient volatile content to enable more easy lighting for the domestic user.

Emission reductions are achieved primarily due to the reduction in volatile content of the fuel, rather than the ash content of the fuel (which may be reduced slightly by coking). On combustion, cokes and semi-cokes emit less smoke (from combustion of volatiles and organic agglomeration of emitted VOCs), compared to the bituminous coal feedstock. The reduction of ash content of flue gases is not the most significant contributor to the "smokeless" nature of use of coke/semi-coke.

The volatile content of the coal feedstock (typically 35 – 40%), is reduced to a final volatile level in the semi-coke product of around 8%. This is low enough to be smokeless but high enough to retain its reactivity for use on open or closed domestic fireplaces and stoves. Domestic feedstocks generally need to be in excess of 20mm diameter in size, and around 80% of manufactured SSF meets that requirement – the remaining 20% can be used in a range of industrial processes.

- *Manufactured smokeless solid fuels (petroleum-based)*

These fuels are derived from refinery outputs, once crude oil feedstock has been refined to produce the main products of petrol and diesel. The heavy bituminous fraction of crude that remains typically has a very low hydrogen content compared to carbon, and can be processed into a "petcoke" smokeless fuel with low volatile content, suitable for use in SCIs. The petcoke fuel is typically very easy to light but may reduce the life-span of the combustion equipment through corrosion promoted by its very high combustion temperature, low ash content and relatively high concentrations of constituent elements such as nickel.

The quality of the petcoke product is very dependent on both the nature of the crude oil feedstock and the design and controls of the refinery process. Where refineries produce a petcoke with a higher volatile content, the product may be more prone to smoke emissions. In addition, the variability of content of some elements is very significant within "petcoke"; for example, sulphur content may vary from around 0.5-6%, and the impact on emissions this will have is very significant. As with other manufactured SSF, specific regulation to control the constituent elements of a petcoke fuel would be required to ensure emissions are minimised.

The following table presents a summary of the approximate emission reductions achieved by using anthracite, coke or SSF instead of coal, taken from a review of emission factors used for domestic combustion within the UK atmospheric emissions inventory, correcting to emissions of pollutant per GJ of fuel input. These reductions will of course vary depending on the appliance used e.g. open vs. closed appliance.

Table 5.11 Reduction in emissions for solid fuels (relative to bituminous coal)

Pollutant	Anthracite	Coke	SSF
CO	8%	-4%	-1%
NO_x	-3%	2%	6%
SO_2	28%	18%	6%
NMVOCs	89%	63%	65%
PM_{10}	68%	97%	46%

Source: UK National Atmospheric Emission Inventory

Across Europe, the price differential between these fuels will vary considerably, depending on local market conditions. In the UK, where the SSF market is reasonably well established as a consequence of fuel use restrictions implemented through the Clean Air Act, a survey in 2003 indicated that for domestic consumers, SSF was approximately 28% more expensive than coal.

Biomass pelletisation
The use of biomass in a pelletised form has been identified as a potential solid fuel pretreatment that could reap emission reductions through the subsequent application of automatically-fed, well-controlled pellet fuel combustion units, to replace established technologies of wood-fired stoves and fireplaces.

Pellets are milled, dried, and extruded to form a low moisture (10%), consistent fuel that is somewhat easier to handle and store, and produces less ash on combustion. Pellets can be made from waste wood, sawdust, recycled pallets or specially grown crops like willow coppice or straw. Pellet-burning appliances burn at a higher temperature and with greater thermal efficiency than traditional wood fireplaces or wood stoves. The net calorific content of wood pellets is also a little higher than traditional wood supplies used in domestic appliances, at approximately 16.8 GJ/tonne compared to around 14.3 GJ/tonne for wood chips (UMBERA 2000).

The benefits from the pelletisation of biomass stem primarily from the creation of a homogenous (in terms of moisture, VOC and ash content) fuel feedstock that can be fed automatically into combustion units from hoppers by virtue of their improved handling and flow characteristics. The biomass material is milled, dried and compacted to produce a pellet feedstock of low moisture and consistent calorific value.

Both the homogenous nature of the biomass pellet fuels and the fact that auto-feed systems can be used (rather than period hand-fuelled biomass systems that dominate currently in some regions of the EU) promote a more stable, well-controlled combustion process, whereby emissions from incomplete combustion of volatiles and carbonaceous materials can be minimised. (Note that the same applies regarding the briquetting of fossil-fuel derived SSF – the benefits from improved combustion conditions are the primary driver behind using this processed fuel type.)

Regulation to control the constituent elements of biomass pellet fuel can further ensure that combustion emissions are minimised. For example, the banning of feedstock wood contaminated by pesticide (e.g. lindane and CCA-type treatments, as used widely in wood-based construction materials) must be implemented. The benefits of biomass are typically cited as low-sulphur, low-heavy metal content and “carbon-neutral”. From a greenhouse gas emissions perspective, the optimisation of biomass combustion to minimise emissions of greenhouse gases such as methane and other VOCs must be considered. Pelletisation to ensure a consistent biomass fuel source should promote more complete combustion of biomass (compared to lump-wood firing), and the development of well-controlled pellet combustion units to replace inefficient domestic fireplaces will improve energy efficiency (crucial to such a low-energy fuel) and reduce emissions.

For a domestic scale pellet burner (W02b) and a standard lump wood stove (W02a), the emission factors are:

Stove	PM_{10} (g/GJ)	VOC (g/GJ)	SO_2 (g/GJ)
Wood pellet stove	50	252	6
Lump wood stove	333	1400	10
Reduction Efficiency	85 %	82 %	40 %

The costs of biomass fuels around Europe will vary considerably depending on the market conditions within each region; in many areas, no biomass pelletisation market is in evidence. Drawing on a recent fuel costs survey across the EU (*Source*: EUBIONET Fuel Prices in Europe 2002/03), the average costs per GJ within Europe for wood logs and biomass pellets are estimated as 7.9 Euros/GJ for wood logs and 12 Euros/GJ for biomass pellets:

Reduction of sulphur content of fuels

A report by AEA Technology (2001b) outlines some of the measures, including reducing sulphur content of fuels, to achieve NECD targets in the UK, and their associated cost-effectiveness. In the residential sector, the marginal cost of abatement of using low sulphur coal or coke is €414 (£260 GBP) per tonne of SO_2 abated. The marginal costs appear very low probably due to the fact that coal or coke with a sulphur content of 0.6% is not much more expensive than the coal or coke currently used in the residential sector. For industrial boilers, the following marginal costs of abatement are €390 (£245 GBP) per tonne abated for coal, €414 (£260 GBP) for coke and €459 (£288 GBP) for fuel oil.

Entec (2004b) provides estimates from the cost curve for introducing fuels with lower sulphur content (as shown in Table 5.12 below).

Table 5.12 Costs of fuels with lower sulphur content (residential sector)

Measure	Abbreviation	Unit cost (€/tonne)	Reduction efficiency
Low sulphur coal – 0.6% sulphur	LSCO	446	52
Low sulphur HFO – 0.6% sulphur	LSHF	494	72
Low sulphur gas oil – 0.045% sulphur	LSMD2	5327	69
Low sulphur coke – 0.6% sulphur	LSCK	447	40

Source: Entec (2004b)
NB. Cost data converted from GBP to €, adjusting GBP to 2003, and using 1.5 conversion factor

Table 5.13 shows the reduction in emissions from the introduction of low sulphur content of fuel controls (in the non-industrial sectors), as set out in the RAINS model.

Table 5.13 Technical efficiencies of RAINS model controls on sulphur content

Control technology	Abbreviation	Original $ktSO_2$/unit (range)	Technical efficiency (range)	Revised $ktSO_2$/unit (range)
Low sulphur diesel oil (0.2% S)	LSMD1	0.141 – 0.376	33.33 – 75	0.092 – 0.094
Low sulphur diesel oil (0.045% S)	LSMD2	0.071 - 0.376	70 - 94.375	0.021
Low sulphur fuel oil (0.6% S)	LSHF	0.482 - 1.253	40 - 76.92	0.284 – 0.3
Low sulphur coal (0.6% S)	LSCO	0.448 – 0.648	14.286 - 40	0.369 – 0.432

NB. A range of reduction efficiencies is used in the model to simulate a reduction from a range of different emission factors to a standard emission factor.
Source: RAINS module (http://www.iiasa.ac.at/web-apps/tap/RainsWeb/) (05/2004)

The introduction of improving fuel quality appears to be highly cost-effective. This is because the price differential between low cost sulphur fuels and conventional fuels is not significant.

5.3.3 Prospective emerging technologies

This section focuses on potential technologies for the future that are still being developed, or that have limited commercial penetration. They are considered technical measures in this context, as there use could lead to reductions in many of the pollutants being considered under this study. All of these technologies are currently being used to differing extents across Europe, with the exception of fuel cells, which are much newer technologies. Their implementation is primarily being driven by climate change policy.

5.3.3.1 Small-scale CHP

Development and use of increasingly smaller Combined Heat and Power units has been evident over recent years, and there is some evidence that CHP is now making limited inroads to the domestic heating market. Emission reductions are realised due to the improved efficiency of conversion of fuel energy into heat and electricity, although the technology currently developed for smaller units delivers a lower electrical efficiency and at a much higher cost than is typically achievable in larger plant.

Figures from the UK Community Energy Programme illustrate that a cost of €2,250 (£1,500) per kW_e is a fairly typical benchmark for smaller community-scale CHP units, whilst for domestic CHP plant, the costs are nearer €5,250 (£3,500) per kW_e. There are very small units available on the market, down to $5kW_e$, of which several thousand have been installed across the EU. Where smaller CHP units have been successfully commissioned, the driving force has mainly been Government-led initiatives (e.g. HECA in the UK) to provide funds to stimulate the market and target schemes that reap benefits of cost-effectiveness, carbon-savings and address issues of fuel poverty (Crispin 2004). The development of micro-CHP through the use of Stirling Engine technology remains predominantly in the research phase, with ongoing study across Europe to incorporate small gas engines into residential-level heating systems.

Potential barriers to the spread of domestic CHP include:

- The degree of electricity market liberalisation across the EU
- The degree of accessibility to mains gas supply
- Commercial viability of systems at domestic scale
- Lack of technical expertise to install and maintain the more complex plumbing and electrical systems required for CHP
- Lack of a developed supply-chain for CHP units and components

A review of biomass CHP applications across Austria, Belgium, Denmark, Finland, Netherlands, Sweden and Switzerland indicates that current technology development has focussed on somewhat larger plant, with biomass-fired steam turbines ranging from 0.6-700 MW_e being the most significant market development to date (Obernberger 2004). Several of these larger schemes service the heating and electricity needs of district heating systems. The Scandinavian nations and Austria are by far the market-leaders in this technology.

There are a total of only 13 existing plant reported in the < 1 MW_e category, with Stirling engine technology recommended as perhaps the most viable technology to develop for small-scale biomass-fired CHP systems. Steam screw-type technology is also regarded as a potentially emerging technology for biomass-fired CHP plant with a thermal capacity of up to 7 MW, with demonstration units in operation.

5.3.3.2 Fuel cells

Fuel cells force two fuels (e.g. hydrogen and oxygen) to produce electrical energy by means of a chemical reaction. There are several different types of fuel cell technology, but the only type currently available on the market for stationary power as a portable power source are PEM-based (Proton Exchange Membrane) fuel cells.[14] An alternative fuel cell technology, Solid Oxide Fuel Cells[15], are reaching pre-commercialisation with several hundreds of residential stationary power units (about 1 kW) being tested in Europe and larger units (250 kW or above) being evaluated by various utility companies world wide.

Fuel cells present the advantages of high energy conversion (40-60%), low greenhouse gas emissions and provide an alternative power option (reducing oil-dependency) for distributed power generation. Solid oxide fuel cells also enable fuel flexibility (pure hydrogen is not needed and direct fuels such as natural gas, fossil fuels or diesel may be used), and they are low-maintenance or even maintenance-free. Hence SOFC may be developed for a range of power applications: stationary, transportation (or mobile), military, and portable.

Faster market penetration is limited by cost, fuel availability and infrastructure, proven reliability and performance compared to other competitive technologies. In terms of applicability to the residential market, current PEM technology have not proven to have a lifetime of more than around 10,000 hours, and it is estimated that this must be improved to above 50,000 hours in order to gain a significant market share.

For all fuel cell technologies, the development of a proper fuel delivery support structure (fuel infrastructure and distribution channels) and wide availability to enable convenient refuelling (tanks, cartridges) is critical. For less well developed technologies such as SOFC, the main challenges to reach full commercialisation within the next decade or so are cost, reliability, and performance. Significant progress has been made in the last 10 years, but further materials and technical improvements in design are required to reduce manufacturing, system costs and operating temperatures.

5.3.3.3 Heat Pumps

The use of heat pump technology to utilise low-grade ambient energy sources to heat domestic and industrial premises is an emerging technology that has made limited progress into the heating market in the EC. In heating applications, heat pumps remove energy from

[14] Proton Exchange Membrane Fuel Cell (PEMFC) can operate on reformed hydrocarbon fuels, with pre-treatment, and on air. PEFC operates at low temperature and provides instant start-up delivering power at a lower cost than any other fuel cell system.

[15] Solid Oxide Fuel Cell (SOFC) is highly efficient, tolerant to impurities and can at least partially internally burn hydrocarbon fuels, making it probably the most desirable of all fuel cell technologies for generating electricity from hydrocarbon fuels. The SOFC electrolyte is a solid so no pumps are required to circulate hot electrolyte. Both hydrogen and carbon monoxide are used in the cell, and SOFC can readily and safely use many common hydrocarbons fuels such as natural gas, diesel, gasoline, alcohol and coal gas.

ambient air, water, soil or bedrock, the heat exchanger transfers energy as heat to the circuit of working fluid within the heat pump itself, and then the distribution system can move the heat from the heat pump for use as space or water heating.

The available heat from a heat pump system may be distributed within a building using under floor piping, fan coil units, air handling systems, or wall-mounted radiators. A power supply is needed to fuel the compressor to drive the heat pump, and increasingly designs are using gas engines to drive such heat pumps. Heat pumps work by driving a working fluid around a refrigeration circuit containing four elements: evaporator, compressor, condenser and expansion valve. The working fluid evaporates as heat is absorbed from the heat source and then condenses again as heat is delivered to the distribution system. In warmer climates, the advantage of heat pumps is that they may be reversed and used for cooling purposes if required.

Heat pumps are very energy efficient as they consume a little in order to deliver three or four times as much energy as heat, depending on the operating conditions. Hence the running costs of a heat pump can be less than those of a traditional gas boiler heating system, but the main barrier to development of the heat pump market is the high initial capital costs of more conventional heating systems.

5.3.3.4 Renewable technologies (excluding biomass)

Renewable technologies could become increasingly important as an alternative to SCIs as governments promote technologies with no associated CO_2 emissions. Specific types of renewable technologies that may have an application include:

- Solar photovoltaics
- Solar water heating
- Wind turbines

The main issue around these renewable technologies is the high investment costs needed, which take many years to recoup. At present, the penetration rate of such technologies is low across non-industrial markets (although the rate of take-up does vary significantly across different countries). Renewables may become more feasible in economic terms in future years, particularly with various national initiatives promoting the use of such technologies (see section 6.2.8.6).

5.3.4 Other technical measures

Improvements to insulation were considered as abatement measures for the residential sector in a report by Peirce (2002), which constructed cost curves for a variety of pollutants. It was considered as a measure based on the assumption that if houses were better insulated, emissions would be reduced due to lower heating requirements. The costs of loft insulation, cavity wall insulation and double-glazing were considered (see Table 5.14), along with the numbers of household where improvements could be made.

Table 5.14 Costs of insulation and associated fuel cost savings

Measure	Installation costs (€)	Fuel costs savings per year (based on €540 annual bill) (€)
Loft insulation	385	93-108
Cavity wall insulation	655	93-108
Double glazing	4625 (for 10 windows)	23-54

Source: Peirce (2002). Cost data converted from GBP to €, adjusting GBP to 2003, and using 1.5 conversion factor

This measure was applied to the housing stock that used oil and solid fuels for water and space heating, and where improvements were deemed to be needed. A reduction of 20% across all emissions was considered to be the effectiveness.

The costs associated with such energy efficiency measures are not taken account of in air quality analyses, as they are generally considered to be measures that are already being undertaken (and funded through climate change policies). Therefore, costs and effectiveness are considered to be zero (Entec 2004a). However, there are good grounds for saying that much more could be done in this area. Effectiveness of insulation measures is shown in Table 5.15.

Table 5.15 Costs and effectiveness of insulation

Measure	Cost of measure (€)	Cost saving (€)	Carbon saving (MtC)	% Reduction in emission
Cavity wall insulation	440	141	1.9	
Low E Glazing	51	10	0.3	
Loft insulation	293	59	0.3	
Tank / pipe insulation	51	22	0.3	
Draughtproofing	125	15	0.1	
Total	960	247	2.8	7.1

Source: Entec (2004a)
NB. Cost data converted from GBP to €, adjusting GBP to 2003, and using 1.5 conversion factor

5.4 CONCLUSIONS

A range of technical measures has been considered in this section; their implementation will be strongly dictated by the emissions sources (described in section 3), and the type of fuel-technology profiles in each country (section 4). Based on these two factors, the best option on the basis of cost-effectiveness can be considered.

All technical measures cannot be compared in terms of cost-effectiveness, because they provide solutions for different problems, such as different pollutants, and different sized fuel based appliances. Table 5.16 below provides a basic overview of the different technical measures considered in this section, based on the fuel-based appliances to which they are applicable, with some broad indication of cost. Effectiveness will be largely dependent on the pollutant, the level of emissions, and the type of technology / fuel considered.

Table 5.16 Consideration of types of technical measures (and potential costs)

Type of fuel	Technical measures	Cost
Biomass (where PM / NMVOCs are key emissions)	Fuel switching (within biomass to pellets) Switching to new fuel-based appliance (gas) Add on technologies (catalysts, insets, accumulator tanks) Behavioural change (to improve operation)	High (due to costs of new appliance) High Medium Low
Solid fuels (where PM / NMVOCs are key emissions)	**Same as for biomass.** Switch to less polluting solid fuel Coal cleaning	 Low Very high
Gas (where NO_x is the main issue)	Switching to more energy-efficient boiler Other energy efficiency measures (better boiler sizing, improved insulation)	High Medium
Oil (for PM / NO_x and SO_2 emissions)	Switching to more energy-efficient boiler Other energy efficiency measures (better boiler sizing, improved insulation)	High Medium
All	Prospective / emerging technologies – fuel cells, renewables etc.	Potentially high

Costs will vary greatly depending on the specific country, investment issues (new central heating or just new boiler), the specific type of technology, and relative fuel costs. The effectiveness of the measure will also be dependent on the pollutant in question

For non-industrial emissions of NOx from natural gas consumption, potential reductions for these smaller units will mainly arise through energy efficiency measures. This may be problematic when defining policy options for this issue, as energy efficiency measures tend to be driven by climate change policies. Relevant energy efficiency measures are described further in section 6.2.8.

Technical measures for reducing emissions from industrial SCIs will include all of those listed for the above. However, the more cost-effective measures are likely to include the secondary abatement equipment that can be fitted. This is particularly the case with PM and NO_x. For SO_2, other than for very large plant, the main technical measure will be using fuels with lower sulphur content.

6 Policy measures to reduce emissions from small-scale combustion installations

6.1 INTRODUCTION

Emission issues relating to SCIs have been identified in Section 3, while sections 4 and 5 have provided an understanding of both the fuels and technologies used across Europe, and the technical means to reduce emissions from SCIs. This section of the report outlines the range of policy measures and non-technical measures that could be implemented to facilitate changes in the use of technologies or fuels, and as a result, reduce emissions from the pollutants considered under the Thematic Strategy.

A distinction is made between technical measures (as outlined in the previous section) and measures described in this section. Technical measures are the physical means by which emission reductions are realised, and include both preventative (fuel switching, appliance replacement) and abatement (treatment of flue gases) measures. This section focuses on the type of policy measures required to ensure or encourage the take up of technical measures, and also assesses potential non-technical measures aimed at changing the behaviour of consumers. A combination of policies and technical measures is usually required to meet emission reduction objectives although certain non-technical measures that impact on behaviour can of course work in isolation of technical measures.

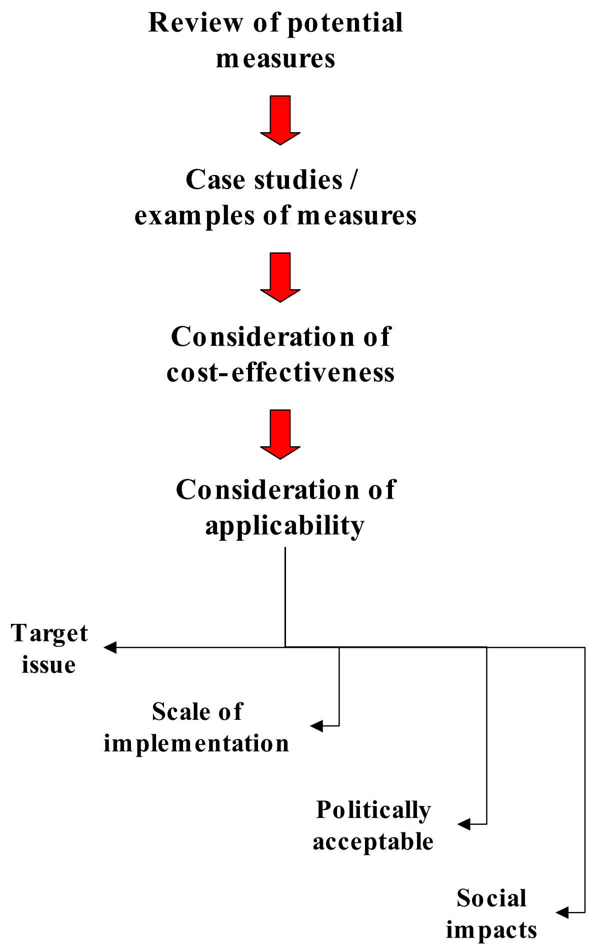
There are three important objectives for this section of the report. Firstly, there is a need to understand what action is being undertaken across Europe to abate emissions from small combustion installations, particularly PM. Secondly, it is important that such measures are broadly understood in terms of their costs and effectiveness in reducing air emissions. And finally, it is important to understand the applicability of each of the policy measures against the key issues identified in Section 3. These three objectives are represented below in Figure 6.1.

Determining cost-effectiveness of a policy measure is largely dependent on technical measures implemented, and based on the other country specific factors. This section provides (at the minimum) a qualitative understanding of cost-effectiveness. A more detailed quantitative analysis has been undertaken for the prioritised measures (as outlined in section 7).

In addition to cost-effectiveness, overall applicability of a measure need to be considered, and includes the following criteria (as highlighted in Figure 6.1):

- Target – is the proposed measure going to target the key pollutants and sectors?
- Scale of implementation – can the proposed measure be implemented at the European level, or is it only effectively implemented at a very localised level?
- Political acceptability – in the context of national legislative frameworks and energy markets, can such measures be realistically implemented?
- Social impacts – what are the potential social impacts on vulnerable groups within society?

Figure 6.1 Approach to determining policy actions for SCI emission reduction



The structure of this section is based around a 'typology' of measures, as outlined in Table 6.1. This typology illustrates the range of measures that we consider to be applicable for addressing emissions from SCIs. These measures could potentially be or have been used to reduce emissions from small-scale combustion installations. For each type of measure, examples of actual implementation are described through case studies, which are important to provide indicative data on the cost-effectiveness of a measure, and the potential issues regarding implementation.

An indication of 'acceptability' is also provided, which denotes whether measures are commonly used across Europe, using a ranking of high, medium or low (H, M, L). This may be a useful indicator to help determine the potential applicability of a measure across Europe. Measures have also been colour-coded to provide a broad indication of what sectors they are most applicable to – the sector categories are non-industrial, industrial and cross-sectoral.[16]

[16] It is recognised that there will be exceptions in this categorisation, with examples of non-industrial labelled measures applicable to industrial sectors, and vice versa.

Table 6.1 Types of measure considered for abatement of emissions from SCIs

Type of measure	Specific measure	Direct impact	Accept-ability
Product standards	Product standards (and ecolabels) and associated emission limits (voluntary and obligatory)	Increased development / manufacture of certain products to specified standards (product standards) and increased uptake of certain products by consumers on the basis of environmental criteria (Ecolabels)	**H**
Local-based measures	Area product / appliance ban	Reduction in use of specific fuel products / appliances in designated area	**M**
	Other measures e.g. reactive measures, appliance replacement, information campaigns	Reduction in emissions from various action taken through these measures	**M**
Fuel quality restrictions	Fuel quality restrictions, bans and voluntary agreements	Reduced or no sale of certain fuel products, based on fuel quality indicators	**H**
Site –specific restrictions	Emissions limit value or BAT approach	Emissions controlled by permitting in line with concentration limits	**H**
	Emission trading	Reduction in emissions encouraged through designating pollution as a commodity	**M**
Emission ceiling	Emission ceilings approach	Emission reductions through the setting of national emission limits	**H**
Environmental taxes	Emission taxes	Incentive not to emit on the basis that emissions can be taxed	**M**
	Fuel taxes	Incentive to reduce fuel consumption or consider alternative due to increased price	**H**
Financial mechanisms	Appliance subsidies / grants	Increase use of specific less polluting appliance(s) due to increased consumer demand	
	Fuel subsidies	Increase use of selected less polluting fuel(s) due to increased consumer expenditure	
	Structural funds	European funding of projects seeking to reduce emissions or that have associated benefits	**H**
Energy efficiency programmes / policies	Boiler efficiency standards	Reduced fuel use due to more efficient boilers / appliances	**H**
	Building standards	Improved insulation leading to lower energy demand	**H**
	Appliance inspection / maintenance obligations	Improved performance (efficiency / combustion) of appliances due to regular inspection / maintenance	**H**
	Grants, loans and subsidies	Increased consumer demand for more efficient appliances	**H**
	Energy taxes	Increase price of energy products to encourage lower consumption levels	**H**
	Promotion of renewable technologies	Increase take-up of renewables, thereby replacing other more polluting technologies	**M**
	Information campaigns	Helping reduce emissions by changing consumer behaviour through information e.g. on boiler operation or purchasing	**H**

6.2 TYPES OF MEASURES

Many of the measures implemented across Europe have been identified from reports on actions by countries under the National Emission Ceilings Directive, and from National Communications under the United Nations Framework Convention on Climate Change (UNFCCC). Two key programmes of research have been led recently by AEA Technology which have helped identify and summarise various measures – (1) review of proposed actions taken by countries under NECD as outlined in their submitted action plans (AEAT 2003) and (2) actions planned as outlined under National Communications and reviewed under the GHG Monitoring Mechanism (EEA 2003). Other information compiled in this section is from stakeholder consultation, literature review or in-house expert knowledge.

The measures highlighted in this section of the report have been the focus of discussion with the Commission / stakeholders about potential actions that could be considered under the Thematic Strategy, and provide the basis for prioritisation of measures and additional cost-effectiveness analysis. The following sections describe each measure in detail, focusing on case studies to describe the experience of implementation and provide some understanding of effectiveness and costs.

6.2.1 Product standards

Similarly to other sector technologies (large combustion plants, vehicles, etc.), emissions from small-scale combustion installations can be limited by specifying emission limits that manufacturers of products (e.g. boilers) have to comply with. Such limits may be introduced through:

- Product standards (and certification), which can either be voluntary or regulatory (covered in section 6.2.1.1)
- Ecolabelling schemes (covered in section 6.2.1.2)

Product standards are widely used across Europe, both by national standards institutions and at the European level by CEN (European Committee for Standardisation), and have been issued for a range of different types of appliance and boiler (as classified by size and fuel use). Standards issued by CEN are usually adopted by member national standards institutions, and become country-based standards. In terms of ecolabels, the European 'Flower' scheme exists but does not have a specific ecolabel for heating appliances. Established national schemes such as the German (Blue Angel) and Nordic (Swan) schemes, however, do cover a range of different heating appliance.

The above measures are generally aimed at products with thermal capacity of less than 300kW, and therefore are primarily relevant for residential and commercial (non-industrial) sectors.

6.2.1.1 Product standards (and associated emission limits)

This section provides an overview of product standards for a range of different appliances, both at the national and European level.

National –based standards
In most European countries, national standards have been introduced on a regulatory and / or voluntary basis. The focus of regulatory limits has been on appliances burning biomass-based fuels and other solid fuels, and has been driven particularly by the need to ensure health and safety standards, and in some instances, to reduce emissions of pollutants such as PM. Other standards relating to natural gas and liquid fuel based appliances are considered in section 7.3.1.

Many non-regulatory product standards are issued by country-based standards institutions, or are issued by the European standards body, CEN, and adopted as national standards. Such standards enable manufacturers to demonstrate that their products meet certain quality criteria, and at a European level, ensure fewer barriers to trade due harmonisation of product standards. These standards may also form the basis of regulatory controls, if a country deems that this is necessary. Table 6.2 lists a selection of national standards relating to different types of solid fuel / biomass combustion appliances used for space heating and hot water.

Table 6.2 Selection of national product standards relating to biomass and solid fuels

Country	Product standard
Germany	Germany has an Amendment of ordinance on Heating Systems (in force since June 1994) and Amendment of ordinance on Small Firing Installations (German Ordinance 1. BImSchV) (in forced since November 1996). This second ordinance lists fuels that may be used in combustion plant that are not subject to licensing, provides emission limits for CO, dust (solid fuels), soot (liquid fuels), and NOx, and outlines monitoring requirements for small combustion plants.
Switzerland	Swiss emission limits are defined by the Ordinance on Air Pollution Control (BUWAL 2000), and again cover small household boilers. Limits are provided for installations with thermal capacities greater than 20 kW that are wood-fired, and those that use coal, coal briquettes and coke. The limits shown in are essentially the same as those limits set under 1.BImSchV. Limits are also set for installations that use light and heavy fuel oils, and gaseous fuels.
Austria	Austria has emission limits for small wood-fired boilers. Energy efficiency requirements are also set out in this regulation (Oravainen 2000).
Norway	In Scandinavian countries, limits have also been introduced for wood burning appliances and boilers. Norway enforces regulations restricting emissions from closed wood combustion appliances (fireplaces and wood stoves). The limits are based on Norwegian Standard NS 3059, which limits maximum TSP emissions to 10g/kg (catalytic models) (average 5g/kg) and 20g/kg (non-catalytic models) (average 10g/kg) (CCME 2002). This regulation applies to all closed appliances produced after 1st July 1997.
Finland	There is no current domestic certification standard in Finland but one is planned for implementation between 2004-2006. It is planned that the standards, which include emission limits, are based on the European standards (EN 303-5 for boilers; EN 13 240 and EN 13 229 for stoves), and will be compulsory for new installations.
Sweden	Sweden has set specific emission limits in densely built-up areas in accordance with building regulations (BFS 1998:38). Solid biofuel boilers (<50 kW) have a limit of 150 mg OGC/m^3 at 10% O_2 while closed fireplaces have a limit of 250 mg OGC/m^3 at 13% O_2 (Sternhufvud 2004). These limits on organically bound carbon are essentially controls on PM.
UK	In the UK, the Clean Air Act places a requirement for type approval of combustion appliances if they are to be used in smoke control areas. The aim of the exemption is to provide assurance that appliances can operate smokelessly over a range of operating conditions. PD 6434 (British Standards 1969) sets out standards for residential appliances (<44 kW). Mean smoke emissions should not exceed 0.1 g/h for each 0.3 kW of mean heat output plus 5 g/h.
Netherlands	In the Netherlands, a mandatory and a more stringent voluntary certification scheme for wood burning stoves exist. The mandatory 'NL-mark' scheme sets limits to the carbon monoxide emissions of wood stoves under standard test conditions (DIN 18891/18895). For free standing stoves the limit is <0.4% CO at 13% O_2, whereas for inserts the limit has been set at <0.5% CO at 13% O_2. The voluntary 'VHR-mark' scheme applies the same limits for CO, but also demands a thermal efficiency of >60%.

Cross comparing the limits set out for different countries and those in CEN standards is difficult due to the different testing conditions, and the use of different metrics for emission limits. This is particularly the case for PM, where different testing conditions and definition of TSP has made agreement on limits difficult – such limits have not been included in CEN standards for smaller appliances, only in EN 303-5.

For smaller appliances, emission limits from various national based standards are set out in Table 6.3 below.

Table 6.3 Testing methods and emission limits for residential solid fuel burning appliances (<50kW)

Country	Standard	Status	Type of appliance	Emission limits (at 13% O_2)	Efficiency (%)
Germany	DIN (DIN 18891/A1)	Mandatory	Freestanding	< 0.4 vol% CO	> 70
	DIN (DIN 18895)	Mandatory	Inset	< 0.5 vol% CO	> 60
	DINplus Anforderung (DIN 18891/A1)	Voluntary	Freestanding	CO < 1500 mg/m3 NOx < 200 mg/m3 CnHm < 120 mg/m3 Dust : < 75 mg/m3	> 75 > 75 > 75 > 75
	DINplus Anforderung (DIN 18895)	Voluntary	Inset	CO < 1500 mg/m3 NOx < 200 mg/m3 CnHm < 120 mg/m3 Dust < 75 mg/m3	> 75 > 75 > 75 > 75
Switzerland	VHe-label (until 2003)	Voluntary	Open fire or inset Freestanding Continuous burning	CO < 1800 mg/m3 CO < 1800 mg/m3 CO < 1800 mg/m3	> 75 > 75 > 78
	VHe-label (since 2004)	Voluntary	Open fire or inset Freestanding Continuous burning	CO < 1500 mg /m3 CO: < 1500 mg/m3 CO: < 1500 mg/m3	> 78 > 78 > 83
Austria	ÖNORM 7520/H3014 (Art.15 a - fireplace ordinance)	Mandatory	Open fire Freestanding and inset	DIN DIN	> 78 > 70
Netherlands	NL-keur	Mandatory	Freestanding Insert	< 0.4 vol% CO < 0.5 vol% CO	- -
	VHR	Voluntary	Freestanding Insert	< 0.4 vol% CO < 0.5 vol% CO	> 60 > 60

Source: Nieuwejaers (2004)

Table 6.4 Boiler product emission limits (regulatory / voluntary) across Europe for TSP

Country	Mandatory limits / Voluntary standards	Feeding method	Fuel	Units	Installation size (kW) 15 – 50	50 - 150	150 - 500	500 - 1000
Germany	Mandatory	Manual or automatic stoking	Wood / solid fuel	mg/m3	150	150	150	150
Switzerland	Mandatory	Manual or automatic stoking	Wood / solid fuel	mg/m3	150	150	150	150
EN 303-5 -Class 1	European voluntary CEN standards	Manual or automatic stoking	Wood	mg/m3	200	200	200	-
EN 303-5 -Class 2				mg/m3	180	180	180	-
EN 303-5 -Class 3				mg/m3	150	150	150	-
EN 303-5 -Class 1			Solid fuels	mg/m3	180	180	180	-
EN 303-5 -Class 2				mg/m3	150	150	150	-
EN 303-5 -Class 3				mg/m3	125	125	125	-
Denmark	Voluntary	Manual stoking	Billets, pellets, saw-dust	ppm	300	300	300	-
		Automatic stoking		ppm	300	300	300	-
Poland	Voluntary	Advanced manual feed under-fire boilers	Solid fuels	g/GJ	120	120	120	120
		Advanced automatic feed upper-fire boilers		g/GJ	100	100	100	100
Austria	Mandatory	Manual or automatic stoking	Wood	mg/MJ	60	60	-	-

NB. These limits are considered in greater detail in section 7.3.1.

Table 6.5 Boiler product emission limits (regulatory / voluntary) across Europe for CO

Country	Mandatory limits / Voluntary standards	Feeding method			15 – 50	50 - 150	150 - 500	500 - 1000
German	Mandatory			mg/m3	4000	2000	1000	500
Switzerland	Mandatory	Manual or automatic stoking	Wood	mg/m3 %	4000 0.32	2000 0.16	1000 0.08	500 0.04
			Solid fuel	mg/m3	4000	1000	250	250
EN 303-5 -Class 1	European voluntary CEN standards	Manual stoking	Biofuel, Solid fuel	mg/m3	25000	12500	12500	-
EN 303-5 -Class 2				mg/m3	8000	500	2000	-
EN 303-5 -Class 3				mg/m3	5000	2500	1200	-
EN 303-5 -Class 1		Automatic stoking	Biofuel, Solid fuel	mg/m3	15000	12500	12500	-
EN 303-5 -Class 2				mg/m3	5000	4500	2000	-
EN 303-5 -Class 3				mg/m3	3000	2500	1200	-
Austria	Mandatory	Manual stoking	Wood	mg/MJ	1100	1100	1100	-
		Automatic stoking		mg/MJ	500	500	500	-
		Manual stoking	Solid fuel	mg/MJ	1100	1100	1100	-
		Automatic stoking		mg/MJ	500	500	500	-
Poland	Voluntary	Advanced manual feed under-fire boilers	Solid fuel	g/GJ	2000	2000	2000	2000
		Advanced automatic feed upper-fire boilers		g/GJ	1000	1000	1000	1000
Denmark	Voluntary	Manual stoking	Billets, pellets, saw-dust	ppm	5000	5000	5000	-
		Automatic stoking	Billets, pellets, saw-dust	ppm	1000	1000	1000	-

Table information

Austria: The CO emission of 1 100mg/MJ is equal to around 1700nm£, or 1,400 ppm calculated for 13% O2 content.
Source: Art. 15 a B-VG "Vereinbarung uber Schutzmabnahmen betreffend Kleinfeuerungen und Art. 15 a B-VG "Vereinbarunguber die Einsparung von Energie", November 1994".
Germany: CO limits apply to wood, while particles limits apply to both wood and solid fuels. Limit units expressed in mg/m^3 on dry gas, oxygen content being brought back to 8% in volume in case of solid fuels, and 13% in case of biomass.
Source: Umweltbundesamt (2001)
Switzerland: Emission for oxygen content (%) – 13% (up to 1 MW); 11% (above 1 MW)
Source: BUWAL (2000)
Denmark: The emission limits given are related to the type-approval and investment subvention system for boilers, which is voluntary. Small boilers are tested according to EN 303-5 standard, but the efficiency and emission limits for type approval differ form those in the EN standard, as described above.
Poland: Also limits set for SO_2, NOx and B(a)P
Source: Kubica (2004)

There is also experience of the use of emission limits further afield than Europe, particularly in North America, where again particles from wood combustion are of particular concern. In 1988, the US EPA introduced a standard restricting emissions of particles from wood burning stoves. The regulation sets out performance standards for new residential wood heating equipment, and included emission limits for particles of 4.1g/h (catalytic) or 7.5 (non-catalytic). In Washington, in 1993, more stringent limits of 2.5 g/h and 4.5 g/h were introduced (CCMCE 2002).

In Canada, the CSA standard B415.1 *Performance testing of Solid Fuel Burning Heating Appliances* outlines specific emission limits for various appliances (CCME 2002). It covers smaller appliances apart from site-built decorative fireplaces and fireplaces with a minimum burn rate above 5 kg/h. It was introduced to regulate appliances going into new installations, and to encourage the development of appliances that had better combustion technologies.

European standards
Standards are set at the European level by CEN, the European Committee for Standardisation, and are labelled EN. An EN standard is developed by a technical committee, and approved by CEN members. Based on this approval, national Standard bodies are then obliged to adopt the European standard as a national standard, and withdraw any pre-existing standards that might conflict. CEN members include all EU25 countries plus Switzerland and Norway. This consensual approach means that in theory a single European standard will be reflected across all member countries (CEN 2004). The main benefit of standardisation is that producers manufacture to the same quality and safety standards, giving consumers the choice of a range of quality-consistent products. CEN standards have been introduced for a range of heating appliances, including boilers and stoves (based on different fuels), and include emission limit requirements to differing extents.

Standards also take account of regulatory limits existing in Member States, which are more stringent than those specified in the standard. In such instances, a Deviation can be introduced, which sets out and stipulates that the regulatory limit is valid instead of that set in the standard.[17] These Deviations provide a useful overview of limits used in Europe, which are more stringent than those set out in the standard.

The main European-wide standard for setting emission limits for solid fuel small-scale boilers is the EN 303-5 standard (Heating boilers for solid fuels, hand and automatically stoked, nominal heat output of up to 300 kW), which was approved by CEN in November 1998. This standard covers solid biofuels (sawdust, pellets, chips, briquettes) and coal-based solid fuels (anthracite, lignite, coke, bituminous coal). Specific minimum energy efficiency limits are set for different classes of boilers, as well as emission limits for CO, organic carbon and particles. The emission limits are set out in Table 6.4 and Table 6.5, and are split into classes, against which appliances can be certified e.g. EN 303-5 Class 1.

For smaller appliances (<50kW nominal heat output), European standards for residential solid fuel and biomass burning heating installations have been prepared by Technical Committee CEN/TC 295 "Residential solid fuel burning appliances". The committee has published a series of EN standards for residential combustion of solid fuel as outlined in Table 6.6. The comparable category in the RAINS model has also been included.

Table 6.6 European standards for domestic appliances <50kW using solid fuel (inc. biomass)

CEN Standard	Description	Limit	Class 1	Class 2	Class 3	Class 4	RAINS Sector
EN 13229:2001 (hEN 13229:2001/prA 2:2003)**	Inset appliances including open fires fired by solid fuels	CO emission class limits (at 13% O2) % Efficiency class limits %	<0.3 (< 1.0) >70 (>30)	>0.3 <1.0 >60 <70	- >50 <60	- >30 <50	Residential-Commercial: Fireplaces
EN 13240:2000 (hEN 13240:2001/prA 2:2003)**	Room heaters fired by solid fuel	CO emission class limits (at 13% O2) % Efficiency class limits %	<0.3 (<1.0) >70 (>50)	>0.3 <1.0 >60 <70	 >50 <60	- -	
EN 12815:2001	Residential cookers fired by solid fuel	CO emission class limits (at 13% O2) % Efficiency threshold value %	<0.3% >75%	>0.3 <0.8% >70 <70	>0.8 <1.0 >65 <70	- >60 <65	Residential-Commercial: Stoves
EN 12809:2001	Residential independent boilers fired by solid fuel - Nominal heat output up to 50 kW	CO emission class limits (at 13% O2) %	<0.3%	>0.3 <0.8%	>0.8 <1.0	-	Residential-Commercial: Single house boilers (<50 kW) - automatic

Source: European Committee for Standardisation http://www.cenorm.be/CENORM/
**Standards (and associated values) in brackets are standards that have been harmonised under New Approach Directives – the values are 'threshold' values as opposed to limits.

A draft EN is also in preparation for wood pellets (prEN 14785/2003). There is currently no agreed EN test method for NOx, VOCs or particulates for installations <50kW nominal heat output, although CEN/TC 295 has begun a review of existing national test methods (see Table 6.7). CO limits have tended to be defined (as opposed to other pollutants) in these standards

[17] An example is the UK, which has emission limits for appliances used in smoke control areas under the Clean Air Act 1993 which are more stringent than those in the EN 303-5 – therefore, a Deviation has been incorporated to this effect, stating that those national based legal limits supersede what is in the standard.

due to health and safety concerns over carbon monoxide poisoning. In terms of emission limits, they are considered to provide a reasonable proxy of emissions from other pollutants.

Table 6.7 National test methods for NO_x, VOCs and particles

Parameter	Standard	Country	Fuel	Limits
NOx	15a-Vereinbarung (law) VDI 2456	Austria	All fuels	150 mg/MJ biogene 100 mg/MJ solid fossils
Dust	15a-Vereinbarung (law) VDI 3481	Austria	Solid fuel	10 g/kg
THC+OGC	15a-Vereinbarung (law) VDI 2067	Austria	Solid fuel	80 mg/MJ, manual 40 mg/MJ, automatic
Particles	NS 3058 and NS 3059	Norway	Wood	60 mg/MJ

Source: Nieuwejaers (2004)

A number of European standards also include oil and natural gas appliances, for which NOx limits are specified. This is clearly important, given the contribution of such fuels to emissions of NOx (both current and projected) in non-industrial sectors. These standards are considered further in section 7.3.1.

Use of product standards in a regulatory framework

European standards are currently being used to some extent within regulatory frameworks relating to legislation covering marketed products. In particular, under New Approach Directives, CEN standards can be converted into harmonised standards, and one of the means (through CE marking) of ensuring that the technical requirements of a product covered by the Directive are complied with.

This ‘New Approach’[18] covers a number of different Directives, which may specify certain legal requirements for specified products. The driver for such harmonisation of product standards under different Directives has two purposes; to ensure the free movement of goods through technical harmonisation of entire product sectors, and to guarantee a high level of protection for the public.

The conversion of the European standards EN 13229 and EN 13240 into harmonised European standards (hens, as shown in Table 6.6) is being done under the Construction Productive Directive 89/106/EC (CPD) (CEC 1989),[19] under Mandate 129 on Space Heating Appliances (in which essential product characteristic are identified as combustion emissions and energy efficiency). The CPD applies to any construction product, which is produced for incorporation in a permanent manner in construction works including both buildings and civil engineering works. Products meeting the essential requirement of this Directive will be eligible for 'CE marking' and may be placed on the market anywhere within the European Economic Area (EEA). Under the CPD the route to CE marking is by complying with the relevant technical specifications, as stated in the relevant associated harmonised standards.[20]

As part of the conversion of the standards, CEN/TC 295 (the relevant CEN technical committee) decided to replace classes of emissions (CO) and efficiencies with threshold

[18] http://www.newapproach.org/

[19] Another relevant Directive under the New Approach includes Council Directive 92/42/EEC of 21 May 1992 on efficiency requirements for new hot-water boilers fired with liquid or gaseous fuels, under which certain harmonised standards have been introduced.

[20] Two other routes exist for compliance under the Directive: 1) European Technical Approval (ETA) and through (2) recognised national standards.

values based on the least stringent class in the EN standards. Such threshold values provide the flexibility for countries to set limits within such thresholds (Nieuwejaers 2004). The technical committee found that using a class designation was not helpful because of the great variation in appliance types and national requirements. For example, if limits are set (rather than thresholds) that are less stringent than national requirements, this will cause difficulties for Member States because under the Directive, the limits in the Directive will take precedent. The amendments to ENs 13229 and 13240 to convert the existing "voluntary" ENs to harmonised standards have recently been voted on positively by the national members of the CEN, and were scheduled to be published in August 2004.

The introduction of standards under this New Approach demonstrates how voluntary CEN standards can be introduced as a means of compliance with mandatory requirements under relevant Directives, as illustrated by the EN 13229 and 13240 under the Construction Product Directive. A significant difficulty is creating a harmonised standard that uses the same emission limits as the voluntary standard.

The proposed Framework Directive on Energy Using Products (EuP) Directive could be a potential mechanism in the near future for the using product standards in a regulatory framework, and in the context of air quality policy, restricting emissions from certain appliances. The main aim of the this Directive, as stated in the proposal (CEC 2003), is to 'create a comprehensive and coherent harmonised Community framework for addressing eco-design[21] requirements' of energy-using products in order to:

- Ensure free movement of such products in the EU (as products meeting the same requirements can be sold anywhere based on harmonised rules)
- Improve environmental performance of these products and thereby protect the environment
- Contribute to security of supply and enhance the competitiveness of the EU economy

It is clear that by definition the type of smaller appliances considered in this study are covered by the scope of this proposed Directive (which does not stipulate the energy source of the product). Energy-using products will be covered under this if they meet certain criteria, the methodology for which to judge compliance is being currently developed, and based on an impact assessment if such a product was included (Papadoyannakis 2004).

As set out in Article 12 of the proposed Directive, the following selection criteria are proposed to determine which EuPs to include:

- The EuP shall represent a significant volume of sales and trade
- The EuP shall have a significant environmental impact
- The EuP shall have the potential for significant environmental improvement without entailing excessive costs
- Community environmental priorities (such as those set out in Decision 1600/2002/EC) shall be taken into account

This Directive has significant scope in terms of the numbers of products it could cover (although a list of products has not been developed at this stage), and in theory could include all smaller residential-commercial sector appliances considered in this study. It is probable

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

that the product standards developed by CEN, and the European eco-labels[22], will have an important role to play in setting out the specific product criteria, including emission limits. In a mandate to CEN (EC 2004c), the Commission ask that CEN draw up a programme of standardisation that will help realise the objectives of the EuP. This proposed Directive is based on the concepts of the New Approach (as described above), and therefore CEN standards are likely to be one of the available means of compliance with criteria set out in the associated Directives (under the EuP framework directive). In the mandate, one area (of relevance to this study) that CEN need to consider is emissions to air.

Summary
The above two policy mechanisms illustrate how product standards could be introduced into a more regulatory framework, and could help ensure that appliances being sold on the market within the EU met specific criteria, including emission limits. In particular, with the EuP Directive, impact assessments are likely to be undertaken for product groups, to determine what the costs of meeting product criteria will be, and the beneficial environmental effects.

The main costs of mandatory limits will be initially to the manufacturers, who will need to ensure that their products meet certain requirements, and get the product accredited to the relevant standards. Additional costs are likely to be passed to the consumers, as reflected in price increases of products that meet the standards set. Most countries have well-established standardisation and testing procedures, and therefore few additional costs are likely to be incurred in ensuring institutional capacity.

The effectiveness of mandatory limits will depend on two key factors – the limit that has been set, and this limit relative to the existing appliance stock (and associated replacement rates). If most of the existing appliance stock already meets the limits set for new appliances, the impact of the new limits will not be significant. However, if the stock has many older boilers, new appliances with associated limits could have a significant impact. The replacement rate of older appliances will also have a significant bearing on effectiveness of the measure.

Additional assessment of the use of product standards at the European level is undertaken in section 7.3.1.

6.2.1.2 Ecolabelling

The aim of ecolabelling is to provide information to consumers so that they can make decisions about purchasing products on the basis of information concerning environmental impacts. Eco-labelling is a voluntary scheme; its success will be dictated by whether industry recognises the label and foresee potential benefits, which will in turn be dependent on whether the label is more widely recognised. At present the EU ecolabel (known as the ‘Flower’) does not cover boilers and heating systems. Two of the main eco-labelling systems in Europe that have both a significant take-up and cover boilers and heating systems include the German scheme called Blauer Engel (‘Blue Angel’), and the Nordic Ecolabel scheme (with the adopted ‘Swan’ symbol).

Both the German Blue Angel and the Nordic Swan schemes have labels for a range of boilers and heating systems, as shown in Table 6.8.

[22] A product with an ecolabel license will be considered compliant in so far as the specific ecolabel meets the requirements of the implementing measure.

Table 6.8 Product covered by Swan and Blue Angel schemes

Blue Angel			Nordic Swan		
Heating Unit type	**No. of products**	**No. of companies**	**Heating Unit type**	**No. of products**	**No. of companies**
Atomising Oil Burners	59	21	Closed fireplaces for biofuel (Stoves)	0	0
Special Gas Boilers	19	9	Oil burner/boiler combinations	7	2
Combined gas burner and boiler units	0	0	Small heat pumps (Heat pumps)	0	0
Combined oil burner and boiler units	23	12	Solid Biofuel Boilers	4	2
Gas calorific –value heating devices	20	12			
Gas heaters and gas heating elements	10	4			
Gas burners, fan assisted	8	4			
Wood pellet boilers	3	3			
Wood pellet heaters	5	1			

Source: www.blauer-engel.de for Blue Angel Scheme; http://www.svanen.nu/ for Nordic Swan scheme.

Both labelling schemes lay down criteria for the boiler / heating units in order to gain the label. Specific criteria include product dependent emission limits, which are listed in Table 6.9 and Table 6.10.

Table 6.9 Emission limits for boilers / burners under the Blue Angel Scheme

Heating Unit type	NO_x (mg/kWh)	CO (mg/kWh)	HCs (mg/kWh) in operation	Soot (smoke spot number)
Atomising Oil Burners	120	60	15	0.5
Special Gas Boilers	70	60		
Combined gas burner and boiler units	70	60		
Combined oil burner and boiler units	110	60	15	0.5
Gas calorific –value heating devices	60	50		
Gas heaters and gas heating elements	100 / 130	80 / 60		
Gas burners, fan assisted	70	60		

Source: www.blauer-engel.de

There are currently ongoing discussions at the European level about the inclusion of a heating system eco-label under the EU Ecolabelling scheme. The ongoing prioritisation study (Oldman 2002) is considering heating systems (all systems which supply heat to buildings such as hot-air, radiators etc whatever the heat source for the purpose of heating the room space) and water heating systems (all devices or systems used to heat water including fossil fuels, electrical and solar systems). However, the paper does not list heating systems as probable for inclusion as a potential product group. It is likely that a feasibility study will be needed for this product group due to the complexities arising as a result of the number of potential heating systems that could be included (Dolley 2004).

Table 6.10 Emission limits for boilers / burners under the Nordic Swan Scheme

Heating Unit type	NO_x (mg/kWh)	CO (mg/kWh)	HCs (mg/kWh) in operation	Soot total
Oil burner	110	60	15	0.5
Oil burner/boiler combination	110	20	10	0.5

Heating Unit type	OGC (mg/m^3 at 10% O_2)	CO (mg/m^3 at 10% O_2)	Particles (mg/m^3 at 10% O_2)	Particles (g/kg fuel)
Solid biofuel boilers (<100 kW)	70	1000 / 2000 (Automatic / Manual)	70	
Solid biofuel boilers (100 –300 kW)	50	500 / 1000 (Automatic / Manual)	70	
Closed fireplaces (accumulating)*	180	2500		3
Closed fireplaces (manual feed)*	180	2500		<10
Closed fireplaces (automatic feed)*	55	250		<10

*13% O_2
Source: Nordic Ecolabelling (2003a, b, c)

The effectiveness of a scheme can be derived by trying to understand the change in consumer behaviour as a result of the introduction of the scheme. The resulting difference in purchases of standard boilers as opposed to ecolabel boilers will provide the basis for calculation of emission reductions. Indirect benefits are not so easily determined. Many manufacturers will specify that their products meet ecolabel requirements even though they do not have a license. Subsequent purchases by consumers may be made on the basis of this specification (Dolley 2004). Therefore, a low uptake of the ecolabel may not necessarily mean low associated benefits.

Costs will include setting up the scheme, which may involve a feasibility study, and will involve the criteria development for the specific product groups. Indirect costs will involve stakeholder participation at product working groups / stakeholder forums.

6.2.2 Local-based measures

Many air quality problems are specific to local geographic areas, particularly urban areas. The European Air Quality Framework Directive has set limits for a range of pollutants to ensure that local 'hot spots' are identified, and that action at the national and local level is undertaken to reduce exceedances. Often local action is considered most appropriate, as measures can be structured to take account of local conditions that are considered important in reducing emissions. The use and effectiveness of local measures is being considered in more detail in a separate study under the CAFE programme.[23] Local measures are also important to consider in the context of this study as a means of targeting emission problems arising from

[23] "Ex-post" Evaluation of Short-term and Local Measures in the CAFE Context (http://www.europa.eu.int/comm/environment/air/cafe/activities/expost_evaluation.htm#expost)

particular circumstances in specific locations, particularly if they are the most cost-effective means of reducing emissions.

PM has been identified as a key emission issue for non-industrial sectors. Across different European countries, emissions of PM are likely to be concentrated in specific geographic areas, and be a feature of the heating market and appliance stock of a specific locality or region. In this context, consideration of local measures is crucial.

A number of types of local-based measures are reviewed in this section, and include:

- Area-based bans on specific appliances or fuels
- Reactive measures to combat short term pollution episodes
- Appliance replacement
- Information campaigns

These measures tend to be implemented by local or regional authorities rather than national government or supra-national organisations such as the European Commission. However, the regulations governing the use of such measures might well be drawn up at national and higher levels.

6.2.2.1 Fuel product / appliance ban in specific areas

Product / appliance bans enforce restrictions on the use of certain types of fuel and / or appliance. The types of fuel that are most commonly targeted under such measures are solid fuels such as wood and coal. Such measures have led to significant reductions in emissions of pollutants associated with solid fuel burning such as PM_{10} and SO_2 (and PAHs), where such sources are significant. Such measures are often implemented at local level through powers granted by central government. Implementation of such a measure at the European level might not be considered feasible or appropriate; however the framework provided by Air Quality and National Emissions Ceiling Directives provide the impetus for action taken by national and local authorities. Such Directives offer flexibility in that they are not prescriptive concerning measures used, therefore enabling national authorities to implement local measures in a considered and appropriate way, to best target emission problems.

Two prominent examples of this type of local measure used in Member States include smoke control orders in the UK, under the Clean Air Act 1993, and in Republic of Ireland, the ban on the sale of coal in specific urban areas, most notably Dublin in 1990. A more detailed description of these measures is provided below, with additional assessment of their cost-effectiveness in section 7.3.2.3 of this report.

Belfast and the use of smoke control areas

In the UK, national legislation has enabled Local Authorities to declare whole or parts of districts in the authority area as smoke control areas (SCAs).[24] A smoke control order details the extent of the smoke control area, in which smoke emissions from the chimney of a building are prohibited. This means that burning of coal or wood (unauthorised fuels) is not permitted, unless done in an exempt appliance, as is the sale or purchase of unauthorised fuels to buildings in SCAs. The regulations also state that where an SCA order is made, appliances (that continue to use a restricted fuel) within the

[24] Further information on the use and location of smoke control orders in the UK can be found at www.uksmokecontrolareas.co.uk

SCA need to be adapted by owners to ensure the SCA order is not contravened (HMSO 1993).

Pye (2003) assessed the impact of solid fuel burning in the residential sector on emissions of PAHs and SO_2, and modelled the impact of smoke control areas (SCAs) on emissions. The effectiveness of SCAs was largely a function of the enforcement of local authorities and the compliance of residents within the SCA, and also the available substitute fuels. Central Belfast was assumed to have good enforcement, and therefore 10% non-compliance was assumed i.e. 10% of residents were thought to be burning coal or wood in non-exempt appliances. In areas outside of Belfast, non-compliance was assumed to be 30%. Effective enforcement is key for this measure, without which significant emission reductions are unlikely.

Vincent (2003) undertook an analysis of the costs and benefits of achieving PAH air quality targets, and estimated the costs of enforcing smoke control areas to be €18 (£12) per household inspected. This number was based on data provided by a District Council that had spent €35,646 (£23,764) on inspecting 1982 properties.

The costs of various options were considered for meeting the requirements of an SCA, including alternative heating systems:

- €2,990 (£1,995) for gas central heating system
- €2,960 (£1,974) for an oil central heating system

Switching from coal to an alternative solid fuel was the least expensive option (although a time period was not considered over which costs could be reduced due to the use of cheaper fuel, such as gas). Alternative solid fuels such as anthracite or solid smokeless fuel are generally more expensive than coal, but have better heating efficiencies (with higher calorific values) means the potential cost differential is small. The costs of oil and gas are much lower (due to end user price and more efficient consumption) but significant capital costs have to be borne initially when replacing appliances.

Vincent (2003) also considered the cost impact on the solid fuel trade although does not provide quantitative data. Impacts depend on whether there is a switch to other solid fuels from coal, or to different fuels such as oil and gas. McLoughlin (2001) provides a summary of the costs of implementing the smoke control area in Belfast. The average cost of house conversion is put at €752 – this is on the basis of having a permitted solid fuel appliance installed. It is noted that a grant of 70% may be provided by the local authority / government for this conversion, although no grants are paid for additional fuels costs that might be incurred. Administrative costs (enforcement etc.) are estimated to be €46 per household.

Sales ban on bituminous coal in Dublin
On September 1st 1990, a ban on the sale, marketing and distribution of bituminous coal was introduced to cover Dublin City and some surrounding areas, due to significant air pollution problems from the burning of coal for home heating. This case study provides a good example of how targeted local measures can significantly reduce air pollution levels, and an indication of the resulting costs and benefits.

During the 1980s, Dublin had significant air pollution problems due to the use of solid fuels for residential heating, which were much cheaper than oil. The government had provided grants for householders to put in solid fuel heating systems, in order to reduce reliance on imported oil, particularly after the 1970s oil crisis (APHEIS 2001). It was also mandatory for new houses to have open fireplaces fitted. Very high levels of black smoke were recorded, during the 1980s, particularly in winter, with maximum daily concentrations of black smoke reaching 1800 $\mu g/m^3$ in 1982 (Clinch 2001).

Clancy (2002) indicates that a 70% drop in black smoke concentrations resulted from the ban, with an average concentration of 50.2 $\mu g/m^3$ between 1984-1990, and an average concentration of 14.6 $\mu g/m^3$ after the introduction of the ban. Levels of sulphur dioxide also dropped by a third. The use of smoke free zones (as used in the UK under the Clean Air Act) had been attempted, with the introduction of a zone in one of the worst polluted areas. This was not particularly successful due to the difficulties of enforcement. The ban on sales was much easier to enforce as it targeted the supply of coal (APHEIS 2001).

The ban was extended to Cork in 1995 and in accordance with a commitment in "An Action Programme for the Millennium", it was extended to five additional areas in 1998 (Arklow, Drogheda, Dundalk, Limerick and Wexford). Regulations introduced in September 2000 (with effect from the 1st October 2000) further extended the ban to five new areas (Celbridge, Galway, Leixlip, Naas and Waterford).

Another example of fuel product restrictions can be found in Greece, where central heating systems in the urban areas of Athens, Thessaloniki and Salamina can only use oil or gas (MURE II 2004). In New Zealand, there has been a recent introduction (in 2004) of restrictions on the use of certain fuel products and appliances in Christchurch. New rules have been introduced using Clean Air Zones, which is similar to the UK's approach under the Clean Air Act. From 2006, the use of open fires has been banned, while solid fuel replacement heaters have to be approved appliances. Solid fuel burners installed before 1993 cannot be used after 2008. Assistance has been provided to help with the costs of conversion under the Clean Heat Project (Canterbury Environment 2004).

The costs of implementing a fuel product / appliance ban include:

- Enforcement costs of the authorities to enforce a ban
- Subsidies paid by local authorities (or national governments) for additional fuel or appliances costs incurred by businesses / residents
- Costs incurred by consumers of adapting appliances or switching fuels
- Loss of income for retailers due to reduced sales of prohibited fuels / appliances

The costs of enforcing such a ban will be dependent on whether the ban is on the sale of a fuel or appliance (Dublin) or on the use of a fuel / appliance (as in the UK). Enforcement of a sales ban is likely to be much cheaper as only monitoring of suppliers will be needed, not the monitoring of end users. The main costs to the implementing authority are likely to be through any grant scheme introduced to help consumers with compliance costs – the total level of costs would be driven by the number of claimants and level of grant available.

A measure like this can be extremely effective at targeting specific localised emission problems if of course burning of solid fuels (including wood) in SCIs is a major emission source. With the complete removal of a specified source, the effectiveness of this measure would be very high. The effectiveness of a ban, however, will be dependent on the levels of enforcement, and the ability of consumers to change to alternative fuels and appliances. It will also be dependent on the pollutant in question, and the type of fuels / appliances taken up as alternatives. The cost-effectiveness of this type of measure is considered further in section 7.3.2.

6.2.2.2 Local air quality reactive measures

If air pollution levels are particularly high in certain areas, on a diurnal or seasonal basis, local authorities can introduce measures that reduce concentration levels in the short term. This type of action seems to be more widely used in the road transport sector, although specific examples of reactive measures relating to the burning of wood in the residential sector include:

- Swedish environmental laws provide local authorities with the powers to prohibit residential combustion of wood at certain times (Sternhufvud 2004).
- In Oregon, certain areas have a traffic lights system – if air quality is good (green), wood heating is permitted; moderate air quality (yellow) requires that only certified wood stoves can be used; if air quality is bad (red), no wood stove can be used (CCME 2002).

The costs of such measures (without enforcement) are likely to be low. The primary cost will be in disseminating information about the implementation of a measure at short notice to the target population. Such measures can be effective in ensuring that high levels of air pollution are stabilised and reduced in populated areas. They will tend to be implemented in localised areas, take account of local conditions, and therefore scale of implementation will be restricted to local areas.

6.2.2.3 Appliance replacement

Another examples of a local measure is the introduction of appliance replacement schemes, which target emission reductions through replacement of the most polluting appliances. In the examples of such measures reviewed for this study, most of the schemes are run and funded by local authorities, who would incur the associated costs. Such schemes are again useful for addressing localised pollution problems, where the use of appliances (in non-industrial sectors) is considered to be a significant source of emissions. The structure of two UK schemes is described in the box below.

UK Appliance replacement schemes

Northern Ireland Housing Executive (NIHE) Heating Appliance Replacement Programme

A high proportion of the NIHE stock of social housing uses solid fuels for central and room heating. The NIHE have therefore introduced a programme to replace solid fuel appliances with gas (if available) or oil (NIHE 2000). The aim is to fit oil or gas boilers in 9000 houses per year, and remove all solid fuel appliances. Under this programme, there will be no solid fuel consumption in this housing stock by 2010. There are a number of drivers for this programme including improving air quality. These include improving energy efficiency, reducing fuel costs (for NIHE and consumer) and reducing levels of fuel poverty.

Alnwick local authority in UK – Heating Appliance Replacement programme

In the UK, local authorities have to designate air quality management areas (AQMAs) where exceedances occur of pollutants such as PM_{10} and SO_2. Due to high levels of residential solid fuel use in its AQMA, Alnwick District Council let a contract to convert its domestic housing stock to mains gas space heating. As this was the main source of SO_2 and PM_{10}, the UK air quality objectives for 2004 were predicted to be met (Alnwick District Council 2004).

ACT State Government (in Australia) has introduced (in 2004) a replacement scheme for wood heaters in Canberra, particularly due to the wintertime pollution problems. Households are eligible that are in a residential area of Canberra, and have a wood heater that is not compliant with Australian Standards. The scheme provides cash incentives to replace old heaters with cleaner heating forms e.g. electric installation (grant $400 or €233), or gas and solar installation (grant $600 or €349). Pensioners and low-income earners are eligible for an additional $200 (€116) payment.

Costs associated with this type of measure are clearly dependent on the number of households for which appliances are replaced. The effectiveness of the measure will be significant where highly polluting appliances are replaced by less polluting appliances, and therefore suitability will need to be judged by local authorities. The implementation of this measure at a regional or national level would be questionable from a cost-effectiveness perspective, as it would not differentiate between areas with recognised air quality problems and areas without.

6.2.2.4 Information campaigns

Information campaigns are used to provide consumers with information that changes consumer behaviour, and can lead to a reduction in emissions. This type of measure is often structured to reflect local needs, although is not exclusively a local-based measure, with national campaigns also being used. Campaigns may disseminate information:

- To optimise operation of an appliance
- On the best available appliances
- On financial schemes that provide loans for replacing appliances

Operation of appliances that use solid fuel or biomass can have a significant impact on emissions, particularly as many such appliances are manual feed and rely on the operator to select the type of input fuel. Operation of a open fireplaces is not as straightforward as often assumed, with many different factors affecting the combustion of fuel. The government of British Columbia has provided the following advice for burning of wood in stoves, in order to improve efficiency and reduce emissions.

British Columbia guidelines on wood stove operation **(BC Government 2002)**

- Burn seasoned, dry, split wood
- Run on high fire, 10 – 15 minutes after refuelling
- Don't reduce the burn rate too much
- Don't have overnight, smouldering burns
- Ensure good draft and proper chimney size
- Install sealed, double wall flue pipe from stove to chimney
- Circulate hot air away from stove area to rest of house

Information dissemination on good practice could be a very important means of educating the users of these appliances. Information on the environmental benefits (energy efficient or low emission) of different appliances could also help consumers in deciding what appliance to purchase when an existing stove or boiler needs replacement. Consumers are not necessarily aware of all the options available, and the potential energy savings.

The cost-effectiveness of such a measure is difficult to determine without extensive surveys of consumer actions. Costs are probably low as they would usually only require low levels of investment (development of web-based information, leaflets, printing instructions on bags of coal, etc.) and could probably be run using few staff. Holland (2001) notes that such measures 'could presumably be undertaken at minimal cost' though the 'impact of this on emission levels is not known'.

In terms of wood combustion, Sternhufvud (2004) notes that information campaigns can be a cost-effective way to reduce emissions if they can help inform how to burn wood in an appropriate way. All Nordic countries have information resources that provide information about burning wood in a way that minimises emissions of PM.

Table 6.11 Information campaigns in Nordic countries

Country	Application	Comments
Denmark	Information campaign in promoting the use of small-scale boilers and stoves, 1997.	Booklet published by the Centre for Biomass Technology "Small Woodstoves and Wood Boilers – an information Campaign FIRE AWAY" (1997).
Denmark	Danish Technological Institute	Danish Technological Institute has a homepage with different pieces of good advice in relation to the correct use of stoves.
Finland	OPET Finland	Part of EU Organisations for Promotion of Energy technologies (OPET). The main activities in small-scale wood combustion sector in Finland are public information campaigns and promotion of pellet markets in Finland.
Norway	Enova SF	Enova SF, government owned entity responsible for state efforts to bring about a shift in energy production and use: inter alias promotion of environment-friendly forms of energy production.
Sweden	Information papers on how to use boilers and stoves correctly.	Information provided by different municipals on how to use wood-burners in an efficient way.

Source: Sternhufvud (2004)

Natural Resources Canada provides information on ways to reduce emissions from residential wood burning (NRC 2004) through its *Burn It Smart* campaign. This campaign provides information on selecting lower emission wood burning appliances and on reducing emissions from existing appliances. Educational resources included:

- Website[25]
- Promotional materials
- Community workshops
- Household audits

Other educational materials are provided by the Lung Association's programme, *C.A.N DO, the movement for Clean Air Now.*[26] Canada Mortgage and Housing Corporation also provides materials on how to reduce indoor air pollution impacts from residential wood-burning appliances (Toronto Public Health (2002)).

[25] http://www.burnitsmart.org/
[26] http://www.lung.ca/cando/

Information campaigns will be most effective where a functioning market for alternative products is already in existence, and where information can help reduce the barriers to fuel/appliance switching by highlighting economic and health benefits.

6.2.3 Fuel quality restrictions

This type of measure covers restrictions on certain types of fuel and / or appliance use, and can be regulatory or voluntary in nature. For the purposes of this study, this type of measure has been classified as:

- Restriction on fuel products sold on the basis of quality criteria
- Ban of specific fuel products (NB. the Dublin coal ban is also relevant here, but is covered in section 6.2.2.1 on local-based measures).

6.2.3.1 Fuel content restrictions

Regulating the quality of fuels sold or purchased is demonstrated by the implementation of two European Directives – the Sulphur Content of Liquid Fuels Directive and the Directive 98/70/EC relating to the quality of petrol and diesel fuels. This second directive is relevant for the transport sector and therefore is not discussed in detail here.

The sulphur content of liquid fuels is Directive 1999/32/EC (CEC 1999) is specifically aimed at reducing SO_2 emissions from heavy fuel oil and gas oil. Heavy fuel oil is used in small industrial boilers and furnaces and is therefore relevant in the context of this study. Gas oil is used across all SCI sectors, including in the residential sector. The basic standards are limits of 1% sulphur content for heavy fuel oil, and for gas oil, 0.2% from 2001, and 0.1% after 2008. Many Member States specify this measure as important in meeting targets under the National Emissions Ceiling Directive (AEA Technology 2003).

Most measures relating to fuel quality identified in Europe restrict sulphur content of petroleum-based fuels e.g. gas and fuel oil, or solid fuels such as coal, and are therefore most relevant to SO_2 emissions. However, improving quality of liquid fuels, for example, may have additional benefits in terms of reducing other pollutant emissions e.g. PM. These additional benefits are considered in more detail in section 7.3.3.

An example of fuel quality restrictions on solid fuels can be found in the UK, in the Sulphur Content of Solid Fuel Regulations (1998) Northern Ireland (HMSO 2002) which ban the sale or delivery of any solid fuel with total sulphur content greater than 2%. This only affects the sale or delivery to private dwellings, and therefore is specifically targeted at the residential market.

Fuel quality based measures tends to be regulatory in nature, but can also be implemented on a voluntary basis. In the Republic of Ireland, an agreement was made between the Solid Fuel Trade Group and Minister of Environment and Local Government, to restrict sale and supply of fuel products on the basis of quality criteria. The agreement was the culmination of the consultation process on a proposed national ban on bituminous coal and petcoke (see section 6.2.3.2). It has two specific purposes: to reduce sulphur content of solid fuels and extend the ban on sale of solid fuels to additional urban areas. For petcoke, average and maximum limits on sulphur content were set, with limits getting more stringent every year (for three years). In 2005, the maximum content is set for 2%. For bituminous coal, the limit was set in 2004 at 0.7% maximum content (DOEI 2002).

The costs of this type of measure are likely to be borne by consumers, where additional costs incurred by manufacturers and retailers are reflected in higher product prices. Details on costs and effectiveness of measures to reduce content of sulphur fuel are provided in the section on technical measures (specifically section 5.3.2). Using fuel with lower sulphur content is considered to be relatively cost-effective due to the low costs compared to technical measures requiring significant investment costs e.g. new technologies. In this instance, the same fuel can be used, and therefore new technologies will not be needed.

No information has been found on the specific costs of the above measure. It is probable that the main costs of this type of agreement are going to result from the impact on retailers in reduced sales, as they will be subject to agreed restrictions. The costs to the consumer are probably going to be through additional costs of purchasing more higher quality solid fuels, and solid fuels permitted in coal ban areas, or switching to alternative fuels. Due to concerns over social impacts, the national authorities might have to meet some of these costs.

Overall effectiveness of this type of measure will depend on a range of factors. Firstly, the quality requirements (e.g. level of sulphur content) of a fuel will dictate the potential reduction. Secondly, the amount of these fuels used (with differing natural quality) in SCIs will also determine the resulting reduction in emissions. Based on the projections in RAINS (see Section 3), significant reductions in SO_2 have occurred as a result of the introduction of lower sulphur fuels through the transposition of the sulphur content of liquid fuels directive into national legislation, showing this measure to be highly effective.

6.2.3.2 Bans on specific fuel products

Although the use of such a measure is limited in European countries, a complete ban on certain fuels could be introduced at a national level on the basis that certain fuels contribute significantly to emissions of specific pollutants. Fuels that might be specifically targeted include petcoke (due to high sulphur content) or bituminous coal (due to associated particulate and SO_2 emissions, and other non-CAFE pollutants such as PAHs). Such bans would tend to be regulatory in nature.

The political feasibility of introducing such a measure at a national level will depend largely on domestic fuel markets, the availability and cost of alternatives, and proposed grants to meet additional costs. If the residential sector were wholly reliant on bituminous coal, it would be impractical to completely remove this fuel. The implementation of such a measure would need careful consideration based on national and regional fuel market characteristics (as outlined in Section 4). This type of measure does not appear to have been widely used across Europe, although in the Republic of Ireland, it was considered as a proposed measure but not fully adopted. The proposals are, however, considered in the text box below.

Proposed national ban on the sale of bituminous coal or petcoke in the Republic of Ireland

In 2001, the Irish Ministry of Environment (DOEI 2001) issued a discussion paper on the possibilities of a nationwide ban on petcoke and bituminous coal. A ban on coal is currently in place in many urban areas, including Dublin. This proposal would have extending the ban to more rural areas. The benefits listed in the consultation document included improvements to air quality, specifically reducing PM emissions (particularly $PM_{2.5}$) from coal burning and SO_2 from use of petcoke. Potential costs such as reduced market for solid fuel traders, increased payment in the smokeless fuel allowance and reduction in solid fuel options (particularly petcoke blends) were identified.

McLoughlin (2001) provides some analysis of this proposal. In particular, he notes that a ban on coal in more rural areas is not necessarily likely to have significant health benefits as particles are more easily dispersed, and population densities are lower. The more significant benefits of the wider ban could be that specified fuels could not be purchased, and used in urban areas (where it is illegal to buy but not to consume). A national ban of petcoke is predicted to reduce SO_2 emissions by 7000 tonnes (4% of current emissions).

McLoughlin (2001) outlines the potential costs to this proposed measure:

- An increase in the fuel allowance payments of up to €33 million per annum (€110 for 300,000 households).
- Many households would not be eligible for allowance payments, and can't afford investment costs involved in switching to oil and natural gas. It is estimated that this would be the case for 38% of households using solid fuel.
- Many households cannot switch to natural gas, as they are not in a gas distribution area, and are therefore restricted in terms of alternative fuel choices.

Another potential cost would be that 50% of fuel trade employees (1500) could lose their jobs.

The resulting action after the consultation was a negotiated agreement with the Solid Fuel Trade Group, as described in the previous section. Further restrictions were placed on the sale of bituminous coal and petcoke in certain areas; however, the ban was not extended nationwide.

The difficulties of implementing this measure are reflected to some extent by the fact that the proposal was not adopted. McLoughlin's (2001) analysis raises some interesting points concerning the implementation of this measure. For PM, the main benefits appear to have been realised by targeted bans e.g. in Dublin, currently implemented. However, if such local bans had not been introduced, the benefits of this action would clearly be significant, as shown for SO_2 reductions from a petcoke ban.

The introduction of a wholesale ban of fuels such as bituminous coal at the European level is likely to be extremely politically sensitive, and its introduction is not considered realistic. Political sensitivities might arise for the following reasons:

- Solid fuel use is in decline in many countries. A ban would have a significant impact on an industry that was experiencing economic difficulties.
- A ban would reduce the availability of fuels, and consumer choice. Equivalent (in terms of price) alternatives might not be readily available.
- A ban may have significant social impacts, forcing lower income groups to buy more expensive fuels or new appliances. The costs may have to be borne by national authorities.

More feasible might be the introduction of sale restrictions of certain fuels at the local level (in urban areas), or restrictions on the basis of fuel quality (similar to action taken by the European Commission targeting a reduction in the sulphur content of liquid fuels). Both of these types of measures are considered in other sections.

The main costs of this measure would be:
- Costs to consumers in adapting appliances or switching fuels
- Costs to the fuel trade sector, due to the loss of sales of banned fuel products

Costs to consumers could be offset in the medium to long term by potential savings through cheaper fuels or more efficient appliances. Enforcement costs would probably be low, as controls would be at the point of supply e.g. through checks on imports and manufacturers. This differs to geographic bans (either on sales or consumption), which would have significantly higher enforcement costs.

6.2.4 Site-specific emission control measures

Site-specific emission controls, including pollutant concentration limits and limits on annual emission totals, are primarily used for targeting emissions from larger installations, in the industrial and institutional sector. This group of measures includes traditional site-based regulatory inspection and maintenance, and flexible mechanisms, such as emission trading schemes. These approaches are not suitable for smaller sized installations (< 1 MW_{th}) due to being significant in number, and the large amount of resources that would be required for monitoring and enforcement. SCIs include large installations up to 50 MW_{th}, and therefore such a measure is relevant in the context of this study.

Two different types of mechanism are considered in this section:
- Installation specific emission permits, through a regulatory based approach
- Tradable emission allowances, operated through a market based mechanism

6.2.4.1 Site-specific emission permits

Site-specific emission permits are a means of controlling emissions from a single large source (usually industrial source) by regulatory authorities, and stipulate the maximum permissible level of emissions over a given period. This may be in terms of absolute emissions over an annual period or more commonly through specifying pollutant concentration limits. Specified limits on emissions, however structured, will mean that an operator of an installation will need to ensure certain levels of operating performance, and standards of technologies / fuels in order to meet such requirements, in order to avoid regulatory sanction. Such a measure also requires significant levels of resource input from the regulator, through monitoring and reporting to ensure that permit requirements are met.

There is no European legislation that specifically targets emissions from installations below the 50 MW_{th} capacity threshold, although there are a number of examples of national legislation across Europe, which have been introduced through domestic legislation. At the European level, larger industrial sites have been the focus of site-specific limits, primarily through the Large Combustion Plant Directive (LCPD), and Integrated Pollution Prevention and Control (IPPC) Directive.

The Directives reflect two different approaches to site-specific regulation. The IPPC Directive uses a BAT (Best Available Techniques) approach, specifying limits on the basis of what can be achieved for a specific site, considering factors such as cost and proportionality of necessary reduction techniques. The LCPD introduces an ELV approach where all plant are subject to the same emission limits regardless of site-specific factors, although an option is available under the revised Directive for a National Plan, that will allow pre-1987 plant to reach an equivalent reduction as a group.

National Legislation

Although not introduced at the European level, many countries in Europe have introduced emission limit requirements specifically for plant below 50 MW_{th}. France, Germany and Belgium have all adopted an ELV-based approach. In France, all combustion installations with thermal capacities between 2 and 50 MW_{th} are subject to specified emission limits. The arête of 25th July 1997 modified relating to small combustion installations (2 – 20 MW_{th}) specifies limits for NOx, SO_2 and dust (particles), and CO (250 mg/Nm^3) and NMVOC (50 mg/Nm^3) in the case of biomass use, and only for new installations. The limits, as set out in Table 6.12 below, are dependent on whether the installation is new (declared after January 1st 1998) or existing (declared before this date) and what fuel is being consumed.

Table 6.12 Emission limits for small-scale (< 20 MW_{th}) boilers in France

Fuels	SO_x	NOx		Particles		
		<10 MW	>=10 MW	<4 MW	>=4 MW <10 MW	>=10 MW*
Natural Gas	35	150 (225)	100 (150)	5		
LPG	5	200 (300)	150 (225)	5		
Gas oil	170	200 (300)	150 (225)	50		
Other liquid fuels	1700	550 (825)	500 (750)	150	100	100
Solid fuels	2000	550 (825)		150	100	100
Biomass	200	500 (750)		150	100	100

Limit units expressed in mg/m^3 on dry gas, oxygen content being brought back to 6% in volume in case of solid fuels, 3% in case of liquid or gaseous fuels and 11% in case of biomass. Bracketed limits are for older installations. All other limits apply to both old and new installations.
* For installations located in agglomerations of more than 250,000 inhabitants, the value is fixed at 50 mg/m^3.
Source: Arête of 20 June 2002 modified and of 30th July 2003 modified.

The French arrête of 20 June 2002 relating to the boilers present in a new or modified installation of a power higher than 20 MW_{th} sets emission limits for SO_2, NOx, dust (TSP), CO, NMVOC, PAH and heavy metals. The French arrête of 30 July 2003 relating to boilers in existing installations greater than 20 MW_{th} sets emission limits SO_2, NO_x, particles, CO, NMVOC, PAH and heavy metals. This legislation is important for covering predominantly industrial installations that would not be covered under the LCPD.

The Flemish government (in Belgium) has very recently set limits for combustion plant less than 50 MW_{th}, 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 MW_{th}, and these are detailed for solid fuel in Table 6.13. Limits also exist for liquid and gaseous fuels.

Table 6.13 Emission limits for solid fuels for installation between 300 kW_{th} and 50 MW_{th} under Flemish law

Plant type	Capacity (MW)	PM	SO_2	NO_x	CO
Existing	0.3 – 5	220 (200)	2000 (1250)	1100 (800)	250 (250)
	5 - 50	220	2000	1100	250
	5 – 20	(200)	(1250)	(800)	(250)
	20 – 50	(200)	(1250)	(600)	(250)
Permitted before 01/01/2005	0.3 – 2	100	2000 (1250)	500	250
	2 – 5	100	2000 (1250)	400	250
	5 – 50	50	2000	400	250
	5 – 20	(50)	(1250)	(400)	(250)
	20 – 50	(50)	(1250)	(400)	(250)
Permitted after 01/01/2005	0.3 – 5	100	1250	300	200
	5 – 50	50	1250	300	200

NB. All units in mg/m^3. Bracketed limits come into force after 31/12/2007. Where no brackets are observed, both sets of installation have the same limits.
Source: Flemish Government Legislation (Vlarem) (2003)

In many new Member States, emission limits currently exist under national-based legislation, and are set according to thermal capacity.

Table 6.14 Site-specific limits for new installation in the Czech Republic, Romania, Slovakia and Slovenia

Country	Thermal capacity (MW)	SO_2 (mg/m^3)			PM (mg/m^3)		
		Solid fuels	Oil-fired	Gas-fired	Solid fuels	Oil-fired	Gas-fired
Czech Republic	0.2 - 5	2500	< 1% S in fuel	35	250	100	10
	5 –50	2500	1700	35	150	100	10
Romania	<100	2000	1700	35	100	50	5
Slovakia	0.2 – 2	2500	-	35	250	100	10
	2 –50	2500	1700	35	150	100	10
Slovenia	1 – 5	2000	-	35	150	50	5
	5 - 50	2000	1700	35	50	50	5

Source: REC (1998)

The above limits generally only apply to new sources, except in the Czech Republic where the limits apply to all existing plant. Emission limits also apply to all installations over 0.2 MW in Poland under the Ordinance detailing Permitted Emissions from Combustion Processes, with limits set on the basis of type of combustion plant, fuel type and type of plant (REC 1998).

Some European countries regulate small combustion plant on the basis of a BAT (Best Available Techniques) approach, including Finland, Denmark and the UK. The emission limits applied to installation less than 50 MW_{th} in Finland are shown in Table 6.15 below.

Table 6.15 Emission levels (based on BAT) for small boiler plant in Finland

Fuel	Size (MW)	NOx mg/MJ	NOx mg/m^3	SO_2 mg/MJ	SO_2 mg/m^3	PM_{10} mg/MJ	PM_{10} mg/m^3
Oil	1-5	(40-60)*	(140-200)*				
	1-15			<240 (<270)	<800 (<900)		
	15-50			150- 180 (150-200)	500-600 (500-670)		
	1-50	15-40*	50-140*			<500	<1700
Natural gas	1-15			<100 (<120)	<340 (<400)		
	15-50			50-75 (60-90)	170-250 (200-300)		
Wood	1-5	100-130 (100-150)	250-325 (250-375)				
	5-10	50-100	125-250				
	10-50	20-50	50-125				
	1-50			100-150 (150-200)	250-375 (375-500)		
Peat	1-50	As for wood.		160-200 (200-250)	400-500 (500-625)	200-300	500-750
Solid fuel	1-50	20-40 (20-50)	55-110 (55-140)	100-150 (150-200)	275-415 (415-550)	<400	<1100

NB. Solid fuels emission concentration limits (peat, coal and wood) are based on 6% O_3 content of dry flue gas; oil and gas based on 3%.
* Emission limit values for light fuel oil is 15 mg/MJ (50 mg/m^3, O_2 = 3%) irrespective of plant size.

In the UK, combustion plant with a thermal capacity greater than 20 MW can be regulated as Part B processes by local authorities under the PPC regulations. The guidance provided by the DEFRA (2004e) on regulation of 20 – 50 MW_{th} plant sets out the following emission limits:

Table 6.16 Emission limits (mg/m^3) based on guidance note for combustion plant (20 – 50 MW_{th}) in the UK (under PPC regulations)

Fuel	NOx	SO_2	PM_{10}	CO
Solid fuel	450 (500) - 650	2000 - 3000[3]	300	150
Liquid fuels (Residual fuels e.g. heavy fuel oil)	450 (600)	1700[2] - 3000	150	150
Liquid fuels (Middle distillates e.g. gas oil)	200 (300)		100 (150)	150
Natural gas	140 (200[1])	35	5	100

NB. For plant operational prior to September 1995, the limits are the same as those operational after this date unless a bracketed limit exists, which is then applicable. O_2 content is thought to be 11% across all limits
[1] This limit was only applicable until 1.1.2003
[2] This limit is used from 1.1.2003 (due to the Sulphur Content of Liquid Fuels Directive)
[3] Limit of 2000 is for non-indigenous coal; 3000 is for indigenous coal

However, few installations will be covered on the basis of their combustion processes – it is much more likely that some combustion installation will be deemed to be associated with a process covered under IPPC, and regulated as part of the installation. This extent to which IPPC covers combustion installation less than 50 MW_{th} is considered in detail in section 7.3.4.

A broad summary of the emission limits for the countries outlined in this section is provided in section 7.3.4.

European Legislation
At the European level, two key legislative instruments are the primary basis for traditional industrial regulation – the Large Combustion Plant Directive (LCPD, EC 2001 - which revises the original 1988 Directive.) and the Integrated Pollution Prevention and Control (IPPC) Directive (EC 1996).

The LCPD targets a reduction in emissions of SO_2, NOx and PM by setting with ELVs (emission limit values) for new installations (post-1987) with a thermal capacity exceeding 50 MW_{th}. For pre-1987 licensed plant, national governments can use ELVs specified in the Directive or derive different limits on the basis of a national plan. The National Plan is a more flexible approach, which allows a group of plant to reduce emissions equivalent to if ELVs had been applied. This Directive obviously has no impact on SCI emissions due to the threshold set at 50 MW_{th}. However, this ELV approach has been adopted in different countries across Europe for installation less than 50 MW_{th}.

While the LCPD specifies ELVs across all installations, the IPPC Directive looks at potential emission reduction through assessment of Best Available Techniques (BAT). European BREF notes for different processes outline what best available techniques (including technologies) should be considered. Emission limits are set on the basis of BREF guidance but also consider the costs and proportionality of the effect of abatement on a site-by-site basis.

The scope of the IPPC Directive is not defined on the basis of thermal capacity (although in terms of combustion processes, most plants are large) but predominantly on a sectoral basis. The exception is for combustion processes, which, if greater than 50 MW_{th} on an aggregated capacity basis (more than one combustion unit), can be regulated under IPPC. If the installation comes under the scope of the LCPD, the associated ELVs would be the minimum requirement in terms of limits. A certain proportion of combustion plant with a thermal capacity less than 50 MW_{th} will be regulated under the IPPC Directive where they provide energy for regulated processes and are defined as part of the installation as 'directly associated activities.'

A European wide measure that introduced site-specific permits for combustion installation less than 50 MW_{th} could be introduced either as a new Directive, or an extended IPPC or LCP Directive. There are three ways that existing permitting mechanisms could be amended to increase coverage of existing installation:

1. Reducing the 50 MW_{th} threshold in the LCP Directive
2. Reducing the 50 MW_{th} threshold in the IPPC combustion process category
3. Increasing the sectoral coverage of IPPC by reducing the sector thresholds (with new BREF guidance for smaller plant).

Additional coverage of industrial installation through the introduction of a new measure needs to be considered carefully for the following reasons.

- 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.

- Enforcement and administration costs for the regulator are not going to differ significantly between a 40 MW_{th} plant and a 15 MW_{th} plant. Therefore, these costs relative to emission reduction potential are likely to be higher for smaller plant.
- Compliance costs for larger plant (40 –50 MW_{th}) will probably not be significantly greater than for plant (10 – 20 MW_{th}) e.g. 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.

For policy makers, emissions reductions will tend to be targeted where they are least cost. This is primarily why larger industrial plant has been targeted, and smaller industrial plant have not. A key question in the context of this study is where the threshold should be set in the 0 – 50 MW_{th} range. The above issues are considered further in section 7.3.4.

6.2.4.2 Emission trading schemes

A more flexible mechanism is to set installation specific limits or targets, and allow operators to meet their target 'in house' by reducing their own emissions below their target and sell or bank the excess emission allowances, or let their emissions remain above their target, and buy emission allowances from other participants. A trading scheme mechanism ensures an overall reduction in emissions is achieved to meet a sector or economy wide target but enables market flexibility as a means of achieving it. In theory, the use of active markets for emission trading of permits should provide the most efficient and cost-effective way of delivering emission reductions.

The best strategy for any individual organisation will depend on the price of allowances in the market compared to the costs of making emission reductions. In theory, this leads to emission reductions across the scheme at least cost because those organisations with lower cost emission reduction opportunities will tend to sell allowances to those with higher cost options. This does, however, require that organisations are aware of the options open to them, and regularly review the situation – European regulation demonstrates many cases where such awareness has been poor. It also requires emission allowances to be withdrawn from the market year on year at a rate that encourages innovation.

Such schemes tend to be targeted at the industrial sector but can also cover large institutional installations e.g. hospitals. Some key examples of emission trading schemes exist, namely the US SO_2 trading scheme, the UK pilot carbon emissions scheme, the Danish GHG pilot scheme and the new EU wide GHG scheme. An outline of these different schemes is provided below.

Emission trading schemes in the US, UK, Denmark and Europe

UK

The UK emission trading scheme is the world's first economy-wide greenhouse gas emission trading scheme. 31 organisations ('direct participants' in the scheme) have voluntarily taken on a legally binding obligation to reduce their emissions against 1998-2000 levels, delivering an estimated 4 million tonnes of additional carbon dioxide equivalent emission reductions (per annum) in 2006 (DEFRA 2002).

Administrative costs to the UK government will be in the region of €199 to €282 (£129 to £183

(GBP)) million, primarily due to the provision of financial incentives to join the scheme, but also through consultancy and resource time. Costs to participants include the need to purchase abatement equipment, verification costs, legal costs, consultancy and staff resources. Costs have been estimated in the region of €196 to €279 (£127 to £181 (GBP)) million.

Denmark
In January 2001, Denmark launched the world's first national GHG emission trading program. Trading is undertaken within the framework of a (mandatory and closed) cap and trade system covering CO_2 emissions only. The system was designed and is run by the Danish Energy Agency. The trading system is subject to change, according to the results of the three-year pilot project. It is limited in nature, covering only eight firms, all within the electricity generation sector, but covers more than 90% of the total CO_2 emissions from the sector (smaller generators are exempt). Overall, it covers approximately 30% of total Danish GHG emissions. The electricity sector is the only GHG emitting sector that is not subject to the carbon taxes and energy efficiency measures that are widely applied throughout Denmark's economy (see above). The emission trading system covers the period 2000-2003. The system sets total quotas for CO_2 emissions from electricity production, introduces emission allowances for the individual power companies and allows for emissions trading and banking. The CO_2 Quota Act lays down a total quota for electricity production of 23 million tonnes in 2000. This is reduced by 1 million tonnes per year, to reach a quota of 20 million tonnes in 2003 (Watkiss 2003).

EU
The European Union agreed to the EU Emissions Trading Scheme in 2003 (EC 2003), with all installations with a net thermal capacity greater than 20 MW eligible to participate. This means that many small combustion installations could potentially be included in this scheme, primarily from the industrial sector, but also from the commercial-institutional sector (hospitals, etc.). The costs and effectiveness of this scheme will differ according to the country of implementation. However, it is clear that such a scheme will include installations within the scope of this study, and is likely to have an impact on emissions of air pollutants.

US
In the US, the Sulphur Dioxide trading scheme was initiated as part of the Acid Rain Programme introduced as the fourth amendment to the 1990 Clean Air Act. Phase I of the scheme, applying to the largest electricity generating plants began in 1995. Phase II of the scheme began in 2000, and brought smaller power generating units into the scheme. The trading scheme uses allowances that each permit emission of one ton (US) of SO_2 from an individual plant. Allowances are allocated among SO_2 sources based on emission performance standards and representative fuel use. Plants must have enough allowances to cover their annual emissions, which are measured by EPA-certified equipment at power plants. Unused allowances may be sold, traded, or banked for future use. There was a fall in SO_2 emissions from 11.87 million tons in 1995 to 10.6 million tons in 2001. The cap for 2010 is set at 8.95 million tons. The scheme has demonstrated the benefits of using an instrument with a defined environmental outcome – in terms of emission levels - but one that leaves decisions to plant operators on how to determine the most economically efficient method of emission reduction. The US Sulphur trading scheme has resulted in cuts of over 50% between the schemes inception in 1990 and 1999. In 1999, the scheme was extended to an increased number of sources (USEPA 2002). A NO_x trading scheme with a similar structure to the SO_2 trading scheme was established in 1999, but data on this are limited at present.

The specific costs of implementing this measure include those associated with setting the scheme up, administrating the scheme, and monitoring the emissions of participants to ensure compliance. The actual costs of reducing emissions under this scheme should be as low as the market rate for emission allowances dictates, as operators of installations that deem traditional abatement measures to be too expensive can purchase additional emission permits. This is one of the benefits of such a mechanism as opposed to the regulatory approach, though note the caveats given above concerning knowledge of control measures and promotion of innovation through the rate at which allowances are withdrawn. Depending on the market costs of a pollution allowance, an operator may be able to realise a negative cost, through reducing emissions at a lower cost than what any surplus can be sold for.

The effectiveness of a trading scheme will ultimately be dependent on the level at which emission levels are capped, and the level of participation within a given scheme. The applicability of an emissions trading scheme to smaller SCIs may be prohibitively expensive given the large number of installations and the lower relative emissions per participant. This is likely to make transaction costs prohibitive. Emission trading across a range of pollutants could cover the larger SCIs, which already fall into schemes such as the EU ETS.

In the context of this study, new emissions trading schemes are not considered in detail. However, it is clear that trading of air quality pollutants is possible, and could be set up in a similar way to the EU ETS.

6.2.5 Emission and fuel taxes

There are two types of taxes that can be introduced to target air pollutants – taxes on fuel (to increase prices and discourage excessive consumption) also known as consumer taxes, and taxes directly imposed on emissions (to encourage take-up of technical measures to reduce emissions). An obvious example of a fuel tax in the road transport sector is the duty imposed on petrol and diesel to encourage lower levels of consumption.

The setting of taxes is of key importance in order to ensure low costs and high effectiveness. In economic terms, an environmental tax should be set at the optimum level, i.e. the point at any given time, when the marginal abatement cost and marginal social damage cost (or benefits of abatement) are equal. Environmental taxes are considered more equitable and efficient than other types of regulatory measure, and can lead to ‘double dividends’ – reduction in emissions at the same time as reduction in labour tax burden.

Taxes are a national policy instrument and are not considered any further as a measure for implementation at the European level. However, they are useful to consider in the mix of measures described in this section. Under the NECD, the type of policy measures adopted by national governments is decided independently of the Commission. Therefore, consideration of measures such as taxes that will not be implemented at the European level is important, as they might be introduced based on a ‘framework’ (such as that set by the NECD) that has been implemented at the European level.

6.2.5.1 Emission taxes

An emission tax or charge is a regulatory measure that can be levied directly at emissions from an installation. This mechanism works on the basis that operators will reduce emissions to reduce charges imposed by the regulator. Such a measure is probably only applicable to larger installations considered in this study, in the industrial and institutional sectors. This is because such a measure is implemented on a site-by-site basis; and would be unfeasible to implement in a sector where there were large numbers of smaller installations. There are examples of other emission taxes from across Europe and further a field. A summary of known emission taxes are summarised by Watkiss (2003) in Table 6.17.

Table 6.17 The use of emission taxes in Europe (and Australia)

Country	NOx / SO_2	Tax description*	Tax rate	Revenues US$ million
Czech Rep.	NOx / SO_2	Air Pollution Fee - emissions from stationary plant	800 CZK (€ 23.5) /tNOx 1000 CZK (€ 29.3) /tSO_2	19.1 (2000) (Combined revenue – all air pollution fees)
France	NOx / SO_2	NOx tax applying to power plants over 20 MW and Waste incineration plants with a combustion potential over 3 t/hr, plus sites exceeding 150 t/year of SO_2, N_2O, NO_x, NMVOC	€ 45.73 per tonne NOx. € 38.11 per tonne SO_2	€ 10.3Mn (1997)
Italy	NOx / SO_2	Tax on NOx emissions from large combustion plants over 50 MW capacity and exceeding emission standards set out in EC Large combustion plants Directive	€ 104.8 /tNOx 53.2 € /tSO_2	63.3 (1999) – includes SO_2 tax
Sweden	NOx	Tax on NOx emissions from plants producing over 25 GWh/year	SEK 40/kg NOx (€ 4.3/kg NOx)	58.9 (2001)
Australia	NOx / SO_2	Load-based licensing scheme, New South Wales only – emissions from stationary plant	Unit cost varies, depending on area-specific threshold and level of emissions relative to this threshold	17.4 (2000) (combined SO_2 and NOx tax)

Source: Watkiss (2003)

In Sweden, a charge on emissions of NO_x was introduced in 1992 through the NO_x Act, which targeted emissions from power generation plants. The threshold set was boilers with a useful energy production of at least 25 GWh per year. Based on an estimated abatement cost between 3 and 84 SEK/kg of NO_x, the emission charge was set at 40 SEK /kg (approximately €5). In 1999, the administrative costs of the scheme (covering about 250 plants) for the Swedish Environmental Protection Agency were about €413,000, representing about 0.6% of the total charge amount. Present investment costs for equipment are estimated to be between €30,000 and 36,000, while operating and administrative costs were on average €12,000 per site. The measure has been reasonably successful, with reductions between 20 and 37% (Naturvardsverket 2000).

The Czech Republic has recently implemented a comprehensive direct taxation system for NOx and SO_2. Air emission charges have been in force in the Czech Republic since 1992, applying to NOx, SO_2 and other air pollutants (including PM and CO). The system differentiates between two source categories – thermal units above 5 MW, and important technologies (e.g. coke, steel) and thermal units of between 0.2 and 5 MW, and other technologies. The rates of the tax are set in relation to the damage to the environment caused by each pollutant, and are the same for each source type (Hajek 2000).

There is a range of different costs associated with the implementation of such a measure. These may include:

- Direct costs to the operator (which will be dependent on the level at which taxes are set)
- Costs of monitoring and verification incurred by the operator

- Enforcement and monitoring costs (borne by the regulator)
- Recycling revenues back to industry

The main costs will be dependent on the cost of technical measures (as outlined in the previous section) that operators will need to implement. The overall effectiveness of this measure will be driven by the number of operators covered by a charging regime, and the level at which a charge is set.

6.2.5.2 Fuel taxes

Taxation on the consumption of fuels (to reduce air emissions) has been specifically targeted on sulphur content of fuels. Other energy taxes have also been introduced but have been introduced as part of climate change policy – such taxes are covered in section 6.2.8.5. Some examples of taxes on sulphur content of fuels are provided in Table 6.18.

Table 6.18 European taxes on sulphur content of fuel

Country	SO_2 tax	Sulphur in fuel tax	Tax description	SO_2 tax rate	Revenues US$ million
Denmark	No	Yes	Tax on all fossil fuels containing sulphur	DKK pr kg SO_2 emitted to the air (€ 1340/tSO_2)	26.4 (2000)
Sweden	Yes	Yes	Sulphur content of fuels (all fuels)	27 SEK (€2.9) per m^3 per 0.1% sulphur content for oils. 30 SEK (€3.2) per kg S content for solid fuels	8.0 (2001)
Norway	No	Yes	Sulphur content of fossil fuels (all fuels)	NOK 0.028 (€0.0087) per litre and 0.25% sulphur content	14.3 (2000)

Source: Watkiss (2003)

The taxes in Norway and Sweden relate directly to the sulphur content of fuel and therefore represent a value for each unit of SO_2. The values are € 0.0087 per litre and 0.25% sulphur content (Norway) and 2.9 Euro per m^3 per 0.1% sulphur content for oils and €3.2 per kg S content for solid fuels (Sweden). The Danish SO_2 tax is charged at a much higher rate than anywhere else. The revenues from the SO_2 tax in all of the countries are significant but not large – i.e. only up to 0.02% of total annual tax revenue (Watkiss 2003).

The costs of this type of tax are going to be borne by consumers (in the same way that petrol taxes are incorporated into consumer prices). In this respect, it is important that taxation schemes take account of consumers who may have difficulties meeting additional price increases, and the availability of reasonably priced alternatives. The effectiveness of the scheme will be dependent on behavioural change of consumers, which will in turn be determined by the level at which a tax is set.

Much of the reduction in SO_2 modelled in the CAFE baseline projections are due to significant reductions in the use of high sulphur content of fuels. However, higher taxes on other types of polluting fuels could be considered, or revised taxes that are set to drive down sulphur content of fuels even further.

6.2.6 Financial mechanisms

6.2.6.1 Grants / Subsidies

The purpose of a subsidy or grant is to reduce the cost of purchasing a specified appliance or boiler. Newer and less polluting or more efficient appliances or boilers on the market for the residential sector, such as condensing boilers, may be significantly more expensive than standard appliances / boilers. A subsidy to reduce costs of such technologies to parity with others on the market is a mechanism through which the uptake can be increased. A grant provided for specific purchase of a less polluting technology similarly increases affordability of such a product. This measure is often targeted at lower income groups who might not be able to afford replacement of boilers / appliances (even if subsidised) due to the initial capital costs.

Subsidies and grants have been widely used for the promotion of energy efficiency appliances and are considered again in this context in section 6.2.8. The costs of providing such financial assistance are likely to fall on the organisations that are providing the grant or subsidies, such as central, regional or local government. The effectiveness of such schemes is very difficult to quantify, in terms of emission reduction, unless data are available on uptake of targeted appliances as a result of the scheme. If such schemes encourage switching to less polluting appliances, they can be very effective in reducing emissions.

Sternhufvud (2004) outlines the use of subsidies in Nordic countries in relation to residential wood burning appliances. Sweden and Denmark do not have any subsidy schemes (although a scheme was run between 1995 and 2001). Norway and Finland have introduced subsidy schemes to promote the take-up of lower emission wood burning appliances – these schemes are described in Table 6.19 below.

Table 6.19 Subsidies used in Norway and Finland (targeted at residential wood burning)

Country	Application	Comments
Finland	Subsidy to exchange current heating system to low emission pellet boiler.	15 % of the investment cost, applied only for buildings with 3 or more apartments, i.e. in practise only semi-detached houses and apartment buildings.
Norway	Subsidy to exchange high emission domestic stoves.	Campaign, e.g., in Oslo in 1999-2000: Offer of €483 (NOK 4,000) to exchange old, high emission stoves by new ones; now fixed offer of €181 (NOK 1,500).
Norway	Financial support/subsidy to project founding.	Enova SF (government owned entity) supports projects dealing with renewable energies: respective projects may receive grants equivalent to 15 to 20% of project costs.
Norway	Mortgage loan / grant to house builders.	The Norwegian State Housing Bank offers an extra €16,910 (NOK 140,000) as mortgage loan and €1210 (NOK 10,000) as a grant to house-builders who intend to invest in alternative forms of energy solution (including use of bio-fuel).
Norway	Tax exemption.	Investments in several renewable energy sources have been exempted from tax (7% investment tax).

Source: Sternhufvud (2004); Converted from Norwegian Krone (NOK) to € based on ECB[27] exchange rate of 8.28.

[27] European Central Bank exchange rates http://www.ecb.int/stats/exchange/eurofxref/html/index.en.html

An example of the use of grants in tackling emissions from wood burning appliances can be found in Canada, where 'change-out' programmes have been implemented through a collaborative effort between government and industry (Toronto Public Health 2002). The public have been encouraged to upgrade their wood-burning appliance (fireplace or stove) to a cleaner appliance, such as a CSA/EPA-certified wood stove or fireplace. Such appliances are US$ 500 –700 more, and therefore a financial incentive is required. Operating costs are of course lower due to higher efficiencies and reduced wood consumption.

The use of subsidies and grants are measures that can be considered at a national or sub-national level but are unlikely to be considered at the European level.

6.2.6.2 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. They are included in this section as a potential means of funding projects that would have significant benefits for air quality through reducing emissions. An example might the granting of Structural Funds to help build a gas pipeline extension, which in turn could lead to increased use of gas and reductions in the use of more polluting fuels e.g. coal.

There are four main Structural Funds:
- The European Regional Development Fund (ERDF)
- The European Social Fund (ESF)
- The guidance section of the European Agricultural Guidance and Guarantee Fund (EAGGF)
- The Financial Instrument for Fisheries Guidance (FIFG)

94% of the funding from Structural Funds (in the 2000 – 2006 programme) is currently concentrated on meeting three priority objectives, focused on regional development:
- Objective 1 – Assist regions whose development is lagging behind other member state regions (per capita GDP does not exceed 75% of the Community average).
- Objective 2 – Assist regions that are facing structural difficulties, due to significant social or economic changes.
- Objective 3 – Modernise systems for training and promoting employment.

In addition to priority objectives, funding is also available through community initiatives including:
- EQUAL - focusing on combating discrimination in the labour market
- LEADER + - focusing on rural development through innovative local projects
- INTERREG III - focusing on crossborder, transnational and interregional cooperation
- URBAN II - focusing on urban regeneration

Enhancing the use of structural funds for emission reduction initiatives is considered in greater detail in section 7.3.5. This could be done either through enabling more funding of air quality projects through the Structural Funds i.e. changing the structure of this mechanism, or through identifying how Member States can better access funding for air quality projects from the existing mechanism.

6.2.7 Emissions ceiling approach

A key European Directives for reducing emissions of sulphur dioxide, nitrogen oxides, NMVOCs and NH_3 is the National Emission Ceilings Directive (2001/81/EC), which sets limits on total emissions to be met in 2010. The principles of this approach are worth considering in the context of this study as a means of reducing emissions from SCIs. The key principles include:

- No prescribed methods for reaching targets, and therefore significant flexibility at the national level
- Shared responsibility at the national level for meeting targets
- Maximising potential for cost-effectiveness of measures at the national level

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. Therefore, measures reported to reduce SCI-based emissions are fewer (based on review by AEA Technology, 2003). Appendix 2 has details of the types of measures reported in national plans that could lead to a reduction in emissions from SCIs. Without detailed investigation, it is difficult to determine whether the NECD was in itself the driver for many of the measures, or if measures were introduced or planned for introduction as part of national policy.

A target for PM_{10} could be considered (and is currently being investigated under the CAFE programme), which could lead to the introduction of many more measures specifically targeting SCIs. . As shown by the emission inventory (in section 3), a significant amount of PM emissions are from non-industrial sources. More measures will therefore need to be targeted at these sectors for significant reductions to be realised. Many of the measures outlined in this section could be implemented by national governments as a result of such an approach, in particular, local measures, that would not be possible to implement at the European level, could be used where appropriate.

The types of costs of such an approach were outlined in a brief Regulatory Impact Appraisal on the NECD by the UK government (DEFRA 2002b). Compliance costs to business would probably be the most significant costs, although the level of such costs would obviously depend on the measures implemented under a national ceiling approach, and the level of reduction required. Other costs might include enforcement costs, to ensure that action was being taken. Reporting costs were also highlighted, with annual reporting to the Commission required.

Another potential variation on the current NECD structure could be to have sector specific targets; the emission ceiling would be sector-based rather than national. Reductions would have to be realised within specific sectors rather across a range of sectors. The flexibility of finding reductions across all sectors would be lost – however, flexibility to use appropriate measures within a sector would still be retained. Analysis of this variation is not being considered further in the framework of this study; however, this could be a variation to be explored in the framework of the RAINS model.

6.2.8 Climate change / Energy efficiency measures

International commitments to reduce emissions of greenhouse gases have led to the development of a series of policies and measures that target energy efficiency and carbon emission reductions. Whilst the implementation of these policies is primarily driven by the need to meet carbon reduction targets, and reduce energy costs and fuel poverty, the measures implemented may have important secondary benefits in terms of emission reduction of air pollutants.

Although not targeting air pollutant emissions directly, many of these measures are used in the commercial-institutional and residential sectors, which air quality legislation has not tended to target in the past. Therefore, measures under the energy efficiency banner are important to consider, and could provide some useful models for new types of legislation directly targeting air pollutant emissions in these sectors. They are also particularly important in terms of NOx emissions from natural gas. Few other technical measures exist to reduce NOx emissions from non-industrial SCIs that consume gaseous fuels – the main measure is to reduce the amount of gas intake through improvements to building efficiency or through improved boiler efficiency.

This section provides an overview of some of the types of measures that are currently implemented across Europe to target improvements in energy efficiency. Much of the information has been taken from country National Communications, submitted under the UNFCCC. A detailed quantitative analysis of how such measures will impact on air emissions has not been undertaken for a number of reasons:

- Similar measures across Europe are structured and implemented differently. Without a detailed knowledge of structure or implementation, estimation of benefits for air emission reduction is difficult.
- Many of the measures do not have any estimate of CO_2 reduction reported in their National Communication. Estimation of the reduction in air emissions could at the least be qualitatively estimated on the basis of CO_2 reductions.

The cost of such measures across Europe are also difficult to determine, and again will differ significantly. The following broad categories of measures are considered in this section:

- Standards for boiler efficiency
- Building standards
- Maintenance / inspection schemes
- Grants, loans and subsidies
- Energy taxes
- Promotion of renewable technologies
- Information campaigns

Some of these measures were covered in the preceding section. This section re-examines such measures in the context of their implementation through energy efficiency / climate change policies.

6.2.8.1 Efficiency standards for boilers

Boiler efficiency standards can reduce emissions of air pollutants due to a reduction in fuel consumption, and more efficient combustion of fuel. The costs of such efficiency requirements are initially borne by boiler manufacturers, though these costs are likely to be passed on to the consumer.

Council Directive 92/42/EEC (21 May 1992) on efficiency requirements for new hot-water boilers fired with liquid or gaseous fuels is the primary EU legislation for minimum boiler efficiency, and applies to boilers with thermal capacities between 4 and 400 kW. This Directive is likely to be amended by a proposed Directive (COM (2003) 453) on establishing a framework for the setting of Eco-design requirements for Energy-Using Products (CEC 2003).

6.2.8.2 Building standards

Specific building standards relating to energy saving could have a significant impact on other air pollutant emissions, primarily because they are aimed at reducing energy consumption. Other benefits may arise through replacement of older heating equipment, which could in turn lead to lower emissions due to more modern design.

The European Union Directive on the energy performance of buildings (EC 2002), driven by the need to address energy efficiency in buildings (as outlined in the European Commission's Action Plan on Energy Efficiency (CEC 2000)), 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.

Measures set out in the Directive include:

- Methodology for calculating energy performance of buildings
- Application of performance standards on new and existing buildings
- Certification scheme for all buildings
- Regular inspection and assessment of boilers / heating (described in the next section)

This measure is likely to have benefits for the reduction of air quality pollutants, due to reducing energy demand. This is considered in more detail in 7.3.6.

6.2.8.3 Inspection / maintenance obligations

Inspection schemes and associated maintenance obligations can be introduced to ensure that existing appliances (in buildings) are functioning properly. A reduced level of appliance performance can lead to poor combustion performance (and potentially increased emission levels) and reduced levels of energy efficiency. Inspection schemes have been introduced in a number of European countries for a range of different appliances. Such schemes tend to be targeted at non-industrial SCIs, in the residential and commercial sector (but not exclusively).

At the European level, the obligation to undertake maintenance was first introduced at the European level through the Council Directive 93/76/EEC of 13th September 1993 to limit carbon dioxide emissions by improving energy efficiency, also known as the SAVE Directive (CEC 1993). Article 6 stated that Member States should implement programmes on the regular inspection of heating installations with an effective rated output greater than 15 kW.

Significant flexibility was introduced in the Directive about how Member States could implement this measure. Article 1 stated that 'programmes can include laws, regulations, economic and administrative instruments, information, education and voluntary agreements.' Due to this flexibility, Member States do not appear to have introduced mandatory inspection schemes as a result of this Directive (CEETB 2004).

The recent Directive 2002/91/EC on the energy performance of buildings (EC 2002a) again places obligations on Member States to introduce inspection and maintenance programmes. Member States can either:

- Implement a regular inspection of boilers fired by non-renewable liquid or solid fuel of an effective rated output of 20 to 100 kW (and other fuels if deemed appropriate). Boilers over 100 kW should be inspected every two years (although for gas boilers this can be extended to four years). For boilers older than 15 years, a one-off inspection of the whole heating installation (not just the boiler) should be undertaken.
- Take an advice-based approach (which could include inspection), which would have a broadly similar impact to the first option. Reporting every two years to the Commission would need to outline the impact of this approach.

Significant flexibility has again been given to Member States, in terms of how they transpose and implement this part of the Directive (as was the case with the SAVE Directive). Inspection regimes may not actually be implemented if Member States decide to take other action. An analysis of effectiveness and costs, based on the EPB Directive, has been undertaken on inspection / maintenance obligations, and is described fully in section 7.3.6.1.

Most member States have legislation or define voluntary guidelines to stimulate maintenance and inspection of residential heating boilers. Many countries have obligatory inspection for oil-fired boilers although fewer have obligatory inspection for gas and solid fuel boilers.

In general terms, the inspection will tend to be limited to the boiler / appliance and flue, rather than other parts of the system. However, there is significant variation across Europe in terms of inspection – some schemes require flue gas measurements (Germany) while other schemes involve cleaning of the flue and / or boiler (Sweden) (Vekemans 2000). 'Inspection' could include one or all of the following:

- Cleaning of boiler / appliance
- Flue gas measurements – for energy efficiency (flue gas losses), air quality (emissions of soot, NOx), safety (CO)
- Checking combustion efficiency
- Checking control systems

In most countries, qualified technicians (e.g. CORGI registration in the UK for gas installation and maintenance; German system 'Bezirksschornsteinfegermeister') carry out inspection and maintenance. A certificate will often be issued once inspection and / or maintenance has been undertaken.

The drive for good maintenance across European countries is primarily to ensure health and safety (e.g. CO levels), and to ensure high levels of energy efficiency. In general, such a measure is not used specifically to target emission levels. For gas based appliances in particular, health and safety is a particularly important consideration. Chimney sweeping and flue cleaning is undertaken to prevent chimney fires, and blockages, both of which relate to health and safety concerns, but also to the basic functioning of the appliance.

Table 6.20 Overview of appliance inspection schemes across Europe

Country	Inspection / maintenance programme
Belgium	Annual inspection require for oil boilers. New regulations are being considered that may meet EPBD requirements.
Denmark	Mandatory boiler inspection required for oil boilers (120 kW or less). Inspection includes measurement of flue gas temperature, and CO / CO_2 content, with an evaluation report provided. Based on inspection, the inspector can insist adjustment / maintenance to be carried out within 4 weeks.
Finland	No mandatory inspection of boilers required – except for sweeping every two years
France	No mandatory inspection required (only above 1 MW do inspection requirements become obligatory). For 1 MW boilers, France introduced a Decree 98-833 (16th Sept 1998) which that a periodic check has to be carried out every three years
Ireland	No mandatory inspection required
Italy	A Presidential Decree 412/1993 in Italy introduced maintenance obligations for three categories of heating generators (>350kW, 35-350kW, <35kW), with those greater than 350 kW inspected twice a year, and less than 350 kW inspected once a year. Certificates of inspection have to be submitted to the local authorities, who have to undertake inspection of installations periodically. Under 35 kW, there is generic check and cleaning of the heat generator. Above 35 kW, check of thermostatic controls and combustion efficiency, and cleaning of heat generator.
Germany	Annual inspection for boilers between 4 and 400 kW mandatory. Combustion efficiency has to be checked, and flues cleaned by competent contractors on an annual basis (EC 2002b)
Greece	The Joint Ministerial Decision No 54678/86, revised by the JMD 10315/93, that sets the requirements for the regular inspection of central heating boiler/burner systems and control of the emissions from boiler plants. It prescribes the levels of emissions and periodic inspections of boiler/burner plants, on an annual basis for the domestic sector, for measurement of CO2, O2 and soot emissions, flue gas temperature and energy efficiency (EC 2002b). Inspection standards are specified below in Table 6.21.
Netherlands	Only boilers greater than 130kW have to be inspected every year. Boilers <130 kW are not covered, although manufacturers provide information on maintenance. Inspection includes a check on combustion products – and if necessary, re-tuning of gas / air ratio (EC 2002b).
Norway	Mandatory inspection required, with regulations stipulating regular inspection of boilers (but not frequency). Boilers are generally inspected once every 5 years for health and safety reasons.
Portugal	No mandatory inspection required
Spain	Mandatory inspection for boilers greater than 100 kW
Sweden	Regular inspection/sweeping is mandatory and if biomass is used, the inspection/sweeping has to be made by an authorised chimney sweep several times a year (if only oil is used it is less frequent).
Switzerland	All boilers are checked for performance once or twice a year. The introduction of inspection was driven by air quality.
UK	No mandatory requirements - only advice provision from manufacturers. However, landlords are legally obliged to ensure that their gas appliances are checked annually.

Source: Santamouris (2003) unless specified otherwise.

Table 6.20 provides an overview of the schemes that are in place across Europe. Most of the information relates to Member States from the EU15 group – whether this indicates that fewer maintenance schemes exist in Eastern and Central European countries is not clear.

The Greek inspection system has been set up under the Joint Ministerial Decision (No.10315) for the regular inspection and maintenance of central heating boilers. A description of the parameters on which inspection is based is provided in Table 6.21.

Table 6.21 Inspection standards for central heating systems in Greece

Parameter	Diesel oil		Gas
	Boiler >450 kW	Boiler >450 kW	
Max. permitted thermal loss of flue gases	12%	14%	10%
Max. permitted CO concentration in flue gases	60 ppm	60 ppm	60 ppm
Max. permitted CO_2 concentration in flue gases	11%	10%	11% LPG 9% Natural
Max. permitted NO_x concentration in flue gases	75 ppm	75 ppm	60 ppm
Max. permitted value of soot index (Bacharach Scale)	1	1	0
Min. temperature of flue gases	160 ºC	160 ºC	160 ºC
Max. temperature of flue gases	250 ºC	280 ºC	250 ºC

Source: MURE II (2004) – Measure A1 GRE 4. Note that the above limits are based on Standards 525-1, 234 and 897 issued by the Hellenic Standards Organisation (ELOT).

At the European level, a standard for the inspection of boilers and heating systems is currently being considered by Technical Committee CEN/TC 228 on Heating Systems in Buildings.[28] What is clear from this document is that it is clearly very difficult to standardise across different countries, which have very different heating market characteristics (as illustrated in section 4 of this report). As previously mentioned, it is also clear that different requirements are necessary for different types of appliance that use different types of fuel. These types of issue may be why the EPB Directive does not specify the structure of the inspection scheme to be introduced.

The effectiveness of this measure will be dictated by the way it is set up, how it is administrated and the methods for enforcement. Under the further analysis, it will be important to see how this is being done in other countries, and what best practise for this type of measure might be. The importance of this measure is that it could apply across all types of appliance, old and new, and therefore, could cover specific appliances with associated high emissions.

CEEETB (2004) cite a German study that calculated savings in Germany in 1999 due to inspections at 123 million litres of fuel oil and 74 million m^3 of natural gas (which would meet the heating requirements of 100,000 single family households). The same report states that in the UK, it was calculated that regular inspection / maintenance could lead to a 15% reduction in energy consumption (NB. the length of time over which this reduction could occurs is not stated). A case study on the MURE website (MURE II 2004) specifies the benefits of the Denmark scheme for oil burners, in which 700,000 heat furnaces are inspected

[28] The document titled ‘Inspection of boilers and heating systems’ (dated June 2004) is a draft document that has not been published. It outlines some of the possible features of standardised inspection.

by 2,500 inspectors. The average heat loss from the flue has been reduced from 19% to 12-13% (over an unknown period of time).

If a system was set up specifically to administrate and enforce a maintenance programme, the costs could well be significant – due to the number of appliances involved. Costs could be significantly reduced if existing systems, such as company registration schemes, could be ‘piggy-backed’ on. Costs could also be significantly reduced by users having to co-ordinate maintenance, and self-certifying that an inspection had been undertaken. In the further analysis, the potential systems for administration and enforcement will be considered.

Actual costs of maintenance would fall on the owner of the building which had the heating appliance installed. Such costs would probably be quite low (if significant maintenance was not required), with a single annual inspection carried out. For the residential sector, the social impacts of this measure would need to be carefully considered, particularly the costs that might be borne by lower-income households. However, such costs might only be borne by the property owner, not the tenants, reducing the economic impact on low-income groups. Subsequent fuel savings could offset these costs.

6.2.8.4 Grants and subsidies

Various schemes have been introduced across Europe that enable consumers (across sectors) to access funds for either improvements to insulation or heating equipment that is more energy efficient.

The *Warm Front* scheme in the UK, launched in 2000, provides grants to households that face financial constraints to help them improve household energy efficiency (DEFRA 2004b). Grants are available for both insulation and heating systems. Between June 2000 and February 2003, over 750,000 households have received assistance under the scheme. It is probable that the cost of this scheme is in the region of at least €600 (£400 GBP) million.[29] An estimated saving of 0.7 Mt CO_2 is expected by 2010 (EEA 2003).

In Germany, a loan programme has been introduced by the KFW bank to help fund improvements to the energy-efficiency of houses and heating systems (KFW 2004). This measure specifically targets the existing housing stock.

6.2.8.5 Energy taxes

Energy taxes increase the price of fuels, and therefore encourage more prudent consumption, or promote the use of lower carbon alternatives. By doing so they lead to a reduction in emissions of other pollutants also. Taxes are set on the basis of the primary unit of fuel (volume or mass) or unit of electricity. Therefore the tax reflects the energy content of fuel rather than the CO_2 emissions (although the CO_2 emissions can be estimated from different fuels). These taxes are therefore differentiated from CO_2 specific taxes, which are a direct tax on emissions of CO_2. Different energy taxes are widely used across Europe, as shown in Table 6.22.

[29] Based on Entec (2004a) stating a figure of €300 (£200) million for grants to 400,000 homes.

Table 6.22 The use of energy taxes in Europe

Country	Energy / CO_2 tax	Tax description*	Energy/CO_2 tax rate	Revenues US$ million
Belgium	Yes	Electricity consumption tax- applies to all sectors	€0.0014 /kWh	193 (2000)
Denmark	Yes	Electricity consumption tax – applies to all sectors	For heating of dwellings – €0.067 /kWh. For other purposes – €0.076 /kWh	1041 (2000)
Finland	Yes, 1990	Additional fuel tax on coal and diesel for security of supply purposes – all sectors		Strategic stockpile fee 46.4 (2001)
Germany	Yes, 1999	Electricity consumption tax – all sectors	€0.0128 /kWh	3356 (2000)
Netherlands	Yes, 1992	Regulatory energy tax. Varies with type of fuel, including electricity and level of use. All sectors	e.g. Electricity use – Up to 10,000KWh – € 0.060/kWh	1902 (2000)
Italy	Yes, 1999	Electricity consumption tax – applies to all sectors, but variable	€0.003 per kWh (industrial) and 0.0021 EUR per kWh (private)	1688 (2000)
Norway	Yes	Electricity consumption tax	€0.013 per kWh	515 (2000)
Sweden	Yes	Electricity consumption tax	€0.021/kWh (domestic). €0.015/kWh (other). €0.0015/kWh (aggregate /mineral abstraction).	1317 (2000)
Switzerland	Varies by canton			
United Kingdom	Yes, 2001	Climate change levy on electricity and non-transport fuels, but not directly related to CO_2	E.g. electricity ordinary rate (0.43p/kWh) €0.0069 per kWh	
Slovenia	Yes	Excise and CO_2 tax on energy products	Variable (5 liquid fuel types)	463 (2000)

Source: Watkiss (2003)

As an option for targeting air emissions, the use of taxes has been addressed in section 6.2.5.

6.2.8.6 Promotion of renewable technologies

A widely used measure for reducing carbon dioxide emissions has been through the promotion of renewable technologies as alternative energy sources. For example, the UK has a scheme to encourage the uptake of renewables by communities and households through the provision of grants (DTI 2004). Renewables include solar thermal, wind turbines, small-scale hydro, heat pumps and wood-based heaters, stoves and boilers. It is clear that such measures could increase consumption of biomass, increasing pollutants such as particulate matter. Other renewable technologies, however, would in general be both carbon and other air pollutant neutral.

Clearly, the take-up of technologies needs to be known before an assessment of the impact of this and other similar schemes can be assessed. To date, 111 community based grants totalling €3.34 million (£2.23 million) have been offered and €1.35 million (£900,000) in grants to households. Specific wood-based technologies that are being promoted are room heaters / stoves with automated wood pellet feed and wood fuelled boiler systems.

In Finland, where biomass use is already significant, the use of wood pellet heating is actively being encouraged. In other countries, solar heating is being encouraged through financial incentives. In the Belgium Walloon region, the SOLTHERM programme has been launched with the objective of installing 50,000 solar heaters by 2010. Solar panels are subsidised at the rate of €620 per $4m^2$ (and €74 per extra m^2). In Austria, grants are available for biomass and solar heating systems (MURE II 2004).

Many other examples of such measures exist, all of which have different projected reductions in levels of CO_2, and therefore, potentially in air pollutant emissions. A key issue is the policy to promote wood burning across many countries of Europe. This has the potential to conflict with air quality policies due to the potential such a policy has to increase the problem of particles. However, the problem may be limited if low emission biomass technologies are promoted.

Costs will be driven by the subsidies and grants on offer to promote renewable technologies. As many technologies, such as photovoltaics, have high capital costs, such measures are likely to incur high costs.

6.2.8.7 Information campaigns and dissemination

In the UK, significant resources have gone into providing consumers across all sectors information about energy efficiency. The programme Action Energy[30] targets industrial energy efficiency, while the Energy Savings Trust provides information on residential energy efficiency. Information campaigns have also been run in the past, including the *Are you doing your bit?* Campaign, run between 1998 and 2002, with funding of approximately €30 million (£20 million), and aimed at raising individual consumer awareness.

In France, ADEME has set up local energy information centres, where information on energy efficiency investments in households can be sourced. This programme costs up to €15 million per annum (MURE II 2004).

It is important that the potential for air quality emission reductions from energy efficiency measures are highlighted, and that potential linkages between these and air quality measures are identified. Energy efficiency measures may be of particular importance given that many of them target household energy efficiency.

6.3 CONCLUSIONS

This section of the report has covered a wide range of measures, primarily due to the scope of this study, both in terms of the pollutants covered, the number of countries, and the range of sectors and appliances for which the SCIs are relevant.

[30] http://www.actionenergy.org.uk/ - Action Energy also provides interest free loans for energy saving equipment to SMEs, tax breaks on investment in energy saving products (through the Enhanced Capital Allowance scheme), and site energy audits.

Following this review, proposed measures for consideration by the Commission for the Thematic Strategy are further assessed in section 7. A key driver for further consideration of specific measures in the next section are the key emission issues highlighted in section 3. Key emission issues include emissions (primarily PM) from solid fuel and biomass use in smaller SCIs (predominantly in the residential sector), emissions from larger industrial or institutional installations, and emissions of NOx from gaseous fuel consumption in the non-industrial sectors.

This section provides the evidence for what can be done, both at a national and European level, to target emission reduction. The next section uses this evidence to help inform the analysis of which measures should be considered, how they might be implemented, and their potential costs and effectiveness. It is clear from this section that very different policy options will be required for targeting the different emission problems that have been identified.

7 Options and Recommendations for European policy

7.1 INTRODUCTION

This section of the report outlines the further analysis of potential policy options for SCI emission reduction, based on the review of technical and policy measures (in sections 5 and 6), and identification of key emissions issues listed below:

- PM and NMVOC emissions from biomass and solid fuel burning, particularly in the residential sector
- PM, SO_2 and NOx emissions from SCIs in the industry sector
- NOx emissions from non-industrial SCIs using natural gas

The proposed policy options, listed in Table 7.1, have been developed in close consultation with the Commission, to facilitate additional scenario analysis using the RAINS model, and for consideration within the framework of the Thematic Strategy being developed through the CAFE programme. Further analysis is needed for these selected options to provide a more detailed understanding of the costs and effectiveness of a given measure, before policy makers consider such a measure. In section 7.3, each of the above measures is considered in turn.

Table 7.1 Policy scenarios considered in SCI emission reduction analysis

Types of policy option	Key emission issue(s)
Introduction of obligatory product standards for appliances below 300 kW	PM / NMVOC, and NOx emissions from non-industrial SCIs
Promotion of local-based measures, particularly in PM urban 'hotspots'	PM / NMVOC emissions from non-industrial SCIs
Stricter or new fuel quality criteria for certain fuel products	PM / SO_2 from solid fuels across all sectors
Introduction of specified emission limits to larger installation (< 50 MW)	Emissions from industrial / large institutional sites
Increased use of Structural Funds to increase access to cleaner fuels e.g. energy network expansion, funding for cleaner technologies	PM / NMVOC emissions from non-industrial SCIs
Development of energy-efficiency measures to further benefit air quality policy e.g. Energy Performance of Buildings Directive	NO_x from gas (non-industrial), other pollutants in the non-industrial sectors

7.2 A FRAMEWORK FOR CONSIDERING POLICY OPTIONS

In section 7.3, policy options are considered on the basis of the key emission issues previously described, the available technical measures (as outlined in Section 5) and potential policy measures where experience of implementation exists (as reviewed in Section 6). Cost-effectiveness (relative to other available measures) might be the key consideration for any given policy measure. However, there are a number of other considerations when selecting policy options, which are listed in the box below:

Other issues for consideration

- Is the measure cost-effective, relative to the other available options?
- Will the measure be broadly acceptable by Member States?
- Is the scale and scope of implementation appropriate? For example, can a specific action realistically be taken at the European level?
- Are the potential social impacts of measure going to be acceptable?
- Will the policy measure be consistent with objectives of measures implemented under other strategies such as on energy and climate change?
- Where applicable, is the measure sufficiently flexible to allow national and regional governments to target localised areas where the problems are most significant?
- Is the measure going to need unacceptably high enforcement and administrative resources, for example due to a large number of installations that need regulating?
- Will the measure have the ability to reduce emissions in sectors where replacement frequency of appliances is low, and where appliance lifetimes are long?

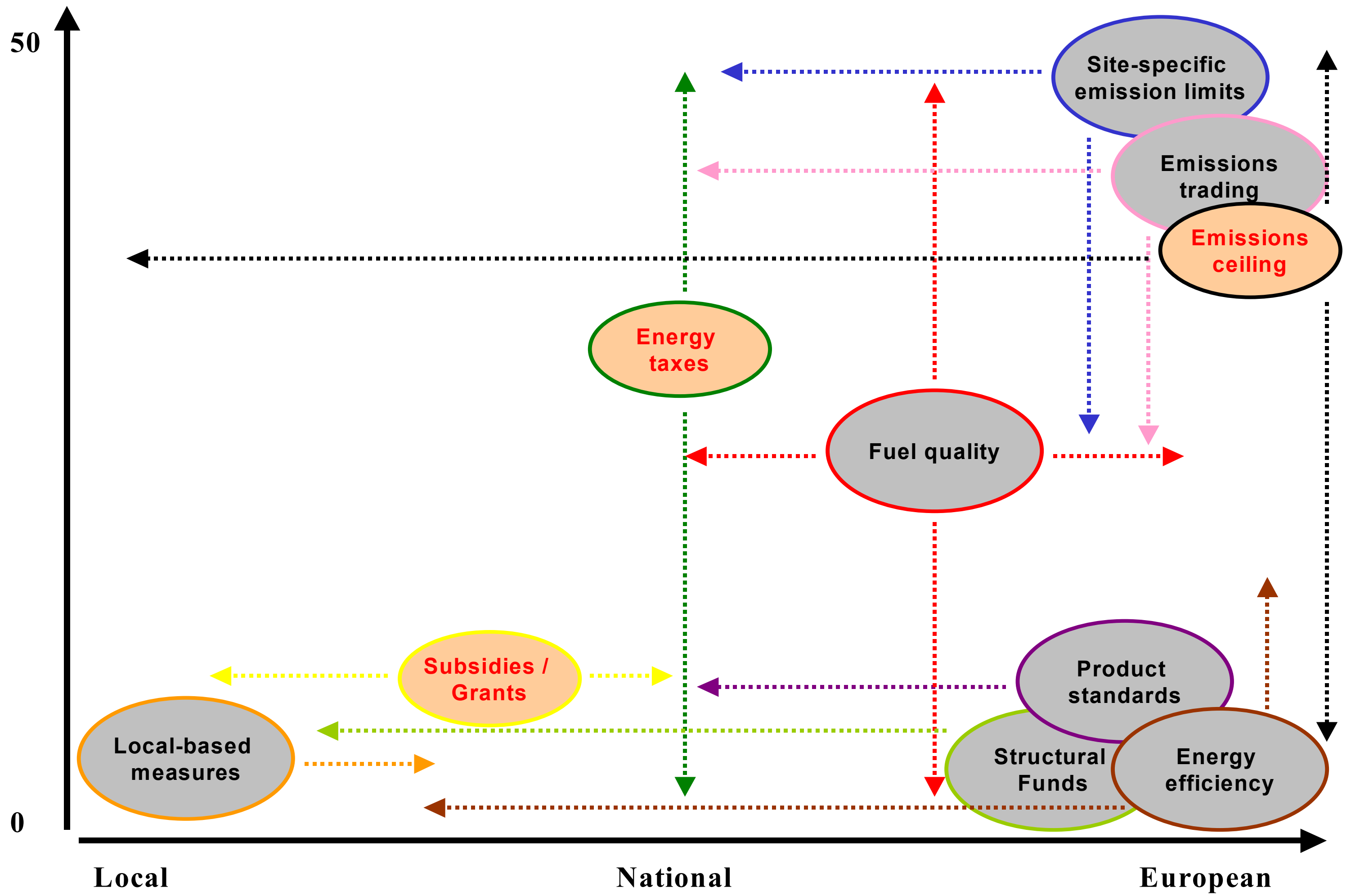
A limited number of measure reviewed in section 6 are not considered for further analysis within this section, and include:

- *Taxes*: Taxation is a matter for national governments, which makes European implementation of this instrument unfeasible. Many countries are using such a measure due to the flexibility of such an instrument, and lower costs relative to traditional regulatory instruments.
- *Subsidies / Grants*: Subsidies and grants tend to be an instrument used by national authorities. However, other financial mechanisms such as centralised funding at the European level is considered in this section.
- *Emission Ceilings Approach*: The NEC Directive could be extended to cover PM, which could increase the actions being undertaken by national governments to target SCIs (as SCIs tend to be a significant source of PM). This analysis is being undertaken under another project, and although recognised as important, is not considered in detail here.

Figure 7.1 provides an overview of the measures considered in this study, the scope in terms of SCI thermal capacity, and the level of implementation. The measures coloured grey are those considered further in this study, within this section of the report. The x axis indicates the scale of implementation, while the y axis indicates the type of installation (in capacity terms) that the measure is applicable to. These measures are positioned in the figure below based on the following reasons:

- Local based measures tend to be implemented at the local level, and are primarily applicable to smaller SCIs, in the non-industrial sectors
- Fuel quality based measures can be implemented at all levels, and apply across all types of SCIs
- Measures introducing site-specific regulation are implemented at both national and European level, and tend to apply to installation above 20 MW_{th}
- Product standards are either issued at national or European level, and tend to apply to SCIs with thermal capacities below 300 kW.

Figure 7.1 Overview of potential policy measures relating to SCI emission reduction



- Energy efficiency measures considered in this study tend to be implemented by national / regional government in the main, but at the European level also, and apply to smaller SCIs, predominantly in the non-industrial sectors.
- Structural Funds are allocated by the Commission, managed by Member States and used at the local level. In the context of this study, they are considered primarily for non-industrial sectors, and therefore smaller SCIs.

7.3 ANALYSIS OF POLICY OPTIONS

This section of the report is key to developing the report conclusions and recommendations, to feed into the Thematic Strategy on Air Pollution, and further develop RAINS scenario analysis of options for SCI emission reduction. In general terms, the analysis of each option has followed the general approach outlined below:

1. Define specific nature of measures for consideration
2. Assess cost-effectiveness of defined measure, using case study examples where necessary, and other potential impacts of the proposed measures, highlighting the advantages of EU action
3. Propose recommendations for consideration in Thematic Strategy
4. Assess the integration of data into RAINS to enhance current data into model, to enable scenario analysis

The options listed in Table 7.1 are now considered in turn.

7.3.1 Product Standards

The primary objective of product standards is to ensure that products entering the market meet certain quality criteria, including environmental-based criteria, such as maximum emission limits. Such criteria ensure that new appliances being bought to replace older appliances (through natural replacement) meets minimum emission standards. In the context of this study, this type of mechanism tends to cover smaller capacity appliances (< 300 kW) that are used primarily for hot water and space heating i.e. non-industrial sectors.

European standards are issued through CEN, and are available across many of the appliances considered in this report. However, in order to ensure manufacturers meet certain standards, two policy mechanisms could be considered to introduce CEN standards into a regulatory framework:

- The proposed Framework Directive on Energy Using Products (EuP) could cover boilers and stoves (based on its proposed scope), and could propose emissions limits as criteria for a given product.
- Under the New Approach Directives (which is the approach that the EuP Directive will also follow), certain harmonised CEN standards can be used to meet the requirements of certain Directives, regarding different products e.g. the use of EN 13229 (Inset appliances including open fires fired by solid fuels) and EN 13240 (Room heaters fired by solid fuel) under the Construction Products Directive (CPD).

The scope of the proposed EuP Directive could include all heating appliances based on the criteria set out in the proposed Directive (although products for inclusion have not been decided to date). CEN is still determining its own programme of work for standardisation that will be in support of the EuP Directive, based on mandate 341 from the Commission; this programme is likely to be driven by priorities determined for different product groups (CEN 2004b). The scope of the CPD, which includes two European CEN standards that are relevant to this study, is for 'construction products' defined in the Directive (CEC 1998) as 'any product, which is produced for incorporation in a permanent manner in construction works, including both buildings and civil engineering works.' This would seem to suggest all heating appliances, as they are incorporated in a 'permanent manner'.

An overview of both obligatory limits and voluntary standards, and their implementation across Europe, is provided in section 6.2.1. In this section, we further consider the policy mechanisms that could be used to introduce product standards, and assess potential emission reductions and costs, based on existing European and national standards. The focus of the analysis will be on reduction of PM, although NOx as is also considered – it is clear from the emissions data that PM emissions will still be significant in future years, particularly from biomass. Product standards have been identified as the key measure for targeting such emissions.

7.3.1.1 Proposed measure for consideration

The two potential mechanisms for introduction of obligatory standards are described in section 6.2.1. Both mechanisms will function in a similar way e.g. they both specify technical criteria for given products, which if met enable manufacturers to sell that product across the EU market.

The purpose of this analysis is to assess the impact of the introduction of certain standards, which specify emission limits for TSP for a range of appliances (TSP has been used (as opposed to PM_{10}) as this is what existing standards use). It is important to note that these measures will only affect 'natural' replacement of appliances e.g. appliances that have either reached the end of life or that need replacement due to faults.

NOx emission limits for gas and oil-based appliances are considered subsequently in section 7.3.1.3.

7.3.1.2 Analysis of measure

The following approach has been taken to assess the impact product standards on emission levels, based on potential emission limits stipulated in the standards (and could be replicated in the framework of RAINS, as described in section 7.3.1.5):

- New technologies that meet a given standard have an associated emission factor that reflects the stated emission limit, and are converted into comparable metrics to those used in the RAINS model e.g. tonnes / PJ.
- We have assumed a 'natural' replacement rate of between 4-5% of the existing appliance stock to be replaced annually. This is based on a 15 to 20 year lifetime of an appliance. No country-specific data on new build has been used (which could have an impact on the proportion of new appliances introduced). .
- The costs associated with the standard is the price differential between the purchase of an appliance that meets the standard, and one which does not. Due to the many cost estimates available, a cost range has been supplied, and is shown below in Table 7.2.

Table 7.2 A comparison of costs of conventional technologies versus advanced

Fuel-appliance type	Cost differential (€)	% increase (conventional vs. advanced)[1]
Domestic stoves – Biomass	325 – 1000	25 – 76
Domestic boilers – Biomass	750 - 3000	20 – 90
Domestic stoves – Solid fuels	150 - 1000	25 – 150
Domestic boilers – Solid fuels	1500	70

[1] For the purpose of this analysis, the costs of advanced appliances are considered to meet the specified product standard emission limits. NB. The broad range of costs are compiled from a number of data sources, including UK manufacturers and in-house data sources

Analysis has been undertaken for four categories of technologies-fuel combinations – solid fuel and biomass small boilers and stoves. The following emission limits for TSP (outlined in Table 7.3), set in a range of European and national standards, are considered in the analysis of this measure.

Table 7.3 Emission limits for analysis of product standards

Product standard / limits	Appliance	Pollutant	Fuel	Limit (mg/m3)	Limits <50 kW (t/PJ)
European (EN303-5)	Manual or automatic fed boiler	TSP	Solid fuel (coal)	125 – 180 (10% oxygen content)	39 - 56
Germany / Switzerland	Manual or automatic fed boiler	TSP	Solid fuel (coal)	150 (8% oxygen content)	42
European (EN303-5)	Manual or automatic fed boiler	TSP	Wood	150 – 200 (10% oxygen content)	60 – 80
Austria	Manual or automatic fed boiler	TSP	Wood	-	60
Norway	Wood stove	TSP	Wood	5 – 10 g / kg	50 (cat) – 100 (non-cat)

NB. The range for the European standards reflects the different classes issued for that standard. Solid fuel unit conversion based on gas volume of 8 m^3 per unit of coal burnt (at 6% O_2 content). All other parameters considered standard reference. Biomass conversion based on gas volume of 4 m^3 per unit of wood burnt.

Emission limits have been selected from existing European CEN standards, and from national-based standards (for comparison). This provides a range of values, to indicate differences in the effectiveness of standards depending on the emission limit adopted. Some relevant European standards for smaller appliances e.g. stoves, issued by CEN have not been considered here, as limits for TSP (or other relevant pollutants) have not been set. Emission limits have been set for CO, which is used for heath and safety reasons, and is considered a proxy for emissions of other pollutants e.g. if CO emission are low, it is likely that other pollutant emissions will also be low.[31]

In Table 7.4, the results of this analysis undertaken using RAINS data show the potential savings in total TSP in 2010, and as a percentage of each technology category. Only categories of stoves and single house boilers have been considered - the medium sized boiler

[31] Analysis on the basis of CO limits has not been considered because CO is not covered in the RAINS model.

category in RAINS includes technologies that would probably not be considered in the context of product standards e.g. they are over 300 kW.

Table 7.4 Product standards analysis of emission reductions of TSP (for 2010)

Appliance type	Fuel	Limits Considered (t/PJ)	Annual reduction (tonnes)	Sector total (tonnes)	% Annual reduction[1]
Single house boilers	Solid fuel	39 (EN high class)	190	5613	3.39
		42 (German / Austrian)	187	5613	3.34
		56 (EN - low class)	175	5613	3.12
Single house boilers	Wood	60 (EN high class / Austrian)	1018	43,080	2.36
		80 (EN - low class)	851	43,080	1.98
Stoves	Wood	50 – 100 (Norway – catalyst / non-catalyst)	8157	255,922	3.19

[1] Reductions relative to specific technology based category

All standards lead to a yearly reduction of between 2% and 3.6% for the specific technology based sectors (e.g. reduction from stoves as a percentage of all stoves using wood). These reductions are primarily due to the use of much lower factors for certain countries in RAINS, particularly factors used for Accession countries. There is limited reduction from automatic wood boilers, with most of the country based emission factors used in RAINS meeting the given standards. If introduced in 2010, total reductions by 2020 are approximately 30% relative to the 2010 total for all appliance types. Therefore, reductions over time are significant.

There are two types of costs figures that would ideally need to be considered in this analysis. Firstly, the additional cost of buying an appliance that meets the standard, and secondly, the change in fuel costs based on the use of a more advanced appliance. EGTEI (2003a) have calculated the mean annual fuel costs for different wood appliances based on energy consumption of 53 GJ per year which would presumably be much lower if the stove was used as a backup fuel (as is often the case). They include €558 for a conventional stove and €461 for a more advanced stove. For boilers, values of €688 for conventional manual feed boiler and €459 for advanced boiler can be used. These figures are highly uncertain due to the potential range of efficiencies appliances might have – therefore, they are not considered in the cost abatement figures. If they were, the cost-effectiveness of this measure is probably significantly higher.

In order to calculate the additional costs of new appliances, the number of appliances is needed. This has been calculated by dividing the activity data in RAINS for each technology group by an average annual energy demand of 55 GJ. Numbers of appliances and associated costs are outlined in Table 7.5 below. The difference in costs between appliances in RAINS and those promoted through standards are difficult to determine accurately, due to the significant range of appliances on the market, and the differences between countries; therefore, a range of costs has been used.

Table 7.5 Costs of different technologies and assumed appliance numbers in product standards analysis

Appliance type	Fuel	Limits Considered (t/PJ)	Appliance number*	Additional cost (€ range)	Total ave. cost (€ million)	Annual cost per tonne abated (€)
Single house boilers	Solid fuel	39 (EN high class)	15,809	1500	24	126,000
		42 (German / Austrian)	15,809	1500	24	128,000
		56 (EN - low class)	15,809	1500	24	137,000
Single house boilers	Wood	60 (EN high class / Austrian)	151,680	750-3000	284	279,000
		80 (EN - low class)	151,680	750-3000	284	334,000
Stoves	Wood	50 – 100 (Norway – catalyst / non-catalyst)	377,260	325 – 1000	250	31,000

* Determined by dividing average energy demand of 55 GJ by total energy saved

Note that the above costs have been calculated for a single year, and have not been discounted over the lifetime of the appliance. This would potentially make this measure even more cost-effective, with costs spread over a longer time period. Potential fuel costs savings have not been taken into account either (which is also likely to improve cost-effectiveness). A differentiation in the costs of an appliance that has the more stringent standards relative to the less stringent standards has not been made; therefore, as illustrated above, the 60 t/PJ standard may not be more cost-effective than the 80 t/PJ standard.

This cost-effectiveness of this measure is largely driven by the emission factor differential between RAINS emission factors (which are in many cases highly uncertain), and those factors used to represent new standards. This is particularly the case for stoves; with RAINS emission factors as high as 700 t/PJ in some countries compared to a standard used of 50.

It is also important to note that a limitation with this analysis is that within different regulations and standards, a variety of metrics are used to define limits – some based on emissions of pollutants per energy input (e.g. g/GJ), others on specific emission concentration limits for pollutants within flue gases (e.g. in mg/m^3 at specified reference conditions) – Although limits have been put on a comparable basis, a comparison is made difficult by:

- Different testing standards used for setting the limit
- Different types of appliances used in testing
- Different types of fuel considered e.g. wood and solid fuels or wood only, and quality of fuels

7.3.1.3 Consideration of NOx emission limits in product standards

The policy mechanisms described in this section are also applicable to appliances, in particular non-industrial boilers that use liquid fuels and natural gas, and are a significant contributor to NOx emissions. Therefore, the focus here is on emission limits used in different standards for NOx.

Various CEN and national standards exist for gas and oil boilers, and tend to have limits for NOx and CO. The NOx limits are listed in Table 7.6 below.

Table 7.6 NOx emission limits (mg/kWh) for gas-fired and oil-fired heating systems

Country / standard	Gas central heating boilers	Oil central heating boilers
Germany / 1.BlmSchV	80	120
Germany / Blauer Engel (Ecolabel)	70	120
Switz. / Luftreinhalteverordnung	80	124
Austria / KFA-Verordnung	108	126
Belgium	150 (atmospheric burner) 120 (others)	120 (<70 kW); 185 (70-400 kW)
CEN proposal (Hubner 1998)	100 (0.0278 kt/PJ)	120 (0.0333 kt/PJ)

Source: Hubner (1998), except Belgium (Nieuwejaers 2004)

European standards for boilers propose a range of values to be used. Based on the report by Hubner (1998), potential limits were proposed for CEN standards that were being developed at the time. It is interesting to consider these proposals, as they are in context of national based standards – if standards are considered for use within the suggested policy measures, country-based standards will need to be considered. This analysis has therefore been undertaken using a limit value of 100 mg/kWh for gas boilers, and 120 mg/kWh for oil boilers (NB. the CEN standards are much less stringent but for the purposes of this analysis, it is interesting to see what might potentially be achieved).

The boilers in the RAINS model that are 'NOC' (not controlled) have average emission factors of 0.05 kt/PJ for gas, and 0.06 kt/PJ for gas oil. If the proposed European standard was introduced as a control option, this could result in significant reductions. Comparing these emission factors suggests that new gas and oil boilers that were installed each year would emit almost 50% less than the stock replaced. It is proposed that this analysis is further developed in the framework of the RAINS model – see section 7.3.1.5.

7.3.1.4 Issues for the Thematic Strategy

The results of this analysis seem to show that this measure can have a significant affect on the total level of emissions, through the natural replacement of appliances, particularly if considered over a 10 year period e.g. reductions of over 30%. Due to the significant amount of projected emissions of PM from biomass, it is important that such a measure is seriously considered. A useful example to consider in relation to PM emissions from biomass is outlined in a paper by Statistics Norway (2004), which considers the potential reductions in Oslo if all conventional stoves were replaced by advanced stoves. A reduction of 70% in PM could be realised – however, emissions would rise with no replacement due to the increase in wood consumption.

Similarly, this measure could be important for NOx reduction, particularly from gaseous and liquid fuels. Gaseous and oil boilers are currently regulated by the Directive on efficiency requirements for new hot-water boilers fired with liquid or gaseous fuels (which will be amended by the proposed EuP Directive). If emission requirements are introduced by the measures considered in this section, in addition to energy efficiency requirements under this Directive, this could be an important step in reducing NOx emissions in future years.

The introduction of product standards that have emission limit criteria in a regulatory framework could be envisaged through the Energy Using Products Directive, but also through greater use of other Directives, such as the Construction Products Directive. With the EuP Directive at the proposal stage, the Commission has the opportunity to further explore how best this policy mechanism can be used to advance the objectives of air quality policy. Currently, the list of products under this Directive has not been decided, or the criteria against which they will be assessed as being compliant or not.

Based on the criteria proposed, all of the products considered in this section could be eligible. However, the timescales for the inclusion of such products will be dependent on whether they are considered priority product s or not. Certainly boilers may be seen as a particular priority group, given there contribution to GHGs, and identification as a priority for improving energy efficiency. In terms of PM and NMVOC emissions, however, stoves may be more important for air quality, particularly as a significant proportion of biomass in the non-industrial sectors is consumed in them. It will be crucial for air quality considerations to be discussed at the point of consideration of product groups under this Directive, and as CEN develop their standardisation programme in support of this Directive.

If introduced into a regulatory framework, emission limits will need to be carefully considered due to potential conflicts with national regulation. If a product standard is proposed in the framework of a European Directive, this will supersede national based regulations (unless special provisions are made). Therefore, manufacturers may be able to design a product to meet criteria (such as emission limits) specified by the Directive, which are less stringent than national regulations. Under a voluntary standard, national deviations avoid this problem; however, deviations would not be recognised in the context of a regulatory framework. The EuP Directive may offer the flexibility to avoid this problem, by allowing other means of meeting product criteria; however, at the present time this is not clear. More flexible threshold values may also be considered rather than limits, enabling countries to determine their own limit according to national-based standards / regulations.

Whether PM targets will be considered in product standards in the future is debatable. They are included in EN 303-5, which relates to household and commercial boilers (up to 300 kW). However, for smaller household appliances CO emissions have only been considered in CEN standards. Many countries view particle limits as important (based on national legislation), particularly for solid fuels and biomass. However, difficulty in reaching consensus on PM limits has meant that CO has been considered a reasonable proxy. Levels of CO will indicate whether combustion is occurring properly; if PM limits are not used, it is important to better understand how good a proxy CO emissions are of other pollutants, such as PM, NMVOC and PAHs (although not being considered under CAFE but still important from this source). CEN/TC 295, the technical committee covering smaller appliances using solid fuels and biomass, are considering other testing methods for pollutants other than CO.

Since product standards are already being used across Europe, the further promotion of this type of measure should be regarded as acceptable, particularly if done through the implementation of the EuP Directive. Further analysis of the economic impact, particularly on consumers and manufacturers, may be needed to properly assess the additional costs that they will face from the implementation of product criteria. (It is proposed that this type of assessment will be done as part of the selection process of products for inclusion under the EuP Directive).

7.3.1.5 Further scenario analysis in the RAINS model

Further analysis could be undertaken in the framework of the RAINS model based in the approach described in this section. Control options could be introduced into the PM and NOx module that represent new product standards. The emission factors associated with the product standards (outlined in this section) would be the abated emission factor.

The cost of this control option is the differential between a new appliance and one that would not meet the requirements of the standard e.g. a conventional type. Therefore, the full costs of the new appliance would not be included in total costs, only the differential. Ranges of additional costs have been used in this analysis, due to the wide variation in price of different models available.

One of the difficulties with this analysis (for PM) is that RAINS categories (in terms of capacity range) and those used in CEN and other national standards do not easily match. Therefore, the application of standards to certain RAINS categories needs to be carefully considered. We have assumed that standards for boilers of 0-100 kW are best matched with the SHB category in RAINS. The medium boiler range has not been considered, as this includes boilers that are too large to be considered under this type of measure.

7.3.2 Local-based measures

Air quality problems are often found in localised urban areas due to dense concentrations of emission sources such as road transport or household heating installations. Consequently, local-based measures are often the most effective means of reducing emissions in these areas, particularly as local conditions and characteristics can be taken into account. An overview of such measures relevant to SCI sources is provided in section 6.2.2. Most of these measures are concerned with the reduction of emissions such as PM, SO_2 and PAHs from the burning of solid fuels and biomass, predominantly in the residential sector. As with product standards, the focus of this section is on assessing the potential of such measures to reduce emissions of PM from the use of solid fuels and biomass in non-industrial sectors, particularly in urban areas.

The main European policy mechanism to ensure action is taken to deal with pollution issues, particularly in urban areas where exceedances are identified, is the Air Quality Framework Directive, and in particular for PM, the First Daughter Directive. An important issue is whether this Directive is ensuring local action is taken to target localised air pollution problems; however, lack of reporting makes it difficult to determine the extent of problems associated with SCIs, and the types of measures being considered across different Member States.

In summary, this section considers:

- The applicability and potential impact of local measures across Europe e.g. identifying countries with urban air quality problems due to emissions from SCI sources.
- The costs and effectiveness of local measures in reducing emission levels based on case study examples.
- The role of the Commission in promoting such measures across Europe

7.3.2.1 Defining local-based measures

Local-based measures are measures implemented to deal with a specific local air pollution issue. They will tend to be implemented at the local level, within a framework that is often set at the national level (or European level in terms of the Air Quality Framework Directive).

Local measures (as considered in this study) can lead to the following action:

- Switching to better quality fuel products e.g. coal-based solid fuels but retaining heating appliance and system
- Switching to more advanced appliances that use the same type of fuel
- Switching to a new appliance-fuel combination

It is likely that different combinations of the above actions will result, depending on the local situation. The ban on coal sales in Dublin resulted in many households using less polluting solid fuels, but also switching to gas or oil (from coal-based fuels) as the primary means of heating. Measures that introduce these changes may be cross-sectoral i.e. they impose restriction across all sectors, but tend to be focused on targeting smaller emission sources, such as households or small commercial premises that are located in urban areas.

7.3.2.2 Geographic applicability of local-based measures

It is important to determine whether there are significant localised pollution problems associated with solid fuel and biomass burning across different countries, and the potential for local-based measures to reduce emissions contribution from SCI sources. Within the broader context of this study, it is also crucial to consider the spatial dimension of emission problems.

A broad understanding of emission problems can be determined from the emissions data (in section 3), in particular PM emissions from wood burning and solid fuel burning. Eastern European countries have particularly high emissions from solid fuels (coal-based), whilst emissions from wood burning are particularly significant in Scandinavian and Baltic countries, and France. However, the spatial distribution of such emission sources is less well understood, and understanding this is crucial to understanding potential impacts of air pollution. If most of these emissions are located in rural areas, the resulting population exposure is likely to be less than if emissions are urban based. Inventory data may also hide the existence of local problems – the inventory may suggest very low levels of solid fuel use in the UK; however, regionally this is important, for example, in Northern Ireland.

It is often assumed that wood burning (in particular) and solid fuels are rural fuels while oil and gas is used in urban areas (for example, see Holland 2001). In general terms, this is probably true – however, the European picture is much more complex, due to a range of country-specific factors such as penetration of natural gas, and use of solid fuels and biomass as backup fuels by urban populations.

Currently, there are no centralised sources of information for Europe that provide a comprehensive understanding of local air quality problems arising from SCIs.[32] The

[32] In the future, the main source of spatial information across Europe will be reporting under the Air Quality Directive (EC 1996). Under this Directive, countries are required to report exceedances, and submit a report of the plans and programmes they are going to undertake to reduce exceedances. A recent Commission Decision document (EC 2004) and working proposal (EC 2003a) on the arrangements for the submission of information

European 'picture' provided in this section is based on a wide range of literature-based sources and consultation with country experts, and provides (at minimum) a basic overview of countries where such problems can be observed.

There are a number of research programmes focused on urban air quality, and the problems relating to PM air pollution.[33] However, very few are looking at or provide (through reporting to date) a comprehensive overview of sector-based emission sources and resulting pollution levels across urban areas in Europe. Very few spatial inventories, including those used in CITY-DELTA,[34] provide additional understanding of the problems associated with SCIs, primarily as inventories are not constructed from 'bottom-up' data e.g. surveys that indicate numbers of households burning a given fuel in specific locations.

Two additional factors make it difficult to comprehensively understand this issue based on the available data. Firstly, the focus of local air quality research and management in Western Europe appears to be on the road transport sector. This potentially means less available information on other sources, such as SCIs, that may be less significant nationally but important locally. Secondly, studies often focus on larger cities, where monitoring systems are in place, and where improvements in energy infrastructure have resulted in a reduced contribution from SCIs. Smaller urban areas may not have the monitoring networks to identify problems from SCIs, or the equivalent investment in energy infrastructure, providing cleaner fuels.

Our understanding of local air quality problems has been constructed on the basis of the emission inventory data (in section 3), a range of literature-based sources, and consultation with country experts. An overview of the evidence on SCI-related urban air quality problems is provided in Table 7.7.

on plans and programmes provides the template for reporting under the Air Quality Framework Directive. In the future it is hoped that such reporting will provide important information on the action being taken across Europe, including in the new member states. The extent of air quality problems resulting from emissions from small combustion installations will be identified to some extent through the action that member states are taking to address the air quality problems. The plans (under the First Daughter Directive) were required for the first time by December 2003.

[33] CLEAR (Cluster of European Air Quality Research) http://www.nilu.no/clear/

[34] CITY-DELTA http://rea.ei.jrc.it/netshare/thunis/citydelta/

Table 7.7 Identification of local air quality problems across Europe due to non-industrial SCI sources

Country	Inventory data	Evidence of local air quality problems
Poland	Significant use of solid fuels	• Largest consumer of coal in Europe, including in the residential sector for heating. Coal combustion from households contributes significantly to low level emissions in big urban areas. In a number of cities, low level emissions have been significantly reduced by the introduction of coal-to-gas conversion programmes e.g. Krakow[3] • Individual coal-based heating systems are one of the main air pollution sources of PM_{10} in Kracow, although good estimates are unavailable to apportion pollution to different types of sources. Modification of heating system has been an important reason for reductions to date (annual PM_{10} mean in 1999 of 45.4 $\mu g/m^3$)[5] • Given the significant use of solid fuels in Poland, it is particularly important to understand contribution of SCIs to urban air pollutant concentrations. Significant differences exist across the country depending on the region, and the specific urban area in question. Across urban areas in Poland, SCIs in the residential sector contribute between 20 to 70% of urban pollution levels, depending on the energy market characteristics of the region, energy costs relative to economic prosperity, and specific emission reduction programmes in certain areas. Another factor is the destruction of the building stock during World War II, with a city such as Lodz experiencing higher emissions from SCIs than a city such as Warsaw. In Warsaw, many newer buildings with more modern appliances (which use less solid fuels) have been built due to the level of destruction.[8] • The following areas in Poland have the following characteristics, leading to significant variation in urban emission contributions from non-industrial SCIs: (1) Upper Silesia – significant use of hard coal for residential heating, with SCIs contributing over 60% (in winter 90%) to urban air pollutants such as PM, SO_2 and B(a)P; (2) Northern / Central Poland – lower than Silesia, due to greater use of gas and oil, and district heating; (3) West / North East Poland – certain urban areas have significant use of solid fuels. [8]
Czech Republic	Significant use of solid fuels	• Not identified as a priority problem in the State Environmental Policy Review[1] and across main urban areas, PM standards generally seem to be met[2] • Major gasification programme (driven by environmental concerns) during the 1990's means many urban households use natural gas for heating (40% of all households)[3] • Similarly to Poland, regional variations across the country are significant e.g. South Moravian, Zlin and Olomouc have high natural gas levels, and lower pollution levels. Other areas of the Czech Republic have much higher coal consumption (although it is not clear whether this is consumed in urban areas or not).[10] • Twinnings project indicates that there are smaller communities that are heavily reliant on solid fuels (where gas networks do not exist). Project did not find exceedances (based on Air Quality Directive limits) of PM in areas investigated[4]
Hungary	Some use of solid fuels	• Significant natural gas network, with over 40% of households supplied. Like many central and Eastern European countries, significant reliance on coal in the 1980s[3] • Indication that air quality problems in Budapest due primarily to road transport[5]
Lithuania	Some use of solid fuels	• Gas distribution network extensively covers residential areas in the major cities; in other cities a fairly extensive network is available[3]
Slovakia	Some use of	• Slovakia has the second densest gas network in Europe after the Netherlands. 90% of the population were connected to the gas network

	solid fuels	in 2000, representing 63% of communities in Slovakia (1804 out of 2867). This number has trebled since the early 1990s. District heating is also a very important source of heating in Slovakia. 100% of the heat used in apartments (49% of households) is supplied by district heating – gas accounts for 73% of district heating[3]
Slovenia	Limited use of solid fuels	• National air quality standards across major urban areas appear to be met[2] • Two cities considered in APHEIS project; in both cases, solid fuel use was more prevalent but due to gasification, use of abatement technology and better quality fuels (SSF), SCIs make a much less significant contribution. In Celje, road transport is the most important source of PM_{10}. It is interesting to note that the use of poor quality coal in home heating used to be the most important source but this fuel has been replaced by gas. The clean action plan (over the last 10 years) has led to 45 km of gas pipeline being built. Gas prices have also been subsidised by the local authority, and bank loans have been made available for households in order to connect. In Ljubljana, road transport is most important source of PM10 (70%), followed by local heating plants and individual home heating systems (30%). The main reduction has been through increased gas consumption, and use of smokeless solid fuels. Annual PM_{10} mean in 1999 of approx. 36 $\mu g/m^3$ in both cities.[5]
Bulgaria	Significant use of solid fuels	• In terms of national ambient air quality standards for PM, Bulgaria has many examples of non-compliance across many cities. Residential heating (using solid fuels) is identified as the significant source of emissions[2] • Further information on problems limited, based on contact with SILAQ staff in Bulgaria
Romania	Significant use of solid fuels	• Many examples of non-compliance with national standards; residential heating (using solid fuels) is significant source[2] • In APHEIS, Bucharest had the highest PM levels, with home heating using solid fuels making a significant contribution. Combustion plants for central heating, and individual heating systems accounted for 32% of emissions. In the study, Bucharest has the highest PM_{10} mean annual concentration in 1999 of 73 $\mu g/m^3$ (although monitoring dataset was not complete)[5]
France	Significant use of biomass	• 9 French cities considered in APHEIS (based on data from the PSAS-9 cities project). Interestingly, apart from Strasbourg, there is no mention of significant air emissions from wood burning, potentially indicating that most wood consumed in the residential sector will either be in rural areas or smaller cities / towns. In 1997. 40% of particle emissions were from the residential sector in Strasbourg, predominantly due to burning of wood (annual PM_{10} mean in 2000 of 22.3 $\mu g/m^3$).[5]
Norway	Significant use of biomass	• A report by Statistics Norway suggests residential wood combustion is one of the most important sources of local air pollution – it was responsible for over 64% of PM emissions (50% in largest cities). 30% of households in Oslo use wood for heating during winter – over 60% of stoves used are conventional, with around 15% new stoves. Approximately 20% used open fireplaces.
Sweden	Significant use of biomass	• PM_{10} emissions from residential wood burning are important. There are few wood boilers but many smaller stoves (10's of thousands). In residential areas, the importance is hard to determine exactly due to uncertainties on fuel use and emission factors[5] • In Stockholm the dominating source of PM is small-scale wood burning, and may account for up to 50% of PM emissions in residential areas. The estimate is, however, very uncertain due to lack of information on emission factors, large variation in the emissions from different types of boilers depending on burning conditions and also uncertainties regarding the amount of wood burned[6] • Swedish research programme (Biomass Combustion Health and Environment) to research emissions from wood burning and associated impacts. In one test site, significant emissions estimated from old wood stoves (accounting for 15% of wood burning stock) of 35 tonnes per year (out of total 66 tonne inventory). New stoves accounted for 1 tonne. 98-percentile levels often exceeded 50 $\mu g/m^3$ near old stoves.[7]

[1] Ministry of the Environment of the Czech Republic 2001; [2] REC (1998); [3] EW (2000); [4] Brandt (2004); [5] APHEIS (2001); [6] Johansson (1999); [7] Omstedt (2001/ 2003); [8] Kubica (2004); [9] Statistics Norway (2004); [10] CHMI (2003)
* 2005 annual mean limit is 40 $\mu g/m^3$; 2010 limit is 20 $\mu g/m^3$ under the Air Quality Framework Directive.

Based on this review, a number of countries, listed below in Table 7.8, can be identified that potentially have localised urban pollution problems relating to the burning of solid fuels and biomass.

Table 7.8 Potential local air quality issues (particularly relating to PM) arising from SCI sources

Fuel use type	Country group	Countries	Comment
Solid (coal)	New Member states	Poland, Czech Republic, Slovakia, Hungary	In particular Poland. Others such as Czech Republic, Slovakia, and Hungary have high levels of gas use but have used significant amounts of solid fuels in the past. This could lead to persistent use of solid fuels in certain areas e.g. smaller urban areas with no gas distribution network.
Solid (coal)	Accession countries	Romania, Bulgaria	Romania and Bulgaria appear to have significant urban air quality problems as a result of solid fuel use
Solid (coal)	Western Europe	UK, Ireland, Germany	Western European countries, including the UK, Ireland and Germany, have all used significant amounts of solid fuel in the past. As seen in the UK (particularly in Northern Ireland), solid fuel use can persist in specific regions, even if not hugely significant in national terms.
Biomass	Scandinavian	Finland, Sweden, Norway (NB. information on Baltic countries not available)	Urban air quality problems (due to PM) from biomass burning have been a concern in specific urban areas of Scandinavia (particularly during the winter heating season).

The following conclusions can be drawn regarding urban air quality problems relating to solid fuel and biomass burning:

- A number of countries, particularly new Member States, in particular Poland, and to a lesser extent, the Czech Republic have significant levels of solid fuel consumption, although generally not in the largest urban areas. It is projected that in future years, significant reductions in solid fuel use are going to occur, particularly as both countries have significant gas supply infrastructure; however, it is quite possible that many regions within certain countries may continue to use solid fuels, particularly in towns and smaller cities which gas infrastructure may not reach for a number of years. Therefore, persistence of use in specific regions (as has been the case in Northern Ireland) may be a problem in the future, even though the inventory indicates significant decline in overall consumption.
- Accession countries, such as Bulgaria and Romania, both use significant amounts of solid fuel, and subsequently have associated pollution problems.
- PM from biomass is a recognised problem in Scandinavian countries, including in urban areas. Biomass consumption is unlikely to decline significantly in the future, and is likely to be promoted under Climate policy – therefore, improving SCI technologies is likely to an important means of reducing such emissions. In Oslo, Norway, 30% of households use wood, with over 20% of them burning in open fireplaces (compared to the national average of 4%). In France, most biomass appears to be used outside of the largest cities although this has not been conclusively determined. In other Baltic countries, with a similar fuel use profile to Scandinavian

countries, similar problems may exist although the extent of such problems is not known.

What is clear from the available data is that it is too simplistic to state that solid fuel and biomass tends to be burnt in rural areas, while gas and oil is used in cities. Many factors will determine whether solid fuels and biomass are used in urban areas including:
- Regional culture
- Climate
- Age of the building stock
- Availability of natural gas / district heating
- Availability of low priced biomass and solid fuels
- Use for backup heating in urban areas

Clearly, biomass is used in many Scandinavian urban areas, often as an occasional fuel and particularly during winter. It is also clear that in many Scandinavian countries a significant proportion of appliances, in particular stoves, are of conventional (rather than advanced) design. Coal-based solid fuels, although declining in use overall, are likely to remain an important fuel source for specific communities in future years, particularly in Poland and Accession countries.

The significant differences in fuel use across Europe confirms that action to reduce emissions from the consumption of solid fuels and biomass needs to be instigated at the local level and that addressing these types of problems is difficult at a European level. What is provided at the European level, through the Air Quality Framework Directive, is the legislative framework that ensures Member States act but without prescribing the specific action to be taken. With this mechanism in place, it is important that reporting is under the Directive takes place, so that the Commission better understands the problem of urban pollution associated with SCIs, and can identify the need for potential further action on the basis of such data.

7.3.2.3 Assessing the cost-effectiveness of local-based measures

Given that local-based measures are likely to be an important means of reducing emissions from specific urban areas, this section considers the cost-effectiveness of two specific examples of local-based measure. Both focus on solid fuels; however, there may be scope by authorities to use similar mechanisms for reducing emissions of PM from biomass (although clearly it is important that this does not conflict with objectives of climate policy driven measures). A specific example is Swedish regulation that stipulates certain standards for wood appliances used in particular built up areas.

The two case studies are the introduction of smoke control areas in Belfast and Northern Ireland, and the ban on sales of bituminous coal in Dublin, both of which are described in detail in section 6.2.2.1. A case study on measures implemented in Krakow is described in section 7.3.5 (on Structural Funds), but is also relevant here.

The use of smoke control areas in Northern Ireland
Further analysis can be undertaken to estimate the cost-effectiveness of using smoke control areas to reduce a range of pollutants through the introduction of cleaner fuels, specifically smokeless solid fuels. This assessment is based on a typical mix of household appliances specific to Northern Ireland (see Pye 2003).

The displacement of bituminous coal by smokeless fuels in a smoke control areas can result in an approximate reduction in the use of this product of 60%, assuming a non-compliance rate of 20% (i.e. 20% of the population continue to burn coal despite restrictions). Reductions in emissions of PM_{10} from the use of solid fuels can range between 37 – 52%, depending on the mix of smokeless fuels used.

The main cost of this measure is the enforcement of SCA restrictions, which are estimated to cost €18 - €46 per household. Another cost is the potential price differential between fuels – this has not been included because although smokeless fuels such as SSF and anthracite tend to be more expensive, they also have higher heating values; therefore, there is no real increase in costs. An abatement cost per tonne for PM_{10} of €4500 – 6400 has been estimated, illustrating how cost-effective such a measure can be. Overall effectiveness is also significant, leading to up to 60% reductions in PM_{10}, based on the mix of fuels considered.

The use of alternative solid fuels as a means of complying with restrictions such as SCAs can be extremely cost-effective (even if much higher enforcement costs were assumed) due to the significant contribution from bituminous coal to PM_{10} emissions, and the relatively low costs of enforcement. Costs may be more significant if it is assumed that a percentage of households will switch to gas or oil (which is likely to be an option for households that can afford this investment).

Sales ban on bituminous coal in Dublin
The costs and benefits of this case study are summarised here but are produced in more detail in the CAFE programme study specifically on local measures.

A ban on bituminous coal sales in Dublin was introduced in 1990, which led to significant reductions in the PM related emissions. Clancy (2002) describes a 70% drop in black smoke concentrations, with a change in average concentration from 50.2 $\mu g/m^3$ between 1984-1990, and an average concentration of 14.6 $\mu g/m^3$ after the introduction of the ban. Levels of sulphur dioxide also dropped by a third. The use of smoke free zones (as used in the UK under the Clean Air Act) had been attempted, with the introduction of a zone in one of the worst polluted areas. This was not particularly successful due to the difficulties of enforcement. The ban on sales was much easier to enforce as it targeted the supply of coal (APHEIS 2001).

The impact of the sales ban on death rates has also been assessed by Clancy (2002); the analysis showed an average 403 fewer non-trauma deaths after the introduction of this measure, including 120 fewer respiratory deaths, 312 cardiovascular deaths but 29 more deaths from other causes. After adjustment for weather, epidemics and death rates in the rest of Ireland, there were considered to be 116 fewer respiratory deaths, and 243 fewer cardiovascular deaths. The paper concludes, after taking account other factors, that 'control of particulate air pollution in Dublin led to an immediate reduction in cardiovascular and respiratory deaths.' A simple approach has been used by McLoughlin (2001) to estimate the value of benefits of pollution reduction, based on unit damage values. Benefits (primarily health) of the ban are calculated at €20.1 million, €4.7 from SO_2 reduction and €15.4 from reductions in PM_{10}.

McLoughlin (2001) has undertaken an analysis of the costs-effectiveness of the Dublin ban. Households who switch away from solid fuel as a result of the ban were estimated to make savings of €10,800 (2001 prices) over a twenty year period, while households that used alternative solid fuels (e.g. smokeless solid fuel) were estimated to incur costs of €5,900 over twenty years. The financial benefits realised by those households that switched fuels is based on the much lower energy costs relative to solid fuels, due to cheaper prices and better efficiencies. These results are of course very sensitive to the relative prices of gas, smokeless solid fuels and coal. (Note that costs over time were not considered in the Belfast case study).

Based on this large differential between the costs (over time) of using solid fuels relative to gas, it might be expected that more people would have switched prior to any ban taking force (although it is clear from Clinch 2001 that the market trend was moving in the direction of switching to other fuels). McLoughlin (2001) explains this lack of change due to:

- Lack of information about the financial benefits
- Initial costs associated with switching to alternative heating systems
- Barriers to change in the rented accommodation sector
- Low income households not willing to consider long pay back periods

In terms of producer costs, the main losers were the coal distributors, with the ban reducing demand for solid fuel by 40%. However, this reduction in demand of one fuel has led to significant increases in the demand for oil and gas. Two types of administrative cost have been identified – enforcement costs and allowance payments for smokeless solid fuel. In Dublin, two staff members enforce the ban – their salaries total just under €60,000. In addition, there are sampling costs and court costs (in the case of prosecutions). A smokeless fuel allowance helps low income families cope with the increased costs of higher priced fuel; it is estimated to cost €7.4 million per annum (McLoughlin 2001).

Most assessments of the coal ban illustrate the significant impact in emissions reductions, and associated health benefits. In an analysis by Clinch (2001), it is also demonstrated that current trends in the fuel market were also important for the success of this measure. The trend of moving to gas and oil was already well established, with a declining use of solid fuels. It is believed that the ban acted as a catalyst, in providing the incentive for consumers to move to gas and oil sooner rather than later, thereby speeding up this fuel switching. This is an important point when considering the effectiveness of this measure – a gradual switch was already being made to other cleaner, more efficient fuels.

It is clear that such a ban had significant environmental benefits in terms of improved air quality as the main source of urban pollution was significantly reduced. Based on the studies reviewed, this measure seems to be highly cost-effective due to the low costs of enforcement and administration of a ban, and the significant reductions that can be realised. The overall net savings of €184 million (consumers that switched versus those who went to alternative solid fuels), outlined by McLoughlin (2001), was realised due to the significant price differential between the fuels. Even without such savings, this appears to be a low cost measure. However, it is important to realise that the conditions were conducive to the success of this measure, with a relatively new gas infrastructure in place, and a trend already established towards fuel switching.

Summary
Both of these case studies illustrate similar types of local action, which were cost-effective and enabled the removal of a highly polluting fuel source. They illustrate the importance of local-based action to target specific localities with that have their own characteristics. Similarly, the Krakow case study in section 7.3.5 provides similar findings. The Dublin ban was a response to European Air Quality Directives; this measure may be important in other recent Acceded or Accession countries where similar problems are observed, and which need to meet European Air Quality standards.

Biomass-based local measures are more likely to focus on improving the appliance stock, with less focus on actual restrictions on use (although measures could encourage the take-up of pellets and other manufactured biomass fuels, although switching of biomass fuels e.g. wood to pellets may result in appliance replacement anyway).

7.3.2.4 The case for additional European level action

The Air Quality Framework Directive should provide the impetus for the implementation of local measures where local exceedances (including those due in main to SCIs) are identified. An additional European measure restricting the burning of certain fuels (including fuel quality) or use of certain appliances, based on criteria such as population density levels, or specific urban boundaries, may not be an attractive option for the following reasons:

- Identification of the problem is very difficult, without which it would be difficult for the Commission to justify such action
- A mechanism exist (Air Quality Framework Directive) that stipulates the need for action if such exceedances do exist, under which flexibility is retained by the Member State concerning what action is required.

It is recommended that the Commission evaluate future reporting under the Air Quality Framework Directive, to determine whether exceedances are being identified, and what action is being taken to target such exceedances. It will also be necessary to ensure that Member States are undertaking comprehensive monitoring in identified zones and agglomerations through which to identify such exceedances.

If reporting under the Air Quality Directive indicates significant exceedances across many countries in Europe, the Commission may want to consider further measures to reduce emissions from solid fuels. However, based on the evidence, it seems likely that solid fuel consumption is concentrated in limited number of countries, and is projected to decrease significantly by 2010 and beyond. In addition, the Air Quality Directive should ensure such local issues are identified, and lead to local measures being implemented to meet limits (as was the case with the Dublin coal ban in 1990).

If considered necessary, the type of measure that could be considered might have the following characteristics:

- Ban on the sale of a coal products not meeting a certain quality e.g. all coal based products except smokeless types e.g. anthracite, manufactured smokeless solid fuel
- Ban to be introduced in urban areas with more than 100,000 inhabitants, equating to a population for Europe of over 131 million. For cities with populations over 250,000, there is a total population of 79 million. This number is likely to be much higher if agglomerations were taken into account, not just city areas. The actual number of

people living in areas where benefits of this measure are realised would be considerably less.

The structure of a measure such as this would be crucial to gaining political acceptability. In addition, justification would need to made on the basis of the costs and benefits, which would only be possible if better data was known concerning the amount of solid fuel use. Currently, such information would only be available through detailed consultation with relevant national authorities (although this type of data is often not compiled by autorities). Similar measures for biomass are unlikely to be considered at the European level, due to potential conflict in objectives with Climate policy.

7.3.2.5 Issues for the Thematic Strategy

The main conclusions from this section are:

- It is difficult to establish exactly how many people are exposed to high levels of PM, where contribution to pollution from SCIs is significant, due to a lack of information both at the European and national level.
- Based on the available evidence, pollution problems from solid fuels and biomass exist in certain countries across Europe (e.g. Eastern Europe, Scandinavia). The spatial pattern of emissions is complex and dependent on a range of country-specific factors (although the general pattern for larger urban areas is that the main fuels used in non-industrial sectors are liquid fuels and natural gas).
- Proper implementation of the Air Quality Directive should ensure that measures are implemented at the local scale, in order to address any exceedances. A national emissions ceiling approach could also lead to implementation of local measures to reduce such emissions.

An important recommendation from this study is that more comprehensive information is needed to enable policy makers to make decisions with regard to whether additional action needs to be taken; an important future source of information is likely to be reporting under the Air Quality Framework Directive. However, it is clear that many Member States do not necessarily have a comprehensive understanding of the urban air quality problems associated with biomass and solid fuel burning, with regard to:

- *Spatial resolution* – the question of where certain fuels are used may be well known at the local level. However, such information is often not centralised at the national level.
- *Emission estimates* – for biomass and solid fuels, there is often a lack of understanding concerning activity data; for solid fuels, the specific products used are not known (which have significantly different emission factors), while for biomass, activity data are difficult to estimate due private 'harvest' and emission factors are very uncertain.

Local-based measures, implemented at the local level by national and regional authorities can be a cost-effective way of targeting local air pollution problems. The policy framework currently in place, under the Air Quality Framework Directive, should be an adequate means of ensuring local problems are targeted, while allowing national authorities the flexibility to determine what action would be best to undertake. Local authorities are often best placed to deal with such problems, as they understand the issues, characteristics of the locality, and infrastructures to implement measures. Given the significant differences across Member States with regard to emission problems, action at this level is most appropriate.

7.3.2.6 Integration into RAINS model scenarios

The type of measures introduced at the local level that might be considered by relevant authorities in responding to emission problems include:

- *Switching to better quality fuels (but retaining current appliance)*
  The measure might be either a ban on the sale of specified solid fuels in specific urban areas e.g. Dublin ban on the sale of bituminous coal, or use of specified solid fuels in certain appliances in designated urban areas e.g. UK smoke control areas under Clean Air Act.
- *Switching to a better quality appliance (but retaining current fuel)*
  This has been done in different countries through replacement programmes e.g. introducing subsidies for advanced wood stoves, or through project funding e.g. introduction of improved technologies in Krakow.
- *Switching to an alternative fuel-technology combination*
  This involves switching primarily from solid fuels to gas or oil. It may also include switching from oil to gas.

All of the above control options are included in RAINS model to some extent. However, the RAINS model operates at the national scale, and therefore assessment of cost-effectiveness in specific localities is not feasible.

7.3.3 Fuel quality based measures

The lifetime of SCIs can be up to 20 years, and therefore, polluting installations may not be replaced for many years. Consequently, an important issue to consider is how the input fuel can be improved in order to reduce emissions without necessarily having to replace the appliance. For solid fuels and biomass, the quality of the fuel product is another significant factor in the levels of emissions from SCIs (in addition to the combustion efficiency), in particular PM, but also for other pollutants including PAHs and heavy metals. To reduce emissions of SO_2, fuel quality is the principal measure.

A broad overview of fuel quality based measures implemented across Europe was provided in section 6.2.3. Based on our understanding from this review of measures, a number of policy options have been proposed for further analysis in this section, and include:

- More stringent sulphur content of liquid fuel limits, beyond those stipulated in the Sulphur Content of Liquid Fuels Directive, with potential additional benefits for reducing PM.
- Introduction of sulphur content of solid fuels restrictions, using a similar policy mechanism to that for liquid fuels
- Increased use of pellets in the residential sector

Another important measure concerning fuel quality for reducing a range of pollutant emissions is the use of ‘cleaner’ solid fuels (e.g. smokeless solid fuels, coke) as an alternative to bituminous / subbituminous coals, which was considered in the previous section on ‘local-based measures.’

7.3.3.1 Proposed measures for consideration

The following measures are cross-sectoral, and apply both to industrial and non-industrial SCIs alike. However, this section primarily focuses on non-industrial sectors, as these are the sectors for which the emission issues have been identified.

Tighter restrictions on the sulphur content of liquid fuels
Restrictions on the sulphur content of liquid fuels across Europe are set out in the Sulphur Content of Liquid Fuels Directive. Sulphur content limits are set for heavy fuel oil and gas oil; for gas oil, which is the main grade of liquid fuel used in non-industrial sectors, sulphur content of this fuel used by Member States should not exceed 0.2% by mass from July 2000, and 0.1% by January 1st 2008. The 0.2% limit has been modelled in RAINS for the commercial-residential sector, showing significant reductions in emissions of SO_2; in addition lower sulphur content fuel (0.045% content) is modelled for future years (2010 and beyond), showing significant levels of penetration in future years. A 1% limit for fuel oil is currently set in the Sulphur Content of Liquid Fuels Directive, which may be what is reflected currently in the RAINS model as low sulphur fuel oil.

Although SO_2 was not identified as a significant emissions priority in this study, the Commission could consider further tightening of sulphur content limits, particularly if additional benefits can be demonstrated as reductions of PM, both primary and secondary. Based on literature review, it is thought that reductions in sulphur content of liquid fuels may lead to reductions of primary PM (particularly from fuel oils), secondary PM, and of course result in further reductions of SO_2 emissions.

The US EPA emission factor research programme (US EPA 1998b)[35] provides an indication of the impact of sulphur content on total particulate matter (TPM) for liquid fuels. It states that primary PM emissions will depend on the grade of liquid fuel; for heavy fuel oils (or residual oils), PM emissions are directly related to oil sulphur content, the relationship of which is expressed below.

$$9.19\ (S) + 3.22\ (lb/10^3\ gal)$$

S indicates that the weight % of sulphur in the oil should be multiplied by the value given. For example, if the fuel is 1% sulphur, then S = 1.

However, the emission factor guidance document goes to state that for medium distillate (gas oil) oil-fired boilers (that would be used more widely across non-industrial sectors) PM primarily results from the carbonaceous particles resulting from incomplete combustion and is not correlated to the ash or sulphur content of the oil. This would suggest that tightening sulphur limits would not affect primary PM emissions.

More recently, research has been undertaken by the CANMET Energy Technology Centre in Ottawa (Lee 2002) which shows that the impact of sulphur levels in distillate oils has an impact on filterable PM. The work concluded that higher sulphur content in fuels 'produced proportionately higher filterable PM emissions' and that 'this suggests that reducing sulphur content of in heating fuels would reduce PM emissions from residential appliances.' Most of the filterable PM was in the sub 2.5 µm range.

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[35] http://www.epa.gov/ttn/chief/ap42/ch01/

Table 7.9 Results of experiment assessing role of sulphur content in distillate oil and emissions of Filterable PM mass concentrations

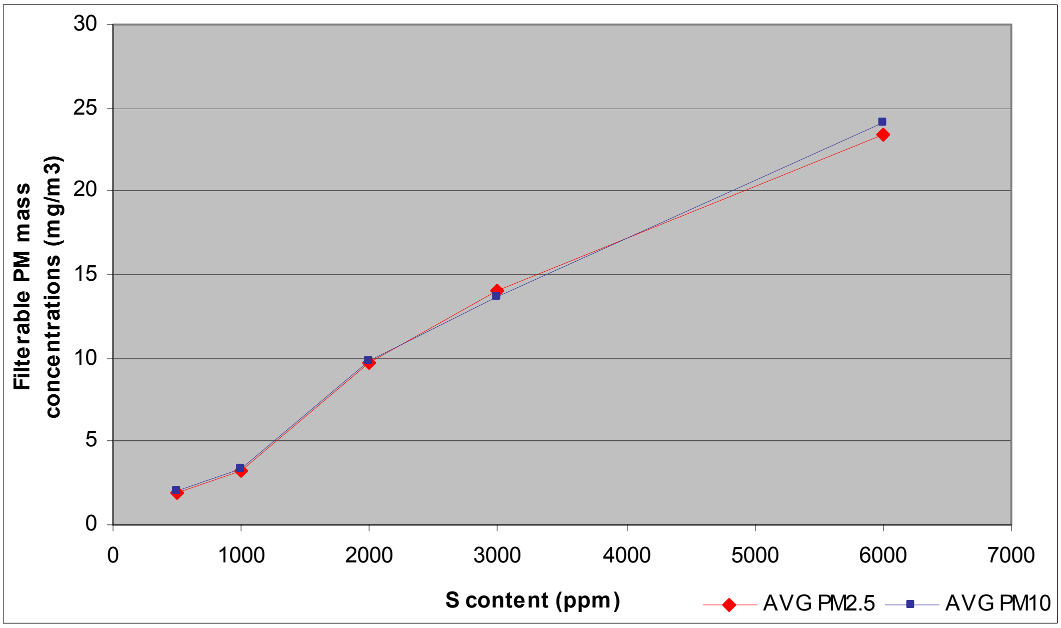
Fuel name*	% S content of distillate oil	Average $PM_{2.5}$ (mg/m^3)	Average PM_{10} (mg/m^3)
LD-500	0.056	1.93	2.09
LD-1000	0.1	3.29	3.35
No.2 oil	0.195	9.76	9.86
LD-3000	0.3	14.09	13.7
LD-6000	0.6	23.36	24.17

* All distillate fuels have very similar properties with the exception of sulphur content.

As the above results have been produced under accelerated laboratory conditions, it is not clear whether the filterable PM is the concentration that would be found in a stack (and considered as primary) or if it is the result of the formation of sulphates under accelerated conditions (and therefore secondary). This study used US EPA Method 5 for the lowest sulphur content fuel (LD-500) and found a concentration of 1.77 mg/m^3 of total PM, compared to 2.09 mg/m^3 using the study methodology. Method 5 measures the particles that would be found in a stack (therefore excluding sulphate formation from SO_2), and possibly indicating that a significant proportion of the 2.09 concentration measurement is primary PM. However, this is inconclusive based on a single value.

What this study does indicate is that overall PM (both primary and secondary) are reduced significantly in relation to sulphur content levels. The results in Table 7.9 have been plotted in Figure 7.2 below, to provide an understanding of the correlation from these tests between sulphur content and filterable PM. The profile indicates significant increases in PM concentration with sulphur content.

Figure 7.2 Sulphur content effects on particulates in distillate heating oils (from Lee 2002 study)



These are interesting results and provide some evidence of the impact of sulphur content. However, as the authors acknowledge, further work is needed to establish such trends. Other research concerning PM reductions resulting from the use of lower sulphur content fuel has been done in the road transport sector. Clearly, drawing direct comparison between stationary combustion units and road vehicles is not possible; however, such data provides additional incentive for further research in the commercial-residential sectors. The reduction factors in Table 7.10 are used in the UK National Atmospheric Emissions Inventory programme to illustrate the reduction in PM_{10} emission factors, based on sulphur content.

Table 7.10 Changes in PM factors resulting from the use of different sulphur content diesel in road vehicles

Reduction in ppm	Reduction as % S content	PM_{10} reduction factor
2000 to 500	0.2 to 0.05	0.87
500 to 50	0.05 to 0.005	0.92
50 to 10	0.005 to 0.001	0.95

Further work will need to be undertaken to further consider the impact of reducing sulphur content on PM emissions. Without further understanding of the potential additional benefits, particularly for PM reduction, the Commission may not want to make existing sulphur limits more stringent. SO_2 emissions would be further reduced by such a measure (and associated secondary particles); however, as illustrated in Figure 3.6, SO_2 emissions are projected to decrease significantly and may not therefore be such a priority for policy if additional benefits are not fully understood.

Table 7.11 illustrates the emissions contribution of PM_{10} from gas oil and fuel oil in future years.

Table 7.11 Emissions contribution of liquid fuels in projected years (%)

Comparison		2000	2010	2020
% of commercial-residential	Gas oil	0.48	0.47	0.56
	Fuel oil	0.89	0.64	0.52
	Total	1.37	1.11	1.08
% of commercial-residential (without biomass)	Gas oil	1.35	3.36	7.49
	Fuel oil	2.49	4.50	7.07
	Total	3.85	7.86	14.56

The contribution of liquid fuels to PM emissions from the residential-commercial sector is low, at just over 1%, and so in terms of overall European emissions of PM is insignificant. If biomass is removed from this comparison, the contribution from liquid fuels becomes more significant, particularly in future years (and as an urban source of PM). In densely populated urban areas with a significant amount of oil being used in boilers that are not necessarily performing adequately, the local contribution from this source may be much greater (see section 7.3.6.1 for an understanding of the impacts of boiler maintenance).

Restrictions on the sulphur content of solid fuels

European-based legislation does not currently set limits for sulphur content of solid fuels. Two examples of limits being used in Member States are described in section 6.2.3.1. In Northern Ireland, regulations stipulate a limit of 2% maximum sulphur content on all solid fuel products, whilst in the Republic of Ireland, a voluntary agreement on solid fuel sales restricts content of bituminous coal to 0.7% sulphur content.

There could be some significant difficulties in introducing this type of regulation across Europe, in particular because so many different solid fuel products exist, which have a wide variety of sulphur contents. Coal, as outlined in section 5.3.2, will have significant variation in the sulphur content of solid fuels, depending on whether it is lignite or anthracite, and the region from which it is mined. In manufactured coal-based products, sulphur content will vary depending on factors such as whether petroleum coke (which tends to be high in sulphur content) has been added to help flammability. Due to these variations in sulphur content, setting limits across the whole of Europe may be difficult.

Two factors need to be considered by the Commission before such a measure is considered further:

- As shown in Figure 3.6, the projected emissions of SO_2 decrease significantly, particularly from solid fuels; therefore, this may not be such an important policy priority.
- The consensus of in-house experts is that the sulphur content of coal does not affect emissions of PM directly (although certain coal products (either natural or manufactured) that tend to have lower sulphur content may also have lower associated emissions of other pollutants e.g. PM).

Given the priorities of the Commission, particularly focusing on PM emissions from small sources, and the significant reductions observed in the use of solid fuels (see Figure 4.2), this measure may be a lower priority. Consideration of such measures in RAINS are considered in 7.3.3.3

Increased use of pellets in the domestic-residential sector
The type of biomass product used in an appliance has a significant impact on the level of emissions of PM and NMVOC; in particular, the use of pellet stoves and boilers has been shown to reduce emissions significantly. Emission factors for pellet stoves (see Appendix 4) illustrate a reduction of over 80% for PM and NMVOC relative to a conventional stove.

The use of biomass fuel products, such as pellets, as an alternative to wood has been shown to result in significant emission reduction. This is because these products are more homogeneous in terms of fuel content and size, and tend to be burnt in more advanced (automatic feed) appliances (see section 5.3.1.2 and 5.3.2.3 for more detail). There are a number of problematic issues for developing a European measure for biomass, based on fuel quality:

- Switching from traditional wood-based fuel to pellets could mean significant levels of appliance replacement, and high costs for different sectors.
- Any type of restriction regarding the type of biomass fuel used could conflict with climate change policies promoting their use.

Due to the above issues, it is considered that any measures to reduce emissions from biomass would be better targeted at product standards, rather than the consumption of specific products. Product standards are described in more detail in section 6.2.1. In addition, it is probable that there is limited variation within pellet-based fuels for PM, so additional measures to actually regulate the product itself may not be required.

7.3.3.2 Issues for the Thematic Strategy

It is clear that significant progress has been made in reducing emissions of SO_2 through sulphur content directives at the European level. It is important for the Commission to consider what additional steps could be taken to further reduce emissions through such measures. The benefits of further stringent limits of SO_2 on liquid fuels, particularly gas oil, to the levels specified for vehicle fuels need to be further researched, and balanced with other policy priorities. From the analysis in this section, even reductions below post-2008 limits could reduce overall PM (the split of primary and secondary is unclear). However, the emission inventory identifies liquid fuels as contributing only a small percentage to overall PM emission, and SO_2 significantly decreasing. Also to be considered is the spatial distribution of liquid fuel use – in densely populated urban centres, liquid fuels may become increasingly important as an urban source of PM (as seen for NOx emissions from natural gas).

The emission inventory indicates a significant decline in the use of solid fuels, and associated SO_2 emissions. Based on this trend, the introduction of regulations for sulphur content of solid fuel may not be a priority. In addition, new legislation would need to be proposed and justified on the basis of the benefits gained. Additional benefits as reductions of PM emissions are not thought to be likely (unless alternative fuel products with lower sulphur content are considered).

Significant reductions of PM are possible with the introduction of pellet fuels as an alternative to wood in the non-industrial sectors. However, it is difficult to envisage a policy mechanism at the European level that stipulated the type of wood products to use, particularly as this has implications for the type of appliance used. Member States will need to put measures in place to promote the use of pellet-based fuels, whilst ensuring the objectives of Climate policy are not hindered.

7.3.3.3 Integration into RAINS model scenarios

The RAINS model can run fuel quality based scenarios, as the inventory is energy-based, and changes to quality can be modelled through changes to emission factors. An overview of how measures discussed in this section are handled in RAINS is provided here, with comment on how additional information could be used, and what scenarios could be undertaken.

Improved sulphur content of gas oil
Lower sulphur content liquid fuels are already modelled in RAINS through the control options LSMD1 – 3. The reduction in SO_2 from the residential-commercial sector due to the introduction of these control options is illustrated in section 3.4.1 (in Figure 3.6). Control option LSMD1 appears to reflect the limit for fuels used after 2001 under Directive 1999/32 (Sulphur Content of Liquid Fuels Directive). To further reflect the impact of this Directive, it is proposed that another control option is used to reflect the post-2008 limit of 0.1% sulphur content (unless this is somehow already reflected in the model, using LSMD2).

The RAINS model will be undertaking maximum feasible runs, which will indicate the possible reductions from this fuel-sector combination of SO_2 e.g. by increasing the use of the lowest available sulphur content liquid fuel. Due to the uncertainty surrounding PM effects from reductions of sulphur content in medium distillates, no additional control option is proposed for the PM module (although there may be implications for modelling of sulphates based on Lee (2002)). An option could potentially be considered in the PM module that reflected the impact of reduction of sulphur content of heavy fuel oil on PM emissions (as set out in US EPA (1998) guidance).

Improved sulphur content of coal
In the RAINS SO_2 module, control options are included for coke and coal with sulphur content of 0.6%. This currently has limited scope in the Baseline data. A scenario could be considered that introduced greater penetration of these low sulphur coals, reflecting the introduction of restrictions, as seen in parts of the Republic of Ireland, where a limit of 0.7% sulphur content in bituminous coal for sale has been set. Such potential reductions and costs will probably be reflected in the maximum feasible reduction scenario.

No literature-based evidence has been found that indicates lower PM as a function of the sulphur content of coal. It may be that alternative solid fuels products e.g. derived coals do have lower sulphur content; if so this will already be reflected. PM emissions are predominantly a function of the type of solid fuel e.g. ash content and the combustion process, depending on the appliance being used.

Increased use of pellets in the domestic-residential sector
The RAINS model already includes technologies for the use of pellets (although for the stove category, it is not clear whether pellet-based stoves are currently included). It is proposed that a subscenario is set up to specifically look at increased switching between conventional wood stoves and boilers to pellet based technologies.

It is not clear what the policy mechanism would be for increasing use of pellet-based technologies as opposed to conventional or advanced non-pellet appliances – clearly, product standards could be one of the means of further driving the use of such technologies. Irrespective of the policy measure, the RAINS model can and probably is, through maximum feasible reduction scenarios, assessing the contribution to reductions that can be made from these technologies. It may be that an additional technology, pellet stoves, could also be included in the framework of the model – particularly as in certain countries, significant levels of PM arise from stoves. The relevant emission factors are included in this report (or can be found in Sternhufvud 2004). A simple scenario may be to increase penetration of pellet-based technologies e.g. by 10% in 2010 and by 20% in 2020.

7.3.4 Installation specific limits

Large installations (>50 MW_{th}) have traditionally been the focus of European industrial regulation, and have provided the potential for significant emission reductions from a relatively small number of sites. The main European Directives for reducing emissions from large installations include the IPPC Directive (EC 1996), the Large Combustion Plant Directive (EC 2001), and Directives on waste incineration. In section 3.5, emissions from industrial SCIs have been estimated, and indicate that in specific countries, they account for a fairly significant proportion of industrial combustion emissions. The main findings are summarised in Table 7.12 below.

Table 7.12 Summary of emission estimates made for industrial SCIs

Comparison	SO_2	NOx	PM_{10}
% Industrial combustion emissions in countries (as a range)	1 – 31**	1 – 29**	13 – 29*
% Industrial combustion emissions in Europe	11.7	11.8	18*
% Total European emissions	8	4	3

* Based on data from three countries only
** Not considering Austria, Latvia and Slovenia – for which the reported data looks erroneous

Industrial SCI sources are not estimated to be significant relative to total European emissions, particular for pollutants PM_{10} and NOx. For industrial combustion emissions, SCIs contribute approximately 12% of SO_2 and NOx emissions, while the percentage total is higher for PM_{10}, at approximately 18% (although this value is based on data from three countries only).[36] Based on these inventory estimates, and the significant associated uncertainties, this source has been identified as a potential priority source. The following questions provide the structure of this section, in determining the basis for further policy action to further reduce emissions from this source:

- Does the current legislation (European and national) already cover a significant proportion of industrial SCIs?
- If not, what policy options could be considered to reduce emissions from this source sector?
- If this source is considered a priority for action and measures are considered, what might the potential impact and costs be?

Analysis in this section is primarily based on national data from specific countries due to the lack of detailed data at the European level. An overview of the inventory methodology for this source, and emission estimates can be found in section 3.3.3.

7.3.4.1 Scope of existing legislation

It is important that the scope of existing regulation is understood e.g. numbers of installations (< 50 MWth) and emissions covered by existing Directives, before considering the need for additional action. This is fundamental to policy makers' understanding of which measures need to be given priority in the framework of any future policy development.

The LCP and IPPC Directives are the most relevant legislation for environmental regulation of larger industrial installations. The LCPD covers combustion installations greater than 50 MW_{th}, and therefore has a clearly defined scope, which does not cover any SCI sources; the IPPC Directive has a broader scope, defined predominantly on the basis of industrial processes. Using country specific data (from the UK), an indication of the extent to which the IPPC Directive covers combustion installation below 50 MW_{th} can be determined.

[36] There are probably a significant number of sites in the public / institutional sector that would also come under the scope this type of regulation. However, due to the way the inventories have been constructed, splitting out the larger institutional sites has not been possible – as a result, emission estimates from such sites are not included in the above data.

Installation-specific data from the EU Emissions Trading Scheme (ETS) application and permitting process in the UK provides a good understanding of which installations already hold existing environmental permits.[37] From these data, sites currently regulated under the IPPC Directive (in the UK, under the PPC regulations (DEFRA 2004a)) can be identified (see Table 7.13 below).[38]

Table 7.13 Data from applications to the EU ETS scheme for England and Wales[39]

Sector	Site number	% Installations regulated through IPPC Directive	% Other[1]
Cement / Lime	31	100	
Ceramics / Bricks	110	4 – 49	51 - 96
Coke Ovens	4	100	
Energy Activities	573	47 – 49	51 - 53
Glass	33	42 – 58	42 – 58
Iron and Steel	12	100	
Oil refineries	13	100	
Paper and Pulp	68	100	
Total	**844**	**53% (average)**	**66% (average)**

[1] Installations either unregulated by European legislation, or regulated through UK national regulation. Note that none of the sites have **single** combustion units below 20 MW_{th}.

The UK data indicates that **all** installations with a single combustion unit of thermal capacity greater than 20 MW_{th} (not aggregated capacity) are regulated under the IPPC Directive either directly as combustion installations[40] or as activities directly associated[41] 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 MW_{th} range if they are already effectively regulated under the IPPC Directive. (Based on the UK data, none of the sites in the '% other' column have single units greater than 20 MW_{th}).

If the UK situation were reflected across Europe, it could mean that the IPPC Directive covered most single combustion units greater than 20 MW_{th}. Although the European situation

[37] Due to the confidential nature of this data, only aggregated statistics have been used in this analysis. The UK decided to ask this for this information in the application process – although it was not necessarily a requirement of the process. Therefore, few other countries may have this level of detailed data.

[38] The PPC regulations were introduced under the Pollution Prevention and Control Act 1999, and are gradually replacing the control regime set up under Part 1 of the Environmental Protection Act 1990. The PPC Regulations have implemented the European Directive on Integrated Pollution Prevention and Control (96/61/EC). The PPC regulations are also the regulatory vehicle for the LCPD.

[39] The proposed National Allocation Plan (NAP) for the UK (DEFRA 2004c) included approximately 1020 sites for inclusion under the EU ETS. Other UK sites (in the NAP) are being permitted by competent authorities in Scotland and Northern Ireland, while offshore installations are being permitted by the UK Department for Trade and Industry.

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

[41] 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).

is not so well understood in relation to this question of scope of IPPC, in our judgement it is probable that most combustion units greater than 20MW_{th} (which is a large combustion unit) will be supplying heat and power to industrial processes regulated under the IPPC Directive. There are likely to be exceptions of course; however, in general terms the scope of the IPPC Directive is likely to extend significantly over the 20 – 50 MW_{th} range.

Industrial SCIs may also be covered by other legislation. The introduction of the EU ETS means that a significant number of previously unregulated installations will be regulated on the basis of CO_2 emission allocations (and this is likely to lead to improved energy efficiency, and the reduction of emissions of air quality pollutants). In the UK, this is likely to be an additional 900 sites, which may be approximately 3-4000 individual combustion units.

Many countries already regulate emissions from plant with thermal capacities less than 50 MW_{th} (see section 6.2.4), either on the basis of obligatory emission limit values (France, Germany, Belgium, Poland, Czech Republic) or using a BAT-based approach (UK, Finland, Denmark). This makes it difficult to determine the percentage of industrial SCI emissions that are unregulated, and therefore where significant reductions could be made.

Finally, the Air Quality Framework Directive could also have an impact on large SCI sources if sites are deemed to be contributing significantly to urban air pollution levels. Although no specific Directive exists that regulates sub 50 MW_{th} plant, existing measures, both at the national and European level, seem to have significant coverage. If site-specific regulatory measures were to be considered, particular attention would need to be paid to the benefits of introducing them, particularly if the IPPC Directive covers the majority of sites in the 20-50 MW_{th} range.

7.3.4.2 Mechanisms for reduction of emissions from larger scale installation less than 50 MWth

There are broadly three measures that could be considered for targeting reductions of emissions from larger installation under a 50 MW_{th} capacity, namely:

- Extending existing legislation e.g. increasing the scope of the LCPD or IPPC Directive
- Introducing a new Directive, targeting installations less than 50 MW_{th}
- Introducing an emissions trading scheme for certain pollutants e.g. NOx, SO_2

Existing legislation

There are two main approaches to traditional site-specific regulation – one that sets out emission limit values (ELVs), which are uniformly applied to all installations in a specific capacity range, and one that considers the site-specific situation, and abatement on the basis of best available techniques (BAT).

The LCPD is an example of the former, setting out emission limits to air for particulate matter, sulphur dioxide and nitrogen oxides from plant with a thermal capacity greater than 50 MW_{th}. An option might be to extend this Directive to cover a greater number of installations, through lowering the current 50 MW_{th} threshold. An important issue to consider in extending the LCPD would be at what level a threshold should be set. The lower the threshold, the greater the number of installations that would be covered, with commensurate greater administration and compliance costs; therefore, careful consideration of this is needed. In addition, there is risk that the costs of compliance for some smaller combustion installations will be disproportionate to the local environmental benefits gained.

The IPPC Directive, which is based on a BAT approach, covers combustion installations in two ways:

- Regulating combustion processes (at an installation) with an aggregated threshold above 50 MW_{th}[42]
- Regulating combustion processes on IPPC regulated sites that are classified as directly associated activities and therefore part of the installation.

The coverage of this Directive could be extended through revising the specific thresholds for combustion processes, or through increasing the scope of other sector processes, which in turn could lead to more combustion processes regulated as directly associated activities. However, the issues with respect to revising thresholds within the IPPC Directive will be similar to those for an extension of the LCPD i.e. increased implementation and regulatory costs which may, in some cases, be disproportionate to the benefits achieved.

There are pros and cons with both types of approach. The ELV approach ensures a minimum standard across all installations. However, it does not enable any flexibility in compliance, as installations have to take action irrespective of the costs and the resulting benefits. The revised LCPD does provide some flexibility in meeting emissions limits by means of a National Plan (although this only applies to pre-1987 plant). This plan allows a group of plant to reduce emissions proportionate to the emissions reductions that would have resulted from the ELVs stipulated under the Directive. Therefore this mechanism is similar in some respects to a cap-and-trade approach.

The BAT approach assesses the best available techniques, and sets site-specific limits accordingly; however, such measures will also be considered on the basis of proportionality e.g. the costs of the measure justifies the benefits that are likely to be achieved. Therefore, unlike a standard ELV approach, greater flexibility is allowed regarding what limits are set. Additional costs may be incurred in considering individual site-specific situations, and emission limits; however, for smaller sites (e.g. not over 50 MW_{th}), it is probable that most emission limits will be specified on the basis of guidance notes, with less consideration of plant-specific conditions, making this approach more similar to the ELV approach.

Further extension of the IPPC Directive would need careful consideration as it also considers other pollution medias: water and land. As CAFE is only considering air quality, it may be that, unless other objectives are being considered, the IPPC Directive may not be extended just on the basis of air quality objectives.

New legislation

A separate small combustion plant directive could be considered that sets out emission limits for installations in certain thermal capacity bands, in the same way as the LCPD. A separate Directive may be more costly to set up and require more political will than extending existing Directives. On the other hand, the LCPD scope is well defined and understood, and therefore, European regulators may prefer it kept that way.

[42] An aggregated threshold means that 50 MW_{th} does not have to be exceeded by a single unit but by a number of units, which are defined as part of the same installation. Note that the LCPD threshold of 50 MW_{th} is for single units.

Emission trading
An increasingly important type of mechanism, particularly under Climate policy (within the EU but also under the Kyoto Protocol), is the use of emissions trading. The basic premise of capping emissions and allowing trading to meet such a cap has a precedent in air quality policy in the US, which has a trading scheme for NOx and SO_2, primarily in the power generation sector. Like more traditional forms of regulation, emissions trading is primarily used for larger plant, because like traditional regulation, this measure requires knowledge of all sites in the scheme, and mechanisms for monitoring and reporting on a site-by-site basis.

With the start of trading under the EU ETS imminent, and processes and administration of that scheme having only just been developed, it may be that a new scheme or amended scheme including air quality pollutants may not be considered at the European level for a few years. However, once the EU ETS has been demonstrated, and is functioning, it may be that other pollutants could ‘piggyback’ on the back of this scheme (as the regulator and regulated are likely to be the same), saving significant financial resources in terms of set up and administrative costs. Such a mechanism could provide significant flexibility in terms of how sites reduce emissions (in a similar way to how the National Plan mechanism might function under the Revised LCPD).

It is not clear whether Member States are considering this type of mechanism for air quality pollutants, with the exception of the Netherlands who are aiming to introduce a NOx trading scheme at the same time as the EU ETS is introduced in January 2005. This has been driven by the need to make national reductions in NOx emissions under the National Emissions Ceiling Directive. According to a report in ENDS Daily (Environment Daily 1765), the scheme is aimed at reducing NOx by 40% from 2000 levels by 2010, with costs to industry at €150 million a year. The scheme is of relevance to SCIs, given that, like the EU ETS, it will also apply to industrial sites with energy use exceeding 20 MW_{th}.

If other European countries were to also to implement a trading scheme for NOx, in line with the EU ETS, trading could occur within the European block. The advantages for air quality policy is that the platform for trading has been set by the EU ETS, with the various mechanisms in place, and processes worked through. In theory, other pollutants such as SO_2 might also be considered.

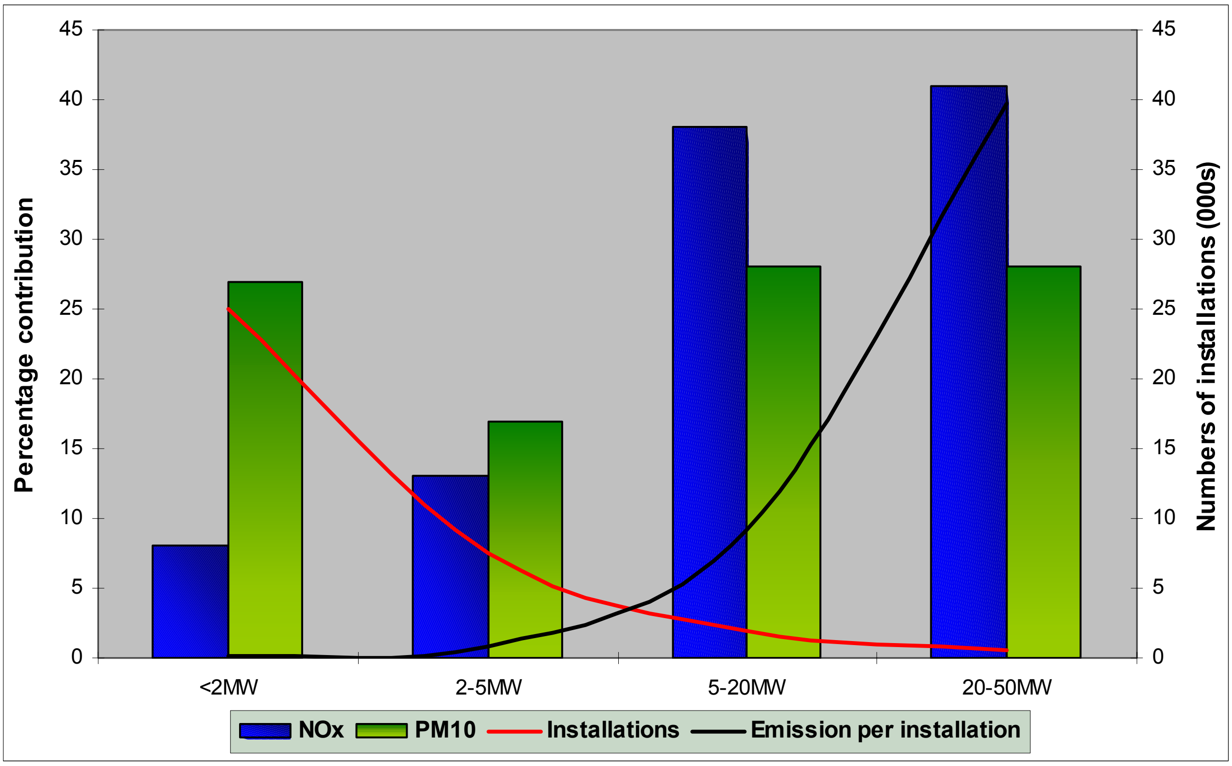
7.3.4.3 The need for additional regulation

An important question is whether this is a priority source of emissions, and if deemed to be, what sort of reductions could be realised and at what cost. Based on historic inventory data, it would appear that this is a significant source of industrial combustion emissions in many countries – whether it is still significant in future years is difficult to assess due to the absence of projections. In considering the need and scope of additional regulation, it is first important to understand the emissions profile of the industrial sector (and institutional sector) for plants less than 50 MW_{th}. The 0 – 50 MW_{th} range includes a significant number of types of plant, from a large power plant (at 49 MW_{th}) supply power to a large industrial process, to a medium sized (1 MW_{th}) boiler providing heating to public building.

Given this range of plant capacities, it is important to consider when a site-specific measure is not cost-effective i.e. the costs of regulation to industry (of compliance) and the regulator (administration and enforcement) outweigh the benefits in terms of emission reductions. It may be that the costs of regulating a 1 MW_{th} plant are similar to those incurred when regulating a 15 MW_{th} plant but with far less potential for reductions. This is why the scope of any measure, as set by the threshold, is important.

Figure 7.3, based on UK data, illustrates the diminishing emissions per installation, as the size of installation gets smaller.

Figure 7.3 Percentage emission contribution and number of sites for installation less than 50 MW_{th}



NB. Profile based on UK data. 'Emissions per installation' has been derived by dividing % emissions (of both PM and NOx) by installations, and then normalising by 50 in order to illustrate trend

Across the capacity ranges, the emissions contribution of NOx (and SO_2 although not shown here) is much greater for larger plant. Based on data from the Netherland and UK, we have made an estimate that potentially 40% of sub-50 MW_{th} emissions are from the 20-50 MW_{th} range. For PM, a similar level of emissions can be seen across the different capacity ranges. The number of installations is much greater in the lower capacity ranges; as a result the level of emissions per installation is much lower. Given this type of trend (more numerous smaller installations producing less emission per unit), which is reflected in other countries (see section 3.5.2), the question is to what capacity range should regulation be introduced.

For an a full and robust assessment, country-based profiles would be needed that including the following data would need to be needed:

- Breakdown of emissions total by fuel type
- Breakdown of emissions total by thermal capacity
- Numbers of installation in certain capacity ranges
- Understanding of technologies being used

However, these data are generally not available as very few countries have the type of inventory development that enables this data to be collated. A key recommendation from this study is that European inventory reporting requirements (under CLRTAP or NECD reporting) should include estimates of industrial SCIs to be submitted. If countries need to report estimates at the international level then this will stimulate further development of national inventories.

Due to lack of data, it is difficult to make any robust assessment of what size installation should be regulated at the European level. Many countries across Europe regulate installations above 20 MW_{th} – however, there are also many examples of countries regulating installations below 20 MW_{th}, down to 1 or 2 MW_{th}. An example is France, where installations between 2 and 20 MW_{th} are regulated through the introduction of emission limit values. Such plants are required to submit to a declaration, while larger plant (> 20 MW_{th}) are issued with authorisations. A declaration is issued to plant that are considered to have lower environmental impacts, with fewer requirements than an authorisation e.g. less frequent inspection and monitoring every three years, the results of which are sent to the local authorities. It is uncertain how often such installations are actually visited by inspectors. The number of installation issued with an authorisation is over 62000 (including 300 LCP) – the number of declarations may be much larger (CITEPA 2004).

Under Flemish law, 5-50 MW_{th} installations are regulated by government inspectors; installations below 5 MW_{th} are regulated by local authorities, with fewer regulatory requirements. Installations in the 1-5 MW_{th} range have to have emission measurements undertaken every two years, while for those less than 1 MW_{th} (to 300 kW), the requirement is every 5 years. Similarly to France, and other countries, regulation requirements for smaller installation are less strict.

A review of limits has also been undertaken, to illustrate the type of limits that are being used across Europe for different size installations, and which could potentially be fed into any additional analysis. New European legislation may want to consider current limits used across Europe, and use these as the starting point for consideration of European wide limits.

Table 7.14 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

These limit values differ depending on a range of factors including the fuel being used in a given country, and the technology that is considered BAT. Some small differences in power range and age of plant have not been included, as they are difficult to incorporate into such a comparison. This type of comparison is difficult to draw any conclusions from concerning what a given limit should be – however, what it does illustrate that there is significant technical knowledge regarding achievable emission limits for this type of plant, and therefore, if the Commission wanted to propose a new measure, country-based experience could be very useful.

The costs of any measure considered will need to be carefully considered. Costs will be determined by the following:

- The existence or absence of national legislation
- The threshold that is set with regards to installation coverage
- The style of regulation adopted for different size installations
- The type of approach e.g. a BAT or ELV approach
- Existing abatement technologies in the stock of plant

The main costs that would need to be considered in view of the introduction of a measure are outlined in Table 7.15.

Table 7.15 Costs of introducing site-specific regulatory options

Type of cost	Potential costs	Comment
Development of measure	Setting up Directive; identification of installation	Due to numbers of installation, identification may be a particular issue. Many countries have put significant resources into identifying eligible installation under the EU ETS.
BREF notes to BAT	Costs likely to be small, as could adapt some current BAT guidance to installations less than 50 MW_{th}	Only applicable for IPPC extension option
Enforcement costs (enforcement and administration)	Regulation of smaller UK site involves permit application of €2013 and annual maintenance fee of €1256 (DEFRA 2004d)*	Total costs will be a function of the number of installations.
Compliance costs	Costs will include the measures undertaken to either meet BAT requirements or specified limits. Some costs will also be incurred through reporting to the regulator.	

* Costs may be incurred directly by the operator or the regulator

7.3.4.4 Issues for the Thematic Strategy

The lack of data makes assessment of options for additional site-specific regulation difficult to consider in a robust manner. However, some useful conclusions and recommendations can still be made, with the necessary caveats highlighted concerning data quality.

Emissions from industrial installations appear to be significant in many countries across Europe, although in terms of overall European emissions, they appear to be a less important source. However, SCIs which remain unregulated may become an increasingly important source of emissions in future years, particularly if regulation of larger plant continues to drive emissions down. An important recommendation is that improved reporting of emission estimates for industrial SCIs is needed, to better develop and justify further policy action. The estimates made as part of this study should be further verified through European inventory development programmes.

The scope of existing regulation, both at the national and European level, appear to be considerable, particularly regarding 20 – 50 MW_{th} plant, which are likely to be the most suitable for site-specific regulation due to their emission contribution per installation. We believe that the IPPC scope has considerable coverage of 20 – 50 MW_{th} plant. In addition, many countries across Europe also regulate sub-50 MWth plant, in particular the 20 – 50 MW_{th} range. The EU ETS is also likely to have some impact on emissions from installation with aggregated capacities of at least 20 MW_{th}.

In view of the limited overall European contribution to emissions and the current scope of policy measures, the need for additional policy action is questionable. However, uncertainties over emission estimates and the impact of existing measures remain; therefore additional policy action has been considered in this analysis. A new Directive or extension of LCPD could be considered, that introduced emission limits for all installations down to 1 MW_{th}, based on limits considered under existing national legislation (based on existing BAT guidance and proposed emission limits). Such a measure would need to consider a 'light touch' regulatory approach for sites less than 15-20 MW_{th}, due to the number of sites that would inevitably be covered by such thresholds. As in France, the emphasis could be on self-regulation and reporting intermittently to local authorities. Sites between 20 – 50 MW_{th} could be regulated as under the IPPC or LCPD Directives, for the following reasons:

- 20 – 50 MW_{th} installations are far less numerous than smaller sites
- The emission contribution per site (and potential for reduction) may justify the costs of this type of regulation.
- They have been comprehensively identified under the EU ETS, and in many countries under national-based legislation.
- The infrastructure for regulation of these installations may already be in place, if indeed the scope of the IPPC Directive is as far reaching as thought.

Another interesting option might be the consideration of NOx or SO_2 emissions trading, although this may only be feasible for installations with an aggregated capacity of 20 MW_{th}, based on the EU ETS trading platform that has been established, and because trading requires an understanding of site-specific emissions contribution. A model for such a scheme may be that being developed in the Netherlands, where NOx emissions trading scheme is proposed for introduction alongside the EU ETS in January 2005.

In conclusion, better data is needed on which to justify any further action, and on which to assess the impacts of different options. However, if action is considered necessary, the Commission could consider closely national based measures, which provide experience of implementation, and the technical background to emission limits.

7.3.4.5 Integration into RAINS model scenarios

Assessment of control options to reduce emissions from industrial installation less than 50 MW_{th} in the framework of RAINS is difficult for the following reasons:

- The RAINS emissions database does not categorise this sector separately
- The emissions estimates provided in this inventory are not derived from energy data, which would be needed in the RAINS model.

The purpose of a scenario on industrial installations less than 50 MW_{th} would be to examine the emission reduction potential (and costs) from the introduction of an additional measure based on site-specific emission limit values.

Before considering the introduction of additional measures in the RAINS model, it would be useful to consider a scenario under which the scope of IPPC type measures were extended to the 20 – 50 MWth range. We are not clear how industrial regulation has been modelled in the RAINS model, regarding the use of control options. However, we propose that the same control options be used for 20 – 50 MW_{th} plant as for the larger combustion plant modelled in RAINS. A key problem in the RAINS model may be identifying this size range (as industrial combustion emissions are not categorised on the basis of thermal capacity).

For the purposes of the scenario analysis, we propose using the following country-based splits to identify the proportion of NOx and SO_2 emissions[43] that are considered to be from SCIs. In order for this analysis to be implemented, we suggest that 40% of the sub-50 MW_{th} industrial combustion emissions are from the 20 – 50 MW_{th} range, based on data from UK and Netherlands (for NOx). We propose that the same fuel splits modelled in RAINS for each country across industrial combustion sectors are used in this scenario – it is probable that the fuels used for large plant will broadly be the same as those used in the 20 – 50 MW_{th} range.

Table 7.16 Country-based splits identifying the sub-50 MW_{th} fraction

Country	% Industrial combustion SO_2 emissions from SCIs	% Industrial combustion NOx emissions from SCIs
AT	90.56	50.85
BE	17.71	8.06
CZ	20.17	16.07
DE	22.64	20.18
DK	19.75	14.63
EE	18.58	28.68
ES	7.59	6.60
FI	31.95	12.54
FR	12.98	14.31
GB	8.74	8.59
GR	14.96	11.46
HU	9.24	24.36
IE	15.86	14.67
IT	8.63	14.51
LT	19.85	20.53
LU	12.16	12.34
LV	74.67	69.49
NL	8.19	12.29
PL	7.61	7.42
PT	12.52	11.51
SE	4.64	2.46
SK	3.21	2.68
SL	6.43	14.15
NO	63.92	12.59
CH	89.10	27.75

[43] PM emissions are not considered due to the significant uncertainties associated with the estimates

* For the shaded countries, the data looks erroneous. We propose that average European percentage values are used.

Additional scenarios for smaller installation are will be difficult to implement, due to lack of information on numbers of installation, and uncertainty of estimates; therefore, none have been proposed.

7.3.5 Structural Funds

The European Union has different financial instruments through which funds are available for a variety of policy areas. The most important are Structural Funds, which are aimed at enhancing development of specific regions. This measure is being considered in the context of this study as a potential means of financing for emission reduction initiatives in Member States, in particular for projects that can reduce pollution in local urban areas. Therefore, it links in with the previous section on local-based measures. In particular, this section has the following objectives:

- To better understand the current situation in terms of how such funds work, where most money is allocated, and the role of the Commission in determining this allocation.
- To illustrate how these financial mechanisms could be used to reduce emissions (in particular PM) from SCIs (particularly where severe urban air quality issues arise), and how they might be restructured to provide funding opportunities for air quality issues in Member States.

If appropriately structured, Structural Funds may be a useful mechanism through which Member States could access significant additional funds for specifically targeting emission problems from SCI sources. A broad overview of Structural Funds in the context of this study is provided in section 6.2.6.2.

7.3.5.1 Potential funding needs and consideration of cost-effectiveness

Before considering whether Structural Funds are an appropriate mechanism for financing local emission reduction projects, two questions need to be considered:

- Are there a significant number of countries that might require such funding to address serious local urban air quality problems arising from SCIs?
- How effective are such funding programmes in reducing emissions from SCIs?

Firstly, as illustrated in section 7.3.2 on local-based measures, there is a range of countries across Europe where significant local air quality problems arise due to SCI sources. Many of these countries are new Member States, for which funding for local-based measures may be limited, and for which additional central funding could be extremely important in enabling the implementation of local-based measures.

Secondly, direct funding of local-based measures can be extremely effective if it enables the complete or partial removal of highly polluting SCI sources. An example of a specific programme of funding in Krakow is provided below (although this programme was primarily financed by non-European sources). This case study illustrates that if funds are available, significant action can be undertaken to reduce highly polluting sources.

Krakow Clean Fossil Fuels Programme

During the 1980s and early 1990s, Krakow had severe air pollution problems, with approximately 40% of total pollution from small sources using solid fuels. This pollution was primarily from the following heating sources:

- 100,000 coal-fired home stoves, which have the highest emission factors (7 million estimated nationwide)
- 17,000 small home solid fuel boilers
- 1,133 fuel fired boiler houses
- 475,000 tonnes of solid fuel consumption per annum

A clean fossil fuel and energy efficiency programme was implemented during the 1990s to reduce emissions from the above sources (Butcher 2001).[44] The programme had five main components:

- Energy conservation and extension of district heating
- Replacement of manual feed solid fuel boilers with natural gas boilers. Most of these boilers had fixed grates, only a small percentage of which had any pollution control.
- Replacement of coal heating stoves with electric heating appliances. The introduction of smokeless briquettes (a lower volatile-content fuel) on to the market had previously been tried due to significantly lower emissions (12 – 15 times less for particulates), and a good transition solution (before implementing replacement). This had little success in terms of market uptake of this fuel due to higher costs.
- Reduction of emissions from boiler houses through introduction of new technologies / improving efficiencies
- Reduction of emissions from coal heating stoves through consideration of cleaner fuels / improved operation. Improved operation was considered to improve operating efficiency from around 50% to over 70%.

Different districts in the city were targeted by different projects, based on their characteristics e.g. good district-heating infrastructure meant more focus on connecting installations to the system.

Total costs of implementation of this programme were approximately $58 million (€47.9 million). $20 million (€16.5 million) came from the US, which was equalled by Polish programme participants. The remainder came from a variety of other sources, including various environmental funds, and boiler house owners. Half of the cost of investments made by US technology companies who were involved in supplying new replacement technologies under this programme was met by the programme fund. The benefit to the companies of involvement was the opportunity to become established in the Polish market.

By the end of the programme, the number of boilers houses using solid fuel had been reduced by 75%, due to connection to the district heating system (40%) or conversion to gas or oil (60%). Coal-fired home stoves had decreased by 22%. Overall solid fuel use had decreased by about 70%. At the end of the 1980s, the mean annual concentration of particulates was over 100 $\mu g/m^3$, exceeding the permitted level by factor of 2 (3 during colder months), while SO_2 exceeded the permitted level by as much as 3.5 times. By the end of the 1990s, particulate emissions had decreased by more than 50% (and exceed permissible limits only slightly during the heating season). SO_2 dropped by approximately 60%, reaching permissible limits for the first time (and during the heating season). The decrease was even more significant in the centre of Krakow. The health benefits of this action were not assessed, but based on APHEIS (2001) assessments, they are probably significant. A reduction in annual mean values of PM_{10} by $5\mu g/m^3$ is considered to reduce the total number of deaths (in Krakow) attributed to chronic effects by 140 per year (central estimate) (or by 18.9 per 100,000 of the population, again based on the central estimate).

[44] The majority of the information provided for this case study is from Butcher (2001).

One of the main barriers to implementing changes described above was the limited financial resource of private householders and boiler house owners to convert t other fuels. Small boiler houses, as seen in the centre of Krakow, struggled to find investment from energy companies due to their small size. Other problems included funding for infrastructure (gas and district heating), and finding suitable locations, and the capacity of the electrical power system to cover increase demand due to conversion to electrical heating.

There is insufficient data to undertake a proper analysis on cost-effectiveness for this case study, taking into account different fuel costs, maintenance requirements etc. However, the available data does indicate significant emission reductions, and illustrates that this measure is reasonably cost-effective when considered over the lifetime of the technologies. Table 7.17 provides an indication of emission reductions per annum (in tonnes) and cost per tonne abated based on a 20 year lifetime of new technologies:

Table 7.17 Emission reductions associated with Krakow technology programme

Pollutant	Emissions (t)	Annual cost (€) per tonne abated (over 20 years)*
TSP	1771	1350
SO_2	1594	1500
NO_x	297	8100
CO	2267	1050
CO_2	67,645	35

*Programme costs of €48 million have been spread over 20 year time period (assumed life time of technologies installed)

This specific case study illustrates a significant impact due to very high emissions at the time of implementation. Clearly, overall effectiveness (and associated costs) of specific local-based action will be dependent on the type of measure introduced and baseline level of emissions. The Krakow case study also illustrates the significant level of costs necessary to implement this type of action, particularly where technology replacement or energy supply infrastructure extension is being considered. Central funding of such projects is often necessary, particularly as these types of projects involve residential sectors, with many households unable to meet significant investment costs, and private investment from industry difficult to attract.

In summary, due to the existence of local air quality problems due to SCIs and the subsequent need for local-based measures, particularly technology replacement or energy supply infrastructure renewal or extension, funding from a mechanism such as Structural Funds is further considered in the next section.

7.3.5.2 The current framework for accessing Structural Funds

In order to assess how Structural Funds could be better used to finance emission reduction projects, it is important to understand the current framework for accessing funds. The primary objective of this mechanism is economic and social cohesion, and therefore relates predominantly to projects where the key driver is economic regeneration and development. Member States submit funding programmes in line with the broad objectives of the fund; once programmes have been agreed, funds are allocated to different objectives within the country programmes. The Member States then decide which projects will be accepted based on their agreed programme documents. The process of allocating Structural Funds is outlined in Table 7.18 below.

Table 7.18 Process of Structural Fund allocation

Process stage	Description
1	The Council proposes a budget for the Structural Funds and agree the main principles. Funds are broken down by country and objective.
2	Member States draw up proposals, grouping by areas of difficulty or vulnerable social groups. The plans are then sent to the EC.
3	Member States and the EC discuss documents, and the allocation of funds for implementation.
4	Once agreed, the EC adopts the plans / programmes
5	National or regional authorities decide details of programmes. The Commission does not partake in this stage of the process but is kept informed.
6	Selected bodies who have applied for funding are then given the go ahead to implement the project.
7	Projects are monitored by the relevant authorities, and the EC is kept regularly informed.

Source: European Commission website for Regional Policy; http://europa.eu.int/comm./regional_policy

The European Commission has the opportunity to input at stage 3 for agreeing the programme documents, including the main priorities identified. This could be where the Commission could further encourage focus on environmental considerations; however, they do not have any jurisdiction to specify specific projects that should be undertaken under the agreed programme.

Based on the research undertaken in this study, very few examples of projects driven by environmental objectives have been funded by the Structural Funds, particularly relating to SCIs. The Structural Funds, as currently structured, do state the need to take account of environmental considerations (as illustrated in the text box below) but are primarily driven by objectives focused on development and regeneration.

Environmental consideration in Structural Funds

In the Structural Fund regulations (EC 1999a), environmental considerations are clearly highlighted, both in articles 1 and 12. Article 1 outlines the objectives of Structural Funds, and states in pursuing these objectives, the community will contribute to 'the protection and improvement of the environment.' Article 12 concerns compatibility of the Structural Funds with other Community policy and action including 'on environmental protection and improvement.' This should ensure that all projects, which receive funding through Structural Funds, take account of environmental considerations. The Member States need to ensure that the regulations are interpreted to ensure that such environmental issues are given due consideration.

Proposed projects that have explicit environmental objectives are eligible for Structural Funds. The European Regional Development Fund (ERDF) (EC 1999b) regulations state that the ERDF should contribute to 'the protection and improvement of the environment, in particular taking account of the principles of precaution and preventative action in support of economic development, the clean and efficient utilisation of energy and the development of renewable energy sources.'

Member States are able to structure their programmes to prioritise funding for environmental objectives if they choose too, either explicitly e.g. as an environment operational programme, or as a cross-cutting theme that is built into the whole strategy. National and regional programmes that relate to the environment and energy area appear to be generally financed through the ERDF, with some explicitly labelled as 'environment' based programmes, while other have environmental themes or priorities. A number of such programmes are listed in Table 7.19.

Table 7.19 Examples of environmental priorities and programmes in Structural Funds

Country	Programme	Description
Lithuania	Objective 1 Programme (2004-2006)[1]	Under priority 1 'Development of social and economic infrastructure', a measure called *Improvement of environmental quality and prevention of environmental damage*.
Hungary	Objective 1 Programme (2004-2006)[2]	Community Support Document has a priority *Improving transport infrastructure and protecting the environment (Priority 3)* and is introduced under Environmental Protection and Infrastructure Operational Programme (EIOP)
Portugal	Objective 1 Programme (2000-2006)	Environment Operational Programme (POA) has two priorities – (1) sustainable management of natural resources and (2) integrating the environment in economic and social activities
Greece	Objective 1 Programme (2000-2006)	Operational programme Environment, with 10 priorities including priority 4 'Air and noise pollution', to reduce air and noise pollution in main urban centres.

[1] Lithuanian Ministry of Finance (2003), Single Programming Document of Lithuania (2004-2006)
[2] Community Support Framework for the Republic of Hungary (2004-2006)

7.3.5.3 Enhancing the role of Structural Funds to reduce emissions from SCIs

Structural Funds could be an important source of financing local-based measures that required significant investment, in particular appliance replacement and energy infrastructure development. Local authorities may want to consider such measures to reduce emissions but may not have the available funds or be able to part-finance such measures through private investment, particularly where they are focused on the residential sector. Projects under the Structural Funds could enable such action to be implemented; examples of such projects are limited but include the part financing of a gas pipeline extension programme in Greece under INTERREG II.[45]

The following proposals might strengthen the role of Structural Funds as a mechanism for financing measures to reduce pollution problems:

- **Improve awareness** within Member States who draw up funding programmes, and applicants for funds within Member States that Structural Funds can be used to resolve specific local air quality problems, including those largely due to SCI sources.

[45] Contact with the Public Gas Corporation in Greece has established that no quantitative assessment of the environmental benefits of this project was undertaken. However, it is clear that such a project could have significant benefits for reduction of air quality emissions by extending pipelines near communities who may be reliant on fuels with higher associated emissions.

- **Broaden regional policy objectives.** A report by REC (2001) states that Structural Funds may become a very important source of financing for environmental projects across many regions. However, they also state that there is no guarantee of support for environmental projects given that Structural Funds are aimed more generally at regional policy.
- **Encourage explicit air quality objectives** within funding programme documents, so that it is clear to fund applicants in Member States that they can access funds for air quality projects that are consistent with programme objectives.
- **Broaden scope of the Cohesion Fund** so that it also covers energy infrastructure (supply and end use technologies). This may be particularly for New Member States, who may well be eligible for Cohesion Funds, and may be in most need of energy infrastructure development.[46] The Cohesion Fund specifically finances projects designed to develop environment transport infrastructure in Member States whose per capita GNP is below 90% of the Community average (EC 1994). However, 'environmental infrastructure' only appears to relate drinking water, wastewater and solid waste treatment.
- **Ensure access** of funds for new Member States, who will only be able to absorb as much financial assistance as what they can part-fund.

7.3.5.4 Issues for the Thematic Strategy

The following conclusions can be drawn from this section:

- A significant number of Member States experience local air quality problems as a result (in part) of SCI sources.
- Local-based measures, in particular technology replacement and energy infrastructure development, can be very effective in reducing emissions, as illustrated by the Krakow example, and be potentially cost-effective. However, such measures often require a significant amount of financial investment.
- The Structural Funds could provide that source of financing if broadened in scope, and Member States were encouraged to pursue environmental objectives through such a mechanism.
- The Structural Funds programme is driven by the need for greater economic and social cohesion – environmental protection and improvement are considerations that need to be assessed in moving towards greater economic and social development, and therefore should fit into the scope of this regional policy mechanism.

It is clear that such central funding can be accessed for projects with explicit environmental objectives, and that such objectives can cut across the range of themes set out in the strategy documents. However, the main aims of the Structural Funds are developmental, to enhance social and economic cohesion, and will always be the overriding priorities reflected in strategy documents. Without restructuring the fund, it may be difficult to promote its use as a means of financing environmental improvement projects. In addition, the Cohesion Fund could be broadened to include energy infrastructure and technologies programmes.

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[46] Prior to Accession, new member states were able to access funds from a similar fund to the Cohesion Fund called ISPA (Pre-Accession Structural Instrument), which provided financing for environment and transport infrastructure projects. PHARE was another funding programme, providing Accession countries with financing to help strengthen institutional capacity, help ensure convergence with EU legislation, and promote social and economic cohesion (in a similar way to the Structural Funds).

It would be difficult to consider changes to financial mechanisms until 2007, as the current programme of Structural Funds is only completed in 2006. The process for post-2006 (2007-2013) programmes will shortly be underway, with Member States putting together plans in 2005, and negotiation with the Commission being undertaken in 2006 for implementation on 1st January 2007. New regulations for the post 2006 programme have already been drafted but not yet implemented (Nychas 2004).

7.3.5.5 Integration into RAINS model scenarios

Modelling the impact of Structural Funds is clearly difficult given that funding will be granted on a project-specific basis. The type of measure and its potential costs will therefore vary significantly. In addition, the RAINS model operates at a country-based resolution – emissions are not spatially disaggregated any further – therefore, assessing the implementation of local or regional based projects is problematic.

Ideally, a RAINS-based scenario would assess the impact of the introduction of Structural Funds on emission levels in specific countries, regions or urban areas, particularly in terms of reducing levels of solid fuel use. Structural Funds would provide funding for specific projects relating to appliance replacement e.g. to upgrade solid fuel burning technologies to gas / oil / more advanced solid fuel technologies in specific urban areas, or to expand the existing district heating / natural gas network. These types of projects would tend to be implemented in areas that had particular problems associated with pollution from residential sector.

The potential impact of this type of measure could still be illustrated in the framework of RAINS in a simplistic way, by reflecting infrastructure development or technology improvement projects.

- *Infrastructure development* – changes in the use of specific fuels due to increase district heating / natural gas network expansion e.g. a switch from solid fuels / oil to district heating / natural gas, which would probably need to be modelled in PRIMES.
- *Technology improvement* – changes in the use of technologies could be simply modelled in RAINS e.g. improved stoves for solid fuel burning.

The following proposed scenario will not provide a detailed analysis of the use of Structural Funds but an indicative understanding of the type of effects that may result from introduction of European funding for these specific types of project.

Technology improvements
Poland, Czech Republic, Slovakia, Hungary, Bulgaria and Romania are countries that are considered to have urban areas with significant levels of solid fuel use, and associated emissions. Within the model, a 10% and 30% switch from older to advanced stoves could be assessed. The costs would be the price differential between the types of stove, as already modelled in RAINS. Administrative costs of the fund have not been considered, as these are likely to be insignificant relative to the cost of the options. This is a very simplistic approach due to modelling limitations. The percentage switching figures are arbitrary, but will provide a good understanding of the necessary investment costs that would need to be provided under any funding initiatives.

Infrastructure development projects
Projects that funded the expansion of the energy supply infrastructure could be envisaged, which would enable switching away from oil and solid fuels to gas or district heating. However costs with which to construct a control option have not been determined.

7.3.6 Energy efficiency based measures

It is clear that strong linkages exist between energy efficiency based measures, which are promoted under climate change programmes and policies, and action that can be taken to reduce emissions from SCIs (an overview of which can be found in section 6.2.8). This is because a significant focus of climate change policy has been the reduction of CO_2 emissions from non-industrial sectors, particularly the residential sector (while air quality policy action has focused less on action in these sectors and more on the main sources of air pollution – large industry and road transport).

Many of these measures focus on improving energy efficiency, and thereby reducing demand for energy. Of particular focus in this section is the Energy Performance of Buildings Directive (EPBD), which is regarded as one of the key European measure for reducing energy use and carbon emissions from buildings, through measures such as improved insulation and maintenance of heating systems. Such measures may have significant additional benefits for emission reduction; such benefits need to be highlighted in the Thematic Strategy, and where appropriate, proposals made for enhancing such benefits.

Gas boilers (used for heating in buildings) have also been identified as an important source of urban NOx emissions, and may be increasingly so in the future with projected increasing demand for gas across Europe. Energy efficiency type measures have also been identified as one of the main ways of reducing NOx emissions, in the absence of other abatement measures.

7.3.6.1 Inspection and maintenance obligations

A key measure outlined in the EPBD is introduction of an inspection scheme (or equivalent action), the features of which are described in section 6.2.8.3. This section assesses what air quality emission reductions could result from the introduction of this measure, and the potential for further reductions based on changes to structure.

The importance of this measure is that it can reduce emissions from the existing boiler stock, unlike other measures (e.g. product standards) that only have an impact where new appliances are introduced. This is particularly important given the long lifetime of appliances, and slow frequency of replacement. Reductions are achieved by ensuring that the existing stock of heating appliances and systems is operating at optimal performance levels e.g. good combustion and energy efficiency.

Inspection schemes have been widely introduced across Europe, although their implementation and objectives differ significantly (see section 6.2.8.3 for an overview of the European situation). This measure will ensure that all Member States have consistent inspection schemes that meet minimum requirements (specified in the Directive).

Proposed measures for consideration

The focus of this measure (as outlined in the EPBD) is primarily boilers used for space and water heating in buildings. In this analysis the following options have been included:

- Full implementation of an obligatory scheme (Article 8 Part A) through the Energy Performance of Buildings Directive (EPBD)
- Enhanced implementation of the EPBD by including all smaller boilers below 20 kW
- Advice-based scheme (as provided for under Article 8 Part B of the EPBD)

Under these proposals, open and closed fireplaces, and stoves are not considered. It is probable that regular inspection of such appliances will have limited benefits for the following reasons:

- With limited combustion control and few moving parts, improvements in fuel efficiency and emissions reduction will be more dependent on the type of fuel used, and how the appliance is operated.
- Appliances tend to be fairly robust over their lifetime, and may not need significant maintenance.
- Any inspection of such appliances is driven by health and safety e.g. ensures flues are not blocked to prevent chimney fires or prevent flue gases entering the building. For advanced stoves, better combustion controls and the use of catalysts may mean inspection (and maintenance) is more beneficial for ensuring an appliance is functioning properly (e.g. the need to replace catalysts).

The Directive states that other fuels (such as biomass) can be included, although this is not obligatory. Biomass is not explicitly included as it is considered carbon-neutral and is therefore not contributing to overall CO_2 emissions.

As previously mentioned, many countries in Europe have already introduced inspection schemes. Therefore, the effectiveness and costs of the above measures will vary significantly from country to country. Germany has an extensive inspection regime, which largely complies with what is stipulated in the Directive concerning inspection (as do Denmark and Greece), and therefore additional costs of implementation under the EPBD are going to be low. Implementation of a comprehensive inspection regime where one does not exist could be costly, and therefore it is likely that countries such as the UK would go an advice-based approach. It is important to note that in countries, such as the UK, where an obligatory scheme has not been introduced, many households have private service agreements with manufacturers / installers that ensures regular servicing takes place.

In order to reflect the existence of inspection schemes (and service agreements), countries have been ranked according to what impact such a European proposal could have. These broad assumptions are shown in Table 7.20 below.

Countries with a ranking of 1 are known to have mandatory schemes, although such schemes may not be compliant with European proposals as currently structured. Therefore, a value of 10% has been assumed for this group, implying that the Directive will lead to 10% of the full improvement seen if no national inspection scheme existed. Rank 2 countries are assumed to have a significant amount of service agreements (or an inspection scheme that would not meet EPBD requirements). Rank 3 countries are expected to have limited servicing – therefore, the

EPBD measure is expected to have the largest impact in these countries. The same percentage figures are applied across each country grouping – determining country specific figures would require additional analysis and verification.

Table 7.20 Assumptions for reduction potential of EPB Directive inspection scheme

Country	Ranking	% Impact of EU measure
Austria	1	10%
Switzerland	1	10%
Germany	1	10%
Denmark	1	10%
Greece	1	10%
Italy	1	10%
Luxembourg	1	10%
Norway	1	10%
Sweden	1	10%
Belgium	1	10%
Spain	2	35%
France	2	35%
UK	2	35%
Netherlands	2	35%
Finland	2	35%
Estonia	3	75%
Czech Republic	3	75%
Hungary	3	75%
Ireland	3	75%
Lithuania	3	75%
Latvia	3	75%
Poland	3	75%
Portugal	3	75%
Slovakia	3	75%
Slovenia	3	75%

NB. Percentage values reflect the impact of the measure, relative to a situation where no inspection / servicing was being undertaken e.g. measure will be only be 10-75% effective due to action already being undertaken.

Each of the three options for inspection and maintenance are described in the following text box.

1. Full implementation of EPBD Article 8 Part A

This option is based on Article 8 (Part A) of the EPB Directive (EC 2002a), with some additional requirements. It has the following features:

- Regular inspection of boilers fired by non-renewable liquid or solid fuel of an effective rated output of 20 to 100 kW
- Boilers over 100 kW should be inspected every two years (although for gas boilers this can be extended to four years). For boilers older than 15 years, a one-off inspection of the whole heating installation (not just the boiler) should be undertaken

It is assumed that the inspection of boilers will itself lead to actual energy efficiency gains (due to adjustments made in boiler operation) and that a certain percentage of boilers are also replaced based on recommendations made by the inspector. 'Regular' inspection is considered to mean an annual inspection.[47] As described in section 6.2.8.3, what is meant by inspection varies considerably from country to country, and depends on the type of appliance being inspected. In the context of this analysis, inspection is predominantly visual, with basic adjustment and servicing of the boiler.

2. Enhanced implementation of EPBD Article A option

This analysis option is to go beyond what has been stipulated in the EPBD, with the requirement that all boilers are included. This option is essentially the same as M1 except that boilers less than 20 kW are also included.

3. Advice-based scheme (as provided for by Article 8 Part B of the EPBD)

Part B of Article 8 of the EPBD allows for an advice-based approach that has an equivalent impact to Part A implementation. This option looks at the implementation of an advice-based scheme, using information on the benefits of regular inspection to encourage action by individuals.

In the analysis, it is assumed that 1.5% of householder request inspection based on leaflets received although this could decrease in subsequent years (Hartless 2004), and all households in the residential sectors are contacted (businesses are contacted through company registers).

Other assumptions (Hartless 2004) for the analysis include:

- 2.5% (< 15 years old) and 5% of boiler (> 15 years old) will be replaced on the basis of advice given during inspection.
- Standard boiler efficiencies are: Gas 70%, Oil 75%, Solid 60%
- Replacement boilers have following efficiencies: Gas 87%, Oil 90%, Solid 73%.

Cost assumptions for the analysis of these measures are set out in Table 7.21 below.

Table 7.21 Cost assumptions in inspection / maintenance analysis

Type of cost	Description	Costs (€)
Determining eligibility	Leaflet sent out to all households to ascertain inclusion in scheme (10 years)	0.14 (per leaflet) [1]
Administration of respondents and scheme	Collation and processing of data in central system (including central system development) (Annual)	0.15 (per respondent)
Inspection requirements	Inspection of boiler only (unless boiler older than 15 years, then heating system inspection).	Heating system 150; Boiler 90 (per inspection) [1]
Enforcement of scheme	Certification or registration may be required, with costs of enforcing this.	Average wage multiplied by number of enforcement officers
Additional training of inspectors	Due to the scope of this option, probable that additional inspectors need to be trained.	Not defined
Reporting under Directive	Requirements for regular reporting to the Commission	Not defined

[1] Costs based on Hartless (2004)

[47] Maintenance requirements (following inspection) are not stipulated in Article 8 of the EPBD, and what is meant by 'regular inspection' is not defined.

Determining the impact of maintenance

One of the key questions for this analysis is what is the impact of maintenance on emissions. Most of the literature reviewed and experts consulted assess inspection in terms of the energy savings, not the impact on air emissions. An analysis by Hartless (2004) uses the following percentage energy savings from inspection of 3% for gas boilers (over 15 years), 2% for Oil over 2 years, and 3% for solid fuel over 2 years. Vekemans (1997), in a SAVE funded project for the European Commission, uses an annual maintenance efficiency figure of 2% for oil boilers. Other studies are also quoted, which confirm an average efficiency of 2 to 3%. Experts consulted as part of this study suggest efficiencies of around 2% for oil boilers, 1% for gas boilers (maximum); less information exists for solid fuel boilers.

The impact on air emissions is thought to be similar to energy savings figures for pollutants such as NOx, and SO_2 – for example, this is how Vekemans (1997) calculates additional benefits of maintenance. However, for PM, there may be differences; depending on the inspection and subsequent maintenance / adjustment, much higher reduction efficiencies may occur for PM, certainly if the combustion efficiency of the boiler is improved. The RAINS model has an option called GHDOM (good housekeeping of domestic oil boilers), which has been developed based on country based information from Austria. This control option leads to a 30% reduction in the typical emissions from an oil boiler. It appears to be the case that certain pollutants will vary significantly as a function of maintenance – USEPA (1998b) indicates that CO emissions may vary by factors of 10 to 100 (although it is not clear what size of installation is being referred to).

No new factors for PM emissions from oil have been identified through literature review, and expert consultation; therefore, this factor from RAINS has also been used in this analysis. However, this factor does seem high if applied annually in consecutive years. It is possible that such reductions could be seen in the first year after maintenance but then if maintained in subsequent years, it may be that such a saving is diminished (given that boiler performance may not have deteriorated to the same level as 12 months ago). It is also probable that this factor will be significantly dependent on boiler age, with a modern boiler unlikely to deteriorate to the same extent as a 15 year old boiler.

Analysis of measures

A basic analysis has been undertaken to estimate the costs and effectiveness of the three options. In the context of the SCI inventory data, the inspection scheme would only be relevant to the residential-commercial sector, where boilers are used for building space heating and hot water.

For the purposes of this analysis, a broad assumption has been made that boilers in residential sector are less than 100 kW and in commercial sector are greater than 100 kW. In reality, it is probable that there is some overlap between the two categories. Gas and oil boilers have been split into residential-commercial on the basis of UNFCCC category splits. For solid fuels, single house boilers (SHB) are assumed to be residential, while medium boilers are assumed to be commercial sector based.

A difficulty with this analysis is determining the split of appliances below and above the 20 kW threshold, and determining the age of the boiler stock, information that is required by the

EPBD scheme (which may be an issue when the measure is implemented where countries do not have this data. A UK profile for the residential sector is shown in Table 7.22 – however, this is likely to vary significantly across Europe depending on specific energy profiles (as described in section 4).

Table 7.22 Profile of UK residential boiler stock

Domestic boilers	**<20 kW**			**20 kW – 100 kW**		
	Gas	Oil	Solid	Gas	Oil	Solid
<= 15 years	32%	33%	75%	41%	55%	4%
> 15 years	21%	5%	19%	6%	8%	2%

Source: Hartless (2004)

For the purposes of this analysis, we have assumed that for EU15 country grouping, 15% of boilers are older than 15 years, and that 30% of gas / oil and 75% of solid fuel boilers are below <20 kW. For new Member States, we have assumed that 25% of boilers are older than 15 years while the sub-20 kW splits are the same.

The emissions reductions associated with this measure are as follows, based on the following energy savings figures: Oil (2%), Solid fuel (2%), and Gas (0.5%).[48]

Table 7.23 Emission reductions from commercial-residential sector inspection / maintenance scheme

Emission reduction (tonnes)	**Year**	**PM_{10}**	**NMVOC**	**NOx**	**CO_2 (000s)**
Option 1	2010	60	132	225	1570
	2020	31	102	246	1393
Option 2	2010	195*	276	321	2279
	2020	84	178	352	2003
Option 3	2010	2	4	19	36
	2020	1	3	20	35

* The proportion of emissions from oil is approximately 24 tonnes. Using the RAINS reduction figure, we estimate a value of 374 tonnes. For 2020, the same numbers are 21 tonnes (based on 2%) and 300 tonnes (based on RAINS factor.

The reduction levels are based on fuel reductions, followed by application of emissions factors. The total reduction is low due to our estimates of the impact of the scheme. If this measure was considered to affect all households in the absence of any national-based schemes, the overall impact would be approximately three times greater. In addition, if the RAINS factor for maintenance was used (30% reduction of PM emissions from oil), these figures would be considerably higher (as described below the table). These emission reductions are very small percentages of totals (as shown in Table 3.3), which is due to using a 2% energy saving figure on which to base emission reductions, and determining that the impact of this measure will be significantly reduced by existing schemes.

Comparing the residential figures (not commercial) with costs provides us with an understanding of the cost-effectiveness in terms of emission reduction; significant benefits not taken into account include those relating to having a fully functioning boiler that is less likely

[48] Energy savings from modern energy efficient boilers are unlikely to have a 0.5% reduction.

to break down, and even more important, health and safety issues relating to the operation of boilers. Commercial sector costs have not been calculated due lack of data on building stock. It is likely that they will be similar to those presented below.

Table 7.24 Cost-effectiveness of options for a European-wide inspection scheme (€ per tonne abated; 'k' denotes € 000s)

	Year	PM_{10}	NMVOC	NOx	CO_2
Option 1	2010	28,395k	8,525k	3,860	615
	2020	46,625k	10,300k	3,600	710
Option 2	2010	19,200k	8,910k	4,875k	770
	2020	38,460k	11,850k	4,525k	890
Option 3	2010	98,155k	24,730k	4,170k	2,290
	2020	186,830k	26,630k	3,800k	2,315

The most promising option appears to be option 2 for NMVOC and PM_{10}, and option 1 for CO_2 and NOx. This is because option 2 covers considerably more solid fuel boilers, which have higher emissions of PM_{10} and NMVOCs, due to the assumption made that many would be too small (<20 kW) and therefore not included in the scheme. For gas and oil, the majority of boilers are covered by option 1. In 2020, the cost per tonne for PM_{10} and NMVOC are higher, due to reduced amounts of solid fuel use in future years. For NOx and CO_2, cost per tonne remains at the same level. The advice-based scheme is not cost-effective at all due to the significant costs of providing information, and the very low response rates assumed.

Scheme administration and inspection costs have been included, while costs of additional training of inspectors to undertake the inspections, enforcement costs to ensure households and businesses are undergoing inspection, and reporting costs under a Directive have not been included. Enforcement could be done through company registration (in the commercial sector) and through certification in the residential sector.

This is a policy measure that is being introduced in 2006. For air quality policy makers the importance of this measure is in the benefits that it will have for reducing emissions of specified pollutants, which need to be identified (and if possible enhanced). The assessment of costs is not so important with the implementation of the Directive already underway.

Significant assumptions have been made in this analysis about how emission reductions are calculated. In the absence of other data, emission reductions are based on energy savings. For oil boilers and PM, additional information from RAINS suggests much more significant reductions. For other fuels and pollutants, data concerning direct emission reductions from maintenance have not been found.

Issues for the Thematic Strategy

For the Thematic Strategy, it is important to recognise the benefits of other policy mechanisms to air quality and emissions reductions, in this case, the inspection scheme outlined under Article 8 of the Energy Performance of Buildings Directive. In terms of our analysis of potential emission reductions, this measure does not have a significant impact for the following reasons:

- Assessment of reductions has been determined on the basis of energy saved (e.g. 2% per annum for oil). Based on this method, reductions are going to be small. Further analysis is needed concerning direct emission reductions of PM as a result of good maintenance, as modelled in RAINS (as 'GHDOM'). This study has done extensive research and has not identified any conclusive studies (for non-industrial sectors) that illustrate what direct emission reductions of PM and other pollutants are from different fuelled boilers due to good maintenance.

- The option for inspection schemes, as set out in Option 1, only covers boilers that are larger than 20 kW. In addition, lack of knowledge of the national boiler stocks across Europe make reductions difficult to determine.
- The impact of a Europe-wide scheme is reduced, due to the existence of many national inspection schemes. These are broad assumptions based on our knowledge of the coverage existing schemes.

In addition, the costs of inspection and maintenance appear to be high relative to energy savings. However, inspection and maintenance is often predominantly about the promotion of health and safety, and ensuring boilers continue to function throughout the year – such benefits have not been considered in this analysis.

It is likely that the focus of the Thematic Strategy regarding SCIs is going to be on action to reduce PM emissions from the non-industrial sector. This measure is likely to be less effective than other measures discussed in this section in terms of overall emission reduction; however, it is an important mechanism for targeting the existing boiler stock. The benefit for the Commission is that a policy instrument, in the form of the EPBD, is already in place, and therefore the benefits for air quality policy need to be highlighted.

Table 7.25 Problematic issues associated with implementation of inspection-based measures

Issue	Comment
Identification of boilers	There is an issue regarding the identification of boilers by inspectors. It is unlikely that many countries will have a detailed database of boilers (at the point the EPBD is implemented) which might mean that significant costs were incurred in identifying eligible boilers. Identification of older boilers (>15 years) may also be problematic in the absence of data. It might be more cost-effective just to consider all residential and commercial boilers.
Number of inspectors	Due to the scope of this measure (and inclusion of many buildings), a large number of inspectors would be needed to cover all boilers above 20 kW.
Scheme enforcement / administration	Again due to the scope of the scheme, enforcement / administration costs could be significant. Households within the residential sector might need to register their inspection with the relevant authorities as done in Italy (or inspectors could register the inspection). In the commercial sector, inspections could be registered with the company registration authorities. A central database would be needed for storing all of this information.
Social impacts	The scope of this measure is significant with many households covered. The costs of inspection and maintenance are going to be incurred by the owner of the heating system. Costs could impact disproportionately on low income groups - Member States may need to consider financial relief for such groups.
Definition of scheme	Defining what inspection actually is can be problematic as it means something different across Europe. A CEN working group is currently looking at standards for inspection schemes.

The problematic issues resulting from the implementation of this kind of measure are considered above in Table 7.25.

7.3.6.2 Improved insulation through the EPB Directive

The main focus of the EPB Directive is to ensure that the energy performance of new and existing buildings is improved. For new build, this applies to all buildings with a useful floor area over 1000 m^2. For existing buildings, the Directive focuses on the same size building as for new build, stating that minimum energy performance requirements need to be met when such a building undergoes major renovation.

The importance of this Directive in the context of this study, as with inspection schemes, is the resulting reduction in energy demand, thereby avoiding a certain amount of emission. Ecofys (2004) undertook a study to assess the impact of the EPB Directive, and determined the technical potential of this measure by considering that all buildings covered by the Directive would be renovated. An annual saving of 11% per annum in CO_2 emissions (for the EU15 group of countries) was noted as the technical potential - the actual savings will of course depend on the rate of renovation. Only a small technical potential was identified for new build on the basis that buildings were currently insulated to high standards.

Scenarios were also considered, where the EPB Directive was extended to >200 m^2 buildings, and to all residential houses. Technical potential reductions were calculated at 21% and 55% respectively as a percentage of emissions from this sector. Assessed over time series (2002-2010), in 2010 savings from the EPB Directive are estimated to be 34 Mt / annum of CO_2, while extended to all houses, 70 Mt / annum.

Based on the projected energy saving, there are going to be significant additional benefits for air quality pollutants. The emissions savings are likely to be dependent on the energy saved (as used to calculate CO_2 emission reduction). This type of energy efficiency measure is particularly important for reducing demand for oil and gas in commercial and residential buildings, which are projected to become more significant sources of urban NOx emissions in the future.

The costs of this measure have not been assessed in the Ecofys report. Costs for insulation-based measures can be found in section 5.3.4, and appear reasonably cost-effective, with payback periods of around 3 years for loft and cavity wall insulation, based on savings in energy costs.

With the near implementation of the EPB Directive, the benefits to air quality can be stressed, particularly as this Directive is focusing on non-industrial sectors at the European level. These are sectors that have been difficult to formulate air quality policy for at the European level; therefore, this type of action needs to be highlighted in terms of air pollutant reduction benefits. Such action is also important for reducing emissions of NOx (not easily targeted with other types of measures) through reducing energy demand,.

7.3.6.3 Integration into RAINS model scenarios

Inspection
Currently, the RAINS model has a control option called GHDOM, which reflects the difference in emission factors between oil boilers that are regularly maintained, and those that are not. An assumption was made that such maintenance was reflected across all Western European countries while for newly acceded countries, less maintenance was assumed in current years but projected to increase in later years. For the rest of Europe, less maintenance was assumed with a slower rate of future implementation.

Based on this study, and the European overview provided in Table 7.20, there is additional data that could potentially be fed into the RAINS model. Such information includes a review of existing schemes across Europe, and data on potential costs and effectiveness. The available data, however, does not provide an understanding of regular inspection outside of obligatory schemes e.g. service agreements with manufacturers. It is assumed that this will be quite high in many European countries.

Modelling how the EPBD Article 8 will be implemented across Europe will be difficult, and hence the consideration of three options in this analysis. With the inclusion of an option for an advice-based approach, countries that do not have inspection schemes currently are likely to go for this least–cost option (although they will have to provide evidence that such an approach is providing an equivalent impact to a full inspection scheme).

Insulation
Insulation could be included as a control option in RAINS in all modules, although might be better modelled in the framework of PRIMES due to the changes to the energy balance. The same applies to the energy savings estimated from increased maintenance.

7.4 CONCLUSIONS

There are some useful recommendations that can be drawn from this analysis, to help develop the Thematic Strategy on Air Pollution in relation to policy options for reducing emissions from small combustion installations. From the inventory analysis in section 3, we believe that the focus of policy recommendations needs to be on options for reducing emissions of PM, particularly from the use of solid fuels (in the shorter term) and from biomass use, which will persist beyond 2020. Therefore, the analysis in this section has been focused on PM (and NMVOCs) reductions.

Two other priorities were identified from the inventory section; firstly, emissions from potentially unregulated industrial (or larger) SCIs, and secondly, NOx emissions from oil and gas use in the non-industrial sector. Both of these issues are also considered in this section. Each policy option is now considered briefly, summarising the key issues from this section, and the recommendations to the Commission.

Product standards
Product standards could be an important mechanism to ensure that new appliances on the market meet specific emission limit criteria. A regulatory framework could be considered to ensure that this occurs, with significant reductions possible through 'natural' replacement at

end of life. Policy mechanisms exist at the European level to further promote the use of product standards, in particular the proposed Energy Using Products Directive, and New Approach Directives such as the Construction Products Directive. This measure is primarily applicable to non-industrial sectors, and is important for reduction of PM emissions, particularly from biomass (which are projected to be significant in the future) and NOx emissions from the consumption of liquid fuels and natural gas.

Key recommendations include

- Further exploration of the potential of the proposed Framework Directive on Energy Using Products as a means for introducing emission limit criteria in product design.
- Undertake further discussions with CEN concerning the development of standards that reflect the needs of EU policy e.g. the use of PM emission limits in standards for stoves. The CEN programme being developed under a mandate from the Commission in support of the EuP Directive may provide a good opportunity.
- Promote the development and inclusion of PM limits in stove and boiler product standards and / or research how well other pollutants are represented by CO limits.
- Further assessment of the cost-effectiveness of this option in the framework of the RAINS model, to confirm and strengthen findings of this study.

Local-based measures

Local action is often the most cost-effective way of dealing with pollution problems, which are specific to a given area, due to the fuel being used, or age of the appliance stock. Such measures can be structured to meet the needs of a specific area. This study has determined countries across Europe that have or have the potential for air pollution problems resulting from SCI sourced emissions. In particular, some Eastern European countries have significant air pollution problems related to the non-industrial consumption of coal. The Air Quality Framework Directive should provide the mechanism that allows flexibility of locally targeted action for such problems, where exceedances are observed.

Key recommendations include

- Ensure full reporting by Member States under the Air Quality Framework Directive to assess the types of actions being undertaken to reduce emissions for SCIs in non-attainment areas.
- Identify and propose the use of local measures in the Thematic Strategy, as a cost-effective means of reducing emissions associated with SCI use in urban areas (based on the case study evidence presented in this study, and analysis undertaken).
- Consideration for further measures would need to be based on stronger evidence of the persistence of solid fuel use in urban areas in future years. This study only provides part of this picture.
- Local based measures considered in this section are all represented in the RAINS model to some extent. Further analysis would be difficult in the framework of the RAINS model, as sub-national spatial resolutions cannot be modelled.

Fuel quality restrictions

The main fuel quality measures include promoting the use of lower sulphur content liquid and solid fuels, promoting the use of biomass products (as opposed to standard wood fuels) and encouraging use of ‘cleaner’ solid fuels as alternatives to bituminous and other lower grade coals. Significant projected reductions in SO_2 may mean that more stringent limits are less of a priority (although potential reductions in sulphates from liquid fuels could be perceived as a significant additional benefit of such a policy). European based action for promotion of biomass based product such as pellets and wood chips has not been identified, due to potential conflicts with climate policy – this is potentially action that needs to be encouraged at the national level in order to reduce projected PM and NMVOC emissions.

Key recommendations include

- Highlight in the Thematic Strategy the importance of improved fuel quality for reducing emissions from SCI (particularly in the non-industrial sectors), particularly due to long lifetimes of appliances, making ‘natural’ replacement a slow process.
- Further explore the potential of introducing more stringent sulphur content limits in the Sulphur Content of Liquid Fuels Directive, particularly in terms of associated PM reductions (primary and secondary). This consideration is important given the potential increased importance of liquid fuels as a source of future PM urban emissions.
- Consider this measure further in the framework of the RAINS model. A potential approach for RAINS is described in more detail in section 7.3.3.3.

Installation specific limits

Large industrial installations have largely been the focus of previous European legislation. A question for this study was to examine whether further action was required for sub-50 MW_{th} plant. Two important factors in considering additional action were scope of existing regulation for larger SCIs, and the contribution to overall emissions of these plant. Based on the inventory, contribution to overall European emissions appear low, although across many countries account for a significant percentage of industrial combustion emissions. Regulatory coverage of industrial plant (SCIs) appears extensive across Europe, in particular the scope of the IPPC Directive on the 20 – 50 MW_{th} range.

Significant uncertainties are present in this data. Therefore, consideration has been given ot the type of potential measures that could be considered, including emissions trading on the back of the EU ETS, extension of the IPPC Directive or LCP Directive, or a new Directive specifically for SCIs.

Key recommendations include

- In view of the emission contribution of industrial SCIs, and the potential scope of existing measures, it is possible that additional site-specific regulation may not be required for large SCI plant (>1 MW_{th}); however, such conclusions have strong caveats attached due to data uncertainty.
- Ensure improved inventory reporting for small industrial combustion installations to better meet the needs of European policy makers.
- Consider further the potential for emissions trading, which could ‘piggy-back’ off the EU ETS platform, and cover all installations with an aggregated capacity over 20 MW_{th} (aggregated) up to LCP. This may also be a useful mechanism for countries to meet NECD targets.
- Further analysis could be undertaken by the RAINS model, in particular to model the effect of plant in the 20-50 MW_{th} range being included under the IPPC Directive. The possible approach is set out in section 7.3.4.5.

Structural Funds
Central European financing could be important in ensuring that projects, which require significant capital investment, can be undertaken. In relation to air quality problems, such projects might include energy infrastructure development or technology replacement programmes. Structural Funds and Cohesion Funds could be a useful source of such finances, if they can be broadened in scope to reflect environmental objectives, and if Member States know that environment improvement and protection is one of their objectives, in addition to wider regional policy objectives.

Key recommendations include
- The Thematic Strategy might usefully reflect the importance of available funding to assist countries (particularly new Member States and Candidate countries) in dealing with local and regional air quality problems associated with emissions from SCIs, and the effectiveness of such funding in achieving emission reductions.
- Further consideration of the possibilities for ensuring Structural and Cohesion Funds provide financial assistance to tackle SCI air quality related issues. This study has determined that there are a number of countries that still have significant local air quality problems due to emissions from SCI sources, who could benefit from such investment.
- Increase awareness of the potential for using Structural Funds, as currently structured, to further prioritise environmental objectives in national fuding programmes.
- Broaden scope of the Cohesion Fund, which specifically relates to environmental and transport infrastructure to include energy infrastructure.

Energy efficiency based measures
Policy measures from different policy areas may have additional air quality benefits. This is clearly true of climate policy, which has measures both at the national and European level aimed at improving energy efficiency and reducing energy demand. An important Directive, which will come into fore in 2006, is the Energy Performance of Buildings Directive. It is recognised that significant benefits will also be seen for air quality policy, through the reduction of energy demand due to better energy efficiency of appliances, improvement to insulation in the building stock, and increased maintenance of heating systems.

Key recommendations include
- Highlight the benefits of action in the climate policy area across Europe, in particular the EPBD, but through other Directives such as that relating to the Energy efficiency of boilers.
- Further research to be undertaken on the direct benefits of maintenance for air pollutant reduction, not only those derived from energy savings.
- Consideration of future changes to the EPBD, to broaden the scope of types (based on size) of the buildings and installations covered.

In conclusion, due to the air quality problems associated with SCIs, it is important that a range of actions are considered, that will target energy demand, fuel quality, and technology improvement. In particular, the approach to reduction of emissions of PM from biomass appear to be one of the most significant challenges. In addition, data needs identified in this study may also need to be resolved, to increase confidence in the study recommendations and findings.

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8 Appendices

Appendix 1	Emission Inventory data
Appendix 2	NECD country plan review of SCI relevant measures
Appendix 3	Stakeholder consultation questionnaire
Appendix 4	Technology based emission factors and costs

APPENDIX 1: EMISSION INVENTORIES

Appendix 1.1 Emissions of non-industrial SCIs (2000)

Table showing annual emissions for all countries from non-industrial SCI sources in 2000, with highlighted cells showing sectors that contribute more than 2.5% of non-industrial SCI emissions.

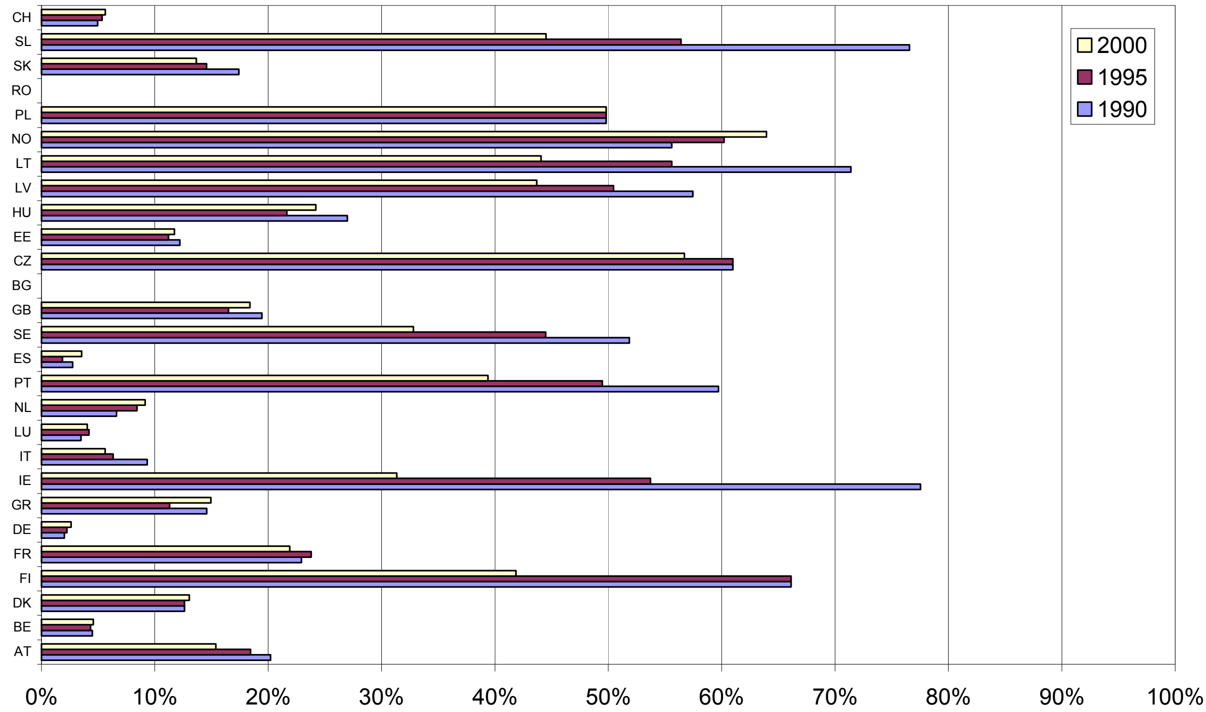
UNFCCC_label	Description	NH_3 (t)	NMVOC (t)	NOx (t)	PM_{10} (t)	$PM_{2.5}$ (t)	SO_2 (t)	NH_3 %	NMVOC %	NOx %	PM_{10} %	$PM_{2.5}$ %	SO_2 %
AFF_Biomass	Medium boilers (automatic) <50 MW using wood, waste, biomass	74	5635	531	1412	1297	218	0%	1%	0%	0%	0%	0%
	Medium boilers (manual) <1 MW using wood, waste, biomass	105	7686	795	1683	1469	347	1%	1%	0%	0%	0%	0%
	Single house boilers (automatic) <50 kW using wood, waste, biomass	70	5315	514	1646	1595	215	0%	1%	0%	0%	0%	0%
	Single house boilers (manual) <50 kW using wood, waste, biomass	90	6661	663	2556	2476	283	0%	1%	0%	0%	0%	0%
AFF_Gaseous_fuel	LPG	0	0	623	22	22	0	0%	0%	0%	0%	0%	0%
	Natural Gas	0	6590	40430	949	949	0	0%	1%	5%	0%	0%	0%
AFF_Liquid_Fuels	Diesel / Light fuel oil	611	3702	36899	659	634	57627	3%	0%	5%	0%	0%	7%
	Gasoline	0	89	1794	50	50	74	0%	0%	0%	0%	0%	0%
	Heavy fuel oil	43	373	7236	1350	630	12836	0%	0%	1%	0%	0%	1%
AFF_Solid_fuels	Medium boilers (automatic) <50 MW using brown coal	31	389	171	3707	4068	3841	0%	0%	0%	1%	1%	0%
	Medium boilers (automatic) <50 MW using coke / briquettes	7	158	479	479	273	2351	0%	0%	0%	0%	0%	0%
	Medium boilers (automatic) <50 MW using hard coal	191	4358	2505	13059	11818	11584	1%	1%	0%	2%	2%	1%
	Medium boilers (manual) <1 MW using brown coal	2	23	10	253	229	229	0%	0%	0%	0%	0%	0%
	Medium boilers (manual) <1 MW using coke / briquettes	1	19	56	56	32	277	0%	0%	0%	0%	0%	0%
	Medium boilers (manual) <1 MW using hard coal	114	2615	1503	8064	5441	6950	1%	0%	0%	2%	1%	1%
	Single house boilers (manual) <50 kW using brown coal	2	23	10	53	47	229	0%	0%	0%	0%	0%	0%
	Single house boilers (manual) <50 kW using coke / briquettes	0	9	28	3	2	139	0%	0%	0%	0%	0%	0%
	Single house boilers (manual) <50 kW using hard coal	38	872	501	728	647	2317	0%	0%	0%	0%	0%	0%
Comm-Institut_Biomass	Medium boilers (automatic) <50 MW using wood, waste, biomass	242	13495	2365	3298	3342	1263	1%	2%	0%	1%	1%	0%
	Medium boilers (manual) <1 MW using wood, waste, biomass	330	19017	3454	4481	3931	1841	2%	2%	0%	1%	1%	0%
Comm-Institut_Gaseous_fuel	LPG	3	0	8159	32	32	0	0%	0%	1%	0%	0%	0%

	Natural Gas	10	4770	84408	106	106	0	0%	1%	11%	0%	0%	0%
Comm-Institut_Liquid_Fuels	Diesel / Light fuel oil	671	3495	65681	686	623	121587	4%	0%	9%	0%	0%	14%
	Gasoline	0	120	5198	23	23	131	0%	0%	1%	0%	0%	0%
	Heavy fuel oil	48	109	11008	1302	538	38687	0%	0%	1%	0%	0%	4%
Comm-Institut_Solid_fuels	Medium boilers (automatic) <50 MW using brown coal	27	287	298	3097	6342	5285	0%	0%	0%	1%	1%	1%
	Medium boilers (automatic) <50 MW using coke / briquettes	9	198	1083	785	446	8566	0%	0%	0%	0%	0%	1%
	Medium boilers (automatic) <50 MW using hard coal	189	2597	3780	12908	11825	29659	1%	0%	0%	2%	2%	3%
	Medium boilers (manual) <1 MW using brown coal	2	17	18	258	323	314	0%	0%	0%	0%	0%	0%
	Medium boilers (manual) <1 MW using coke / briquettes	1	23	127	92	53	1008	0%	0%	0%	0%	0%	0%
	Medium boilers (manual) <1 MW using hard coal	113	1558	2268	8700	5330	17796	1%	0%	0%	2%	1%	2%
Residential_Biomass	Fireplaces using wood, waste, biomass	696	52598	5642	38003	36868	1866	4%	6%	1%	7%	7%	0%
	Single house boilers (automatic) <50 kW using wood, waste, biomass	2152	162308	17402	65318	63277	5689	12%	19%	2%	12%	13%	1%
	Single house boilers (manual) <50 kW using wood, waste, biomass	2784	210378	22564	102363	99164	7462	15%	25%	3%	19%	20%	1%
	Stoves using wood, waste, biomass	2720	205855	22086	107220	104849	7370	15%	25%	3%	20%	21%	1%
Residential_Gaseous_fuel	LPG	14	0	16451	99	99	0	0%	0%	2%	0%	0%	0%
	Natural Gas	832	17720	217345	457	457	0	5%	2%	28%	0%	0%	0%
Residential_Liquid_Fuels	Diesel / Light fuel oil	1628	6217	98322	1726	1607	136603	9%	1%	13%	0%	0%	16%
	Gasoline	45	268	7116	89	89	197	0%	0%	1%	0%	0%	0%
	Heavy fuel oil	117	300	17210	3141	1355	41058	1%	0%	2%	1%	0%	5%
Residential_Solid_fuels	Single house boilers (manual) <50 kW using brown coal	104	2119	1178	4179	3730	14902	1%	0%	0%	1%	1%	2%
	Single house boilers (manual) <50 kW using coke / briquettes	50	1732	3961	678	386	24781	0%	0%	1%	0%	0%	3%
	Single house boilers (manual) <50 kW using hard coal	2066	41106	28953	67955	60401	146458	11%	5%	4%	13%	12%	17%
	Stoves using brown coal	103	2088	1143	4117	3684	14777	1%	0%	0%	1%	1%	2%
	Stoves using hard coal	2066	41106	28953	67725	60402	146458	11%	5%	4%	13%	12%	17%

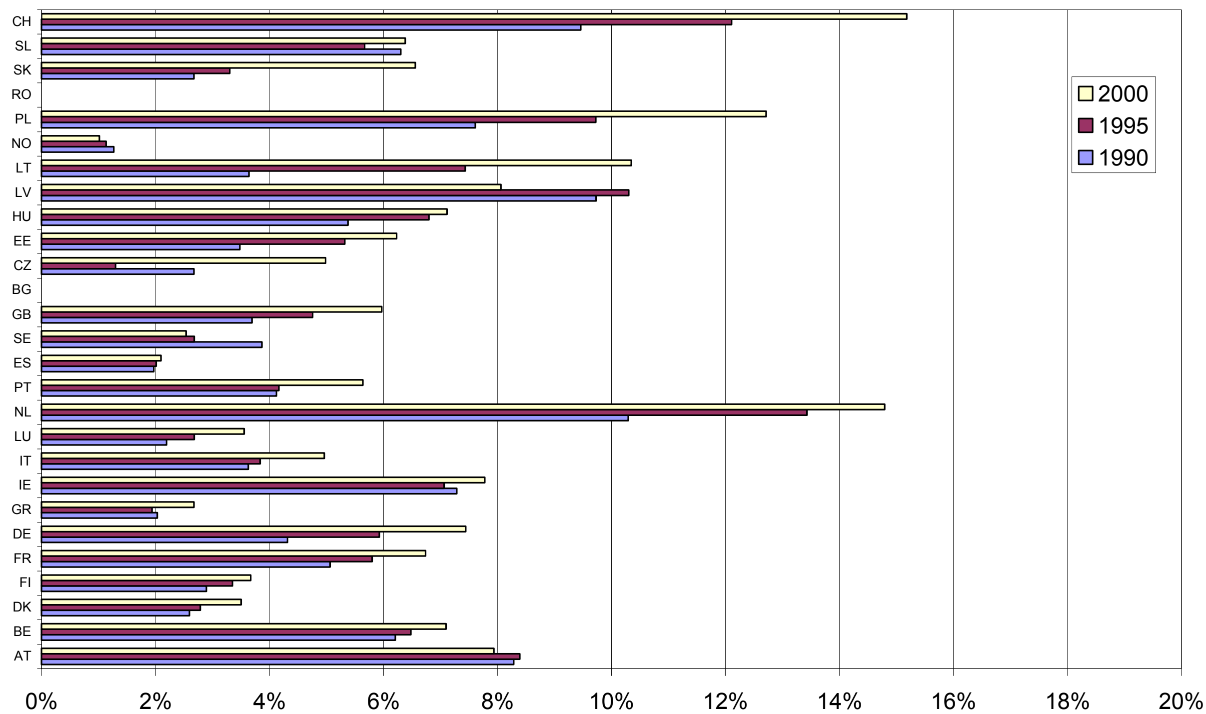
Appendix 1.2 Contribution of non-industrial SCIs to national emission totals

An increased share in total national emissions over time in the following four graphs reflects, in part, falling emissions in other sectors.

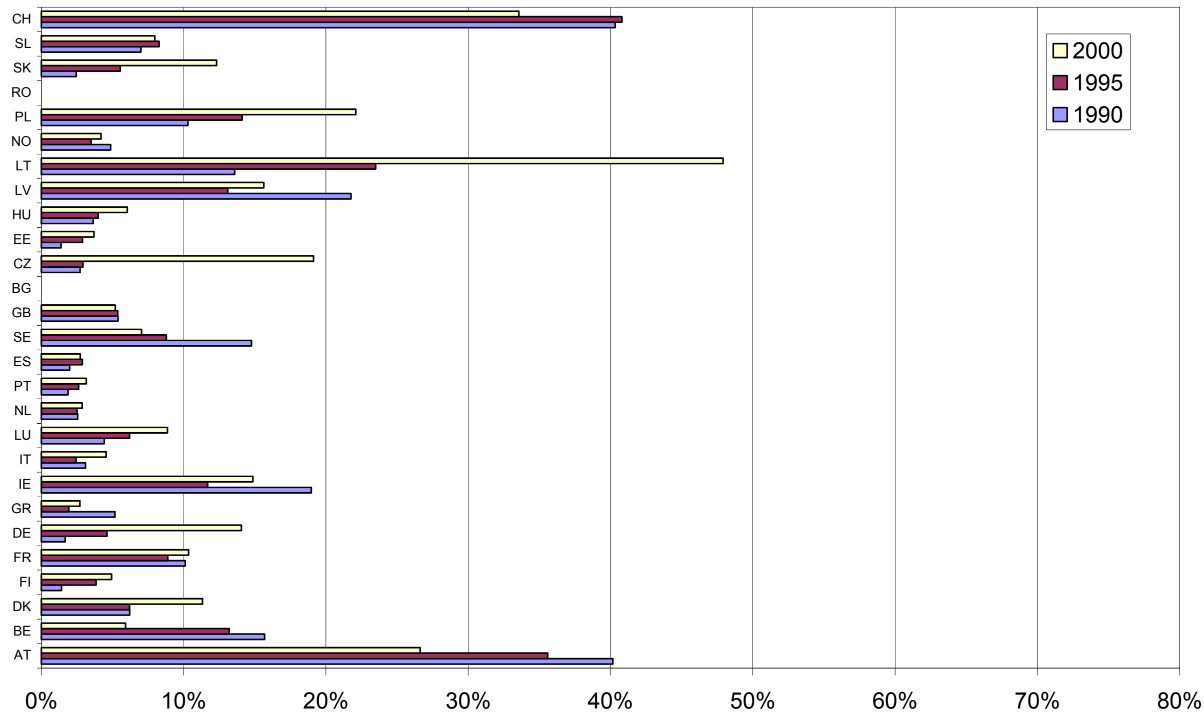
Percentage contribution of national emission total made by non-industry small combustion installations: PM_{10}



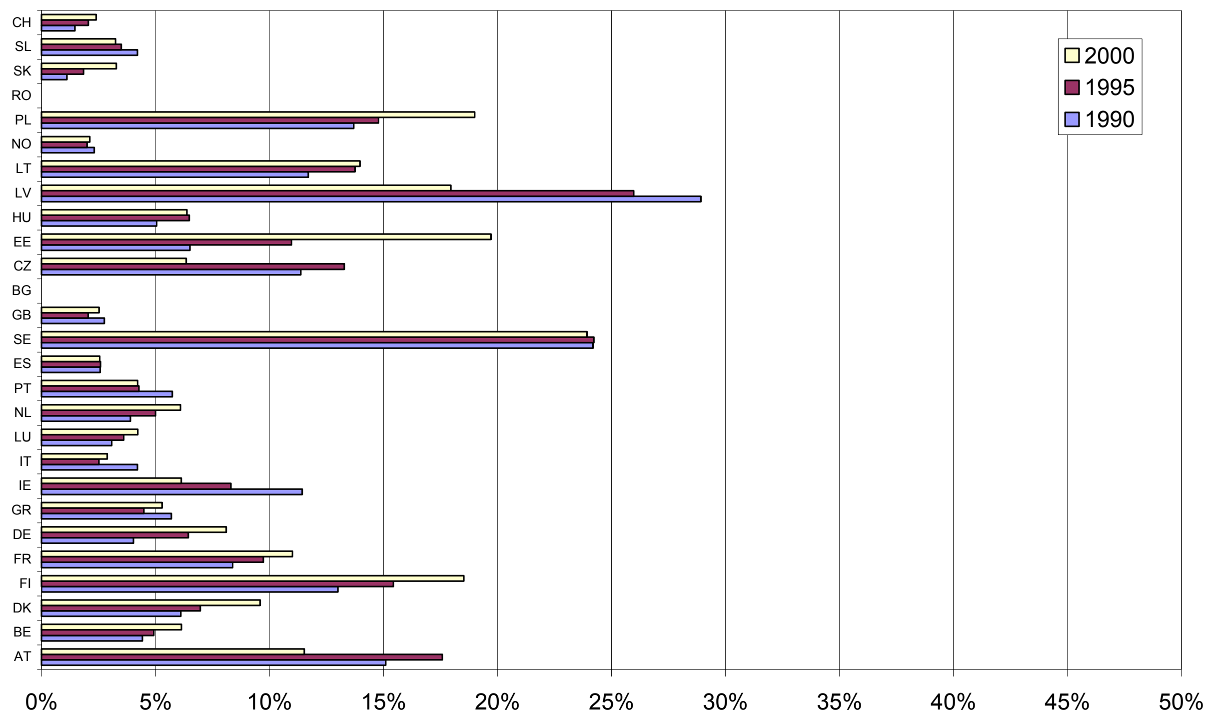
Percentage contribution of national emission total made by non-industry small combustion installations: NOx



Percentage contribution of national emission total made by non-industry small combustion installations: SO_2

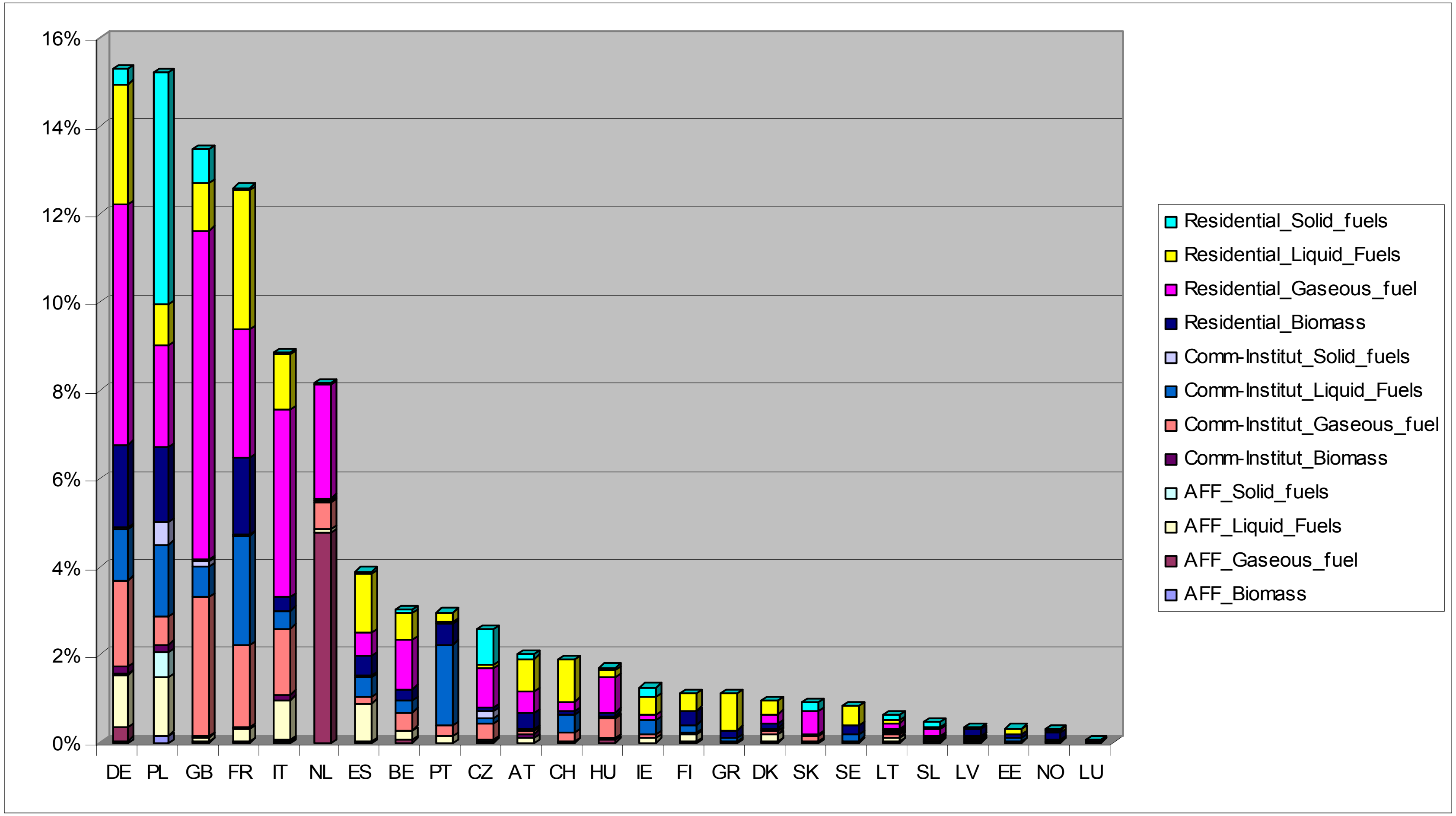


Percentage contribution of national emission total made by non-industry small combustion installations: NMVOC

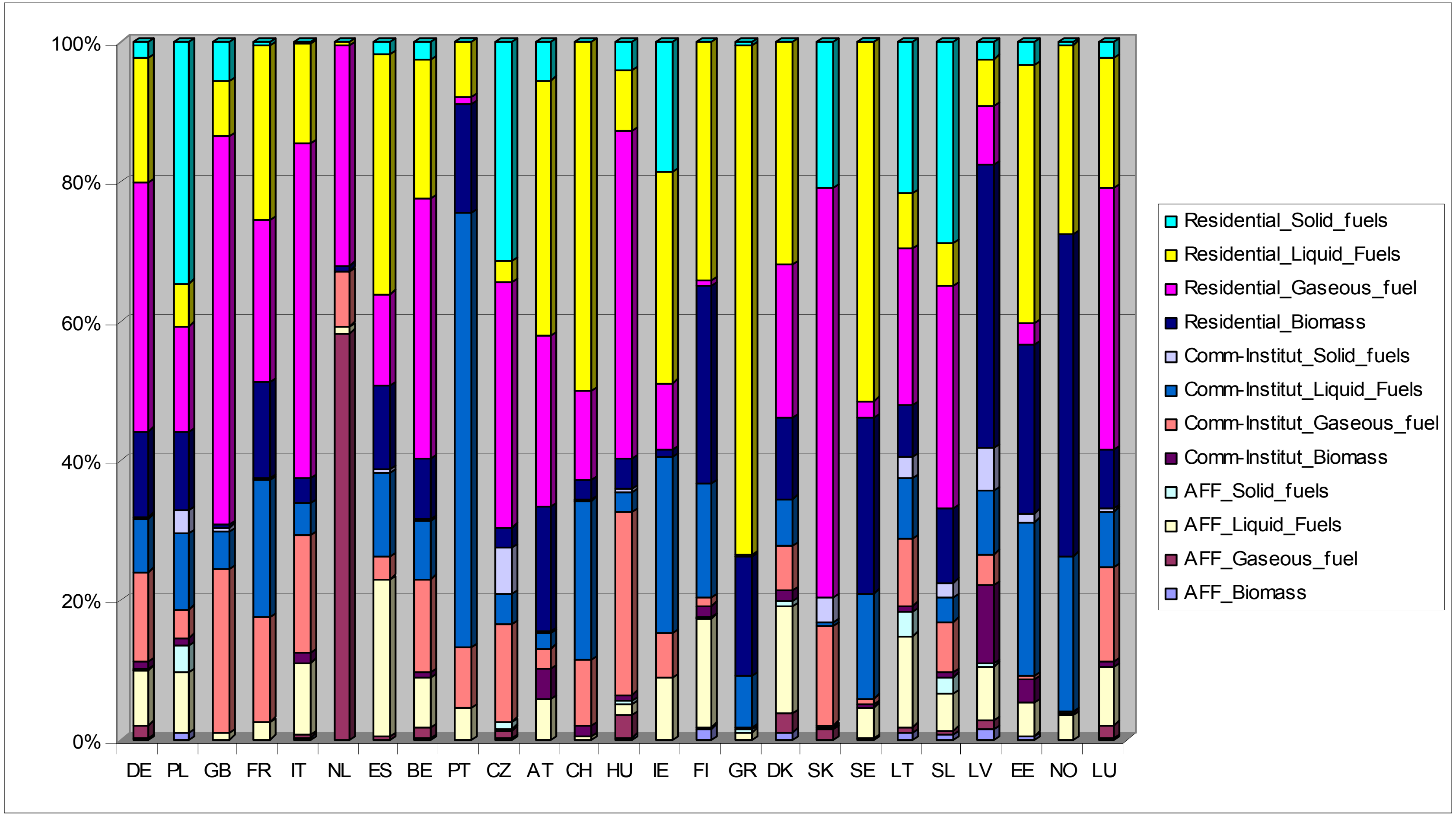


Appendix 1.3 Sectoral emissions from non-industrial SCIs in Europe

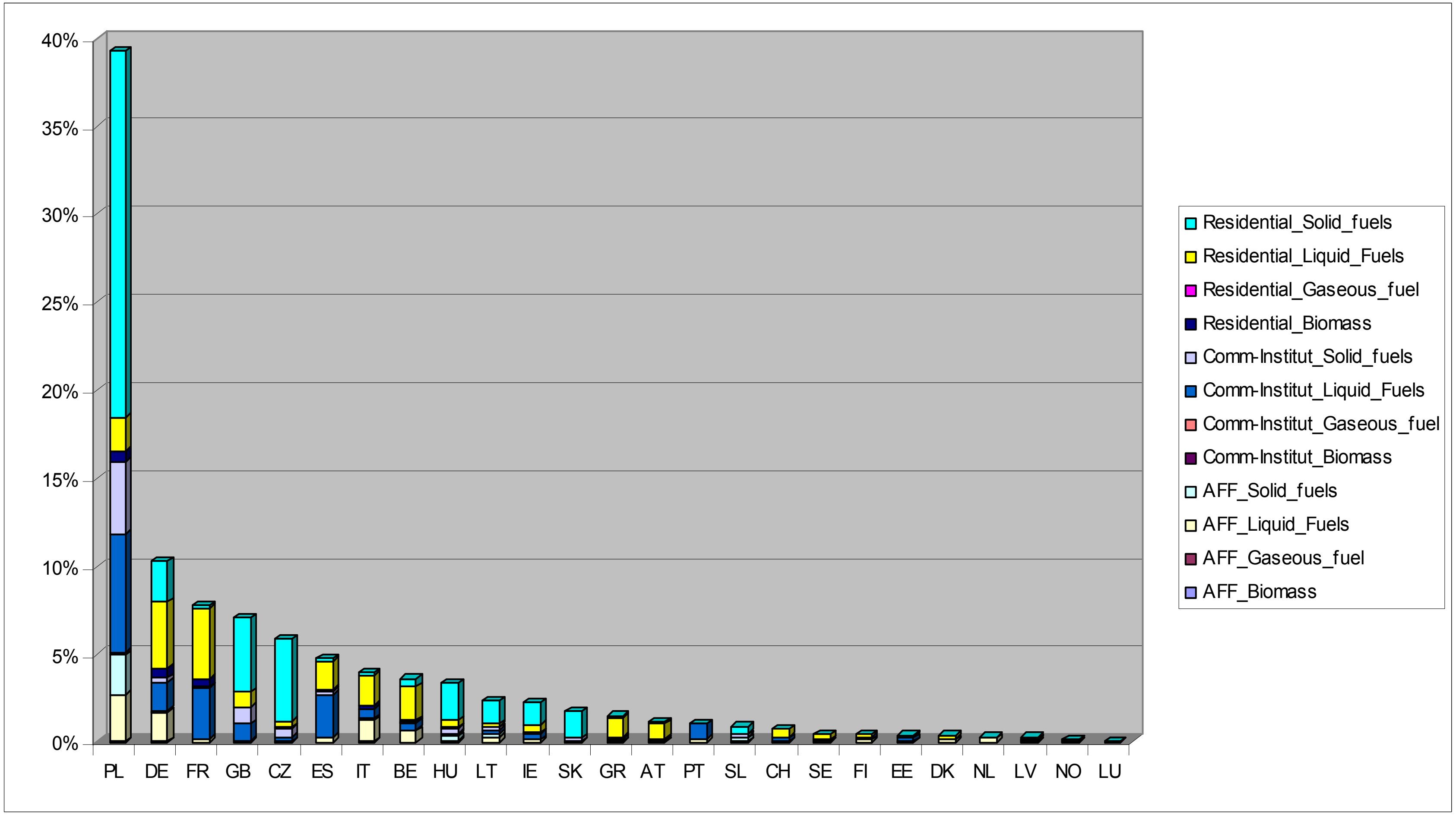
NOx emissions (2000) from non-industrial SCIs by country (as percentage of overall European non-industrial SCI emissions)



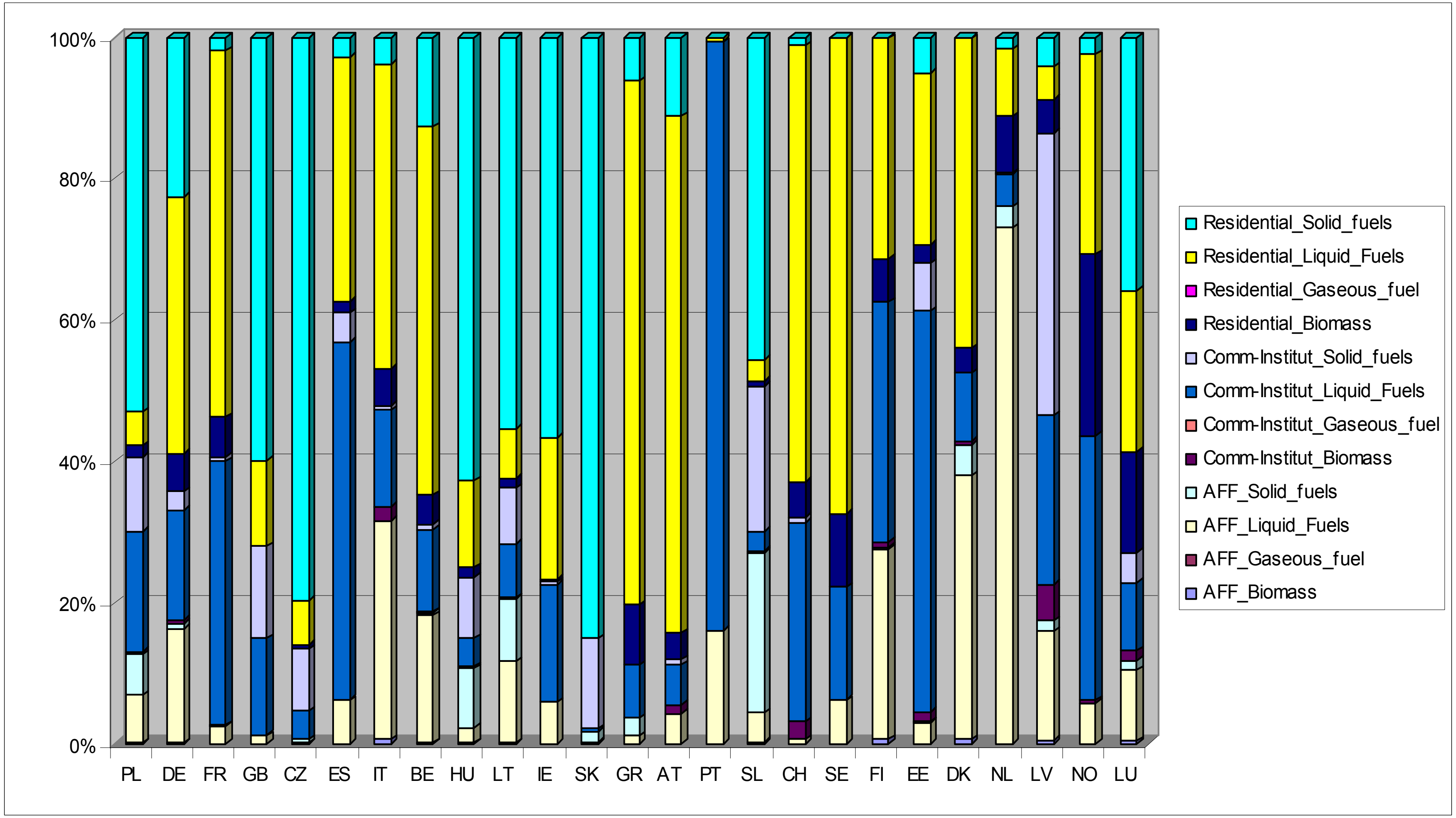
Percentage contribution of NOx emissions (2000) from non-industrial SCIs



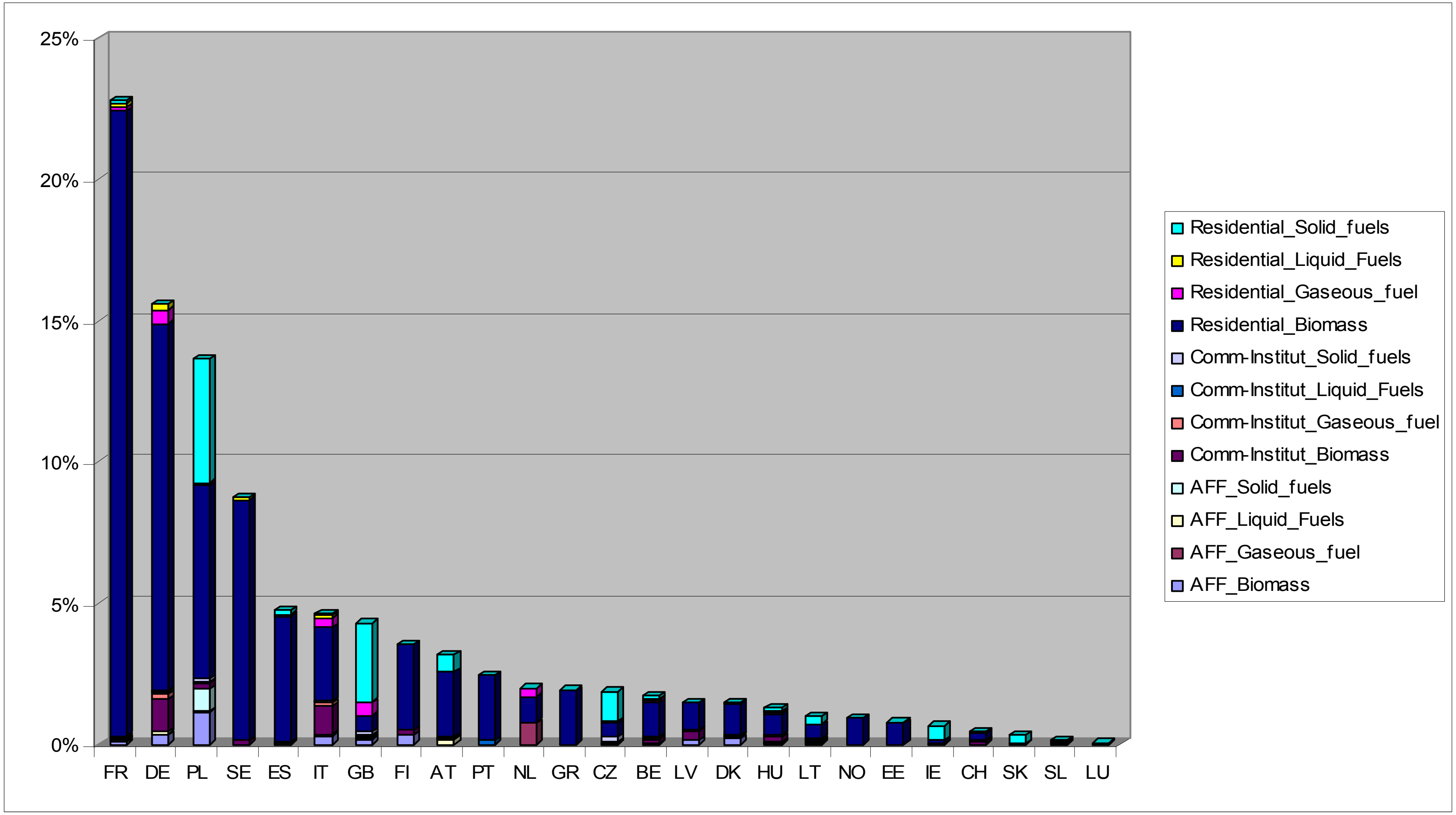
SO_2 emissions (2000) from non-industrial SCIs by country (as percentage of overall European non-industrial SCI emissions)



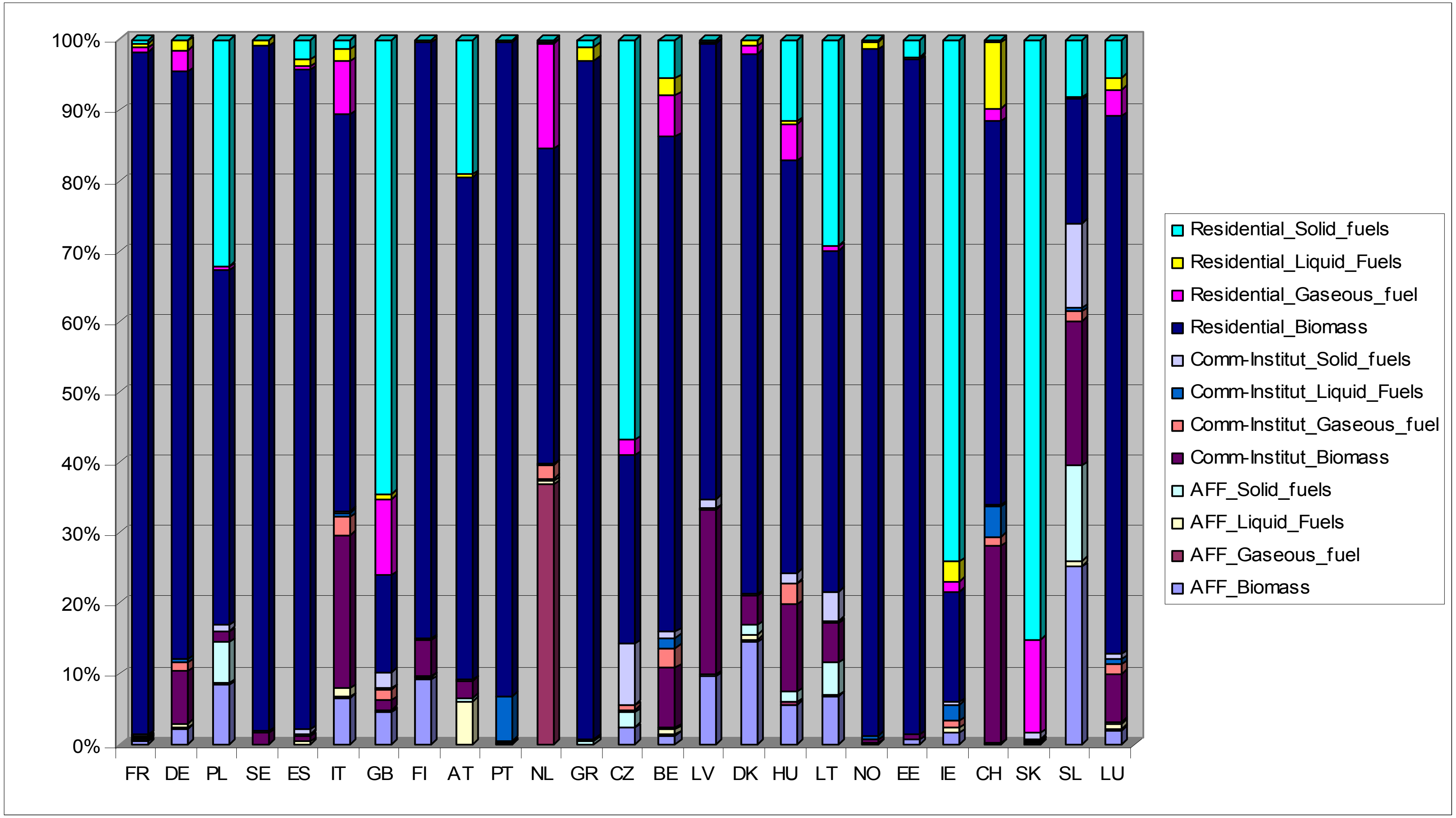
Percentage contribution of SO_2 emissions (2000) from non-industrial SCI



NMVOC emissions (2000) from non-industrial SCIs by country (as percentage of overall European non-industrial SCI emissions)

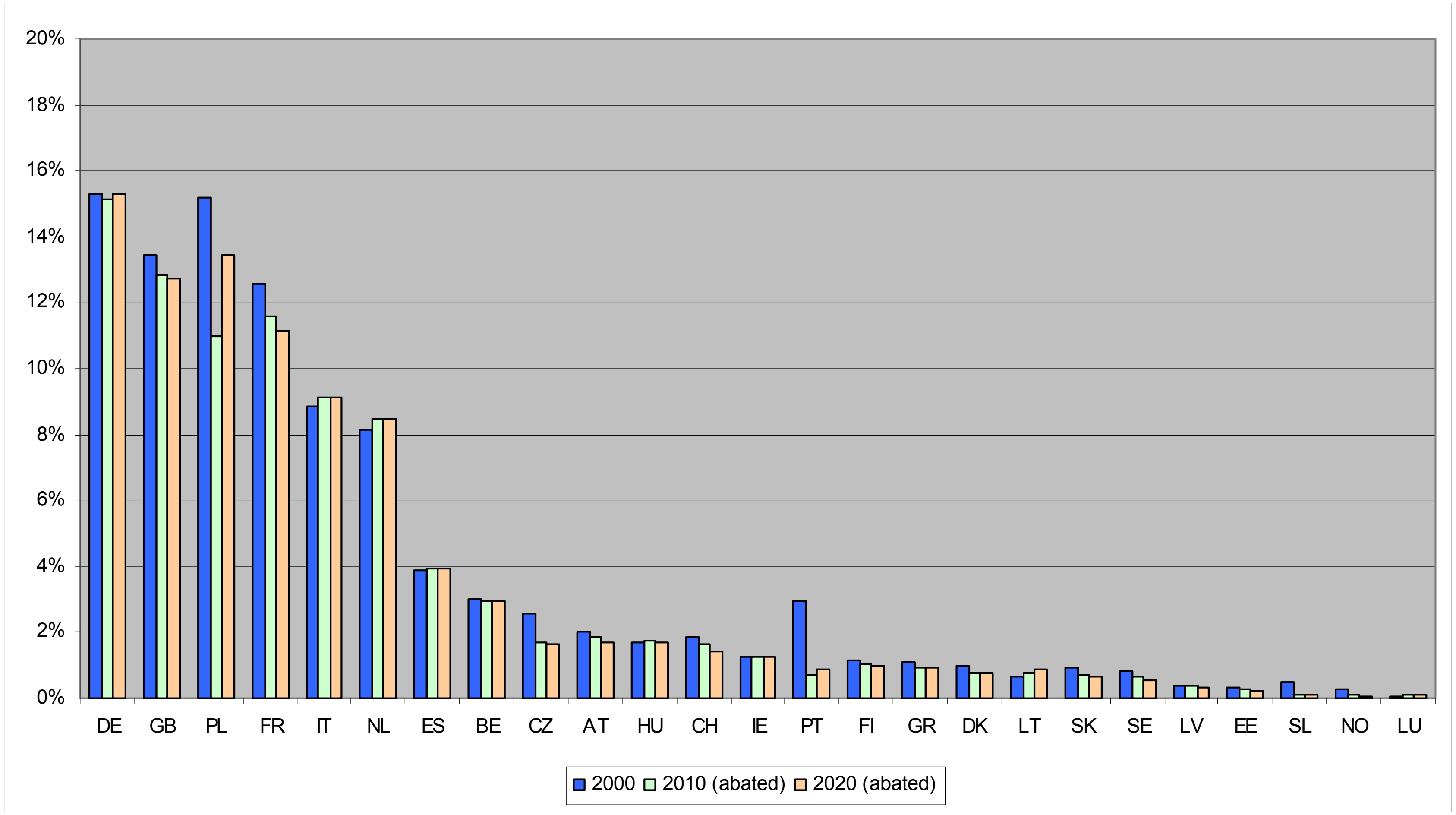


Percentage contribution of NMVOC emissions (2000) from non-industrial SCI

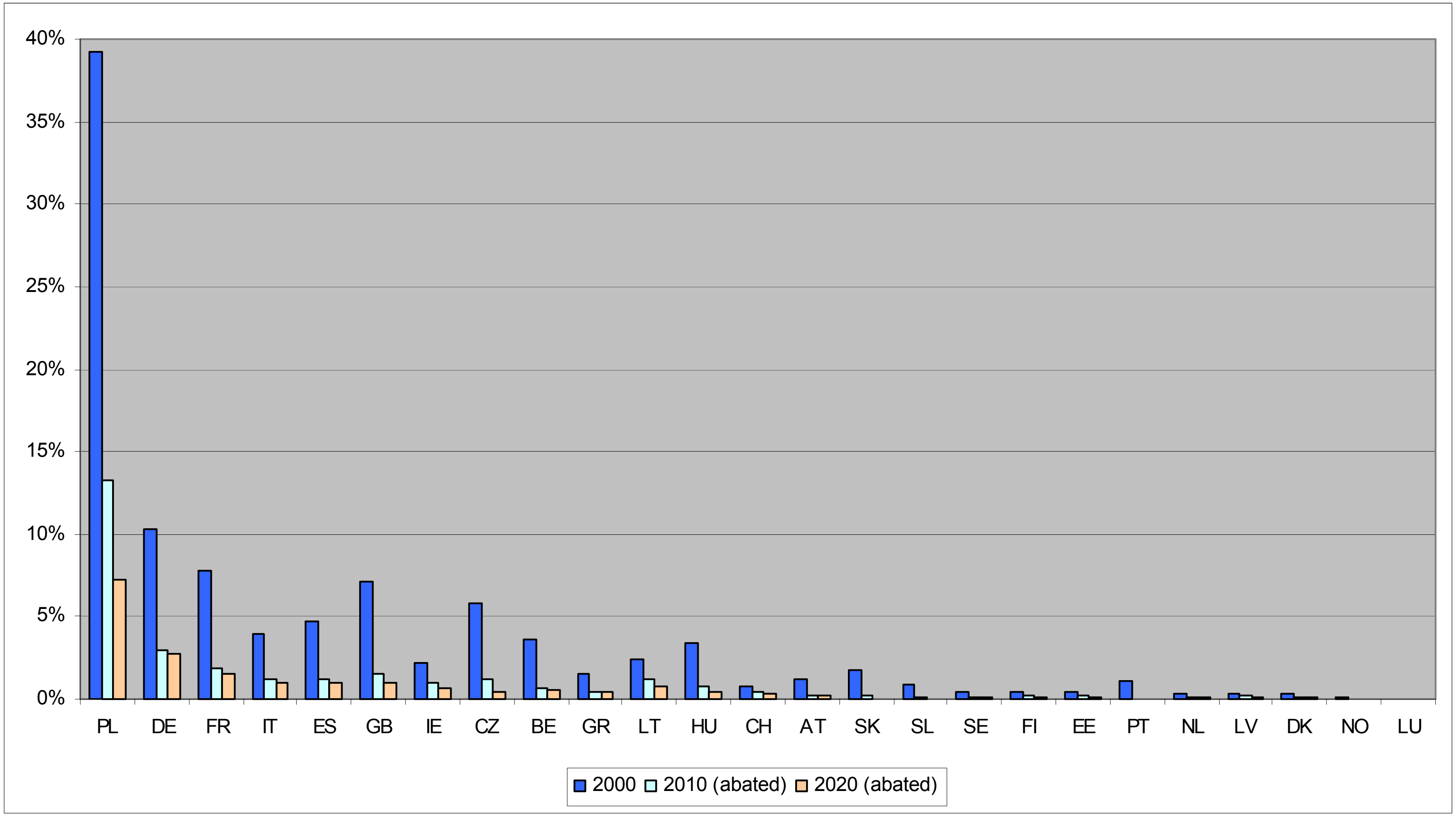


Appendix 1.4 Projected emissions from non-industrial SCIs in Europe

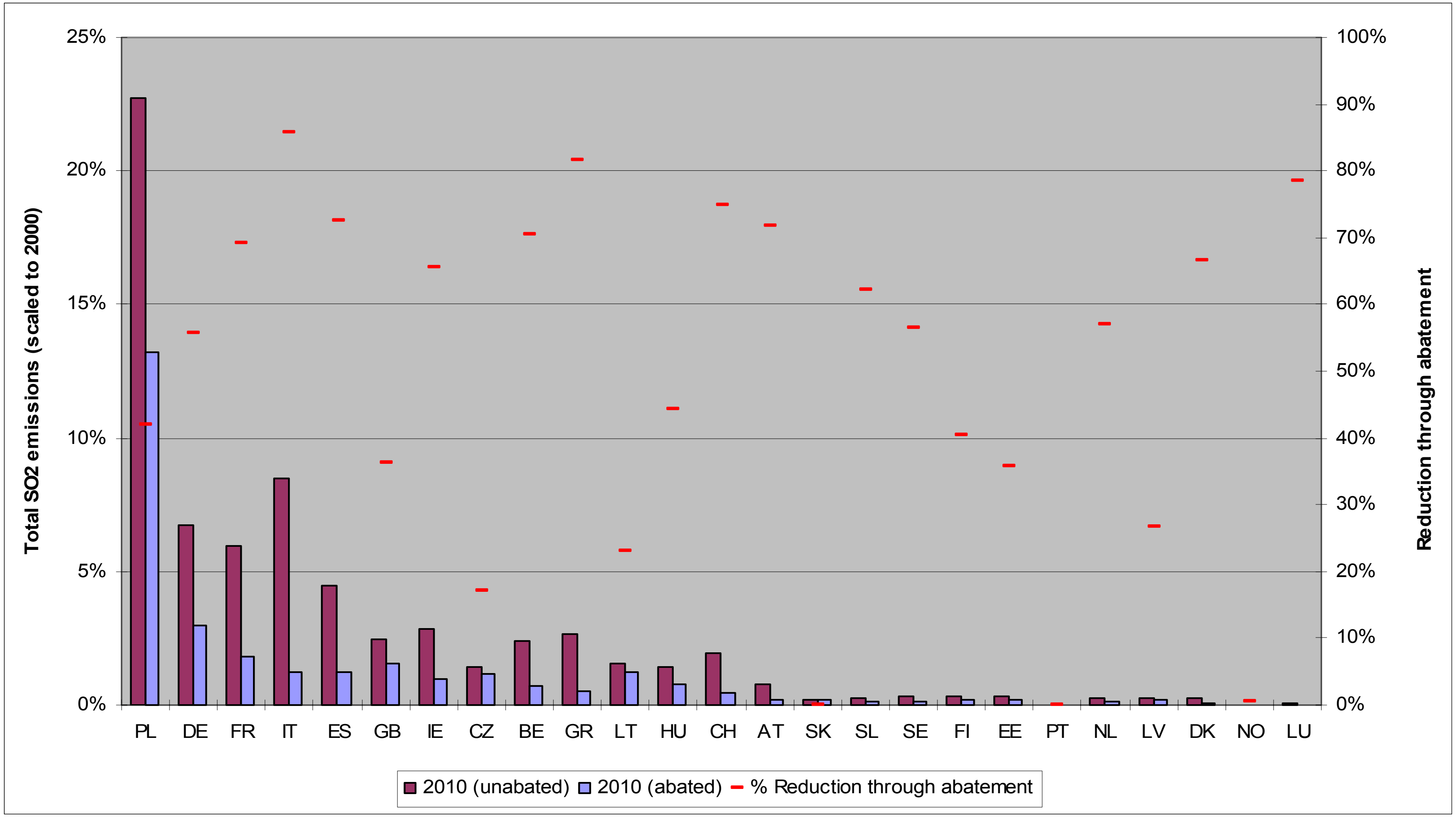
NOx emissions (2000-2020) from non-industrial SCIs by country (as percentage of overall European non-industrial SCI emissions)



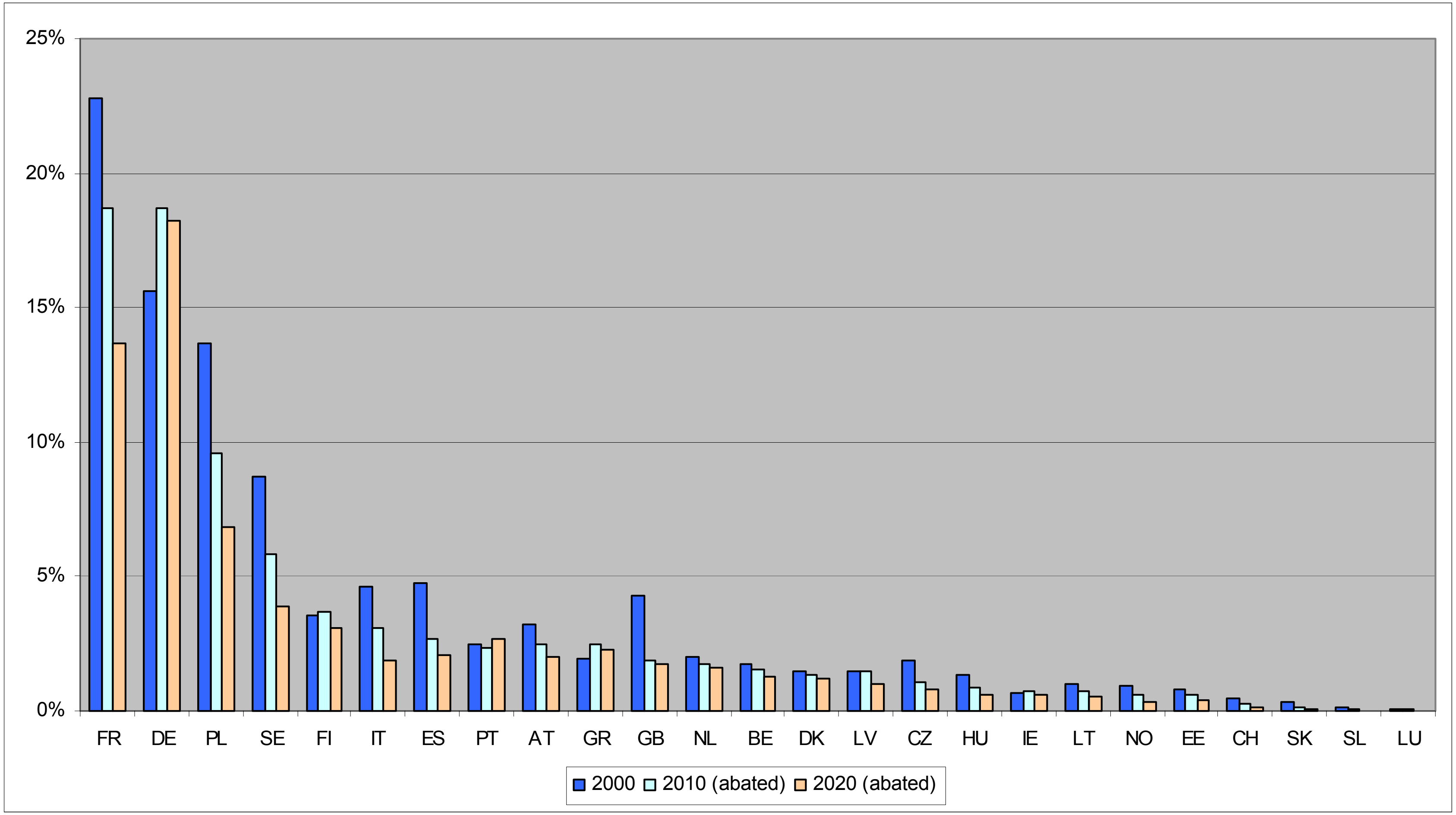
SO_2 emissions (2000-2020) from non-industrial SCIs by country (as percentage of overall European non-industrial SCI emissions, with 2010 a d 2020 normalised to year 2000 total)



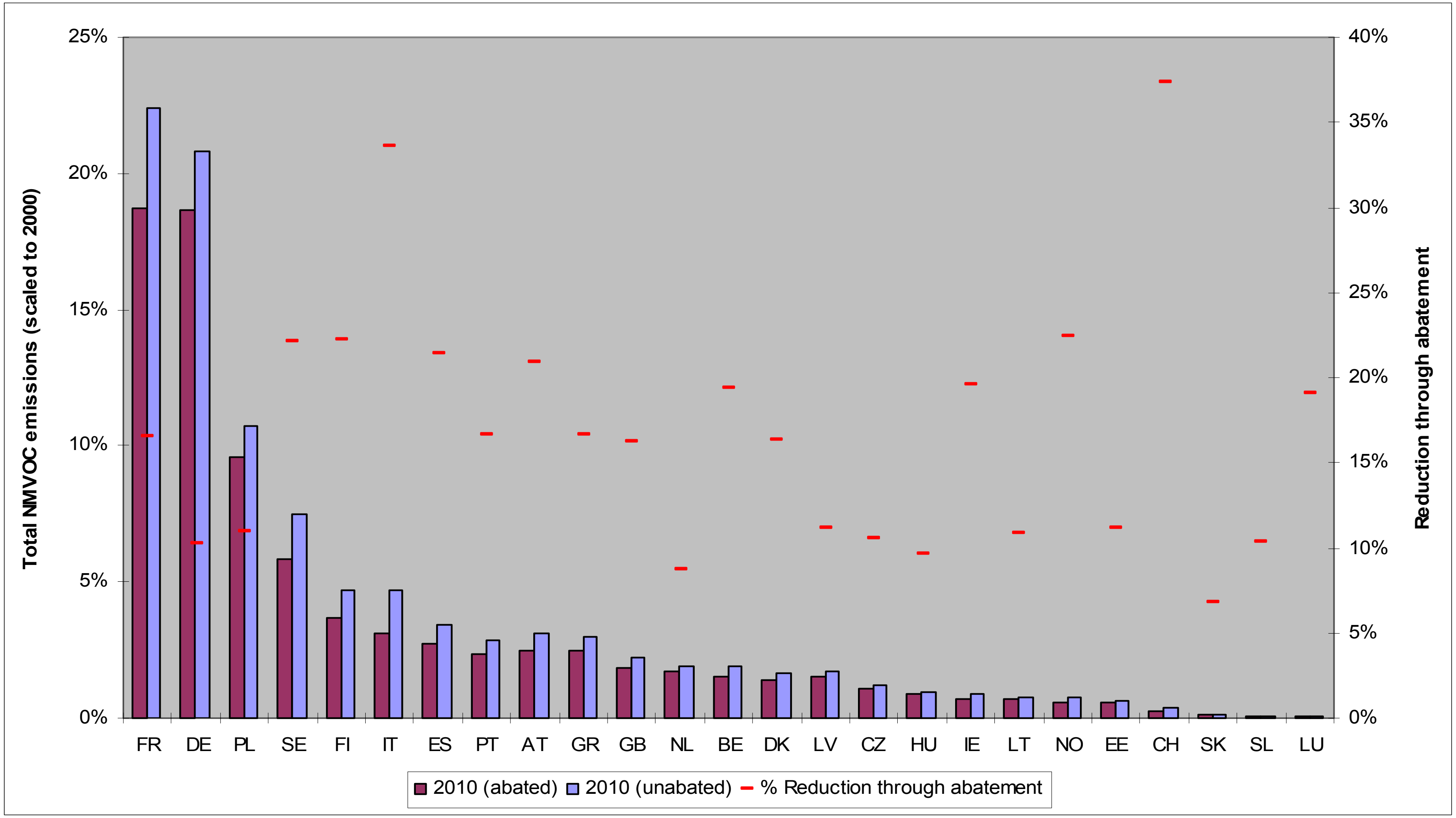
SO_2 emissions (2010) from non-industrial SCIs – abatement measures (as percentage of overall European non-industrial SCI emissions, and normalised to 2000 emissions)



NMVOC emissions (2000-2020) from non-industrial SCIs by country (as percentage of overall European non-industrial SCI emissions, and 2010 and 2020 data normalised to 2000 emissions)



NMVOC emissions (2010) from non-industrial SCIs – abatement measures (as percentage of overall European non-industrial SCI emissions, and normalised to 2000 emissions)



APPENDIX 2 MEASURES RELATING TO SCI EMISSIONS SPECIFIED IN NECD COUNTRY PLANS

Current or proposed actions under Country plans to achieve National Emission Ceilings

Country	Name	Objective	Type of instrument	Pollutant affected	Status	Implementing entity
Finland	Wood-burning Stoves and Fires emission limits	Reduce domestic emissions	Regulatory	NOx	Proposed	Government
Finland	Programme Promoting Renewable Energy Sources	Reduce fossil fuel emissions	Regulatory / Fiscal	SO_2, NOx	Adopted	Government
Finland	Energy Conservation Programme	Energy saving	Regulatory / Fiscal / Voluntary	SO_2, NOx	Adopted	Government
Austria	BGBl. 1998/380 idF BGBl. 2002/65, BGBl. 1989/19 idF BGBl. II 2002/389	Air monitoring, Emissions limit. For SO_2, Boiler plants (>10 MW_{th}), For NOx, Boiler plants (>0.35 MW_{th})	Legal	SO_2, NOx, VOC	Implemented	
Austria	For smaller boiler plants emission limits under the Directive 2001/80/EG (or stricter limits) are defined	Air monitoring, For smaller boiler plants maximum sulphur content of fuels is defined		SO_2	Implemented	
Austria	Heating of houses, Bundes-verfassungs-gesetz Art 15a	Emission reduction	Legal	NOx, VOC	Implemented	
Austria	BGBl. 1983/292 idF 1994/133	Reduction of sulphur content in fuel oil and prohibit the use of other fuel oils	Legal	SO_2	Implemented	Regional authorities
Austria	Policies and measures to increase the use of renewable energy sources	Reduction of emissions through energy source change	Both legal measures and voluntary agreements	SO_2, NOx, VOC	Implemented	Several local and regional authorities
Austria	Combustion plant regulation BGBl. 1997/331	Emission reduction	Legal	SO_2, NOx, VOC	Implemented	Combustion plants
Denmark	Energy Action Plan	Energy supply and efficiency		SO_2, NOx	Adopted	Government
Denmark	Statutory Order No. 532	Limit sulphur content in fuels	Regulatory	SO_2	Implemented	Government
Denmark	Statutory Order No. 688	Limit sulphur content in fuels	Fiscal	SO_2	Implemented	Government
France	Arête of 25th July 1997 modified	Set emission limit values for small combustion installations (2-20 MW_{th})	Regulatory	SO_2, NOx, PM	Implemented	Government
France	Arête of 20th June 2002 modified	Set emission limit values for new installations with a thermal input between 20 and 50 MW_{th}	Regulatory	SO_2, NOx, PM, CO, NMVOC, PAH and HMs	Adopted	Government
France	Arête of 30th July 2003 modified	Set emission limit values for existing installations with a thermal input between 20 and 50 MW_{th}	Regulatory	SO_2, NOx, PM, CO, NMVOC, PAH and HMs	Planned	Government

France	Low NOx boilers for domestic and tertiary sectors	Develop market for low-NOx boilers in domestic / tertiary sectors by creating fiscal incentives. Second step could be compulsory use of low-NOx boilers.	1st phase: fiscal; 2nd phase: regulatory	NOx	Planned	Government
France	Statutory order 2 February 1998	Pollutant limit values related to air emissions, water consumption and waste	Regulatory	Several	Implemented	Government
France	EU directives on sulphur content of liquid fuels	Set sulphur content of liquid fuels	Regulatory	SO_2	Implemented	Government
France	Buildings Directive	Promote better energy efficiency in buildings	Regulatory, economic, fiscal	SO_2, NOx, VOC	Directive adopted, Transposition planned	Government
Germany	Ordinance on Small Firing Installations (1.BimSchV)	Limitations on pollutions from non licensed small combustion installations	Regulatory		In place	Government
Germany	Ordinance on Sulphur Content of Fuels (3.BimSchV)	Implementation of the Council Directive 1999/32/EC relating to a reduction in the sulphur content of certain liquid fuels	Regulatory		In place	Government
Germany	Ordinance on Installations Subject to Licensing (4.BimSchV)	Catalogue of installations that are subject to licensing	Regulatory		In place	Government
Germany	Ordinance on the Licensing Procedure (9.BimSchV)	Detail of the licensing procedure	Regulatory		In place	Government
Germany	Technical Instructions on Air Quality Control (1.BimSchVwv – TA Luft)	Regulations of emission and pollution limitations to be regarded by the public authorities in licensing procedures for those emission sources not covered by the ordinances mentioned above	Regulatory		In place	Government
Germany	Renewable Energy Sources Act (Erneuerbare Energien Gesetz - EEG)	Promotion of substitution of fossil fuels by renewable energy sources	Economic		In place	Government
Germany	Biomass Ordinance on Biomass Use for Energy Production (Biomasseverordnung - BiomasseV)	Promotion of biomass use for production of electricity and heat	Regulatory		In place	Government
Germany	Combined Heat and Power Act (Kraft-Wärme-Kopplungsgesetz)	Reduction of emissions from combustion of fossil fuels for electricity and heat production by increasing the share of most fuel efficient technologies such as CHP and fuel cell technology. Improvement of existing plants (CHP) and promotion	Economic		In place	Government

		for new plants (CHP as well as fuel cell technology).				
Germany	Energy Saving Act (Energieein-sparungsgesetz – EnEG)	Energy savings are required through building standards. This regulation issued as a climate change policy avoids additionally the emissions of pollutants due to fewer fuels that have to be fired for a certain energy service..	Regulatory		In place	Government
Germany	Energy Saving Ordinance (Energieeinsparver-ordnung - EnEV)	(See above)	Regulatory		In place	Government
Germany	National Climate Change Programme	Reduction of emissions of pollutions by a co-benefit from the governmental decision on the limitation of greenhouse gas emissions to achieve the EU burden-sharing target of 21% by the commitment period 2008 - 2012 compared to 1990			In place	Government
Italy	Directive 99/32/EC Sulphur content of fuels	Limits on sulphur emissions	Regulatory	SO_2	Implemented /adopted	Government
Italy	Decree 24/04/01 Requiring electricity and gas distributors to meet energy efficiency targets through end users	End user energy efficiency improvements	Regulatory	SO_2, NOx	Not given	Electricity and Gas Distributors
Italy	Draft law on reform and reorganisation of the energy sector	Increase electricity generation from renewable sources	Regulatory	SO_2, NOx	Planned	Government
Netherlands	Tighten the Heating Equipment (Type approval) Decree and increase the percentage of High-Efficiency combi-boilers.	Reduce emissions from households target group	Regulatory	NOx	Extra policy proposed/ planned	Government
Portugal	Programme P3E, Energy Efficiency in Buildings	Promotion of energy efficiency in buildings through the revision of thermal regulations and energy certification	Regulatory and information	Indirect effect on SO_2 & NOx	Implementation 2002 onwards	Government
Portugal	Directive 1999/32/EC transposed by the Decree-Law no. 281/2000	Ordinance on Sulphur Content of Fuels	Regulatory	SO_2	Implemented	Government
Portugal	Programme E4, Energy Efficiency and Endogenous Energy Resources (Resolution of the Council of Ministers 154/2001)	Programme for the promotion of energy efficiency and endogenous energy resources	Fiscal	Indirect effect on SO_2 & NOx	Implemented	Government
Portugal	Ordinance no. 383/2002	Revision of the financing scheme for	Fiscal	Indirect effect	Implemented	Government

		energy		on SO_2 & NOx		
Portugal	Programme solar Heated Water for Portugal	Promotion of the heating of water through solar energy	Fiscal	Indirect effect on SO_2 & NOx	Implementation 2001	Government
Portugal	Framework Directive on EcoDesign of end-use equipment	EcoDesign of equipment	Regulatory	SO_2, NOx, NMVOC	Proposed	Government
Spain	Royal Decree 287/2001 implementing EU Directive 99/32/CE	Reduce SO_2 emissions		SO_2	Expected in 2003	Government
Sweden	Energy tax	Environmentally related taxation	Taxation	CO_2, SOx, NOx	Existing	State
Sweden	Emission limits for small wood combustion installations (Boverkets byggregler)	Limits for new installations in densely populated areas	Legal	VOC (and PAH)	Existing	-
Sweden	Environmental laws (Miljöbalken 1998: 808)	Installations' energy use should be economical, renewable energy sources should be used	Legal	Several	Existing	State
Sweden	Local energy advisory work	Reduced energy use	Advisory work	Several	Existing, new resources as of 2003 (540 million SEK for the next five years)	Regional and local authorities
Sweden	Introduction of new energy efficient technology	Simulation of use of new technology	Financial support	Several	325 million SEK for 2005-2007	
Sweden	SCR- and SNCR for combustion installations and process ovens	Reduced emissions from combustion installations	New technology	NOx	Existing	
UK	Sulphur Content of Liquid Fuels Directive	Maximum sulphur limits from burning fuel oil	Regulatory	SO_2	Implemented	Government

Source: AEA Technology (2003)

Note that this excludes the following EU15 countries – Luxembourg, Belgium, Greece and Ireland.

APPENDIX 3 STAKEHOLDER CONSULTATION QUESTIONNAIRE

Questionnaire

This questionnaire outlines the key issues / questions that we would like to consult on as part of this study. 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 emissions from SCIs.

This questionnaire covers all key issues that we would like to cover. However, we do not necessarily expect that each consultee will complete this fully but will provide expertise in specific sections that are relevant.

A. Emission Inventory
1. Do you agree with the priority sectors, as highlighted in red, for historic and projected emission estimates? **YES –** The sectors highlighted are the most important in the priority order given as a % for 2000 and 2010. Please provide details: **NO** – There are sectors that are not highlighted that are also important. Please provide details: **NO** - There are sectors highlighted as important that are not. Please provide details:

2. For the priority sectors identified do you have (or know sources of) any information on the following that would help us develop a more robust assessment of emissions? Information may include:

- **Emission factors**
- **Fuel consumption**
- **Data on types of appliance-fuel use**
- **Knowledge of planned or existing changes in appliance (technology)-fuel use e.g. coal to gas; open fires to closed appliances**
- **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 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 emissions from SCIs (e.g. subsidies, legislation)?

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

NB. Measures and instruments may include one or more of the following elements:

Measure/Instruments	Example
Subsidies/charges	For the introduction of new boiler technologies. To encourage fuel switching or appliance replacement.
Local air quality standards	Strategies for air quality management zones which include provisions for small combustion installations
Emission standards	Setting emission levels or performance standards for new domestic boilers and/or fuels
Energy demand management	Insulation programmes, Energy conservation
Enforcement procedures of relevance	Inspection / maintenance
Other	

APPENDIX 4 TECHNOLOGY SPECIFIC EMISSION FACTORS AND COSTS

Overview of costs and emission factors for solid fuel appliances

Measure code	Description	Thermal capacity	Applicability (%)	Primary Fuel	Capital cost (€ 2004)		O&M costs (€ 2004)	Lifetime (yrs)
					Investment	Installation		
SF01a	Open fireplace	<25 kW	-	Range of solid fuels	500[5]			25
SF01b	Closed fireplace / conventional stoves	<25 kW	75	Range of solid fuels	750[5]			15
SF01c	Advanced closed stoves	<25kW	75	Range of solid fuels	1000[5]			
SF02a	Conventional single house boilers	<50 kW	-	Range of solid fuels	500-1000[6], 2400[5]			15
SF02b	Advanced under-fire boilers	<50 kW	95	Range of solid fuels	500-1000[6]			15
SF03a	Conventional boilers, manual-feed	50-1000kW	-	Predominantly coal	500-2000[6]			15
SF03b	Advanced under-fired boilers, manual-feed	50-1000kW	100	Predominantly coal	1000-2000[6]			15
SF03c	Advanced over-fire boilers, auto-feed	50-1000kW	95	Predominantly coal	1000-3000[6]			15
SF04a	Larger sized boilers, manual-feed	1 – 50 MW	-	Predominantly coal	100,000 per MW (estimate)			15
SF04b	Larger sized boilers, auto-feed	1 – 50 MW	95	Predominantly coal	100,000 per MW (estimate)			15

[5] UK supplier information
[6] CITEPA (2003b)

Overview of costs and emission factors for solid fuel appliances (continued)

Measure code	TSP		PM_{10}		$PM_{2.5}$		NO_X		NMVOCs		SO_2	
	EF	Reduction efficiency	EF	Reduction efficiency	EF	Reduction efficiency	EF	Reduction efficiency	EF	Reduction efficiency	EF	Reduction efficiency
SF01a	300[1]	-	270[1]	-	240[1] - 270[2]	-	100[1,2]	-	400[1]-600[4]	-	900[4]-1000[2]	-
SF01b (c.f.SF01a)	300[1] - 500[2]	-25%	270[1] - 450[2]	-25%	240[1] - 450[2]	-25%	100[1]	0%	400[1]-600[4]	0%	900[4]-1000[2]	0%
SF01c (c.f. SF01a)	-											
SF02a	300[2]	-	250[2]-260[4]	-	200[2]	-	200[2]	-	300[4]	-	900[4]-1000[2]	-
SF02b (c.f.SF02a)	230-290	13%					160-190[4]	13%	300[4]	0%	900[4]	0%
SF03a	200[2]	-	150[2]-170[4]	-	150[2]	-	200[2]	-	200[4]	-	900[4]-1000[2]	-
SF03b (c.f.SF03a)	120[4]	40%					150-170[4]	20%	80[4]	60%	400[4]	60% (Fuel-dependent)
SF03c (c.f.SF03a)	100[4]	50%					200[4]	0%	50[4]	75%	400[4]	60% (Fuel-dependent)
SF04a	70[2]	-	50[2]-60[4]	-	50[2]	-	180[2]	-	20[4]	-	900[4]-1000[2]	-
SF04b (c.f.SF04a)	70[2]	0%	50[2]-60[4]	0%			200	-11%	20	0%	900[4]-1000[2]	0%

[1] CITEPA (2003b)
[2] Sternhufvud (2004)
[3] IIASA (2002) – average emission factors based on wide range of literature sources – Eastern Europe
[4] UNECE (2004) (EMEP/CORINAIR 4th draft of small combustion source chapter) - average emission factors

Overview of costs and emission factors for biomass appliances

Measure code	**Description**	**Thermal capacity**	**Primary Fuel**	**Capital cost** (€ 2004)		**O&M costs** (€ 2004)	**Lifetime (yrs)**
				Investment	Installation		
W01a	Open fireplace	<25kW	Wood	NA	NA		25
W01b	Advanced closed fireplace	<25kW	Wood	2300[1]	1000[1]		15
W02a	Conventional stoves	<25kW	Wood	2300[1]	1000[1]		15
W02b	Modern low emission stoves – pellets	<25kW	Pellets	2250[5]	1000[1]		15
W02c	Modern low emission stoves - wood	<25kW	Wood	2300[1]	1000[1]		15
W03a	Conventional manual feed boiler	<50kW	Wood	4500[1]	750[1]		15
W03b	Modern low emission boilers - pellets	<50kW	Pellets	6900 - 7540[2]			15
W03c	Modern low emission boilers - wood	<50kW	Wood	4500[1]	750[1]		15
W04a	Conventional manual feed boiler	50-1000kW	Wood	75,000[7]			15
W04b	Modern manual feed boiler	50-1000kW	Wood	80,000 (estimate)			15
W04c	Modern auto-feed boiler	50-1000kW	Wood / Pellets	94,000[7]			15
W05a	Large boiler with abatement plant	1-50MW	Wood	350,000 per MW [7]			15
W05b	Large boiler with abatement plant	1-50MW	Biogas	350,000 per MW [7]			15

[1] CITEPA (2003a)
[2] Sternhufvud (2004)
[5] UK supplier information
[7] "Biomass heating", Future Energy Solutions UK publication 2002 – price estimates made for 250kW plant

Overview of costs and emission factors for biomass appliances (continued)

Measure code	TSP		PM_{10}		$PM_{2.5}$		NO_X		NMVOCs		SO_2	
	EF	Reduction efficiency	EF	Reduction efficiency	EF	Reduction efficiency	EF	Reduction efficiency	EF	Reduction efficiency	EF	Reduction efficiency
W01a	750[1]	-	700[4] - 713[1]	-	698[1] - 800[2]	-	50[1]	-	1700[1]	-	10[4]	-
W01b (c.f. W01a)	310[1]	59%	295[1]	58%	288[1]	61%	50[1]	0%	300[4]	82%	10[4]	0%
W02a	310[1] - 400[4]	-	295[1] - 350[4]	-	100[2] - 288[1] / 350[4]	-	50[1]	-	1200[4]-1600[1]	-	10[4]	-
W02b (c.f. W02a)	4-65[4]	85%	50[4]	85%	30 (est.)	85%	70-195[4], 50[1]	- 100%	7-252[4]	83%	6[4]	40%
W02c (c.f. W02a)	30[2]	91%	30[2]	91%	20[2]	91%	50[1]	0%	400[4]	66%	10[4]	0%
W03a	250[1]	-	220[4]-238[1]	-	233[1] - 700[2]	-	50[1]	-	400[1]	-	50[4]	-
W03b (c.f. W03a)	32-43[8]	84%	32-43[8]	85%	30[2]	87%	40[8]-50[1]	0-20%	40[8]	90%		
W03c	20[1]-40[4]	88%	19[1]-40[4]	86%	19[1] - 80[2]	87%	50[1]-150[4]	-200%	80[1]	80%		
W04a	180[4]	-	180[4]	-			150[4]	-	250[4]	-	50[4]	-
W04b (c.f. W04a)												
W04c (c.f. W04a)	32-43[8]	81%	32-43[8]	81%			27-37[8]	77%	0-17[8]	94%		
W05a	2	-	2	-			69	-	4	-	2	-
W05b	0.5	-	0.5	-			540	-	14	-	19	-

[1] CITEPA (2003a)
[2] Sternhufvud (2004)
[3] IIASA (2002) – average emission factors based on wide range of literature sources – Eastern Europe
[4] UNECE (2004) (EMEP/CORINAIR 4th draft of small combustion source chapter) - average emission factors
[7] "Biomass heating", Future Energy Solutions UK publication 2002 – price estimates made for 250kW plant
[8] Bostrom C-A, UNECE TFEIP (2002)
[9] Danish NERI EFs for decentralised CHP units

Overview of costs and emission factors for gas-based appliances

Measure code	Description	Thermal capacity	Applicability (%)	Primary Fuel	Capital cost (€ 2004)		O&M costs (€ 2004)	Lifetime (yrs)
					Investment	Installation		
G 01a	Gas fireplace	<25kW	-	N Gas	450[5]			25
G 02a	Gas stove	<25kW	-	N Gas	750[5]			25
G 02b	Gas stove with back boiler	<25kW	15	N Gas	1650[5]			25
G 03a	Single house boiler, non-condensing	<50kW	-	N Gas	750[5]			15
G 03b	Single house boiler, condensing	<50kW	100	N Gas	1125[5]			15
G 04a	Non-condensing boiler	50-1000kW	-	N Gas				15
G 04b	Condensing boiler	50-1000kW	100	N Gas				15
G 04c	Medium boiler with low-NO_X burners	50-1000kW	50	N Gas				15
G 05a	Large gas boiler	1-50MW	-	N Gas				15
G 05b	Large gas boiler with NO_X abatement	1-50MW	95	N Gas				15

[5] UK supplier information

Overview of costs and emission factors for gas-based appliances (continued)

Measure code	TSP		PM_{10}		$PM_{2.5}$		NO_X		NMVOCs		SO_2	
	EF	Reduction efficiency	EF	Reduction efficiency	EF	Reduction efficiency	EF	Reduction efficiency	EF	Reduction efficiency	EF	Reduction efficiency
G 01a	0.5[4]	-	0.5[4]	-		-	50[4]	-	20[4]	-	0.5[4]	-
G 02a	0.5[4]	-	0.5[4]	-		-	50[4]	-	10[4]	-	0.5[4]	-
G 02b	-	10%	-	10%		10%	-	10%	-	10%	-	10%
G 03a	0.5[4]	-	0.5[4]	-		-	70[4]	-	10[4]	-	0.5[4]	-
G 03b	-	10%	-	10%	-	10%	-	10%	-	10%	-	10%
G 04a	Neg.	-	Neg.	-	Neg.	-	70[4]	-	3[4]	-	0.5[4]	-
G 04b (c.f. G 04a)	-	10%	-	10%	-	10%	-	10%	-	10%	-	10%
G 04c (c.f. G 04a)	-	-	-	-	-	-	30[5]	57%	-	-	-	-
G 05a	Neg.	-	Neg.	-	Neg.	-	70[4]	-	2[4]	-	0.5[4]	-
G 05b	-	-	-	-	-	-	50[5]	29%	-	-	-	-

[4] UNECE (2004) (EMEP/CORINAIR 4th draft of small combustion source chapter) - average emission factors
[5] UK supplier information

Overview of costs and emission factors for oil-based appliances

Measure code	Description	Thermal capacity	Sector applicability	Primary Fuel	Capital cost (€ 2004)		O&M costs (€ 2004)	Lifetime (yrs)
					Investment	Installation		
LF01a	Closed stove	<25kW	Residential / Agric.	Burning Oil	750[5]			15
LF01b	Closed stove, low-S oil	<25kW	Residential / Agric.	Low-S Burning Oil	750[5]			15
LF02a	Single house boiler, non-condensing	<50kW	Residential / Agric.	Burning Oil	1200[5]			15
LF02b	Single house boiler, condensing	<50kW	Residential / Agric.	Burning Oil	1800[5]			15
LF03a	Medium boiler, non-condensing	50-1000kW	All (except industrial)	Burning Oil				15
LF03b	Medium boiler, condensing	50-1000kW	All (except industrial)	Burning Oil				15
LF04a	Large boiler with abatement	1-50MW	Commercial-institutional / Industrial	Gas Oil				

[5] UK supplier information

Overview of costs and emission factors for oil-based appliances (continued)

Measure code	TSP		PM_{10}		$PM_{2.5}$		NO_X		NMVOCs		SO_2	
	EF	Reduction efficiency	EF	Reduction efficiency	EF	Reduction efficiency	EF	Reduction efficiency	EF	Reduction efficiency	EF	Reduction efficiency
LF01a	10[4]	-	10[4]	-			50[4]	-	20[4]	-	100[4]	-
LF01b (c.f. LF01a)	10[4]	0%	10[4]	0%			50[4]	0%	20[4]	0%	50[4]	50%
LF02a	1[4]	-	1[4]	-			70[4]	-	15[4]	-	140[4]	-
LF02b	-	7%	-	7%	-	7%	-	7%	-	7%	-	7%
LF03a	1[4]	-	1[4]	-			100[4]	-	15[4]	-	140[4]	-
LF03b	-	7%	-	7%	-	7%	-	7%	-	7%	-	7%
LF04a	1[4]	-	1[4]	-			100[4]	-	5[4]	-	140[4]	-

[4] UNECE (2004) (EMEP/CORINAIR 4th draft of small combustion source chapter) - average emission factors