INFORMATION EXCHANGE ON REDUCTION OF DIOXIN EMISSIONS FROM DOMESTIC SOURCES

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Abbreviations

ADEME	Agence de l'Environnement et de la Maîtrise de l'Energie (France)
AMAP	Arctic Monitoring and Assessment Programme
AR	Activity Rate
AT	Austria
ARPALombardia	Lombardy Environmental Protection Agency
BAFA	Bundesamt für Wirtschaft und Ausfuhrkontrolle
BAT	Best Available Technology
BE	Belgium (FL Flanders, WA Walloon, BCR Brussels Capital Region)
BG	Bulgaria
BImSchV	Bundes-Immissionsschutzverordnung (Federal Emission Control Act) (Germany)
CASES	Cost Assessment for Sustainable Energy Systems
CCA	Chromate Copper Arsenate
C&D	Construction and Demolition
CDR	(EIONET) Central Data Repository
CHMI	Czech Hydro meteorological Institute
CITEPA	Interprofessional Technical Centre for Studies on Atmospheric Pollution
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CORINAIR	CORe INventory of AIR emissions
CHP	Combined heat and power plants
CRF	Common Reporting Format
CSTB	Centre Scientifique et Technique du Bâtiment
CH	Switzerland
CY	Cyprus
CZ	Czech Republic
DE	Germany
DK	Denmark
DG	Directorate-General
DG Tren	Directorate-General Energy and Transport
DIN	Deutsches Institut für Normung e. V.
dioxin	PCDD/PCDF and dioxin-like PCB (dl-PCB)
dl-PCB	Dioxin-like Polychlorinated Biphenyl
ECCP	European Climate Change Programme
EE	Estonia
EEA	European Environment Agency

EF	Emission Factor
EFA	European Fireplaces Association
EFTA	European Free Trade Association
EIONET CDR	European Environment Information and Observation Network Central Data Repository
ELV	Emission Limit Value
EMEP	European Monitoring and Evaluation Programme
EMPA	Eidgenössische Materialprüfungs- und Forschungs-Anstalt (Switzerland)
ENEA	Agency for New technology, Energy and the Environment
EPA	Environmental Protection Agency
EPBD	Energy Performance in Buildings
E-PRTR	European Pollutant Release and Transfer Register
ETS	Emission Trading Scheme
EuP	Energy using Products
ExternE	Externalities of Energy (EC Research Project Series)
FI	Finland
FR	France
FNR	Fachagentur für Nachwachsende Rohstoffe
GHG	Greenhouse Gas
GHS	Greener Homes Scheme (Ireland)
GJ	Gigajoule
GR	Greece
HDV	Heavy-Duty Vehicle
HELCOM	Helsinki Commission
HETAS	Heating Equipment Testing and Approval Scheme (UK)
HU	Hungary
IARC	International Agency for Research on Cancer
IE	Ireland
IEE	Intelligent Energy Europe
INERIS	Institut National de l'environnement industriel et des risques
IPCC	Intergovernmental Panel on Climate Change
IPCS	International Programme on Chemical Safety
IT	Italy
I-TEQ	International Toxicity Equivalent Quotient
ITGiS	Institute of Heating and Sanitary Technology, Łodz (Poland)
JRC	European Joint Research Centre
kg	Kilogram
kt	Kiloton
kW	Kilowatt

kW_{th}	Kilowatt Thermal
LCME	Liaison Committee on Medical Education
LDV	Light-Duty Vehicle
LPG	Liquefied Petroleum Gas
LRTAP	Long-Range Transboundary Air Pollution
LT	Lithuania
LU	Luxembourg
LV	Latvia
mg	Milligram
MJ	Megajoule
MS	Member State/States
MSW	Municipal Solid Waste
MT	Malta
MW	Megawatt
MW_{th}	Megawatt Thermal
NA	Not Applicable
ND, n.d.	Not Displayed
NEEAP	National Energy Efficiency Action Plan
NEEDS	New Energy Externalities Development for Sustainability
NFR	Nomenclature for Reporting
ng	Nanogram
NH_3	Ammonia
NIP	National Implementation Plan
NIR	National Inventory Report
NL	The Netherlands
Nm^3	Standard Cubic Metre
NMVOC	Non-Methane Volatile Organic Compounds
NO_x	Nitrous oxides (total concentration of NO and NO_2)
OECD	Organisation for Economic Co-operation and Development
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic
PAH	Polycyclic Aromatic Hydrocarbons
PAH-4	Four-Ring Polycyclic Aromatic Hydrocarbons
PARCOM	Convention for the Protection of the Marine Environment of the North-East Atlantic (originally: Paris Convention 1974)
PCB	Polychlorinated Biphenyl
PCDD	Polychlorinated Dibenzodioxin
PCDF	Polychlorinated Dibenzofuran
PCP	Pentachlorophenol

PJ	Petajoule
PL	Poland
PM	Particulate Matter
$PM_{2.5}$	Particulate Matter less than 2.5 micrometers in aerodynamic diameter
PM_{10}	Particulate Matter less than 10 micrometers in aerodynamic diameter
POP	Persistent Organic Pollutant
ppm	Parts Per Million (10^{-6})
PRTR	Pollutant Release and Transfer Register
PT	Portugal
PVC	Polyvinyl Chloride
R&D	Research and Development
SCI	Small Combustion Installations
SE	Sweden
SET	Strategic Energy Technology
SI	Slovenia
SK	Slovak Republic
7th FWP	Seventh Framework Programme
SNAP	Selected Nomenclature for Air Pollution
SO_2	Sulphur Dioxide
SSF	Solid Smokeless Fuel
t	Tonne (metric ton)
TEQ	Toxicity Equivalent Quotient
TFEIP	(UNECE) Task Force on Emission Inventories and Projections
TJ	Terajoule
TOC	Total Organic Carbon
UK	The united Kingdom
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
US-EPA	United States Environmental Protection Agency
VAT	Value Added Tax
VOC	Volatile Organic Compound
WFOSiGW	Regional Fund for Environmental Protection and Water Management (Poland)
WHO	World Health Organization
WHO-TEQ	World Health Organization Toxic Equivalent Quotient
µg	Microgram

1 Summary

This project is designed to compile the current state of knowledge on dioxin[1] releases from domestic sources. Furthermore, the results highlight the state of current reporting on domestic sources in MS emission inventories under the Regulation (EC) No 850/2004 of the European Parliament and of the Council on persistent organic pollutants & amending Directive 79/117/EEC, the so-called EU POP Regulation. Additionally, the state of measures and approaches for emission reduction in this field as taken by EU Member States is specified.

This information is intended to be used for information exchange and knowledge transfer between Member State authorities in accordance with the Dioxin Strategy.

Outcome from literature search on dioxin emissions from domestic sources

90 literature sources have been identified in a worldwide search for primary measurement data and emission factors (EFs) for domestic heating and cooking appliances, charcoal grills, open burning of waste, candle burning and mobile domestic sources. Investigations included air emissions and releases into residues and focused on appliances <50 kW. There are not many recent primary measurement studies which could be identified besides the ones already included into the UNEP Toolkit and the UNECE Guidebook. Means from studies identified largely confirm the EFs presented in the UNEP Toolkit.

There is little specific information on formation mechanisms and influencing factors for dioxin formation in domestic sources. As for industrial sources, organic compounds, chlorine and metals in the fuel foster dioxin formation, whereas sulphur is an inhibiting factor. Combustion conditions have a major influence. In this context good combustion quality (correct oxygen supply, stable temperature and dry wood) are regarded as factors reducing the emissions. Nevertheless, it is agreed that results are controversial and processes are not fully understood. Surrogate markers for combustion quality (CO, PM, PAH) seem not to be feasible indictors for dioxin emissions. Clear correlations cannot be observed. Post-combustion processes strongly influence study results. Especially condensation processes and memory effects have to be taken into account.

There are very few primary studies specifically investigating releases pathways from domestic sources, but it can be noted that in domestic sources, air (exhaust gas) and ashes/soot are the relevant release pathways for domestic combustion sources.

Current scientific knowledge on PCDD/PCDF emission factors

30 scientific studies provided information on PCDD/PCDF emissions mainly for coal and wood combustion. EFs for the release of dioxins into air for coal fuels in general range from 6 to 455 µg TEQ/TJ, which corresponds to a multiplier of almost 100. Medians[2] or arithmetic means[3] of the studies vary less but still range from 20 to almost 400 µg TEQ/TJ, what

[1] In the meaning of PCDD, PCDF and dl-PCB

[2] In a series of measurement the median is the measurement result which value is in the middle of the data set (i.e. from 11 single measures the median is the 6th highest/lowest value).

[o] The arithmetic means from a series of measurements is the sum of all results divided by the numbers of measures

corresponds to a multiplier of 20. The reasons for this variability of EFs are different technical standards or operation of heating facilities, fuel qualities or study design. Inclusion of results from certain types of Polish coal or of other maximum values raises the range of measurement results to a factor to >500. At the level of means and medians the variability in this case is up to 400. EFs for wood fuels and other biomass in general range from 2 to 850 µg TEQ/TJ. The range of means and medians in most of the studies however, is 30-130 µg TEQ/TJ. Higher results (up to several thousand µg TEQ/TJ are generally observed in field studies and attributed to bad combustion conditions, bad maintenance or co-combustion of waste or contaminated wood. EFs for herbaceous fuel are highly limited. Values are in the dimension of 500-950 µg TEQ/TJ (recalculated from 7.2 – 13 µg TEQ/t) which is higher than those for wood. This situation is reflected by the fact that recently a proposal was made to introduce a specific EF for other biomass (450 µg TEQ/TJ) into the UNEP Toolkit.

Measurement data for gas and oil combustion are scarce. EFs range from 0.5 to 20 µg TEQ/TJ, with a median for oil of 2.5 µg TEQ/TJ and a median for gas of 1.9 µg TEQ/TJ. The difference in EFs attributed to gas and oil in the international estimation tools cannot be fully confirmed by the measurement data, which may be a result of the low number of analyses. The range of EFs for open burning of coal, garden waste and other waste is huge. EFs range from about 200 µg TEQ/TJ (8-500 µg TEQ/t) for coal, to roughly 300- 2,000 µg TEQ/TJ (4 - 30 µg TEQ/t) for green waste, straw and other biomass (depending on combustion conditions). For open burning of MSW EFs of 97 to 6,700 µg TEQ/TJ (3.5 – 240 µg TEQ/t) were observed. Far higher values of several thousand µg TEQ/t can be reached if waste is mixed with PVC or electronic scrap and in case of accidental fires. Poor information is available for EFs from charcoal combustion in barbecues and PCP treated wood. In the single investigation of PCDD/PCDF emissions from candle burning EFs were very low (0.004 – 0.05 µg TEQ/t) so that emissions appear to be negligible.

Data for releases into residues and data for dl-PCB are limited. Values are available for coal, wood and biomass combustion and for open burning of waste. Data for releases into residues suggest a low relative importance of this “compartment” in the residential sector, with a share of 10% of the corresponding air emissions. A comparison of the relative contribution of dl-PCB to the overall TEQ releases is hampered by a lack of data for dl-PCB. A minor contribution (10%) of dl-PCB to air emissions from coal and wood in comparison to PCDD/PCDF is suggested in the two studies doing simultaneous measurements.

Results of data collection from MS

In total 23 Member States provided information on emission estimation for dioxin releases from domestic sources. PCDD/PCDF emissions into air are generally included, whereas dl-PCB and releases into water and waste are currently not covered. Reporting mobile domestic sources and on open burning of waste is scarce. Lack of reliable data is the reason for other MS not to do estimates. The majority of MS currently reports with summary figures under SNAP 0202 or IPCC 1A4b (“residential”) without further differentiation into emissions from different appliances. This level of detail does not allow drawing conclusions on major sources and appropriate measures for emission reduction from domestic sources.

Current application of EFs in reporting on PCDD/PCDF emissions from domestic sources

UNECE Guidebook and UNEP Toolkit are the major estimation tools available for dioxins. The majority of MS uses the EMEP-CORINAIR methodology. The UNECE Guidebook and UNEP Toolkit provide sets of EFs to be used for domestic emission estimates. Whereas the UNEP Toolkit only differentiates by fuel, the UNECE Guidebook provides specific EFs for different types of domestic appliances. In addition, the POP Protocol presents some EFs. But many MS completely or partly use individual EFs derived from national measurements or an evaluation of scientific literature. This practice is especially common for solid fuels (wood & coal). As EMEP-CORINAIR currently does not foresee reporting on releases into waste, there is almost no MS reporting in these fields. The EFs chosen for reporting of emissions vary to a large extent without appropriate justification in some cases. More information exchange on applied EFs would be thus highly recommendable to increase comparability of results. EFs would need to be elaborated further on an international scale (UNECE and/or UNEP). In addition efforts might need to be strengthened to establish reporting on releases into waste.

MS reporting on mobile domestic sources is highly incomplete. So far only DE reported on specific emission estimates for mobile domestic sources using the UNEP Toolkit factor for two-stroke engines. In addition only 3 MS summarise emissions under SNAP 0809 “other mobile sources and machinery” using Toolkit EFs for diesel and gasoline.

With only 6 MS reporting, information on open burning of waste is also extremely incomplete. Applied EFs are derived from the UNEP Toolkit recommendations. The major problem in this sector is the generation of reliable activity rates. More training and information exchange on this issue might hence be helpful.

Generation and application of activity data

Activity data are the result of fuel consumption and composition of the appliance pool. In general calculation is performed by means of National Energy Statistics and/or statistics from energy providers (fuel consumption). Appliance pools are partly determined by means of Census information related to dwelling and housing types and annual sales figures for specific appliances. However, currently there remain important deficits in generation of AR, namely concerning specification of the appliance stock, wood consumption, fuel consumption for mobile sources and open burning of waste or other types of fires. As a number of examples for good practice for generation of AR exist, an intensified information exchange on available methodologies and inclusion of specific guidance in the guidebook would be desirable to improve the reporting.

Reported shares of fuels in the domestic sector show a wide range between EU Member States. Apart from a group of MS with predominant use of liquid and gaseous fuels, there is a group of MS where solid fuels dominate in the domestic sector. In addition per capita fuel consumption and PCDD/PCDF emission also vary over a wide range. Due to the high importance of the fuel shares on PCDD/PCDF releases, this is an important factor for the selection of appropriate reduction measures.

Major deficits and obstacles for emission estimation

Due to a lack of measurement data available EFs suffer from high uncertainty. In addition deficits in activity rates (e.g. differentiation of appliances, domestic fuel consumption, data for waste burning) are the major obstacles reported by MS. Deficits in AR especially concern types of appliances and wood consumption. The large range of EFs applied by MS, poor differentiation in reporting, deficits in reporting on mobile sources and open burning of waste, lack of reporting for dl-PCB and lack of information on EFs or AR applied, are other important deficits observed, which need to be overcome.

Member State measures to dioxin emissions from domestic sources

In total, 18 Member States have taken emission reduction measures in the domestic sector. Legal measures (ban of waste burning, emission limits for GHG and PM, mandatory energy efficiency standards) are the predominant approach taken by MS to address dioxin emissions from domestic sources. Awareness raising is the second major approach taken. Labelling schemes and subsidy programmes are partly used to support energy efficiency and renewable energy targets. R&D measures are scarce. Information on efficiency of measures is poor.

A dioxin specific approach is the ban of certain fuels for use in domestic heating appliances, as reported from 7 MS. An unspecific approach is the setting of limit values for GHG or PM and the mandatory energy efficiency standards. Mandatory inspections can be an additional tool to promote good enforcement of the legislation but generally only relate to energy efficiency. Bans for domestic combustion or open burning of waste are established in 16 MS with certain exemptions for combustion of garden waste. Major focus of awareness raising measures, which are established in 11 MS, is the prevention of waste combustion, proper operation of heating appliances and energy saving measures. Only 2 MS have started R&D activities to develop abatement technologies in the residential sector. Other 4 MS put a focus on determination and verification of EFs, which is not a reduction measure but a measure to improve emission estimates. Eco-labelling schemes for solid fuel fired domestic appliances are established or planned in 10 MS. The focus is on energy efficiency, low CO and dust (PM) emissions. Effects on dioxin are only indirect (reduced fuel consumption). Subsidy schemes for domestic heating appliances mostly focus on eco-labelled wood fired appliances. Another focus is on low emission and high efficiency boilers and alternative renewable energies.

Major deficits and obstacles for emission reduction

Member States experience important general problems and difficulties in addressing domestic emissions of dioxin. Lack of binding limits and obligations, enforcement difficulties due to scattered structure and sophisticated and expensive monitoring and political aspects (financial burdens to citizens, competing policy requirements, low priority) are the most important obstacles encountered. In addition, it has to be noted that current measures are mostly not driven by dioxin but by climate change aspects requesting increased energy efficiency and use of renewable energies. In general the importance of dioxin emissions is regarded as low in comparison to PM, PAH or climate gases. Deficits in information and level of activities between MS vary to a large extent. Limited information is available in MS as concerns dioxin related effectiveness of reduction measures taken. In principle, emission inventories could serve as a basic information source for changes in dioxin emissions. However, this requires more detailed information in the case that emission inventories in different reporting periods are based on revised EFs or on differing methods to determine ARs. A decrease of emissions from the domestic sector was observed in UK, FR and RO. No corresponding information has been reported from other MS. Data for efficiency of subsidy programmes are available (AT, DE) but are not related to dioxin.

Selection of good practice for emission reduction

The selection of good practice for emission reduction is based on a number of selection criteria taking into account the objectives of the Dioxin Strategy (minimisation of releases) but also feasibility aspects such as restrictions from competing policies and costs. Consequently, the following parameters have been evaluated for the reported types of measures.

1. Reduction of PCDD/PCDF emissions in relation to status quo *(→overall emission reduction potential)*
2. Consistency with related or competing policy requirements (→*politically achievable* reduction potential)
3. Related costs (→*practically achievable* reduction potential)

In this context reported measures, comprising policy approaches such as legal standards, awareness raising, labelling, subsidy schemes or R&D measures have been allocated to the categories:

1. Change of fuel
2. Energy efficiency measures (change of appliance, insulation, inclusion of smallest appliances, monitoring and control)
3. Promotion of renewable energy
4. Abatement technologies

In addition, district heating is investigated as additional type of potential reduction measure

The reduction potential of measures is quantified via the differences in the corresponding EFs and energy efficiency of different types of appliances. For comparison, the EFs and the information on energy efficiency provided in the UNECE Guidebook have been used as far

as possible, as they allow comparing different types of appliances in addition to different fuels.

Competing policy areas to be taken into account in the domestic sector are climate change and energy efficiency legislation, as well as air quality laws. Costs arise from installation and operation of appliances, information and control.

Results from calculation of reduction potential

Based on currently recommended EFs and a net heat consumption of 20 GJ/a per household, the reduction potential of various measures taken in the domestic sector is the following:

Exchange of fuels: The reduction potential of an exchange of solid by gaseous fuels is high compared to all other current approaches. The absolute reduction for a standard setting is 0.7 to >44 µg PCDD/PCDF TEQ/a or 94-99.9%. In comparison to liquid fuels, the reduction is still a factor of five. But also an exchange of solid by liquid fuels constitutes an effective measure. The absolute reduction is 0.4 – 44 µg PCDD/PCDF TEQ/a or 63 - 99% depending on the technical standard of the solid fuel fired appliance replaced.

Elimination of waste burning is an important primary measure in the field of solid fuel fired appliances. If compared in terms of a worst case scenario (exclusive heating of a standard dwelling with MSW or contaminated waste versus virgin wood) the annual reduction potential is 62 µg PCDD/PCDF TEQ/a compared to contaminated wood and 1.5 mg PCDD/PCDF TEQ/a compared to MSW. The importance of illegal waste combustion may be underestimated. Investigations in CH and DK showed that a share of abuse up to one third is typical for rural regions and in urban regions still approaches 10 %.

Exchange of appliances: Energy efficiency measures in terms of replacing standard appliances by modern versions are associated with an important reduction potential due to lower EFs and increased energy efficiency. The maximum emission reduction in comparison with standard stoves is 35 to 43 µg PCDD/PCDF TEQ/a and thus almost in the same dimension as reached with oil and gas. Energy efficiency measures in the field of liquid and gaseous fuel fired appliances provide limited emission reduction due to the low EFs.

Insulation and regulation of dwellings can reduce the annual emissions by more than 50% of the prior level independently from the heating source and thus has to be regarded as a highly important measure for emission reduction than can be combined with other measures.

Inclusions of smallest appliances into the control and limit schemes have a reduction potential in terms of increased energy efficiency due to the fact that currently >95% of the solid fuel fired appliances in the domestic sector are smaller than 15 kW.

Awareness raising, labelling, subsidies and control: Legal obligations are not easy to enforce in the domestic sector. In this context awareness raising and education on potential health and environmental effects as well as monitoring and control is a necessary supportive measure in implementing and enforcing the reduction potential of energy efficiency and combustion quality measures.

This is well illustrated by the example of CH where an important reduction of illegal waste combustion has been realised within about five years in the absence of any monetary sanctions or penalties in that phase. This result is remarkable, because it shows that the effect of being aware of the existence of inspection and control alone, even without further sanctions, has already led to an awareness of the problem and a change in behaviour.

Renewable energy programmes: The replacement of solid fuel fired appliances by biomass appliances entrains a significant emission reduction; whereas replacement of oil and gas fired appliances result in increased dioxin emissions. Thermal solar installations can considerably reduce the energy need of a dwelling. A combination with improved insulation is recommendable to further increase the effect. Geothermal energy supply can be a good option in appropriate regions namely if used as district heat, but associated risks should be further evaluated.

District heat: With respect to its net reduction potential district heating entails important emission reduction in relation to simple solid fuel fired domestic devices and can be more or less equivalent to modern automated appliances. District heating by means of large scale combined heat and power plants (CHPs), is hampered by transport losses, limited thermal efficiency and inflexibility. Small scale decentralised plants and modernisation (lowered EF, reduced losses) can reduce or eliminate this negative effect. From an overall point of view, CHP generated district heating is generally advantageous compared to locally installed heating systems, due to the possibility to recover waste heat.

Secondary reduction measures: The potential of flue gas treatment measures in the domestic sector is hard to assess due to the lack of measurement data. However as a first indication it might be important to note, that very recent preliminary measurement data suggest no effect on dioxin emissions.

Proposals and recommendations for improved emission estimates and emission reduction

Based on the identified deficits and the related difficulties in establishing emission inventories, the following actions are summarily proposed to improve emission estimates:

- Enhanced information exchange between MS authorities involved
- Continued work on ARs for solid fuels and MSW
- Further work on EFs for PCB, other biomass and unreported sources (e.g. charcoal)

Based on the identified deficits with respect to dioxin related reduction measures from domestic sources, the project team would suggest to:

- Continue efforts for elimination of waste burning (domestic and back-yard) by means of bans, waste management and awareness raising/education (including strengthened control)
- Establish and disseminate guidance on good heating practice and awareness raising at local level and in the population including information on associated risks (including strengthened monitoring and control)

- Further promote and investigate in low emission heating approaches (eventually including detailed cost-benefit analyses and weighing of contrary policy aspects)

Combined approaches can be regarded as best practice in the field. The selection of priority measures depends on the specific characteristics of the Member State and may involve the:

1. Elimination of waste burning
2. Promotion of good operation practice for solid fuels
3. Increased use of low emission solid fuels (e.g. SSF or low chlorine coal)
4. Insulation and improved temperature regulation
5. Extension of gas/oil heating and district heating in urban areas
6. Promotion of energy efficient solid fuel fired appliances in rural areas
7. Promotion of solar thermal panels as supportive energy source

2 Background, Objectives and Project tasks

2.1 Background

The Community Strategy for Dioxins, Furans and Polychlorinated Biphenyls (COM (2001)593)[4] (later referred to as Dioxin Strategy) and Regulation (EC) No 850/2004 (hereinafter called POP Regulation) form the major background to this study.

The Dioxin Strategy covers polychlorinated dibenzodioxins (PCDDs) and dibenzofurans (PCDFs) (together commonly referred to as dioxins) and polychlorinated biphenyl's (PCB). Among PCB special attention is given to the small group of so called dioxin-like (dl) PCB due to their toxicity, which is similar to the one of dioxins. According to the Strategy Document increasing importance of non-industrial sources has been observed during the last years with respect to dioxin emissions in relation to industrial sources as a consequence of regulatory measures taken in the field of industry. This finding has been confirmed by a number of recent studies. In addition a number of National Implementation Plans stress investigation into measures for dioxin emission reduction from domestic sources as a priority action.

The POP Regulation is the European legislation adopted to ensure a coherent and effective implementation of the Stockholm Convention and the POP Protocol under the Convention on Long-Range Transboundary Air Pollution (LRTAP) within the European Union. It is the common aim of these legal documents to continuously reduce and eliminate where possible the production, use and releases of persistent organic pollutants including unintentionally released POPs. In this context the POP Protocol (Annex II) lists "residential combustion" as major stationary sources for PCCD/PCDF emissions and also the Stockholm Convention (Annex C) lists "residential combustion" as a source which may form dioxins.

Reporting on dioxin emissions is regulated in the legal framework as well. Pursuant to the POP Regulation Member States (MS) are obliged to establish inventories of releases into air, water and land for unintentionally produced POPs including dioxins until June 2006 in "accordance with their obligations under the Stockholm Convention and the POP Protocol". The POP Protocol requires as a minimum the methodologies and temporal and spatial resolution specified by the Steering Body of EMEP (The Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe). In addition the new European Pollutant Release and Transfer Register (E-PRTR) requires reporting on emissions from numerous sources and for various substances including diffuse sources (e.g. domestic) and POPs. Thus an important legal framework for reporting on POP emissions from domestic sources has been set up in the last years.

However, it has to be taken into consideration that the importance of diffuse sources is difficult to estimate due to lack of data. So far compiled information on how domestic sources are estimated in different EU Member States is not available.

[4] http://ec.europa.eu/environment/dioxin/index.htm

2.2 Objectives

Based on this background it is the objective of the Commission to compile:

- the current state of knowledge on emissions of dioxins and all related processes (formation mechanisms, enhancing factors, etc)
- to highlight and investigate the state of current reporting on domestic sources in MS emission inventories under the EU POP Regulation
- to specify the state of measures and approaches for emission reduction in this field taken by EU Member States

Related to the above-mentioned targets this study is focused on domestic sources in order to support the Commission in this field.

This information shall be used for information exchange and knowledge transfer between Member State authorities in accordance with the Dioxin Strategy, which states that exchange of information and experience between MS as concerns education, training and awareness raising is an important action to be taken by the European Commission.

Pursuant to the objectives and the focus of attention of the Dioxin Strategy, investigations in the study will focus on PCDD/PCDF and dioxin-like PCB (dl-PCB). .

2.3 Project tasks

To achieve these objectives the following major tasks have been fulfilled:

1. Overview of current knowledge on dioxin emissions
2. Data collection on current state of emission calculation and reduction measures
3. Assessment of the data collected
4. Expert Workshop
5. Recommendations
6. Information brochure for dissemination of information

The compilation of current knowledge on dioxin emissions (1) covers different types of domestic sources and includes a review of sources for information on emission factors by means of literature search. The compilation of information on methods to calculate emissions from domestic sources and on approaches taken by MS for emission reduction in this field (2), was performed by means of a questionnaire and expert interviews. The evaluation of collected information (3) included identification of deficits and selection of examples for good practice. The expert workshop (4) served to present and discuss results and to work as further source for information collection, information exchange and awareness raising.

Recommendations (5) comprise proposals how to fill data gaps and how to address problems related to emission reduction from domestic sources. The information (6) brochure summarises the results and provides material for national, regional and local authorities and other stakeholders or decision makers for information exchange and as source for inspiration.

The correlation of the different tasks within the project is illustrated in Figure 2-1.

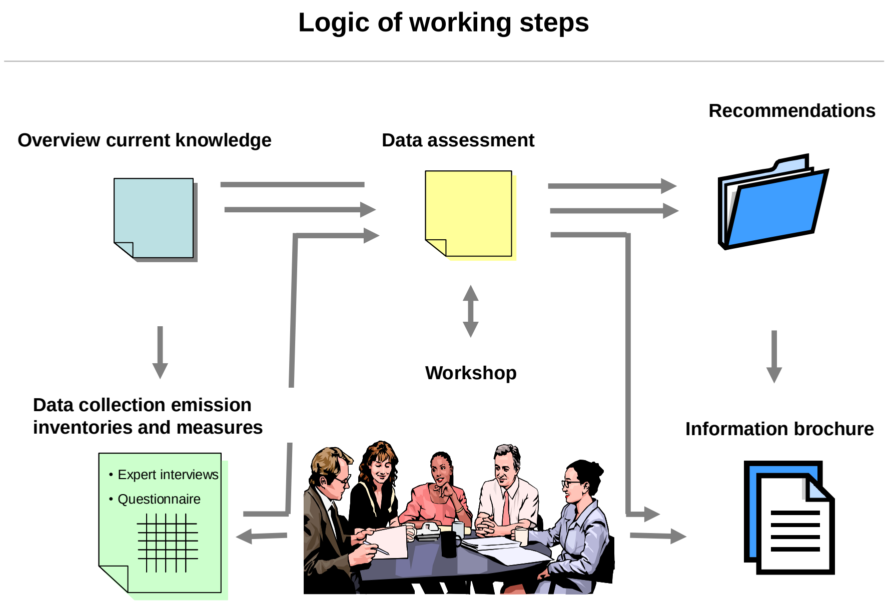


Figure 2-1: Correlation of working steps and tasks within the project running time

In accordance with the agreed time schedule and milestones, this report contains results from information collection, data assessment and workshop, as well as a selection of examples of good practice and proposals for action to improve emission estimates and emission reduction.

3 Current knowledge on Dioxin Emissions from Domestic Sources

Key message: 90 literature sources have been identified in a worldwide search for primary measurement data and EFs for domestic heating and cooking appliances, charcoal grills, open burning of waste, candle burning and mobile domestic sources. Investigations included air emissions and releases into residues and focused on appliances <50 kW.

This chapter presents the results from literature searches on dioxin releases from domestic sources. In this context “dioxins,” in accordance with the technical project description and the objectives of the Dioxin Strategy, shall be understood as PCDD/PCDF and dioxin-like PCB (dl-PCB).

In accordance with the project objectives, the major focus of the investigation was a compilation of recent measurement data and emissions factors. The search was not intended to repeat all the work performed during the elaboration of the UNECE Guidebook and the UNEP Toolkit and the results do not pretend to be fully exhaustive, but major works and studies from 1995 onwards have been compiled.

Our searches concentrated on combustion applications with a fire rate/heat input <50 kW_{th} in order to especially address single domestic appliances. In this context it has to be taken into account that the majority of single room appliances such as ovens, fireplaces and cooking devices have a firing rate even lower than 15 kW, generally ranging between 4 kW and 8 kW. However, in case specific information for smaller appliances was lacking installations with a firing rate/heat input greater than 50 kW_{th} have been included in the evaluation. Figure 3-1 provides an overview on investigated domestic sources.

Source types and fuels investigated

- Heating and cooking appliances such as gas, oil, wood and coal boilers/stoves/inserts/fireplaces
- Charcoal grills
- Open/backyard burning of waste
- Candles
- Mobile domestic sources

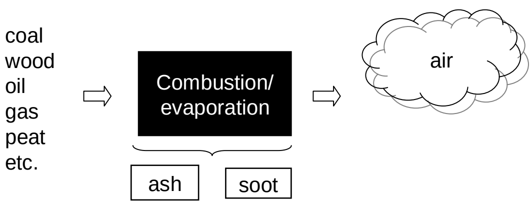


Figure 3-1: Overview of domestic emission sources and fuels investigated with respect to dioxin releases

The following data sources were searched for information:

- Scientific publications
- Websites and databases at European level
- Conventions and International Organisations: e.g. UNECE, UNEP, OECD, OSPAR, HELCOM, AMAP, WHO, including e.g. IARC, IPCS
- Extra-European Authorities: US-EPA, Environment Canada, Australia, Japan
- National authorities of EU Member States and EFTA countries
- Other

In total, more than 90 literature sources have been identified, which are related to one of the above-mentioned issues.

3.1 Calculation and measurement of PCDD/PCDF emissions

3.1.1 Calculation of results: Emission factors and pollutant concentrations

PCDD/PCDF and dl-PCB air emissions are calculated based on the toxic equivalent system taking into account the varying toxicity of individual congeners and are expressed as the toxicity equivalent quotient (TEQ) using the NATO/CCMS scheme (I-TEQ) or the WHO scheme (WHO-TEQ). Emission calculation is based on concentration measurements in exhaust gases or residues. However, concentrations in exhaust gases or residues are not good indicators for emissions/releases, as final emissions depend on the amount of gas or residue produced, O_2 content in the gas or other factors. Hence emissions are reported in terms of emission factors (EFs) when possible, which relate emissions to the amount of fuel combusted following the equation:

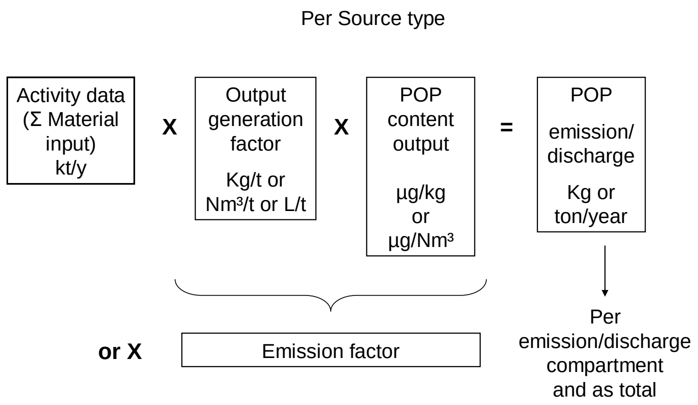


Figure 3-2: Equation for calculation of annual emissions via emission factors

In accordance with this scientific recommendation, a majority of identified studies from the period 1995 to 2005 provided a calculation of EFs based on the flue gas measurements made.

Fuel consumption can principally be calculated by mass (e.g. tonnes) or by caloric value (e.g. Terajoule TJ). Accordingly reporting in literature is partly in tonnes and in TJ. It has, however, to be taken into consideration that different fuels have different caloric values and that the final heating effect is the most important parameter in combustion. Thus, a reporting in µg TEQ/Terajoule (TJ) is the most precise and best method for comparison, which according to expert recommendation (see workshop results) should be the unit of choice.

To make results comparable, reporting in µg TEQ/t is converted into TJ with the aid of average caloric values derived from literature. This approach entrains uncertainty (by use of average caloric value), but given other uncertainty factors such as study design, sampling and analysis method, this can be tolerated.

It has also to be noted that in the field of dioxin analysis typically measurements to determine EFs, are not repeated in order to do a statistical analysis. Means and medians do not reflect statistical results from a repeated analysis but result from averaging of measurements where parameters (stove, fuel, etc.) were varied in order to reflect the daily practice. If available means and medians have been used as calculated by the authors of the publications otherwise hey have been calculated on the basis of reported data by the project team.

3.1.2 Measurement strategies: laboratory settings versus home conditions and related difficulties

When considering strategies related to emission measurements, it is important to be aware of different possible approaches, which can be used in general. In particular, the following two different approaches can be identified for dioxin measurements in the field of domestic heating and cooking:

- Laboratory scale measurement conditions under defined and reproducible conditions
- Field measurements at the actual location of emission under reality conditions

When considering several aspects important for evaluating emission rates (e.g. firing conditions, sampling point, etc.) it becomes obvious that the two different approaches for measuring might lead to significant variations related to the results obtained for emission rates.

Laboratory tests

PCDD/Fs emission factors from small-scale wood combustion – in contrast to other relevant sectors (i.e. waste incineration) – are often obtained with testing under laboratory conditions. On the one hand laboratory test measurements enable the investigation of emissions under defined conditions; however, they introduce on the other hand a bias due to the differences with the conditions in reality.

Field measurement

Only few experimental measurements have been set up to simulate the real situation usually found in households, and at the same time to allow a correct sampling of flue gases, capable of producing representative data on exhaust composition and emission factors. Also only few measurements have been performed at real domestic installations as it is more difficult and also expensive to do. A standardisation of such measurements seems impossible because

people have different firing habits and use different firewood. Consequently the measurements cannot be reproduced.

Against this background, emission factors proposed by different sources are often not representative for the typical and real emissions from small wood combustion devices. Sources of uncertainty in the assessment of PCDD/Fs emission factors from small-scale wood combustion are numerous, and could be classified in the following categories:

Operational practice

- Maintenance
- Type of fuel
- Burning cycle
- Ignition procedures /Co-incineration of wastes
- Influences of transient conditions

Measurements conditions

- Influence of sampling point
- Gas/particulate phase
- Measurement of the condensable fraction
- Dilution

In the following each of these issues is discussed and explained further taking into account the differences between laboratory testing and testing under real conditions.

Operational conditions

An important difference between laboratory settings and home conditions, concern the operation of the appliances. Laboratory test are generally made by technicians who are experienced at firing the stoves and to achieve an efficient combustion to meet the legal criteria (e.g. energy efficiency, CO limits etc.]. Consequently laboratory combustion often follows the best conditions and is performed on new or clean installations. On the other hand the maintenance of the device, the cleaning of the combustion chamber and of the chimney is rare in real conditions. It is a wide spread practice of operators to limit the maintenance of the combustion system, also for old appliances. In addition fuel characteristics, as type of wood or moisture content, could vary among domestic users and in laboratory conditions.

Usually test laboratories (especially that for compliance purpose) use wood without bark, logs of regular size and weight, disposed regularly in the combustion chamber. In this context also the storage of fuels is an aspect to be considered, because it influences the real moisture content of wood used. Typical for laboratory tests is the use of wood of defined moisture content.

Finally PCDD/Fs emission are influenced by the common practice to use paper, paper board or small wood pieces in varying amounts, even wood shavings and plastic. In this context it seems important that higher PCDD/FS emissions have been detected (i.e. Hübner et al., 2008) when relevant amounts of other combustible materials (such as household wastes) are co-fired or used in order to facilitate lightning-up or to speed up the combustion. Ignition

phases are not considered during laboratory experiments, in particular for regulatory compliance purposes

This leads to the fact that emission factors from laboratory tests tend to be lower than those to expect under real life conditions.

Burning cycle influence

PCDD/Fs emission depend on combustion conditions, related to the amount of wood fed in the chamber; emissions are dependent on parameters (such as temperature or O_2 availability) that vary during the combustion cycle and depend on the particular appliances use and burning habits such as wood fuel refilling frequency, amounts after the first loading or duration of the daily use of the appliance. There is no specific reference on how to burn wood during testing/experiments and whether test procedures should consider real situation or regular and comparable cycle. A point to be considered in the evaluation of PCDD/Fs emission factors from SCIs is the influence of transitory phases on small-scale wood combustion emissions due to temperature variations. In some experimental measurements (e.g. Angelino et al., 2008) a close correlation has been observed between the PM produced and the VOC concentration; thus it is possible to presume that also PCDD/Fs could be highly influenced by temperature variations during transient phases. The EMEP-Emission Inventory Guidebook (EEA, 2006), clearly stresses the need to take into account start-up emissions and in properly assessing their contribution to the average value as they significantly influence the emission of the total cycle. The measurements during transient conditions pose special challenges due to the intrinsic analytical and instrumental difficulties and to the complete lack of validated methods in the field. The available measurement methods for domestic sources are useful for monitoring long-term (many hours) emission but loose information on the short-term variations during SCI operations.

Measurements conditions (Sampling point and fraction)

Measuring PCDD/PCDF according to the CEN standard EN 1948, requires isokinetic sampling of particles (because a large part of the PCDD/PCDFs are normally associated to the particles), a cooling of flue gases to below 20°C and an absorption of vapour phase PCDD/PCDFs.

Most experience with PCDD/F measurements is coming from measurements at large incinerators or other industrial installations with rather constant flue gas conditions, regarding flow/velocity, humidity and temperature. Measuring PCDD/PCDF from domestic combustion (SCI) is far more complicated. This is mainly because of the low flue gas velocity in the chimney, which will vary very much during a combustion cycle (in the range of 2 m/s and close to zero), whereas the wide variability of the humidity and temperature is not so important for correct sampling.

Measuring directly in the chimney is consequently very difficult, because isokinetic sampling is almost impossible. This is not only a problem for correct sampling of the PCDD/PCDFs carried by PM, but also for the vapour phase PCDD/PCDF, which shall be sampled flow proportional, because the concentration of PCDD/PCDF will vary through the combustion cycle.

The most extensively used and general applicable method is based on whole flow dilution in a dilution tunnel where a constant flow of diluted flue gases enables constant volume

sampling (CVS). With this method it is possible to make reliable measurement of PCDD/F emissions from SCIs.

3.2 PCDD/PCDF emissions into air

Key message: More than 30 scientific studies provide information. Available data are mainly for coal and wood combustion. First studies are from the 1980s, whereas a peak in investigations was around 2000.

In the course of the literature search more than 30 scientific studies have been identified from the period 1995-2005 relating to measurement of PCDD and PCDF concentrations in exhaust gases or residues of domestic sources. First studies extend back to the 1980s, but a peak of activities with studies in a larger number of Member States could be observed around the year 2000. The majority of information originates from central Europe and the Scandinavian countries. Information from Mediterranean countries is scarce. In France, a first specific measurement project jointly performed by INERIS, LCME, CITEPA and CSTB [preliminary title: “Evaluation de l’impact des appareils de chauffage domestique au bois sour la qualité de l’air intérieur et extérieur”] is currently being finalised and not yet published. In Italy, a project on emission measurement from wood combustion (including PCDD/PCDFs) managed by ENEA (Agency for New Technology, Energy and the Environment) and ARPALombardia (Lombardy Environmental Protection Agency) and funded by the Italian Ministry of the Environment is scheduled to start in September 2008.

Although measurements have been almost exclusively performed in stoves and boilers, the range of fuels and appliances tested is large. In total, about 192 stove-fuel combinations were found in the analysed literature. The year of manufacture of the tested appliances ranges from 1955 to 1999, but it has to be taken into account that a number of investigated stoves/boilers were reported without information on the year of manufacture.

With the exception of the early 1990s when liquid fuels (oil) and gas were also tested, measurements focussed on different types of solid fuels, such as coal, coke, wood, straw and hay in different forms (e.g. pellets, briquettes, nuts, blocks, chips), and types (e.g. anthracite, lignite, beech, spruce, birch).

In order to obtain more information about PCDD/PCDF emissions from uncontrolled combustion of wastes, a number of studies on waste burning in barrels (backyard burning) and open fires have been performed in recent years especially in France, Sweden and the United Kingdom.

3.2.1 EFs for domestic coal combustion

Key message: EFs into air for coaly fuels identified in primary measurement studies range from 6 to 455 µg TEQ/TJ, which corresponds to a multiplier of almost 100. Inclusion of results from certain Polish coal or of other maximum values raises this factor to >500.

Means or medians in the studies identified, range from 20 to almost 400 µg TEQ/TJ for normal coal and are significantly higher for Czech and especially Polish coal (1,000 – 8,500 µg TEQ/TJ). The results are largely consistent with the data basis used for the UNEP Toolkit (33-233 µg TEQ/TJ).

Recent proposals have been made to change recommended UNEP EFs to: keep 100 µg TEQ/TJ for automated boilers, use 200 µg TEQ/TJ for manual furnaces, 500 µg TEQ/TJ for co-fired appliances and to reduce to 1,000 µg TEQ/TJ for automatic boilers fired with high chlorine coal.

A recent review proposal for UNEP Toolkit factors suggests elevated EFs for manually fired devices and a lowered EF for automatic appliances fired with high chlorine coal.

EFs from single primary studies identified

EFs for coal are presented in 15 of the collected studies [e.g. Quass et al 2000, Thanner & Moche 2002, Kubica 2000, Lee et al. 2005, Schleicher et al 2002, Boos et al 2005, Hübner et al. 2005, Erken et al. 1996, Hobson et al 2003, Davies et al .1992, Geueke et al. 2000, Grochowalski 2002, Williams 2001, Kakareka et al. 2003, Pfeiffer et al. 2000b] partly reported in TEQ/TJ and partly in TEQ/t (see annexes 1.1.1). In order to facilitate comparison, data reported in TEQ/t are recalculated using an average caloric value for coal fuels of 22 MJ/kg.

Single measurement results vary considerably but certain general observations can be made. Thus, it can be said that EFs in German studies range between 6-80 µg TEQ/TJ. Somewhat higher results (up to several hundreds of µg TEQ/TJ) where measured in studies from Austria and the UK, and in the study from Quass et al. 2000. A review study from the UK [Enviros 2006] does not provide specific measurement results, but concludes with min.-max emission concentrations of PCDD/PCDF into the air from domestic coal combustion. Results are in the dimension of 70-4,500 µg TEQ/TJ (recalculated). Extremely high results (up to >10,000 µg TEQ/TJ) have been observed in analyses investigating specific types of Polish coal (e.g. Wujek coal). A recently published study from the European Joint Research Centre (JRC) in Ispra [Paradiž et al 2008] concluded that the EF for coal combustion in stoves in the Krakow region is in the dimension of 3,000 µ TEQ/TJ.

In order to achieve a better comparability of study results and to be able to illustrate possible differences between different types of fuels, an analysis of means and medians for the various studies has been performed.

Coal fuels	Mean µg TEQ/TJ	Median µg TEQ/TJ	Source
Hard coal: Poland	8500		Grochowalski 2002
	7743	8805	Thanner & Moche 2002
	2407		Quass et al. 2000
	2400		Boos et al. 2005
	1032		Geueke et al. 2000
	543		Williams et al. 2001
Hard coal, coke: Czech Republic	1475		Thanner & Moche 2002
Other coal	129	79	Boos et al. 2005
	26	20	Erken et al. 1996
	73		Geueke et al. 2000
	154	131	Quass et al. 2000
	121		Hobson et al. 2003
	162		Davis et al. 1992
	73		Kakareka et al. 2003
	30		Pfeiffer et al. 2000b

Table 3-1: Overview on means and medians of PCDD/PCDF emissions from coal combustion in domestic appliances (µg TEQ/TJ)

The following table compiles means and medians for studies calculating results in µg TEQ/t. The recalculation has been performed with an assumed average caloric value of 22 MJ/kg due to the variety of fuels and lack of more precise data in a majority of cases.

Coal	µg TEQ/t		recalculated as µg TEQ/TJ		Source
	mean	median	mean	Median	
Hard coal, Poland	58		2,636		Quass et al. 2000
	217	246		~11,000	Thanner & Moche 2002
	13	9			Kubica 2003
Coke Czech Republic	42	44		2,000	Thanner & Moche 2002
other	4	3		136	Quass et al. 2000
	3			136	Lee et al. 2005/ Lohmann et al. 2005
	8.5			386	Schleicher et al. 2002

Table 3-2: Overview on means and medians of PCDD/PCDF emissions from coal combustion in domestic appliances (µg TEQ/t)

In addition to the studies mentioned above, seven further studies [e.g. Kolenda 1992 (DE) Launhardt et al. 1998 (DE), Thuß et al. 1995 (DE), Vikelsøe 1994 (DK), Alemand 2003 (FR), Raventos et al. 2000 (FR) and Derouxbaix 2000 (FR)] have been identified. In these studies however, results were provided only as concentrations. Due to the wide range of investigated appliances and fuels, a comparison with EFs is not possible without important assumptions and extrapolations (e.g. flue gas amounts produced), which make the results highly uncertain. Consequently, results will generally not be analysed in this report, but will only be

compiled in Annex 1.1.2 for reasons of completeness. In order to complete the compilation and evaluation of literature data, a summary explanation of the derivation of EFs recommended in the international estimation tools is also presented in this chapter.

Background to UNEP Toolkit Emission Factors

The EF of 100 µg TEQ/TJ for coal combustion in the UNEP Toolkit is based on mean values which in most cases ranged between 1-7 µg TEQ/t (33-233 µg TEQ/TJ) and an average heating value of 30 MJ/kg. The EF of 15,000 µg TEQ/TJ for high chlorine coal is based on the data from Kubica et al. 2004, who reported EFs from 108.5-663.9 µg TEQ/t (mean 400 µg TEQ/t) for Polish coal with high chlorine content. This mean was divided by a caloric value of 25 MJ/kg.

Background to UNECE Guidebook Emission Factors

The background for the recommended EFs in the UNECE Guidebook is less clear as only general information on sources is provided. From the data compiled in the annex to the chapter on non-industrial combustion, it could however be concluded that the EF of 1,000 versus 500 µg TEQ/TJ for stoves presented in the UNECE Guidebook are based on the following studies: [Grochowalski A. 2002, Quass et al. 2000, Geuecke et al. 2000 and Hübner et al. 2005]. The weighing of single results is not known, but values are consistent with the findings of the studies mentioned. The same applies to the 500 µg TEQ/TJ for small boilers and fireplaces [correlates with Hobson et al. 2003], the 100 to 400 µg TEQ/TJ for boilers [correlates with Williams et al. 2001, Kakareka 200, Hübner et al. 2005] and the 40 µg TEQ/TJ for automatic boilers [correlates with Kubica et al. 2002, Kakareka 2003, Pfeiffer et al. 2000].

Proposal for revised UNEP Toolkit Emission Factors for the domestic sector

Based on a review of literature data, a proposal for revised EFs has recently been made on behalf of the German EPA. The project [Rentz et al. 2007] intended to further differentiate and refine current emission estimates under the Stockholm Convention (using the UNEP Toolkit) and to add further EFs for residues and dl-PCB.

Residential heat production		Air	UNEP Toolkit
PCDD/PCDF		µg TEQ/TJ	
Automatic furnaces (< 1MW)	High-chlorine coal	1,000	15,000
Manual furnaces	High-chlorine coal	15,000	15,000
Automatic furnaces (< 1MW)	Coal/coke	100	100
Manual furnaces	Coal/coke	200	100
Manual furnaces	Co-fired (coal/waste/biomass)	500	

Table 3-3: Proposed revised EFs for PCDD/PCDF emissions from domestic combustion of coal (Rentz et al. 2007)

For comparison with current EFs applied in EU Member States see chapter 4.5.

3.2.2 EFs for domestic combustion of wood and other biomass

Key message: EFs into air for wood fuels and other biomass in general, range from 2 to 850 µg TEQ/TJ. Single measurements rise up to almost 5,000 µg TEQ/TJ.

Means or medians in the studies identified vary from 13 to 270 µg TEQ/TJ with most of them in the range of 30-130 µg TEQ/TJ. Considerably higher values (several thousand µg TEQ/TJ) are found in bad combustion conditions or if contaminated wood is combusted. Differences in air emissions from different types of stoves or boilers cannot generally be confirmed with the collected data, although indications for differences have been identified in some of the studies.

Data from herbaceous biomass (hay, straw etc) are still very limited, but PCDD/PCDF emissions are higher than those from combustion of virgin wood in the studies performing a parallel investigation (~700 µg TEQ/TJ). It thus appears to be reasonable to further investigate into specific EFs for different types of biomass.

In general, results for wood correspond relatively well to the 100 µg TEQ/TJ recommended in the UNEP toolkit However, measured EFs exceed the UNEP toolkit EF of 1,500 µg TEQ/TJ for contaminated wood.

An expert proposal has recently been made to change UNEP Toolkit factors: to 450 µg TEQ/TJ for automatic furnaces burning herbaceous fuels, lowered to 50 µg TEQ/TJ for automatic wood fired devices, and lowered to 500 µg TEQ/TJ for automatic devices firing contaminated wood

EFs for wood from single primary studies identified

EFs for wood are investigated in even more studies than EFs for coal (studies from AT, DE, DK, PL, SE and UK) [Thanner & Moche 2002, Boos/Hübner 2005 and Erken et al. 1996, Pfeiffer et al. 2000, Hedman et al 2006, Vikelsøe et al. 1994, Lee et al. 2005, Lohman et al 2005, Gönzi et al 2005, Schleicher et al. 2002]. Studies compare a large range of different types of wood. In addition, other biomass [Kubica 2003, Schleicher 2002, and Gönzi 2005] and wood mixed with waste [Hedman 2006, Gullet 2003, Schatowitz 1994, and Collet 2000] are investigated in individual cases. (See annexes 1.1.3). Results are partly reported in TEQ/TJ and partly in TEQ/t. In order to facilitate comparison, data reported in TEQ/t are recalculated using an average caloric value for wood fuels of 14 MJ/kg.

Results in the range of 3-45 µg TEQ/TJ have been observed in the extensive German studies performed by Pfeifer et al. 2000 and Erken et al. 1996, in the UK studies performed by Lee et al. and Lohmann et al. 2000 and in the Danish study performed by Schleicher et al. 2002. In the study from Boos/Hübner 2005 as well, most of the EFs were between 30-100 µg TEQ/TJ. Results in the study of Thanner & Moche (2002) vary between 20 and 690 µg TEQ/TJ for beech wood. Single measurements in the dimension of 1,000-4,500 µg TEQ/TJ in the study of Boos/Hübner 2005 represent bad combustion conditions (chamber too small, bad maintenance and worked over nominal heat input) or addition of waste (including potential memory effects). On the other hand, the average EF was 1,400 µg TEQ/TJ (range

270-5,100) in the Danish study from Glasius et al. 2005 and 2007 where “real life” measurements on 13 houses in a small village were performed.

As means and median values of studies increase the comparability of results and facilitate the derivation of EF recommendations, a corresponding evaluation of the major studies has been performed below.

Wood	Number of samples	µg TEQ/TJ mean	median	Source
	8	320	265	Thanner & Moche 2002
Single stove	12		80	Boos et al. 2005
Central heating boiler	13		70	Boos et al. 2005
	16	16	13	Erken et al. 1996
Bad condition/waste	6	2467	2350	Boos et al. 2005

Table 3-4: Overview of means and medians of PCDD/PCDF emissions from wood combustion in domestic appliances (µg TEQ/TJ)

The following table compiles means and medians for studies calculating results in µg TEQ/t. The recalculation was performed with an assumed average caloric value of 14 MJ/kg due to the variety of fuels and lack of more precise information in many cases.

Wood	Number of samples	µg TEQ/t		µg TEQ/TJ		Source
		mean	median	mean	median	
	various	0.5	0.5		35.7	Pfeiffer et al. 2000a
	18	5.1	5		357	Hedman et al. 2006
	24	1.9			126.7	Vikelsoe et al. 1994
	various	0.6			42.9	Lee et al. 2005
	various	0.2			14.3	Lohman et al. 2005
	8	2.8	1.2		85.7	Schleicher et al. 2002

Table 3-5: Overview of means and medians of PCDD/PCDF emissions from wood combustion in domestic appliances (µg TEQ/t)

Apart from these primary measurement reports, a number of further studies and reviews [e.g. Collet 2000, Gullet et al. 2003, Glasius et al. 2005/2007, Schatowitz 1994, Enviros 2006, Allemand 2003 and Baggio et al. 2001] do not provide specific measurement results but mean or min.-max emission concentrations of PCDD/PCDF into the air from wood combustion. Results range from minimum values of 0.3 to maximum values of 780 µg TEQ/TJ (converted from TEQ/t by means of caloric value) and thus are in the same dimension of the results from other studies.

Variations in EFs due to different types of wood (beech, spruce, logs, woodchips, etc.) have been reported by various authors, but are difficult to prove on the basis of reported data due to the high overall variability. But in any case, the difference seems to be less than between wood and other biomass.

Background to UNEP Toolkit Emission Factors for wood combustion

Emission factors for wood combustion in the UNEP Toolkit are derived from mean values between 0.2-5 µg TEQ/t. An average heating value of 12-15 MJ/kg was assumed for recalculation, this corresponds to 15 – 370 µg TEQ/TJ). On this basis, a value of 100 µg TEQ/TJ (1.4 µg TEQ/t) was chosen as best estimate. According to the description in the UNEP Toolkit, the 15 - 54 µg TEQ/TJ (0.2-0.7 µg TEQ/t) from DE and 24 µg TEQ/TJ from the CH study were deemed to represent the lower end of the spectrum whereas the values of the

AT study 185 - 361 µg TEQ/TJ (2.4 – 4.7 µg TEQ/t) where regarded as extremely high in the light of the overall distribution of the assessed studies.

Background to UNECE Guidebook Emission Factors for wood combustion

The background for the recommended EFs in the UNECE Guidebook is less clear as only more general information on sources is provided. From the data provided in the annex to the chapter on non-industrial combustion it could however, be concluded that the EFs of 800 versus 300 µg TEQ/TJ for wood stoves are based on results from [e.g. Kakareka et al. 2003, Caserini et al. 2003, Hübner et al. 2005]. The EFs for wood boilers (400-200 µg TEQ/TJ) seem to be based on [Kakareka et al. 2003, Pfeiffer et al. 2000, Hübner et al. 2005] and the 30 and 50 µg TEQ/TJ for pellet ovens and automated boilers appear to be derived from [Pfeiffer et al. 2000]. The allocation however is not completely clear. A number of other results on e.g. open fireplaces cannot be detected in the EFs attributed.

Proposal for revised UNEP Toolkit Emission Factors for domestic wood combustion

A proposal for revised EFs has recently been made on behalf of the German EPA by [Rentz et al. 2007] based on another review of literature data. The project had the objective to further differentiate and refine current emission estimates under the Stockholm Convention (using the UNEP Toolkit) and to add further EFs for residues and dl-PCB.

Residential heat production		Proposed revised EF	UNEP Toolkit
PCDD/PCDF		µg TEQ/TJ	µg TEQ/TJ
Automatic furnaces (< 1MW)	wood	50	100
Manual furnaces	wood	100	100
Automatic furnaces (< 1MW)	contaminated wood	500	1,500
Manual furnaces	contaminated wood	1,500	1,500

Table 3-6: Proposed revised EFs for PCDD/PCDF emissions from domestic combustion of wood (Rentz et al. 2007)

EFs for contaminated wood and bark

Whereas the co-combustion of paper with wood fuels does not seem to change the emissions, the addition of plastics raises the emissions minimum by a factor of 10 [Hedman et al. 2006]. The same conclusions result from a number of further studies [e.g. Enviros 2006] that do not provide specific measurement results but only mean or min.-max values. If contaminated wood is burned, emissions are reported to range from 785 – 28,570 µg TEQ/TJ (11-400 µg/t).

In a wood stove test performed in Denmark in 2000 [Schleicher et al. 2002], it has been observed that bark increases the emissions from wood combustion especially at normal air supply. In the study, fuel containing 15% bark resulted in elevated PCDD/F emissions in comparison with barkless wood (360 versus 136 µg TEQ/TJ).

The UNEP Toolkit factor for contaminated wood is based on data from LUA 1997 and IFEU 1998 (0.2-5 µg TEQ/t) and the fact that values reported for clean biomass combustion were consistently one order of magnitude below the values reported for the combustion of contaminated biomass, such as treated and/or painted wood. LUA (1997) gave emission

factors of 50 µg TEQ/t for slightly contaminated and 500 µg TEQ/t for highly PCP-treated wood, which would result in emission factors of 3,300 µg TEQ/TJ and 50,000 µg TEQ/TJ respectively.

The study on the revision of the UNEP Toolkit factors proposes reducing the EF for automated appliances to 500 µg TEQ/TJ, whereas it should be kept to 1,500 for manually operated appliances (see Table 3-6).

EFs for herbaceous biomass

The few results for other biomass combustion (straw) [e.g. Kubica 2003, Schleicher 2002] are in the range of about 500 to 950 µg TEQ/TJ (recalculated from 7.2 and 13 µgTEQ/t). Although these results are of comparably similar dimensions of some results for wood combustion, it has to be noted that compared to wooden pellets or wooden briquettes within the two studies a considerable difference in EFs was observed. This difference has also been observed in the Launhardt & Thoma 2000 study which provided results only as concentrations but also identified emissions which were a factor of ten above the results for virgin wood.

As a consequence, it might be reasonable to further investigate specific EFs for different types of biomass as already suggested in the UNECE Guidebook and discussed by the expert working group on domestic sources related to the UNEP Toolkit. The current proposal from a recent study [Rentz et al. 2007] is the application of an EF of 450 µg TEQ/TJ for combustion of herbaceous biomass (straw, hay, etc) in automatic furnaces (<1MW).

A comparison of literature values with the EFs applied by MS and recommended in the international estimation tools is provided in chapter 4.4.4.

3.2.3 EFs for domestic oil & gas combustion

Key message: Measurement data for gas and oil combustion are scarce. EFs range from 0.5 to 20 µg TEQ/TJ with a median of 2.5 µg TEQ/TJ for oil and of 1.9 µg TEQ/TJ for gas. The EF for oil in the international estimation tools is not fully confirmed by these measurement data.

Recent primary measurement data for oil and gas combustion have been identified in Pfeiffer et al. 2000 (see annex 1.1.4.) The individual EFs range from 0.5 to 20 µg TEQ/TJ. In this context the median for oil is 2.5 µg TEQ/TJ (0.07 µg TEQ/t) and the one for gas is 1.9 µg TEQ/TJ (0.06 µg TEQ/t).

Background to UNEP Toolkit Emission Factors for liquid and gaseous fuels

The EF for oil in the UNEP Toolkit of 10 µg TEQ/TJ is based on an average of 0.5 µg TEQ/t obtained from measurements ranging from 0.04 – 2 µg TEQ/TJ and divided by a caloric value of 44-46 MJ/kg. The values from AT (40 µg TEQ/t) and CH (0.5 µg TEQ/TJ) were considered as outliers and were not taken into account.

The EF for gas in the UNEP Toolkit was derived from values between 0.04-0.07 ng TEQ/m³ [LUA 1997, IFEU 1998, Environment Canada 1999]. On this basis, an average of 0.05 ng

TEQ/m³ (µg TEQ/t) was chosen and divided by a caloric value of 32-35 MJ/m³. This led to the recommended value of 1.5 µg TEQ/TJ.

Background to UNECE Guidebook Emission Factors for liquid and gaseous fuels

The basis for the UNECE Guidebook EF for oil is the UNEP Toolkit, Pfeiffer et al 2000, Kakareka et al. and Caserini et al. 2003. The EF for gas is derived from the UNEP Toolkit and Pfeiffer et al. (see chapter 4.4.2).

3.2.4 EFs from open burning of coal, biomass and other waste

Key message: Mean EFs from few studies range from about 200 TEQ/TJ (8-500 µg TEQ/TJ) for open coal combustion, to 314 and 2,200 µg TEQ/TJ (4.4 – 31 µg TEQ/t) for straw and garden waste with RDF. EFs of 97 – 6,700 µg TEQ/TJ (3.5 – 240 µg TEQ/t) were observed for open burning of MSW. Maximum values of 13,000 µg TEQ/t can be reached if waste is mixed with PVC or electronic scrap.

EFs for biomass and other waste fit well to those determined in the UNEP Toolkit. The recent proposal for revised EFs suggests: an increased factor for combustion of agricultural residues under bad conditions and considerably reduced factors for uncontrolled domestic waste burning (52 µg TEQ/t) and combustion of C&D waste (17 mg TEQ/t).

Open burning of coal was investigated by [Schleicher et al 2002] who measured mean emission factors of 273 and 500 µg TEQ/TJ (6 and11 µg TEQ/t) for a garden grill and by [Lee et al. 2005] who reports on a mean EF of 136 µg TEQ/TJ (3 µg TEQ/t) for an open fire with house coal. [Davis et al 1992] reported on EFs for a domestic open coal fire of 87-238 µg TEQ/TJ and [Erken et al. 1996] reported EFs of 8-81 µg TEQ/TJ (mean/median 43 µg TEQ/TJ) for an open fireplace (8 measurements). As 43 µg TEQ/TJ and 500 µg TEQ/TJ appear to be very low and high; EFs of around 200 µg TEQ/TJ might be a reasonable choice.

Some recent studies from SE [Gönzi et al. 2005], UK [Collet et al. 2005] and BE [Wevers et al. 2004] investigated the PCDD/PCDF emissions from open burning of different waste types in barrels and open fires (see annex 1.1.5). The number of samples is limited.

Garden waste, agricultural residues

Gönzi reports mean values of 4.4 TEQ/t for straw and 31 TEQ/t for garden waste and RDF. This corresponds to 314 and 2,200 µg TEQ/TJ if the data are converted with an assumed average caloric value of 14 MJ/kg, as applied for wood. Comparable results are reported by Wevers at al. 4.7 and 4.4 µg TEQ/t for relatively good combustion conditions. On the other hand, this study observed an EF of 20 µg TEQ/t for bad combustion conditions.

Open burning of MSW

For the combustion of MSW in an oil barrel Wevers et al. reports an EF of 35 µg TEQ/t (corresponding to almost 4,000 µg TEQ/TJ if recalculated with 9 MJ/kg). Collet reports EFs of 242 and 233 µg TEQ/t (corresponding to 80,000 µg TEQ/TJ) for MSW burning. If waste is mixed with PVC or electronic scrap even max values of 13,000 µg TEQ/t can be reached [Hedman et al. 2005]. Wood treatment with chromate copper arsenate (CCA) investigated in a US study does not seem to significantly increase PCDD/PCDF releases from wood combustion. In addition, a study investigating dioxin emission factors from accidental burning

of buildings has been included for reasons of completeness [Caroll 2001 (see annex 1.1.7)].

Background to UNEP Toolkit Emission Factors for open burning of biomass and other waste

UNEP toolkit EFs for open burning of biomass are based on the studies of Gullett et al. (2002) and Ikeguchi et al. (1999). Gullett performed biomass burns of wheat straw and rice straw in an open burn simulation facility. The emission factors ranged from 0.337 to 0.602 µg TEQ/t. Ikeguchi et al. 1999, tested emissions from leaves, bundles of straw and rice husks. The emission factors were 4.6, 20.2 and 67.4 µg TEQ/t respectively. Results were used to define a low EF for favourable conditions (0.5 µg TEQ/t) and a high EF for less favourable conditions such as prior use of pesticides that contain precursors or catalysts for the formation of PCDD/PCDF, poor burning conditions, high humidity or wet ground (30 µg TEQ/t).

EFs for the burning of domestic and similar waste in uncontrolled conditions are based on US trials where domestic waste was combusted in a barrel (US-EPA 1997a, Gullett et al. 1999, Lemieux et al. 2003). Emissions to air seem to vary considerably depending on the conditions of combustion (highly variable) and the composition of the waste, from under 9 µg WHO-TEQ/t of waste to over 6,655 µg WHOTEQ/t. The mean value from 25 experiments gave 706 µg WHO-TEQ/t (median 148 µg WHO-TEQ/t). On this basis, a value of 300 µg TEQ/t has been decided upon.

Proposal for revised UNEP Toolkit Emission Factors for open burning processes

A recent proposal for revised EFs for open burning processes [Rentz et al. 2007] suggests higher factors for forest fires and field burning of agricultural residues but lower EFs for landfill fires, uncontrolled domestic waste burning and burning of C&D wood.

Open burning processes	Air µg TEQ/t		Toolkit
PCDD/PCDF	median	mean	
Forest fires	11.3	14.7	5
Agricultural residues (impacted)	20.2	43.1	30
Agricultural residues (not impacted)	0.57	0.55	0.5
Landfill fires	238	381	1,000
Uncontrolled domestic waste burning	52	261	300
Open burning of C&D wood	17	30	60

Table 3-7: Proposal for revised EFs for PCDD/PCDF emissions from open burning processes (Rentz et al. 2007)

3.2.5 EFs from burning of candles

Information on PCDD/PCDF emissions from open burning of candles is highly limited, but it seems that emission factors are very low so that overall emissions seem to be negligible (see annex, 1.1.6.)

3.2.6 EFs from the burning of charcoal and PCP-treated wood

So far there is almost no information on PCDD/PCDF emissions from charcoal combustion. One of the scarce information sources is a Swiss study [Nussbaumer et al. 1993 and Schatowitz 1994] which calculated an EF of 0.04 µg TEQ/t grilled meat on the basis of a measured PCDD/PCDF concentration in the flue gas of 0.028 ng TEQ/m³. This is the value that is also used in Annex IV to the Aarhus POP protocol for emission estimation for charcoal combustion. On the other hand a more recently performed measurement study from DK [Schleicher et al. 2002] concludes on EFs in the range of 5-15 µg TEQ/ton of charcoal burnt.

Current concentrations of PCDD/PCDF in PCP treated wood are discussed in a recent survey of dioxin emission from PCP-treated wood performed on behalf of the Danish EPA [Danish EPA 2004]. According to this study, maximum concentrations of dioxins in wooden pallets imported from PT, ES and FR were in the dimension of 4.5 µg TEQ/ton of wood. Current (2003) concentrations in historically treated wood were analysed as ranging from 30 – 800 µg TEQ/ton wood with an expected annual evaporation rate of 0.5% of the actual content.

3.2.7 EFs from mobile domestic sources and other fuels

None of the scientific studies identified addressed PCDD/PCDF emissions from mobile domestic sources.

3.3 PCDD/PCDF releases into residues

Key message: Data for releases into residues are limited. Values are available for coal, wood and biomass combustion and for open burning of waste.

Information on concentrations in solid combustion residues is less frequent than for emissions into air. Nine studies from AT, CH, DE, DK, FR, SE and UK provide related information for small domestic appliances, whereas a French study provides corresponding information for an industrial wood combustion installation with flue gas cleaning. Releases into residues are calculated on the basis of concentration measurements in the residual products from combustion following the equation: EF = concentration in residue (µg TEQ/tonne). The caloric value of the original fuel does not play a role and consequently there is no discussion of the reporting unit to be chosen, as in the case of air emissions.

3.3.1 Releases from combustion of coal

Key message: EFs range from 0.2 to 4.8 µg TEQ/t for ash (except for high chlorine coal, with a median of 17 µg TEQ/t) and show a median of 569 µg TEQ/t for soot. They are low compared to the 5,000 µg TEQ/t (coal) and 30,000 µg TEQ/t (high-chlorine coal) in the UNEP toolkit and closer to the proposal for revised EFs of 500 and 5,000 µg TEQ/t.

EFs for release into **ashes** [Thuß et al. 1995/1997, Oehme & Müller 1995] are calculated as 0.2 to 4.8 µg TEQ/t (17 for one sample of high chlorine coal), whereas the study of [Thanner & Moche 2002] measured EFs of 1.9 – 45 µg TEQ/t (median 17 µg TEQ/t). EFs for releases into **soot** have only been investigated in the study of [Thanner & Moche 2002] investigating mainly Polish coal under real combustion conditions. In this study EFs vary from 115 – 980 µg TEQ/t (median 569 µg TEQ/t). (See annex 1.2.1). The UNEP Toolkit factors for releases into ashes are based on concentrations between 4-42,000 µg TEQ/t analyzed by [Dumler et al. 1995]. These were used to generate a recommendation of 5,000 µg TEQ/t as a first estimate. For Polish coal, a value at the upper end of the reported concentrations (30,000 µg TEQ/t) was initially chosen.

The proposal for revised UNEP Toolkit EFs [Rentz et al. 2007] suggests additional factors for mixed ashes and soot for automatic furnaces fired with high chlorine coal and co-fired manual furnaces, and one considerably lowered EFs for normal coal combustion.

Residential heat production		Mixed ash	UNEP Toolkit	Soot	UNEP Toolkit
PCDD/PCDF		µg TEQ/t		µg TEQ/t	
Automatic furnaces (< 1MW)	High-chlorine coal	15		5,000	
Manual furnaces	High-chlorine coal	15		5,000	30,000
Automatic furnaces (< 1MW)	Coal/coke	5		500	
Manual furnaces	Coal/coke	5		500	5,000
Manual furnaces	Co-fired (coal/waste/biomass)			3,000	

Table 3-8: Proposed revised EFs for PCDD/PCDF releases into ashes from domestic coal combustion (Rentz et al. 2007)

3.3.2 *Releases from combustion of wood*

Key message: EFs are 0.3-8 µg TEQ/t (ash) and 487 µg TEQ/t (soot) for clean wood. Results for contaminated wood or bad combustion conditions reach up to 700 µg TEQ/t (ash). Results are of the same dimension as the EFs of 10 µg TEQ/t (ash) (biomass) and 1,500 µg TEQ/t (ash) (contaminated) indicated in the UNEP toolkit.

EFs for releases into **ashes** [Thanner & Moche 2002, Launhardt & Thoma 2000, Vikelsøe et al 1994, Oehme & Müller 1995, Hedman et al. 2006, Deroubaix 1999,] are mostly in the dimension of 0.3 - 8 µg TEQ/t. Higher factors are observed (33-700 µg TEQ/t) in bad combustion conditions or if contaminated wood is combusted. (See annex 1.2.2). EFs for releases into **soot** from domestic wood combustion are available in the study from [Thanner & Moche 2002]. The four samples range from 254 – 695 µg TEQ/t (mean 487 µg TEQ/t). Launhardt et al. 2000 detected ash concentrations of 60 µg TEQ/t.

The UNEP Toolkit EFs for releases into ashes are based on the results of Wunderli et al. 1996 (average 10 µg TEQ/t for virgin wood; 1,000 µg TEQ/t for contaminated wood) as a first estimate. Rentz et al. 2007 suggest a lower factor for mixed ashes from automatic furnaces fired with contaminated wood and a higher factor for mixed ashes for automatic and manual furnaces without differentiation into wood and other biomass in a proposal for revised UNEP Toolkit EFs.

Residential heat production		Mixed ash	UNEP Toolkit	Soot
PCDD/PCDF		µg TEQ/t		µg TEQ/t
Automatic furnaces (< 1MW)	herbaceous biomass	30	10	
Automatic furnaces (< 1MW)	wood	30	10	
Manual furnaces	wood	30	10	
Automatic furnaces (< 1MW)	contaminated wood	500	1,000	1,000
Manual furnaces	contaminated wood	1,000	1,000	1,000

Table 3-9: Proposal for revised EFs for PCDD/PCDF releases into ashes from domestic wood combustion (Rentz et al. 2007)

3.3.3 *Releases from combustion of other biomass*

Key message: Results from a small number of measurements range between 8-24 µg TEQ/t for bottom ash and 400-4,000 µg TEQ/t for fly ash. EFs were considerably higher than EFs into residues from wood combustion.

Releases into ashes from combustion of herbaceous biomass (straw and hay) are available from a study by Launhardt & Thoma 2000. Reported EFs into residues are 8-24 µg TEQ/t for bottom ash and 400-4,000 µg TEQ/t for fly ash (see annex 1.2.3). As for air emissions, PCDD/PCDF concentrations observed were considerably higher than for the wood analysed simultaneously in the same study. This result would also suggest a differentiation for wood and biomass as concerns EFs into residues, and not one factor for both fuels as suggested by Rentz et al. In addition, a differentiation into oven ashes and soot should at least be an option to consider.

3.3.4 Releases from open burning of garden waste and other waste

Key message: EFs are in the dimension of 0.01-0.3 µg TEQ/t (waste combusted) for garden waste, but 100-2,400 µg TEQ/t (waste combusted) for MSW and PVC.

Apart from landfill fires, the scarce available data on releases from open burning of waste correspond well to the factor given in the UNEP Toolkit, even if the recommended toolkit factor for accidental fires (400 µg TEQ/t) may be exceeded by far in specific industrial settings.

EFs for releases into ashes from open burning of waste are available from [Hedman et al. 2005] and as reviewed data in [Enviros 2006]. EFs are in the dimension of 0.01-0.3 µg TEQ/t of combusted waste if garden waste is incinerated. They increase to several hundred µg TEQ/t of combusted waste or higher if MSW and especially PVC are incinerated (see annex 1.2.4).

Further studies [Nakao et al. 2002, Alawi et al. 1996] (annex 1.2.5) provide exemplary additional information on PCDD/PCDF emissions from landfill fires (mean 8.2 µg TEQ/t) and accidental fires (440-23,000 µg TEQ/t).

The **UNEP Toolkit factors** are based on the following studies: open burning of domestic waste is based on results from US barrel burns (Lemieux *et al.* 1997). For accidental fires, the EF is based on a German estimate (LUA 1997). The EF for vehicle fires is based on limited testing in Germany (Wichmann *et al.* 1995) and for fires involving C&D wood an emission factor of 10 µg TEQ/t wood burned is suggested by UK work on industrial wood combustion (Dyke *et al.* 1997). Treated wood, mixed fire loads and poor conditions may considerably increase the amount of PCDD/PCDF in residues.

3.4 Air emissions of dl-PCB

Key message: Only a limited amount of data exists. Values are available for domestic coal and wood combustion as well as for open burning of waste. There are no EFs for dl-like PCB emissions from domestic sources in the current UNEP/UNECE system.

Analysis and calculation of EFs for dl-PCB have been performed less often than for PCDD/PCDF, which explains the fact that international estimation tools do not provide figures for this type of PCBs. Nevertheless, a number of recent studies [Thanner & Moche 2002 (AT), Gullett et al. 2003 (USA), Lee et al. 2005 (UK), Lohmann et al. 2006 (UK) and Hedmann 2006 (SE)] investigated dl-PCB emissions from wood and coal combustion as well as from open burning of waste. A compilation of data is provided in annex 1.4.

3.4.1 EFs for dl-PCB from coal/coke combustion

Key message: There are only a few measurements from an Austrian study suggesting a mean EF of 445 µg TEQ/TJ.

EFs for coal are presented almost exclusively in an Austrian study [Thanner & Moche 2002]. As illustrated in annex 1.4.1, EFs from the few samples vary between 44 and 745 µg TEQ/TJ (0.89 and 16.4 µg TEQ/t). This seems to be very high but has to be compared to PCDD/PCDF levels of several thousand µg TEQ/TJ observed in the same study. Apart from this, the only available information is an average value of 0.2 µg TEQ/t for open fires reported by Lee et al 2005. Based on a review of available information, 100 µg TEQ/TJ as an EF for coal/coke combustion, is suggested by [Rentz et al. 2007] to be used in a revised version of the UNEP Toolkit for manual and automatic furnaces (<1 MW).

3.4.2 EFs for dl-PCB from wood combustion

Key message: EFs range from 1.4 to 93 µg TEQ/TJ (median: 26 µg TEQ/TJ). The addition of paper does not alter emissions.

EFs into air for dl-like PCB from wood combustion are available from [Thanner & Moche 2002, Hedman et al. 2006, Lee et al. 2005 and Lohman et al. 2006]. Values vary from 0.02 to 1.3 µg TEQ/t (median: 0.3 µg TEQ/t). With an average caloric value of wood of 14 MJ/kg, this corresponds to 1.4 and 93 µg TEQ/TJ. An analysis from combustion of wood mixed with plastics resulted in 23 µg TEQ/t. The addition of normal paper does not seem to significantly increase the emission rate. (For original data see annex 1.4.2). 15 µg TEQ/TJ have been suggested as the EF for clean biomass (wood, straw, hay etc.) in the proposal for domestic heating and cooking with solid fuels in a revised UNEP Toolkit for manual and automatic furnaces (<1 MW) [Rentz et al. 2007].

3.4.3 EFs for dl-PCB from open burning of garden and other waste

EFs range from 0.3 to 16 µg TEQ/t for garden waste (~20-1,150 µg TEQ/TJ if calculated on the basis of the caloric value of wood). There is a 10-fold higher result if PVC is mixed into the waste

Two recent studies [Hedman et al 2005, Collet 2004] investigated dl-PCB emissions from open burning in barrels and open fires (see annex 1.4.3). Garden waste (biomass) EFs into air ranged from 0.3 to 16 µg TEQ/t, which is higher than that for the combustion of dry wood by at least a factor of 10. A maximum value of 250 µg TEQ/t has been measured where garden waste was mixed with PVC (33%).

There is no suggestion for an EF for open burning of garden waste in the proposal by Rentz et al. 2007, but EFs for forest fires and open burning of C&D waste are recommended. It seems that both EFs are at the lower end of the range recently measured. There is not enough information to cross-check the proposed EF for uncontrolled domestic waste burning, or the EF for open burning of C&D waste.

Open burning processes	Air	µg TEQ/t
dl-PCB	median	mean
Forest fires	0.4	0.6
Uncontrolled domestic waste burning	0.8	24
Open burning of C&D wood	0.8	1.0

Table 3-10: Proposal for revised EFs for dl-PCB emissions from open burning processes (Rentz et al. 2007)

3.5 Releases into residues of dl-PCB

The amount of data for dl-PCB releases into residues is small. Few results are available for coal and wood combustion as well as for open burning of waste. EFs are provided separately for ashes and soot. Data are compiled in annex 1.4. There are no EFs for dl-like PCB emissions from domestic sources in the current UNEP/UNECE system.

3.5.1 Releases into residues for coal/coke combustion

Key message: Data are scarce. EFs into ashes range from 0.17 to 0.8 µg TEQ/t ash (median: 0.35 µg TEQ/t ash). EFs into soot vary between 5.02 and 38.02 µg TEQ/t soot (median: 16.3 µg TEQ/t soot). Values are in line with the proposal for revised UNEP EFs.

As illustrated in annex 1.4.1, information on dl-PCB releases from coal combustion is only available in the [Thanner & Moche 2002] study. EFs for coal/coke into ashes range from 0.17 to 0.8 µg TEQ/t ash (median: 0.35 µg TEQ/t ash). EFs into soot vary between 5.02 and 38.02 µg TEQ/t soot (median: 16.3 µg TEQ/t soot). [Rentz et al. 2007] suggest 0.3 µg TEQ/t mixed ash and 18 µg TEQ/t soot as appropriate EFs for a revised UNEP Toolkit, which is very much in line with the values above.

3.5.2 Releases into residues for wood combustion

Key message: EFs into ashes range from 0.1 to 4.9 µg TEQ/t ash with mean values of 0.23 and 1 µg TEQ/t ash. EFs into soot show a mean value of 14.16 µg TEQ/t soot. Values in the same dimension are proposed for a revised UNEP Toolkit.

EFs for releases into ashes range from 0.1 to 4.9 µg TEQ/t ash (see annex 1.4.2), with a mean value of 0.23 µg TEQ/t ash for the Austrian study and a mean of 1 µg TEQ/t ash for the Swedish study. EFs into soot are reported in the Austrian study, with a mean value of 14.16 µg TEQ/t soot. In the proposal for revised UNEP Toolkit factors for domestic heating and cooking, [Rentz et al. 2007] suggest 0.2 µg TEQ/t mixed ash and 15 µg TEQ/t soot. This appears to be at the lower end of the range identified above with respect to mixed ashes, whereas it is fully in line with the values for soot.

3.5.3 Releases into residues for open burning of waste

The data basis is limited to three measurements performed by Hedman et al. 2006 (see annex 1.4.3). EFs for releases into ashes account for 0.02 µg TEQ/t of waste combusted for garden waste and range from 0.2- 2.6 µg TEQ/t of combusted waste in the case of waste mixed with PVC.

3.6 Formation mechanisms and Influencing factors for PCDD/F and dl-PCB emissions

Key message: There is scarce specific information on domestic sources. As for industrial sources, organic compounds, chlorine and metals in the fuel foster dioxin formation, whereas sulphur is an inhibiting factor. Combustion conditions have a major influence. In this context combustion quality (correct oxygen supply, stable temperature and dry wood) are regarded as factors reducing the emissions. Nevertheless it is agreed that results are controversial and processes are not fully understood. Surrogate markers for combustion quality (CO, PM, PAH) seem not to be feasible indicators for dioxin emissions. Clear correlations could not be observed. Post-combustion events strongly influence study results. Especially condensation processes and memory effects have to be taken into account.

In the context of the present study in total 43 sources with information on the formation of PCDD/PCDF and dl-PCBs were analysed. In general, however, formation processes have not been investigated for domestic sources, but have intensively been discussed for waste incineration. Specific information about formation processes in domestic combustion was only included in 9 studies.

The data compiled in this report based on the literature analysis comprise approximately 190 stove-fuel combinations (excluding open burning of waste). Due to this huge range of study designs and a lack of details on fuels or appliances in a large number of studies, data in general due not allow a more detailed evaluation of potential correlations between fuels or appliances and PCDD/PCDF emissions. However, few of the mechanisms discussed can be confirmed by an analysis of the collected data.

PCDD/PCDF and dl-PCBs are colourless, odourless organic compounds containing carbon, hydrogen, oxygen and chlorine (halogenated aromatic hydrocarbons) formed as unintentional by-products or contaminants in thermal and certain chemical processes as well as produced naturally from volcanoes, bush and forest fires.

Based on the general knowledge on dioxin formation it can be concluded that in thermal processes there are two mechanisms at work which may result in PCDD and PCDF or dl-PCB emissions. In this context, the following parameters play an important role:

1. Presence of substances that enhance or reduce the formation
2. Combustion conditions that enhance or reduce the formation
3. Additional factors (e.g. post-combustion processes)

3.6.1 Substances that enhance and reduce the formation of dioxins

The formation of dioxins and furans can be enhanced by the presence of:

- Organic carbon (e.g. Nakao 2006)
- Chlorine (e.g. Thuß 1995/97, UNEP Toolkit)
- particles with a high surface area
- metals such as copper, chromium, nickel or cadmium (e.g. Öberg 2007, UNEP Toolkit)

On the other hand the formation of dioxins and furans is reduced by the presence of:

- Sulphur (e.g. Thomas & McCreight 2008, UNEP Toolkit).

The formation rate is especially high if there are elevated metal or chlorine contents at low sulphur levels. Especially the formation of PCDD seems to depend largely on the chlorine content of the fuel. This correlation can be confirmed by the data compiled for this report, where a weak correlation between PCDD/PCDF emission and the S/Cl-ratio in the fuels can be observed for wood and coal combustion. Especially clear correlations between PCDD/PCDF emissions and Cl levels can be observed for certain types of Polish and Czech coal. Elevated levels of chlorine or chlorine containing pesticides (50 times higher than in wood) are also used as explanation for elevated emissions from combustion of herbaceous biomass.

3.6.2 Combustion conditions that enhance or reduce the formation of dioxins

PCDD/PCDF and dl-like PCB present in the combusted materials are destroyed if the combustion takes place at sufficient temperature for a sufficient time.

On the other hand in general terms, the formation of PCDD/PCDFs and dl-PCBs is reported to be increased by poor combustion conditions with:

- low oxygen levels or incomplete mixing of fuel and oxygen (e.g. Enviros 2006, UNEP Toolkit)
- an increased level of moisture in the fuel (e.g. Enviros 2006, UNEP Toolkit);
- low flame temperatures (e.g. smouldering rather than full combustion) (e.g. Enviros 2006);
- temperatures of 200-650 °C in the post combustion zone (e.g. Enviros 2006, UNEP Toolkit)
- low residence times at high temperatures (e.g. Enviros 2006)
- low combustion efficiency (e.g. UNEP Toolkit)
- low firing rate (e.g. Pfeiffer et al. 2000)
- or a slow temperature quench/high temperature in the post combustion zone (e.g. UNEP Toolkit, Paradiž et al. 2008)

- high dust emissions (e.g. Thuß et al. 1997)

In addition a number of additional parameters have been mentioned in the Finnish presentation (Christina Saarinen) during the expert workshop:

- Manner of use (ignition, load size, manner and speed of refilling, skills of the user)
- Fuel characteristics (humidity, size, quality)
- Draught (weather, ventilation, stack)
- Combustion characteristics (temperature constancy (ignition, burning, ember phase), retention time, mixing, heat storing ability, location of fireplace in relation to heated space)

Especially PCDF emissions show some correlation with the quality of the combustion process in case of solid fuel combustion. Nevertheless it is agreed that the generation processes of PCDD/PCDFs are still not fully understood. Emissions vary largely in the course of a combustion process. Combustion processes consist of distinct phases and each phase has its specific PCDD/PCDF emission profile.

Especially disturbance in combustion conditions shall be a major parameter for PCDD/PCDF formation (e.g. Wikstrøm et al 2003). Even the simple stoking of the fire, usually required to keep the fire burning properly, may be a significant source of pollution increase, if frequently repeated. Consequently the EMEP-Emission Inventory Guidebook (EEA, 2006), clearly states that emphasis has to be given to start-up emissions and to proper assessment of their contribution to the average value as they significantly influence the emission of the total cycle. Hence automated combustion processes are more stable concerning emissions. Nevertheless study results are not consistent as concerns the effect on dioxins. This is mainly due to the high variability in combustion conditions and temperature in domestic settings, so that the experiences gained in industrial settings cannot be transferred directly to SCI. In the domestic setting some of the known parameter (e.g. combustion temperature) can affect the dioxin formation in the opposite direction than expected. This could be related to less evaporation of chlorine and copper, or just to a temperature in the chimney, which too low to promote PCDD/PCDF formation in the chimney. As the numerous parameter which affect the dioxin formation, also can affect each other, it is very difficult to find which one is the critical one for the formation of dioxin and to predict the results.

On the basis of the data pool compiled in this report neither for wood nor for coal, a clear tendency as function of the combustion conditions can be derived and there is no significant difference in resulting PCDD/PCDF concentrations which could be allocated to a certain type of appliance if an overall evaluation is performed. Results are overlapping and the variability between studies is much more important than the differences within one study.

A clear correlation between temperature in the heat exchanger and PCDD/PCDF emissions could not be confirmed from the 80-100 analyses [Launhardt & Thoma 2000, Erken et al. 1996, Quass et al. 2000] for which related information was available (see Figure 3-3). The different "PCDD/PCDF emissions at the same temperature, represent different types of coals (including polish and Czech coal) investigated.

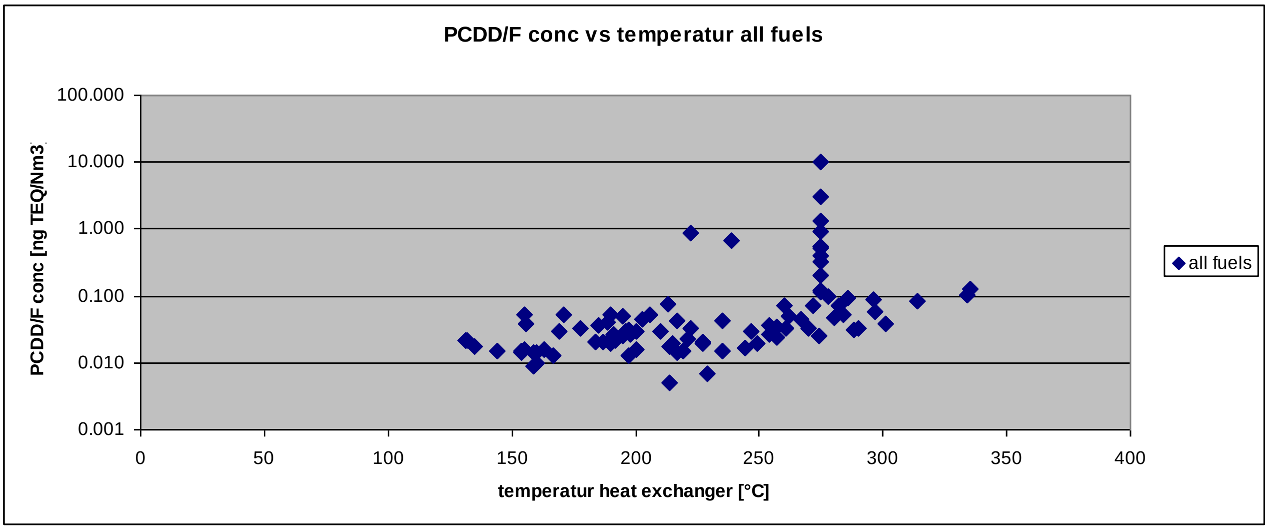


Figure 3-3: Correlation between temperature and PCDD/PCDF emissions from literature data

The only correlation that can be derived from the data base is the fact that there is a tendency to differences in emission rates between **stoves and boilers**, which can be explained by a lower and more stable temperature in boilers due to the higher firing rate. This is correlated to a temperature at the heat exchanger which already is below the critical temperature range in the post-combustion zone; (see above) resulting in lower PCDD/PCDF concentrations in the flue gas (see Figure 3-4).

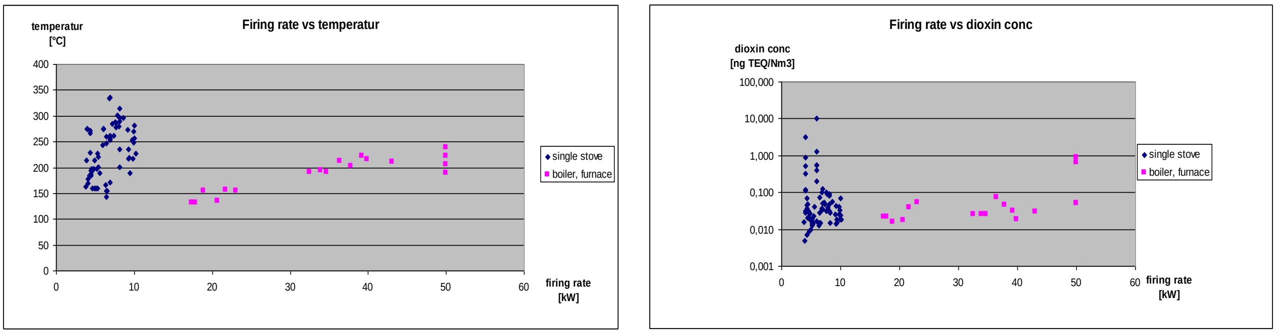


Figure 3-4 Correlation between temperature and firing rate or PCDD/PCDF concentration and firing rate

3.6.3 *Additional factors influencing measurement results*

Processes after the combustion itself (post-combustion events) strongly influence the quantity of PCDD/PCDFs measured in the exhaust fumes. For SCIs the “post combustion zone” is in the upper part of the stoves and in the chimney, and for boilers it is the water cooled surfaces of the combustion chamber and the chimney.

Insulation of the chimney prevents the cooling of the flue gas, and consequently preserves the flue gas temperature at a level (above 200 °C) which is favourable for the dioxin formation. This observation and the correlation to the temperature rather than the residence time in the chimney were clearly demonstrated in a recent JRC study by [Paradiž et al. 2008].

Condensation processes in the chimney and adsorption to soot may reduce the PCDD/PCDF concentrations in the exhaust gas (length of chimney as important parameter). Adsorbed dioxin can be released again, when temperature is high. Dioxin can also be formed in the chimney, on the particles in the flue gas as well as on the particles on the inside surface of the chimney, when the temperature is above app. 200°C. According to e.g. (Wikstrøm et al. 2003) the ash bound chlorine content alone is a sufficient chlorine source for PCDD/PCDF formation. Consequently *memory effects* from previous combustions are strong and may result in elevated PCDD/PCDF concentrations for days or weeks.

Apart from the other parameter mentioned above, ***study design*** (including sampling points and sampling conditions) was reported by experts to be therefore of high importance for achieved results. In order to avoid bias by memory effects it is recommended to first measure the "chimney history". To avoid bias from sampling points it is recommended to measure simultaneously at 400° and at the top of the chimney (see also chapter 3.1.2.).

3.6.4 Applicability of surrogate markers

A number of studies and participants at the expert workshop held in the framework of this project investigated and discussed, whether the mass emissions like CO and (particulate matter) PM levels in exhaust gases, which are used as quality of the combustion process in a household stove or boiler, can be correlated with PCDD/PCDF emissions.

On the one hand, new ovens tend to emit less PCDD/PCDF than old ones [e.g. Hübner et al. 2005, Gullett et al 2003, Hedman 2005]. On the other hand, low CO or PM levels in exhaust gases can still be associated with high PCDD/PCDF concentrations and vice versa in low oxygen due to a low temperature [e.g. Danish studies Schleicher et al 2002, Vikelsøe 1994, Launhardt & Thoma et al. 2000]. In other studies the PCDD/PCDF emission does not seem to have any correlation to the stove age, type of chimney, and combustion technique [e.g. Pfeiffer et al 2000] or between PCDD/PCDF formation and the temperature in the combustion chamber [e.g. Shibamoto 2007]. In general the current state of scientific knowledge concludes that CO and PM are useful indicators as to the quality of a combustion process but are inadequate to derive emission factors for PCDD/PCDF or to predict concentrations. Available data do not provide evidence for a correlation between PM/CO levels and PCDD/PCDF. Some investigation supports such a conclusion, and others don't, due to the fact that too many other parameters are affecting the dioxin formation.

3.7 Release pathways, environmental fate and health risks

Key message: Primary studies specifically investigating release pathways from domestic sources are scarce. Due to absence of flue gas treatment in domestic sources, air (exhaust gas) and ashes/soot are the only release pathways for domestic combustion sources. PCDD/PCDF and dl-PCB are very stable. These compounds are distributed through indirect routes via particulate matter and accumulate in the fatty tissue. PCDD/PCDF and dl-PCB are transported to all environmental compartments such as air, soils and sediments and plants. From there they accumulate in animals and humans. In soils and sediments, the half-life is assumed to be between 10 and 100 years. Contamination occurs essentially by deposition. Exposure of animals and humans is predominantly via food intake. Aquatic species accumulate more dioxins than terrestrial animals.

In general, there are no primary studies specifically investigating release pathways from domestic sources. General information on release pathways however is well-known and can be extrapolated to domestic sources. The analysis and discussion of release pathways, environmental fate and health risks are not within the focus of this study and will be restricted to the more general information available.

PCDD/PCDF and dioxin-like PCBs generated during combustion of solid fuels, biomass or wastes are primarily released via air (bound to particles) and as residual contamination in ashes. In the case of flue gas treatment devices, the POPs are accumulated in filter ashes and to a smaller extent in scrubbing waters. Given the fact that domestic combustion or open burning comprises processes without flue-gas treatment, air (smoke) and ashes/soot are the only ***release pathways*** in this case. One study [Lohmann et al. 2000] specifically assessing the role of the domestic burning of coal and wood on ambient levels of PCDD/Fs and PCBs, concluded that low-chlorinated PCDFs and dl-PCBs #126 and #169 measured in ambient air were indicators for contribution from domestic burning. Local sources were estimated to account for 25% of the TEQ in the air.

A JRC study [Christoph et al. 2006] investigated impacts of PCDD/PCDF emissions from domestic sources on environmental pollution. In this context less then 1% of the PCDD/F-concentrations in air were detected in the gas phase. The study observed that emissions from domestic heating are released near the ground due to the shorter chimneys and thus only lead to local contamination. Furthermore it could be shown that domestic combustion resulted in higher PCDD/PCDF concentrations per unit mass PM10 in ambient air during wintertime. Based on the observations made the study concludes that reduction measures targeted towards particulate matter will reduce at the same time the levels of PCDD/PCDFs originating from combustion, which have been shown to be predominantly particle bound.

The ***environmental fate*** of chemicals describes the processes by which chemicals move and are transformed in the environment. These processes depend on persistence in air, water, and soil; reactivity and degradation; migration in groundwater; removal from effluents by standard waste-water treatment methods; and bioaccumulation in aquatic or terrestrial organisms [US EPA 1996].

The physico-chemical characteristics of PCDD and PCDF are closely linked to the degree of chlorination of their aromatic structures. Chemical characteristics include low water solubility, high lipid solubility, high molecular masses and low volatility. This lipophilic character enables them to cross cell membranes and accumulate in the fatty tissue of the organism. Due to their low volatility, these compounds are not transported directly through the environment, but are distributed through indirect routes via particulate matter, and are transported through the food chain. PCDD/PCDF and dl-PCB are transported to all environmental compartments such as air, soils and sediments, plants and animals and also accumulate in humans.

PCDD/PCDFs are stable up to 800°C and are not totally destroyed until 1,300°C. In the environment, photolysis is one of the rare degradation processes. Photodechlorination appears to be the most important of these reactions. In addition, microorganisms such as bacteria, yeast and fungi can metabolise them. The ***cumulative and toxic properties*** of PCDD/PCDFs depend closely on the number and position of the chlorine atoms in the two benzene rings. Of the 210 congeners theoretically present in the environment after emissions, only the 17 compounds substituted in positions 2,3,7 and 8 (that is, 7 PCDD congeners and 10 PCDF congeners) are the object of intense accumulation in living organisms, where they undergo a slow biological decay that varies according to the type of congener (more rapidly for PCDFs than for PCDDs and also for low chlorinated than for highly chlorinated ones).

In surface ***soils*** (a surface layer of 1 to 2 cm at maximum) the ***half-life*** is assumed to be in the order of 10 years and for the vegetal soil layer about 100 years irrespective of the congener. Contamination occurs essentially by the deposition of atmospheric particles. The vertical migration of PCDDs and PCDFs in soils is minimal, and more than 90% of these compounds are found in the first 10 cm of topsoil. Contamination of ***sediment***, like that of soils, depends on the pollution sources, the distance between the sampling area and the point sources, the circulation of water masses, and the dilution capacity of the fresh or salt-water systems. Data on plant contamination vary geographically as well as by the product sampled. Conifer needles, cabbage or grass are often selected as sentinel species for atmospheric deposition. Vegetables can be contaminated by various routes of exposure and penetration. Generally however, atmospheric deposition is the principal pathway, whereas the transfer from roots to leaves is negligible.

As regarding ***exposure of animals and humans***, food exposure appears absolutely predominant, compared with other sources it is >95%. With respect to animals, aquatic species (fish, molluscs and crustaceans) accumulate more dioxins than terrestrial animals (e.g. cows, pigs, and poultry). Gastrointestinal absorption of dioxins is generally substantial, with bioavailability ranging from 60% to 90% in animals and humans. Capacity for elimination is low and varies from one species to another. Lactation is a major route for excretion. Fat mobilization during lactation accounts for the high dioxin levels found in milk and milk products. Experimental and field data make it possible to establish transfer coefficients between the various compartments (air, soil, grass, fat, milk).

Health risks from PCDD/PCDFs and dl-PCB for the general population generally result from dietetic exposure so that it cannot be specifically allocated to domestic sources. Health risks that are discussed include carcinogenic effects, dermatological effects, endocrine disruption,

neurological and neurodevelopmental and reproductive effects. Specific information about "health risks" from domestic sources is included in two literature sources from Germany [Wrbitzky et al. 1998, Beyer et al. 1997]. Studies revealed that PCDD/PCDF levels in chimney sweepers differ significantly from the collective of the not occupationally exposed population due to the occupational contact with the relatively high contaminated soots.

A JRC study [Christoph et al. 2006] investigated impacts of PCDD/PCDF emissions from domestic sources on environmental pollution including the bio-availability of particle bound PCDD/PCDF. The study concluded that the comparably high PCDD/F concentrations found in ambient air of the Krakow/Malopolska region observed especially in winter time do not result in enhanced PCDD/PCDF levels in the Malopolska ecosystem and are also not associated with elevated levels in human milk. This is explained by the fact that particle bound PCDD/PCDF shows a low bio-availability.

3.8 Conclusions on relations between releases into air and into residues, and between PCDD/PCDF and dl-PCB

Key message: In domestic combustion up to 90% of the overall PCDD/PCDF releases are into air. A comparison of the relative contribution of dl-PCB to the overall TEQ releases is hampered by a lack of data for dl-PCB. A minor importance of dl-PCB in air emissions from coal and wood in comparison to PCDD/PCDF is suggested in the two studies making simultaneous measurements. A systematic investigation into these relations would consequently be recommendable to allow for final conclusions.

3.8.1 Shares of air emissions and releases into residues for PCDD/PCDF

A comparison of available data on PCDD/PCDF emissions into air and releases into residues from domestic combustion of solid fuels is provided in Figure 3-5.

Comparison of PCDD/PCDF air emissions and releases into residues for domestic combustion

Coal	Air: coal/coke means 20 - 400 µg TEQ/TJ High chlorine coal means 1,000 - 8,500 µg TEQ/TJ Residue: 0.2-3 µg TEQ/t (ash) mean 569 µg TEQ/t (soot)
Wood	Air: means 13-270 µg TEQ/TJ (mostly 30-130 µg TEQ/TJ) Residue: 0.3- 8 µg TEQ/t (ash) mean 489 µg TEQ/t (soot)
Other Biomass	Air: 500 and 950 µg TEQ/TJ (suggested 450 µg TEQ/TJ) Residues: 8-24 µgTEQ/t (ash) 400-4,000 µg TEQ/t (soot)
Waste	Air: 0.42-31 µg TEQ/t (garden waste) 230 – 13,000 µg TEQ/t (mixed, PVC) Residue: 0.1-0.3 µg TEQ/t waste (garden waste) 100-2,400 µg TEQ/t waste (mixed, PVC)

Figure 3-5: Comparison of PCDD/PCDF air emissions and releases into waste from domestic combustion (literature search results)

For comparison of air emissions and releases into residues it has to be taken into account that air emissions are related to the caloric value of the combusted fuel, whereas the releases into residues are expressed per tonne of residue (ashes and soot) generated during the process. Consequently, all releases have to be transformed by appropriate factors into releases per tonne of fuel combusted.

Investigated studies in general do not provide information on the amount of ashes generated during a domestic combustion process, but the project team has calculated average figures in the framework of a previous project on POP levels in various types of residues[5].

Within the framework of the project work, the generation factor for ashes during domestic combustion has been identified as 0.1 tonne ash/tonne coal and 0.017 tonne ash/tonne wood. The amount of soot generated during domestic combustion is 0.0006 tonne ash/tonne coal and 0.0003 tonne ash/tonne for wood.

Fuel	EF Air µg TEQ/t fuel	EF Bottom ash µg TEQ/t fuel	EF Soot µg TEQ/t fuel
Normal coal/coke	Means 0.4 – 8.8	0.02 – 0.3 (mean 0.16)	0.34
High chlorine coal	22-187	1.7	
Wood	0.18 – 3.8	0.03 – 0.8	0.15
Herbaceous biomass	7.2 – 13	>0.8 – >2.4	>0.12 – >1.2
Open burning garden waste	14.4 - 31	0.1 – 0.3	n.a.
Open burning MSW	3.5 – 240	100 – 2,400	n.a.

All together, releases into residues from coal combustion range from 0.36 – 0.64 µg TEQ/t coal. When comparing maximum values, the share of releases into residues from domestic coal combustion is 6.8%. With mean values the share is 10%. This is also valid for open burning of garden waste where the share of releases into residues is roughly 10% as well. Results include some uncertainty, as the number and origin of data differs and means are partly compared with min-max values, but data are sufficient to provide information on the dimension of the repartition.

Releases into residues from wood combustion range from 0.18 – 0.95 µg TEQ/t wood. When comparing maximum values, the share of releases into residues from domestic wood combustion is 20%. With mean values it is 22%. The same applies for other biomasses where a share of ~20% can be identified as well.

5 "Study to facilitate the implementation of certain waste related provisions of the Regulation on Persistent Organic Pollutants (POPs)" at http://ec.europa.eu/environment/waste/studies/index.htm

3.8.2 Relative contribution of PCDD/PCDF and dl-PCB to total TEQ

Due to a lack of data for dl-PCB, the assessment of the relative contribution of PCDD/PCDF and dl-PCB to the total TEQ releases of domestic sources is problematic and associated with considerable uncertainty.

Air emissions

A direct comparison of dl-PCB and PCDD/PCDF emissions has only been made in the studies from Thanner & Moche 2002 (AT) and from Hedman et al. 2006 (SE). In the Austrian study a major difference in air emissions has been observed for CZ and PL coal. In these measurements dl-PCB EFs averaged around ~500 µg TEQ/TJ whereas mean PCDD/PCDF EFs into air were 1,500 – 8,805 µg TEQ/TJ. The difference was still existent but far less pronounced for wood, where dl-PCB EFs of 2-30 µg TEQ/TJ are contrasted by PCDD/PCDF EFs of 20-690 µg TEQ/TJ. Some difference was also identified in the Swedish study, where dl-PCB EFs for wood combustion ranged between 1.4 – 236 µg TEQ/TJ, while PCDD/PCDF EFs were 85-786 µg TEQ/TJ. These study results would consequently suggest a minor importance of dl-PCB in air emissions from coal and wood in the dimension of 10%. In a overall comparison of available data, the dimension of differences is lower due to the effect of variability between study results. But also in this comparison it becomes obvious that dl-PCB contributes less to the overall TEQ than PCDD/PCDF. A further confirmation of this observation should be sought by routine simultaneous analysis of the two compounds in measurement activities.

Releases into residues

As in the case of air emissions, a direct comparison of releases can only be made for the studies from Thanner & Moche 2002 (AT) and from Hedman et al. 2006 (SE). In the Austrian study the concentrations in ashes (incl. soot) ranged from 0.2 to 39 µg TEQ/t for dl-PCB and from 1.9 to 980 µg TEQ/t for PCDD/PCDF in the case of coal combustion. For wood combustion the observed concentrations in the Austrian study ranged from 0.16 to 16 µg TEQ/t for dl-PCB and 0.1 – 700 µg TEQ/t for PCDD/PCDF in ashes. The values in ashes from wood combustion were confirmed in the Swedish study.

3.9 Uncertainty evaluation of literature data

The literature search showed that few studies can be identified in addition to those evaluated for the development of the UNEP Toolkit and the UNECE Guidebook or as covered in a number of previous review reports. In general, it can be observed that there is a rather homogeneous pool of studies available which is used as basis for all estimation work. Apart from some additional and new studies, the scientific studies investigated for, and evaluated in this report are almost identical to those used for the generation of EFs in the international estimation tools (UNECE Guidebook and UNEP Toolkit). Only few studies cited in the international estimation tools, such as those of [Bremmer et al. and Thomas et al. (UNECE Guidebook), LUA 1997, Wunderli et al. 1996, Dumler et al. 1995 (all UNEP Toolkit)] have not explicitly been evaluated in this report but even those have been taken into account in the discussion in chapter 3.

Thus conclusions with respect to uncertainty of EFs relate similarly to the international estimation tools and this report. In general, it can be stated that the uncertainty of EFs is considerable, because the number of samples for specific fuels is generally quite limited in the individual studies. Based on the primary studies investigated in this report, it can be concluded that the number of analysis in most cases is <20 and often even <10 for a given type of fuel. Furthermore, uncertainty is high because of the large variability of study designs which represent an important parameter for observed results. In addition, the reliability of EFs suffers from the variability of PCDD/PCDF emission during domestic combustion processes (especially if manually fed) and the fact that emissions depend strongly on the operators' behaviour which is difficult to control.

This fact has already been stated in the UNECE Guidebook, which attributes the lowest category of reliability D ("an estimate based on single measurements, or an engineering calculation derived from a number of relevant facts") to EFs for domestic combustion. It was also noted and discussed in previous studies on POPs where the high level of uncertainty was mentioned as a major factor for the considerable uncertainty of emission estimates. This comprised studies such as the one on "Identification, assessment and prioritisation of EU measures to reduce releases of unintentionally produced/released Persistent Organic Pollutants" [BiPRO 2005], the "Study to facilitate the implementation of certain waste related provisions of the Regulation on Persistent Organic Pollutants (POPs)" [BiPRO 2006], or the "Dioxin Emission Inventory in Candidates Countries" [Pulles et al. 2005].The report on "Uncertainties of Dioxin Emissions in Central Europe" [Pulles et al. 2006] concluded on the basis of scenarios for the domestic sector and a Monte Carlo analysis of all major sources that the 90% confidence interval for the percentage contribution of small non-industrial sources to the total emissions lies between 7% and 70% percent.

4 Current state of estimation of dioxin emissions from domestic sources

This chapter provides an overview of the current state of practice as concerns estimation of PCDD/PCDF and dl-PCB emissions from domestic sources. The description includes a compilation of the methodologies and a specification of emission factors (EFs) and activity rates (ARs) applied as far as information has been available.

Reporting requirements and nomenclatures used in International Conventions

Emission inventories are to be drafted by Member States pursuant to a number of international obligations. In this context standard requirements and harmonised nomenclatures for source sectors have been drawn up.

The *Convention on Long Range Transboundary Air Pollution (LRTAP)***,** with the Aarhus Protocol on Heavy metals and POPs requests the use of the EMEP/CORINAIR Emission Inventory Guidebook (UNECE Guidebook) and the use of Selected Nomenclature for sources of Air Pollution SNAP. This nomenclature defines 11 main source categories (level1). Parties to the Convention are requested to submit annual emission data for various POPs for level 1 but are also invited to report emissions of more detailed sub-groups (SNAP level 2)[6].

The *United Nations Framework Convention on Climate Change (UNFCCC)* requests parties to report on greenhouse gases, using the IPCC Guidelines on reporting and a common reporting format CRF[7].

In the process of harmonisation of reporting requirements for parties to different international Conventions the two systems have been adapted and harmonised, so that they are made fully compatible with SNAP 97 and IPCC 1996. In 2001 the UNECE Task Force on Emission Inventories and Projections (UN/ECE TFEIP) developed the NFR (*Nomenclature For Reporting)* source sector classification system for the Reporting Guidelines with a correlation between the SNAP, NFR and CRF/IPCC reporting source categories. A transposition table between relevant SNAP and IPCC codes is presented in Annex 2.1.

[6] http://reports.eea.europa.eu/EMEPCORINAIR4/en/BNPA_v3.1.pdf
[7] (http://www.unfccc.int/resource/docs/cop5/07.pdf

Focus and results of data collection from EU Member States

Key message: In total 23 Member States provided information. PCDD/PCDF emissions into air are generally included, whereas dl-PCB and releases into water and waste are currently not covered. Reporting on mobile sources and open burning of waste is scarce.

Information collection on the state of estimation of dioxin emissions in EU Member States was based on a questionnaire developed for this purpose by the project team (for more details see annex 6) and subsequent expert interviews which have been conducted to refine received information or to close open gaps. Investigations comprised information collection on applied estimation methodologies, EFs and ARs. MS were asked for information as concerns reporting on residential combustion, mobile sources in household & gardening and open burning of waste.

It is noteworthy that cooperation of addressed Member State authorities was high. More than 85% of the questionnaires were answered.

Hence evaluation of the status quo in estimation for domestic emissions of dioxin and reduction measures in the domestic sector could be based on responses to the questionnaire responses of 23 Member States. These have been refined and additional information could be collected by numerous expert interviews.

Both topics where in addition further discussed and specified in an expert workshop attended by more than 40 experts from science, industry and authorities (for more details on presentations, results and participants see annex 7 to this report.

Based on the collected information it can be concluded that in general, Member States include *estimations for PCDD/PCDF* emissions from domestic sources in their emission inventories, but the level of detail varies (see chapter 4.1). Only Greece, Portugal and Spain reported (oral communication) that estimates for domestic sources are not included in the National Emission inventory. No information on the issue could be gathered from Malta and Latvia.

On the contrary, *emission estimates for dl-PCB* are generally not included in current National Emission Inventories. Annual releases for small-scale combustion have only been estimated by SE.

Major information sources for National Emissions are the Inventory reports provided to EIONET CDR. A compilation of relevant links to the latest MS inventories is provided in Annex 2.2.

4.1 Source types and appliances included in national emission reporting for the “residential” sector

Key message: The majority of MS currently reports with summary figures in SNAP 0202 or 1A4b without further differentiation into emissions from different appliances. This level of detail does not allow drawing conclusions on major sources and appropriate measures for emission reduction from domestic sources.

LRTAP and UNFCCC foresee categories **IPCC 1A4b/SNAP 0202** (residential plants) and **SNAP 0809** (household & gardening) for reporting on emissions from the residential sector. SNAP 0202 is further differentiated into combustion plants >50 MW (020201), boilers <50 MW (020202), gas turbines (020203), stationary engines (020204) and **other equipments such as stoves, fireplaces, cooking, etc (020205)**. IPCC 1A4b is further divided into **1A4b i** “Residential plants” and **1A4b ii** “Household and gardening” covering non-commercial machinery and off-road vehicles.

Current state of reporting

After evaluation of the answers it can be stated, that a majority of MS currently reports on domestic PCDD/PCDF emissions without further differentiation.

SNAP 0202 is the categorisation reported by FR, IT, PL, RO, SI, UK. Residential in this case is interpreted as households. A comparable level of detail is achieved in a number of other Member States (CY, CZ, EE, LV, NL and SK) reporting their emissions as category **1A4b or 1A4b(i)**. In these cases estimations are only calculated on the basis of sum figures for fuels without further differentiation into different appliances.

If SNAP 0202 is further differentiated, it mostly specifies emissions for **020202** (boilers <50 MW) and **020205** (stoves, fireplaces) such as in AT, BE-WA, DE and SE. Boilers <50 MW (020202) and stationary engines (**020204**) are the sources covered in the reporting from DK.

Mobile sources in household and gardening (1Ab4ii or SNAP 0809) are generally not included in the reporting as a separate source category for PCDD/PCDFs. Only DE does a separate calculation for mobile sources in household and gardening. FI include the reporting on this source in category 1A3 “Transport” whereas BG, DK and PL include it in 1A3e/SNAP 0810 “other off road”.

A compilation of the source allocation in various Member States is provided in Annex 2.3.

Relevance of domestic heating

In assessing inclusion of domestic heating in emission inventories, it has to be taken into account that regular heating is not required in Mediterranean Member States such as Malta, Portugal, Spain, Greece, and southern Italy. If heating is necessary it was reported to be mainly performed by gas or electrical heating appliances, that would result in low dioxin emissions. On the other hand open fires clearly have a higher importance in these Member States than in central or northern European countries, and an increasing use of oil seeds has

been reported by CY. Furthermore considerable amounts of wood combustion in the domestic sector have been allocated to Mediterranean MS in a recent project on firewood technology in the EU[8] (see also chapter 4.7.2).

Unreported additional sources

Apart from NL and CY, none of the MS reported on PCDD/PCDF emissions from charcoal combustion for barbeques. As Cyprus reports on an important share of PCDD/PCDF emissions from **charcoal consumption,** it is further investigated whether charcoal consumption could be more than a negligible source if reporting was extended (see Table 4-1)

The EF of 70 µg TEQ/t charcoal used by Cyprus appears very high, even more as Danish investigations into emissions from charcoal combustion [Schleicher et al. 2002] resulted in an EF in the dimension of 5-15 µg TEQ/t.

The information available from the NL is an annual PCDD/PCDF emissions from barbeques of 22 mg/a, based on an EF of 0.02 µg I-TEQ/tonne meat consumed and a yearly meat consumption in the country of 84 kg/cap.

Based on the Energy Statistics Database of the United Nations Statistics Division, annual charcoal consumption in EU Member States varies from 13 kg/capita in CY to 0.2 kg/capita in HU with an EU average of 3.1 kg /capita. Calculated with an EU Population of 493 Mio inhabitants and the different EFs indicated above, the following results are extrapolated at EU scale.

EF applied	PCDD/PCDF emission
70 µg TEQ/t charcoal	106 g TEQ/a.
0.02 µg I-TEQ/t meat	0.68 g TEQ/a
5-15 µg TEQ/t charcoal	7.5-22.5 g TEQ/a

Table 4-1: potential annual PCDD/PCDF emissions from charcoal combustion in EU 27

As illustrated, there is a wide range of potential PCDD/PCDF emissions from charcoal use, from important to negligible, depending on the approach taken. Hence it could be recommendable to perform a further investigation into this issue.

PCDD/PCDF emissions due to **evaporation from PCP-treated wood** are another "forgotten" domestic source. Emissions occur due to the fact that technical PCP as used for impregnation contains 14% of other substances including traces of PCDD/PCDF developed during the formation process of PCP. Hence PCP is generally accepted as precursor substance for dioxins. Dioxins can be generated during combustion of treated wood but emissions can also occur due to simple evaporation. An annual evaporation rate of 0.5% of the original dioxin content can be expected according to a Danish survey of dioxin emission from PCP-treated wood [Danish EPA 2006]. Only NL reports this type of emissions in the domestic sector. Reporting is based on an evaporation model extrapolating emissions from historic consumption data (banned in the NL since 1989). According to this model, air

8 www.eufirewood.info

emissions in the NL were in the dimension of 18 g TEQ/a in 2004. An extrapolation of these releases with the EU population of 493 m inhabitants would result in recent emissions for EU 27 of roughly 550 gTEQ/a. An extrapolation with Danish figures from 2004 (0.2 – 4.9 g TEQ/a) would result in emissions of roughly 250 g TEQ/a (range 18 – 447 g TEQ/a) in the EU. These figures contain an important uncertainty, because the use of PCP-treated wood in domestic construction works, was not equally spread throughout the EU, but was more common in Atlantic climates with moderate temperature and frequent rains. Nevertheless, some investigation into this issue might be of interest also for other MS.

Conclusions on current reporting

With the current level of detail, reporting on PCDD/PCDF emissions from domestic sources in the vast majority of Member States is not sufficient to draw detailed conclusions on the major sources for PCDD/PCDF emissions from domestic sources. It does not allow a differentiation by type of appliance but only by type of fuel. There is an important lack of reporting on mobile sources and potential additional sources such as charcoal combustion or evaporation from PCP or other pesticide-treated wood in domestic dwellings that need further clarification and harmonisation to avoid both over- and underestimates. Information on dl-like PCBs is almost non-existent. Nevertheless, an assessment of major sources can be performed on the basis of information on activity data and the exemplary information on specific emissions from single Member States, which can be assumed to be transferable to other countries.

4.2 Status of MS reporting on open burning of waste

Key message: Estimations for PCDD/PCDF emissions from open burning of waste has only been performed by eight MS, but even there the level of detail and type of waste covered varies. Lack of reliable data is the reason reported from other MS for not compiling estimates.

Apart from stationary appliances for heating or cooking purposes or machinery allocated to the IPCC category “residential”, domestic PCDD/PCDF emissions can also occur via waste burning habits from Member State residents. As combustion conditions are often poor and the material burned may be a mixture of various kinds, this might be considered an important source for PCDD/PCDF emissions from the domestic (non-industrial) sector. On the other hand, knowledge on the importance of this sector throughout the EU is still limited and information is not easy to obtain. Consequently, the information collection of the current state of emission estimation for this source category is of low priority.

Reporting on this source could be performed in SNAP 090402 (unmanaged waste disposal) corresponding to IPCC 6A2, SNAP 0907 (open non-in field burning of agricultural waste) corresponding to IPCC 6C (waste incineration), SNAP 1103 (Forest and other vegetation fire) without a corresponding IPCC code or in SNAP 1003 corresponding to IPCC/NFR 4F4 (Field burning of agricultural wastes).

Current state of reporting

Based on the reported information from the large majority of Member States (23 out of 27) reporting on this source in the EU is incomplete. DE and the UK included more comprehensive information on different types of open burning of waste in their inventories. IE focuses on illegal backyard burning. BG only estimates emissions from burning of agricultural wastes, PL reports on agricultural, landfill and forest fires and SE has rough estimates for illegal burning of municipal waste. IT reported to provide estimates for the waste and agricultural sectors, without specifying the SNAP category. BE-FL provides annual emission figures of PCDD/PCDFs from backyard burning of waste (55% of the annual total). All other Member States do not have estimates at all. This is in part justified by the fact that waste combustion and backyard burning is prohibited but in general it is mainly due to the fact that reliable figures and statistical data are not available. Annex 2.5 provides a compilation of the original information reported by Member States.

4.3 Applied estimation methodologies

Key message: The UNECE Guidebook and the UNEP Toolkit are the international tools providing the methodological framework for estimation for dioxins emissions from domestic sources. In this context it can be stated that the majority of MS uses the EMEP-CORINAIR methodology compiled in the UNECE Guidebook. As EMEP-CORINAIR currently does not foresee reporting on releases into water and waste, there is almost no MS reporting in these fields.

In general, Member States apply the EMEP-CORINAIR methodology to estimate PCDD/PCDF emissions. For emission estimation the methodology offers a simple approach using default EFs for coal, gaseous fuels, liquid fuels and wood; generally covering a variety of subtypes of fuel in each category and not differentiating between diverse types of appliances. Apart from this, the methodology foresees a more sophisticated approach using specific EFs by type of appliance, including even specific types of advanced combustion techniques. The methodology however, does not provide EFs for releases into water, residues and land. Due to a lack of representative, own measurement data, releases to land and water are thus generally not estimated. A compilation of the provided information is presented in Annex 2.6.

Differences in methodologies for estimation

Whereas the basic methodology is largely the same and is restricted to air emissions, Member States tend to partly or completely use their own EFs based on measurement or literature search in order to better adapt the estimate to their specific situation. A quantitative comparison of the emission factors applied is performed in chapter 4.4.

A complete set of MS own EFs is used by CZ, DE, FR and NL. Own factors for wood have been developed for AT and BE-FL. BE-BCR uses a specific EF for coal combustion and PL uses the EFs calculated in the European Dioxin Inventory (2000) to estimate emissions from diesel and coke. CY, EE, HU, LV, LU, RO, SI and SK are using the default emission factors provided in the UNECE Guidebook. EFs from the UNEP Toolkit are reportedly used by BE-FL, EE and IE.

The use of own emission factors or calculation models is performed in particular for solid fuels such as coal and wood but can be extended to liquid and gaseous fuels as well. The range of EFs applied is especially large in the field of solid fuels, and for wood in particular. This fact has not been seen as a major problem by MS representatives in the expert workshop performed within the framework of this project, but it has an important impact on the comparability of data compiled at the EU level. The CZ reportedly used its own estimation model, which however is in fact a specific logarithm for calculation of the activity rates (see Annex 2.10), based on CHMI project data (Emission inventory for domestic heating by small sources since 2001 (P. Machalek, J. Machart, CHMI, 2003

So far only CY and RO reported on emission estimation and emission factors for releases into land/residues, wherein the UNEP Toolkit is used as an estimation tool.

4.4 Current Use of EFs for domestic cooking and heating

Key message: The UNECE Guidebook and UNEP Toolkit provide sets of EFs to be used for domestic emission estimates. Whereas the UNEP Toolkit only differentiates by fuel, the UNECE Guidebook provides specific EFs for different types of domestic appliances. In addition, the POP Protocol presents some EFs. In addition MS have developed National EFs for their reporting. Such EFs are especially common for solid fuels and vary over a wide range without satisfying explanation in a number of cases.

More information exchange on applied EFs would be thus highly recommendable to increase comparability of results. EFs would need to be elaborated further on an international scale (UNECE and/or UNEP). In addition efforts might need to be strengthened to establish reporting on releases into waste.

Estimation of PCDD/PCDF emissions from domestic sources is based on emission factors either generated at Member State level based on scientific studies and measurement activities, or literature search, or compiled in the international estimation tools, e.g. the UNECE Emission Inventory Guidebook, third edition, December 2006[9] and is in the following referred to as UNECE Guidebook (2006), and the Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases – Edition 2.1, December 2005, prepared by UNEP Chemicals, Geneva[10] hereinafter referred to as the UNEP Toolkit (2005).

This chapter provides a compilation and an overview of the emission factors provided in the established estimation tools as well as of the factors used in the various Member States by type of fuel, in order to allow a direct comparison as well as an evaluation of the range of factors applied.

4.4.1 Determination of EFs in international estimation tools

UNECE Guidebook:

The Guidebook chapter "non-industrial combustion" sources covers emissions from small combustion installations, with a thermal capacity ≤50 MW_{th}, excluding industrial sources. However, due to the fact that some industrial sources of a lower capacity might have very similar emission characteristics to the ones described as "medium size boilers", the data might also be used as defaults for these sources.

Default emission factors are reported to be estimated representative values derived from collected data as well as national expert judgements. Namely the following studies were used:
[Thanner G. et al. 2002, Hobson M et al. 2003, Davies et al 1992, UNEP Chemicals 2003, Geueke K-J. et al 2000, Pfeiffer et al .2000, Grochowalski 2002, Kubica 2002 and 2003, Williams et al. 2001, Quass et al 2000, Kakareka 2003, Casserini et al. 2003, Lee et al. 2005, Gullet et al. 2003, and Hübner et al. 2005]. A detailed compilation of EFs used is provided in Annex 2.7.

9 http://reports.eea.europa.eu/EMEPCORINAIR3/en/page002.html
10 www.pops.int

Within the sector "Residential," activities are further sub-divided into:

- fireplaces,
- stoves,
- small boilers (single household/domestic heating) – indicative capacity <50 kWth,
- medium size boilers (<50 MWth),
    - manual feeding (indicative capacity <1MWth),
    - automatic feeding,

Due to the variety of fuels that can be used and the differences in combustion technologies from very simple to sophisticated, these appliances result in different emission level for PCDD/PCDFs although flue gas treatment is generally not performed in any of the small appliances. According to the UNECE Guidebook, the different types of appliances can be characterised as follows (see also chapter 3.3.4.1. of UNECE Guidebook 2006):

1. Fireplaces: Simple radiation device used as supplemental heating appliance primarily for aesthetic reasons. Can be subdivided into solid or gas fuelled, open, partly closed and closed; constructed as brick/cut stone or cast iron/steel. Open fireplaces usually have a very low efficiency and significant emissions, partly closed fireplaces are retrofitted with doors and other devices to increase their efficiency. Closed fireplaces have doors, systems for air distribution and discharge of exhaust gases. Efficiency is >50% with similar emissions to stoves, so that they can be rated in the same category.

2. Stoves: Stoves are mainly simple combustion devices (radiation or heat storing) used for heating and cooking purposes Conventional up-draught stoves, using only primary supply air from below corresponding to over-fire boilers have an efficiency of 40-50%. This technology is used in the majority of older appliances and is associated with higher emissions. Classic energy efficient stove have an efficiency of 55-70% and lower emissions due to secondary air supply (down-draught combustion technology corresponding to under-fire boiler). Advanced stoves are characterised by multiple air inlets and pre-heating of secondary air and achieve 70% efficiency at full load and lower emissions. Pellet stoves are equipped with a fan and air supply control system to improve combustion conditions, resulting in high efficiency 80-90% and low emissions. Heat storing stoves achieve efficiency of 60-80%.

3. Boilers: Boilers have a nominal capacity of 12-50 kW and are wide spread in temperate regions. According to the combustion process applied boilers can be differentiated into over-fire boilers (cheap simple) and under-fire and inverse-fire boilers (advanced boilers) with increasing combustion efficiency. The simplest boilers are over-fire boilers for wood logs. The principle is that combustion takes place in the whole fuel batch as in wood-stoves with only primary air supply. Combustion in the cheap and simple over-fire boilers is not optimal and efficiency is similar to conventional stoves. In under-fire boilers the fuel is burning mainly from the bottom with also secondary air supply. The under-fire boiler can normally be switch between under-fire and over-fire by a flue gas valve. In advance under-fire coal boiler gasification and partial combustion takes place in the bottom of the fuel storage and the final, major combustion takes place in a separate combustion chamber. Inverse-fire or down-draught boilers have the primary combustion air supply above the fuel This group of boilers comprises downdraught wood boilers as state of the art for lump wood, stoker coal burners for coal with high efficiency in wide

load range and wood pellet boilers with high efficiency and emissions comparable to liquid fuel boilers. Combustion in under-fire and inverse fire boilers is more stable resulting in higher efficiency and lower emissions. Besides combustion technology, a differentiation can be made with respect to the feeding of boilers and stoves into overfed (the fuel is fed from above into the combustion chamber) and underfed (the fuel is fed from above into the combustion chamber). These differences in technology are especially important and used in modern automated biomass or coal (retort boilers) fired appliances.

UNEP Toolkit:

The “Toolkit” is designed as a simple and standardized methodology for compilation of consistent national and regional PCDD/PCDF inventories. According to its description it is a screen, not an exhaustive registry, and speed and ease of use have been deemed more relevant than the unattainable goal of 100% accuracy. It is important to know that the Toolkit is designed to be applicable to all countries and default EFs have been developed for use by countries that do not have their own measured PCDD/PCDF data. The Toolkit factors are designed for worldwide use. Thus they contain classes for low and no control processes (based on data from early stages of PCDD/PCDF measurement) and tend to represent simple devices, namely for solid fuels. The Toolkit recommends to use local measured data where available side-by-side with default EFs in order to help to refine and improve the Toolkit for use in other countries.

The emission factor for each class represents the best estimate (medians or means) based on measured data at existing sources with similar technology, process characteristics, and operating practices. The vast majority of emission factors are based on published data found in peer-reviewed literature or in governmental or institutional reports. In order to make the emission factors user-friendly, manageable, and robust, it was necessary to aggregate these original data into order of magnitude estimates (for the majority of the classes within the subcategories).

The category “Heat and Power Generation” contains besides subcategories “Fossil fuel fired power plants”, “Biomass power plants” and “Landfill biogas combustion” the residential categories:

- Household heating and cooking (biomass)
- Domestic heating (fossil fuels)

For household heating and cooking with biomass, EFs were derived from studies carried out in AT, BE, DK, DE, NL, SE, CH and the UK (no specific references stated). In this context, according to the explanation in the Toolkit it is shown that the main difference for emissions was the purity of the fuel. (virgin biomass or contaminated biomass such as treated and/or painted wood or straw heavily impacted with chlorinated pesticides) and that the number of data to calculate EFs for other biomass was very limited.

With regard to combustion of fossil fuels, the EFs reflect the assumption that reasonably well-operated and maintained heating appliances are used in order to maximise the heat output. In this context, central heating systems (modern, highly efficient and fairly clean burning) and individual stoves (small furnaces but with air circulation system inside) are differentiated. Central heating systems are generally fired with gas or oil. Coal is mainly used in individual stoves. It is assumed that only coal leads to PCDD/PCDF releases into ashes.

(For details on backgrounds to EFs see chapter 3.

POP Protocol Annex IV:

Annex IV to the POP protocol provides information on ranges of PCDD/PCDF concentrations in exhaust gas from wood combustion. No references are presented for the origin of concentrations and EFs recommended for use.

4.4.2 Emission factors provided in international estimation tools

The UNECE Guidebook 2006 and the UNEP Toolkit provide a range of default emission factors for domestic combustion of different fuels. Whereas the emission factors in the UNECE Guidebook are restricted to air emissions, the UNEP Toolkit in addition offers release factors for residues. The POP Protocol in its Annex IV provides average emission concentrations and EFs for domestic combustion of charcoal and wood.

A comparison of the emission factors recommended in the international estimation tools is provided in the following tables. In order to highlight differences and similarities in EFs suggested for use, the compilation of data is performed by type of fuel. Additional details on the UNECE factors are provided in Annex 2.7.

Interpretation of the default EFs for 1A4bi in the UNECE Guidebook

In order to make a correct interpretation of the level-one default emission factors in the UNECE Guidebook, it has to be taken into account that for the calculation of the level-one default emission factors for residential sources (NFR: 1A4bi) in the UNECE Guidebook the share of fireplaces, stoves and boilers was assumed as:

- 5% fuelled by solid coal fuels
- 65% fuelled by biomass
- 30% fuelled by gaseous fuels

EFs for the mix calculation were taken from the detailed methodology tables. In this context within solid coal fuels about 5% was assumed to be briquettes. Concerning liquid fuels it was assumed that 10% was used in stoves and 90% in boilers. It is important to know that advanced stoves and boilers were not taken into consideration for the calculation of the EF for the overall category “residential”, as it was assumed that their share is currently lower than 5% in most of the countries.

Consequently, the recommended figures tend to significantly over-estimate emissions in all MS with a lower share of biomass-fired appliances or with advanced stoves and boilers in place.

EFs for coal combustion in international estimation tools

Table 4-2 presents a summary of EFs for domestic coal combustion as recommended in the international estimation tools.

Coal µg I-TEQ/TJ	Residential 1A4bi	Stove	Advanced stove, fireplace, small boiler <50 kW	Medium size boilers 50 kW -1 MW	Advanced manual boilers <1 MW	Medium size boilers 1-50 MW	Advanced automated boiler*	Power plant/boiler
UNECE Guidebook	800	1000	500	400	200	100	40	
UNECE Guidebook coal briquettes		300	200	100		2		
UNEP Toolkit Coal		100						10
UNEP Toolkit High chlorine coal		12,000						50

Table 4-2: Overview of EFs for domestic coal combustion in international estimation tools
* includes 12-50 kW (see UNECE Guidebook 2006 chapter SCI and this report chapter 4.4.1)

As illustrated in the table, the UNECE Guidebook tries to differentiate between various types of combustion technology and recommends lower EFs for briquettes, whereas the UNEP Toolkit is restricted to a differentiation between high chlorine and normal coal. The recommended EF for normal coal is low in comparison to the UNECE Guidebook. In absolute figures it reflects the level of a medium size boiler in the UNECE Guidebook.

In Poland low EFs for automated boilers have been measured for typical single household retort stoker boilers 25 - 30 kW (see also Kubica K. (2002/3): “Low emission coal boilers as alternative for oil and gas boilers for residential and communal sectors; Coal hasn’t to contaminate” Katalog ochrony środowiska – Ekoprofit nr 1 (61)/2002, Katowice, 2002 (Polish), Krystyna Kubica, Procc. of the 2007 ICCST, The University of Nottingham,UK 28th – 31st August 2007).

According to oral communication with Mrs Kubica these EFs are achievable with all standard nominative capacities of single household retort stoker boilers.

EFs for wood combustion and other biomass in international estimation tools

An overview on EFs proposed for domestic combustion of wood and other biomass is presented in Table 4-3.

EFs for wood in international estimation tools

UNECE µg I-TE/TJ	1A4bi	fireplace stove		Boiler			Pellet	Automatic
Wood*	700	800	300	500	300	200	50	30

* = Wood, peat, wood wastes and agricultural wastes (straw, corn cobs, etc)

UNEP Toolkit	Stove µg TEQ/TJ	Power plant/boiler µg TEQ/TJ
Clean wood/biomass	100	50
Mixed biomass		500
Contaminated wood/biomass	1,500	

POP Protocol	Air µg TEQ/TJ
Natural wood (beech)	12 - 70
Wood chips forest	43 - 140
Chipboard	16 -50
Urban waste wood	1400 - 9400

Table 4-3: Overview of EFs for domestic wood combustion in international estimation tools

As illustrated above there is a significant difference between the EFs recommended in the UNECE Guidebook for conventional technologies on the one and pellets and automated devices on the other side. In this context it should be noted that recommended EFs for manually fed devices, the UNECE Guidebook factors seem to reflect the upper edge of literature data compiled in chapter 3. This can be explained by the fact that EFs shall also reflect real life practice (possibly partial co-combustion of waste or contaminated wood or badly maintained appliances) associated with higher emissions than laboratory scale measurements (see also 3.1.2).

EFs in the UNEP Toolkit and EFs recommended in the Aarhus POP Protocol appear to be low in relation to the UNECE Guidebook, except of those for contaminated wood. It is noteworthy that the Toolkit factor is at the low edge of the range proposed in the POP Protocol.

EFs for liquid fuels and gas in international estimation tools

The compilation of recommended EFs for liquid fuels and gas shows the far lower variability of emissions expected in these cases.

Liquid fuels µg TEQ/TJ	1A4bi Residential	Domestic stoves	Boilers (all sizes)	Power plant/boiler
UNECE Guidebook*	10	10	10	
UNEP Toolkit heavy fuel				2.5
UNEP Toolkit oil shale				1.5
UNEP Toolkit light fuel				0.5
UNEP Toolkit oil		10		

* = Liquid fuels: Gas oil (gas/diesel), fuel oil (residual oil, residual fuel oil)

Table 4-4: Overview of EFs for domestic combustion of liquid fuels in international estimation tools

Gaseous fuels µg TEQ/TJ	1A4bi Residential	Domestic stoves	Boilers (all sizes)	Power plant/boiler
UNECE Guidebook*	0.5	1.5	2	
UNEP Toolkit		1.5		0.5

* = Gaseous fuels: Natural gas, liquefied petroleum gas (LPG), other

Table 4-5: Overview of EFs for domestic combustion of gaseous fuels in international estimation tools

4.4.3 EFs applied by MS for reporting on domestic coal combustion

Key message: EFs applied by MS vary over a wide range (multiplier 500), what complicates the interpretation of MS reporting. Without thorough justification of the EFs applied, significant distortion can occur which considerably reduce the reliability of documented data. The lack of information from 9 MS is another deficit which should be clarified. EFs for charcoal are scarce and diverging. Hence information exchange on EFs applied should urgently be intensified to allow better interpretation and eventual harmonisation of estimates.

Results on application of EFs for coal

X 500

- EFs applied in MS: 4 µg TEQ/TJ (FI, LT) to 2,150 µg TEQ/TJ (BCR)
- MS tend to use lower factors than UNECE level 1
- UNECE factor (800 µg TEQ/TJ): BE-WA, DK
- UNEP factor (100 µg TEQ/TJ): BE-FL

Literature: means 20 - 400 µg TEQ/TJ
(Polish coal 1,000 – 8,500 µg TEQ/TJ)

EFs applied by EU Member States partly reflect corresponding studies

Surprisingly low factors:

RO, EE: 70 µg TEQ/TJ,
BG: 60 µg TEQ/TJ (anthracite)

FI, LT: 4 µg TEQ/TJ

PL: coke 26 µg TEQ/TJ

Important differences: Charcoal

CY: 70 µg TEQ/TJ

NL: 0.02 µg TEQ/ton meat

DK: 5-15 µg TEQ/t charcoal

Figure 4-1: Ranges of and interrelations between currently applied EFs for domestic coal combustion

Currently used emission factors as reported by Member States are presented in Table 4-6. The majority of MS does not differentiate EFs by type and technical standard of the heating devices as foreseen in the UNECE Guidebook, nor are open fireplaces calculated separately. In most cases, one overall emission factor for all stationary residential combustion uses is presented. From a number of Member States additional specifications on fuels covered by one EF have been provided.

Coal		1A4bi Residential µg TEQ/TJ	Domestic stoves µg TEQ/TJ	Small boiler (<50 kWth) µg TEQ/TJ
UNEP Toolkit	Coal and high chlorine coal		100-12;000	
UNECE Guidebook	Coal and briquettes	800	300-1,000	40-500
POP Protocol Annex IV	Charcoal	12 -70		
AT		380		
BE-FL	Coal	100		
BE-WA		800		
BE-BCR		2150		
BG	Anthracite/hard coal	66*		
	Brown coal/lignite	218**		
CY	Charcoal [µg TEQ/t charcoal]	70		
CZ	Hard coal and coke	185*		
	Brown coal/lignite	319**		
DE	Briquettes brown		30	30
	Anthracite (raw, briquettes, coke)		40	60

Coal		1A4bi Residential µg TEQ/TJ	Domestic stoves µg TEQ/TJ	Small boiler (<50 kWth) µg TEQ/TJ
DK	Coal, coke, petroleum coke	800		
	Charcoal [µg TEQ/t charcoal]	5-15		
EE		70		
FI		4		
FR	Coal	385		
FR	Patent coal	312		
IE	Anthracite, Lignite, Bituminous coal, petroleum coke, coke	200		
IT (Lombardy 1999)		87*		
LT	Hard coal	2.4		
	Brown coal	4.5		
NL	Coal		66.7*	
	Briquette		25**	
	Charcoal for barbeque [µg TEQ/t annual meat consumption]	0.02		
PL	Hard coal	416*		
	Coke	26***		
	Brown coal	900**		
RO			70	
SK	Hard coal	146		
	Brown coal	225		
UK	Hard coal	87*		
	Coal	120**		
	Coke, petroleum coke	104***		
	SSF			

* = caloric value 24 MJ/kg; ** caloric value 20 MJ/kg; *** = caloric value 23 MJ/kg (original data in annex 2.8)

Table 4-6: PCDD/PCDF emission factors for domestic combustion of coal currently used in EU Member States

Based on the reported data, emission factors applied in EU Member States range from 4 µg TEQ/TJ to 2,150 µg TEQ/TJ, which is more than a factor of 500.

Member States generally use lower factors than the UNECE Guidebook default factor. This is partly the result of a mixed calculation taking into account the shares of conventional and advanced installations. In addition, it can be observed that a considerable distinction is made in a number of Member States between brown and hard coal.

Emission factors below 100 µg TEQ/TJ are applied by DE, Flanders, BG (hard coal), EE, PL (coke) and UK (hard coal). Extremely low factors have been reported by FI and LT.

On the other hand the Brussels Capital Region (BCR), which calculates with the highest emission factor reported and except for Poland using a slightly higher factor for brown coal. A direct application of the UNECE level 1 factor seems to take place only in the Walloon Region and in Denmark.

A comparison with national measurement studies (see chapter 3.2.1) shows that EFs currently applied are partly consistent with these (e.g. DE, AT, UK). EFs used by CZ and PL somehow reflect the elevated chlorine content of some local coal types used.

4.4.4 EFs applied by MS for reporting on domestic wood combustion

Key message: There is an important range of EFs applied (factor 30) and 11 MS did not report EFs for wood, although wood or other biomass was/is a traditional fuel in rural areas almost all over Europe. MS tend to use lower EFs than UNECE default factors. Similar to the situation for coal, the range of EFs can have a considerable impact on the reported annual PCDD/PCDF emissions from domestic sources in a MS. Thus an intensified exchange on the EFs applied would be urgently requested to increase reliability for annual reporting.

Results on application of EFs for wood

- EFs in MS: 20 µg TEQ/TJ (FI) to 700 µg TEQ/TJ (BE)
- MS generally use lower factors than UNECE level one
- UNECE factor (700 µg TEQ/TJ): BE-WA, BCR
- UNEP factor (100 µg TEQ/TJ): IE, SK

X 30

Literature: Medians 13 – 270 µg TEQ/TJ (mostly 30 – 130 µg TEQ/TJ)
(up to 5,000 µg TEQ/TJ in bad conditions or for contaminated wood)

Major national studies consistent with EFs currently applied

Important differences: Peat
IE: 200 - 500 µg TEQ/TJ
EE: 100 µg TEQ/TJ
FI: 17.5 µg TEQ/TJ

Surprisingly low factors:
FI: 21 µg TEQ/TJ
BE-FL: 1.2 – 9.9 µg TEQ/TJ

Figure 4-2: Ranges of and interrelations between currently applied EFs for domestic wood combustion

Currently used emission factors as reported by Member States are presented in Table 4-7. As illustrated, one overall EF is presented by most of the MS. From a number of Member States additional specifications on fuels covered by one EF have been provided.

Wood		1A4bi Residential µg TEQ/TJ	Fireplace µg TEQ/TJ	Domestic stoves µg TEQ/TJ	Small boiler (<50 kWth) µg TEQ/TJ
UNEP Toolkit	Clean wood			100	
UNEP Toolkit	Contaminated wood/biomass			1,500	
UNECE Guidebook	Wood	700	800	800	500
POP Protocol Annex IV	Natural wood	12-70			
POP Protocol Annex IV	Wood chips	43-140			
POP Protocol Annex IV	Chipboard	16-50			
POP Protocol Annex IV	Urban waste wood	1,400-9,400			
AT		25.2 Central heating		750	380 Apartment heating
BE-FL	Wood untreated (89%)		9.9	1.2	
BE-FL	Wood treated (11%)		165	87	
BE-WA		700			
BE-BCR		700			
CZ		397**			
DE				40	40
DK	Wood	419			
	Straw	500			
EE	Wood, waste wood, peat	100			
FI	Wood	21			
FI	Peat	17.5			
FR		20-100			
IE	Wood	100			
IE	Sod peat	500			
IE	Peat briquettes	200			
IT Lombardy	Wood			170°	30°°
LT		90			

Wood		1A4bi Residential µg TEQ/TJ	Fireplace µg TEQ/TJ	Domestic stoves µg TEQ/TJ	Small boiler (<50 kWth) µg TEQ/TJ
NL	Wood			300	
	Domestic waste burning			12,400	
PL		357*			
RO	Fuel not specified				100
SK		100*			
UK		171*			

* = caloric value 14 MJ/kg; ** calculated with 12.6 MJ/kg as indicated in national report (original data in annex 2.9)

Table 4-7: Current PCDD/PCDF emission factors for domestic combustion of wood and related fuels in EU Member States

Lombardy region: ° = also for open fireplace, traditional stove, °° = closed fireplace or insert, 3 µg TEQ/TJ for innovative low emission system and boiler, pellets plant or BAT system burning wood; BAT pellets plant.

Emission factors applied in EU Member States range from 20 µg TEQ/TJ to 700 µg TEQ/TJ which is more than a factor of 30. In relation to the emission factor from the UNECE Guidebook it can be stated that Member States in general use lower factors in their calculations. To some extent, the EFs provided seem to be the result of a mixed calculation, based on calculated shares of conventional and advanced installations. (In Denmark for example the EF of 419 µg TEQ/TJ is due to an increased use of pellets in the last few years.) Emission factors of 100 µg TEQ/TJ or lower are applied by DE, Flanders, EE, FR, LT and SK. In Flanders the emission factors for wood have been calculated as an average of literature data and are summarized in a study for the Environment, Nature and Energy Department of the Flemish government (2001-2002).

As far as can be concluded from the figures, the UNECE level 1 default emission factor is applied only in the Walloon Region and the Brussels Capital Region. Noteworthy are also the considerable differences in EFs for peat applied by FI, IE and EE.

4.4.5 EFs applied by MS for reporting on domestic liquid fuel combustion

Key message: MS reporting on domestic "oil" combustion is often based on EFs from the international estimation tools. Nevertheless, the EFs applied show a variation factor of almost 20. Information is missing from 14 MS.

Results on EF for liquid fuels

- EFs: 0.5 µg TEQ/TJ (FI) to 25 µg TEQ/TJ (IT, LT)
- UNECE default (10 µg TEQ/TJ): BE, DK, EE, IE, RO
- EFs <5 µg TEQ/TJ : AT, DE, CY, FR

X 20

Literature: 0.5 - 20 µg TEQ/TJ (single measurements)
median for oil 2.5 µg TEQ/TJ

Figure 4-3: Ranges of and interrelations between currently applied EFs for domestic combustion of liquid fuels

With respect to liquid fuels the UNECE Guidebook 2006 provides one single emission factor to be applied for all different types of domestically used boilers or stoves. The same emission factor is recommended by the UNEP Toolkit for use of domestic stoves, whereas considerably lower emission factors are provided for combustion of heavy fuel in power boilers and for combustion of oil shale in fossil fuel fired power plants. Emission factors reported as currently used by Member States are presented in Table 4-8.

Tool/Member State		1A4bi Residential µg TEQ/TJ	Domestic stoves µg TEQ/TJ	Small boiler (<50 kWth) µg TEQ/TJ
UNEP Toolkit	Heavy fuel			2.5**
UNEP Toolkit	Oil shale			1.5**
UNEP Toolkit	Light fuel			0.5**
UNEP Toolkit	Oil		10	
UNECE Guidebook	Liquid fuels			
POP Protocol Annex IV		n.d.		
AT		1.5 (light)		
AT		1.7 (other)		
BE-FL		10		

Tool/Member State		1A4bi Residential µg TEQ/TJ	Domestic stoves µg TEQ/TJ	Small boiler (<50 kWth) µg TEQ/TJ
BE-WA		10		
BE-BCR		10		
CY		2.3*		
CZ		11.6*		
DE	Light and petrol			3.0
DK	Residual oil, gas oil, kerosene	10		
EE	Jet fuel, shale oil	10		
FI		0.5 (light)		
FI		0.4 (heavy)		
FR		5		
IE	Gas oil, kerosene, LPG	10		
IT (Lombardy 1999)		25*		
LT		25		
RO	Diesel		10	

* = caloric value 42.7 MJ/kg

** = power plant/boiler no quantification of size

Table 4-8: Current PCDD/PCDF emission factors for domestic combustion of liquid fuels in EU Member States

As illustrated in Table 3-12, only 13 Member States provided information on emission factors used. The range of emission factors applied is 1.5 µg TEQ/TJ to 25 µg TEQ/TJ, which corresponds to a factor of almost 20. While five Member States (BE, DK, EE, IE, RO) reported the use of 10 µg TEQ/TJ in their calculations, remarkably lower emission factors are used by FI and AT.

On the other hand CZ, which reported the emission factor in µg TEQ/tons, seems to use a slightly higher factor for calculation, whereas an EF, which is considerably higher than the UNECE default factor has been reported by LT and IT. CY reported the use of the UNEP Toolkit factor for diesel 4-stroke-engines as a default factor, because domestic heating is mainly performed by combusting diesel oil.

EFs from measurement data (see chapter 3.2.3) are in the same dimension as the EFs recommended in the international estimation tools. However, the difference between EFs for oil and gas as given in the estimation tools cannot be fully confirmed by the compiled data.

4.4.6 EFs applied by MS for reporting on domestic gas combustion

Key message: EFs for gas are very low compared to solid fuels, and the range of applied factors is small. Reporting seems to be largely based on EFs from the international estimation tools But there is lack of reporting from 17 MS, which is a gap in the dioxin emissions inventory that would benefit from being clarified. One reason could be reporting under 1A4a or 1A1a due to the fact that heat is mainly produced in a district heating plant and not in the single household

Results on EF for gaseous fuels

- EFs: 0 µg TEQ/TJ (BE-BCR, FR) to 2.5 µg TEQ/TJ (AT)
- UNECE residential default EF (0.5 µg TEQ/TJ): BE-WA, FI
- No information on EFs applied: BG, CY, FI, HU, IT, LU, PL, NL, SE, SI, PT, ES, MT, GR

Literature: 0.5 - 20 µg TEQ/TJ (single measurements)
median for gas 1.9 µg TEQ/TJ

Figure 4-4: Ranges of and interrelations between currently applied EFs for domestic combustion of gaseous fuels

For gaseous fuels, the UNECE Guidebook 2006 provides three different emission factors to be applied for the different types of domestically used boilers or stoves. Surprisingly, the default factor for the residential sector is lowest, and the one for fireplaces and domestic stoves is lower than for medium size boilers. Currently used emission factors as reported by Member States are presented in Table 4-9.

In general, emission factors are not differentiated by type of appliance nor are open fireplaces calculated separately, but one overall emission factor for all stationary residential combustion uses is presented.

Tool/ Member State		1A4bi Residential µg TEQ/TJ	Domestic stoves µg TEQ/TJ	Small boiler (<50 kWth) µg TEQ/TJ
UNEP Toolkit	Natural Gas		1.5	0.5 *
UNECE Guidebook	Gaseous fuels	0.5	1.5	2**
AT		2.5		
BE-FL		1.5		
BE-WA		0.5		
BE-BCR		0		
CZ		1.45***		
DE	Gas and liquefied gas			1.7
DK	Natural gas, LPG,	2		
EE		1.5		
FI	Natural gas	0.5		
IE		1.5		
RO			1.5	
SK		1.45***		

Table 4-9: Current PCDD/PCDF emission factors for domestic combustion of gaseous fuels in EU Member States

* = power plant/boiler without specification of size; ** = medium size boilers 50 kWth – 50 MWth); *** calculated with a caloric value of 30 MJ/m³

As illustrated in the table, only 10 Member States provided information on emission factors used. Apart from Member States not responding at all, no EFs were reported by BG, CY, FI, FR, IT, LU, PL, SE and SI, UK.

Based on the reported figures, 2 Member States seem to use the UNECE level 1 default factor, whereas DK uses the factor for medium size boilers. On the other hand, the Brussels Capital Region calculates zero PCDD/PCDF emissions from combustion of gas based on a PARCOM recommendation. A comparable approach seems to be taken in the NL even though specific information has not been provided.

4.5 Current Use of EFs for mobile domestic sources

Key message: So far only DE reported on specific emission estimates for mobile domestic sources using the UNEP Toolkit factor for two-stroke engines. In addition only 3 MS summarise emissions under SNAP 0809 “other mobile sources and machinery” using Toolkit EFs for diesel and gasoline.

At international scale applicable emission factors are only provided in the UNEP Toolkit (2005) for the transport sector. Other international estimation tools do not contain EFs for this type of source.

4 stroke engine (µg TEQ/t)			2-stroke engine (µg TEQ/t)		Diesel engine (µg TEQ/t)	Heavy oil fired engines (µg TEQ/t)
Leaded	Unleaded	Unleaded with catalyst	Leaded	Unleaded		
2.2	0.1	0.00	3.5	2.5	0.1	4

Table 4-10: PCDD/PCDF emission factors into air for fuel combustion in mobile engines (UNEP Toolkit 2005)

As illustrated in Table 4-10, the UNEP Toolkit contains EFs for leaded and unleaded fuel, both for four and two stroke engines, diesel engines, and heavy fuel fired engines. Use of a catalyst shall result in the application of a lower emission factor.

4.5.1 EFs applied by MS for reporting on mobile domestic sources

As domestic mobile sources such as lawn mowers, chain saws, etc. use similar types of engines as road or other transport vehicles, EFs for transport are used for this sector in the absence of more specific EFs. DE is using the UNEP EFs for unleaded gasoline to approximate emissions from gardening equipment.

The other MS do not provide such specific emissions but just calculate summary emissions from gasoline and diesel consumption in other mobile sources and machinery including off-road vehicles on the basis of EFs for diesel and gasoline:

Member State (µg TEQ/t)	gasoline	diesel
BG	1.25	15.43
DK	0.21*	
PL	0.1	0.04

* = Energetic value 41 MJ/kg;

Table 4-11: Current PCDD/PCDF emission factors for fuel combustion in mobile domestic sources in EU Member States

As illustrated above, there is a considerable deficit in MS reporting on mobile domestic sources. Reporting should be performed by other MS as well. Further clarification and information exchange on this issue should be promoted.

4.6 Current Use of EFs for open burning processes

Key message: Only 6 MS report on open burning of waste. Applied EFs are derived from the UNEP Toolkit recommendations. The major problem in this sector is the generation of reliable activity rates. Information exchange on the generation of activity data would be helpful to complete the reporting in this field.

An overview on recommended EFs and literature data is provided in Figure 4-5.

UNEP Toolkit and MS reporting:

0.5 -30 µg TEQ/t (green waste, agricultural waste, bonfire)

300 µg TEQ/t open burning MSW

400 µg TEQ/t accidental fires

POP Protocol: 3,200 µg TEQ/t

Data compiled from literature:

1-30 µg TEQ/t for green waste and bonfire (30-1,900 µg TEQ/TJ*)

200-5,000 µg TEQ/t (20,000-500,000 µg TEQ/TJ**) for MSW or industrial waste especially if mixed with PVC or electronic scrap.

0.01-6,500 µg TEQ/t : Accidental burning of buildings

* With caloric value 14 MJ/kg; **with caloric value 10 MJ/kg

Figure 4-5: Overview on EFs determined in international estimation tools and literature for open burning processes

Open burning is a source category allocated to a separate category in MS reporting. Nevertheless it is a non-industrial source at least partly related to domestic activities and thus is covered in this project. Emission factors for estimation of PCDD/PCDF emissions from this source type are limited. There is no information in the UNECE Guidebook, but the UNEP Toolkit (2005) provides a series of emission factors for different types of anthropogenic open burning such as in field burning of agricultural wastes, landfill fires, accidental fires of building and vehicles and uncontrolled burning of domestic waste (backyard burning) or wood (burning of construction and demolition waste, bonfires).

			Open Burning Processes	Potential Release Route (µg TEQ/t)				
Cat.	Subcat.	Class	Sub-categories	Air	Water	Land	Product	Residue
6	**a**		**Fires/burnings – biomass**					
		1	Forest fires	5	ND	4	NA	ND
		2	Grassland and moor fires	5	ND	4	NA	ND
		3	Agricultural residue burning (in field), impacted, poor combustion conditions	30	ND	10	NA	ND
		4	Agricultural residue burning (in field), not impacted	0.5	ND	10	NA	ND
	b		**Fires, waste burning, landfill fires, industrial fires, accidental fires**					
		1	Landfill fires	1,000	ND	600	NA	600
		2	Accidental fires in houses, factories	400	ND	400	NA	400
		3	Uncontrolled domestic waste burning	300	ND	600	NA	600
		4	Accidental fires in vehicles (per vehicle)	94	ND	18	NA	18
		5	Open burning of wood (construction/demolition)	60	ND	10	NA	10

Table 4-12: PCDD/PCDF emission factors for open burning (UNEP Toolkit 2005)

In addition, Annex IV to the UNECE POP Protocol contains estimates for waste combustion in domestic firing installations. Average PCDD/PCDF concentrations in the exhaust gas are reported as 114 ng TEQ/m³ corresponding to an EF of 3,230 µg TEQ/t. This is a factor of ten higher than the value (300 µg TEQ/t) recommended in the UNEP Toolkit. (Given an average energetic value of municipal solid waste in the dimension of 10 MJ/kg, the factor corresponds to 300,000 µg TEQ/TJ).

The UNECE Guidebook provides an EF for open burning of agricultural waste of 10 µg TEQ/t.

4.6.1 EFs applied by MS for reporting on open burning of waste

As already mentioned in chapter 4.2, emissions from illegal burning of waste are generally not estimated in EU Member States and information on other types of open burning have not been explicitly requested as they are outside the investigation scope of this project.

Nevertheless, a limited number of Member States reported information in this field.

Member State (µg TEQ/t)	Accidental fires	Industry	Vehicles	On-field burning Agriculture, Forestry	Forest fires	Illegal burning of waste	Bonfires open burning of C&D waste
CY	250			30		300	60
DE	50 (Buildings)	550	10	5	5	300	
DE		250 (Farms)					
IE						300	

Table 4-13: Current PCDD/PCDF emission factors for open burning in EU Member States

Cyprus provides information on these emission sources under IPCC 4F (field burning of agricultural waste) and 6C (waste incineration). An EF of 30 µg I-TEQ/t is used for field burning of agricultural waste. This corresponds to the figure indicated in the UNEP Toolkit for category 6a3 (“Agricultural residue burning (in field) impacted, poor combustion conditions”). The EF for uncontrolled burning of domestic waste is used for open burning of domestic/municipal and aircraft wastes; for bonfires and open burning of construction waste, Cyprus uses the EF (60 µg TEQ/t) indicated for “open burning of wood”. The emissions from accidental fires are calculated by means of an EF of 250 µg/case, corresponding to a combined factor for vehicle and building fires.

DE provided emission calculations for all types of open burning; specifying individual EFs for accidental fires in buildings, industry, agricultural farms, vehicles, open combustion of biomass in gardening, agriculture and forestry and illegal burning of waste in its National Implementation Plan (NIP). IE reports information for illegal burning of waste under SNAP 090108. In 2005 it was estimated that approximately 38,000 tonnes of waste were burned leading to an emission of 11.4 g TEQ/a.

Reporting on releases into land or residues

Currently there is almost no reporting on releases into land or residues from open burning processes. Only Cyprus reports on releases to land (IPCC category 4F “field burning of agricultural waste”). The UNEP Toolkit EF of 10 µg TEQ/t is used for this purpose.

Consistency with measurement data from literature

The EFs for air emissions proposed in the UNEP Toolkit and used by MS obviously correspond well with the EFs (4-30 µg TEQ/t for open burning of agricultural waste and 4-240 µg TEQ/t for MSW) determined in literature for these types of combustion (see chapter 3.2.4). On the other hand the factor proposed in the UNEP Toolkit for combustion of MSW (300 µg/t) is at the lower end of the range of literature results (200-5,000 µg TEQ/t), whereas the EF provided for this type of process in Annex IV to the POP Protocol, corresponds well.

With respect to releases into residues, the consistency between measurement data from literature and UNEP toolkit factors is not complete. Literature data (0.01-0.3 µg TEQ/t for garden waste and 100-2,400 µg TEQ/t for PVC or MSW) tend to be lower for green waste, but higher for MSW combustion.

4.6.2 *Further information on open burning (without information on EFs applied)*

Only a small number of MS reports on emissions from illegal or open burning of waste.

IE: **11.4 g TEQ/y** (illegal burning of waste)
BE-FL: **23 g TEQ/y** (open burning of waste)
DE: **7g TEQ/y** (illegal burning of waste); 0.2 g TEQ/y open burning biomass
UK: **51.8 g ITEQ/y** (open burning of waste) including bonfires (6.8 g ITEQ)
SE: **0.001–1.2 g TEQ/y** (open burning of waste)

Figure 4-6: Overview of reported annual PCDD/PCDF emissions from open burning of waste in EU Member States

BE-FL reported for 2006 on regional emissions from open burning of waste in the dimension of 23 g TEQ/a, which corresponds to almost 55% of the regional PCDD/PCDF emissions.

In the UK small scale waste burning is very important with a total emission of 51.8 g ITEQ/a. This number includes burning of garden waste, burning of other domestic wastes, e.g. furniture in the garden, because of cost of transportation and disposal, bonfires (the November 5th bonfires may alone emit 6.8 g ITEQ), demolition waste burned in open fires at the place of demolition.

In SE resulting PCDD/PCDF emissions from open burning of waste are estimated at 0.001–1.2 g WHO-TEQ/y (the highest value (1.2 g WHO-TEQ/a) is based on burning of computer scrap; the second highest value is already 20 times lower 0.06 g TEQ/y). Resulting emissions of dl-PCB are estimated at 0.02–4 mg WHO-TEQ/y based on the combustion experiments.

PL reported that in 2003 the number of PCDD/F emissions increased by 11% mainly due to higher number of landfill and forest fires (SNAP11), and open burning of stubble, straw and waste land fires (SNAP10).

The range of annual total emissions is important, especially if correlated to the number of inhabitants. In this case the reasons are not the EFs used but differences between the activity rates attributed to this sector (see also chapter 4.7). Estimation methodology should be further discussed and spread to other MS, so that they can start reporting as well.

Conclusions: There is a major deficit in MS reporting on open burning of waste, although this activity is a major emission source for certain MS. Thus bias in annual emissions reporting can be assumed. Reporting should be performed by other MS as well. Further clarification and information exchange on this issue should be promoted.

4.7 Activity Rates

Figures for domestic fuel consumption in a given type of appliance are the second parameter necessary for the calculation of annual emissions. These activity rates (AR) are crucial for the reliability of estimates and for the importance of the sector in a MS. Hence this chapter presents information on the state of knowledge and approaches taken to generate AR as well as on the importance of different fuels in various MS.

4.7.1 Generation and application of activity rates

Key message: Activity data are the result of fuel consumption and composition of the appliance pool. In general calculation is performed by means of National Energy Statistics and/or statistics from energy providers (fuel consumption). Appliance pools are partly determined by means of Census information related to dwelling and housing types and annual sales figures for specific appliances. However, currently there remain important deficits in generation of AR, namely concerning specification of the appliance stock, wood consumption, fuel consumption for mobile sources and open burning of waste or other types of fires. An intensified information exchange on available methodologies and inclusion of specific guidance in the guidebook would be desirable to improve the reporting

18 Member States provided information on the generation of activity data. The results of the investigation are the following:

- Energy statistics are the major source of information
- Energy statistics are still the only source of information in quite a number of MS

On the other hand there are a number of good examples for more differentiated reporting on domestic sources. These techniques allow making use of the differentiated default EFs (stoves versus ovens and boilers; simple, old-fashioned versus modern advanced; manually fed versus automated) provided in the UNECE Guidebook and to include estimations for open burning of waste or emissions from charcoal consumption. The following specific information and examples for good practice in generating more detailed activity data was provided by MS:

1. Micro census and socio-economic survey data for differentiation into energy use by type of dwelling and heating (e.g. AT, BE (all regions), CZ, DE)
2. Register of installed appliances (DE) and projected boiler change rates (AT) for differentiation into type of appliance
3. Exclusion of all apartments with remote heat supply (district heating) from SNAP 0202 (residential) (CZ)
4. Calculation of wood consumption via random interviews with citizens and extrapolation (DK)
5. Calculation of wood consumption via survey on domestic wood use (IT)

6. Estimation of wood consumption by means of “heat deficit” derived from consumption data for fossil fuels and per capita energy need (SK)
7. Calculation of charcoal consumption via import statistics (CY)
8. Calculation of charcoal consumption via annual meat consumption (NL)
9. Assumed figure for open burning of C&D waste per construction site (e.g. Cyprus)
10. Calculation of accidental fires via fire fighters statistics (DE)
11. Estimation of open burning of biomass via separate collection rates, assuming burning of 0.01-1% (DE)
12. Estimation of illegal open waste burning as share of total waste incineration (1%) (SE)
13. Estimation of illegal waste burning of MSW as share (0.01-0.1%) of the annual generation figure (DE)
14. Estimation of illegal waste burning via difference between waste generation and waste collection quantities (e.g. IE)

A detailed compilation of the data sources used, or assumptions made with respect to shares of fuels and types of appliances as reported by the Member States is provided in Annex 2.10.

In addition a wood resource balance could be used as a valuable tool to assess all different sources and uses of wood as part of comprehensive assessments of bio-energy and sustainable wood supply. The study “Wood Resource Availability and Demands” (Mantau et al., 2008) uses a wood resource balance approach, but is approaching the limits of what can be achieved with data presently available internationally. In some cases national studies or datasets exist which are yet to be exploited, however, widespread weaknesses and gaps remain.

4.7.2 Relative importance of different types of fuel in the domestic sector in EU Member States

Key message: Reported shares of fuels in the domestic sector show a wide range between EU Member States. Apart from a group of MS with predominant use of liquid and gaseous fuels, there is a group of MS where solid fuels dominate in the domestic sector. Due to the high importance of the fuel shares on PCDD/PCDF releases, this is an important factor for the selection of appropriate reduction measures (see also chapter 6.2).

Per capita fuel consumption and PCDD/PCDF emission also vary over a wide range amongst MS, which partly can be explained by climatic conditions, living standard, fuel shares and technical standards. Data for wood combustion are elusive because not all wood that is combusted is commercially traded.

Heating needs and habits vary between EU Member States due to a range of parameters such as climatic conditions, technical standards and traditions. Consequently, the share and total consumption of fuel vary over a large range. Figure 4-7 provides an overview of the use of different types of fuels in EU Member States, which is an important parameter for PCDD/PCDF emissions and gives an indication of appropriate reduction measures.

Predominantly liquid and gaseous fuels	Gas 95%: NL Gas >60%: BE-BCR, CZ, SK, UK Oil and gas > 80%: BE-BCR, BE-WA, CY, DE, FR Oil and gas 60%-80%: DK and IE Coal <10%: CY, EE and SK Coal <1% BE, DE, DK, FR
Predominantly solid fuels	Wood and coal >90%: BG with wood contributing 73% Wood and wood waste ~80%, 4% coal, 2% peat: EE Coal (mainly hard coal) 55%, wood ~30%: PL

Figure 4-7: Overview of dominant fuel types in EU Member States

The share of different fuel types is an important factor for the overall emissions from the domestic sector in a Member State (see also chapter 4.4.2) and thus a crucial parameter in the decision on reduction measures to be taken. Table 4-14 provides a more detailed compilation of the share of different fuels in domestic energy consumption [TJ/a] as reported by 13 MS and 3 regions with the questionnaire.

MS	Gas [%]	Liquid fuels [%]	Electricity [%]	Wood [%]	Coal [%]	Other [%]
BE-BCR	62	23	15	0.9	0	0
BE-WA	37.8	55.5		5.17	1.5	
BG	7	0.2		73.3	19.5	
CY		94		0.5	5.5	
CZ	63	0.14		8.5	28	
DE	53	37.6		9.7	1.8	
DK	34.3	26.1		32	1.5	3.3 straw
EE	12.8			79.8	4.2	0.9 peat, 0.09 oil shale
FI	0.6	14	33	20 (incl. recycled fuels)	0.01	0.2 peat 33 district heat/heat pumps
FR	48.5	32		19.2	0.8	
IE	27.6	49.8		0.7	9.5	12.4 peat
IT (Lombardy)*		42		57	1.2	
NL	94	n.d.		n.d.	n.d.	
PL		16.5		28.2	55	
SK	70			24	7	
UK	69	8	22		1	

* by weight

Table 4-14: Overview of share of different fuels in energetic heat consumption in the residential sector (MS response)

As illustrated above, MS with a high share of gaseous and liquid fuels are associated with low PCDD/PCDF emissions and MS with a high share of solid fuel consumption in the domestic sector are associated with high emissions (see chapter 4.4.). In this second group, measures related to a change in fuel structure might considerably contribute to reduction of PCDD/PCDF emissions from the domestic sector, whereas corresponding measures will not be effective in MS pertaining to group one.

For other Member States that did not provide specific data with the questionnaire, some information on domestic fuel consumption could be derived from NIR (National Inventory Reports) and other sources. This provides additional data for AT, BE (total), HU, LU, PT, RO and SE. As illustrated, wood is an important fuel in AT, ES, PT, RO, SE and SI. Consumption data for SE appear to be very low. District heating is prevalent in this country and the fuel consumption for district heating might be reported under industrial heating instead of domestic heating.

MS	Gas [%]	Liquid fuels [%]	Electricity[%]	Wood[%]	Coal[%]	Other [%]
AT	22	22	22	22		11 district heat
BE	46	49		2.7	1.6	
ES				12-13% (increasing)		
HU	no differentiation for domestic sector					
LU	50	40				

MS	Gas [%]	Liquid fuels [%]	Electricity[%]	Wood[%]	Coal[%]	Other [%]
PT	8	39		53		
RO	33		12	33		20 district heat
SE	2.1	29.4		68.5		
SI *				26% (mainly cooking)		

Table 4-15: Share of different fuels in energetic heat consumption in domestic heating and cooking (NIR data)

* www.eufirewood.info

A compilation of absolute consumption figures by MS (reported data and data searched from other source) is provided in annex 2.11.

Per capita fuel consumption and PCDD/PCDF emissions

The level of the per capita fuel consumption in a MS is, first of all, a function of climatic conditions. But it can also be linked to heating habits, bad insulation or increased affluence. In any case it gives an additional indication of the potential effect of energy reduction measures, either by installation of modern appliances or by means of improved insulation and heating habits. Accordingly, per capita PCDD/PCDF emissions can reflect the shares of different types of fuel in domestic energy supply, the technical state of the national appliance stock, dwelling conditions and climate aspects. Both figures on the other hand can also give some indications on possible deficits or biases in reporting.

MS	Year	Fuel consumption [TJ/a]	Inhabitants [Mio]	Fuel consumption [GJ/a cap]	EMEP (CEIP) PCDD/PCDF g TEQ/a	PCDD/PCDF [µg TEQ/a cap]
AT	2006	268,109	8.3	32.30	27.08	3.26
BE	2006	316,737	10.5	30.17	36.38	3.46
BG	2006	32,346	7.7	4.20	70.75	9.19
CY	2006	3,964	0.76	5.22	0.7	0.92
CZ	2006	160	10.3	0.02	14.12	1.37
DE	2006	2,011,902	82.5	24.39	14.4	0.17
DK	2006	60,144	5.4	11.14	14.46	2.68
EE	2006	14,916	1.3	11.47	1.26	0.97
ES	2006	113,000	43.8	2.58	28.55	0.65
FI	2006	169,718	5.3	32.02	0.89	0.17
FR	2006		62.9		20.6	0.33
GR	?	11,397	11.1	1.03		
HU	2006	200.000	10	20.00	16.28	1.63
IE		125,142	4.2	29.80	7.55	1.80
IT	2006		58.8		31.39	0.53
LT	2006		3.4		9.38	2.76
LU	?	9,798	0.46	21.30		
LV	2006		2.3		3.18	1.38

MS	Year	Fuel consumption [TJ/a]	Inhabitants [Mio]	Fuel consumption [GJ/a cap]	EMEP (CEIP) PCDD/PCDF g TEQ/a	PCDD/PCDF [µg TEQ/a cap]
MT	?		0.4			
NL	2006		16.3		4.22	0.26
PL	2006	311,404	38.2	8.15	199.4	5.22
PT	2006	84,666	10.6	7.99	4.94	0.47
RO	2006	330,028	21.6	15.28	75.8	3.51
SE	2006	58,011	9	6.45	2.78	0.31
SI	2006	13,573	2	6.79	5.91	2.96
SK		83,252	5.4	15.42	3.65	0.68
UK		1,349,166	60.4	22.34	4.41	0.07
Totals Averages			492.92	14.67	598.14	1.24

Table 4-16: Overview of total and per capita fuel consumption and PCDD/PCDF air emissions in EU Member States

According to available data for domestic fuel consumption from a majority of MS, the mean fuel consumption in 2006 was 14.7 GJ/a. According to the figures, the country-specific consumptions range from 1.03 GJ/a in GR to 32 GJ/a in AT and FI. The figure of 0.02 GJ/a for CZ might be the result of the reported high level of "block heating" or district heating, leading to the situation that emissions are reported under industrial activity although the heat is delivered to households. The figure was not taken into account for the calculation of the average consumption..

Whereas figures for a number of countries such as AT, BE, DE, DK, FI, LU, IE, UK appear to be realistic given the climatic conditions, reported consumptions from a number of other Member States e.g. SE, PL, SI, BG appear to be very low. The same applies for a number of Mediterranean MS with considerable difference in reported consumption between e.g. PT and CY on the one hand and ES and GR on the other. Non-reporting (e.g. for private wood) or reporting under another category might be one reason behind.

With regard to annual per capita emissions of PCDD/PCDF, the EU average is 1.24 µg TEQ/a according to reported figures. The range between MS is from 0.07 µg TEQ/a in the UK to 9.2 µg TEQ/a in BG. Many of the figures appear to be plausible, such as lower per capita emissions in e.g. SE, NL, FI, DE, FR. On the other hand some of the figures (e.g. UK & FI versus NL, SK versus CZ or DK versus SE), appear to be inconsistent, even when taking into account differences in fuel shares or technical standards of domestic heating appliances. The application of differing EFs (see chapter 4.4.3 and 4.4.4), uncertainties of AR and differences in inclusion of minor sources are the major reasons behind. It is therefore recommended to exchange on this issue and eventually adapt reporting in these cases. Reduction measures can only be chosen on the basis of reliable consumption and emission figures (see also chapter 6.2).

4.8 Deficits and major obstacles for emission estimation from MS point of view

Key message: The high uncertainty level of the available EFs (due to lack of measurement data) and deficits in activity rates are the major obstacles for emission estimation reported by MS. The wide range of EFs applied by MS, the poor differentiation in reporting on PCDD/PCDF emissions from domestic sources, deficits in reporting on mobile sources and open burning of waste, lack of reporting for dl-PCB and lack of information on EFs or AR applied are other important deficits observed that hamper and impede the estimates.

Within the questionnaires, 16 MS and the three Belgian regions reported information on deficits and obstacles for emission estimation.

In this context, the high uncertainty of currently available EFs for dioxin emissions from the domestic sector is seen as a major problem. This deficit, which has been mentioned by AT, BE-FL, BE-WA, CY, CZ, DK, EE, SE, SI, is associated with a lack of measurement data. This lack of appropriate data and the need of such data to confirm or change current EFs was stated by AT, CZ, EE, FR, GR, IE, IT, PT, RO, SE, SK and the UK. In addition immanent problems of emission estimation in the domestic sector such as the high variability of emissions especially from manually fed boilers/stoves (AT, BE-FL, SE) and the difficulty to assess extent and effect of incorrect operation of coal and wood boilers (AT) were addressed and discussed.

Besides lacking and uncertain EFs and immanent problems of domestic combustion, MS regard difficulties with the generation of activity data as the other major problem that affects emission estimation in the field. Most important deficits and challenges are observed with decreasing importance in the fields of open burning processes (CY, IE, IT, PL, RO, UK), types of appliances (BE-WA, EE, FR, LU), domestic wood combustion (BE-FL, DK, IE) and technical standards of wood firing appliances (DK, FR).

Further specific aspects reported by single MS are lack of information on energy efficiency (CZ), difficulties to classify activities (namely open burning processes) (CY) and lack of data to assess activity rate for mobile sources (IE).

A detailed compilation of information reported by Member States is presented in annex 2.12.

5 Current state of Member State measures to reduce dioxin emissions from domestic sources

Key message: Except for bans of waste burning which are widely established, and awareness raising on open burning of waste and health risks, no direct dioxin related measure has been taken by MS. Measures in general are focussing on energy efficiency, good firing practice and renewable energy. Two MS promote research into flue gas cleaning. Other activities are destined to improve knowledge about dioxin emissions in the domestic sector.

This chapter provides a description and discussion of measures for reduction of dioxin emission in the residential sector taken in EU Member States. Investigations on approaches taken in EU Member States included different types of approaches such as implementation and enforcement of existing legislation, communication and educational measures including awareness raising or guidance on best practice, research and development measures, and economic incentives such as labelling, taxes or subsidies.

Information on the approaches and measures were collected by means of questionnaires sent to the authorities. Additionally, phone interviews were realized to obtain more detailed information on certain measures. Furthermore, in some cases specific information was searched for by means of internet sources given in the questionnaires and interviews. Results are based on questionnaires of 23 MS. No information was provided from Spain, Latvia, Malta and Portugal.

An overview on the types of approaches taken is provided in Table 5-1.

MS	Legislation/ Standards	Awareness raising	Research & Development	Labelling schemes	Subsidies programmes	Effectiveness
AT	x	X	x	x	x	x
BE-FL	x	X				
BE-BR	x					
BE-WA	x				x	
BG	x	X				
CY	x	X				
CZ	x		x			
DE	x	X	x	x	x	
DK	x	X	x	x	x	x
EE	x		x			
ES	No information available					
FI	x		x	x		x
FR	x	X		x	x	x
GR	No measures have been taken					
HU	No information available					
IE	x	X				
IT	x					
LT	No measures have been taken					
LU					x	
LV	No information available					
MT	No information available					
NL	x	X				
PL	x	X	x	x	x	x
PT	No information available					
RO	x					x
SE	x	X		x	x	
SI	x					
SK	x	X				
UK	x		x			x
TOTAL	18	11	6	7	7	7

Table 5-1: Overview of measures taken in the MS to reduce dioxin emission from domestic sources

5.1 Legal measures and standards

Legal measures and standards are established by MS in the fields of domestic combustion and of open burning of waste.

5.1.1 Legal measures related to domestic combustion

Key message: Legal measures (bans on waste burning, reduction of GHG releases, emission limits for CO and PM, mandatory energy efficiency standards) are the predominant approach taken by MS to address dioxin emissions from domestic sources. However, except for bans on solid fuels, no direct dioxin related measure has been taken by MS in the field of legislation. Legislation and standards are focussing on energy efficiency and PM. Mandatory inspections can be an additional tool to verify compliance with the legislation.

Legal measures comprise the following approaches:

- Bans of certain fuels
- Programmes for fuel change
- Emission limit values
- Efficiency standards
- Mandatory inspections and measurements

16 MS reported on specific measures in this field. The most specific approach taken by Member States to tackle the problem of dioxin releases from the domestic sector is the ban on certain fuels (namely coal and waste) and the change from solid fuels to liquid or gaseous fuels as reported from 7 MS (see Table 5-2).

Legislation/Program	MS	Specification
Ban on certain fuels	AT	Exclusive use of regular fuels
	IE	Ban on sale of smoky coal products in large urban areas
	IT	Coal heating boilers banned in some municipalities; in SCI with thermal efficiency lower than 65% has been banned in winter in the municipalities of the Lombardy Region (altitude below 300 meters), by a regional law.
	UK	Ban for “smoky” solid fuels in smoke protection areas
National programmes and strategies	BG	National programme: Implementation of natural gas in the domestic sector
	PL	National programme: Reduction of POP emission, Executive programme for II State Environmental Policy
	EE	Application of energy saving technologies in the domestic sector

Table 5-2: Legal MS measures and programmes for dioxin emission reduction from domestic sources by change of fuel

Emission limit values and standards for energy efficiency of domestic appliances are the type of measure most widely applied in MS. In total, 10 MS reported use of this type of measure for emission reduction in the domestic sector. This approach is partly associated with a legal obligation to perform regular inspection and control measurements. But it has to be taken into account that this type of measure is not directly targeting dioxin and that the benefit can therefore only be indirect. (For discussion of deficits see also chapter 5.7).

An overview of the application of legal limits and standards as well as on control requirements is provided in Figure 5-1.

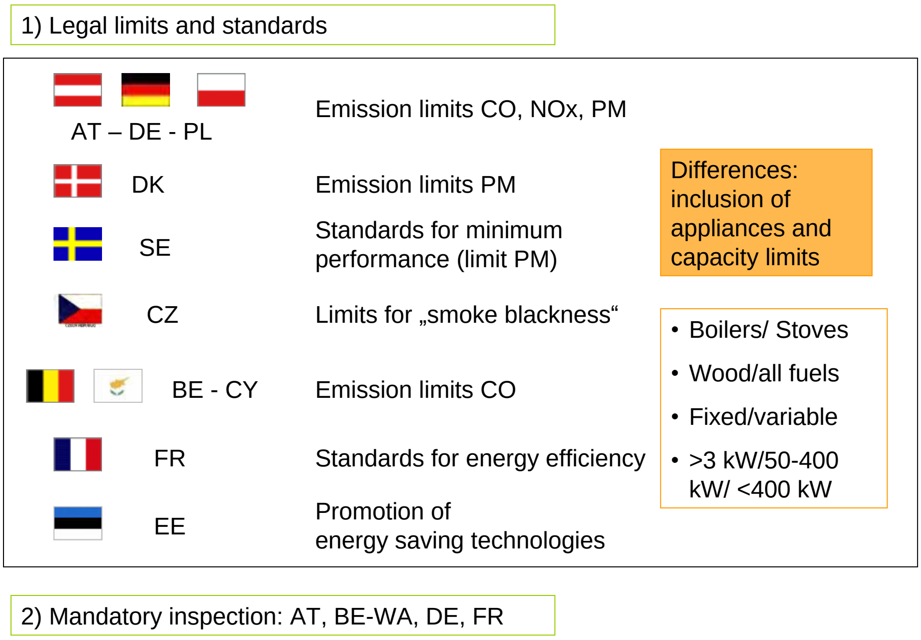


Figure 5-1: Legal limits, standards and control provisions for domestic emission reduction in EU Member States

Further details on the type of appliances subject to legal limits and mandatory control is provided below.

Legislation	MS	Specification
Emission limit values	AT	Boilers and stoves <400 kW
	BE-BR	Central heating boilers and burners <40 kW
	BE-WA	Central heating boilers and burners <40 kW
	CY	Small boilers burning biomass
	CZ	Small combustion sources <200 kW
	DE	Combustion installation >15 kW
	DK	Residential wood burning appliances
	PL	Boilers depending on capacity and fuel
	SE	New small scale installations (<300kW)
Inspections, measurements	AT	Regular inspection for boilers
	BE-WA	Regular inspections for boilers (foreseen 2008)
	CZ	Boilers <200 kW: CO emission measurement (in some cases)
	DE	Annual emission measurements for automatic boilers Inclusion of manually fed boilers planned

Legislation	MS	Specification
	FR	Boilers 0.4 – 2 MW: Control regularly

Table 5-3: Details of legal limits and control provisions for domestic emission reduction in EU Member States

In Latvia, Greece and Luxembourg, according to national reporting, no specific measures have been taken. No specific information is available so far for FI and SK.

Further details on measures taken by EU Member States are presented in Annex 3.1. For effects on dioxin emissions see chapter 6.2.2.

5.1.2 *Legal measures related to burning of waste*

Key message: Bans on domestic combustion or open burning of waste are widely established in EU Member States, even though exemptions are partly granted for garden waste. A rapid implementation of corresponding measures in the remaining countries (8 MS) is desirable.

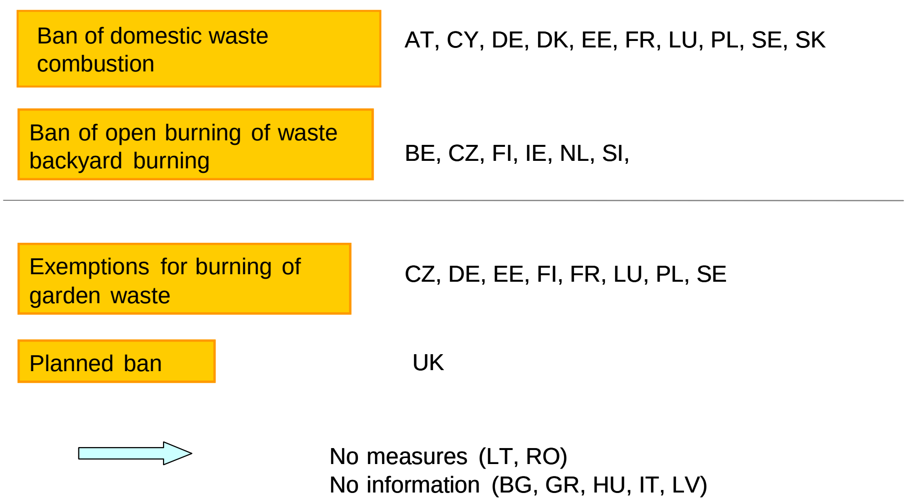


Figure 5-2: Overview of MS against waste burning as a measure to reduce dioxin emissions from domestic sources

The uncontrolled burning of waste (open burning or domestic co-combustion) is not included in the category of "residential" emissions but has to be reported separately under the international Conventions. Bans on domestic combustion or open burning of waste are reported to be established in 16 MS within the legal framework for waste management, protection of air quality or of the environment. Implementation of the prohibition is normally dedicated to local authorities. Whereas domestic waste combustion is generally forbidden, an exemption from the ban is authorised from local authorities in a number of MS (e.g. CZ, DE, EE, FI, FR, LU, PL, SE) for combustion of garden waste. This comprises either certain areas (e.g. rural areas) or periods of the year (e.g. autumn) and can be further restricted to certain types of residues which cannot be composted (e.g. dry branches and twigs).

According to the provided information, RO, UK and LT have not yet set up legal provisions to prohibit waste burning, but the UK is planning to remove the exemptions made for households in the near future. No information on measures taken in the field has been provided by BG, GR, HU, IT and LV. The original information provided by MS is compiled in Annex 3.2.

5.2 Awareness raising

Key message: Awareness raising is the second major approach taken to address emissions from domestic sources. Except for information on open burning of waste and health risks from dioxin no direct dioxin related measures have been taken by MS in the field of awareness raising and education. Measures in general focus on energy efficiency and good firing practice. For effects on dioxin emissions see chapter 6.2.2

Proper combustion of solid fuels in manually operated apartment heating facilities, stoves and open fireplaces, as well as co-combustion of waste in small combustion appliances is extremely difficult to enforce even if legal bans are set in place. Thus, citizens' awareness is a crucial parameter for reducing emissions, and awareness raising is an instrument currently widely used in Member States.

In total, 11 MS (AT, BG, CY, DE, DK, FR, IE, NL, PL, SE, and SK) reported on measures in the field of education and awareness raising. Measures taken in this category comprise the following issues:

- Firing habits, Appropriate operation of heating appliances
- Backyard burning, Burning of waste
- Energy efficiency, Energy saving
- Environmental impacts, Health risks

Information and education on firing habits, heating appliances and appropriate operation (BE-FL, DE, DK, EE, FI, FR, IT, PL, SE) as well as information on the impacts of backyard burning and open burning of waste (BE-FL, BG, CY, IE, NL, PL) seem to be high priority topics in Member States that have responded to this issue. In addition, educational measures and information in the field of energy efficiency and energy saving have been reported to be regarded as appropriate tools for emission reduction (AT, DE, SK) since such approaches seem to have a positive side effect on dioxin emission. Furthermore, DE, FR and PL reported realizing measures to generally increase knowledge of dioxin emissions and their environmental and health risks.

Measures implemented in public campaigns range from environmental consultancy, local initiatives, seminars, brochures and posters distributed to the public, to the use of high profile media such as radio, newspapers and television.

An overview of such measures is provided in the figures below. A specific education campaign (interactive with advertising, radio and TV campaigns) has only been reported from Ireland.

Figure 5-3: Irish education campaign for reduction of open waste burning

Other MS (AT, BCR, DE, DK, EE, FI, FR, PL, SE, SK) focus on information on good heating practice and especially on information on energy saving measures in the domestic sector. Information is provided mainly by means of web pages where citizens can find brief information and download brochures. Additional active information campaigns (TV spots) have only been reported by DK and to a certain extent by Poland.

These categories of campaigns do not directly influence dioxin emissions. An effect can only be expected from reduced fuel consumption. (For calculation of the reduction potential see chapter 6.2.2). Annex 3.3 provides further details on the measures taken, listing homepages for further information where available.

Besides such measures reported by MS, information has been identified, that systematic investigations for illegal waste combustion could considerably reduce the share of abuse within a period of five years, without monetary sanctions or penalties being in place. This is a good example for the “power” of awareness raising by means of inspection and control.

5.3 Research and Development

Key message: Only two MS undertake real reduction measures in terms of promoting research in technologies for flue gas cleaning. Other activities are destined to improve emission estimates by determination and verification of EFs.

Measures in the field of research and development for reduction of dioxin emissions from domestic sources are scarce. Planned or ongoing activities have only been reported by AT, CZ, DE, DK, PL, UK. Actions comprise:

- Research studies on dioxin emissions in different appliances (AT, PL)
- Measuring campaigns to fill data gaps and derive more appropriate EFs (AT, CZ, PL, UK)
- Development of abatement technologies for the domestic sector (DE, DK)
- Expert conferences for information exchange (PL)

Improved additional EFs

AT	New measuring campaign solid fuel fired appliances
CZ	Four year project (Technical University of Ostrava) EF for dioxins and comparison with energy efficiency and SO2, NOx, CO, PM and O2 Some most representative boilers selected. First results end 2008.
PL	Research study with Institute for Chemical Processing of Coal (EF for different appliances)
UK	Work ongoing to improve lack of data on emission estimates

RD projects abatement technology

DE	Installation of dust filters (fabric, electrostatic, wet scrubber) for flue gas cleaning in small appliances; FNR
DK	One 0,3 million € project on testing flue gas cleaning technologies, which can be mounted on existing stoves and boilers

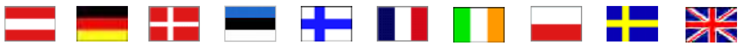
Figure 5-4: Overview of R&D measures taken in MS in relation to dioxin emissions from domestic sources

AT, CZ, PL and the UK reported undertaking measuring campaigns to improve EFs for solid fuel combustion in the residential sector. Further details on the reported measures are provided in Annex 3.4.

5.4 Labelling

Key message: Eco-labelling schemes for solid fuel fired domestic appliances are established or planned in 10 MS. The focus is on energy efficiency, low CO and dust (PM) emissions. Effects on dioxin are only indirect (reduced fuel consumption via increased energy efficiency).

An overview on existing schemes, their focus and differences is presented in Figure 5-5.



In place: AT – DE – DK – FI – FR – IE - PL – SE – UK – (NO) - Industry

Major criteria: CO, NOx, PM, energy efficiency

Covered appliances:
wood boilers, stoves and inserts, small solid fuel fired installations, closed fireplaces, solid fuel fired boilers, room heaters

⇨ Differences in tightness of limits and covered appliances

Focus on wood

Figure 5-5: Overview of eco-labelling schemes for domestic appliances in EU Member States

The inclusion of domestic heating systems into national energy efficiency labelling systems is seen as an option to reduce emissions from domestic appliances, although the focus is not on dioxin. 10 MS reported on established or planned eco-labelling for domestic heating appliances. In addition, Industry developed voluntary labelling schemes and energy efficiency standards at European or national level (EFA, HETAS).

Labelling schemes are focusing primarily on wood fired installations (boilers and stoves), but other solid fuels can also be included. See e.g. DINplus, Nordic Swan, the Irish Greener Home Scheme, the Polish certificate, the planned Slovak label and the UK label. A more detailed description of the covered appliances and the performance requested is provided in Table 5-4.

MS	Eco-Label/Certificate
AT	“Österreichisches Umweltzeichen 37”: requirements for **automatic and manually fed wood boilers and stoves**. The guideline is updated January 2008; CO 60-700 mg/MJ nominal load, NOx (100-120 mg/MJ, dust (15-30 mg/MJ).
DE	“Umweltengel” (Blue Angel) official label since 1978; **wood pellet stoves and boilers**; energy efficiency >90%; CO 90-180 mg/Nm³ rated load, NOx 150 mg/Nm³, dust 20-25 mg/Nm³
DE	“DINplus” voluntary scheme for **small solid fuel appliances**; CO 1500 mg/Nm³, NOx 200 mg/Nm³, dust 75 mg/Nm³.
DK	“Nordic Swan”: official Nordic eco-label since 1989 for **automatic and manually fed closed fireplaces** (including low heat release and sauna stove), solid fuel fired boilers. Update 2008; minimum efficiency: <60%-78%; CO 150 - 1000 mg/Nm³, dust stove 1-<15 g/kg fuel; dust boiler 40-70 mg/Nm³; NOx boiler 340 mg/Nm³
FI	“Nordic Swan” see above

MS	Eco-Label/Certificate
FR	"Flamme Vert "(Green Flame): voluntary agreement since 2000 for wood combustion installations (**closed fireplaces, inserts, stoves, cookers and boilers**); continuous improvement of performance 2004-2009 envisaged; efficiency 2006: 65-75%; CO boilers 3500-6500 ppm; dust 165 ppm; CO stoves/fireplace/insert: <0.6% smoke volume.
IE	Greener Home Scheme launched 2006; minimum efficiency **boilers/stoves/inserts** >80%; CO at nominal rate 500-750 mg/Nm³
PL	Environmental Safety Certificates granted since 1999 by the Institute for Chemical Processing of Coal in Zabrze for low power **boilers**: minimum efficiency 75-80%; CO 1200-5000 mg/Nm³; NOx 400-600 mg/Nm³, dust 125-200 mg/Nm³, Environment Friendly Equipment (or installation) initiated and granted since 2004 by the Institute of Heating and Sanitary Technology in Lodz (ITGiS:) and approved by the Faculty of Energy and Environmental Engineering of the Silesian University of Technology
SE	Nordic Swan for domestic stoves see above
SE	"P-marking system": requirements on emission and energy efficiency, construction, safety and operational reliability. **pellet fuelled burners, boilers, stoves, and wood-fired room heaters**: minimum efficiency 70-86%; CO 1500 mg/m³ - 0.3%; dust (pellet stove) 100 mg/m³.
SK	The Operating Programme Environment (2006-2013) foresees the development of an eco-label for heating systems in the framework of air protection and climate change
UK	The Heating Equipment Testing and Approval Scheme (HETAS) set standards of safety, efficiency and performance for testing and approval of solid fuels, solid mineral fuel and wood burning appliances.
Europe	EFA labelling scheme for high-quality fireplaces (**room heater, slow heat release, insert, stoves tiled and pellet**) in Europe; introduced by the European association of fireplace-manufacturers, requirements for emissions and efficiencies minimum efficiency 70-90%, CO 450-2500 mg/Nm³; dust 50-300 mg/Nm³

Table 5-4: Overview of Member State activities in the field of eco-labelling for small domestic appliances

As illustrated, labels somewhat differ concerning covered appliances and pollutants and set different standards with respect to permitted levels of pollutant emissions.

5.5 Subsidies for change of fuels or low emission domestic appliances

Key message: Subsidy schemes for domestic heating appliances are reported as established in 8 MS and 2 Belgian Regions. One focus is on eco-labelled wood fired appliances, another is on low emission and high efficiency boilers and alternative renewable energies. Subsidy programmes for biomass or coal have a clear reducing effect on dioxin emissions if used in the field of solid fuel fired heating appliances, but they increase emissions if used to replace liquid or gas fired devices.

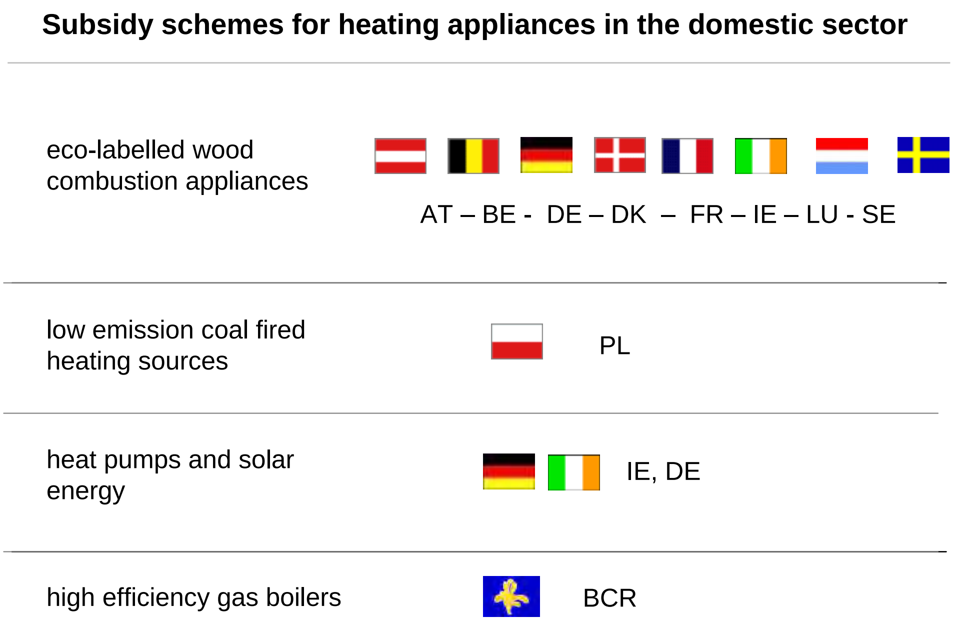


Figure 5-6: Overview of reported subsidy schemes for heating appliances in the domestic sector

Subsidy systems, financially supporting changes in domestic appliances or changes of fuels are another instrument relatively broadly used in EU Member States. 9 MS (AT, BE-WA, DE, DK, FR, IE, LU, PL, SE) reported on financial subsidy programmes to lower emissions in the domestic sector. Subsidies are either paid for replacement of old heating systems or for purchase of new efficient and low emission appliances. Subsidies are either connected with specific criteria, e.g. controlled combustion and ventilation or to the existence of an eco-label. The focus is on energy efficiency and renewable energy but can have a side effect on dioxin emissions as well. Although not especially mentioned, subsidy programmes to promote improved insulation are also in place in a number of Member States.

CZ also indicated that in the near future economic support is expected to speed up the change of existing technologies related to domestic sources. Reasons for the installation of a subsidy programme are mainly the ambient air quality and exceeded air pollution limit values of PM. Further details on reported measures already realized by other MS are presented in the table below.

MS	Description of subsidy programmes
AT	New more effective central heating biomass boilers (wood chip and pellet stoves) subsidised with about 15-45% of the installation costs regional programmes for new buildings and the renovation of buildings.
BE-BCR	Grants for installation of gas heating facility (50% of bill €400 max), heat pump 50% of bill 2500-€5000 max), solar system 50% of bill, €3000-€6000 max)
BE-WA	Incentives to buy wood-fired stoves with good environmental criteria (maximum capacity = 20 kW, minimum thermal yield = 65%, maximum CO emissions = 8000 ppm at 10% O2)
DE	Subsidies for purchase of low-emission and high efficiency boilers. BAFA (Bundesamt für Wirtschaft und Ausfuhrkontrolle) (www.bafa.de) Since 2000, 158,000 biomass installations could be supported. The majority of the installations are very small appliances. (wood pellets, wood chips and manually operated split log installation) Up to now a budget of €42 million has been spent within the programme Automatically fed biomass installation (5 kW to 100 kW): €36 per kW nominal power. Minimum funding pellet ovens: €1,000, pellet boilers: €2,000; pellet boilers with buffer vessel >30 l/kW: €2,500 Automatic wood chip installation (5 kW to 100 kW): €1,000 as a lump sum. Split log gasification boiler (5 kW to 100 kW) with buffer vessel (55 KW): €1,125. Additional bonus funding: regenerative combination, efficiency, etc
DK	Danish government State Budget for 2007 €4.4 m for initiatives to reduce pollution from residential wood burning stoves, including speed-up of decommissioning old high emission wood burning boilers The Danish subsidy scheme for small bio fuel boilers requires a type approval of the boilers as a precondition for granting subsidies.
FR	Subsidies are available for eco-labelled wood combustion domestic appliances (Flamme verte). Devices can be purchased at reduced VAT 5.5% instead of 19.6%; from 2005 to 2009, a tax credit of 50% of the cost of the appliance is granted to appliances whose efficiency is at least 65% and which meet some emissions criteria. Also applicable in cases of renovation of houses >15 years of age These two conditions apply only if the appliance is being installed by an accredited supplier (and not by the consumer himself) in the main residence of the consumer (“residence principale”), and if the consumer is a French taxpayer. In practice, the consumer needs to pay all of the costs (with VAT at 5.5%) and claim the tax credit against the next tax submission.
IE	The Greener Homes Scheme (GHS) sets residential renewable energy grants and aims at increasing the use of sustainable energy technologies within Irish homes. Homeowners can avail themselves of grant support e.g. towards the cost of installation of wood chip/pellet boilers that meet eligibility requirements. Grants: Wood Chip or Pellet Stove (€1,100), Wood Chip or Pellet Stove with integral boiler (€1,800), Wood Chip or Pellet Boiler (€3,000); So far 5,535 Biomass Schemes have been applied for in IE
LU	Subsidies for wood heating with controlled combustion and ventilation.
PL	Funds: In 2001, rules for providing financial assistance for low-emission coal-fired heating sources in the Silesian Region have been established, supported by the funds of the Regional Fund for Environmental Protection and Water Management (WFOSiGW) and the Swiss Government. This activity is being continued with national resources resulting in thermal effectiveness reaching 85%
SE	Regional programme (Varmland region): up to €1,000 subsidy for the installation of an approved wood boiler and accumulator tank, and up to €530 if an accumulator tank is installed to an existing wood boiler. Nearly €0.5 m is available in this program for 2008.

Table 5-5: Detailed information on subsidy programmes for reduction of dioxin emissions from domestic sources in EU Member States

As illustrated in the table, programmes generally focus on wood heating appliances but may also include other renewable energy sources such as solar energy or heat pumps. Grants

are generally graded and can reach up to 50% of the bill.

Eco-labelled wood or coal fired appliances have higher energy efficiency than standard solid fuel fired appliances and are associated with lower EFs. Consequently, they have a reducing effect on dioxin emissions if used to replace solid fuel fired appliances. On the other hand they have higher EFs than oil and gas fired domestic appliances. Thus, subsidies for biomass fired appliances are associated with an increase of dioxin emissions if used for replacement of gas and oil fired boilers or stoves.

Heat pumps and solar energy do not lead to dioxin emissions and thus have a reduction effect. Insulation measures for dwellings would also have an important reduction potential in all climates where heating in the colder period is needed. Therefore, subsidies in this field would be beneficial for dioxin emissions, although only little information has been provided by MS on this issue. For quantitative information see chapter 6.2.3.

5.6 Current MS knowledge on effectiveness of reduction measures

Key message: There was little response to the question on effectiveness of reduction measures taken. Information on efficiency of measures is poor. In principle, emission inventories can serve as a basic information source for changes in dioxin emissions. A decrease of emissions from the domestic sector was observed in UK, FR and RO, whereas most of the MS stated not to have information on the effectiveness of measures on dioxin emissions. Data for efficiency of subsidy programmes are available (AT, DE) but are not related to dioxin.

The question concerning information on the effectiveness of reduction measures taken has only been answered by 8 EU Member States, of which only two provided quantitative information on observed trends in annual PCDD/PCDF emissions (FR and RO). In FR emissions have decreased by 57% from 1990 to 2005 due to reduced wood and coal combustion. In Romania the effect is marginal (30 mg TEQ reduction from 2000 to 2005). AT and DE dispose of registers for installed biomass stoves and boilers or sales figures for wood pellets that indicate an increased use of modern biomass heating appliances. Some general statements without further specification have been provided by DK and FI. Further details on reported information are provided in annex 3.7.

Some additional information on trends for “PCDD/PCDF air emissions from domestic sources has been provided via presentations at the expert workshop.

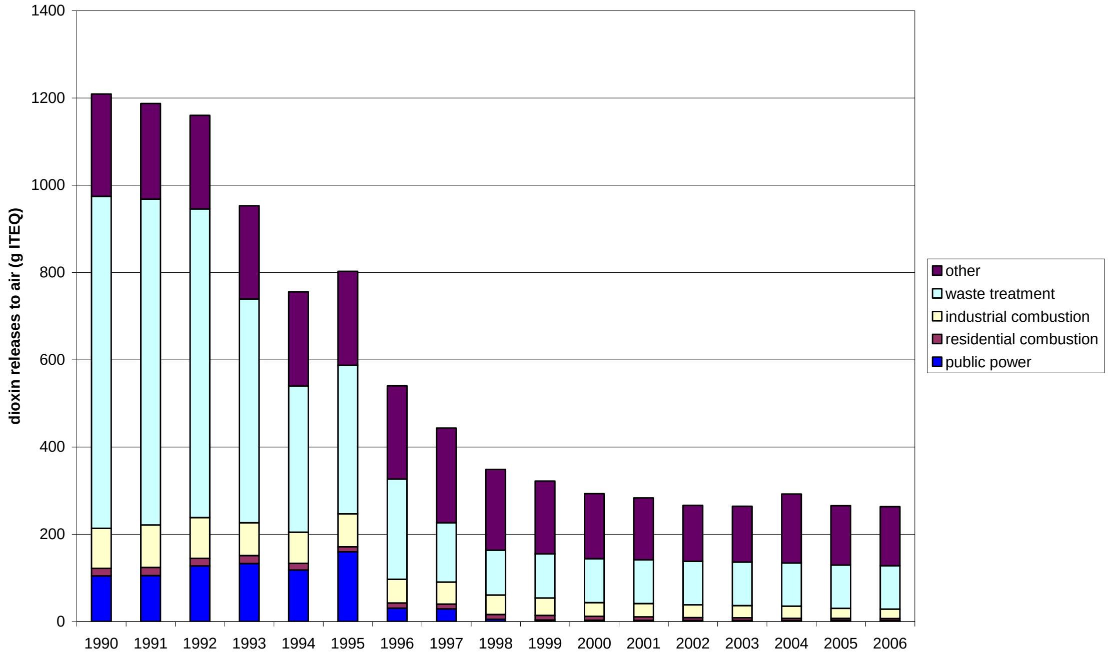


Figure 5-7: Trend of PCDD/PCDF air emission in the UK

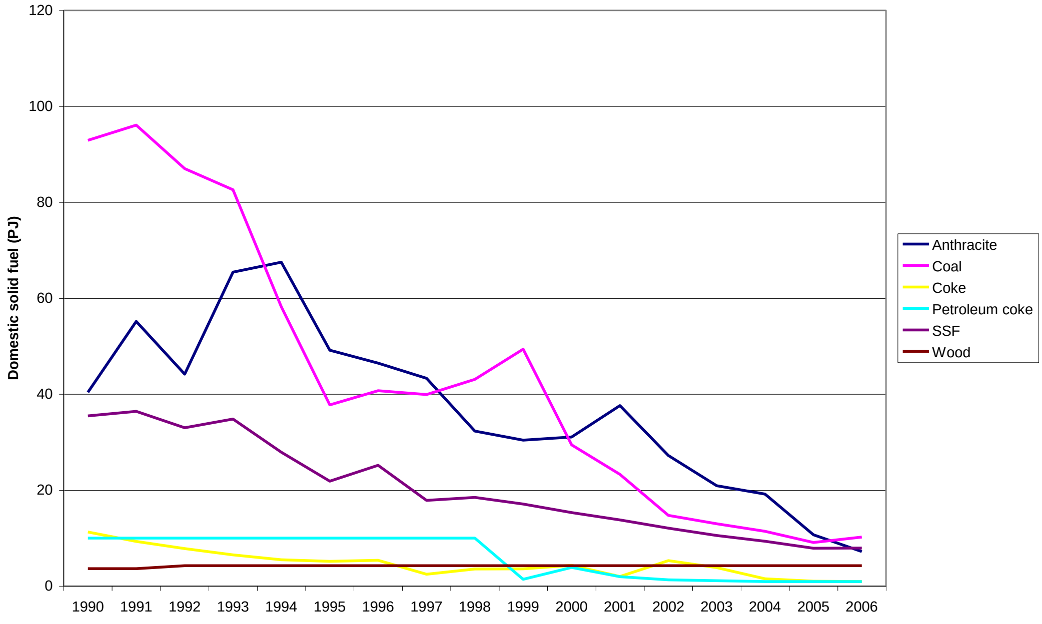


Figure 5-8: Trend of fuel use in domestic combustion in the UK

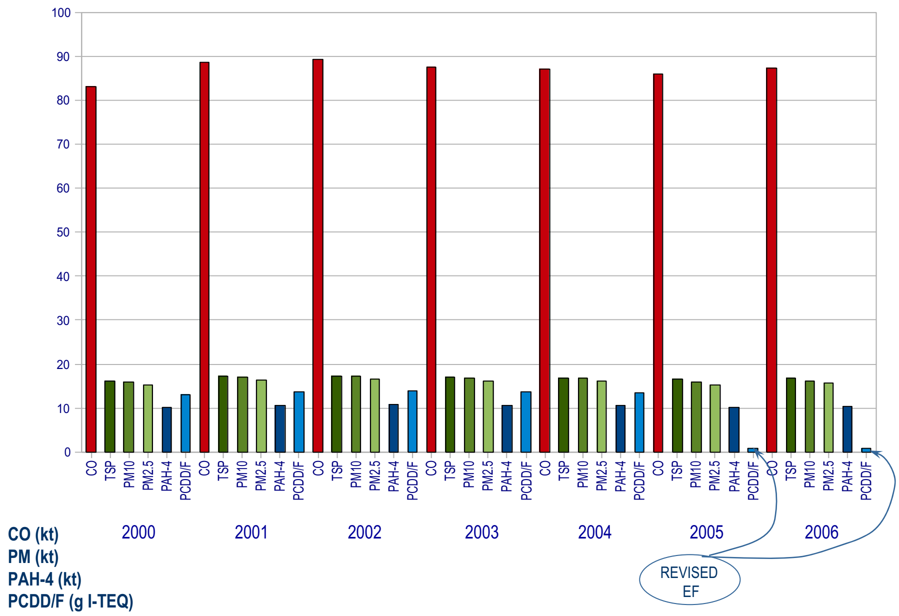


Figure 5-9: Trend of domestic PCDD/PCDF emissions in Finland (note changed EF in 2005 leads to significantly reduced emissions)

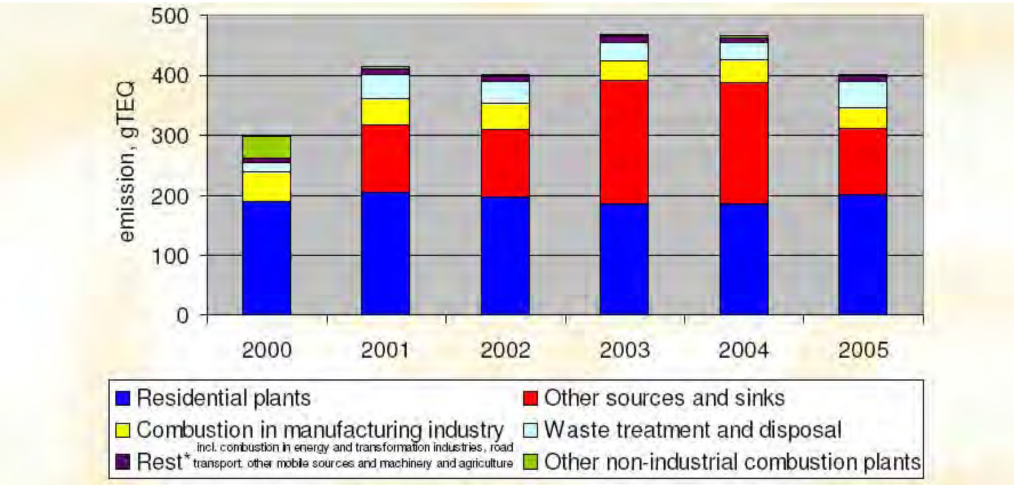


Figure 5-10: Trend of domestic PCDD/PCDF emissions in Poland

As illustrated in Figure 5-7 and Figure 5-8, some decrease of domestic emissions can be observed in the UK from 1997 to 2006, which is mainly due to a strong decline in coal combustion. On the other hand it shows the large increase in relative importance of the domestic sector. This observation is confirmed by other MS. In FI the annual emissions remained stable until the EF for domestic wood combustion was changed from 330 µg TEQ/TJ to 21 µg TEQ/TJ in 2005 (see also chapter 3.2.2 and Table 4-3). In Poland domestic dioxin emissions remain constant from 2000 to 2005. This corresponds to a rather stable share of fuels (coal >50%) and an increase in wood consumption which counteracts a reduced EF for modernised coal fired appliances.

As illustrated above dioxin related information on effectiveness of measures taken is scarce and currently only provided by the UK. Investigations into the trend of PCDD/PCDF air emissions from domestic sources in principal could be best performed by means of an evaluation of MS reporting to EMEP WebDab. However, it has to be taken into account that reporting is far from being complete. A compilation of reported information is provided in Annex 6 to the final project report for the “EU-wide inventory of releases from diffuse sources”. [11]

5.7 Problems and deficits in addressing dioxin emissions from domestic sources

Key message: Member States experience difficulties in addressing domestic emissions of dioxin. A lack of binding limits and obligations, enforcement difficulties due to scattered structure and sophisticated and expensive monitoring and political aspects (financial burdens to citizens, competing policy requirements, low priority) are the most important obstacles encountered. Current measures are mostly not driven by dioxin aspects but by climate change policies aiming for increased energy efficiency and use of renewable energies. In general, the importance of dioxin emissions is regarded as low in comparison to PM, PAH or climate gases. Deficits in information and level of activities between MS vary considerably.

5.7.1 Major problems and obstacles as identified by MS

In total, 13 MS reported on problems and obstacles in the context of reduction measures for dioxin emissions from domestic sources. In this context the following five aspects were mentioned as the most important problems encountered.

1. Infrastructural problems
2. Awareness/information problems
3. Financial problems
4. Technical problems
5. Organisational/juridical problems

Infrastructural problems have been stated by CY, CZ, DK, which highlighted the difficulty to control millions of households. The high number and widespread distribution of installations generates high administrative efforts (a huge number of inspectors needed) and costs (huge number of measurements needed). Infrastructural deficits such as a lack of gaseous or liquid fuel fired appliances in residential dwellings were stressed as another obstacle from BG and CY because an installation of an adequate grid would require huge financial investments.

Awareness of the issue in the general population, information deficits and the difficulty to adequately reach citizens as stated e.g. by BE-WA, DE, NL, RO is regarded as another important obstacle to successfully reduce emissions, even more as cooperation and voluntary compliance is crucial in the domestic sector.

[11] http://eper.eea.europa.eu/eper/ or directly at http://www.bipro.de/__prtr/index.htm

High **investment costs** necessary for installation of modern heating devices (PL, RO, SE) and costs for dioxin emission monitoring were raised as important factor hampering activities. The replacement of appliances and the establishment of a modern infrastructure are associated with a considerable financial burden for the individual citizen or the local, regional or national administration. This aspect is not only closely related to infrastructural deficits but also an important factor for technical obstacles (e.g. high costs for monitoring, high costs for retrofitting or flue gas treatment measures) and infrastructure (controls)

Technical problems, such as the limited potential for retrofitting (DE), sophisticated sampling and measurement methods (RO) or the high emissions immanent to certain fuels are regarded as another topic of concern. The limited possibility to retrofit existing installations leads to the fact that appliances have to be exchanged if not compliant with set requirements. The sophisticated sampling and analysis methods that are required for dioxin measurements require a high level of training of the inspectors and allow analysis in a very limited number of laboratories only. Elevated dioxin emissions are an immanent property of certain fuels (e.g. biomass) so that strict limits may in principal lead to the need for a complete combustion ban, whereas these fuels may be promoted under other policy goals.

Organisational/juridical problems have been reported as being a “lack of emission limits and related obligations” (CZ, DE, SI) or a federal structure (AT, BE-WA). The fact that up to now there is no legal framework imposing emission limits or control mechanisms for dioxin emissions from domestic sources is certainly a major parameter hindering implementation or enforcement of any reduction and control measures.

The NL highlighted the fact that further emission reduction might be achievable through targeted product policy, which should be an EU task rather than a national one due to the common market. A detailed compilation of provided information is compiled in Annex 3.8.

6 Selection of good practice for dioxin emission reduction

Based on the investigations related to measures taken in EU Member States to reduce dioxin emissions from domestic sources and on the compilation of major difficulties to address this source sector, a selection and description of examples of good practice is performed in this chapter.

6.1 Selection criteria for case studies

Key message: The dioxin emission reduction potential and consistency with related or competing policies and costs have been identified as major criteria for selection of examples of good practice for reduction measures related to dioxin emission in the domestic sector.

In the light of the overall objective of EU legislation and the International Convention on POPs to reduce dioxin emissions/releases into the environment as far as possible, the dioxin emission reduction potential is regarded as the major selection criterion. In addition, it seems to be reasonable to evaluate measures also in the light of related, competing and complementary requirements for combustion installations in the field of air protection and climate change and to take into consideration economic constraints and developments as discussed in chapter 4.8. Finally, related costs of specific measures will be taken into consideration and will form a third selection criterion.

Thus, the following parameters will be evaluated for different measures as selection criteria:

1. Reduction of dioxin emissions in comparison to the status quo (→*Overall emission reduction potential)*
2. Consistency with related or competing policy requirements (→*politically achievable* reduction potential)
3. Related costs (→*practically achievable* reduction potential)

6.1.1 Overall emission reduction potential

Emission reduction is the crucial parameter for the appropriateness of a reduction measure. In this context it has to be taken into consideration that the absolute reduction potential of a measure is a function of the combusted fuel, of the type and standard of the heating or cooking appliance used and of the annual energy need in a country or region. Consequently, the final impact depends on the specific situation (fuel share, appliance stock, climatic conditions, etc) in a Member State. For the purpose of this study a standardised setting was chosen, that allows direct comparison of the potentials of specific types of measure (for further details see chapter 6.2).

This chapter is differentiated into primary and secondary measures and the categories:

- Change of fuel
- Energy efficiency measure
- Promotion of renewable energy
- District heating
- Abatement technologies

Different policy approaches as reported by Member States (see chapter 5) are subordinated under this aim with further differentiation if needed or if appropriate.

Primary reduction measure: change of fuel

Reduction of dioxin emissions by means of a change of the combusted fuel depends on the differences in the corresponding EFs and energy efficiencies. Differences are expressed as relative reduction potential (% of the point of reference) and in absolute figures as far as possible. A change of fuel involves measures such as a replacement of solid fuels by liquid or gaseous fuels as well as the elimination of waste burning (waste replaced by regular fuels or uncontrolled burning replaced by landfilling or controlled incineration). Possible approaches to achieve this aim are legal bans, policy programmes, awareness raising or subsidy measures.

Primary reduction measure: energy efficiency measure

This type of measure comprises a change of appliances (both for solid fuels and for liquid/gaseous fuels), insulation measures and inclusion of the smallest appliances into control and limit schemes. This could be imposed by legal measures including extension of efficiency requirements and emission limits to the smallest appliances but also comprising "soft" policy approaches such as awareness raising, labelling and subsidies, monitoring and control.

- ***Change of appliance***
  A basic energy efficiency measure is the replacement of an old appliance by a modern version with improved heating performance. The impact on dioxin emissions depends on the difference in EFs allocated to different types of appliances and on the difference in energy efficiency of different types of appliances. As the reduction potential is expected to depend on the combusted fuel, a calculation will be performed separately for solid and liquid/gaseous fuels.

- ***Insulation***
  For this type of measure, the difference in dioxin emissions can be calculated as a function of reduced energy consumption. The intensity of the effect depends on the type of fuel applied and thus will be calculated separately.

- ***Inclusion of smallest appliances into control and emission limit schemes***
  In the domestic sector many small heating appliances are used which are not covered by classical air protection legislation but can release significant quantities of pollutants and climate gases. To subject even smallest appliances to limit values for energy efficiency and combustion quality and/or to make limit values stricter is thus a potential approach for emission reduction. In order to assess the overall effect of such

a measure, the numbers of this type of appliance have to be taken into account.

- ***Monitoring and control (e.g. via chimney sweepers)***
  Monitoring and control of legal emission limits can reduce emissions since it increases adherence to combustion quality and allows identification and elimination of non-conforming appliances. The reduction potential depends on type and frequency of control, sanctioning of non-conformity and a combination with educational tasks if relevant.

Primary reduction measure: promotion of renewable energy sources

This measure is similar to the change of appliances discussed under energy efficiency measures, with the difference that in this case only biomass, solar energy or geothermal energy are used to replace pre-existing installations. The impact on dioxin emissions depends on the difference in EFs allocated to different types of appliances and on the difference in energy efficiency.

Primary reduction measure: district heating

In addition to changes of types of appliances in single households, emission reduction might also be achieved by means of an increased use of district heating plants instead of installing modern solid fuel fired installations in single households. The advantage of this measure could be the more effective and stable combustion process and lower emission factor achievable with larger boilers as well as the possibility to install flue gas treatment facilities. One disadvantage would be the loss of energy from the power plant to the single households as well as the additional costs for distribution systems.

Secondary emission reduction measures: flue gas treatment

The reduction effect of flue gas treatment can be quantified via the differences in PCDD/PCDF concentrations in the flue gas. It needs to be considered that dioxins would be concentrated in the filter material, which necessitates management of the residues.

The following types of measures will not be discussed separately but are subordinated under fuel change, energy efficiency measure, promotion of renewable energy and abatement technology as an additional policy approach.

Awareness raising and educational measures

Awareness raising and education are not specific individual types of reduction measures but they focus on either prevention of waste burning, good heating practice, fuel change or energy savings. With regard to waste, the emission reduction effect is a function of the difference between the EFs for waste burning and combustion of regular solid fuel. With respect to the purchase of new appliances it is a function of the differences in EFs and energy efficiency of the appliances to be compared, or the amount of waste saved from domestic combustion.

Labelling schemes and subsidy measures

The impacts of labelling schemes or subsidy systems are also related to the differences in EFs and energy efficiency of the appliances under comparison. The overall reduction potential of each type of measure is consequently depending on the number of installations

purchased.

6.1.2 Related and competing policy requirements

Related and competing policies affecting the domestic sector arise from aspects of air quality and climate change. Specific legislation includes the Framework Directive on Air Quality (Dir. 2008/50/EC amending and replacing 1996/62/EC), Directives 2001/81/EC (Emission ceilings by 2010 for NOx, VOC, SO_2, NH_3) and Directive 2003/87/EC (Emission trading) as well as from the current situation in the energies market.

Climate change

The European Commission has taken many climate-related initiatives since 1991, when it issued the first Community strategy to limit carbon dioxide (CO_2) emissions and improve energy efficiency. These include a directive to promote electricity from renewable energy (Dir 2001/77/EC) and proposals on the taxation of energy products.

In 2000, the Commission launched the European Climate Change Programme (ECCP). The second European Climate Change Programme (ECCP II) was launched in October 2005, including working groups to review energy supply and energy demand as well as the Emission Trading Scheme. In December 2008 the European Commission adopted a far-reaching package of proposals to fight climate change and promote renewable energy up to 2020 and beyond the "Climate action and renewable energy package" (CEP).

The EU is committed to reducing its overall emissions to at least 20% below 1990 levels by 2020, and is ready to scale up this reduction to as much as 30% under a new global climate change agreement when other developed countries make comparable efforts. In this context it has set binding targets for **increasing the share of renewables in energy use to 20% by 2020.**

The "Climate action and renewable energy package" sets out the contribution expected from each Member State to meeting these targets and proposes a series of measures to help achieve them. This includes a proposal for a Decision to reduce greenhouse gas emissions to meet the Community's greenhouse gas emission reduction commitments up to 2020 (the so-called "Effort Sharing" Decision)[12] as well as a proposal for a directive amending the current EU ETS Directive (Directive 2003/87/EC)[13].

The sectors covered by the system shall cut their emissions until 2020 by 20% compared with levels in 2005. Emissions from sectors not included in the EU ETS – such as transport, housing, agriculture and waste – will be cut by 10% from 2005 levels by 2020. Each Member State shall contribute to this effort according to its relative wealth, with national emission targets ranging from -20% for richer Member States to +20% for poorer ones. The national renewable energy targets proposed for each Member State will contribute to achieving emissions reductions and will also decrease the European Union's dependence on foreign sources of energy.

Energy efficiency

EU efforts to reduce energy consumption in the building sector began in 1993 with the SAVE

[12] {COM(2008) 30 final} {SEC(2008) 85}

[13] Brussels, 19.10.2006; COM(2006)545 final, Action Plan for Energy Efficiency: Realising the Potential {SEC(2006)1173} {SEC(2006)1174} {SEC(2006)1175}

Directive (Council Directive 93/76/EEC) on limiting CO_2 emissions through improved energy efficiency, which required member states to implement and report on energy efficiency programmes in the building sector. The SAVE Directive was replaced in 2006 by Directive 2006/32/EC on end-use energy efficiency and energy services. Directive 2006/32/EC requests MS to reduce their energy consumption by 9% until 2016 and to establish measures for information. According to Article 14(2) of the Directive, Member States shall submit their first National Energy Efficiency Action Plan (NEEAP) to the Commission by June 30, 2007. In their NEEAPs, Member States should show how they intend to reach the 9% indicative energy savings target by 2016.

Directive 2002/91/EC on energy performance in buildings (EPBD), which had to be transposed by MS by January 2006, provides an integrated method for calculating energy efficiency and requests Member States to create minimum standards for energy efficiency. The directive applies to new buildings and to existing buildings subject to major renovations. In an effort to promote awareness and energy efficiency improvements, member states must ensure that "energy performance certificates are made available when buildings are constructed, sold or rented out." In public buildings larger than 1000 square meters, these certificates must be clearly displayed in the main entrance.

According to information from the EU Commission, implementing the EPBD is progressing well in those member states that have existing regulatory frameworks for building efficiency. Ireland, Denmark, Germany (a prominent leader in the field of building efficiency), the Netherlands and the UK are making good progress. In certain member states, such as Denmark, compulsory energy audits and labelling schemes for buildings already existed before 2006. Most member states, however, have not made swift progress in the implementation of the directive, and have chosen to delay implementation until 2009. Instruments for implementation of the EPBD are the Intelligent Energy Europe (IEE) Programme providing funds for instance for a Green Building Platform and Concerted Action for an information-sharing platform. Further important EU communications and policies in this context are the “Green Paper on Energy Efficiency” (published by DG Tren in 2005) which presents a number of options to increase funding for energy efficiency; the 2006 Energy Action Plan[14] and the Directive on Eco-design requirements of energy-using products (Dir. 2005/32/EC). The Commission is also pushing for a Strategic Energy Technology (SET) Plan that would place more emphasis on research into energy-saving technologies such as fuel cells, hydrogen and sustainable coal and gas technologies.

Air quality

Further backgrounds for MS activities are the Framework Directive on Air Quality (Dir. 2008/50/EC amending and replacing 1996/62/EC and setting quality standards e.g. for PM to be complied with as of 2010 and Directive 2004/107/EC on target values for PAH emissions into air, also originating to a large extent from domestic sources.

[14] {COM(2008) 30 final} {SEC(2008) 52}, {SEC(2008) 53}, {SEC(2008) 85}

6.1.3 Costs

Costs can be divided into costs for operators and costs for MS authorities. Additional costs for operators may arise from installation of new appliances (investment costs) or from operation via purchase of fuel that is more expensive, inspections or services. Cost for MS authorities may arise from enforcement and control, awareness raising and educational measures or from subsidy schemes.

In the light of the reduction objective, costs are only the third selection criterion. It has to be taken into account that costs are highly variable and market dependent, so that it is very difficult to fix and finally determine them.

Indicative costs for the installation of a new firing appliance are in the dimension of:

€5,000 -€15,000 for a gas fired boiler

<€16,000 for an oil boiler

€10,000-€15,000 for a biomass pellet boiler or automatic coal boiler

€5,000-€10,000 for a sophisticated biomass stove with integrated boiler

€800-€1,300/m^2 for a photovoltaic installation

€21,000 for a heat pump

Installation of flue gas treatment devices is in the range of €1,500 (electrostatic precipitator) and €4,000 (tissue filter and wet scrubber).

Average prices for the installation of insulation are in the dimension of €100/m^2 for wall or roof, €100-€400/m^2 for the exchange of windows and €40/m^2 for insulation of the basement.

Costs for fuels (without VAT) currently are in the dimension of €9/GJ for coal, €11/GJ for wood, €10-15/GJ for pellets, €18/GJ for gas and €16/GJ for oil. Differences can be assumed to be especially important between log wood/biomass and gas, given the fact that wood can originate from private grounds available without any or at very low costs. The comparison of costs however, also has to take into account the different energy efficiencies of solid and liquid/gas fired appliances, which can reduce or even inverse expected differences. A more detailed analysis of costs will not be performed at this stage but will only be performed for selected case studies.

6.2 Calculation of reduction potential of potential measures

In accordance with the classification for the selection criterion in chapter 6.1, calculations in this chapter are performed for the categories fuel change, energy efficiency measures, renewable energy, district heating and secondary measures (flue gas treatment)

EF applied for calculation

Due to consistency reasons and lack of better alternatives, reduction potential in this study are calculated on the basis of the international estimation tools that reflect the currently agreed state of knowledge despite of inherent uncertainties. EFs and energy efficiencies as indicated in the UNECE Guidebook are generally used for calculation of results, as they allow comparison of different types of appliances in addition to different fuels. In cases where EFs are not available in the UNECE Guidebook, the EFs from the UNEP Toolkit are used. As reduction potentials are generally specific for a certain fuel, calculations are differentiated by fuel whenever appropriate. Estimates based on the differences of EFs are conservative and represent the minimum reductions that can be achieved. EFs reflect the average performance of an appliance category. A fuel switch is associated with the purchase of new appliances that are state of the art and typically better performing than the average of their group.

Quantification of results

In order to make results comparable, reduction potentials are calculated for an assumed average EU useful heat need (the energy/heat which finally arrives in the room and can be felt) of20 GJ/household year. In order to produce illustrative results and to be able to derive recommendations on the number of appliances to be changed, the tables in the following chapters present annual emissions and reductions in absolute figures and percentages at the level of a single household standard appliance. As the energy consumption necessary to achieve the defined useful heat depends on the energy efficiency (η) of the heating appliance, but the emissions depend on the energy consumption (correlation via EF), these parameters are also included and taken into consideration for the calculation of the reduction potential.

Adaptability to individual Member State

Results of the calculations constitute an indication of potentials based on standardised, comparable, reproducible and solid methodology. Results however, may not be taken as universally valid but flexible to progress in knowledge. For calculation of national potentials Member States would need to adapt the results to their individual data.

Within the framework of this project, a calculation of results could not be performed at MS level. However, by using statistical data, the results can be easily extrapolated to a specific MS setting by national or regional authorities. In addition adaptation can and should be made when progress in knowledge occurs. Sets of measures can be combined into appropriate solution packages for all MS depending on the specific national state of action and infrastructure in the domestic sector.

6.2.1 Reduction potential of change of fuel

As explained in chapter 6.1.1, the reduction effect of fuel change is based on the differences in EFs attributed to the fuels in the widely applied and agreed international estimation tools and in energy efficiency.

Change from solid to liquid fuels

Based on current knowledge of EFs and energy efficiency, the change from solid to liquid fuels constitutes an effective measure for PCDD/PCDF emission reduction of up to 99% or 35 µg TEQ/20 GJ.

As illustrated in the tables below, the change from solid to liquid fuels leads to significant emission reduction in the domestic sector, if based on current EFs and energy efficiency information from the UNECE Guidebook. The reduction effect is especially high for standard stoves whereas it is limited in comparison to pellet driven boilers and stoves or automatic appliances.

Wood exchanged by liquid fuel		liquid fuel fired device	Wood			
			standard stove	advanced stove/boiler/fireplace	pellet stove	automatic boiler
EF	µg/TJ	10	800	300	50	30
Energy efficiency	η	0.8	0.45	0.7	0.85	0.9
Energy consumption	GJ/a	25	44	29	24	22
PCDD/PCDF emission	**µg TEQ/a**	**0.25**	**35.56**	**8.57**	**1.18**	**0.67**
Emission reduction	**µg TEQ/a**		**35.31**	**8.32**	**0.93**	**0.42**
Emission reduction	%		99.30	97.08	78.75	62.50

Table 6-1: Annual PCDD/PCDF emissions and reduction potential of change from wood to liquid fuels for domestic heating (per useful heat of 20 GJ/a per dwelling)

The replacement of a standard wood fired stove by an oil fired device results in a PCDD/PCDF emission reduction of 35 µg TEQ/a (>99%). The reduction is far less for an advanced appliance (8.3 µg TEQ/a). In comparison to a pellet stove or automated wood fired boiler, the annual emission reduction would only be 0.9 and 0.4 µg TEQ/a (corresponding to 79% and 63%) for a standard dwelling with a useful heat need of 20 GJ/a.

A comparable situation with a slightly higher reduction potential can be observed in cases where coal heated appliances are replaced by oil fired devices (see Table 6-2).

Coal exchanged by liquid fuel		liquid fuel fired device	Coal		
			standard stove	advanced stove/small boiler	automatic boiler
EF	µg/TJ	10	1000	500	40
Energy efficiency	η	0.8	0.45	0.7	0.9
Energy consumption	GJ/a	25	44	29	22
PCDD/PCDF emission	**µg TEQ/a**	**0.25**	**44.44**	**14.29**	**0.89**
Emission reduction	**µg TEQ/a**		**44.19**	**14.04**	**0.64**
Emission reduction %	%		99.44	98.25	71.88

Table 6-2: Annual PCDD/PCDF emissions & reduction potential of change from coal to liquid fuels for domestic heating (per useful heat of 20 GJ/a dwelling)

Here the replacement of a standard stove results in a PCDD/PCDF emission reduction of 44 µg TEQ/a (>99%). The reduction is much lower for an advanced appliance (14 µg TEQ/a). In comparison to automated boilers, the annual emission reduction is only 0.6 µg TEQ/a (corresponding to 71%).

Change from solid to gaseous fuels

The PCDD/PCDF reduction potential that can be achieved by a change from solid to gaseous fuels reaches up to 99.9% or 44 µg TEQ/20 GJ. This is higher than the potentials of any other measure related to regular fuels. In comparison to liquid fuels, the reduction potential is another factor of five.

An important PCDD/PCDF emission reduction can be achieved by changing from solid to gaseous fuels if the effects of different EFs and energy efficiencies are summarised, (all information is based on the UNECE Guidebook). The potential in comparison with different types of wood fired installations is illustrated in Table 6-3, whereas the effect in relation to coal fired appliances is documented in Table 6-4.

Appliances exchanged for gas fired appliances		Gas fired boiler	Wood fired appliances			
			standard stove	advanced stove/boiler/fireplace	pellet stove	automatic boiler
EF	µg/TJ	1.5	800	300	50	30
Energy efficiency	η	0.8	0.45	0.7	0.85	0.9
Energy consumption	GJ/a	25	44	29	24	22
PCDD/PCDF emission	**µg TEQ/a**	**0.04**	**35.56**	**8.57**	**1.18**	**0.67**
Emission reduction	**µg TEQ/a**		**35.52**	**8.53**	**1.14**	**0.63**
Emission reduction %	%		99.89	99.56	96.81	94.38

Table 6-3: Annual PCDD/PCDF emissions & emission reduction potential of change from wood to gaseous fuels for domestic heating (per useful heat of 20 GJ/a and household)

As illustrated in the tables, the potential is especially important in comparison with simple appliances. If a standard wood fired stove is replaced by a gas fired boiler, this leads to a PCDD/PCDF emission reduction of 35.5 µg TEQ/a (from 35.6 µg TEQ/a to 0.04 µg TEQ/a), which corresponds to a reduction of >99.8%. The reduction potential for an advanced

appliance is already lower (8.5 µg TEQ/a). In comparison to a pellet stove or automated wood fired boiler, the annual emission reduction is only 1.1 and 0.6 µg TEQ/a (corresponding to 97% and 95%).

Appliances exchanged for gas fired appliances		Gas fired boiler	Coal fired appliances		
			standard stove	advanced stove/small boiler	automatic boiler
EF	µg/TJ	1.5	1000	500	40
Energy efficiency	η	0.8	0.45	0.7	0.9
Energy consumption	GJ/a	25	44	29	22
PCDD/PCDF emission	**µg TEQ/a**	**0.04**	**44.44**	**14.29**	**0.89**
Emission reduction	**µg TEQ/a**		**44.41**	**14.25**	**0.85**
Emission reduction %	%		99.92	99.74	95.78

Table 6-4: Annual PCDD/PCDF emissions & reduction potential of change from coal to gaseous fuels for domestic heating (per useful heat of 20 GJ/a and household)

The PCDD/PCDF emission reduction for a standard coal fired stove is 44.4 µg TEQ/a if replaced by a gas fired device (99.9%). The reduction potential for an advanced appliance is 14.3 µg TEQ/a or 99.7%) and the annual emission reduction for an automated coal fired boiler, which can be achieved if replacing it with gas heating is only 0.85 µg TEQ/a (96%) under similar conditions.

Elimination of domestic waste burning and high chlorine coal

Elimination of domestic combustion of MSW or contaminated wood is associated with a reduction potential of up to 99.7% or 1,477 µg TEQ/a in a worst case scenario. The reduction potential is even higher for back-yard burning as this activity is always in addition to emissions from domestic heating and cooking.

Note: resulting figures cannot be directly compared to other measures as applied EFs differ, due to lack of information on this issue in the UNECE Guidebook.

A similar reduction potential (from >530 to 44 µg TEQ/a) is observed if high chlorine coal is replaced by standard coal.

Elimination of domestic burning of contaminated wood or mixed municipal waste is another measure involved in changes of fuels. The UNECE Guidebook does not provide any EFs for this type of activity; therefore the EFs recommended in the UNEP Toolkit are used for comparison in this case.

		Clean wood	Contaminated wood	MSW
EF	µg TEQ/t	1.40	21.00	300.00
Energy efficiency	η	0.45	0.45	0.45
Required fuel consumption*	t/a	3.18	3.18	4.94
PCDD/PCDF emission	**µg TEQ/a**	**4.4**	**66.64**	**1,482**
Emission reduction	µg TEQ/a		62.24	1,477
Emission reduction %			93.4	99.7

* caloric value for wood 14 MJ/kg, for MSW 9 MJ/kg

Table 6-5: Emission reduction potential for PCDD/PCDF of a ban on combustion of contaminated wood and MSW (per 20 GJ/a with an assumed energy efficiency of the device of 45% (simple type))

As illustrated in Table 6-5 the maximum reduction potentials that can be achieved by exclusive heating with virgin wood instead of contaminated wood, are more than 62 µg TEQ/a per household (93%) and might reach a level of 99% (or 1.5 mg TEQ/a per household) in relation to combustion of MSW. If the combustion of contaminated wood or MSW is performed in a device with higher energy efficiency (e.g. 70%), the reduction potential is lower but still remains considerable. The energy efficiency and combustion quality of appliances is not affected by this measure.

Note: absolute figures cannot be directly compared to other measures due to the difference in EFs applied. But an indication of the relative effectiveness of the measure can be drawn.

The same principle applies for back-yard burning of MSW but the reduction potential is even higher, because emissions caused by burning are not balanced by saved regular fuel consumption but are fully in addition to emissions from regular domestic heating and cooking. In other terms an elimination of back-yard burning avoids redundant combustion, which is performed on top of normal energy needs. Similar reduction potential can be achieved if use of high chlorine coal is prevented. Due to the difference of EFs annual PCDD/PCDF emissions fall from >530 to 44 µg TEQ/a in that case.

Reduction potential of awareness raising and educational measures and subsidy measures (purchase of gas fired installations)

Legal obligations are not easy to enforce especially in the domestic sector. In this context, awareness raising and education on potential health and environmental effects can be regarded as important supportive measure to implement policy aims.

The impacts of “soft” measures such as awareness raising and funding cannot be calculated as a fixed sum, but depend on the quantity of waste prevented from being burned and the number of “gas/oil“ installations purchased to replace solid fuel fired devices.

6.2.2 Reduction potential of energy efficiency measures

This type of measure depends on EFs and/or energy efficiency (see chapter 6.1.1). It comprises change of appliances (towards higher energy efficiency), insulation measures, awareness raising, labelling and subsidy programmes, inclusion of very small appliances and control measures.

Reduction potential of high energy solid fuel fired appliances

The PCDD/PCDF reduction potential of a change to more efficient solid fuel fired appliances can be as high as 98% or 43 µg TEQ/20 GJ.

The reduction potential of an exchange of a given heating appliance by a more energy-efficient one using the same type of fuel is the result of several partial effects such as the difference in EFs and the difference in energy efficiency. The reduction potentials are calculated separately for wood and coal fired appliances and provides an additional differentiation for standard and advanced stoves as the ones being replaced. The results for wood fired appliances are documented in Table 6-6 and Table 6-7. The calculation for coal fired appliances is performed in Tables 6-8 and 6-9.

Replacement of simple device by energy efficient model		Wood fired standard stove	Advanced stove	Pellet stove/advanced boiler	Automatic boiler
EF	µg/TJ	800	300	50	30
Energy efficiency	η	0.45	0.7	0.85	0.9
Energy consumption	GJ/a	44	29	24	22
PCDD/PCDF emission	**µg TEQ/a**	**36**	**9**	**1.2**	**0.7**
Emission reduction	**µg TEQ/a**		**27**	**34.8**	**35.3**
Emission reduction	%		76	97	98

Table 6-6: Annual PCDD/PCDF emissions and reduction potential of an exchange of wood fired standard stoves by high efficient models (per 20 GJ/a useful heat)

Based on UNECE Guidebook factors and average energy efficiencies, emissions vary from 36 µg TEQ/a for a standard stove to 0.7 µg TEQ/a for an automated wood fired boiler. This corresponds to reduction rates from 76 – 98%. Table 6-7 illustrates that the reduction potential is considerably lower, when an advanced wood stove is replaced by a pellet stove or an automatic boiler.

Replacement of simple device by energy efficient model		Advanced wood fired stove	Pellet stove/advanced boiler	Automatic boiler
EF	µg/TJ	300	50	30
Energy efficiency	η	0.7	0.85	0.9
Energy consumption	GJ/a	29	24	22
PCDD/PCDF emission	**µg TEQ/a**	**9**	**1.2**	**0.7**
Emission reduction	**µg TEQ/a**	--------	7.8	8.3
Emission reduction %	%	--------	86	92

Table 6-7: Annual PCDD/PCDF emissions and reduction potential of an exchange of advanced wood fired stoves by more energy efficient models (per 20 GJ/a useful heat)

Table 6-8 illustrates the reduction potential of the installation of high energy efficient coal fired heating devices in comparison with a simple coal fired stove.

Replacement of simple device by energy efficient model		Coal fired standard stove	Advanced stove	Automatic boiler
EF	µg/TJ	1,000	500	40
Energy efficiency	η	0.45	0.7	0.9
Energy consumption	GJ/a	44	29	22
PCDD/PCDF emission	**µg TEQ/a**	**44**	**14**	**0.9**
Emission reduction	**µg TEQ/a**		**30**	**43.1**
Emission reduction %	%		68	98

Table 6-8: Annual PCDD/PCDF emissions and reduction potential of an exchange of coal fired standard stoves by highly efficient models (per 20 GJ/a useful heat)

As illustrated in Table 6-8, resulting PCDD/PCDF emissions range from 44 µg TEQ/a for a standard stove to 0.9 µg TEQ/a for an automated coal fired boiler, on the basis of UNECE Guidebook emission factors and energy efficiency information. Whereas the most important reduction potential can already be achieved by installation of an advanced stove instead of a simple stove, an additional emission reduction of 13 µg TEQ/a 20 GJ can be reached when choosing an automatic model (see Table 6-9).

Replacement of advanced device by energy efficient model		Advanced coal fired stove	Automatic boiler
EF	µg/TJ	500	40
Energy efficiency	η	0.7	0.9
Energy consumption	GJ/a	29	22
PCDD/PCDF emission	**µg TEQ/a**	**14**	**0.9**
Emission reduction	**µg TEQ/a**		**13.1**
Emission reduction %	%		94

Table 6-9: Annual PCDD/PCDF emissions and reduction potential of an exchange of advanced coal fired stoves by more energy efficient models (per 20 GJ/a useful heat)

Reduction potential of an exchange of gas or oil fired appliances

Energy efficiency measures in the field of liquid and gaseous fuel fired appliances provide limited emission reduction compared to solid fuel fired appliances, but can still be effective, if there is a large number of dwellings involved. In comparison to solid fuel fired devices, the reduction potential of more energy efficient oil and gas fired appliances is limited. It amounts only to 55% or 0.2 µg TEQ/20 GJ for oil and 0.03 µg TEQ/20 GJ for gas.

As there is no indication for reduced PCDD/PCDF emissions from modern oil or gas fired installations, the reduction potential of a replacement of old appliances by modern ones is a function of the increased energy efficiency. In this context, the energy efficiency of the simple appliance is assumed to be 50%, whereas the energy efficiency of a new appliance is 90%.

Replacement of standard device by energy efficient model		Standard oil fired device	High efficient oil fired device
EF	µg/TJ	10	10
Energy efficiency	η	0.5	0.9
Energy consumption	GJ/a	40	22
PCDD/PCDF emission	**µg TEQ/a**	**0.4**	**0.22**
Emission reduction	**µg TEQ/a**		**0.18**
Emission reduction %	%		55

Table 6-10: Annual PCDD/PCDF emissions and reduction potential of the exchange of simple oil fired stoves by more energy efficient models (per 20 GJ/a useful heat)

Replacement of standard device by energy efficient model		Standard gas fired device	High efficient gas fired device
EF	µg/TJ	1.5	1.5
Energy efficiency	η	0.5	0.9
Energy consumption	GJ/a	40	22
PCDD/PCDF emission	**µg TEQ/a**	**0.06**	**0.03**
Emission reduction	**µg TEQ/a**		**0.03**
Emission reduction %	%		55

Table 6-11: Annual PCDD/PCDF emissions and reduction potential of the exchange of simple gas fired stoves by more energy efficient models (per 20 GJ/a useful heat)

As illustrated in the tables above, the reduction potential of an installation of modern low emission appliances is comparably low from the point of view of PCDD/PCDFs, due to the low EF for oil and especially for gas. The achievable emission reduction for oil is only 0.2 µg

TEQ/a for a standard dwelling and in the case of a gas-heated apartment, the reduction is not above 0.03 µg TEQ/a in a similar setting.

Reduction potential of insulation measures

Insulation and regulation of dwellings reduce the energy consumption independent of the heating source by more than 50% and thus can be an effective measure for emission reduction in combination with many other possible measures. The effect is most significant for low performance solid fuel fired appliances where it can reach 26 µg TEQ/20 GJ. .

According to information from national authorities and energy statistics, optimized insulation of dwellings can reduce the energy consumption by roughly 40%. As this effect is related to heat loss, it is independent of the energy efficiency of the installed appliance. But it is related to the EF of the fired fuel in the specific appliance. In Table 6-12, the potential is presented separately for standard and advanced appliances and different fuels.

Heating appliance		Without insulation		With insulation
	Energy efficiency η	Energy consumption GJ/a	Emission [µgTEQ/a]	Emission [µgTEQ/a]
Standard stove				
Wood	0.45	44	36	14
Coal	0.45	44	44	18
High chlorine coal	0.45	44	533	213
Liquid fuel (old, low standard)	0.5	25	0.44	0,16
Gas (old, low standard)	0.5	25	0.07	0,02
Advanced boiler/stove				
Wood	0.7	28.6	8.6	3
Coal	0.7	28.6	14	6
High chlorine coal	n.d	n.d	n.d	n.d
Liquid fuel	0.9	22	0.22	0.09
Gas	0.9	22	0.03	0.01
Automatic coal fired device				
Automatic coal fired boiler	0.9	22	0.80	0.35
Modern biomass fired appliances				
Pellet stove/boiler	0.85	23.5	1.18	0.47
Automatic biomass fired boiler	0.9	22	0.67	0.26

Table 6-12: Annual PCDD/PCDF emissions & reduction potential of insulation measures (per 20 GJ/a household with assumed reducing effect of 40%)

As illustrated, the effect on PCDD/PCDF emissions is especially important for high-emission fuels and simple appliances, whereas it is quite limited for houses with gas fired appliances.

Insulation of the chimney is not recommendable from the point of view of PCDD/PCDF emissions. Insulated chimneys prevent the cooling of the flue gas, and consequently the flue gas temperature will be higher, compared to a not insulated chimney. This can lead to an increased PCDD/PCDF formation, if the temperature is above approximately 200 °C in the chimney. It will also increase the chimney draught and a better combustion, which also might increase PCDD/PCDF formation (see also chapter 3.6.2). Condensation boilers provide an advantage in this respect as an insulation is not necessary in this case. Condensation technology however, is difficult to apply for wood or other biomass fired boilers, due to the combination of vapour and particle emissions.

Reduction potential of awareness raising and educational measures, labelling schemes and subsidy measures (purchase of energy efficient and low emission installations)

Awareness raising and education on potential health and environmental effects can be regarded as an important complementary measure to implementing policy aims.

The impacts of “soft” measures such as awareness raising, labelling and funding cannot be calculated as a fixed sum, but depend on the number of “good“ installations purchased as a consequence of the measures. In this context, the level of active approach towards citizens (mass media campaigns, meetings, and school education) as well as the design and accessibility of information on a homepage are deemed important parameters for effectiveness.

Due to the impact of reduced energy needs, a stricter requirement for energy efficiency, as well as inclusion of the high emitting devices is an important factor for the reduction potential of labelling schemes. As concerns subsidies the reduction potential is related to the funds made available and the number and type of appliances targeted.

Reduction potential of inclusion of smallest appliances into control and emission limit schemes

Inclusions of smallest appliances into the control and limit schemes can be effectively assessed due to a large number of smallest appliances in the domestic sector.

The reduction potential of the inclusion of smallest appliances depends on the number and relative share of this type of installation in a country. With regard to EFs, there is currently no information on a further differentiation in the group <50 kWth. The annual energy consumption of a household is influenced by various parameters such as size and efficiency of appliance, climatic conditions, personal habits and the energy efficiency of the building.

On the other hand, inclusion into control and emission limit schemes offers the possibility of gaining better knowledge of the real emissions and to establish standards with respect to mass emissions and combustion quality. By this means it might be possible to identify and exchange low performance appliances while well performing appliances could be allowed to further operate. Pilot studies could allow evaluating the actual effect.

The exact number of very small appliances in the domestic sector is currently not known on an EU scale. Corresponding information is currently being collected and compiled in a preparatory study for Eco-design of EuP (Lot 15: Solid fuel fired small combustion installations)[15]. The project is on-going and will continue until September 2009.

A detailed inventory of the situation in Germany has been made by Struschka et al. 2007. According to this information, about 97% of all solid fuel fired appliances are <15 kW. This share is lower for other fuels. Nevertheless, 18% of oil-fired boilers are in the category <10 kW, and 57% are <20 kW. For gas-fired appliances the distribution is still 19% <20 kW. .

Given the common scientific findings and understanding that the very small and simple appliances are the ones with highest EFs, a stricter control and stricter requirements – for appliances <15 kW as well –might lead to the elimination of the “worst sources”. Consequently, a reduction of this limit and control of manually operated solid fuel fired devices is expected to be beneficial.

Reduction potential of monitoring and control (chimney sweepers)

Monitoring and control could be a supportive measure in implementing and enforcing the reduction potential of energy efficiency and combustion quality measures.

Monitoring and control of legal emission limits cannot be easily quantified but it can be assumed that it reduces emissions, since it increases adherence to combustion quality and allows identification and elimination of non-conforming appliances. In this context it is important to ensure regular control, to sanction non-conformity and to combine the monitoring with educational tasks if relevant. Expert knowledge of local customs and heating habits as well as local presence of control personnel can play important roles in educational activities and compliance. A corresponding body exists in the form of chimney sweepers, at least in some of the Member States. The reduction potential of this measure is a function of the administrative powers and the expert knowledge of its professionals. Chimney sweepers are active on the local level and are numerous in comparison to environmental inspectors. If chimney sweepers were turned into an environmental inspection force in all Member States, considerable effects on heating habits and an increased replacement of “bad performance” appliances could be expected.

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[15] Latest working documents – including Task 2 on market data– are available at http://www.ecosolidfuel.org/documents_15.php.

6.2.3 Reduction potential of renewable energy systems (wood & other biomass, solar energy, heat pumps)

The replacement of coal and wood fired appliances by modern biomass appliances brings about a significant dioxin emission reduction of up to 99% or 44 µg TEQ/20 GJ, whereas replacement of oil and gas fired appliances results in an increase of dioxin emissions of up to 1.1 µg TEQ/20 GJ.

The reduction potential of solar energy depends on climatic conditions and the overall energy need of a dwelling, but may achieve 40% in average. In case of installation of a renewable energy system an additionally optimised insulation is the option of choice as the absolute PCDD/PCDF emissions can be further reduced by a combined approach

The reduction potential of renewable energy sources is similar to an energy efficiency measure for wood fired appliances (see chapter 6.2.2). However, the promotion of renewable energy sources also includes the aspect of replacing a pre-existing coal, oil or gas fired appliance with a modern pellet or automatic biomass boiler, as well as the reduction potential of e.g. solar energy. The reduction potential is the result of differences in EFs and energy efficiency. The potential is presented separately for replacement of simple standard appliances (Table 6-13) and for more sophisticated advanced appliances (Table 6-14).

As illustrated in Table 6-13, the replacement of standard solid fuel fired stoves has a particularly strong PCDD/PCDF reduction effect. This is in the dimension of 34-44 µg TEQ/20 GJ in cases of installation of a biomass heating facility and in the range of 14-18 µg TEQ/a (per standard household) if a solar panel is installed to support the conventional heating system. The reduction is much higher if the replaced heating device was fired with high chlorine coal.

The replacement of advanced stoves (see Table 6-14) by a modern biomass installation reduces emissions by 7.4-13.6 µg TEQ/20 GJ. The reduction potential of a supportive solar panel (standard size) is 3.5 – 5.7 µg TEQ/ 20 GJ.

On the other hand, the replacement of oil and gas boilers by biomass fired appliances increases PCDD/PCDF emissions. However it has to be noted that, increases in absolute figures are low to moderate. Emissions increase by 0.4-1.1 µg TEQ/20 GJ. Solar panels reduce PCDD/PCDF emissions also in the case of an oil or gas heated dwelling due to the reduced energy need, but the absolute effect is not high. The reduction is in the dimension of 0.1 µg TEQ/20 GJ for oil-heated dwellings. For gas heated dwelling, the reduction potential only amounts to 0.01-0.02 µg TEQ/a (per standard household). Heat pumps have in principle the same reduction potential as solar energy but are impeded by low energy efficiency (30%) and are limited to certain geological conditions.

Eco-labelling for biomass fired heating appliances, can be a supportive measure as it can be a tool to increase the energy efficiency. The achievable overall reduction potential of labelling schemes is a function of purchased appliances and thus closely related to awareness raising and subsidy schemes. Subsidy programmes are another supportive measure, as it can considerably increase the number of purchased devices. The efficiency of any specific measure of this type is a function of the number of supported installations. In this context, awareness raising may play another important role.

Standard stove				Renewable energy source					
Fuel	Energy efficiency η	Original Energy consumption [GJ/a]	Annual emission [µg/TEQ a]		Energy efficiency [η]	Resulting Energy consumption [GJ/a]	Annual emission [µg/TEQ a]	Emission reduction [µg/TEQ a]	Emission reduction [%]
wood	0.45	44	35.6	1) Pellet stove	0.85	23.5	1.18	34.4	97
			35.6	2) Automatic boiler	0.9	22	0.67	34.9	98
			35.6	3) Solar panel	n/a	26.7	21.4	14.2	40
coal	0.45	44	44.4	1) Pellet stove	0.85	33.3	1.18	43.3	97
			44.4	2) Automatic boiler	0.9	22	0.67	43.8	99
			44.4	3) Solar panel	n/a	26.7	26.7	17.7	40
coal chlorine	0.45	44	533.3	1) Pellet stove	0.85	23.5	1.18	532.2	~100
			533.3	2) Automatic boiler	0.9	22	0.67	532.7	~100
			533.3	3) Solar panel	n/a	26.7	400.5	132	40
liquid fuel	0.8	25	0.25	1) Pellet stove	0.85	23.5	1.18	-0.93	-371
			0.25	2) Automatic boiler	0.9	22	0.67	-0.42	-167
			0.25	3) Solar panel	n/a	15	0.15	0.10	40
gas	0.8	25	0.038	1) Pellet stove	0.85	23.5	1.18	-1.14	-3,037
			0.038	2) Automatic boiler	0.9	22	0.67	-0.63	-1,678
			0.038	3) Solar panel	n/a	15	0.02	0.018	40

Table 6-13: Annual PCDD/PCDF emissions & reduction potential of renewable energy sources in comparison to simple conventional heating facilities (per 20 GJ/a)

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	Advanced stove			Renewable energy source					
Fuel	Energy efficiency η	Original Energy consumption [GJ/a]	Annual emission [µg/TEQ a]		Energy efficiency [η]	Resulting Energy consumption [GJ/a]	Annual emission [µg/TEQ a]	Emission reduction [µg/TEQ a]	Emission reduction [%]
Wood	0.7	28.6	8.6	1) Pellet stove	0.85	23.5	1.18	7.4	86
			8.6	2) Automatic boiler	0.9	22	0.67	7.9	92
			8.6	3) Solar panel	n/a	17.14	5.14	3.46	40
Coal	0.7	28.6	14.3	1) Pellet stove	0.85	23.5	1.18	13.1	92
			14.3	2) Automatic boiler	0.9	22	0.67	13.6	95
			14.3	3) Solar panel	n/a	17.14	8.57	5.73	
Coal chlorine	n/a	n/a	---	1) Pellet stove			---	---	---
			---	2) Automatic boiler			---	---	---
			---	3) Solar panel			---	---	---
Liquid fuel	0.9	22	0.22	1) Pellet stove	0.85	23.5	1.18	-1.0	-429
			0.22	2) Automatic boiler	0.9	22	0.67	-0.7	-200
			0.22	3) Solar panel	n/a	13.33	0.13	0.09	40
Gas	0.9	22	0.03	1) Pellet stove	0.85	23.5	1.18	-1.1	-3,429
			0.03	2) Automatic boiler	0.9	22	0.67	-0.6	-1,900
			0.03	3) Solar panel	n/a	13.33	0.02	0.01	40

Table 6-14: Annual PCDD/PCDF emissions & reduction potential of renewable energy sources in comparison to advanced conventional heating facilities (per 20 GJ/a)

For the additional reduction potential of insulation measures and the reduction potential of awareness raising and educational measures, labelling schemes and subsidy measures see chapter 6.2.2.

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6.2.4 Reduction potential of district heating

Key message: District heating entails important emission reduction up to almost 100% or 44 µg TEQ/20 GJ in relation to solid fuel fired domestic devices if based on gas, solar or geothermal energy. The reduction potential is lower but still remains positive for biomass or coal fired CHP. Large scale district heating is hampered by transport losses, limited thermal efficiency and inflexibility. These deficits however, are outweighed by the benefit of the use of by-product heat. The reduction potential of small scale decentralised heat plants without electricity generation is lower than that of CHPs but still can be positive depending on EFs and energy efficiency achieved. Currently available EFs (UNECE) might not reflect the state and emission level of modern plants.

Current state-of–the-art district heating offers the additional use of heat generated by electricity production as Combined Heat and Power plants (CHP). Accordingly, an increased share of district heat is generated in large power plants. Another option is the use of smaller heating units serving specific residential districts. In the following, the reduction potential of both types of power generation plants is discussed.

The reduction potential of district heating is determined by the following major parameters: Differences in EFs or in energy efficiency, losses of caloric energy as a function of required transport over distances (transport losses), the demand structure for domestic heating which is mainly a function of climate conditions and population density (annual average energy supply) and the use of by-product heat, which replaces primary energy consumption in dwellings served.

Table 6-15 compiles the reduction potential of district heating via large scale CHPs. Large scale CHPs are hampered by process inflexibility with excess heat production in summer times. Consequently the calculation of the reduction potential of large scale district in heat in this chapter takes into account a capacity utilisation of 85%, an annual average energy supply of 30% of the energy produced and average transport losses of 10%. Thermal energy efficiencies and EFs applied are illustrated in Table 6-15. As regards emissions and transport losses, further improvement is reported to be possible in the field of piping systems, but room for technological improvements (namely increased energy efficiency) is in particular seen in the power production process itself. Whether this will have an additional effect on dioxin emissions, is not known up to date. EFs for large scale district heat are derived from the UNEP Toolkit due to lack of alternative reliable data.

As illustrated in the table all types of CHPs have a positive reduction potential, in comparison to local heating due to the fact that without district heat (DH) the emissions of the CHP and the emissions of the local appliance would have to be added, whereas in case of DH only the emissions from the CHP arise.

Local domestic heating	PCDD/PCDF emissions	CHP plants							
		Wood CHP (η_{th} = 0.55); (EF = 50*)		Coal CHP (η_{th} = 0.55); (EF = 10*)		Oil CHP (η_{th} = 0.55); (EF = 1.5*)		Gas CHP (η_{th} = 0.55); (EF = 0.5*)	
		[µgTEQ/a]	Red. [%]	**[µgTEQ/a]**	Red [%]	**[µgTEQ/a]**	Red [%]	**[µgTEQ/a]**	Red [%]
Wood Standard stove (EF = 800*) (η = 0.45) (	**Without DH***	39.96		36.36		35.68		35.60	
	With DH	4.1	89.6	0.8	97.8	0.12	99.7	0.04	99.8
Wood automatic pellet boiler (η = 0.9) (EF = 30)	**Without DH**	4.77		1.47		0.79		0.71	
	With DH	4.1	14	0.8	45.6	0.12	84.5	0.04	94.2
Coal Standard stove (η = 0.45) (EF = 1000)	**Without DH**	48.54		45.24		44.56		44.48	
	With DH	4.1	91.6	0.8	98.2	0.12	99.7	0.04	99.1
Coal Automatic coal boiler (η = 0.9) (EF = 40)	**Without DH**	4.99		1.69		1.01		0.93	
	With DH	4.1	17.8	0.8	52.7	0.12	87.9	0.04	95.6
Oil standard device (η = 0.8) (EF = 10)	**Without DH**	4.35		1.05		0.37		0.29	
	With DH	4.1	5.7	0.8	23.8	0.12	27	0.04	89.9
Gas standard device (η = 0.8) (EF = 1.5)	**Without DH**	4.14		0.84		0.16		0.08	
	With DH	4.1	1	0.8	4.8	0.12	24.5	0.04	49.4

Table 6-15: Overall (domestic and industrial) PCDD/PCDF emission reduction potential of a change from local heating to district heat from CHPs (per useful heat of 20 GJ/a)
* PCDD/PCDF emissions are the sum of CHP and domestic emissions

Table 6-16 illustrates the reduction potential of small decentralised heat plants. In contrast to CHPs, the thermal energy efficiency of heat plants is 90 % and the annual average heat supply is about 100% because energy generation is controlled by costumers' demand. As regards transport losses, a share of 10% is included into the calculation.

Domestic appliance			Small decentralised heating plants									
			Wood heat plant (η = 0.9) (EF = 300*)		biomass heat plant (η = 0.9) (EF = 500*)		Coal heat plant (η = 0.9) (EF = 200*)		Oil heat plant (η = 0.9) (EF = 10*)		Gas heat plant (η = 0.9) (EF = 2*)	
Fuel and appliance type		PCDD/PCDF [µgTEQ/a]	PCDD/PCDF [µgTEQ/a]	Red. [%]	PCDD/PCDF [µgTEQ/a]	Red. [%]	PCDD/PCDF [µgTEQ/a]	Red. [%]	PCDD/PCDF [µgTEQ/a]	Red. [%]	PCDD/PCDF [µgTEQ/a]	Red. [%]
Wood	Standard stove (EF = 800) (η = 0.45)	35.56	7.4	79	12.3	65	4.9	86	0.25	99	0.037	100
	Automatic pellet boiler (η = 0.9) (EF = 30)	0.67	7.4	-1011	12.3	-1752	4.9	-641	0.25	63	0.037	93
Coal	Standard stove (η = 0.45) (EF = 1000)	44.44	7.4	83	12.3	72	4.9	89	0.25	99	0.037	100
	Automatic coal boiler (η = 0.9) (EF = 40)	0.89	7.4	-733	12.3	-1289	4.9	-456	0.25	72	0.037	94
Liquid fuels	Standard stove (η = 0.8) (EF = 10)	0.25	7.4	-2863	12.3	-4838	4.9	-1875	0.25	1	0.037	80
Gas	Standard stove (η = 0.8) (EF = 1.5)	0.04	7.4	-19653	12.3	-32822	4.9	-13069	0.25	-558	0.037	-32

Table 6-16: PCDD/PCDF emission reduction potential of a change from local heating to decentralized heat from small district heating plants (per useful heat of 20 GJ/a)

According to this calculation, small decentralized heating plants have a reduction potential in relation to standard devices fired with solid fuels, whilst an emission reduction in comparison to high energy efficient appliances can only be realised by oil and gas heated plants. Furthermore only gas heated plants have a positive potential compare to oil heated dwellings.

It has to be noted that the calculation is based on the EFs compiled in the UNECE Guidebook, as the only specific information source. However, it should be taken into account that these do not represent advanced technical standard, and probably underestimate the reduction potential. EFs as provided by the UNEP Toolkit or as low as indicated for modern automated domestic appliances might be more realistic for modern plants. In this case small scale heating plants could be equivalent to domestically installed modern devices from the emission point of view.

In the case of small scale CHP (technically feasible and increasingly envisaged), thermal energy efficiency would decline, but the advantages of *by-product heat* (see above) would become relevant.

6.2.5 Reduction potential of secondary emission reduction measures (flue gas treatment)

Key message: The potential of flue gas treatment measures in the domestic sector is hard to assess due to the lack of measurement data. However as a first indication it might be important to note, that very recent preliminary measurement data suggest no effect on dioxin emissions. Further investigations into impacts and implications of abatement technology (filters) in domestic settings would be needed and should be aimed at.

Three different types of flue gas treatment and scrubbing devices are currently under development or marketed in Germany. All contribute to a general emission reduction. The focus in all cases is PM emission.

1. Fabric filters (baghouse) produced by the company Oskar Winkel/KÖB are currently available for installations of 25-30 kW and bigger. According to the producer's information, the installation of the filter reduces PM emissions by 96%.

2. Electrostatic filters developed by EMPA (Swiss) and marketed by the company Kutzner & Weber, are mainly installed for single house heating installations and small boilers <15 kW but are applicable up to 40 kW. The PM reduction potential is 50-90% (~73%).

3. The wet scrubber (Hydrocube) produced and marketed by the company Schräder has a double function for heat recovery and flue gas treatment. The device is available for installation in boilers from 15-500 kW. It is suitable for oil, gas and wood-fired installations and according to the producer, has a PM reduction potential of >70%. Due to the heat recovery, the energy efficiency of the appliance can be increased by an additional 12% on average.

Although dioxins are mainly adsorbed to PM what implies that removing PM means removing dioxins, very first measurements performed in DK showed no reducing effect. Hence the technology can not be recommended from the point of view of PCDD/PCDF emissions before it has not been further assessed.

6.3 Evaluation of overall potentials and discussion of advantages and disadvantages of measures

In the following, reported measures are discussed in the light of the selection criteria, in order to enable the selection of examples of good practice. The assessment will be performed by approach and category. The allocation of reported measures follows as far as possible the "areas of activity" (change of fuel, energy efficiency measures, promotion of renewable energy and abatement technology) as identified in chapter 6.1.

Aspects such as the scale of a measure (local, Regional, national), the character of a measure or approach taken (e.g. voluntary-mandatory) and the field of policy (education-communication, economic incentive, legal obligation, etc.) will be taken into account for the ranking if appropriate and possible. The assessment will take into consideration the selection criteria identified in chapter 6.1, in order to determine those measures that are qualified for selection as best practice. This results in a recommendation for selection of case studies in the form of an expert judgement based on current preliminary knowledge.

6.3.1 Change of fuel (regular fuels)

Legal requirements/programmes for changing of combusted fuels

As indicated below, a number of MS reported on legal measures taken or official programmes initiated to change the use of fuels in the domestic sector from certain solid to other fuels. Legal requirements and national programmes were motivated primarily by the need to reduce dust emissions and to reduce emissions of various types of pollutants other than dioxins. The impact on dioxin emissions however, were also an additional driving factor as far as can be seen.

	MS	Legal requirements and standards
M-BG1	BG	National programme exists for implementation of natural gas in the domestic sector.
M-IT1	IT	In some municipalities, coal heating boilers have been banned (but use of coal for heating was already very limited beforehand).
M-PL1	PL	Programme on the reduction of so-called "low emission sources"[16] (Initially implemented in the Silesian Region in 1995, extended to other regions as well; includes development of central heating systems (district heating, gas heating, etc) in densely populated areas, progressive change in fuel structure; promotion of gas/oil use for cooking purposes.
M-UK1	UK	Ban of smoky fuels in certain areas
M-IE 1	IE	Ban of smoky fuels in certain areas

Table 6-17: Overview of legal measures/programmes for fuel change in the domestic sector

Subsidy programmes for changing of fuels

In this category, only one measure was specifically reported by Member States. This is the programme to develop central heating facilities and to offer access to electric and gas heating and cooking in densely populated areas, which started as pilot project in the Silesian

[16] The name of the programme refers to the fact that industrial sources were regarded as a far more important problem at that time in Poland

region in Poland. Whether the programmes in other MS (e.g. BG. IT) are associated with funds or subsidies was not reported.

Reduction potential:

As demonstrated in chapter 6.2.1, change from solid to liquid or gaseous fuels is associated with a high reduction potential in the dimension of up to 35 - 44 µg TEQ/20 GJ. Based on the figures elaborated in chapter 6.2.1, the exchange of solid fuels by gas is more effective than replacement by oil or replacement of “smoky” by so-called smokeless solid fuel (SSF) fuels (see EFs in chapter 4.4.3). Whether the solid fuel replaced is wood, coal or peat, is less critical. The reduction potential of the measure is a function of the installations to be replaced and thus can be increased by combinations of a legal ban with subsidies and awareness raising.

The effect is greater:

- if the scope of the measure is wider
- if there exist more installations with solid fuel
- if the existing appliances park is “older“

Policy conformity:

With regard to climate objectives, a change from solid to liquid or gaseous fuels is in line with policies as long as coal-fired appliances are replaced. In this case even a reduction of CO_2 emissions results (see Table 6-18).

Fuel	CO_2 in t/TJ
Brown coal	112
Hard coal/anthracite	92
Oil	79
Gas	52

Table 6-18: CO2 emissions in relation to combusted fuel

On the other hand, this type of measure may interfere with the objective of a 20% share of renewables (if wood is replaced). This can be avoided if it is restricted to urban areas. This type of measure is contrary to energy autarchy principles in all MS which do not possess their own natural oil or gas resources. In addition, implementation of this measure is difficult in rural or loosely populated areas.

Costs:

Costs arise from installation of new oil or gas heating facilities and fuel costs, and the need to establish a distribution infrastructure. In this context the establishment of a gas distribution net is by far the dominating parameter. Average costs for an oil or gas heating facility are in the dimension of €10,000. Fuel costs are currently somewhat higher for oil and gas than for coal or wood (see chapter 6.1.3) For a subsidy programme, additional costs for national or regional authorities arise which depend on the level of the subsidy.

A change from solid to liquid or gaseous fuels is an effective reduction measure from the PCDD/PCDF point of view. It is most recommended for MS with a high share of solid fuels and very simple heating appliances. Due to autarchy and climate objectives, it is politically recommended for densely populated urban areas in countries with currently high shares of solid fuels and where it will not interfere with the 20% objective for renewables. In addition, it may be appropriate for MS with own natural gas or oil resources. Extension should be started at – and be linked to – pre-existing gas pipelines, because extensions within existing gas pipeline networks result in lower costs.

Based on the discussion of available information in the light of selection criteria, the final recommendation for this type of measures is the following:

Appropriate and recommended for urban areas,

with gas as a favoured fuel

6.3.2 Ban of waste burning

Legal restrictions for domestic or open burning of waste

The majority of MS has established bans for waste burning which in general are quite similar, except for the possible inclusion of open burning of garden waste, which is still permitted in a number of MS.

	MS	Requirements for the burning of waste
M-AT1	AT	Waste burning is prohibited.
M-FL1	BE-FL	Legal framework for control of waste burning established.
M-BR1	BE -BR	Open burning of waste is forbidden.
M-WA1	BE -WA	Open burning of waste is forbidden.
M-CY1	CY	Prohibition of burning of any kind of waste in municipal areas; open burning of agricultural waste is illegal (amendment sent for approval at end of 2007).
M-CY1	CZ	Open burning of waste is prohibited. Local authorities can set conditions for open burning of dry vegetable material only.
M-DE1	DE	Burning of waste in small combustion appliances is not permitted; Control by chimney sweepers. Burning of garden waste is regulated at local level; “burning days” in autumn may be permitted in single communities, whereas the majority of cities have already banned this practice.
M-DK1	DK	Burning of any types of waste in domestic heating appliances or in bonfires is forbidden in Denmark.
M-EE1	EE	Backyard burning of waste is forbidden or authorized only for certain types and under certain conditions.
M-FI1	FI	Open burning of waste not allowed.
M-FR1	FR	Open burning of waste is forbidden. However, in some cases dispensations are possible.
M-IE1	IE	Backyard burning of waste is illegal.
M-LU1	LU	It is not allowed to burn waste, but the burning of gardening waste is tolerated in many cases. The burning of wood is not regulated.
M-NL1	NL	Open barrel burning and open burning of waste is forbidden.
M-PL1	PL	Burning of household waste is prohibited. Plant residues, certain types of agricultural waste are allowed to be burned off in areas where

	MS	Requirements for the burning of waste
		separate collection of organic waste is not organised.
M-SE1	SE	Private burning of household waste is illegal. Local authorities can issue local relegations on what private individuals are allowed to burn (e.g. garden waste).
M-SI1	SI	Open burning is forbidden (Environment Protection Act (OJ RS 41/2004).
M-SK1	SK	The burning of waste is prohibited.
M-UK1	UK	Planned Change of Paragraph 2 of Waste Management (England and Wales). Regulations 2006 SI No 937 and modification of Section 33 of the Environmental Protection Act 1990. Removal of exemption for households to pollute the environment with their own controlled waste.

Table 6-19: Overview of MS measures related to domestic/open burning of waste

Awareness raising to eliminate waste burning

In addition to legal bans – which in many cases cause difficulties related to enforcement – a number of MS has established awareness raising programmes to reduce uncontrolled backyard burning, burning of agricultural waste or domestic combustion of waste and waste wood (see also Annex 3.3).

MS	Description of awareness raising approaches
BG	Information for the population on impacts of backyard burning and waste combustion.
CY	Information about uncontrolled backyard burning and waste seminars to inform the public (planning stage).
DE	Planned: Mandatory training of users conducted by chimney sweepers prior to commissioning any solid fuel driven heating installation, or in cases where the operator has changed
DK	Information campaign to improve firing habits. Performed during wintertime; including local initiatives, leaflets, and homepages and TV spots.
IE	Several campaigns regarding illegal collection of waste and backyard burning. Campaigns make use of mass media such as television, radio and newspapers, advertisements, hotlines, leaflets (“Race Against Waste campaign” “Dump the Dumpers’ phone hotline”. “See something, say something” campaign.
IT	Guide to use dry wood and prevent burning of plastics and painted wood (Province of Bolzano).
NL	Information and awareness campaigns on good practice for residential open fireplaces (e.g. impacts of burning of plastics and painted wood).
PL	Public education related to burning of certain types of wastes, threats connected with PCDD/F (brochure).

Table 6-20: MS measures to raise awareness on risks of waste combustion

Reduction potential:

The reduction potentials of heating exclusively with virgin wood and of elimination of backyard burning of waste are considerable (see chapter 6.2.1). For evaluation of the effect of an inclusion of garden waste into a ban it should be noted, that the emissions from combustion of dry garden waste seem to be in the same dimension as those from wood combustion. They are far lower than the ones occurring at waste combustion (see chapter 3.4.3 and chapter 4.6). Nevertheless, combustion of garden waste leads to additional

PCDD/PCDF emissions (not performed for heating purpose and thus not replacing other fuels), so that a complete ban of waste burning is regarded as desirable.

The final reduction potential of this type of measure depends on the compliance of citizens. Thus, it should be closely linked to awareness raising and might be supported by intense control at local level. Involvement of the local authorities and citizens is a crucial aspect in this respect. The reduction potential of awareness raising measures depends on the willingness and the economic resources of the citizens (effectiveness). Effectiveness of awareness raising measures strongly depends on the attractiveness and timing. Pro-active measures, actively addressing citizens such as for example TV spots, radio messages, newspaper campaigns, advertisements, meetings and school education are associated with a high effectiveness. In the group of more passive measures, such as websites, the presentation of the information (layout and accessibility) are important parameters. In addition other parameters such as, for example, the availability of free public waste management services can promote compliance of citizens

Policy conformity:

Elimination of waste combustion is in line with climate change objectives, energy efficiency requirements, and requirements of environmentally sound waste management

Costs:

Costs arise mainly for operators (purchase of regular fuels, waste taxes/fees depending on the system applied), but seem to be comparably low (~€100/tonne).

Conclusion: Elimination or reduction of waste burning (open and domestic) is an important reduction measure advisable for all MS. A major focus should be put on awareness raising activities. In the context of domestic combustion, information should also stress “hidden” dangers such as PCP treated wood pallets appearing as untreated so that they might easily be used by citizens by mistake. With respect to open burning of garden waste, guidance for home composting and the establishment of collection services or shredder services for citizens are additional tools to support compliance.

Based on the discussion of available information in the light of selection criteria, the final recommendation for this type of measures is the following:

Appropriate and recommended

Due to its pro-active character (TV spots, radio and newspaper advertisement, posters) and the fact that it has already been accomplished, the Irish example seems to be one of the best examples of good practice in this sector. The same applies for a recent campaign in DK. Examples from other countries might be as valuable, but not enough information has been made available to enable a more detailed assessment.

6.3.3 Energy efficiency measures

Reported energy efficiency measures comprise efficiency standards for domestic appliances including mandatory control schemes, awareness raising programmes, labelling schemes and subsidy programmes as compiled below. Energy efficiency measures are often closely related to renewable energy sources (see also chapter 6.3.4).

Legal emission limit values and efficiency standards for appliances

Due to the requirements of the Framework Directive on Air Quality (2008/50/EC) and the Energy Efficiency Directive (2002/91/EC) emission limit values (ELV) and energy efficiency standards for heating appliances are a widespread measure in MS.

Measure	MS	Legal requirements and standards
M-AT1	AT	Installation of boilers and stoves without type approval is forbidden.
M-AT2	AT	ELV for CO, NOx, TOC, **PM for boilers and stoves <400 kW,** not yet ratified.
M-BR1	BE-BR	Emission limits for NOx and **CO emissions from central heating boilers** <400 kW (7 June 2007.
M-WA1	BE-WA	Emission limits for NOx and CO emissions from central heating boilers and burners <400 kW fuelled by liquid or gaseous fuels.
M-CY1	CY	Low emission limit values for CO (in preparation).
M-CZ1	CZ	Small combustion sources (thermal output <200 kW) must comply with permissible smoke blackness; CO emission measurement in some cases.
M-DE1	DE	Federal Emission Control Act (1st BImSchV) covering combustion sources >15 kW, limit values for **CO (0.5-4 g/m³) and dust** (150 mg/m³).
M-DE2	DE	Inclusion of heating facilities from 4 kW for boilers, single stoves.
M-DE3	DE	Restriction on operation level (open fireplaces only occasional operation permitted).
M-DK1	DK	Mandatory environmental standards for residential wood burning appliances based on limits for **PM** (effect in 2008).
M-EE1	EE	Energy saving technologies in the residential sector.
M-PL1	PL	Emission standards from heating installations including SO2, NOx, **and particulate matter (dust)** depending on the thermal capacity of boilers and type of fuel used.
M-SE1	SE	Limit values for “minimum performance” in new small-scale installations (<300kW).

Table 6-21: Overview of ELV and energy efficiency for appliances in the domestic sector

For control of the set emission limits and energy efficiency standards a number of MS reported to have established mandatory control schemes.

Mandatory inspections for emission limits and energy efficiency

Measure	MS	Legal requirements and standards
M-AT1	AT	(Multi) annual inspections of certain types of boilers required.
M-WA1	BE-WA	Regular inspections for boilers should come into force in September 2008.
M-DE1	DE	Regular emission measurements (annual) performed by the chimney sweepers for automatic pellet and wood-chip driven boilers. For hand operated installations, an analysis is performed once after the start of operation.
M-DE2	DE	Regular emission measurements for both automated and hand operated pellet boilers (biannually).

Measure	MS	Legal requirements and standards
		Control of compliance of single stoves will be performed prior to commissioning ("test-bench limits").
M-FR1	FR	contrôles périodiques des installations consommant de l'énergie thermique: boilers have to be controlled regularly.

Table 6-22: Overview of legal requirements for inspection of domestic sources

Furthermore a majority of MS have established information activities and awareness raising to promote energy efficient heating to comply with Directive 2002/91/EC.

Awareness raising to improve burning habits and promote energy efficiency

MS	Energy efficiency (PAH or dust emissions)
AT	Energy efficient use of heating systems http://energytech.at/
BE-BR	Information on energy saving measures provided on EPA website including change of heating installations http://www.bruxellesenvironnement.be/Templates/Particuliers/Niveau2.aspx?id=54&langtype=2060
DE	Brochure on proper domestic combustion of solid fuels including appropriate disposal of resulting residues and management of a website with recent information on emissions from domestic combustion (e.g. dust) and latest developments. http://www.umweltbundesamt.de/energie/index.htm; http://www.umweltbundesamt.de/uba-info-presse/2007/pd07-005.htm. http://www.heizprofi.com/_upload/Heizfibel_2007.pdf (Industry)
DK	National information campaign by Danish EPA to improve the firing habits (in winter, including local initiatives, Leaflets, homepages and national TV-spots). The current campaign is considerably stronger than the previous. www.fyrfornuftigt.dk; http://www.mst.dk/ http://www.mst.dk/NR/exeres/5450F455-2F05-4989-8A52-1E341F4E7C90.htm
EE	1. Guidance: "Good practice in residential combustion" published in 2006 especially to reduce PM2.5 and PAH emissions from domestic combustion. 2. "Guidance for energy saving in the residential sector" published 2000 by the Ministry of Economic Affairs.
FI	Guidelines for wood burning http://www.faisonsvite.fr/
FR	Since 2004 and the launch of the programme "Economies d'énergie, faisons vite, ça chauffe!" ("Energy savings, let's act quickly, it's warming!"). ADEME carried out numerous actions for awareness raising with the general population of their fundamental role for energy control and renewable energy sources development. Public information about wood heating. Flamme Verte, mark and tax credit, practical guidance, such as "Heating with wood" and "Heat and comfort without waste" http://www.faisonsvite.fr/
IE	Information on proper heating, energy saving and renewable energy (greener home scheme) http://www.sei.ie/index.asp?locID=5
IT	Regional (Bolzano) public information and awareness for residential devices.
PL	Public education related to use of low-performance furnaces and boilers.
SE	Information campaigns to improve drying of firewood and better operation of boilers in order to reduce overall pollution (focus on PM and PAHs).
SK	Biomass Strategy and energy saving campaigns.
UK	Domestic combustion; http://www.defra.gov.uk/environment/climatechange/uk/household/

Table 6-23: MS measures to raise awareness on proper heating and promote energy efficiency

Awareness raising activities reported by MS focus on websites providing short summaries, as well as practical guides for energy savings and links to recommended appliances, service providers or subsidy programmes. More details on selected websites are presented in Annex 4.

Subsidy programme for increased energy efficiency

The Brussels Capital Region established a subsidy system for purchase of high efficiency gas boilers. 50% of the bill and a maximum of €400 are paid to house owners to speed up the exchange of older devices.

In Poland the change to modern coal fired appliances is promoted by means of regional subsidy programmes. Subsidy programmes for increased energy efficiency in other MS focus on biomass installations and hence are discussed in chapter 6.3.4.

Reduction potential:

Although not directly addressing dioxins, the dioxin reduction potential of energy efficiency measures (installation of highly efficient devices) can almost reach that of change to oil or gas heating if solid fuel fired appliances (e.g. coal ovens) are replaced. Besides a lower EF achieved the achieved reduction in fuel consumption is the major reason for this. An additional effect of about 60% reduction can be achieved by optimised insulation and domestic temperature regulation (see chapter 6.2.2). Proper operational practice is known to be an effective measure to reduce PCDD/PCDF emissions from manually operated solid fuel fired appliances; even if there are no standardised data to quantify this effect.

The absolute effect of this type of measure is a function of the number and type of appliances exchanged and depends on the compliance of citizens. Thus appropriate awareness raising, labelling, and subsidies and intensified control, are crucial parameter as indicated in chapter 6.2.2.

Policy conformity:

Energy efficiency measures are fully in line with current policy priorities and legal obligations from air protection and climate policies.

Costs:

Costs for the installation of new appliances are in a dimension of 10,000 €. If not combined with a change of fuel no further costs are to be expected. Hence related costs tend to be lower than for fuel change activities especially if compared to a change to gas.

Costs for mandatory inspections arise from controls and emission measurement. According to German information, they are currently in the dimension of €100/a.

Costs for awareness-raising arise from the production of brochures, establishment and maintenance of homepages or any other media used. They depend on type, intensity and time frame of the activity but according to provided information can account for hundreds of thousands of Euro to be borne by MS authorities. Although difficult to estimate, costs for labelling schemes to be covered by industry, may be in a similar range.

Conclusions: Although energy efficiency measures are not directly related to PCDD/PCDF emissions these types of measures have a reduction potential that can almost reach the dimension of a switch to oil and gas, especially with respect to solid-fuel fired appliances such as coal and wood. The fact that the measures are fully in line with other policies for the domestic sector and lower in costs than the installation of a gas heating infrastructure, are an additional important impetus to make use of it.

Due to the important additional reduction potentials of insulation and temperature regulation, a combined approach should be aimed at whenever possible.

This type of measure is suitable for all MS and is highly recommended in all cases were a change to gas is not feasible. It is most effective for MS and regions with high shares of simple solid fuel fired heating systems (coal, wood). A combined approach using awareness-raising and subsidies in addition to limits for energy efficiency seems to be recommendable.

Based on the aspects and parameters discussed above, the final recommendation for measures to promote energy efficiency is as follows:

Highly appropriate and recommended

Potentials depend on, and will be largely improved by, a combination of various policy approaches such as limits, insulation, education and market instruments.

6.3.4 Renewable energy sources

According to reported information, promotion of renewable energies in MS is mainly performed by means of labelling, education and subsidy programmes.

Labelling schemes for promotion of high performance renewable energy appliances

Labelling schemes for wood fired appliances are established in AT, DE, IE, FR and the Nordic countries (DK, FI, SE and NO) (see chapter 5.4). Current labelling schemes differ in detail and strictness of limits but do not address POPs and exclusively focus on energy efficiency, CO, NOx and particle/dust. A detailed description of existing labelling schemes is presented in Annex 3.5.

A comprehensive investigation of labelling schemes in the EU related to solid fuel fired small combustion installations, has been performed in a recent study commissioned by DG Tren "Preparatory Study for Eco-design requirements of EuPs (Lot 15)".

Subsidies for purchase of high performance appliances

Subsidy programmes for small-scale biomass combustion were reported to be established in AT, BE, DE, DK, FR, IE, LU, SE, (see chapter 5.5). Apart from this, subsidies for solar panels and heat pumps have been reported from IE and DE. A more detailed description of selected programmes is provided in Annex 3.6.

Reduction potential:

As calculated in chapter 6.2.3, biomass-fired appliances have a considerable reduction potential that almost reaches the dimension of a change to oil and gas, if compared to standard conventional coal or wood fired appliances. On the other hand there is a slight increase emissions (~1 µg TEQ/20 GJ) when biomass fired appliances are used to replace oil and gas fired boilers. Apart from the achievable EF (currently only UNECE data), the energy efficiency of the biomass appliance and the number of exchanged appliances are the major reduction parameters.

Thermal solar panel can reduce the energy need and hence the dioxin emissions in average by about 40%. The reduction potential of other renewable energy sources like geothermal energy depends on appropriate hydro-geological conditions. While heat pumps are hampered by low energy efficiency, the use of geothermal energy for district heat (see also chapter 6.2.4 or 6.3.5) can be an appropriate option, when associated risks have been further resolved and clarified.

The maximum reduction potential for biomass fired appliances can be calculated as a function of current or envisaged fuel shares, technical standard of appliances and energy need:

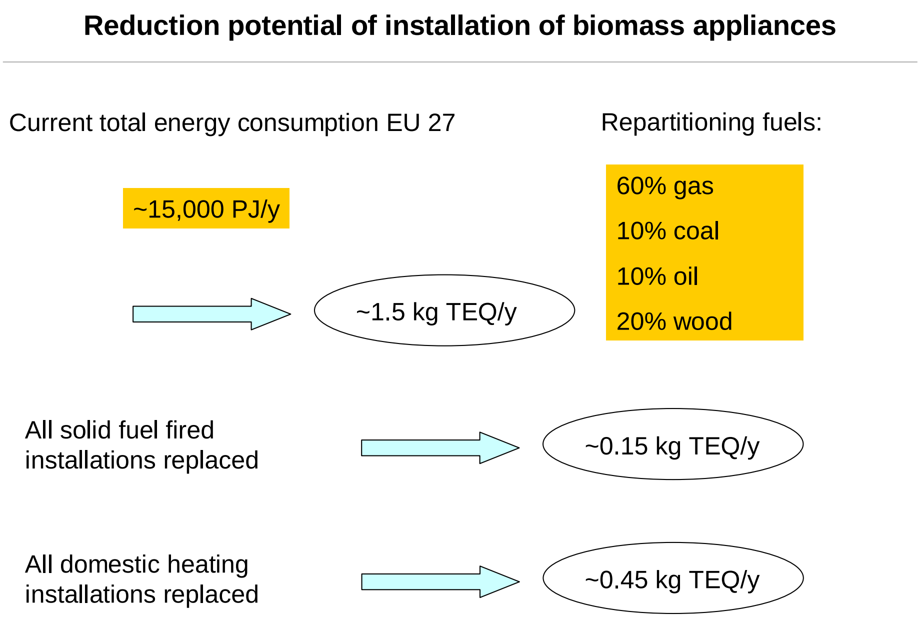

Figure 6-1: Exemplary reduction potential of installation of modern biomass appliances in the domestic sector at EU scale

As illustrated in figure 6-1, PCDD/PCDF emissions could be reduced from currently about 1.5 kg TEQ/a to 0.15 kg TEQ/a by installation of modern biomass-fired heating appliances instead of existing solid fuel fired heating devices. If also gas and oil fired appliances were replaced, annual PCDD/PCDF emissions of 0.45 kg/a would result.

This calculation is based on an estimated EU average repartitioning of fuels as indicated in the figure and the EFs attributed to the different fuels and appliances in the UNECE Guidebook. The calculation corresponds to a share of different technologies and energy efficiencies as follows:

- Wood stoves: 10% old standard stoves; 60% advanced stoves/boilers; 30% high efficient automated appliances.
- Coal stoves: 10% old standard stoves; 60% advanced stoves/boilers; 30% high efficient automated appliances
- Liquid and gas fired boilers: 50% standard boilers with an energy efficiency of 80%; 50% modern energy efficient appliances with an energy efficiency of 90%

As regards the decisive parameters for the reduction potential of eco-labelling for biomass fired appliances or subsidy programmes, see chapter 6.2.2.

Policy conformity:

Promotion of renewable energy appliances is explicitly requested by climate change policy. Main disadvantages of biomass appliances are increased emissions of PCDD/PCDFs, PM, acids and other pollutants when compared to liquid and gaseous fuels. Labelling is thus fully consistent and a direct consequence of related air quality policy. However, the availability of appropriate biomass is limited, so that a restriction to significant expansion has already been observed in certain MS (see chapter 6.7.6).

Costs:

Costs for installation of new appliances are significant. As an indication it can be stated that the installation of a new firing appliance is in the dimension of €10,000 and €800-€1,300/m^2 for a photovoltaic installation.

Overall costs of labelling procedures might be in the dimension of several hundred thousand Euros per year for all manufacturers in total, but are regarded as reasonable for a single manufacturer in relation to other sales and marketing efforts.

Costs for subsidies amount to 10-50% of the actual investment costs.

Conclusions: From the information provided on renewable energy programmes, no specific country measure can be identified as a best option. However, subsidy programmes and eco-labels can be regarded as preferable if covering several renewable sources and types of appliances, if providing a percentage subsidy and if setting a high energy efficiency limit.

Based on the evaluation of available information in the light of the selection criteria, the recommendation for measures to promote renewable energy is as follows:

Appropriate and recommended

due to increase of emissions in relation to oil and gas fired appliances and other restrictions in feasibility (e.g. climate, energy efficiency, etc).

Potentials will be improved by combination of different policy approaches.

6.3.5 Small and large scale district heating

Increased use of large district or small scale decentralized heating has not been reported by any of the MS as a measure to reduce domestic PCDD/PCDF emissions. On the other hand, it was discussed during the expert workshop held during the project running time that for example the UK intends to focus on the expansion of the district heating sector to fulfil its obligations with respect to renewable energy. District heating is common practice already in many Member States and largely based on CHPs. The major fuel used is gas on European scale, but renewable energy and waste is increasingly used. The Nordic countries in particular already started to use waste incineration and energy recovery from landfill gas for district heating.

Small decentralised heating systems start with a capacity of 50 kW, whilst large scale district heating installations provide several MW. Typically small decentralised heating systems focus on renewable energy, and are often constructed to target a given energy demand while the basis for large scale district heating is a given energy supply for which suitable demand structures are searched. The basic parameters to identify economically feasible solutions are equal for both systems. Small decentralised heating systems fit well with short distances and low energy demand while large scale district heating can be applied also over long distances and typically needs high demand on heat.

Reduction potential:

With a reduction potential in the dimension of 35.5 µg TEQ/20GJ useful heat, in relation to simple solid fuel fired domestic devices district heating can be more or less equivalent to modern automated appliances. On the other hand district heating with solid fuels clearly increases PCDD/PCDF emissions (up to 7.4 µg TEQ/20GJ), in comparison with domestic gas and oil devices, similarly to domestic heating with biomass. On the other hand CHP generated district heating is generally advantageous from an overall point of view.

Policy consistency:

District heating definitely is in line with climate policy. Directive 2004/8/EC stipulates an increased use of combined heat and power (CHP) plants in order to achieve a CO_2 emission reduction in the energy production sector. District heating might also be in line with the waste management hierarchy requesting increased energy recovery from waste incineration and landfill.

Small decentralised heating systems are typically also in line with climate policy. However, an appropriate technology and scale has to be applied, isolated heat generation without providing electrical energy might in some cases not be regarded as best available technology.

Costs:

The costs for a district heating installation consist under a macroeconomic view of three major elements: The power station, the heat distributing system and the installations within the dwellings.

There is a major difference in the cost calculation of small decentralised heating systems and large district heating:

- In case of large scale district heating the pivotal reason for the construction is to obtain electric energy. The produced heat is a "by-product" and the use of district heating can be seen as a favourable extra. Huge power stations with a capacity of 800 MW cost about 1 billion to 1.5 billion €. This means that every MW of capacity costs about 1.5 million €.
- In case of a small decentralised heating system the major target often still is the use of the heat. Therefore the corresponding costs are directly linked to the heating. Small heating plants with a capacity of about 4 MW cost about 2 million €. This means that every MW of capacity costs about 0.5 million €.

The average costs for a district heat distribution system is about 500.000 €/km. This price is a mean value and can vary in a wide area due to parameter such a consistency of the soil, diameter of the pipe, area of construction (urban or countryside) or pipe quality. A parameter for the economic feasibility of a heat distribution system is the linear heat density, which represents the annually used thermal energy per meter of pipeline. It can be stated that at least about 5-7 GJ/m should be consumed.

The final installation cost factor is the connection to the households. This consists of the heat exchanger, a controller and a meter. This sums up to about 1.600 € plus installation costs for an average household.

All costs have to be regarded on the basis that a district heating system has a durability of about 25 years.

Operational costs in terms of fuel prices are linked to gas and oil in most of the Member States and roughly in the dimension of €16/GJ.

Conclusions: Small decentralised heating systems and large scale district heating provide a reduction potential for domestic PCDD/PCDF emissions depending on types of fuel and installation. The applicability of one or the other solution depends on availability of a power station, the high of demand and the distances to be covered. The measure is in line with competing policies. Consequently the measure seems to be recommendable with a certain regional limitation.

Based on the discussion of available information in the light of selection criteria, the final recommendation for this type of measures is as follows:

Appropriate and recommended

6.3.6 Abatement technologies

Abatement technologies represent secondary emission reduction measures eliminating generated pollutants from flue gases. From the reported R&D measures only two MS (DE and DK) directly address emissions from small domestic appliances, whereas all other measures are related to improving knowledge of emission estimation.

Reduction potential:

As discussed in chapter 6.2.5 a positive reduction potential of abatement technologies could not be confirmed.

Policy conformity:

Consistency with related or competing policy, namely the Framework Directive on Air Quality is given, as the major focus of the abatement technologies is elimination of particulates (PM).

Costs:

Pursuant to provided information, costs are mainly related to installation, and under current market conditions are in the dimension of €1,500-€4,000.

Conclusions: Up to this stage the reduction potential of abatement technologies on PCDD/PCDF emissions is to be regarded negligible and waste management aspects in addition have to be taken into account (disposal filter material). This type of measure hence does not represent an appropriate measure from the current state of knowledge.

Based on available information, the final recommendation for abatement technology has to be as follows:

Not appropriate and not recommended based on current state of knowledge

6.3.7 *Conclusions on overall potentials and recommendation for sets of measures*

Based on currently recommended EFs and a useful heat of 20 GJ/a selected as EU standard for an average dwelling the reduction potential of various measures taken in the domestic sector is as follows:

Reduction measure	Emission reduction [µg TEQ/a]	Resulting emission [µg TEQ/a]	Comment	Policy conformity	Costs	Score
Solid to gaseous fuels	0.9 - >45	0.04	Upper edge for simple stove lower for automatic boiler; slightly higher for coal than for wood; much higher for high chlorine coal	In line with climate policy objectives as long as coal-fired appliances are replaced.	High investments in infrastructure may be necessary heating facility ~ €10,000 Elevated operational costs	3
Solid to liquid fuels	0.4 -35	0.25		In line with climate policy objectives as long as coal-fired appliances are replaced	heating facility ~ €10,000 Elevated operational costs	3
Replacing simple stoves by modern high energy efficient solid fuel fired devices	7- 43	0.7 – 1.2 (wood) 0.9 – 14 (coal)	Upper edge for simple devices lower for advanced appliances; slightly higher for coal than for wood; much higher for high chlorine coal	fully in line with current policy priorities and legal obligations from air protection and climate policies	€5,000-15,000	1
Solid fuels fired devices to biomass fired devices	7.4 – 43.8	0.7 – 1.2	Upper edge for simple devices lower for advanced appliances slightly higher for coal than for wood; much higher for high chlorine coal	explicitly requested by climate change policy	€5,000-€15,000 for biomass	1
District heat (purely domestic)	44 – negative	0 -12	Highest potential for gas and oil power plants in comparison to solid fuel fired standard stoves; increased emissions of solid fuel fired plants in comparison to modern local devices	in line with current policy priorities and legal obligations	High investments in infrastructure may be necessary	2
District heating (overall)	44.4 – 0.04	4.1 – 0.04	Highest potential for gas and oil power plants in comparison to solid fuel fired standard stoves;	in line with current policy priorities and legal obligations	Up to several Mio investment costs depending on pre-existing	2

Reduction measure	Emission reduction [µg TEQ/a]	Resulting emission [µg TEQ/a]	Comment	Policy conformity	Costs	Score
			increased emissions of solid fuel fired plants in comparison to modern local devices		infrastructure	
Elimination of waste burning	~66 -1,400 (worst case)	17	Upper edge for MSW, lower for contaminated wood; assumes complete heating with either MSW or contaminated wood. 1-10% of these figures might be realistic	For open waste burning in line with climate change objectives and energy efficiency For domestic waste combustion neutral in the light of climate change or energy efficiency	None or up to ~€100/tonne depending on fee system	2
Oil and gas fired devices to biomass fired devices	-0.3 to -1.1	0.7 – 1.2	Upper edge of the increase if gas heating is replaced by pellet stove/advanced boiler, lower edge if oil heating is replaced by automated boiler	explicitly requested by climate change policy		2
Replacing low efficient gas and oil boiler by high energy efficient ones	0.03 – 0.18	0.03 – 0.18	Upper edge for oil lower for gas	fully in line with current policy priorities and legal obligations from air protection and climate policies	€5,000-15,000	2
Insulation	0.0002 - 14	0.02 - 27	Upper edge for solid fuel fired standard stoves lower for gas and oil Assumed 40% reduction in energy need	fully in line with current policy priorities and legal obligations from air protection and climate policies	€100/m² of wall or roof, €100-€400/m² for the exchange of windows and €40/m² for insulation of the basement	1
Solar thermal energy	0.01 - 27	0.02 - 18	Highest potential in dwellings with standard solid fuel fired appliances, lowest in gas heated dwellings	in line with current policy priorities and legal obligations	€800-€1,300/m² for a photovoltaic installation (total €4,000-6,000)	2
Abatement technology	n.d.		No effect on PCDD/PCDF according to preliminary results		€1,500-€4,000	5

Table 6-24: Overview on reduction potential, policy conformity and costs of identified reduction measures

The compilation of reduction potentials, policy conformity and costs clearly shows that lowest resulting emissions can be achieved by installation of gas heating, but that related costs are very high and policy conformity is limited. It furthermore shows that major part of the

identified maximum reduction potential can also be achieved by means of installation of low emission solid fuel fired devices, whereas the remaining reduction potential is relatively low for oil and gas fired appliances. The elimination of domestic combustion of waste and the elimination of the use of high chlorine coal are further measures with high reduction potential at low costs.

The use of insulation and solar thermal energy are supportive measures with an additional relative reduction potential independent of the major fuel. The absolute effect is the higher the higher pre-existing emissions have been. Policy conformity is equal, whereas costs for insulation by far exceed those for installation of solar energy.

As concerns secondary reduction measures in terms of abatement technology current knowledge does not provide evidence for a benefit in the light of dioxin emissions, so that this type of measures can not be recommended so far.

For Member States with a high share of solid fuels in domestic heating investigations and efforts into low emission solid fuel fired appliances accompanied by insulation and solar energy is a highly recommendable option. Whether this is performed by district heat or local heating facilities depends on the EF and energy efficiency achievable for the two options as well as the population density and should be decided case by case.

6.4 Selection of case studies

Based on the results of the previous chapters case studies will be elaborated in the following categories. :

1. Gas heating
2. Energy efficiency measures
3. Renewable energy sources
4. Waste management

In this context the following examples of good practice are selected and shall be further elaborated.

1. Development of gas heating systems in densely populated areas (NL)
2. Energy efficiency measures for solid fuel fired installations (DE - combined approach-change of appliances. insulation. awareness raising. subsidies
3. Renewable energy programmes – (Increased use of biomass. solar heat. geothermal energy – combined approach –DE, IE)
4. Increased use of district heating potential provided by appropriate combined heat and power plants (to be discussed)
5. Strengthening the competence of chimney sweepers (DE, AT, CH)
6. Elimination of domestic and open waste burning by means of awareness raising (IE. PL, DK)
7. Regulation for the use of solid fuel appliances in Hvidovre Municipality (DK)

In addition, in the context of elaboration of recommendations on best practice, a more general approach will be included and aspects such as proportionality and optimum mix will be taken into account. Thus, recommendations will be elaborated as far as possible on the basis of different scenarios concerning shares of fuels and appliances, infrastructure (centralised/decentralised) and mix of approaches. Measures in various fields will be tentatively aggregated to an exemplary final set of good practices, from which the MS shall be able to choose according to their needs and possibilities.

6.5 Case Study 1 - Development of gas heating systems in densely populated areas

6.5.1 Justification of selection

Gas heating results in lower PCDD/PCDF emissions than any other fuel, and therefore is desirable from the reduction point of view.

The case study shows the parameters and experiences for successful development of gas distributing systems and the consequences on PCDD/PCDF emissions for the NL and UK. Based on technical, administrative and financial backgrounds, transfer possibilities of the measure to regions in Europe are discussed. Benefits related to PCDD/PCDF reduction in particular and their dependence on distances will be visible as well as potential obstacles.

6.5.2 Technical Background

Infrastructural measures to provide natural gas to households for heating are a technically well established field and – due to safety standards – do not lead to major technical problems.

The Netherlands

Since the discovery of natural gas in the Netherlands in 1959 – the Groningen Gas Field in the North East of the Netherlands is one of the largest in the world, with an ultimately recoverable reserve of some 2,700 billion cubic metres – the economy has largely adapted its energy needs to gas as its main energy source, especially for heating and cooking purposes. The specific structure of urban development in the Netherlands, especially the high population density in most parts of the country, brought this development forward, since this circumstance led to favourable conditions for the construction of an efficient gas pipeline network.

UK

Until the 1950 the major energy source in the UK was bituminous coal for domestic and industrial heating. Due to legal pressure and economic development changes in fuel use occurred, particularly towards the development of a natural gas network. Thus nowadays there is a widespread availability of natural gas. The process is however still ongoing in Northern Ireland where only recently a natural gas network has been installed which is still not fully developed.

In accordance with the installation of smoke control areas and due to economic and logistical reasons, gas heating has spread mainly in urban areas so that the majority of UK cities and towns are covered by now. The development of the gas network started initially with town gas networks which then were converted in the early 1970s to natural gas

The development of the gas network was supported by the fact, that natural gas was partly produced itself in the UK. Until 2004 import and export of gas was balanced. However,

currently the production lowers by 2% each year. Hence it is expected that 50% of the national needs will have to be imported by 2010.

Gas heating is a very good option from an environmental point of view. It has little PCDD/PCDF or PM emissions and also CO2 emissions are low compared with other fossil fuels. In western countries, the gas system is already very dense, which facilitates a further densification.

On the other hand gas-heating can be associated with the disadvantage if the gas has to be imported from other countries. This leads to import dependency from other countries.

6.5.3 Administrative Background

The Netherlands

In the 1960s there started an active policy of the Dutch government towards distribution of gas to households, industry and services all over the Netherlands in order to substitute the highly polluting use of coal and of blast furnace gas as a by-product of metallurgical plants with fluctuating quality. In this context as a supporting policy, coal has been and still is highly taxed in the Netherlands.

By this approach the Netherlands developed the highest percentage of gas-grid connected households in the world (estimated as 95% to 98%). Depending on the structure of dwellings, detached houses are usually equipped with central-heating boilers of their own, whereas in large apartment houses, combined heating and power stations, e. g. block-heating stations prevail.

UK

In the UK the law initiating a replacement of polluting solid fuels was the Clean Air Act 1956. The law was passed in response to the serious air pollution events known as smog caused by a combination of smoke and sulphur dioxide emissions from coal burning and particularly the so called great London smog of 1952 which lasted 4 days later mortality data analysis showed killed at least 4000 people during the event.

The Clean Air Act enabled local authorities to declare smoke control areas in which only certain designated smokeless fuels could be burnt or more efficient combustion appliances used which reduced the particle emissions. Some local authorities had already addressed the matter in local by-laws earlier; however, the nationally coordinated action started once the 1956 Act entered into force and the administrative arrangements were put in place in 1958.

The legal background was supplemented by the 1968 Clean Air Act. Then the 1956 and 1968 Acts were combined and updated as the Clean Air Act 1993 (http://www.hmso.gov.uk/acts/acts1993/Ukpga_19930011_en_1.htm).

Due to the now widespread availability of natural gas, new smoke control areas are now rarely declared. The only cases in the last decade were in Northern Ireland which only recently was provided with a natural gas network.

The existing smoke control area by-laws however still affect the choice of fuels used. The smoke control areas tend to be urban areas so that the majority of UK cities and towns are covered by them. Rural areas are covered only in some cases, typically where a local authority wanted 100% smoke control so applied it everywhere.

6.5.4 Financial Background

<u>*UK*</u>

As part of the process of encouraging the growth of smoke control areas, central government subsidised the installation of clean burning appliances from 1958 until the end of the 1992.

The total subsidy from central government over the period of central government grants was £53,365,000 at contemporary values so considerably more at today's prices. This covered:

1. Government grant paid to Local Authorities: covering approximately one third of cost of converting private dwellings

2. Government Grant paid to Local Authorities covering approx two-fifths of the full costs involved

Local Authorities contributed an additional third of the costs of adaptations to private dwellings; the owners would need to pay the rest.

Hence the total direct (private investment) cost (at historic values) could be estimated as perhaps twice the Government Grants. However this does not include the cost to householders of more expensive fuels required or greater operating and maintenance costs. The amount also does not include the infrastructure costs of the increased towns' gas network which was developed initially and then converted in the early 1970s to natural gas

The costs for the implementation of gas heating infrastructure split into the costs for the householder, who has to pay for the connection and installation of the new system (direct private investment costs) and for fuel and maintenance (operational costs), and the costs for the provider, who has to install and maintain the gas distribution system (infrastructure costs).

Costs for a single household: According to expert opinion, the total cost of installing a gas heating installation is in the dimension of €6,000 for a European country like the NL. This cost does not include the internal distribution infrastructure (pipes and radiators) inside the house, but include a gas fired boiler and the average costs for the connection (on private territory) to the gas network. The cost situation can differ from the given example depending on the various providers. In some cases contribution toward network costs can be included in the connection costs. This contribution toward network costs can be calculated in different ways, e.g. fixed costs for each meter, proportional costs from exploitation depending on the

connected capacity.

Costs for the provider: The costs for the installation of the gas network are very roughly as follows:

- €500,000/km for large pipes
- €250,000/km for medium pipes
- €150,000/km for small pipes.

The prices can vary considerably and can be much lower if the construction is done in soft soil in the countryside and if no streets, railroads etc. are standing in its way. The durability of a gas distributing system is expected to be about 50 years.

6.5.5 Expected/realised benefits

The main target of the measure is “clean” energy supply with reduced environmental emissions, namely as regards PM, SO_2 and NO_x. Furthermore a reduction of PCDD/PCDF emissions can be achieved. Based on the existing EFs the achievable reduction potential is in the dimension of 40 µg TEQ/20GJ useful heat.

According to the provided data the policy was highly successful in both countries.

The Netherlands

Since detection of the gas resources and start of the active policies in the fifties the NL have established a 94 % share of gas heating which might stand for a successful example to other countries or regions. No specific information is available as regards shares before the programme start, but current emissions are very low.

UK

In the UK the share of gas heating increased to almost 70% from a predominant coal use within the last 50 years. Although there are no specific data on this, it has to be taken into account that single room heating and open fires are extremely widespread and popular in the United Kingdom. Hence it can be assumed that many million typical traditional open fires were replaced with glass fronted gas fired stoves or boilers or other new appliances. On this basis the following reduction in dioxin emissions could be achieved:

If calculated with the current UK emission factor for domestic bituminous coal use, the maximum cumulative reduction in emissions (domestic and industrial) is 3,600 g over the period form 1956 to the present compared to present emissions of 265 g TEQ. This is based on the 1945 to 1956 average coal consumption and assumes that the reduction in coal use after was fully due to the Clean Air Act (this ignores that some of the changes in fuel use would have occurred in any case). In the domestic sector emissions in the period from 1990 alone dropped by a factor of five from 20 to 4.5 g TEQ/a (see also figures Figure 5-7 and Figure 5-8).

In addition smoke control areas caused significant improvements in winter visibility, anecdotally when meteorological conditions were appropriate the fog would clear when you drove into a smoke control area. Hence people could directly see policy efficiency.

6.5.6 Expected/realised efforts and obstacles

In the UK problems with awareness and a general resistance to government interference in people's homes regarded as serious invasion of privacy where the main obstacles to tackle. These however, were mainly overcome from the seriousness of the 1952 smog and that similar if smaller smogs continued to reoccur until smoke control was well underway. Lack of availability of suitable smokeless fuels was another deficit that led to slow roll-out of smoke control areas until fuel supply could keep pace with demand. As late as the 1970s there was not enough natural gas availability to replace all oil and coal use in London.

No specific problems have been reported by the NL, however safety problems (explosions) due to leaking form old pipes (>50 years old) and the financial implications of modernising and dense grid have been communicated orally

Further obstacles that might occur are the permitting requirements and the financial dimension of construction work as well as the comparably high fuel price. In addition there are potential political obstacles, both as regards sustainability and energy autarchy.

6.5.7 Conclusion of the case study

The change from domestic heating with wood, oil or coal to gas heating systems clearly decreases the PCDD/PCDF emissions. The measure provides several advantages under environmental and economic aspects. However, replacing renewables with fossil fuels counteracts climate change policy goals. The NL is a prime example for successful gas heating systems, but it is in general recommendable if the following parameters are fulfilled:

- Reasonable distances to existing supply sources
- Sufficient number of users/energy consumption
- Appropriate environmental conditions
  (for example, risk of earthquakes)

6.5.8 Potential for transfer within Europe

A general proposal for an extension of a gas distributing system needs to consider different political and economical aspects; even regional specifications have an influence.

The political aspects are, among others:

- Dependency on other countries
- Possible changes of gas prices
- Resources within the country
- Possible alternatives to coal, geothermal heat, etc.

Economical feasibility depends among others, on the following aspects:

- Size of existing gas distributing system and whether the new project provides

coverage of a whole area or a densification

- Distance to the next pressure pipeline
- Area of the new system, urban or rural, parallel to street or rail roads...
- Availability of investors/financial resources

Natural gas is available in principle in many places in the EU due to various pipelines (see Figure 6-2). If related to the overview map on densely populated areas it becomes clear that the further “development of gas heating systems” is applicable in many areas.

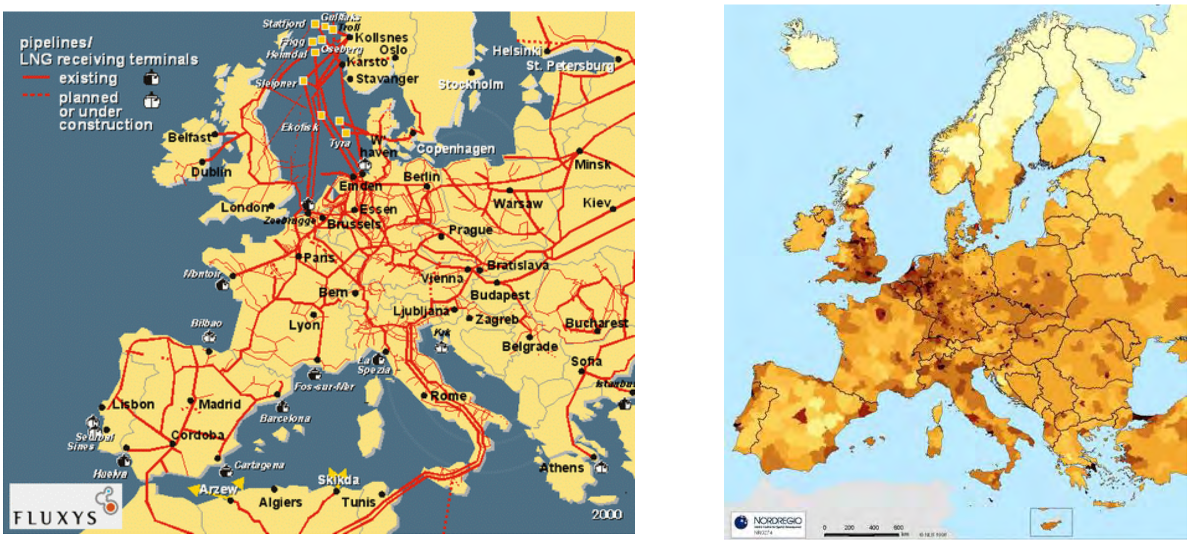

Figure 6-2: European gas distributing system and population density

6.6 Case Study 2 – Energy efficiency measures for solid fuel fired installations (DE and PL)

6.6.1 Justification of selection

Emission factors from wood and coal fired standard appliances are high. Therefore, reduced fuel consumption has an important effect on the reduction of annual PCDD/PCDF emissions. Hence fuel reduction measures in this field can be regarded as good practice and will be further elaborated in this chapter. This case study 2 shows experiences with measures to increase energy efficiency for solid fuel fired installations in Germany and Poland and demonstrates consequences on PCDD/PCDF emission. Based on technical, financial and administrative issues as well as on benefits and obstacles, potentials for a transmission to other MS or regions are discussed.

6.6.2 Technical Background

Main technical measures to increase energy efficiency for solid fuel installations in the domestic sector are:

- Improved insulation
- Change to a heating system with higher energy efficiency

Insulation measures

Insulation can be applied to the outer walls, the windows, the roof and the basement of a house. The major parameter with respect to the increase in energy efficiency is their so called “heat conductance value (λ). The thermal transfer factor for all insulation layers is called the thermal transmission coefficient (U = W/ (m^2K)). This is the relevant parameter for assessing the energy needs of a building.

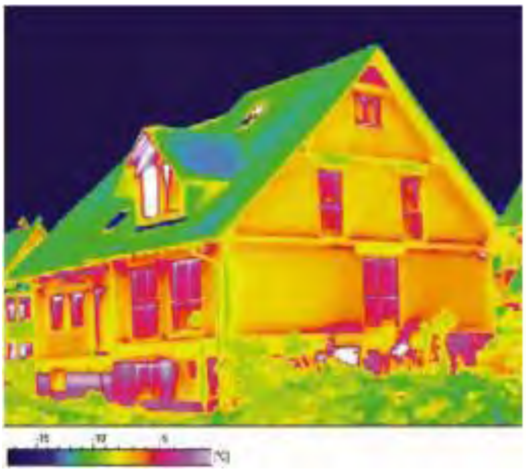

Figure 6-3: Major energy losses from buildings that can be reduced by insulation measures (Source: http://www.gemeinde-lembach.at/artikel.shtml?newsid=4386)

The most important energy losses in a building depend on climate conditions and

construction features. In a rough assessment however, they are in the range of 30-40% for outer walls, 10-25% for doors and windows, 15-35% for the roof and 10-15% for the basement.

Insulation of outer walls:

Available materials on the market vary according to the application and comprise synthetic as well as natural materials. Frequently used insulation materials are polystyrene and mineral fibres, technically insulated natural materials have to a large extent already been on the market for 20 years. The heat conductance value varies between 0.025 W/ (m^2K) for the best insulating polystyrenes, and ca. 0.04 W/m^2K for biological materials such as mineral or natural fibres. Lower lambda values of a material can be compensated by thicker layers. Insulation layers are always protected with an appropriate covering layer.

Insulation of windows

Insulation of the outer walls is optimally combined with window replacement which reduces the thermal bridges and ventilation of the house to 0.7-0.5% of the house's volume. Insulation of windows can only be reached by replacement of the existing windows. U values from traditional windows are 5.6 W/ (m^2K), whereas they can be reduced to 2.8 and 1.2 by specific double-glazed construction and reach 0.65 W/ (m^2K) for triple-glazing.

Insulation of the roof and of the basement

For the insulation of the roof or the basement of a house, the same materials are in principle applicable as for the insulation of outer walls, and therefore not specifically addressed here.

High-energy efficient boilers and stoves

Simple old stoves burn the fuel in one burning chamber with more or less complete combustion depending on the actual temperature and Oxygen supply. Modern high-energy efficiency stoves in principal burn the remaining organic compounds in a second step. Automotive oxygen sensors control electronic fuel injection and regulate the air-fuel ratio.

In practice, energy efficient stoves use secondary air in the combustion chamber to increase their efficiency and reduce the emission of pollutants. In addition, pre-heating of secondary combustion air by heat exchange with hot flue gases can be performed. Pellet stoves can be fed only with pelletised fuels which are distributed to the combustion chamber by a fuel feeder. Pellet stoves are equipped with a fan and an electronic control system to supply the combustion air. For this reason they are characterized by high efficiency (above 80% and up to 90%) and low emissions of CO, NMVOC, TSP and PAH. Heat storing or heat accumulating stoves are characterized by relatively low emissions of pollutants when compared to classical radiating stoves. Some more advanced room heating stoves employ a counter flow system. As a further means to assure an optimum oxidation, stoves (namely for wood combustion) are sometimes also equipped with a catalytic converter which further optimises the oxidation process and thus increases energy efficiency.

With regard to boilers, technological achievements include under-fire boilers that have a two-part combustion chamber. Whereas the first part is used for storage and partial volatilisation and combustion, combustible gases are oxidized in the second part of the combustion chamber. Combustion in under-fire boilers is more stable than in over-fire boilers, due to continuous gravity feed of fuel onto the fire bed. The energy efficiency can be further increased by a fan and control system for the primary and secondary air. Furthermore, a so-called downdraught (flue gases are forced to flow down through holes in a ceramic grate) is a technology that increases combustion efficiency.

Additionally, a fully automatic feeding system as used for stoker coal burners or wood pellet boilers (see Figure 6-4) is a further measure to harmonise the combustion process and increase efficiency. As indicated before, this is an important factor for PCDD/PCDF emissions, which are significantly related to temperature changes and turbulences in the combustion process.

The ultimate option with respect to energy efficiency is the use of a condensation boiler, with a closed combustion chamber, that can operate with efficiency above 90%. Recovering part of the latent heat from flue gases contributes to increased energy efficiency and in optimal operation reduces the temperature at the chimney inlet to below 60°C, which is also beneficial from the PCDD/PCDF point of view (for more details see UNECE Guidebook and Kubica et al, 2004).

Via these technical modifications of the combustion process modern boilers and stoves are characterized by high energy efficiency in the range of 80-98% (see also chapter 6.2.2). Installation of an additional heat exchanger can further raise the energy efficiency to nominally above 100%.

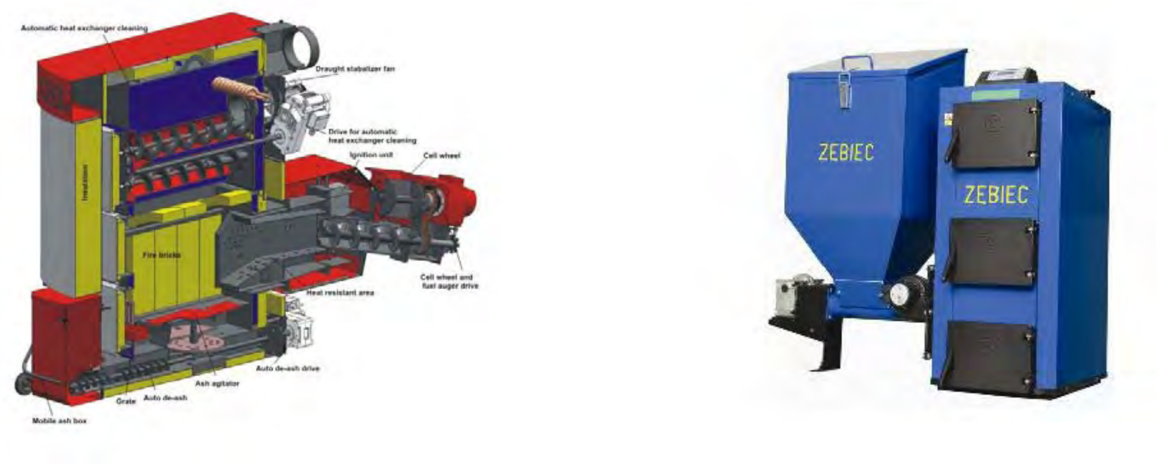

Figure 6-4: Automated boilers for (a) wood chips or pellets or (b) coal (http://www.zebiec.com.pl)

In the following, some background information is provided with respect to the activities undertaken in DE and in PL as well. Particular attention is given to the Silesia region in PL where the basic problem has been that for more than a decade the region struggled with problems related to the high and uncontrolled emissions from the energy and municipal sectors. This was chiefly caused by ineffective solid fuel combustion in domestic and municipal sectors. Therefore, the need for fast and highly effective action was identified.

6.6.3 Administrative Background

Directive 2002/91/EC on energy performance in buildings (EPBD), which had to be transposed by MS by January 2006, forms the major background to energy efficiency measures in MS (see chapter 6.1.2).

Germany:

In DE, the legal background to energy efficiency measures is formed by the Energy Saving Directive “Energieeinsparverordnung” (EneV), which implements the EPBD. Legal limit values have been established to foster improved insulation and to enhance the replacement of old boilers (year of manufacture before 1985) by new appliances. (No limit has been established so far for stoves).

In order to promote energy efficiency in the building sector and support measures to increase energy efficiency of houses, several public subsidy programmes, managed by the Kreditanstalt für Wiederaufbau (the KfW Banking group) have been established. The KfW provides a series of loans at low interest rates to interested citizens.

- Ecological construction (KfW Ökologisch Bauen)
- Modernisation (KfW Wohnraum modernisieren)
- Energetic Restoration (Insulation) of Old Dwellings (KfW Altbau energetisch sanieren)
- Renewable Energies (KfW Erneuerbare Energien)

Apart from these funding schemes, awareness raising activities have also been launched by German authorities. In addition to these national programmes, other initiatives are performed at regional and local level.

Poland:

In Poland growing concerns on environmental impacts of domestic heating initiated a plan of actions promoting clean air and energy efficiency activities by means of the successive modernisation of combustion processes, including those carried out in household furnaces or stoves.

Due to the traditional appliance stock and the ready availability of coal as local fuel, the Polish activities focussed on improvement of domestic coal combustion technologies, by means of modern coal boilers. This focus on coal is based on the objective to direct demand structures in a way that they can be served with national resources. In this context it is important to know, that in Poland the production of hard coal is higher than the domestic

consumption. With regard to natural gas, domestic production stagnated after an increase up to the year 2004 at a level of about 180,000 TJ per year, while imports have constantly increased since 2002 and reached 415,736 TJ in 2006.

Activities in Poland are mainly supported by Voivodeship Fund for Environmental Protection and Water Management. The mission of the Fund is to promote and implement Sustainable Development principles. The Fund support the implementation of the national environmental policy principles at the regional and local level through various forms of funding and financing projects, which meet the short and long-term objectives included in the regional environmental protection programmes. Financial support is provided to the wide range of partners – local authorities, NGOs, R&D, and companies from the public and private sector.

A special programme of low-level[17] emission reduction (PONE) in the Silesia region of Poland concentrated on the reduction of emission derived from individual houses and performed in two phases during the years 2002-2004 and 2006-2007 in the town of Tychy. This programme has since then been promoted and extended in other country regions pursuant to the local, regional and country level environmental protection programmes according to the provisions of the Environmental Protection Law.

Pursuant to the Polish policy objectives the PONE programme was predominantly used to invest in modern coal-fired plants (90% of all realised and implemented modernisations in the first phase, 94% in the second phase).

A part of the PONE programme was dedicated to public education on threats and hazards resulting from the use of low-performance furnaces and boilers as well as those associated with the burning of certain types of wastes other than those permitted by relevant legislation. This included awareness raising on the threats connected with dioxin emissions.

This awareness raising activity called “Clean energy for my house”, was realised by the Polish Ecological Club of Upper Silesia, and took place from February to September 2006. It consisted of four conferences, a questionnaire campaign and an educational and informational campaign.

The four conferences took place in the cities of Katowice, Ustroń, Łędziny and Częstochowa between May and June 2006, with 100 participants in each case. The subjects of the four conferences were:

[17] (The term “low emission sources” has to be seen against the background of industrial “high emission sources”).

- Clean energy for the municipal sector – Clean air in Silesia
- Energy production from coal and biomass versus sustainable development at the commune level
- Via economical initiatives and ecology to local sustainable development – clean and effective energy
- The commune energy supply – Modern technologies for energy production from coal and biomass. Heat engineering and individual heating

The questionnaire campaign took place in the four Silesian communes of Katowice, Tychy, Knurów and Skoczów, with a total number of 500 participants.

The educational and informational campaign consisted of the following elements:

- TV broadcast
- Radio programme
- Elaboration and printing of educational leaflets on potential dangers connected with toxic contaminants and inefficient solid fuel combustion. (Total edition run of leaflets was 2,000 copies, including a reprint action).
- Elaboration and printing of educational posters with information about the environmental impact of inefficient solid fuels and municipal waste combustion. (500 posters were printed in a size of 50 x 100 cm).
- Preparation and publication of articles for the annual Ecological Bulletin[18.] (The total edition run of this bulletin was 8,000 copies).

The administrative procedure of the PONE programme worked along the following conditions and steps:

- Preparation and verification of a programme register established by an operator, a person chosen by the City authority. The register contains information on: installation and boiler producers, suppliers, fitters, boiler price list and additional information about the possibilities of fuel purchase and credit obtainment.
- Presentation of the programme aims and principles to potential participants in an unimpeded and unlimited manner. The selection of fitter, supplier and boiler could be made within the prepared register framework. In addition, participants could propose new technologies that were not acknowledged in the original register. In many cases, the suggestions were added to the programme framework.
- Selection of appropriate dwellings for modernisation. Only owners of old and inefficient coal fired boilers were allowed to participate in the programme

18 http://www.polskiklubekologiczny.org/index.php

- Authorisation for operation of the new boiler by the City Hall inspectors, under the condition of fulfilling all necessary requirements of building regulations, BHP and fire protection. The chimney sweep certification was also needed, guaranteeing the effectiveness of chimney and ventilation installations.
- The participant was allowed to resign from programme participation at any stage of its preparation without any financial consequences up to the moment of signing the actual boiler house modernization agreement.

6.6.4 Financial Background

Major costs for energy efficiency measures arise from insulation and exchange of appliances (see chapter 6.1.3). Further costs can arise from awareness raising and educational activities.

Germany:

Table 6-25 provides an exemplary calculation of the investment costs needed to adapt an old house to the EneV minimum standard, or to reach a further improved energy efficiency standard.

Energy consumption	Reduction potential	Heating energy $_{max}$ /a	Costs /m²
Old house	100%	250 kWh/m²a 90 GJ/100m²a	- €300 - €450/m²
EneV minimal standard		90 kWh/m²a 32 GJ/100m²a	**€0**
German KfW 60 standard		60 kWh/m²a 21 GJ/100m²	+ €20 - €40/m²
German KfW 40 standard	-86%	40 kWh/100 m²a 14 GJ/100 m²a	+ €70 - €130/m²
Passive house standard		15 kWh/100 m²a 5.4 GJ/ 100 m²a	+ €100 - €160/m²

Table 6-25: Typical costs for each of the above discussed technical measures

Up to now, such investment costs have been supported with public funding via KfW credits of €1.5 billion. On the other hand increased energy efficiency lowers annual operating costs. With the assumption of a solid-fuel price of €200/t (without VAT), improved insulation can add up to €314-€490 economising costs/year. These savings are particularly economical. CO_2 taxes for funding of the investments increase the economic factor and consequently the realisation of the advised measures.

In addition in the year 2007, 37,000 newly installed high-efficiency stoves and boilers with efficiency >89% were funded in Germany. This represents 10.7% of the installed wood heating units (see also case study 3).

No information could be obtained about investments into public awareness programmes which are performed at national, regional and local level.

Poland:

In 2001 rules for providing financial assistance for low-emission coal-fired heating appliances supported by the funds of the Regional (Voivodeship) Fund for Environmental Protection and Water Management (WFOŚiGW) and the Government of Switzerland (via the Polish-Switzerland Fund during the period 2001-2003), have been introduced in the Silesian Region. The costs and the financing of the PONE programme are shown in Table 6-26.

Capital cost of programme in Polish Złoty (PLN); 1 PLN = €0.2641 (2008)	Phase I 2002 - 2004	Phase II 2006 – 2007
Total gross capital expenditure	15,855,000	8,509,321
Total gross resources from clients	5,434,237	2,962,874
Funding from WFOŚiGW of which:	10,420,763	5,546,446
donation/subsidies	n.d.	451,280
credit	n.d.	5,095,167

Table 6-26: Costs of the PONE programme for implementation of modern boilers in Tychy, Poland (Source: Krystyna Kubica, Institute of Thermal Technology, Silesian University of Technology, Gliwice, Poland)

From Table 6-26, it becomes apparent, that the house owners contribute on average an equity ratio of 34% (Phase I) and 35% (Phase II) to the investment. The share of subsidies was 5%, of credits 60% in Phase II. In Phase I, the share of subsidies and credits was similar to Phase II, although not accounted for in particular. The credits obtained from WFOŚiGW are at a reduced interest.[19] Therefore, the direct subsidies in phase II of the programme amount on average to PLN 645 (or €170) per boiler, accompanied by a share of indirect subsidies in the shape of reduced interest rates or special conditions for credits.

6.6.5 Expected/realised Benefits

Germany:

The major target of the measures is a reduction of fuel consumption in the domestic sector by means of improved insulation. In old houses, an optimised combination of insulation measures can save up to about 70% of the heating energy need. After finalisation of insulation measures, all outer surfaces (walls, roof, etc.) should have similar U values of 0.1-0.3 W/m²K). A compilation of estimated thermal transmission coefficients (U) for old and optimum houses as well as the current legal limit to be achieved in Germany is provided in the table below.

[19] E-mail information gained by Krystyna Kubica, Institute of Thermal Technology, Silesian University of Technology, Gliwice, Poland

W/ (m²K).	Old houses (estimate)	EneV Limits	Passive solar houses (estimate)
Outer walls	0.5 (clay brick 30cm) 3 (cement 30 cm)	0.45	0.1
Outer walls with insulation		0.35	
Windows	2.5 – 4	1.7	0.6
Roof, Ceiling	1 – 2	0.3	0.1
Basement walls	0.5 – 3	0.4 U	0.1 – 0.2

Table 6-27: Thermal transmission values for different types of houses U = W/m²K

Within the framework of the programme for "Energetic Restoration of Old Houses", 0.5% of the old houses (built before 1978) and about 2% of old wood heated houses are restored every year, by means of receiving an improved insulation. In line with the so-called "improvement of the building envelope," 5% of these houses get an additional exchange and adaptation of the heating system to comply with the new limits for building energy efficiency.

Given the fact that 7.9% of the households in Germany are heated with wood and 1.2% with coal, a maximum reduction can be calculated as a first indication for a reduction potential of the measure taken. For this purpose it is estimated that only old stoves are exchanged and that the amount of coal and wood-fired stoves is according to the ratio of 1.2% and 7.9%. Based on the results of chapter 6.2.2 this would lead to a best case PCDD/PCDF emission reduction of 1.1 g TEQ/a for wood-fired stoves and 0.3 g TEQ/year for coal-fired stoves which adds up to about 1.3 g TEQ/a.

Poland:

The main objective of the PONE programme was an overall emission reduction due to an increase in thermal effectiveness of domestic appliances. After the initial phase with Swiss support, the PONE programme was continued with regional resources resulting in thermal effectiveness of 85%. Table 6-28 shows the numbers of boilers installed/replaced during the two phases of the programme, categorised by the fuel types of the boilers.

Types of boilers / Number of realized and implemented modernizations	Phase I 2002 - 2004	Phase II 2006 – 2007
Coal automatic boilers thereof: pea coal fine coal	1,356 818 538	659 428 231
Oil boilers	24	0
Gas boilers	120	41
Number of realized and implemented modernizations in total	1,500	700

Table 6-28: Total number of modern boilers installed during the PONE programme in Tychy, Poland (Source: Krystyna Kubica, Institute of Thermal Technology, Silesian University of Technology, Gliwice, Poland)

The first phase of the Tychy programme resulted in an overall emission reduction of 90%. This decrease was especially strong for CO. The detailed figures for analysed substances are shown in Table 6-29.

Substance	Emission [tonne/a]			
	Before PONE	After PONE	Reduction	Reduction [%]
CO	1,218.3	61.9	1,156.4	94.9
SO_2	162.5	67.0	95.4	58.8
NO_2	59.0	49.6	9.4	15.9
TSP	568.7	53.6	541.1	90.6
TOTAL	**2,008.5**	**232.1**	**1,802.4**	**89.7**

Table 6-29: Reduction of emission pollutants within Phase I of the PONE programme (2002 – 2004) in Tychy, Poland (Source: Krystyna Kubica, Institute of Thermal Technology, Silesian University of Technology, Gliwice, Poland)

The overall annual reduction in emissions per boiler for both phases of the PONE programme (i.e. in total 2,200 modernisations) amounted for (CO, SO_2, NO_2, TSP) as follows:

- Before modernisation: **1,339.2 kg**
- After modernisation: **154.7 kg**
- Total decrease: **1,184.5 kg**

Taking into consideration only phase I, the result is 1,201.6 kg. This indicates that boilers replaced in the first phase have been more inefficient on average than those in the second phase, although the difference between both phases is not very large. The combined ecological effect for all 2,200 implemented modernisations therefore reached 1.18 tons x 2,200 = 2,606 tons.

For PCDD/PCDF no measurements are available, but an EF of 40 µg TEQ/TJ could be identified for the newly installed retort boiler and a 30% reduction of annual coal consumption was achieved. On this basis a reduction of PCDD/PCDF emissions in the dimension of 30-40 µg TEQ/a and dwelling could be assumed (for comparison see Table 6-6).

6.6.6 Expected/realised efforts and obstacles

Germany:

The major problem for increased implementation is a lack of awareness of house owners of the advantages of the measure in combination with relatively high investment costs for a complete renovation. To overcome these problems, public money has been used in Germany. An appropriate relation between awareness raising programmes, funding schemes and additional taxes could be achieved.

Poland:

In the context of the PONE programme the acceptance of the measures has been evaluated by means of the questionnaire. On this basis it can be stated that the programme was received exceedingly well and no particular obstacles from the public or during the performance of the programme have been identified.

6.6.7 Conclusion of the single case study

Germany:

The case study shows, that by means of public funding and information campaigns annually 0.5% of old houses do undergo renovation with the possibility to reduce the annual thermal energy need by up to more than 70% from 90 to 32 GJ/100m²a. The additional exchange of simple wood and coal stoves can diminish wood based PCDD/PCDF emissions by nearly 90%.

Poland:

Socio-technical research showed a very high rate of citizen support (96%) for all aims and goals included in the programme framework. In a survey, 48% of the participants decided that actions undertaken for low emission reduction are important, 43% declared that actions are very important and only 9% of all respondents claimed that the significance of the actions undertaken is not very important. In total 2,000 appliances could be exchanged over a period of five years a 30% reduction of annual coal consumption was achieved, and a reduced EF of 40 µg TEQ/TJ could be identified for the newly installed retort boilers.

6.6.8 Potential for transfer within Europe

The target course of energy efficient measures and the wide variability of possible actions predestine this type of measure for implementation in all EU Member States. Further strong pressure is placed in this direction via the legal obligation at EU level to achieve increased energy efficiency in the building sector. In the context of the transfer potential, climatic conditions play an important role. Consequently, insulation measures are relatively more important the more continental the local climate is (long cold winters). Insulation also plays a major role in cases of poor pre-existing construction standards. With regard to all measures, it is advisable, both from the environmental and from the economic point of view, to focus on poorly insulated dwellings with old, simple heating appliances first. Due to the positive effect of the two legal obligations, information and financial incentive, the measure is best implemented by means of a combined approach.

6.7 Case Study 3 – Renewable energy programmes – (Increased use of biomass, solar heat, geothermal energy – combined approach – DE, IE)

6.7.1 Justification of selection

Climate change policy, including the envisaged obligation for MS to reach a 20% share of renewable energy supply in domestic heating and cooking, resulted in an intensive promotion of biomass heating systems and other alternative energy sources in the last few years. Solar heat and geothermal energy are alternatives without PCDD/PCDF emissions and can contribute to both CO_2 and PCDD/PCDF emission reduction. In order to identify best practice in this field, the costs, disadvantages and benefits of renewable energy sources will be further elaborated in this chapter. This case study 3 is based on experiences and data from Germany, but reference to experiences in Ireland and Austria is also made. Based on technical, financial and administrative benefits and obstacles, possibilities of a transmission to other Member States and regions are discussed.

6.7.2 Technical Background

Main technical measures to increase the use of renewable energy sources are:

- Replacement of existing appliances by biomass-fired heating appliances
- Installation of solar panels
- Installation of single dwelling heat pumps
- Installation of regional geothermic power plants

These measures can be combined with improved insulation (see case study 2) and may favourably be realised at a broader scale in terms of district heating systems (see case study 4).

Biomass-fired domestic heating appliances

Biomass-fired heating appliances in the domestic sector (single installations) comprise the following different types:

- Manually fed heating systems for log wood (for central heating 8KW-50KW) or in a small scale 4KW-12KW for room heating)
- Automatically fed pellet stoves using industrially produced standardised wooden pellets (for central heating 8KW-100KW or in a small scale >4KW for single room heating)
- Automatically fed wood chip stoves for central heating using non standardised wood chips produced by farmers (>30KW)

Wood chip fired boilers are also available in a larger scale, and then used for district heating

(see case study 4).

Efficient stoves use a two-step burning process. In the first step, the wood undergoes a gasification process in which the carbon chains are degraded to short gas molecules. In a second step, the gas is completely burned. It is important that combustion temperature and O_2 supply are controlled and regulated automatically. (For more technological detail, see case study 2).

The energy efficiency of a biomass-fired appliance mainly depends on the control, regulation and quality of the combustion process. In Germany, the minimal energy efficiency of funded biomass-fired installations is >89%.

Thermal solar installations (not photovoltaic solar collectors)

Solar panels use solar energy to produce either electric energy or heat. In this case study only thermal solar installations are discussed, because photovoltaic collectors produce electrical energy which is usually sold to the power company. Thermal solar panels transform the solar radiation into heat which can then be used for water heating or even for additional room heating. Transportation of energy is performed by gravitation or by a small-scale electric pump that transports the hot medium from the solar panels to the buffer vessel. In order to be able to efficiently use warm water during the night and in rainy periods as well, enlarged buffer vessels for sanitation water (~75-100 l/person) have to be installed. In addition, solar collectors can be used as supportive heating devices in low-energy houses. Warm water in this case should be passed directly into a floor-heating system which does not require the temperature of typical radiators.

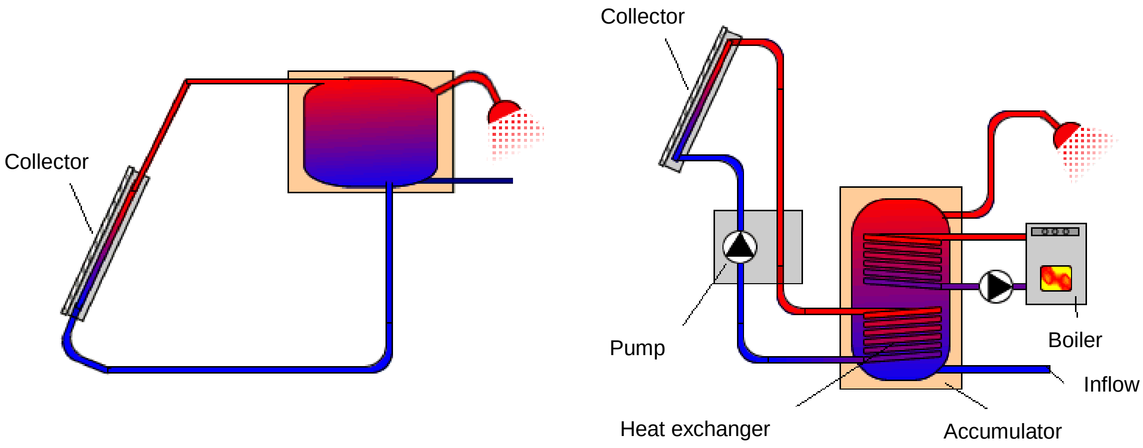

Figure 6-5: Solar installations (a) without and (b) with pump and heat exchanger and an additional boiler for low radiation periods (Source: Wikipedia)

The following systems of thermal solar constructions are currently available on the market:

- Round glass tube collectors with vacuum insulation.
- Flat collectors without vacuum insulation

The two types of solar collector use the same working principle. However, the round vacuum glass collectors have the advantage of a better insulation in the cold season. While a flat collector delivers small amounts of energy only in the cold season, a vacuum collector in combination with large buffer and energy recovery systems can contribute up to 95% of the caloric need in “passive solar” houses (see also case study 2).

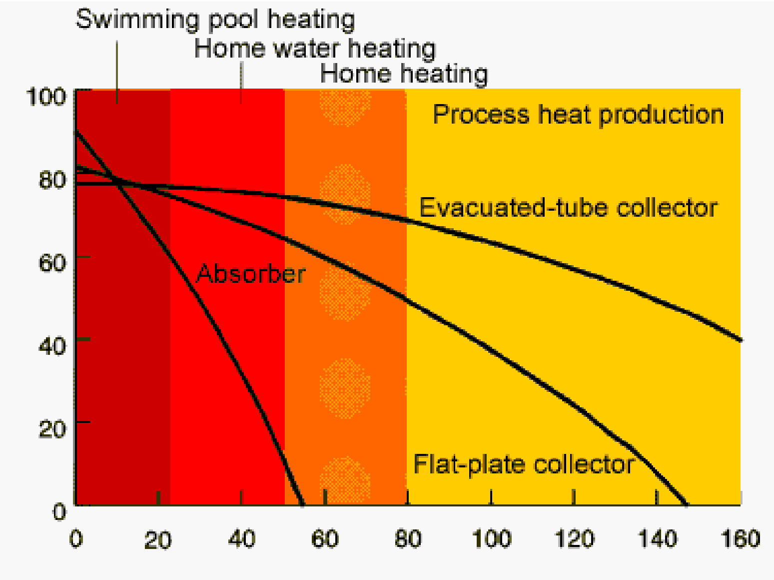

Figure 6-6: Efficiency of different types of solar collectors (per 1,000 W/m²) Source: http://www.solarserver.de/wissen/sonnenkollektoren-e.html
x-axis = required temperature; y-axis = energy efficiency in %;

In Germany only roughly 6% of the installed collectors are vacuum collectors. The market is dominated by flat collectors which are cheaper (€150-€600/m²) than vacuum collectors (€400-€1,200/m²). Absorbers are in use for swimming pools and churches; they are not installed in normal houses. In Germany, solar panels cannot be used as a unique heating system but are only additive energy-saving installations to a complete heating system.

Dependency from climate conditions

Solar energy supply depends largely on climatic conditions. The caloric power of the sun (angle of radiation) and sunshine hours are relevant for the solar thermal input to the collectors. The stronger the radiation and the longer the sunshine hours, the better are efficiency and heat generation. Radiation maps help to identify optimum regions, but in principle, solar energy as an additional energy supply can be used in all of central Europe and even in Scandinavian countries.

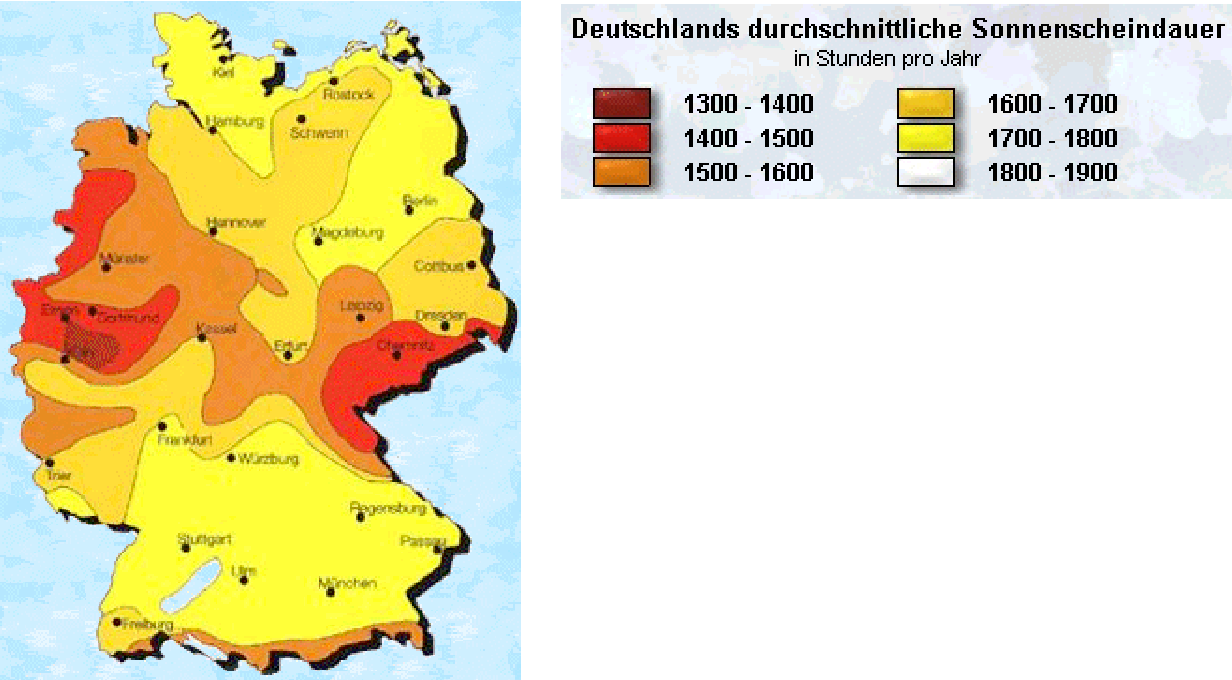

Figure 6-7: Sunshine in Germany hours/year (Source: http://www.photovoltaik-im-web.de/)

As illustrated in the figure, the cloudless direct solar radiation varies in Germany from 1,300 hours per year up to 1,900 hours per year. Under these conditions in general a thermal solar panel of 1.5-2 m² per person is generally sufficient to provide 60% of the annual sanitary water supply.

An optimised approach to energy saving and accordingly from the PCDD/PCDF point of view, would be the combination of a well insulated house, with modern heating and solar warm water and a supplementary heating supply. With this solution under German climatic conditions up to 450 l of heating oil can be saved annually.

The construction of solar panels consumes only little energy, so that a net positive energy balance is received after a maximum of 3 years. Maintenance is easy and can be restricted to an annual check in the context of servicing the heating installation.

Heat pumps

Heat pumps follow the same technical principle as a refrigerator, but they generate usable heat instead of cold. With the help of a thermodynamic circuit of a heating medium (using evaporation and condensation) heat is transferred from relatively low temperatures to higher temperature. Heat pumps for domestic heating purposes use temperature differences in the surrounding environment (mainly soil but also air and water) as an energy source. The circuit flow of the heating medium needed to achieve the heat transfer requires electrical energy. Heat pumps are connected to an extended pipeline system which can be installed as either horizontal or vertical loops or any other form thereof (see Figure 6-8).

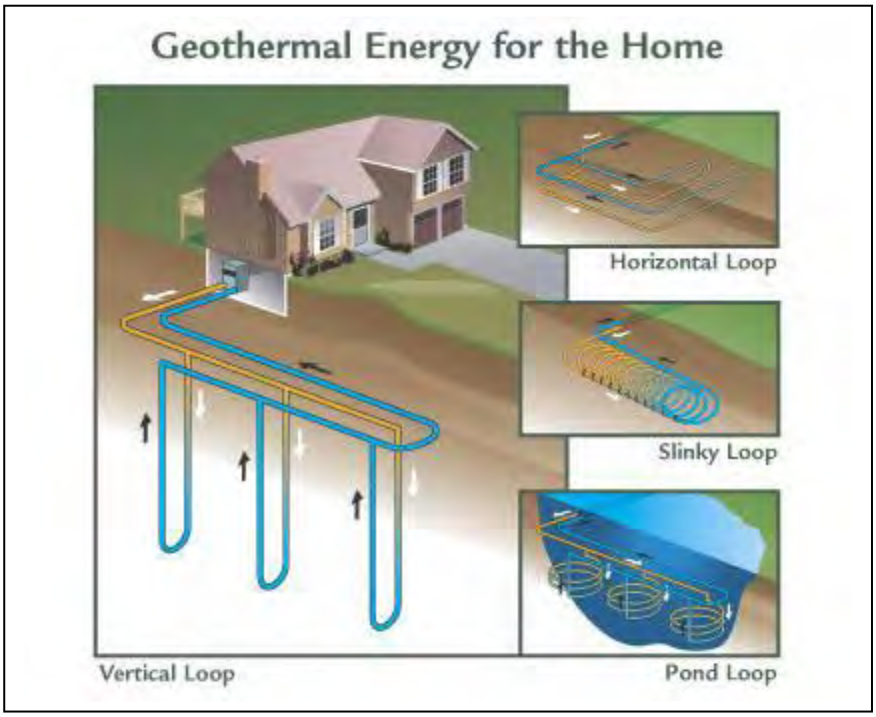

Figure 6-8: Technical principal of domestic heat generation by means of a heat pump (Source: http://www.island-power.com/geothermal.htm)

Heat pumps as such generate low emissions except for indirect emissions related to the energy production for electrical pumps and compressors. They could consequently be an interesting option from the PCDD/PCDF point of view. However, sometimes problems occur with changes in soil or water ecosystems due to modified temperature as a result of the operation of a heat pump.

The major deficit of heat pumps is the absolute dependency on the outside temperature which is generally contrary to the heating needs. Consequently the absolute energy efficiency is quite low and in wintertime a heat pump can almost constitute an electrical heating device. Even according to the information of the producers, annual coefficient of performance is only 4-5 times the invested electrical energy at optimum conditions.

If a heat pump is run by electricity from a conventional coal-fired or nuclear power plant with an efficiency factor of 33%, the annual coefficient of performance of the heat pump has to be above 3.0 in order to reach a positive primary energy balance. But even with an annual coefficient of performance of 4.0, there is no advantage compared to an efficient gas-fired heating system with regard to the energy and CO_2 balance.

In bad conditions, with a low temperature of the surrounding air, water or ground or a high temperature of the heated water >45°, the efficiency is reduced to less than 3, which means that it would be more efficient to use the electrical energy directly for heating instead of consuming it for the heat pump.

Geothermal power plant

Geothermal energy uses the high temperature (up to 150°) of deep zones in the ground to produce heat. For geothermal heat generation, groundwater of 40°-100° is introduced to a heat exchanger in a heat power plant. Cooled water is pumped back into the earth. In situations where the ground temperature is above 100°, electrical energy can also be produced. A prerequisite for the exploitation of geothermal energy as a renewable energy sources is the existence of thermal springs at a depth of 1,000-2,000 metre. Geothermal energy supply is consequently a primary option in regions with a high geothermal heat flow in the ground. Because of the high costs for the required deep drilling, geothermal energy supply is not used on a small scale for local heating but is always used in large-scale units for district heating. The technical principle of thermal energy heat or electricity generation is illustrated below.

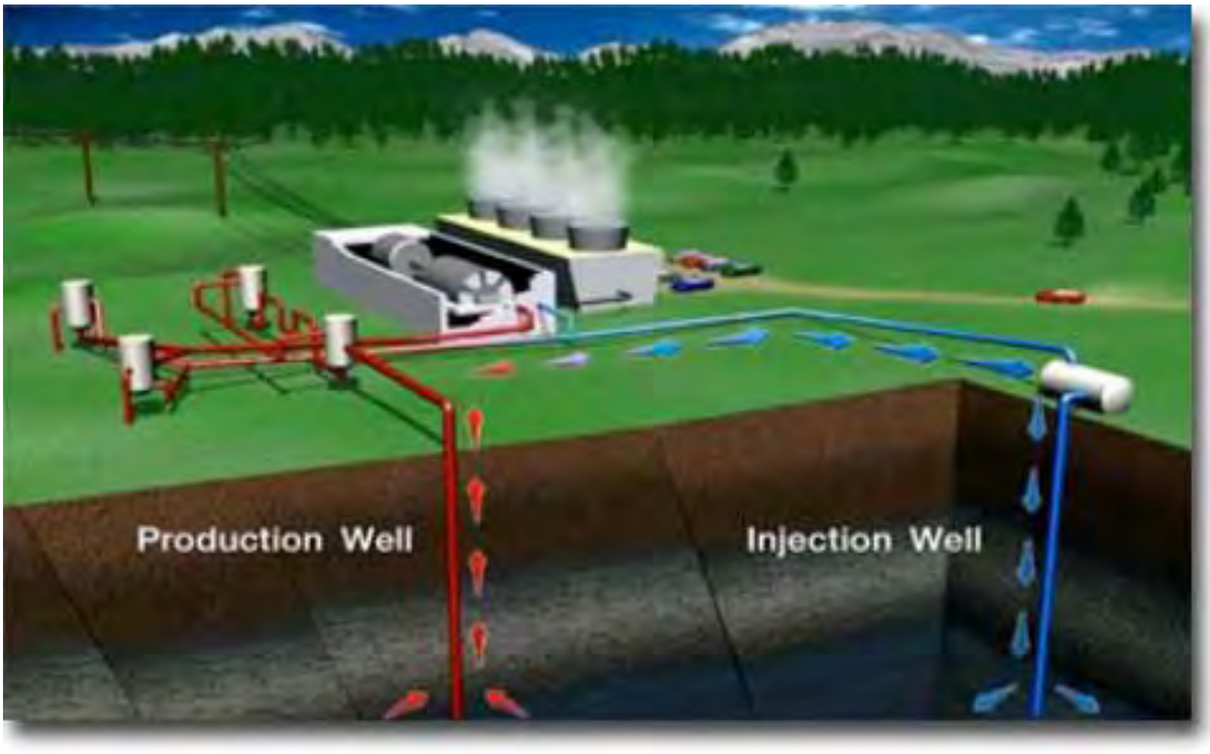

Figure 6-9: Large-scale geothermal energy plant with potential use for district heating (Source: http://newcoreenergy.com/main/?howGeothermalPowerGenerationWorks&PHPSESSID=3a3e42fdf7e80a913781be5f8e4658b8)

Regions in Germany which are suitable for large-scale geothermal energy generation are illustrated in the figure below.

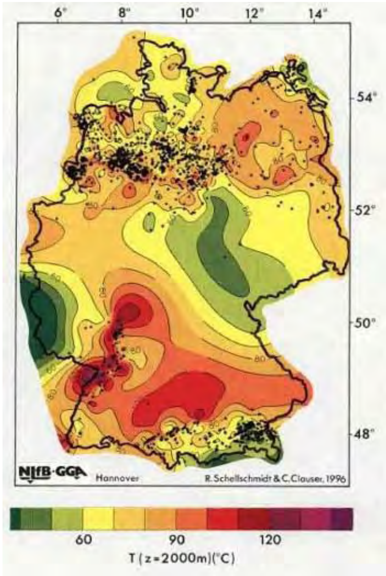

Figure 6-10: Areas in Germany with hydrothermal potential and hydrothermal resources (temperature distribution 200 m below surface)
(Source: http://klimakatastrophe.wordpress.com/2008/03/03/deutschland-auf-dem-weg-zum-strom-aus-100-erneuerbarer-energie-eine-illusion/

The main disadvantages of this option are the huge investment costs and potential destabilisations of the underground geology. In addition, geothermal power plants cannot be constructed in every region but need suitable hydro-geological conditions to become feasible.

Current share of renewable energy use in Germany

Over the past few years, as in other countries, a strong growth in renewable energy use could be observed. As illustrated in Table 6-30, heat supply from renewable sources in present times is absolutely dominated by biomass installations, contributing more than 90% of the overall 2900,000 TJ/a in 2005. But this also shows that domestic biomass heating has already almost reached the envisaged share.

	2005 [TJ/a]	2010 [TJ/a]	2020 [TJ/a]	2050 [TJ/a]
Biomass domestic heating	180,000	210,000	220,000	220,000
Biomass district heating	80,000	140,000	200,000	250,000
Solar thermal installations	10,800	12,200	50,000	120,000
Solar thermal district heating		<1,000	10,000	210,000
Geo thermal district heating		<10,000	30,000	280,000
Heat pumps	>20,000	>20,000	30,000	80,000
Total heat supply from renewable energy	290,000	400, 000	540,000	1,160,000
Estimated share of total heat generation	6,3%	<14%	14-23%	48-58%

Table 6-30: Share of and further potential for expansion of renewable sources for energy supply in Germany (Dr. Joachim Nitsch, DLR-Institut für Technische Thermodynamik, Presnetation KfW Symposium, Berlin 2006

One reason for this observation is the fact that biomass resources have almost reached their limits even in a country like Germany with quite an important forest industry. Free capacities

are only available in the compact wood and residues sector (stump wood, bark, and unused crown compact wood) in forests. In addition, regionally, large biomass capacities such as straw and other materials from nature management mowing residues, reed, etc) are available that might be further used (see biomass total).

On the other hand, geothermic energy is at the very beginning of its expected commercial use and large increases in the future are currently expected for solar thermal installations and geothermal energy both in form of local and district heat. The first geothermal power plant was constructed in 1913 in Italy. In Germany, the first power plants started operation in 1998. Meanwhile, 24 bigger plants are operating in Germany.

6.7.3 Administrative Background

Germany

Based on EU requirements, recent legislation sets mandatory requirements related to energy supply from renewable sources. The new Renewable Energy Heat Act (EEWärmeG), coming into force in January 2009, has the aim of increasing the share of renewable energy for heat production by up to 14% by the year 2020. For this purpose, from 2009 every newly constructed house in Germany has to use renewable energies. In addition, an eco-label system has been installed in Germany in order to fix high energy efficiency standards and emission limits for new heating appliances in Germany.

A national programme to promote the use of renewable energy in Germany was started in 2000. The programme is managed by the Federal Office of Economics and Export control (Bundesamt für Wirtschaft und Ausfuhrkontrolle)[20]. The number of newly installed facilities increased constantly over the past few years. In 2007 a total of 165,572 installations were supported. Of these installations, the vast majority were additional solar thermal facilities (126,000). The remaining 37,000 installations were solid biomass-fired appliances (pellets, wood chips or split logs).

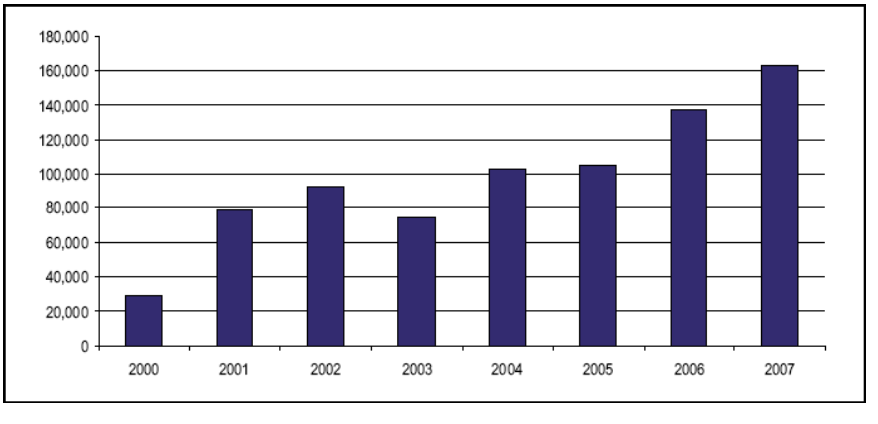

Figure 6-11: Number of renewable energy facilities supported by the market incentive programme for renewable energy in Germany in the years 2000 to 2007 (Source: BAFA (2008)

Ireland

20 http://www.bafa.de/bafa/de/energie/erneuerbare_energien/biomasse/index.html

Sustainable Energy Ireland (SEI), formerly known as the Irish Energy Centre, was set up by the government in 2002 as Ireland's national energy agency. The goal of SEI is to promote and assist the development of sustainable energy. Sustainable Energy Ireland is funded by the National Development Plan 2007-2013, with programmes part-funded by the European Union. The current third phase of the Greener Homes Scheme assists homeowners who intend to purchase a new renewable-energy heating system for existing homes (i.e. dwellings already occupied for a minimum of one year and already equipped with a heating system). New homes are no longer eligible. This is in line with the recent coming into force of the revised Building Regulations 2008 which, for the first time see a compulsory requirement for some component of renewable energy in all new homes. Due to the existence of this legislation it is no longer appropriate to utilise public funds to support such installations in newly built houses.

6.7.4 Financial Background

Costs for alternative heating systems consist of the replacement of the pre-existing heating appliance and operational costs. Costs in principal have to be covered by operators. Subsidy systems shift a part of the load to public administration or funds. Costs vary between MS and will change according to market conditions. Nevertheless, there are some indicative average costs for installation of heating devices fired with renewable energy sources.

Pellet stove/boiler	Thermal solar panel	Heat pump air/water	Heat pump water/water	Connection to geothermal heat supply	Gas condensing system
€10,000 - €15,000	~€4,000-6,000/8m² plus 30% for round glass collectors Plus ~€4,000 if supportive heating intended	€10,000 - €13,000	~€25,000	€6,000	€5,000

Table 6-31: Costs for heating appliances and energy prices in all cases, costs for service, sweeper and basic charge not included

Funding programmes

In Germany, the BAFA-managed subsidy programme consists of basic funding and several additional bonus funding schemes. Available grants are illustrated below:

Funding instrument	Quantification and conditions
1. Basic funding:	Automatically fed biomass installation from 5 kW to 100 kW nominal power
1.1. Solid biomass (with the exception of wood chips) also combination boiler	€36 per kW of established installed nominal power. minimum funding: pellet ovens: €1,000, pellet boilers: €2,000
1.2. Pellet boilers	with newly installed buffer vessel (>30 l/kW): €2,500
1.3. Wood chips:	€1,000 as a lump sum. Only fundable if accompanied by buffer vessel >30 l/kW.
1.4. Split log gasification boiler:	€1,125. Only fundable if accompanied by buffer vessel >30 l/kW
2. Bonus funding:	Additional subsidy for particularly innovative or efficient biomass installations
2.1 Regenerative combination bonus:	In addition to a solar installation €750 can be granted for a fundable biomass installation.
2.2 Efficiency bonus	Biomass installation is established in a building with a verified very low energy need.
2.3 Bonus for particularly efficient circulation pumps	Additional bonus of €200 for additional installation of a particularly efficient circulation pump.
3. Heat from renewable energies in schools and churches	Within the context of installation of renewable energy heating in public institutions (e.g. schools, universities, churches, etc.), educative measures (such as display panels) can be funded in addition to a maximum of €2,400

Table 6-32: German funding system for renewable energy installations for biomass (http://www.bafa.de/)

The grants available for the different renewable energy alternatives within the Greener Homes Scheme Phase 3 are presented in Table 6-33:

Renewable energy technology	Grant support available
Solar Thermal Space and/or Hot water Heating (Evacuated Tube)	€300/m2 (max. of 6 m2)
Solar Thermal Space and/or Hot water Heating (Flat Plate)	€250/m2 (max. of 6 m2)
Heat Pump – Horizontal ground collector	€ 2,500
Heat Pump – Vertical ground collector	€ 3,500
Heat Pump – Water (well) to water	€ 2,500
Heat Pump – Air source	€ 2,000
Wood Chip or Pellet Stove	€ 800
Wood Chip or Pellet Stove with integral boiler	€ 1,400
Wood Chip or Pellet Boiler	€ 2,500
Wood Gasification Boiler	€ 2,000

Table 6-33: Levels of grant supports available within the current Phase 3 of the Greener Homes Scheme in Ireland (http://www.sei.ie/Grants/GreenerHomes/)

Installation of a renewable energy device can reduce the operational costs of domestic

heating. Savings in operating costs depend on the type of dwelling and the type of installation and are presented in comparison to a gas heating system.

Operational costs						
	Gas	Pellet boiler	Thermal solar panels	Heat pump air/water	Heat pump water/water	Geothermal energy
Fuel cents / 3.6 MJ	Natural gas 5,98	Pellets 3,91		electrical energy 13	electrical energy 13	geothermic energy 5
Standard house[4] 20 GJ/100 m^2a	430/730[1]	280/580[1]	minus 30% of the energy costs	310/370[2]	310/370[2]	360/1000[3]
Old house[5] 72 GJ/100 m^2a	1900[1]	1342[1]	minus 8.25% of the energy costs	1210	1210[2]	1970[3]

1 including €300 for boiler service and chimney weepers

2 including €60 for a separate counter and low energy prices

3 including €640 for the counter: example Unterschleißheim, Bavaria

Table 6-34: Operating costs, the following data are representative of an average house

Based on investments and savings in operating costs, solar installations always have an amortisation time of over 12 years.

6.7.5 Expected/realised benefits

For all renewable energy sources, the major expected and realised benefit of biomass-fired installations is the positive effect on the CO_2 emissions and the consistency with climate change objectives. When looking at the figures in Germany, the established programmes have been highly effective and an important number of appliances have been installed in the last 7 years. Solar energy and geothermal energy use provide a clear benefit also from the PCDD/PCDF point of view, whereas modern biomass-fired devices show a reduction potential only in relation to less effective and higher emitting solid fuel fired devices. In MS like Germany were gas or oil fired appliances are often replaced by biomass installations for cost and climate reasons, the PCDD/PCDF emissions consequently tend to increase. A special benefit of geothermal energy supply in terms of district heat is the fact that in appropriate regions it can be provided during all seasons.

6.7.6 Expected/realised obstacles

Biomass-fired appliances: The main obstacles for use of biomass fired appliances are the investment costs and the availability of appropriate biomass. This is limited, so that a clear restriction to significant expansion has already been observed in Germany and Austria and can be expected even far more severe in Member States with less forests and vegetation. The problem is aggravated by an increasing number of biomass CHP plants that are constructed in recent times.

Solar installations: The main obstacles for wider use of solar energy supply are the investment costs (overcome by subsidies) an inappropriate climatic conditions (cloudy, frequent rain, poor radiation intensity) resulting in low efficiency.

Heat pumps: The major obstacle for further promotion of heat pumps is its low annual coefficient of performance and the poor heat supply in the heating season. Hence scepticism has been raised by the German Federal Environmental Agency (Schuberth and Kaschenz, 2008) but also from the German environmental organisation (BUND 2007, BUND 2008). BUND especially emphasizes the lack of justification of subsidizing heat pumps as currently undertaken.

Geothermal power plants: The major obstacles for increased use of geothermic power stations are the huge investment costs and lack of knowledge on long-term impacts as well as scepticism as regards potential destabilisations of the underground geology. A further obstacle is the fact that geothermal power plants need suitable hydro-geological conditions and hence can only be used in certain regions.

6.7.7 Conclusion of the case study

The measures taken have been well accepted and have been effective as concerns number of appliances installed. The envisaged combinations of different technologies and the shift towards non-biomass based technologies proved workable with the established subsidies and measures. On the other hand, the investments made are high and not all of the alternative technologies demonstrated energy feasibility.

From the PCDD/PCDF point of view, the following conclusions can be made:

1. Promotion of modern certified biomass installations is a good practise in all cases where no district heat or gas distribution system is available and oil heating is not feasible. Therefore, the application of biomass house heating systems is mainly recommended in rural regions. In regions with a high density of houses, district heating systems should be preferred. Whenever possible the installations of modern biomass fired heating installations should be combined with improved insulation. The installation of appropriate flue gas treatment systems might be a further important measure of good practice as soon as the relevant knowledge has been gained.
2. Solar panels constitute a veritable option as they are not associated with emissions of either PCDD/PCDF or other pollutants but can considerably reduce the consumption of conventional fuels.
3. Heat pumps are less recommendable due to their poor energy performance and high investment needs.
4. Geothermal energy supply via power plants and district heat is a valid option from the energy and emission point of view, but negative environmental long-term effects or potential destabilizations might occur so that further results should be awaited for before general recommendations can be made.

6.7.8 Potential for transfer within Europe

Biomass: Promotion of biomass-fired installations can in principle be performed in all EU Member States, but in practice it has the highest potential in those regions with good availability of appropriate biomass.

Solar energy: Europe has a high potential for increased use of solar caloric energy. Especially in central and northern Europe, vacuum collectors could increase savings of heating energy. Whereas on an EU average only 8% of the energy supply is from solar energy, a final potential of 30% of the heat supply in the domestic sector is deemed possible by German authorities. Especially in countries with comparable or better solar radiation, installation of solar collectors is to be recommended.

Country	Total kW_{th}	Added kW_{th} 2007	Added % 2007	Solar collectors W_{th}/inhabitant	Inhabitants Mio
Austria	2,024,839	196,700	10	243	8.3
Belgium	102,283	29,400	29	10	10.5
Cyprus	437,640	45,500	10	547	0.8
Denmark	269,696	16,100	6	5	55.4
Estonia	1,029	245	24	1	1.3
Finland	14,345	2,800	20	3	5.3
France	609,420	178,500	30	96	62.9
Germany	6,295,580	665,000	11	764	82.4
Greece	2,499,140	198,100	8	225	11.1
Hungary	9,975	5,600	56	1	10.1
Ireland	21,553	10,500	49	5	4.2
Italy	770161	171,500	22	13	58.8
Latvia	3,745	1,050	28	1	2.3
Lithuania	2,415	490	20	0.7	3.4
Netherlands	236,839	13,930	6	14	16.3
Poland	164,428	46,900	29	4	38.2
Portugal	144,165	17,500	12	13	10.6
Romania	48,720	350	1	2	21.6
Slovenia	84,910	8,400	10	42	2
Spain	674,916	183,400	27	15	43.8
Sweden	183,676	17,826	10	20	9.0
United King.	213,444	37,800	17	3	60.4

Table 6-35: Caloric solar energy use and annual increase 2006/2007. Relation between collector area and capacity is 1 m^2 = 0.7 kW_{th}

As the major obstacle for wider use of the technology are the investment costs, which are to be borne in addition to the installation cost for conventional heating, followed by a variation of the discount rate, appropriate subsidies constitute the strongest incentives to foster the market launch performance of solar heating.

Heat pumps/geothermal district heat: Heat pumps in principal could have a potential in warmer regions of the EU or in regions with specific geological conditions (hot springs or underground water close to the surface). In other regions, the coefficient of performance does not seem to be appropriate for an environmental and economically feasible operation. In all regions with appropriate geological conditions a potential for district heating in combination with geothermal power plants exists, whereas there is clearly no potential in all other areas.

6.8 Case Study 4 – Increased use of district heating

6.8.1 Justification of selection

By using “by-product heat”, district heating with CHPs can substitute existing domestic appliances without causing any additional emissions, thus “saving” the domestic emissions that would take place with local heating. In addition district heating may offer further advantages such as increased energy efficiency compared to a domestic device, economic benefits, more steady combustion and reduced EFs.

On the basis of information provided in a scientific review of potentials for district heating systems in the light of climate change [UBA 2007] this case study summarises the relevant parameters and experiences from AT, DK, SE and DE. Furthermore transfer possibilities to various regions in Europe are discussed.

6.8.2 Technical Background

District heating consists of a central heating installation (power boiler, large scale power plant), producing hot water, which is transported in isolated pipes to the connected dwellings. According to the size of the installation and the transport distance, district heating is to be differentiated into large scale district heating and decentralised small heating plants.

The benefit and potential of district heating is determined besides energy efficiency, and emissions by transport losses, hence a sufficient number of households need to be available to ensure a proper use of the offered energy. Major parameter for the determination of a district heat potential are the local or regional population density, the local heat need and appropriate fuel/energy availability. Investigations and calculation can be performed with Geographic Information System (GIS).

Short distance decentralised heating or CHP plants (starting from 200 kW) entail particular benefits as regards use of renewable energies (biomass, thermal solar energy and geothermal energy). An important share of the expected potential will not become usable without a strong increase in district heat.

District heating with biomass

In order to further lower the emissions of modern biomass fired boilers towards emissions of oil and gas heating, the installation of gas treatment equipments is necessary. This is associated with important costs, that are economically viable only for large combustion devices >2 MW. Apart from air quality and cheaper fuels combustible, there are two further reasons to promote small scale district heat:

- The possibility of a CHP with electricity generation and a second output
- The possibility to use biogas from agricultural production which can not be completely

used in the farm itself

Thermal solar panels

The applicability of solar panels and their contribution to domestic heating is limited, mainly due to storage problems (buffer vessels), although important additional potentials would exist. Sufficiently large buffer vessels, allowing using summer energy in winter times, are economically viable and practically feasible however only at high consumption scale. Further advantages can be lower installation costs and more effective installation of large scale solar panels on unused public areas.

Geothermal energy

For economic use of deep geothermal energy, it is particularly important to develop huge quantities of heat per drilling. Such energy need can only be generated by a combination of various users in a distribution grid.

Austria

In Austria the installation of decentralised biomass district heat network started in the end of the nineties. Since then 1% of all dwellings are newly connected to district heat annually so that the district heat share to energy supply is growing by 6% per year. District heat generated by means of CHP increased by 2003 to almost 72%. The district heat grid is expected to grow by 80-100 km per year until 2010 to 3,700 km.

Denmark

In Denmark already 60% of all dwellings are heated by means of short distance or long distance district heat, which is consequently dominating the heating market. In district heat areas the achieved connection rate is 90%, with the remaining 10% being expected to follow on the occasion of sales and modernisation of dwellings. This is due to the fact that Denmark started already in the fifties and sixties of the last century to promote this type of energy supply to replace solid fuel fired appliances. More than 80% of the Danish district heat is generated in CHPs. Fuels shares used in CHPs apart from fossil fuels are renewable energies (15%), waste and industrial waste heat (21%). The remaining share of pure heat generation from fossil fuels is as low as 3.7%. The high share of district heat could be achieved only by means of an extended distribution network covering besides urban agglomerations also smaller municipalities with lower heat density. The relation between distribution network and production capacity in average is 0.53 kW/m, but can be even far lower also in agglomerations.

Sweden

Also in Sweden district heating has a high share in the thermal energy supply and there is a dynamic development. From 45% in 2001 the share increased to 55% in 2003. In the long-term perspective district heat production shall achieve 288 PJ/a. In Sweden all towns with more than 10,000 inhabitants are covered by a distribution net. In addition also 80% of smaller municipalities with 3,000-10,000 inhabitants are equipped with district heating facilities. The fuel mix used in Sweden for district heat is highly differentiated. Solid biomass contributes 30%; another 38% is other biomass. Waste heat from municipal solid waste incineration provides a share of 10% and additional 6% are industrial waste heat. In contrary to other Member States the share of CHP with 35% is still relatively low.

Germany

Today publicly available district heat is produced to 80% in CHPs. Only 19% are generated in pure heating plants. The dominant fuel is combusted is gas (52%) and coal (29%). The amount of consumed CHP heat is in the dimension of 550 PJ/a within a grid of 19,000 km. About 300,000 households are connected. Currently the share of long distance district heat for room heating is about 15 %.

For reasons of sustainability CO2 emissions in Germany shall be reduced by 40% until 2020 and by 80% until 2050. These targets can only be achieved by means of increased energy efficiency, increased use or renewable energy, an clear expansion of decentralised CHP (short-distance heat and single objects), and the maintenance and modernisation of large scale CHPs. According to the environmental protection scenario Plus II of the German Ministry for Environment, the share of district heat (long and short distance) shall double until 2050 compared to today, with decentralised small scale systems taking an increasing share. Renewable energies are envisaged to achieve a share of 75% in this area. Until 2050 fossil fuel fired CHPs shall provide 25% of the thermal energy need. In addition, predicted to start from 2010 almost 600 PJ shall be provided by decentralised small heating plants fired with biomass or using solar energy. In addition 300 PJ are foreseen to be provided from geothermal plants according to the environmental protection scenario Plus II of the German Ministry for Environment [BMU 2004].

Exemplary calculation of district heating reduction potentials from large CHPs in Germany

In the following an exemplary calculation of the reduction potential of different types of CHP district heating systems is performed on the basis of German fuel shares and emission factors in the domestic sector.

The case study comprises large scale power stations with an installed power capacity of 800 MW, which is a typical size for a coal power station. Biomass power stations are typically much smaller, so that a system of 20 biomass power stations each with a power capacity of 40 MW, are considered in this case study for reasons of comparability.

Table 6-36 presents all major assumptions for the calculation within the case study.

Capacity utilisation power station	83	%
Annual hours of operation	8497	h
District heating grid losses	10	%
Annual mean thermal energy uptake from households	30	%
Emission Factor wood domestic heating	40	µg TEQ/TJ
Emission Factor coal domestic heating	50	µg TEQ/TJ
Emission Factor oil domestic heating	3	µg TEQ/TJ
Emission Factor gas	1.7	µg TEQ/TJ
Efficiency wood stove	65	%
Efficiency coal stove	65	%
Efficiency oil stove	80	%
Efficiency gas stove	80	%
Share of domestic wood heating	9	%
Share of domestic coal heating	2	%
Share of domestic liquid heating	37	%
Share of domestic gas heating	53	%

Table 6-36: Background for case study calculations

By modification of these parameters results can be easily extrapolated to other settings and situations.

Table 6-37 presents the yearly energy output of plants with a capacity of 800 MW (or an equivalent number of biomass power stations with 40 MW) as sum of the electric and thermal energy.

Characteristic	Gas CHP plant	Coal CHP plant	Biomass CHP plants	unit
Electrical energy	3,774	2,317	2,340	GWh/a
Thermal energy	1,986	3,641	3,420	GWh/a
Thermal energy efficiency	30	55	38	%
Emission Factor	0.5	10	50	µgTEQ/TJ
Overall power plant PCDD/PCDF emissions	13,466	269,330	1.620.000	µg TEQ/a
Thermal energy PCDD/PCDF emission *	4,040	148,131	837.216	µg TEQ/a
Household emissions equivalent to provided energy	22.527	41.300	38.789	µg TEQ/a
Household emission reduction potential per year	18.487	-106.831	-798.427	µg TEQ/a

* Only PCDD/PCDF emissions from the energy consumption attributable to thermal energy production

Table 6-37: Energy consumption, PCDD/PCDF emissions and reduction potential of large power stations

The PCDD/PCDF emissions relevant for domestic heating are those related to thermal energy. These emissions will be produced in any case due to the decision of producing electrical energy. The various power plants have differing internal losses as well as differing

thermal efficiency. Therefore, each power plant delivers varying amounts of thermal energies to households. If this energy is delivered to households, it does not have to be produced in the households itself and thus can result in a “reduction potential”. The emissions, equivalent to provided energy that would be generated in households, are calculated on the basis of the typical fuels share, energy efficiency and EFs for domestic heating in Germany (see above).

The results clearly show that in relation to PCDD/PCDF emissions, only district heating from gas power stations is associated with a positive reduction potential in this setting. For coal or biomass power stations, PCDD/PCDF emissions related to the delivered heat are higher than the equivalent PCDD/PCDF emissions from households.

However, as stated above, the main impetus for installing a power station is the demand for electrical energy. The production of heat is a “side effect”. If there is no district heating and no other use for the heat, it has to be cooled down. In such a case, the PCDD/PCDF emission of the power plant has to be added to the emissions of the domestic appliances. Therefore, if other alternatives to use the generated heat are not available, the decision of whether to install district heating or not, results in a reduction potential as follows:

PCDD/PCDF emission [µg TEQ/a]	gas	coal	biomass
Without district heating (sum power plant and domestic appliance)	26.567	189.431	876.005
With district heating (only power plant emissions relevant)	21,425	148.131	837.216
Emission reduction (corresponding to domestic emissions saved)	**22.527**	**41.300**	**38.789**

Table 6-38: PCDD/PCDF emissions & reduction potential by using large district heating plants

Based on these results it can be stated that, gas power stations are the only option with an overall reduction potential in Germany.

The reasons that coal and biomass power stations with district heating show disadvantages compared to pure domestic heating are as follows:

- The annual average use of the thermal energy output of power plants is only ~30%.
- 91% of German households are heated with gas or oil with low EF
- The domestic stoves in use are considered to be state-of-the-art, with low EF

6.8.3 Administrative background and other activities

Directive 2004/8/EC of the European Parliament and of the Council on the promotion of cogeneration is based on a useful heat demand in the internal energy market and forms the major background to the promotion of district heat on European level. Article 6 of this Directive asks Member States to establish an analysis of the national potential for the application of high-efficiency cogeneration, including high-efficiency micro-cogeneration.

Austria

In Austria a marketing campaign was launched in 1996 by industry, which contributed to the high acceptability district heating observed. According to provided information, Austrian citizens today regard district heating as the optimum heating systems. Requirements from the Kyoto-Protocol and stable energy prices are used as arguments to continue in the direction of further expansion and transformation of current central heating systems.

Denmark

In 1997 Denmark has brought into force a specific district heating law, obliging municipalities to avoid parallel development of gas and district heat by means of a proactive planning. District heat has been developed into the corner stone of Danish climate change policy. The acceptance of district heating in the Danish population is further fostered by the fact that industry is offering consulting free of charge.

Germany

In Germany the Kraft-Wärme-Kopplungs-Gesetz (CHP Act 2002), the Erneuerbare-Energien-Gesetz (Renewable Energy Act) and the Erneuerbare-Energien-Wärmegesetz (Renewable Energy/Heat Act) form the legal background for promotion of this type of energy supply.

6.8.4 Financial Background

Similar to gas heating the establishment of the distribution network and the construction of the heat generation facility entail major investment costs in the dimension of Millions and Billions of Euro depending on size and type of the facility. Estimations provided for Austria are in the dimension of €110 Mio annually to expand the grid by up to 100 km and install appropriate production capacity.

Consumer costs for large scale district are generally linked to gas and oil amounting to €15/GJ heat in average.

For the economic competitiveness of district heating the demand structure which is mainly a function of climate conditions and population density is a crucial parameter.

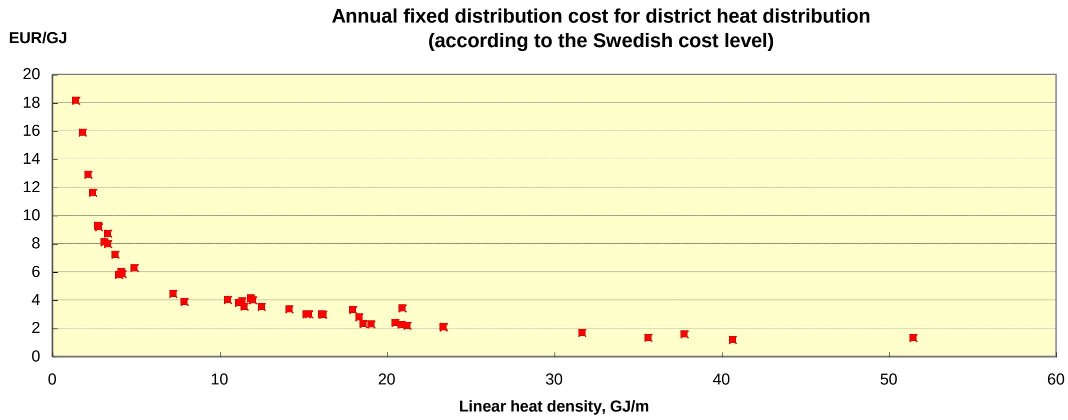

Figure 6-12: Costs per GJ in proportion to the linear heat density

As illustrated in Figure 6-12 the annual cost for district heating are related to the linear heat density, with a strong increase below a linear heat density of 5-7 GJ/m [VFB District energy 2006] which is thus regarded as threshold level for economically viable operation. This means that for each meter of pipeline, 5-7 GJ have to be delivered and consumed annually. The linear heat density (capacity) combines the distance of the user from the district-heat-delivering power station, with the purchased quantity. It is an indicator of user density along the district-heating grid. Such a dependency is a key to deciding on transferability of the case study results to other European regions.

<u>Austria</u>

There are specific grants for production of heat in biomass CHP and connection to district heat is subsidised in most of the Austrian regions. In addition CHPs are privileged as regards allocation of CO_2 certificates within the scope of emission trading.

<u>Denmark</u>

Low construction costs for the distribution network partly by means of advanced technology are one major parameter for the high competitiveness of district heat. Fuel costs remain as the highest cost factor. This advantage is further fostered by the obligation to break even that means to only cover costs and by extra taxing of fossil fuels, whilst biomass is only charged by added value tax. The law stipulates that operating companies may only apportion actually occurring costs to consumers. Furthermore important budgets (€6-7 Mio annually) are allocated to information and awareness raising by industry.

Sweden

Sweden has established funding systems for connection to district heat, installation of small district heating networks and change from electricity to other heating systems. Furthermore district heat is promoted by the increasingly applied “green or environmental” tax systems imposing an extra charge to fossil fuels in terms of energy tax, CO_2 tax and sulphur tax. This is summing up to 40 cents per litre fuel oil and 24 cents per m² gas. In contrary a strongly reduced tax rate is applied for CHP.

Germany

In Germany, national funding, regulated in the 2009 renewable energy heat act, covers up to 20% and a maximum of €5 million of the construction and upgrading of district heating grids. The Renewable Energy Act allows additional funding of district heat grids if >50% of the CHP energy is produced from biomass.

6.8.5 Expected/realised benefits

The major intention of current activities are the maintenance and densification of existing district heating grids and a further increase in small decentralised heating systems. Furthermore the use of renewable energy shall be increased. Major expected advantages are:

- A flexible combination of fossil and renewable energy
- A economically favourable operation of solar energy and geothermal energy
- Cleaner combustion of biomass with the possibility to use cheaper fuels
- Increased energy efficiency (additional co-generation of electricity)

The benefits related to PCDD/PCDF emissions (see chapter 6.2.4) depend on the following parameters:

- The primary energy used/technology applied at the power station
- The primary energy used/technology applied in households
- The losses that occur in the district heating system
- PCDD/PCDF emissions of potential alternatives for the heat generated (e.g. industrial installations).

6.8.6 Expected or experienced obstacles

District heating namely large scale district heat requires sufficient heat density in order to be economically and ecologically viable. In this context it is important to note that:

- Huge investment costs
- Demographic developments and modernisation of dwellings lead to reduced energy needs in areas with existing grids.
- Competing development and expansion of gas heating infrastructure
- The focus in the field of CHP (legally and economically) was and is on electricity and not on heat generation
- CO_2 emission trading is discriminating against district heating in comparison to local heat supply
- Psychological aspects and acceptance deficits (district heat is partly regarded as out-dated backward oriented technology)
- Long lasting authorisation procedures for a district heating system
- Low annual up-take rates for district heat generated in large scale CHPs

These obstacles might vary in each specific local region and in every Member State. As various successful examples show they can be overcome if the conditions as indicated in the case study are fulfilled.

6.8.7 Conclusion of the case study

District heating both on large and small scale has successfully been promoted and expanded in quite a number of member States.

- It is regarded as environmentally sound and easy to operate heat supply
- Various dynamic changes such as demographic developments, settlement structure, energy prices) challenges district heat
- To be economically viable, district heating requires a linear heat density of about 6 GJ/m
- District heating without electricity generation is not considered state-of-the-art
- Nevertheless competitiveness in comparison to other systems and new chances are also seen in the future if appropriate support is given by policy
- Long distance large scale district heat tends to be stagnating or decreasing whilst considerable growth is observed in the field of small scale biomass plants
- No recent data are available as regards impacts on overall dioxin emissions in particular in comparison to modern low emission domestic devices (for this information see chapter 6.2)

6.8.8 *Potential for transfer within Europe*

District heating is a common practice in many EU Member States. In this context CHP already plays a dominant role in many of the Member States. In western and middle European countries and the Nordic States in average 70% of all district heat is produced in CHP, whereas this share is still lower (55%) in middle-east and eastern European Member States. However, due to an ongoing modernisation of old heating plants into modern CHPs these differences fade.

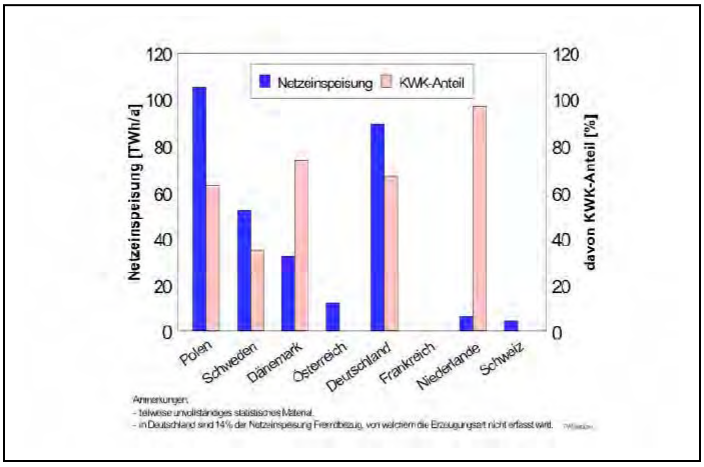

Figure 6-13: district heat generation (blue) and share of CHP (rose) in selected Member States (Source UBA 2007)

As regards the overall fuels mix used for district heat, there are important differences between Member States. Coal is the predominant fuel in PL, SK, CZ and DE (56-82%). High gas shares (50-75%) are observed in AT and the remaining middle-eastern and eastern European Member States. In total eastern European Member States have an average share of fossil fuels of 85%, whereas, this is only about 60% in the western and northern states. In general shares for gas and coal are more or less equal (30% each for gas and coal) except of AT with a predominance of gas. Renewable energies contribute in EU average with a share of 10% (33% in EU 15 versus 6% in EU 10) and the use of waste and industrial waste heat amount to 11% of district heat. Based on the available data natural gas is the dominant fuel in CHP (40%) at EU scale.

According to EUROSTAT data overall CHP heat production in 2002 was in a dimension of 3,000 PJ with almost 50% of the share produced in DE (550 PJ) followed by Poland (308 PJ), Finland (274 PJ) and France (263 PJ).

The annual consumption of long-distance district heat is currently in the order of 2,000 PJ, which corresponds to 10% of the total heat need (including warm water). In general an annual increase of consumption by 1% can be observed during the last years also in BG, CZ, EE, HU, LT, LV, PL, RO and SK, where district heating had heavily declined after the end of communistic times.

The shares of district heating and consumption of district heat in the domestic vary widely between Member States. Whilst in Western Europe the current average is only 7%, 37% of

the dwellings are connected in Eastern Europe. A specific situation occurs in Island where - due to easy availability of geothermal energy - district heating has a share of 96%. Market shares below 5% can be observed in Mediterranean Member States like Italy, but district heating in the domestic sector is also negligible in FR, NL and the UK.

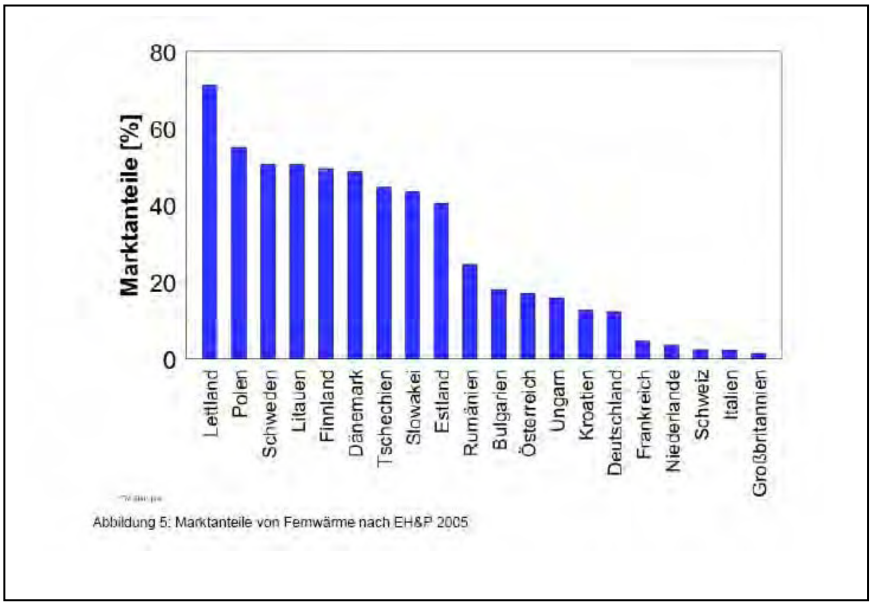

Figure 6-14: Market shares of long distance district heat in EU Member States according to EEH&P 2005 (Source UBA 2007)

Hence there is quite an important potential for installation of district heating systems in FR, IT, UK and the Mediterranean Member States (depending on climatic aspects and cost benefit calculations). In addition there is an important potential as regards modernisation or changes in shares of combusted fuels in the middle and eastern European Member States with pre-existing networks but predominant combustion of fossil fuels.

A concrete realisation of identified potentials for new installation, modernisation or extension of district heating grid needs to be decided on local level. For this purpose profound analyses of local heat potentials as described above have to be used.

6.9 Case Study 5 – Strengthening the competence of chimney sweepers (Germany)

6.9.1 Justification of selection

Chimney sweepers can play an important role in the control of emissions, the education of involved persons and the detection of illegal behaviour, due to their specific knowledge and competence. So far, few Member States take advantage of this potential, such as Germany, Austria, Northern Italy, and France and to some degree the Czech Republic. Beyond these Member States, Switzerland also plays a leading role, especially in the development and implementation of tools for detecting impermissible domestic combustion. These tools have also been tested and adopted in a few EU Member States. Basis for the justification of the selection of this case study is the added value that is expected if the concepts developed in Germany, Austria and Switzerland could be adopted in general within the European Union. The case study can give first answers on this question and specific recommendations for the application of efficient concepts and tools supporting both awareness and control.

6.9.2 Technical Background

In order to guarantee a safe discharge of exhaust gases, chimneys are cleaned and checked by sweepers. Especially when firing solid fuels in fireplaces or wood-fired central heating systems, soot is developed by incomplete combustion that can cause chimney burning if it is not periodically removed. An obstruction of the chimneys via leaves, birds' nests or age-related damage can also create dangers due to the back-pressure of the exhaust. Therefore, from the historical perspective, the function of chimney sweepers used to be vital for households.

Apart from these general and traditional tasks that chimney sweepers have throughout the EU, in some Member States – Austria, Germany, France and the Czech Republic[21] – they are equipped with several additional measuring and controlling powers, which are explained in the following. These are the functions than can be strengthened in order to improve household combustion activities and reduce PCDD/PCDF and other emissions.

The chimney sweeper controls the condition of the chimney and several parameters of the combustion process. One parameter is the content of carbon monoxide (CO) in the flue gas of firing appliances. Carbon monoxide is a highly toxic, odourless and colourless carbon monoxide which can lead to life-threatening health risks. Another parameter measured by the chimney sweeper is the flue gas loss of a heating system, i.e. the heat dissipating partially unutilised through the chimney during the fireplace operation. Threshold values for this flue gas loss, i.e. maximum percentages, are dependent on parameters such as the capacity of the appliance. Electronic measurement equipment is checked twice a year by an authorised auditing agency.

Another controlling function of the chimney sweeper is the statutory fireplace inspection at

21 For the Czech Republic, this only pertains to CO measurement of boilers in some cases.

periodic intervals. Here, a visual inspection takes place to determine whether the installation location and the fuel are admissible. Distances to combustible items such as doors, ceilings and walls are checked, and the chimney is controlled with regard to constructional deficits and faulty connections. In Austria, the power in kW of the heating system determines the interval of how often the sweeping has to be undertaken (between once and twelve times a year). Also, a special ash test is applied there that helps to detects illegal behaviour via analysis of the ash. This test has been developed by EMPA (Swiss Federal Laboratories for material testing and research; Eidgenössische Materialprüfungs- und Forschungsanstalt) in St. Gallen, Switzerland can be carried out quickly and at low cost using a mobile suitcase carried to the fireplace (Noger 2001). The content of this suitcase is shown in Figure 6-15.

Figure 6-15: The ash test suitcase developed by EMPA
(Source: http://www.ag.ch/umwelt-aargau/pdf/UAG_11_25.pdf)

After a visual evaluation of the fireplace, fuel and ash, two ash samples are taken, one of them to be stored for later verification. The test can be performed on site in about 30 minutes. The test determines whether thresholds for chlorine, zinc and lead have been exceeded. The threshold values are 2,000 mg/kg ash for chlorine, 600 mg/kg ash for zinc and 100 mg/kg ash for lead. These thresholds are not immediately legally relevant but rather are benchmarks for identifying the combustion of impermissible material – in cases where there is suspicion of thresholds being exceeded a more detailed laboratory analysis of the ashes can follow. Of these substances, chlorine is a good indicator for the generation of PCDD/PCDF, since in the presence of a catalyst, e.g. an iron grate, the chlorine content of the fuel is the limiting factor for the production of PCDD/PCDF.

Experience in Austria has shown that, although one of the causes for the occurrence of chlorine is typically the combustion of impermissible substances such as particle boards, a more frequent cause for elevated levels detected by such an ash test is incorrect handling of the furnace or the use of wood that is too moist.

These measures performed by the chimney sweepers, unlike a theoretically possible measurement of PCDD/PCDF content in the exhaust gas, do not directly measure or control PCDD/PCDF emissions. However, the medium or long-term effectiveness of the measures on a reduction of PCDD/PCDF emissions is indirect:

- A binding order to remedy defects of a heating system in order to stop bad heating behaviour or to substitute an outdated fireplace by a modern one, leads to a substantial change of the mix of domestic heating systems towards higher efficiency and lower PCDD/PCDF emission factors.
- Apart from this, a quantitative reduction of PCDD/PCDF emissions due to the information and educational advertising of chimney sweepers (supported by suitable brochures and campaigns) can also be significantly assumed.

6.9.3 Administrative background

In Germany, the tasks of chimney sweepers are constituted in a law from the year 1935 that determines the obligation to sweep chimneys and also installs a district monopoly having existed up to 2008. This law was slightly reformed in 1969, with particular regard to the regulation of the monopoly. The detailed administrative basis for the rights of the chimney sweepers, e.g. related to the threshold values to be controlled, is the German Federal Emission Protection Law (Bundesimmissionsschutzgesetz) and the First Ordinance for the Execution of this law (1. Bundesimmissionsschutzverordnung BImschV).

According to this ordinance, threshold values for dust particles (0.15 g per cubic meter) and for carbon monoxide (between 0.3 and 4 g per cubic meter, depending on nominal heating capacity and type of solid fuel) exist for solid-fuel fired fireplaces with a nominal heating capacity above 15 kW. For solid fuel fired fireplaces below 15 kW there are no limit values of these pollutants but additional restrictions to the admissible types of fuel, especially wood. Further emission limits for nitrous oxides (80 to 120 mg per kWh fuel energy feed) and for flue gas losses (9 to 11%, depending on the nominal heating capacity) exist for oil- and gas-fired combustion installations. The ordinances regulating the costs for sweeping, measuring and controlling activities are part of the legislation of the respective German states (Bundesländer). In cases of non-compliance to the ordinance, the chimney sweeper has the authorisation to call for a refurbishment or change of the heating unit and reports the results to the public authority.

The reason for performing a chlorine ash test in Austria is often due to a complaint of citizens on emissions in the neighbourhood (similar to the complaints mentioned for Ireland, explained in the following case study in Chapter 6.10). The official channels of such a complaint are via the mayor and municipal council of a township who then commissions an expert for the inspection. Although the demand for such an inspection is estimated as high, the final decision to carry it out is taken only in selected cases. In Austria, there are no legally

binding threshold values measured by the test but it is made to detect illegal combustion behaviour.

In Switzerland, legal limit values exist for carbon monoxide and dust particles, not for other pollutants; here the legal limits are defined according to the origin and type of the fuels used that are permitted or illegal. The status of legislation and implementation in detail varies from canton to canton due to their high level of self-government.

6.9.4 Financial background

Taking the situation in Germany as the reference, chimney sweep services are associated with annual costs of €50 to €100, related to a one-family home, which have to be paid by house and flat owners. The services of the chimney sweepers are completely covered by the fees, i.e. the government does not support the chimney sweeper organisation. From the German chimney sweepers association a manual on a draft sweeping and control regime, that provides background information on the specification and the determination of charges for sweeping and inspection has been made available (Stehmer 2007).

6.9.5 Expected/realised benefits

The benefits of strengthening the competence of chimney sweepers in the EU can be subdivided into general benefits and those benefits related in particular to PCDD/PCDF emissions.

- General benefits

One main argument in favour of the German chimney sweeper or a comparable monitoring system in general is that a periodic and independent control and measurement guarantees an increase in safety, i.e. a reduction of the risks of fire, accidents, explosions or poisoning cases due to the occurrence of carbon monoxide.

- Benefits with regard to reduced dioxin emissions via a change towards law-compliance regarding combustion behaviour of households

Here, the long-time experiences in Switzerland with the quick ash test can serve as a conspicuous example. Initial unannounced samples at several hundred households in the years 2000 to 2003 discovered a high percentage (60 to 70%) of fuel abuse or incorrect use. This range was confirmed by independent studies over several different regions of Switzerland. The result confirmed a large need for action already identified during that time.[22] As complaint situations become manifest in most cases by exceeding of the permitted chlorine content of fuels, there is a direct relation to an increase in PCDD/PCDF development.

Now, several cantons have announced and implemented complete inventory counts, and as

[22] EMPA Swiss Laboratories for testing and research, PowerPoint presentation on the EMPA quick ash test. This quantitative result supports the broader information gained by Dominik Noger.

a consequence, the share of abuse has been reduced to a maximum of one third. A share of up to one third is typical for rural regions; in urban regions it approaches 10%. This reduction in behaviour not conforming to the law has been realised within about five years, although there are not yet any monetary sanctions or penalties attached to an abuse in this phase. This result is remarkable, because it shows that the effect of being aware of the existence of inspection and control alone, even without further sanctions, has already led to an awareness of the problem and a change in behaviour.

It has to be emphasized that, in cases where limit values are exceeded, but it is not due to using the wrong fuel but to obvious or detected technical defects of the fireplace, the renovation of the fireplace can be ordered after such an inspection. Therefore, if the cause of PCDD/PCDF emissions is not the fuel but the heating facility, this cause can also be immediately and efficiently reduced on a sustainable basis.

6.9.6 Expected/realised efforts and obstacles

A systematic relationship between the information and control activities of chimney sweepers and a reduction of PCDD/PCDF emissions is undoubted. However, the definite quantitative relationship of costs and effectiveness, e.g. of a change in the structure of domestic heating systems, cannot be estimated without assumptions either somewhat arbitrary or requiring empirical or econometric foundation.

A direct, reliable measure of PCDD/PCDF emissions in household chimneys requires a certain amount of equipment and time (known from experience with industrial chimneys) that does not make it practicable for routine household measures. Therefore, measurement has to aim at other substances serving as indicators for the occurrence of PCDD/PCDFs which are easier to measure.

6.9.7 Conclusion of the single case study

The case studies have shown that an inspection and control system for domestic boilers, especially those heated by wood, has significant advantages both for an increase in safety and for a heating operation more compliant to the law and therefore for a reduction of PCDD/PCDF emissions.

Having looked at the development and use of the supporting tool of ash tests (especially the one developed by EMPA) within this inspection system, it can be shown that in spite of its universal usefulness and quick application, its practical explanatory power is limited. Therefore, ongoing research for the development of another test procedure has been motivated in Switzerland.

Most cases of abnormality of the ashes can already be gathered by a visual inspection of the fuel stock and the ashes, i.e. nails or remaining parts of waste, contaminants and foreign particles indicating that contaminated wood, waste or other substances have been burnt (see Figure 6-16). In such cases, the detection by a chemical ash test is obsolete because proof of an abuse can be gained at the visual stage.

Figure 6-16: Comparison of ash from natural finish (untreated) wood (left dish), wood mixed with chipboard (central dish) and wood mixed with domestic waste (right dish), as identified by visual inspection

Source: EMPA Swiss Laboratories for testing and research, PowerPoint presentation on the EMPA quick ash test

There have been a series of tests and applications in Germany, Austria and the Czech Republic, accompanied by information, education and training courses given by the developers. Apart from these countries mentioned, the quick ash test has not been applied in an authorised way in other EU countries.[23]

The three chemical substances chlorine, lead and zinc did not prove sufficient for the detection of fuel abuse, since also the appearance of copper, chromium, cadmium, nickel and arsenic, in combination with the results for chlorine, zinc and lead, are indicators of the use of non-permitted fuels. This (and further problems and caveats with regard to the quick ash test) led to the development of a combined chemical and X-ray supported test that is envisaged and recommended to replace the existing quick ash test in Switzerland. At present, one X-ray apparatus for surface detection has initial costs of about €50,000, and its handling still requires more skill and operating experience by the user than the quick ash test in order to gain reliable results. However, the goal of the development is to reduce the average costs to €20 per inspection.

6.9.8 Potential for transfer within Europe

The combined function of the chimney sweeper organisations in German-speaking countries, consisting of the two spheres of information; communication and awareness raising on the one hand, and inspection, control (including the ash tests described) and if necessary also sanctioning authority on the other, has proved to be effective for a change in the domestic burning behaviour of households, and can be transferred to other countries.

[23] Due to the information available to Dominik Noger and the other experts interviewed.

6.10 Case Study 6 – Elimination of domestic and open waste burning by means of awareness raising (Ireland)

The professionally planned and designed set of awareness raising measures performed in Ireland in the years 2003 to 2007, held together by the central campaign and slogan “Race against Waste”, has proved exemplarily successful. Main indicators of success have been an increase in the recycling rate from 13% to 35% in Ireland during these years and the sustainable use of the campaign as a catchword in the media even long beyond the official end of the campaign.

6.10.1 Justification of selection

Awareness raising measures are general not stand-alone measures but usually accompany other policy measures and foster their public acceptance. Due to the pro-active character of the combination of campaigns and other measures especially in Ireland, where a set of high profile media releases are used, it seems most interesting how these activities are received within the population and have already lead to a measurable change in behaviour.

6.10.2 Technical background and applicability: What is this campaign?

The Department of the Environment Heritage and Local Government initiated a national communications and awareness campaign for waste management in Ireland in 2003. The campaign aimed to raise national awareness of waste issues and change in behaviour in terms of waste management among people at home, at work and in their local community.

The overall programme package as a bunched instrument represents a combined set of communication and education measures aimed at changing behaviour, not a technical measure. Technical, chemical and biological information, addressed in a target-group specific way for the population, on the relationship between uncontrolled low temperature burning in backyards and the occurrence of dioxins and furans as well as other pollutants and their effects are explained within the Race Against Waste campaign, see e. g. the well structured information at http://www.raceagainstwaste.ie/learn/backyard_burning/. The set of measures consists of the central “Race against Waste” campaign, accompanied by three further components: a media campaign on backyard burning and illegal waste collection, a phone hotline “Dump the Dumpers” and the “See something say something” campaign.

The Stakeholder Consultation unit, in conjunction with Mary Murphy Associates and Lyle Bailie, was responsible for the development and implementation of the campaign and devised the campaign name, brand and slogan Race against Waste – Reduce, Reuse, Recycle. The campaign was delivered through an innovative advertising, communications and PR strategy that focused on every person in Ireland, at home, at work and in their community. The main characteristics of this campaign are highlighted in the following:

- The *Race Against Waste* Campaign, which was the most extensive waste information campaign ever run in Ireland, took place over the period 2003 – 2007.

- The campaign, which was launched in October 2003, combined a multi-media national awareness campaign and a supporting communications strategy and aimed to get people acting to reduce, reuse and recycle waste.
- The campaign directly engaged specific audiences who are creating waste – communities, businesses, large organisations and homes – with the objective of improving environmental behaviour.
- It provided advice and information directly to the public through a low call telephone line and e-mail, ran a programme of action for businesses, including nationwide seminars, and informed the public through on-going public relations and advertising campaigns.

As mentioned, the campaign was accompanied by three further measures: The EPA's Office of Environmental Enforcement (OEE) also ran two high profile media campaigns in the autumn of 2005 and 2006 regarding illegal backyard burning, dioxin releases and illegal waste collection. Advertisements were placed in 23 regional newspapers, and in addition radio adverts on 15 local stations. In the summer of 2007 the EPA ran amalgamated advertisements against backyard burning and illegal waste collection.

In addition, the EPA launched a "Dump the Dumpers" phone hotline in June 2006 to enable the public to call a phone number on a 24-hour basis and report illegal waste activities. Information received during phone calls is followed up and checked by the enforcement authorities – local authorities, the EPA's Office of Environmental Enforcement and the Gardaí through the Environmental Enforcement Network.

Supporting this measure, the Environmental Enforcement Network (operated by the Office of Environmental Enforcement within the Environmental Protection Agency) produced a leaflet "See something? Say something!" to make it easier for members of the public to make an environmental complaint. The leaflet was launched by the Minister for the Environment, Heritage and Local Government in April 2007. Instances such as illegal burning of waste, illegal dumping and water pollution are examples of where the public can assist by informing the relevant authorities of the problem.

6.10.3 Administrative Background

The requirement to provide environmental information and implement environmental awareness activities, measures and campaigns derive from various UN Conventions, EU Treaties and are contained in a number of domestic environment policy documents of Ireland. Examples are documents such as "Changing our Ways", "Preventing and Recycling Waste: Delivering Change", the "National Climate Change Strategy" and the "National Biodiversity Strategy".

Within the Environmental Protection Agency (EPA) of Ireland that was established and authorised with statutory duties and powers in 1993 under the Environmental Protection Agency Act, the Office of Environmental Enforcement (OEE) was established in 2003 as a distinct office. One occasion was that the EU Commission decided to prosecute Ireland at the European Court of Justice for failure to implement the Waste Directive, and therefore radical steps were needed to deal with the situation. Since a strategic review of the work of

the EPA identified a need to ensure better enforcement of environmental legislation against a background of concern, e.g. about illegal dumping of waste, the OEE was established in order to be dedicated to the implementation and enforcement of environmental legislation in Ireland. The OEE also co-ordinates a national Environmental Enforcement Network (EEN). This network includes the EPA, all local authorities, government departments, An Garda Siochana, the National Bureau for Criminal Investigations, the Northern Ireland Environment and Heritage Service, the Police Service of Northern Ireland, the Fisheries Boards, the Health Service Executive, the Revenue Commissioners, and the Director of Public Prosecutions.

Race against Waste is recognised nationally as an organisation in its own right. It was seen as an extension of the Department of the Environment, Heritage & Local Government providing a nationwide range of services and a one-stop shop for reliable advice and information on all matters pertaining to waste for householders, communities, public & private sector organisations and businesses. Stakeholders and organisations and sectoral 'gate-keepers' saw Race Against Waste as a problem-solving entity, which supported them in implementing better waste management rather than just a media campaign that tells them what to do.

With regard to the further accompanying campaigns and measures described above, two of the main priorities undertaken by the OEE (in co-operation with local authorities) are

- publishing an account of the nature and extent of unauthorised waste activity in Ireland (including backyard burning that was identified as a significant issue by 80% of local authorities) and setting out an action plan now implemented by the agencies through the Environmental Enforcement Network.
- receipt of complaints from the public about environmental pollution (e.g. odour) and to focus inspections on facilities giving rise to most complaints

When encouraging people to make an environmental complaint, the EEN suggests in their information leaflet "See something? Say something!" a three-step procedure of whom to approach first and next if the problem could not be solved on the preceding level. People are asked

- firstly to contact the person or business directly, then
- contact the local authority (the respective county or city council) – in all cases when the polluter is not a business or facility with an EPA licence, i.e. also in cases of backyard burning of household waste)
- contact the EPA as a last resort.

6.10.4 Financial Background

Costs of the "Race against Waste" campaign have amounted to €3.6 million for each of the three years 2004 to 2006 and another €179,359 in the year 2007.

The costs of both of these campaigns have been financed by a special fund known as 'The

Environment Fund'. The financing proceeds from two levies, one on plastic bags (€0.15 cents per bag) and one on landfill of waste (€15 per tonne), both introduced in 2002, are lodged into the Environment Fund. In 2006, as a penalty, a levy of €20 per tonne of waste disposed of at unauthorised facilities was introduced as an amendment of the landfill levy.

This Environment Fund is "ring-fenced" and can only be used to make payments that relate to projects to benefit the environment, such as schemes to prevent or reduce waste, waste recovery activities, the promotion of awareness of the need to protect the environment, including national and regional campaigns and other initiatives or other purposes for protection of the environment. Therefore, there is an earmarking of special governmental revenues and expenditures, applying the “polluter pays” principle, a mechanism well-known in environmental economics: The waste producer has to pay according to his waste contribution for the waste reduction campaign.

6.10.5 Realised benefits

The greatest indication of the success of the campaign is the increased rates of recycling in Ireland over the duration of the project. This has risen from 13% to 35% which is regarded as impressive and helps to reach the recycling target for waste of 50%[24] stipulated in the new Waste framework Directive 2008/98/EC to be attained by 2020. While many new changes have occurred in terms of waste management in Ireland over the intervening period that have instigated and sustained a change in waste behaviour, Race against Waste can certainly take credit for contributing to this success in Ireland.

The legacy of the campaign is that Race against Waste is still a recognised brand now in 2008, despite the fact that investment in it ended in October 2006. Furthermore the phrase has become a catchphrase that is still used by newspaper editors and radio presenters who accuse people of “losing the Race against Waste or praise them for “winning the Race against Waste”, still to this day.

Further outcomes and outputs achieved by the Race against Waste campaign have been:

- a continuation of the high quality TV advertisement and media campaign until 2006
- a focus on training of local authority Environmental Awareness Officers to take on the issues of the campaign
- a recycling guide published as an insert to the Golden Pages of the telephone book giving details of recycling facilities by area.
- workshops held for youth group leaders about management of waste as part of the Youth Programme.
- the development of an on-line Waste Audit Tool for business.
- Development of a RAW Event Guide and a RAW guide for the Football Association of Ireland on sustainable waste management of large public events
- the continuation of some elements even after the official end of the main RAW

[24] To be reached at least for glass, paper, metal and plastics

campaign, such as the RAW web site, the waste audit tool and the distribution of RAW waste information materials

The quantitative results of the additional “See something? Say something!” campaign have been that since its inception the Dump the Dumpers phone line has received 4,108 calls, of which 3,874 are relevant. The breakdowns of the (relevant) complaints into categories are shown in Table 6-39.

Category	Number
Abandoned vehicle	177
Authorised facility	580
Burning of waste	293
Fly-tipping (less than 20 bags of waste)	1,298
Illegal dumping (over 20 bags of waste)	507
Illegal landfills	121
Illegal waste collection/transport	928
Sum of relevant calls	3,874

Table 6-39: Categories of complaints to the “Dump the Dumpers” phone line from inception to present

Source: EPA, Office of Environmental Enforcement, Ireland

A review of the data received by the phone service for the period between June 2006 and June 2007 indicated that 70% of the complaints could be resolved, that means the site(s) were located and the area cleared of waste. The number of resolved cases for the following 2007-2008 period information is not yet available.

6.10.6 Realised efforts and obstacles

The beginning of the campaign saw the establishment of the Race against Waste brand through advertising. The advertising strategy aimed to ‘shock’ people into the need for taking action on waste management and followed this up with ‘how’ this could be done. This was supported and as time went on surpassed, by a strong press and media campaign, which together with grassroots events informed the target audience about integrated waste management and built an understanding of the urgency to reduce, reuse and recycle. These programmes were backed up by an extensive website and phone based information service, and crucially, were shaped and supported through the active participation of national and regional stakeholders.

Key to the success of Race against Waste was the consultation with key stakeholders at an early stage of the project to encourage them to take ownership of the waste issue in their sector. Examples of the sectors and organisations consulted with included chambers of commerce, IBEC, ENFO, the tourism sector, local authorities, local communities (through Tidy Towns Competition), EPA, the Health Service Executive and the Gardai.

A key recommendation from the stakeholder consultation process in Year 1 was that Race Against Waste needed to provide action, that the action needed to be sector-specific and that networking of sectors is very important to achieving change at a local level. The emphasis of the campaign therefore became extremely focused in Years 2 and 3 in order to create

effective and relevant programmes of action, to encourage participation in Race Against Waste and to maximise networking opportunities for participants.

This led to the production of a number of guides and seminars to assist small businesses, large organisations and local communities in the implementation of better waste management practices. As the campaign progressed the content of these seminars was tailored to the specific needs of each sector, making them more useful and relevant.

In addition to the guides for small and large organisations and local communities, a number of information leaflets on a range of waste-related topics were produced. These were distributed among green schools, the Environmental Awareness Officers, community and “Tidy Towns” groups, universities and through events attended by the Race against Waste team. These aimed to help raise awareness of waste and sustainability issues among these groups.

The environmental, business and public sector communications specialist Mary Murphy Associates (MMA) devised and delivered a multi-faceted public relations campaign to add immense value to the stakeholder engagement element and to explain the issues being raised in the advertising. MMA drafted and placed hundreds of press releases over the three year campaign to generate photographs, editorial comments and articles throughout national and local print and electronic media motivating people to get involved in “reduce, reuse, recycle” initiatives and often, endorsing the Race Against Waste campaign approach.

Tough issues such as incineration had to be tackled as well. There were many myths and considerable opposition to incineration when the campaign was started in 2003. Therefore, study tours were organised for local authority officials and media to show them first-hand what an incinerator looks like, how it works and how it interacts and impacts on the community around it. Over 100 journalists from national and local press, radio and TV were invited to Amsterdam to show them incineration; the result was in most cases extremely positive articles, radio and TV reports; in a few cases the reports were objective and neutral on how well the plant operated.

Another issue to tackle was the myth that what is put into the green bin or the recycling centre got land-filled or incinerated. Therefore study tours were organised to show the public, through the media, where the newspapers and drinks cans put into Irish recycling facilities end up and what they are turned into. Again, about 25 positive articles were generated that motivated the public to keep on putting items out for recycling.

The value of showing people what to do, rather than just telling them, has been extolled. So, for Race against Waste case studies on hundreds of individuals, large and small businesses and public sector organisations from hospitals to Government Departments and local authorities have been researched and written up. The case studies have been used to motivate others in the various sectors to get a handle on their waste. Instead of the campaign or the government telling people how good it is to recycle or reduce or compost in their workplace, business people or managers told people what they were doing, how easy it was and moreover, that they were saving money in the process.

There were many other PR initiatives that combined with the stakeholder engagement and

advertising campaign, resulted in everyone throughout the country knowing what Race against Waste was and more importantly, understanding all of the reasons why they should manage their waste better and how to do it.

Due to all these significant efforts described, especially with regard to a well-prepared, innovative and multi-faceted public relations concept, and the inclusion and participation of all relevant stakeholder groups, there have been no significant obstacles to public acceptance.

As an experience from the “Dump the Dumpers” hotline, it was mentioned that callers tend to overestimate the quantity of waste. For example the phone line received 121 calls regarding illegal landfills, but the vast majority (90%) of these were actually illegal dumping which the agency was already aware of.

6.10.7 Conclusion of the single case study

The campaign proved to be a successful instrument to reduce open waste burning and thus can be seen clearly as an example of good practice for the reduction of PCDD/PCDF emissions from the domestic sector. As consequences of the campaign:

- recycling rates in Ireland have risen from 13% to 35% over the duration of the project
- beyond quantitatively measurable results the campaign has become a recognised brand in the consciousness of the population lasting far beyond the duration of the project itself. One indicator is the sustainable presence in the media: The slogan has become a catchphrase that is still used by newspaper editors and radio presenters up to today.
- As an indicator of the wide recognition as a highly successful awareness campaign, the team won a number of awards, including the GDBA award for Best Website in 2005, the Best Public Information Campaign by the Public Relations Institute of Ireland, the Public Relations Consultants Association and the Institute of Public Relations (Northern Ireland) Awards for Excellence in 2004, and further numerous advertising awards.

It has been identified that the key to the success of Race against Waste was the integration of advertising with a stakeholder-driven approach, i.e. the consultation with key stakeholders at an early stage of the project to encourage them to take up ownership of the waste issue in their sector.

6.10.8 Potential for transfer within Europe

Although up to now no estimation has been made for a pan-European awareness programme, it was identified by the national experts as a question worth exploring, since a lot of positive experience could be shared. And there is quite a potential for improvement in municipal solid waste management in other MS as well. Some insights into this issue can be gained by the results of a series of awareness raising campaigns regarding the landfill and

shipment of waste.[25]

In principle, the programmes can be transferred into all MS even if specific solution and certain adaptation have to be made to fit the local infrastructure, conditions and mentality.

[25] See also the website http://www.bipro.de/waste-events/ for awareness raising measures with regard to waste in other countries.

6.11 Case Study 7 – Regulation for the use of solid fuel appliances in Hvidovre Municipality (DK)

6.11.1 Justification of selection

Awareness raising measures are in general no stand-alone measures but usually accompany other policy measures and foster their public acceptance. Due to the pro-active character of the combination of campaigns and other measures, it seems most interesting as to how these activities are received within the population and have already led to a measurable change in behaviour.

6.11.2 Technical Background

The Hvidovre municipality is situated just south of Copenhagen and has almost 50,000 inhabitants, which is almost 1% of the Danish population of 5.5 million inhabitants. There are in total about 3,800 solid fuel appliances, mainly wood stoves, in the municipality.

The Technical Department in Hvidovre Municipality receives regular complaints about nuisance from solid fuel appliances, mainly wood stoves. The nuisance typically arises because of incorrect firing, too low chimneys or because of stoves in poor condition.

Burning wood in stoves contributes to pollution by PM, mostly in the surrounding outdoor air, but also inside the houses. The National Environmental Research Institute (NERI) has carried out studies showing that wood-burning stoves and boilers in Denmark are the source of almost 50% of pollution related to the so-called primary particles or fine particles. The source of the second half of the fine particles is traffic. In the village of Gundsømagle, which is an area with many stoves and low traffic, NERI has measured a level of fine particles comparable to that of the road with the heaviest traffic in Copenhagen.

In the global perspective, heating by burning wood in stoves is CO_2 neutral, because the burning does not create more CO_2 than if the tree was rotten in the woods. But in the local perspective it is different, as the pollution with particles creates bad air quality in the immediate environment. This air can aggravate – if not cause – respiratory diseases. If firing is done with other things other than clean dry wood, toxic dioxin can also be formed. For example, imported disposable pallets can be treated with pentachlorophenol (PCP), which is not visible on the wood, and burning PCP will readily form high amounts of PCDD/PCDFs.

6.11.3 Administrative background

The Hvidovre municipal council has for several years wanted to do more to reduce pollution and nuisance from wood stoves. In 2006, a budget of €7,000 was allocated for a public awareness campaign with the aim of minimizing pollution from wood stoves and the campaign was repeated in 2007. When adopting and issuing this regulation, it was decided to repeat the part of the campaign about good firing practice.

In January 2008, a new order from The Environment Ministry Departmental Order No. 1432

of 11 December 2007 (The Wood Burner Order) came into force. The order enables the municipalities to provide regulations for pollution control measures for solid fuelled domestic energy producing appliances, in clearly specified areas. In the comments to the order, it is indicated that the aim of the order is also to give the municipal councils increased authority and to improve the basis for their options to act in relation to pollution and complaint about nuisances. Against this background, the Technical Department has considered it appropriate to establish this regulation for the use of solid fuel appliances.

The regulation for the use of solid fuel appliances in Hvidovre Municipality covers all sorts of solid fuelled appliances in residential areas. The key elements in the regulation are:

- The owner and/or the user of a solid fuelled appliance are responsible for the observation of the regulation.
- Coal, coke, waste wood (which means any type of treated wood including wooden pallets) or household waste is not allowed to be burned in solid fuel appliances.
- Only clean wood with moisture content (water content) of less than 20% is allowed as fuel in solid fuel appliances, e.g. firewood, wood pellets and wood briquettes.
- Firewood shall be stored in a dry, well-ventilated place, for example, in a woodshed, in a carport or under a lean-to, to avoid the dryness and quality to deteriorate. Freshly felled and chopped wood shall be kept dry for at least 1 year before it may be used in solid fuel appliances.
- Lightning up a solid fuelled appliance may only be conducted with dry brushwood, kindling wood, firelighter, crumpled newspaper or the like. Lighting up shall be made with plentiful air supply and must last for a maximum of 15 minutes.
- Firing overnight, e.g. by filling up the appliance with firewood, and reducing the air supply to a minimum, in order to still have embers the next morning, is not allowed.
- The owner/user must ensure that the use of a solid-fuelled appliance does not create significant smoke nuisance for the neighbours. The smoke from solid fuel appliances may not create visible or smelling flue gas settling down on the neighbours.
  If necessary the municipality of Hvidovre can decide that the current chimney stack height shall be increased. The use of solid fuelled appliances can also be banned, if the local situation such as terrain, location and height of buildings, trees, chimney, etc. is not suitable.
- Offending the regulation is punished with a fine, unless a higher penalty is enforced through other legislation.

The published version of the regulation will contain advice and guidance on the use of stoves that are beyond that which can be included in the regulation. All solid fuel appliances are registered in the Construction and Housing Register. The new regulation will be distributed to all the addresses that are registered with a solid fuel appliance.

6.11.4 Financial Background

Work on the rule started in early 2008 and has – so far – only taken about 12-15 working days, for material search, writing, internal meetings and consultation, external consultation, preparation for political approval, etc.

The costs for implementing the regulation amount to only €3,000 for printing and distribution of the regulation and some relevant supplemental information material to all of the 3,800 addresses in the municipality which are registered as having a solid fuel appliance in the Construction and Housing Register.

6.11.5 Expected/realised benefits

The main expected results from introducing the regulations are:

- A decreased PCDD/PCDF emission, because of a reduced burning of waste and waste wood, especially a reduction of the use of pallets impregnated with PCP.
- A general improvement of the air quality in the municipality.
- It will be much easier for the municipality to deal with and settle complaints about smoke nuisances.

A regulation for the use of solid fuel stoves will cause the citizens to have clear and uniform rules on the proper use of solid fuel stoves, and it will be easier for the Technical Department to deal with and act upon complaints on smoke nuisances.

It is anticipated, that the regulation can lead to more complaints on smoke nuisances, because potential complainants will have more exact knowledge about the rules and can more easily evaluate situations where a neighbour breaks the rules. Consequently, more work to handle complaints on smoke nuisances is anticipated.

It is very likely, that this regulation will be adopted by other Danish municipalities, and will be used directly or with some changes.

6.11.6 Expected/realised efforts and obstacles

No major obstacles were anticipated.

6.11.7 Conclusion of the single case study

The regulation has just been entered into force on the 1st December 2008, and so far no results and experiences are available.

6.11.8 Potential for transfer within Europe

Comparable regulations can in principle be transferred to an EU Member States and might be especially useful with appropriate adaptation in regions with high share of heating or leisure activities with solid fuels in particular wood.

However, as experiences of the practical implementation and enforcement of the regulation are not yet available, it is recommendable to wait and eventually optimise the measure before transferring it to other regions in Europe.

7 Conclusion and Recommendations

Conclusions on domestic emission, estimates and reduction measures

The compilation of information on current knowledge on EFs showed that existing EFs are associated with considerable uncertainty and that the development of detailed EFs in the field of solid fuels might be difficult to achieve as differences in on-the-ground combustion conditions are the predominant parameter for resulting emissions, and conditions of the standardized measurements used for determination of EFs are hardly ever met. Considering that considerable amounts of MSW are illegally combusted even in countries, with strict enforcement traditions, highly specific EFs may give the illusion of a precision in emission estimates that does not exist. Therefore, for the combustion of wood and coal, a simple system of EFs that takes into consideration the problem of variability and improper or illegal behaviour (e.g. as reflected by the high EFs for simple manually-fed appliances in the UNECE Guidebook) could be appropriate and might be structured according to stove type. In addition, it should be further discussed in the scientific community whether a specific EF for other biomasses, such as hay straw, reed, mowing residues, wood waste needs to be developed in the light of increasing use of this type of fuel. Commonly accepted EFs based on an agreed methodology should be aimed for.

The compilation of information on the current state of emission estimates showed clear short-comings in the field of activity data for domestic combustion. These are especially significant for wood, other biomass and waste and for the determination of type and technical standard of appliances. EFs and ARs are the crucial parameters for emission estimation and closely connected. Hence, a sophisticated system of EFs does not help if it is not matched with an equally refined system of ARs. In this respect, the current reporting system is settled as appropriate on the level of the smallest common denominator of available EF and AR quality.

The compiled information on reduction measures showed that dioxin emissions are currently not a driving force for environmental policy in the domestic sector. Programmes focus on pollutants such as PM, PAH and CO_2. Nevertheless in general these measures will also considerably reduce PCDD/PCDF emissions.

It has to be taken into consideration that domestic emissions became relevant mainly because major efforts towards the reduction of PCDD/PCDF emissions in the industrial sector have been successfully undertaken and that overall emissions have considerably decreased. On the other hand it has to be kept in mind that the WHO-recommended maximum intake level is still exceeded by up to 50% and that increased use of biomass in domestic combustion will raise PCDD/PCDF emissions in future again to a certain extent. Hence, vigilance should be kept up and extended to proposed legislation in order to keep current PCDD/PCDF emission levels low and to work towards reaching the WHO-recommended maximum intake level. Furthermore, impact assessments of relevant policies should discuss the implications on PCDD/PCDF emissions as well.

Recommendations for reduction of data gaps and improved emission estimates

Based on the identified deficits and the related difficulties in establishing emission inventories, the following actions are proposed to improve emission estimates:

- Establishment of EU wide data base with applied EFs (including justification) for information exchange and harmonisation purposes (could also be of benefit for PRTR reporting)
- Expert meetings and/or networking between concerned MS authorities for information exchange on EFs and generation of ARs for solid fuels (use existing fora like UNECE, UNEP)
- EU wide R&D projects for verification of EFs , focus on solid fuels in different types of appliances under real life conditions) including EFs for dl-PCB, other biomass and unreported sources (e.g. charcoal)

Recommendations for measures to reduce dioxin emissions from domestic sources

The choice of the most appropriate measures depends on the specific situation of a Member State. The following elements are proposed:

- Continue efforts for elimination of waste burning (domestic and back-yard) by means of bans, waste management and awareness raising/education (including strengthened control)
- Establish and disseminate guidance on good heating practice and awareness raising at local level and in the population including information on associated risks (including strengthened monitoring and control)
- Further promote and investigate in low emission heating approaches such as gas heating, district heating and installation of low emission solid fuel fired appliances
- Further promote insulation and improved temperature regulation or ventilation practice as appropriate additive measure in all settings, but especially effective in the context of solid fuel heated houses
- Further extend use of solar energy as additive measure in all settings, but especially effective in combination with solid fuels, in all regions where climate conditions are appropriate

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ANNEX

Contents

1 Annex Emission Measurements Domestic Sources

1.1 Emissions into air

1.1.1 Dioxin emission factors for domestic combustion of coal

1.1.1.1 Emission units in µg TEQ/TJ (coal)

Year	Short reference	MS	domestic appliance (type)	Manu-facture	Fuel	EF air µg TEQ/TJ
1999	Thanner & Moche 2002	AT	stovetyp 1 low priced multi-fuel stove	~1999	coal Poland	8,990 9,470 12,100 11,700
1999	Thanner & Moche 2002	AT	stovetyp 1 low priced multi-fuel stove	~1999	coke Czech Republic	1,500 1,980
1999	Thanner & Moche 2002	AT	stovetyp 2 cast iron stove for coke	~1979	coal Poland	4,190 3,640 8,620
1999	Thanner & Moche 2002	AT	stovetyp 2 cast iron stove for coke	~1979	coke Czech Republic	1,560 860
1999	Thanner & Moche 2002	AT	stovetyp 3 danish style cast iron wood stove	~1990	coal Poland	3,230
1999/2000	Boos et al. 2005 resp. Hübner et al. 2005	AT	Single Stove (continuous burning)	~1960	wood, coal	29
1999/2000	Boos et al. 2005 resp. Hübner et al. 2005	AT	Single Stove (continuous burning)	1990	wood,coal	27
1999/2000	Boos et al. 2005 resp. Hübner et al. 2005	AT	Single stove (kitchen)	~1970	wood, coal	130
1999/2000	Boos et al. 2005 resp. Hübner et al. 2005	AT	Single stove (kitchen)	~1970	wood, coal	48
1999/2000	Boos et al. 2005 resp. Hübner et al. 2005	AT	Single stove (kitchen)	1985	wood, coal	2,400
1999/2000	Boos et al. 2005 resp. Hübner et al. 2005	AT	Residential heating boiler for solid fuels	1981	coke	71
1999/2000	Boos et al. 2005 resp. Hübner et al. 2005	AT	Residential heating boiler for solid fuels	1999	coke	87
1999/2000	Boos et al. 2005 resp. Hübner et al. 2005	AT	Residential heating boiler for solid fuels	1978	coke	280
1999/2000	Boos et al. 2005 resp. Hübner et al. 2005	AT	Residential heating boiler for solid fuels	1987	coal	380

Year	Short reference	MS	domestic appliance (type)	Manu-facture	Fuel	EF air
						µg TEQ/TJ
1994/1995	Erken et al. 1996	DE	fireplace	~1986	lignite briquette	61
1994/1995	Erken et al. 1996	DE	fireplace	~1986	lignite briquette	38
1994/1995	Erken et al. 1996	DE	fireplace	~1986	lignite briquette	11
1994/1995	Erken et al. 1996	DE	fireplace	~1986	lignite briquette	8
1994/1995	Erken et al. 1996	DE	Stove continuous burning	~1982	lignite briquette	37
1994/1995	Erken et al. 1996	DE	Stove continuous burning	~1982	lignite briquette	62
1994/1995	Erken et al. 1996	DE	Stove continuous burning	~1982	lignite briquette	19
1994/1995	Erken et al. 1996	DE	Stove continuous burning	~1982	lignite briquette	16
1994/1995	Erken et al. 1996	DE	Continuous heating device	~1985	lignite briquette	13
1994/1995	Erken et al. 1996	DE	Continuous heating device	~1985	lignite briquette	19
1994/1995	Erken et al. 1996	DE	Continuous heating device	~1985	lignite briquette	10
1994/1995	Erken et al. 1996	DE	Continuous heating device	~1985	lignite briquette	11
1994/1995	Erken et al. 1996	DE	boiler 2	~1987/90	lignite briquette	20
1994/1995	Erken et al. 1996	DE	boiler 2	~1987/90	lignite briquette	49
1994/1995	Erken et al. 1996	DE	boiler 2	~1987/90	lignite briquette	21
1994/1995	Erken et al. 1996	DE	boiler 2	~1987/90	lignite briquette	35
1994/1995	Erken et al. 1996	DE	Stove continuous burning	~1982	lignite briquette	32
1994/1995	Erken et al. 1996	DE	Stove continuous burning	~1982	lignite briquette 2	31
1994/1995	Erken et al. 1996	DE	Stove continuous burning	~1982	lignite briquette 2	20
1994/1995	Erken et al. 1996	DE	Stove continuous burning	~1982	lignite briquette 2	17
1994/1995	Erken et al. 1996	DE	Continuous heating device	~1985	lignite briquette 2	33
1994/1995	Erken et al. 1996	DE	Continuous heating device	~1985	lignite briquette 2	14
1994/1995	Erken et al. 1996	DE	boiler 2	~1987/90	lignite briquette 2	19
1994/1995	Erken et al. 1996	DE	boiler 2	~1987/90	lignite briquette 2	32

Year	Short reference	MS	domestic appliance (type)	Manu-facture	Fuel	EF air
						µg TEQ/TJ
1994/1995	Erken et al. 1996	DE	Stove continuous burning	~1982	lignite briquette 3	54
1994/1995	Erken et al. 1996	DE	Stove continuous burning	~1982	lignite briquette 3	25
1994/1995	Erken et al. 1996	DE	Stove continuous burning	~1982	lignite briquette 3	15
1994/1995	Erken et al. 1996	DE	Stove continuous burning	~1982	lignite briquette 3	12
1994/1995	Erken et al. 1996	DE	Continuous heating device	~1985	lignite briquette 3	27
1994/1995	Erken et al. 1996	DE	Continuous heating device	~1985	lignite briquette 3	12
1994/1995	Erken et al. 1996	DE	boiler 2	~1987/90	lignite briquette 3	17
1994/1995	Erken et al. 1996	DE	boiler 2	~1987/90	lignite briquette 3	30
1994/1995	Erken et al. 1996	DE	Stove continuous burning	~1982	Anthracite 1	24
1994/1995	Erken et al. 1996	DE	Stove continuous burning	~1982	Anthracite 1	31
1994/1995	Erken et al. 1996	DE	Stove continuous burning	~1982	Anthracite 1	21
1994/1995	Erken et al. 1996	DE	Stove continuous burning	~1982	Anthracite 1	20
1994/1995	Erken et al. 1996	DE	Continuous heating device	~1985	Anthracite 1	10
1994/1995	Erken et al. 1996	DE	Continuous heating device	~1985	Anthracite 1	13
1994/1995	Erken et al. 1996	DE	Continuous heating device	~1985	Anthracite 1	6
1994/1995	Erken et al. 1996	DE	Continuous heating device	~1985	Anthracite 1	10
1994/1995	Erken et al. 1996	DE	boiler 1	~1986/87	Anthracite 3	14
1994/1995	Erken et al. 1996	DE	boiler 1	~1986/87	Anthracite 3	13
1994/1995	Erken et al. 1996	DE	fireplace	~1987	hard coal briquettes	81
1994/1995	Erken et al. 1996	DE	fireplace	~1987	hard coal briquettes	68
1994/1995	Erken et al. 1996	DE	fireplace	~1987	hard coal briquettes	47
1994/1995	Erken et al. 1996	DE	fireplace	~1987	hard coal briquettes	31
1994/1995	Erken et al. 1996	DE	Stove continuous burning	~1982	hard coal briquettes	21
1994/1995	Erken et al. 1996	DE	Stove continuous burning	~1982	hard coal briquettes	19
1994/1995	Erken et al. 1996	DE	Stove continuous burning	~1982	hard coal briquettes	11
1994/1995	Erken et al. 1996	DE	Stove continuous burning	~1982	hard coal briquettes	23
1994/1995	Erken et al. 1996	DE	Continuous heating device	~1985	hard coal briquettes	18
1994/1995	Erken et al. 1996	DE	Continuous heating device	~1985	hard coal briquettes	17
1994/1995	Erken et al. 1996	DE	Continuous heating device	~1985	hard coal briquettes	7

Year	Short reference	MS	domestic appliance (type)	Manu-facture	Fuel	EF air µg TEQ/TJ
1994/1995	Erken et al. 1996	DE	Continuous heating device	~1985	hard coal briquettes	10
1994/1995	Erken et al. 1996	DE	Stove continuous burning	~1982	hard coal coke	50
1994/1995	Erken et al. 1996	DE	Stove continuous burning	~1982	hard coal coke	69
1994/1995	Erken et al. 1996	DE	Stove continuous burning	~1982	hard coal coke	23
1994/1995	Erken et al. 1996	DE	Stove continuous burning	~1982	hard coal coke	36
1994/1995	Erken et al. 1996	DE	Continuous heating device	~1985	hard coal coke	18
1994/1995	Erken et al. 1996	DE	Continuous heating device	~1985	hard coal coke	49
1994/1995	Erken et al. 1996	DE	Continuous heating device	~1985	hard coal coke	28
1994/1995	Erken et al. 1996	DE	Continuous heating device	~1985	hard coal coke	20
?	Hobson et al. 2003	UK	Domestic open fire <5 kW	?	Yorkshire housecoal	120.8[1)]
?	Davies et al. 1992	UK	Domestic open fire	?	Smokeless coal, bituminous coal anthracite	87.5-238[1)]
?	Geueke et al. 2000	DE	Stoves	?	Lignite Germany	70; 58[1)]
				?	Lignite Czech Rep.	20; 21[1)]
				?	Anthracite	95, 175[1)]
				?	Hard coal Poland	633, 1,430[1)]
?	Grochowalski 2002	PL	Stoves	?	Coal	6,000; 11,000[1)]
	Williams et al. 2001	PL	Household, advanced manual fuelled boler, 30 kW	?	Coal J	285
					Coal W	804; 540.1
?	Quass et al. 2000	DE	Stove A, Simple design	?	Lignite Germany	117.6[1)]
				?	Lignite Czech Rep.	39.4[1)]
				?	Anthracite	145[1)]
				?	Hardcoal briq. Ger.	310.4[1)]

Year	Short reference	MS	domestic appliance (type)	Manu-facture	Fuel	EF air µg TEQ/TJ
				?	Coke Germany	26.6[1)]
				?	Hardcoal Poland	1,127[1)]
			Stove B, Modern design	?	Lignite Germany	192.9
				?	Lignite Czech Rep.	69.4[1)]
				?	Anthracite	364.3[1)]
				?	Hardcoal briq. Ger.	186.7[1)]
				?	Coke Germany	90.3[1)]
				?	Hardcoal Poland	3,687[1)]
?	Kakareka et al. 2003	BY	Small and medium boiler, non controlled combustion	?	Coal	104[2)]
			Small and medium boiler, partly controlled combustion	?	Coal	42[2)]
?	Pfeiffer et al. 2000b	DE	Fireplaces, stoves and boilers (households)	?	High rank coal and products	27.4
				?	High rank coals	20.3
				?	Briquettes	37.3
				?	Coke from high rank coals	39.4
				?	Brown coal briquettes	23.3

Table 1-1: Range of EF for coal combustion in different domestic appliances in the EU [µg TEQ/TJ]

1) Original factors in g/kg of fuels, for recalculation H_u of 24 GJ/t (d.b.) for hard coal was, of 17 GJ/t (d.b.) for lignite and brown coal, of 30 GJ/t (d.b.) for anthracite, of 30 GJ/t (d.b.) for coke were assumed
2) Original factors in µg TEQ/Mg of fuel (default emission factors), recalculated

Year	Short Reference	Type of appliances	Type of fuel	Specification (mean, median, min, max)	EF air µg TEQ/t
2006	Enviros 2006	Domestic heating	Smokeless coal/anthracite (SSF)	min	2
				max	50
			Bituminous coal	min	1.5
				max	100

Table 1-2: Range of dioxin emission factors from domestic coal combustion in the UK

1.1.1.2 Emission units in µg TEQ/t (coal)

year	Short reference	MS	domestic appliance (type)	Manu-facture	Fuel	EF Air mean µg TEQ/t
~2000	Quass et al. 2000	DE	Stove A through-burning, only primary air supply	1955-62	Lignite DE	2.00
~2000	Quass et al. 2000	DE			Lignite CZ	0.67
~2000	Quass et al. 2000	DE			Anthracite DE	4.35
~2000	Quass et al. 2000	DE			Hard coal briq. DE	7.46
~2000	Quass et al. 2000	DE			Coke DE	0.85
~2000	Quass et al. 2000	DE			Hard coal PL	27.05
~2000	Quass et al. 2000	DE	Stove B under-burning, thermostat, + secondary air supply	1983	Lignite DE	3.28
~2000	Quass et al. 2000	DE			Lignite CZ	1.18
~2000	Quass et al. 2000	DE			Anthracite DE	10.93
~2000	Quass et al. 2000	DE			Hard coal briq. DE	4.48
~2000	Quass et al. 2000	DE			Coke DE	2.89
~2000	Quass et al. 2000	DE			Hard coal PL	88.49
1999	Thanner & Moche 2002	AT	stovetyp 1 low priced multi-fuel stove	~1999	coal Poland	251.67 265.02 338.75 327.67
1999	Thanner & Moche 2002	AT			coke Czech Republic	42.66 56.41
1999	Thanner & Moche 2002	AT	stovetyp 2 cast iron stove for coke	~1979	coal Poland	117.21 101.84 241.32
1999	Thanner & Moche 2002	AT			coke CZ Czech Republic	44.45 24.38
1999	Thanner & Moche 2002	AT	stovetyp 3 danish style cast iron wood stove	~1990	coal Poland	90.49
~2000	Kubica 2003	PL	Boiler		"Julian" coal [nut]	8.40
~2000	Kubica 2003	PL	Boiler		"Wujek" coal" [nut]	26.30
~2000	Kubica 2003	PL	Boiler		"Wujek" coal" [pae]	7.50
~2000	Kubica 2003	PL	Boiler		Briquettes of "Wujek" coal and Sawdust	9.90
~2000	Kubica 2003	PL	Boiler			7.60

year	Short reference	MS	domestic appliance (type)	Manu-facture	Fuel	EF Air mean µg TEQ/t
~2000	Kubica 2003	PL	Boiler		"Wujek" coal and Sawdust	22.30
~2000	Kubica 2003	PL	Boiler		"Wujek" coal and Rape straw	23.40
~2000	Kubica 2003	PL	Retort boiler 25 kW		"Julian" coal [pea]	1.70
2000	Lee et al. 2005	UK	Open fire		House coal	3
2000	Lohman et al. 2006	UK	modelling		coal	3
2002	Schleicher et al. 2002	DK	Garden grill		Briquettes type A	11
2002	Schleicher et al. 2002	DK	Garden grill		Briquettes type B	6

Table 1-3: Range of EF for coal combustion in different domestic appliances in the EU

1.1.2 Dioxin concentrations in exhaust gas from combustion of different types of coal briquettes

year	Short reference	MS	domestic appliance (type)	Year of manu-facture	fuel	Conc. Air mean ng TEQ/Nm³
~1994	Thuß et al. 1995 & 1997	DE	tiled stove with air circulation	?	"salt" coal briquettes (2,000 ppm w/w Cl)	0.087
~1994	Thuß et al. 1995 & 1997	DE	tiled stove with air circulation	?	"salt" coal briquettes (2,000 ppm w/w Cl)	0.134
~1994	Thuß et al. 1995 & 1997	DE	tiled stove with air circulation	?	"salt" coal briquettes (2,000 ppm w/w Cl)	0.106
~1994	Thuß et al. 1995 & 1997	DE	tiled stove with air circulation	?	"normal" coal briquettes (300 ppm w/w Cl)	0.013
~1994	Thuß et al. 1995 & 1997	DE	tiled stove with air circulation	?	"normal" coal briquettes (300 ppm w/w Cl)	0.021
~1994	Thuß et al. 1995 & 1997	DE	tiled stove with air circulation	?	"normal" coal briquettes (300 ppm w/w Cl)	0.01

Table 1-4: Dioxin concentrations in exhaust gas from combustion of different types of coal briquettes

1.1.3 Dioxin emission factors for domestic combustion of wood

1.1.3.1 Emission units in µg TEQ/TJ (wood)

Year	Short reference	MS	domestic appliance (type)	Manufac-ture	Fuel	EF air µg TEQ/TJ
1999	Thanner & Moche 2002	AT	stovetyp 1 low priced multi-fuel stove	~1999	beech wood	70 20 690
			stovetyp 2 cast iron stove for coke	~1979	beech wood	70 260 630
			stovetyp 3 danish style cast iron wood stove	~1990	beech wood	550 270
1999/2000	Boos et al. 2005 resp. Hübner et al. 2005	AT	Single Stove (continuous burning)	~1985	wood	2,300
				~1985	wood briquettes (oak)	27
				1990	wood (logs)	150
				~1985	beach wood (logs)	23
				~1960	beach wood, lignite briquettes	29
				1990	wood, lignite briquettes	27
			Single stove (kitchen)	~1970	Spruce wood (small logs)	1,000
				1980	wood (small logs)	150
				1993	wood logs (beech oak)	73
				~1970	spruce wood, lignite briquettes	130
				~1970	wood, lignite briquettes	48
				1985	wood, coal	2,400
			Single stove (tiled stove)	1956	beech Wood (logs)	4,500
				1990	beech Wood (logs)	45
				1998	beech Wood (logs)	120
1999/2000	Boos et al. 2005 resp. Hübner et al. 2005	AT	Residential heating boiler for solid fuels	1983	Wood	30
				1988	Wood	72
				1986	Wood	82
				1983	Wood	86

Year	Short reference	MS	domestic appliance (type)	Manufac-ture	Fuel	EF air µg TEQ/TJ
				1979	Wood	2,600
			Residential heating boiler, fan-assistent	1990	Wood	18
				1989	Wood	21
			Automatic charged wood heating boiler	1999	pelleted wood	2
				1992	wood chips	3
				1982	wood chips	6
				1991	wood chips	2,000
1994/1995	Erken et al. 1996	DE	fireplace	~1987	birch wood	38
				~1987	birch wood	11
				~1987	birch wood	4
				~1987	birch wood	3
			stove continuously operating	~1982	birch wood	34
				~1982	birch wood	23
				~1982	birch wood	13
				~1982	birch wood	14
			continuous heating device	~1985	birch wood	10
				~1985	birch wood	28
				~1985	birch wood	10
				~1985	birch wood	9
			boiler 2	~1987/90	birch wood	16
				~1987/90	birch wood	18
				~1987/90	birch wood	11
				~1987/90	birch wood	12
	Pfeiffer et al. 2000b	DE	Fireplaces, stoves and boilers (households)	?	Natural wood	29.5

Table 1-5: Range of EF for wood combustion in different domestic appliances in the EU [µg TEQ/TJ]

1.1.3.2 Emission units in µg TEQ/t (wood)

year	Short reference	MS	domestic appliance (type)	Manu-facture	Fuel	EF Air mean µg TEQ/t
1999	Thanner & Moche 2002	AT	stovetyp 1 low priced multi-fuel stove	~1999	beech wood	1.03 (1.56) 0.24 10.68
1999	Thanner & Moche 2002	AT	stovetyp 2 cast iron stove for coke	~1979	beech wood	1.13 4.07 9.77
1999	Thanner & Moche 2002	AT	stovetyp 3 danish style cast iron wood stove	~1990	beech wood	8.49 4.17
~2000	Kubica 2003	PL	Boiler 35 kW	?	Lump wood	33.20
~2000	Kubica 2003	PL	Boiler 35 kW	?	Wooden briquettes (sawdust(	2.00
~2000	Kubica 2003	PL	65 kW low capacity boiler	?	Rape straw	13.40
~2000	Kubica 2003	PL	65 kW low capacity boiler	?	Wheat-rye straw	12.40
~1996	Pfeiffer et al. 2000a	DE	Masonry heater open (prim. Air) /open (sec. Air)	1989	wood	0.63
~1996	Pfeiffer et al. 2000a	DE	Tiled-stove heating insert open (prim. Air) /open (sec. Air)	1990	wood	0.79
~1996	Pfeiffer et al. 2000a	DE	Tiled-stove heating insert medium (prim. Air) /open (sec. Air)	1990	wood	0.44
~1996	Pfeiffer et al. 2000a	DE	Tiled-stove heating insert closed (prim. Air) /open (sec. Air)	1990	wood	0.14
~2005	Hedman et al. 2006	SE	boiler for pellet fuel or oil	?	wood pellets	11.0
~2005	Hedman et al. 2006	SE	boiler for pellet fuel or oil		wood pellets	2.0
~2005	Hedman et al. 2006	SE	boiler with two separate fireplaces one for oil, one for solid fuels (wood or coke)		wood pellets	6.0
~2005	Hedman et al. 2006	SE	boiler with two separate fireplaces one for oil, one for solid fuels (wood or coke)		birchwood	12.00
~2005	Hedman et al. 2006	SE	boiler with two separate fireplaces one for oil, one for solid fuels (wood or coke)		coniferous wood	6.3
~2005	Hedman et al. 2006	SE	boiler with two separate fireplaces one for oil, one for solid fuels (wood or coke)		birchwood + paper	5.0
~2005	Hedman et al. 2006	SE	boiler with two separate fireplaces one for oil, one for solid fuels (wood or coke)		birchwood + paper + plastic	290

year	Short reference	MS	domestic appliance (type)	Manu-facture	Fuel	EF Air mean µg TEQ/t
~2005	Hedman et al. 2006	SE	modern wood boiler	?	birchwood	2.8
~2005	Hedman et al. 2006	SE	modern wood boiler		birchwood	1.2
~2005	Hedman et al. 2006	SE	modern wood boiler		coniferous wood	1.2
~2005	Hedman et al. 2006	SE	modern wood stove	?	birchwood	3.5
~2005	Hedman et al. 2006	SE	modern wood stove		birchwood	5.9
1991/ 1993	Vikelsøe et al. 1994	DK	4 types of stoves		wood	1.9
2000	Lee et al. 2005	UK	open fire		wood	0.6
2000	Lohman et al. 2005	UK	modelling		wood	0.2
~2004	Gönczi et al. 2005	SE	steel barrel		straw	4.4
2002	Schleicher et al. 2002	DK	Wood stove		Air dried birch firewood	5.1
2002	Schleicher et al. 2002	DK	Wood stove		Kiln dried beech wood, without bark	1.9
2002	Schleicher et al. 2002	DK	Wood stove		Air dried birch firewood	0.61
2002	Schleicher et al. 2002	DK	Wood stove		Kiln dried beech wood, without bark	0.64
2002	Schleicher et al. 2002	DK	19 kW Stoker boiler		Wood pellets	0.53
2002	Schleicher et al. 2002	DK	19 kW Stoker boiler		Wood pellets	0.21
2002	Schleicher et al. 2000	DK	Farm size boiler		Straw	5.3
2002	Schleicher et al. 2002	DK	Farm size boiler		Straw	9.2

Table 1-6: Range of EF for wood combustion in different domestic appliances in the EU

1.1.3.3 Ranges and means of concentrations and EFs for dioxins (wood)

Year	Short reference	Type of appliances	Type of fuel		air (ng TEQ/m³)	EF air µg TEQ/t
~1995	Collet 2000	3 MW industrial boiler + bag filter	bark & sawdust		0.019	0.32
~1995	Collet 2000	2.4 MW industrial boiler + bag filter	wood chips & sawdust		0.011	0.05
2001/2002	Gullet et.al. 2003	woodstoves, fireplaces	Oak, pine	min	0.0004	0.25
				max	0.0025	1.4
			artificial log	mean	0.0006	2.4
2005	Glasius et al. 2005	Five wood stoves and one wood boiler	Wood	min (12 samples)		0.3
2005	Glasius et al. 2005	Five wood stoves and one wood boiler	Wood	max		17.7
2007	Glasius et al. 2007	12 wood stoves and one wood boiler	Wood	min (26 samples from 13 houses)		0.027
				max		140
				mean		19
				median		3
1997	Collet 2000	2 MW, with bag filter	wood, "non-doped" (0.6 ppm PCP)		1.28	11.5
		2 MW, with bag filter	wood, "doped" (20-36 ppm PCP)		2.33	21.0
		400 kW pilot installation, optimum conditions	wood pallets treated with PCP (0.1% PCP)	min	0.063	0.76
				max	0.186	2.23
~1994	Schatowitz et al. 1994	various furnaces – 6 - 850 kW	beech wood sticks, natural wood chips, uncoated chipboard chips	min	0.019	
				max	0.076	
			waste wood chips	min	2.7	
				max	14.42	
			charcoal	mean	0.028	
			household waste	mean	114	
2006	Enviros 2006	Wood stove open fireplace	Untreated wood	min		0.043
				max		11
2006	Enviros 2006	Wood stove open fireplace	Contaminated wood	min		11
				max		400
2003	Allemand 2003	open fireplaces	wood	mean***		1.8

Year	Short reference	Type of appliances	Type of fuel		air (ng TEQ/m³)	EF air µg TEQ/t
2003	Allemand 2003	stoves	wood	mean***		1.8
2003	Allemand 2003	closed fireplaces	wood	mean***		1.8
2003	Allemand 2003	boilers (old)	wood	mean***		1.8
2003	Allemand 2003	boilers (class 1)	wood	mean***		1.8
2003	Allemand 2003	boilers (class 3)	wood	mean***		1.8
2003	Allemand 2003	<9MW industrial or collective heating installations	wood	mean***		0.72
2000	Baggio et al. 2001	30 kW gasifying boiler (reverse flame)	Wood log (beech)	min		0.004
				max		0.01

Table 1-7: Range of dioxin concentrations in exhaust gas and of EF for wood combustion in different domestic appliances

* This value, as well as the 5 following values, has been derived from the figures that are given in the study: EF: 100 ng ITEQ/GJ; Average heat of combustion of the wood used at CITEPA: 18.2 MJ/kg

** EF: 40 ng ITEQ/GJ; Average heat of combustion of the wood used at CITEPA: 18.2 MJ/kg

*** EF used by INERIS/CITEPA

1.1.3.4 Dioxin concentrations in exhaust gas from combustion of different types of wood and other biomass

Year	Short reference	MS	domestic appliance (type)	Year of manu-facture	fuel	Conc. Air mean ng TEQ/Nm³
1992/1993	Kolenda et al. 1994	DE	Hand fed chute incinerator	?	wood blocks, coated and uncoated plywood, wood residues	1.05
1992/1993	Kolenda et al. 1994	DE	Hand fed chute incinerator	?	wood blocks, coated and uncoated plywood, wood residues	0.45
~1998	Launhardt & Thoma 2000	DE	multi-fuel furnace with an automatic charging and electronic control unit	~1997/1998	spruce wood - chipped	0.052
~1998	Launhardt & Thoma 2000	DE	multi-fuel furnace with an automatic charging and electronic control unit	~1997/1998	wheat straw - pelleted, chopped	0.656
~1998	Launhardt & Thoma 2000	DE	multi-fuel furnace with an automatic charging and electronic control unit	~1997/1998	hay (set aside land) - pelleted, chopped	0.891
~1998	Launhardt & Thoma 2000	DE	multi-fuel furnace with an automatic charging and electronic control unit	~1997/1998	Triticale (whole crop) - pelleted, chopped	0.052

Year	Short reference	MS	domestic appliance (type)	Year of manu-facture	fuel	Conc. Air mean ng TEQ/Nm³
~1997	Launhardt et al. 1998	DE	Tiled stove with "modern" combustion technology (design for wood combustion) upward burning	early nineties	birch	0.0043
~1997	Launhardt et al. 1998	DE	Tiled stove with "modern" combustion technology (design for wood combustion) upward burning	early nineties	conifer	0.006
~1997	Launhardt et al. 1998	DE	Tiled stove with "modern" combustion technology (design for wood combustion) upward burning	early nineties	spruce (humid)	0.011
~1997	Launhardt et al. 1998	DE	Tiled stove with "modern" combustion technology (design for wood combustion) upward burning	early nineties	conifers briquettes type A	0.015
~1997	Launhardt et al. 1998	DE	Tiled stove with "modern" combustion technology (design for wood combustion) upward burning	early nineties	conifers briquettes type B	0.022
~1997	Launhardt et al. 1998	DE	Tiled stove with "old" combustion technology (design for wood and coal combustion) upward burning	70s to 80s	conifer	0.015
~1997	Launhardt et al. 1998	DE	Tiled stove with "old" combustion technology (design for wood and coal combustion) upward burning	70s to 80s	conifer	0.007
~1997	Launhardt et al. 1998	DE	wood boiler (with flue blower and combustion control) downwardburning	Early nineties	birch	0.003
~1997	Launhardt et al. 1998	DE	wood boiler (with flue blower and combustion control) downwardburning	Early nineties	birch	0.003
~1997	Launhardt et al. 1998	DE	wood boiler (with flue blower and combustion control) downwardburning	Early nineties	birch	0.007
~1997	Launhardt et al. 1998	DE	wood boiler (with flue blower and combustion control) downwardburning	Early nineties	conifer	0.004

Year	Short reference	MS	domestic appliance (type)	Year of manu-facture	fuel	Conc. Air mean ng TEQ/Nm³
~1997	Launhardt et al. 1998	DE	wood boiler (with flue blower and combustion control) downwardburning	Early nineties	spruce	0.015
~1997	Launhardt et al. 1998	DE	wood boiler (with flue blower and combustion control) downwardburning	Early nineties	spruce chips	0.004
~1997	Launhardt et al. 1998	DE	wood-burning fireplace upwardburning	Early nineties	conifer	0.011
1991/1993	Vikelsøe et al. 1994	DK	4 types of stoves		wood	0.18
2000	Raventos et al. 2000	FR	NON-domestic boiler, equipped with multi-cyclone flue gas treatment	1998	Wood fibre board, hard	≤ 0.016
				1998	Wood particle board, melaminated	0.084
2000	Raventos et al. 2000	FR	NON-domestic boiler, equipped with multi-cyclone flue gas treatment	1998	Wood particle board (non-chloride hardener)	≤ 0.014
					Plywood (with non-chloride phenolic resine)	0.016
2000	Raventos et al. 2000	FR	NON-domestic boiler, equipped with multi-cyclone flue gas treatment	1998	Wood particle board (chloride based hardener)	0.016
1999	Deroubaix 1999	FR	NON-domestic boiler, collective heating installation, equipped with multi-cyclone flue gas treatment	1998	bark	0.07
					wooden pallets	0.13
1999	Deroubaix 1999	FR	NON-domestic boiler, collective heating installation, equipped with multi-cyclone flue gas treatment	1998	wooden pallets	0.02
					wooden pallets	0.05
2003	Allemand 2003	FR	industrial or collective heating boiler	?	natural wood and wood with a few additives	0.05
2003	Allemand 2003	FR	industrial or collective heating boiler		particular wood (containing PCP, with mixed painted wood…)	1.80

Table 1-8: Dioxin concentrations in exhaust gas from combustion of different types of wood and other biomass

1.1.4 Dioxin emission factors for domestic combustion of oil/gas

1.1.4.1 Emission unit in µg TEQ/GJ (oil/gas)

domestic appliance (type)	Manufacture	Fuel	EF Air mean µg TEQ/TJ
Fireplaces, stoves and boilers (households)	?	oil	2.5
Fireplaces, stoves and boilers (households)	?	gas	1.9

Table 1-9: Range of EF for oil and gas combustion in different domestic appliances (Source Pfeiffer et al. 2000b)

1.1.4.2 Emission unit in µg TEQ/t (oil/gas)

domestic appliance (type)	Manufacture	Fuel	EF Air mean µg TEQ/t
Old oil-fired heating unit with vaporizing burner (as tiled-stove heating insert)	1970	oil	0.13
Old central heating boiler for domestic fuel oil with atomizing oil burner	1970/1981	oil	0.12
Old central heating (variable) boiler for solid, liquid or gaseous fuels with atomizing oilburner (change of the fuel without modifications of the boiler)	1968/1983	oil	0.12
Old central heating (change-over) boiler for solid, liquid or gaseous fuels with atomizing oil burner (change of the fuel with modifications of the boiler)	1971/1983	oil	0.02
New oil-fired heating unit with vaporizing burner (as tiled-stove heating insert)	1993	oil	0.07
New central heating (cast iron) boiler with atomizing oil burner	1994/1994	oil	0.04
New central heating (steel) boiler with atomizing oil burner (blue flame)	1994	oil	0.04
Old independent gas-fired convection heater with natural draught burner	1970	gas	0.05
Old instantaneous water heater with natural draught burner	1970	gas	0.14
Old special gas boiler with atmospheric burner and permanent pilot	1972	gas	0.04
New independent gas-fired convection heater with natural draught burner and avoidance of NOx formation	1993	gas	0.02
New instantaneous water heater with natural draught burner	1993	gas	0.06
New special gas boiler with atmospheric burner and avoidance of NOx formation	1995	gas	0.81
New special gas boiler with atmospheric infra-red radiation burner	1994	gas	0.06

New central heating boiler (cast iron) with fan-assisted gas burner	1994/1994	gas	0.05
New central heating boiler (cast iron) with fan-assisted gas burner (ceramic head)	1994/1994	gas	0.07

Table 1-10: Range of EF for oil and gas combustion in different domestic appliances (Source Pfeiffer et al. 2000a

1.1.5 Dioxin emission factors for open burning of waste

year	reference	MS	burning (type)	fuel	EF Air			
					mean µg TEQ/t	min µg TEQ/t	max µg TEQ/t	
2003	Collet 2004	FR	simulated burning in open air	mixture of forest litter (South-West FR, inland), 45.1% LV, 54.0% HV*, natural moisture	10.4			One sample
2003	Collet 2004	FR	simulated burning in open air	mixture of forest litter (South-West FR, close to the cost), 46.3% LV, 53.7% HV, natural moisture	1.02			One sample
2003	Collet 2004	FR	simulated burning in open air	mixture of forest litter (South-East FR, close to the cost), 33% LV, 67% HV*, natural moisture	25.9			One sample
2003	Collet 2004	FR	simulated burning in open air	mixture of forest litter (South-East FR, inland), 38% LV, 62% HV*, natural moisture	12.1			One sample
2003	Collet 2004	FR	simulated burning in open air	mixture of forest litter (South-East FR, inland), 38% LV, 62% HV*, sprinkled with sea water & then dried	3.32			One sample
2003	Collet 2004	FR	simulated burning in open air	70.5% banal industrial waste + 29.5% household waste	242			One sample
2003	Collet 2004	FR	simulated burning in open air	33.5% banal industrial waste + 66.5% household waste	233			One sample
~2004	Gönczi et al.	SE	steel barrel	garden waste + other wastes		2.2	9600	max value with PVC
~2004	Gönczi et al.	SE	steel barrel	Paper waste + other wastes		7.3	890	max value with computer scrap
~2004	Gönczi et al.	SE	steel barrel	straw	4.4	3.4	10	

year	reference	MS	burning (type)	fuel	EF Air			
					mean µg TEQ/t	min µg TEQ/t	max µg TEQ/t	
~2004	Gönczi et al.	SE	open fire	Garden waste + RDF	31	27	36	
~2004	Hedman et.al. 2005	SE	backyard burning	garden waste, paper, paper and plastic packaging, refuse-derived fuel, PVC, electronic scrap		2.2	13,000	
2006	Enviros 2006	UK	Bonfire	Bonfire, good conditions		0.5	20	
2006	Enviros 2006	UK	Bonfire	Bonfire, poor conditions'		20	30	
2006	Enviros 2006	UK	Domestic waste burning	waste - low PVC		5.3		
2006	Enviros 2006	UK					3200	
2006	Enviros 2006	UK	Domestic waste burning	waste - high PVC	4900			One sample
2005	Wasson et al. 2005	USA	open burn research facility	CCA treated wood	1.70			

* LV: low vegetation comprising litter, needles, fallen pine cones, moss, heather, ferns and broom (in South-West) and the litter, needles, fallen oak leaves and pine cones, moss, herbs, heather, rosemary and cistus (in South-East)
HV: high vegetation comprising collected bark and thin branches (diameter < 4 cm) of pine and oak with their leaves

Table 1-11: Range of EF from open burning of waste in EU Member States

1.1.6 Dioxin emission factors for open burning of candles

Year	Short reference	Type of appliances	Type of fuel	POP		EF Air µg TEQ/t)
~1994	Lau et al. 1997	open-burnt candles	paraffin, stearin beeswax candles	PCDD/F (I-TEQ)	min	0.004
					max	0.047

Table 1-12: Range of EF from open burning of candles in EU Member States

1.1.7 Dioxin emission factors for accidental burning of wood and PVC

Year	Short reference	Type of appliances	Type of fuel	Specification (mean, median, min, max)	EF air µg TEQ/t
	Carroll 2001	accidental house fire	wood 21,000 kg per new house (standard construction)	min	0.01
				max	173.00
			pvc 180 kg per new	min	3.00

Year	Short reference	Type of appliances	Type of fuel	Specification (mean, median, min, max)	EF air µg TEQ/t
			house (standard construction)	Max	6,554.00

Table 1-13: Range of EFs from accidental burning of wood and PVC in house fires in the USA

1.2 Releases into soot and ashes

1.2.1 Dioxin concentrations and emission factors to solid residues from combustion of coal

year	Short reference	country	domestic appliance (type)	Manu-facture	POP Concentration output		EF	
					Soot	Ashes	soot	ashes
					ng TEQ/kg	ng TEQ/kg	µg TEQ/t	µg TEQ/t
1999	Thanner & Moche 2002	AT	stovetyp 1 low priced multi-fuel stove	~1999	107.9 169.9 753.4 595.1	39.95 9.9 42.9 24.4	--- 5.80 2.66 1.90	2.38 0.73 3.160 1.800
1999	Thanner & Moche 2002	AT	stovetyp 2 cast iron stove for coke	~1979	369.1 612.5 917.7	1.89 12.63 7.66	1.53 5.89 6.33	0.10 1.98 0.54
1999	Thanner & Moche 2002	AT	stovetyp 3 danish style cast iron wood stove	~1990	673.1	7	3.48	0.57
1999	Thanner & Moche 2002	AT	stovetyp 1 low priced multi-fuel stove	~1999	291.3 285.1	3.49 0.87	17.96 4.68	0.36 0.07
1999	Thanner & Moche 2002	AT	stovetyp 2 cast iron stove for coke	~1979	743.2 655.7	0.68 1.12	4.64 3.86	0.07 0.17
~1994	Thuß et al. 1995 & 1997	DE	tiled stove with air circulation	?		17[3)]		17
~1994	Thuß et al. 1995 & 1997	DE	tiled stove with air circulation	?		4.8[4)]		
?	Oehme & Müller 1995	CH	„Fireplace“ wood stove	?		0,55[5)]		
2006	Enviros 2006	UK	Domestic heating	?				0.03-0.2[6)]
2006	Enviros 2006	UK	Domestic heating	?				0.03-0.4[7)]

Table 1-14: Range of PCDD/PCDF concentrations and EF in solid residues from burning of coal in EU Member States

1) Combustion of coal from Poland
2) Combustion of coke from Czech Republic
3) combustion of lignite from eastern part of Germany – salt content 2,000 ppm
4) combustion of lignite from eastern part of Germany – salt content 300 ppm (normal)
5) combustion of charcoal
6) combustion of smokeless coal/anthracite (SFF)
7) combustion of bituminous coal

1.2.2 *Dioxin concentrations and emission factors to solid residues from combustion of wood*

year	Short reference	country	domestic appliance (type)	Year of Manu-facture	POP Concentration output		EF	
					soot	ashes	soot	ashes
					ng TEQ/kg	ng TEQ/kg	µg TEQ/t	µg TEQ/t
1999	Thanner & Moche 2002	AT	stovetyp 1 low priced multi-fuel stove	~1999	n.a. n.a. 555.4	0.13 0.23 1.56	n.a. n.a. 2.25	0.001 0.002 0.030
1999	Thanner & Moche 2002.	AT	stovetyp 2 cast iron stove for coke	~1979	381.1 237.7 648.8	0.73 0.23 0.33	1.02 0.61 0.67	0.01 0.003 0.004
1999	Thanner & Moche 2002	AT	stovetyp 3 danish style cast iron wood stove	~1990	--- ---	--- ---	--- ---	--- ---
~1998	Launhardt & Thoma 2000	DE	multi-fuel furnace with an automatic charging and electronic control unit	~1997/ 1998	61	5 / 23[1)]		
~1992	Vikelsøe et al. 1994	DK	four types of stoves	?		1.9		
?	Oehme & Müller 1995	CH	wood fired boilers	?		1.12		
~2005	Hedman et.al. 2006	SE	boiler for pellet fuel or oil	?		83		n.a
~2005	Hedman et.al. 2006	SE	boiler for pellet fuel or oil			33		n.a
~2005	Hedman et.al. 2006	SE	boiler for pellet fuel or oil			71		n.a
~2005	Hedman et.al. 2006	SE	boiler for pellet fuel or oil			<8.2		0.061
~2005	Hedman et.al. 2006	SE	boiler for pellet fuel or oil			35		0.190
~2005	Hedman et.al. 2006	SE	boiler for pellet fuel or oil			<2.9[2)]		0.066
~2005	Hedman et.al. 2006	SE	boiler for pellet fuel or oil	?		680[3)]		12
~2005	Hedman et.al. 2006	SE	modern wood boiler	?		<0.9		2.3
~2005	Hedman et.al. 2006	SE				3.6		25
~2005	Hedman et.al. 2006	SE				1.8		3.8
~2005	Hedman et.al. 2006	SE				1.5		45
~2005	Hedman et.al. 2006	SE				1.9		n.a.
1999	Deroubaix 1999	FR	NON-domestic boiler, collective heating installation, equipped with multi-cyclone flue gas treatment	1998	10.88			
1999	Deroubaix 1999	FR		1998	68.98			
1999	Deroubaix 1999	FR		1998	69.59			
1999	Deroubaix	FR		1998	21.63			

year	Short reference	country	domestic appliance (type)	Year of Manu-facture	POP Concentration output		EF	
					soot	ashes	soot	ashes
					ng TEQ/kg	ng TEQ/kg	µg TEQ/t	µg TEQ/t
	1999							
2006	Enviros 2006	UK	Wood stove open fireplace					0.01 – 0.6 4)
2006	Enviros 2006	UK	Wood stove open fireplace					1 – 60 5)

Table 1-15: Range of PCDD/PCDF concentrations and EF in solid residues from burning of wood in EU Member States

1) fly ash from combustion of wood
2) combustion of wood + paper
3) combustion of wood + paper + plastic
4) combustion of untreated wood
5) combustion of contaminated wood

1.2.3 Dioxin concentrations and emission factors to solid residues from combustion of straw/hay

year	Short reference	country	domestic appliance (type)	Manu-facture	POP Concentration output		EF	
					Soot	Ashes	soot	Ashes
					ng TEQ/kg	ng TEQ/kg	µg TEQ/t	µg TEQ/t
~1998	Launhardt &, Thoma 2000	DE	multi-fuel furnace with an automatic charging and electronic control unit	~1997/1998	1,691	24 / 995 1)		
~1998	Launhardt &, Thoma 2000	DE	multi-fuel furnace with an automatic charging and electronic control unit	~1997/1998	1,711	12 / 3,976 2)		
~1998	Launhardt &, Thoma 2000	DE	multi-fuel furnace with an automatic charging and electronic control unit	~1997/1998	247	8 / 401 3)		

Table 1-16: Range of PCDD/PCDF concentrations and EF in solid residues from burning of straw/hay in EU Member States

1) fly ash from combustion of straw
2) fly ash from combustion of hay
3) fly ash from combustion from triticale

1.2.4 *Dioxin concentrations and emission factors to solid residues from open burning of waste*

year	Short reference	country	domestic appliance (type)	Manu-facture	POP Concentration output		EF	
					Soot	Ashes	soot	ashes
					ng TEQ/kg	ng TEQ/kg	µg TEQ/t	µg TEQ/t
2004	Hedman et al. 2005	SE	backyard burning - barrel					0.01[1)]
2004	Hedman et al. 2005	SE	backyard burning – barrel					0.2[2)]
2004	Hedman et al. 2005	SE	backyard burning - barrel					0.3[3)]
2004	Hedman et al. 2005	SE	backyard burning - barrel					0.03[4)]
2004	Hedman et al. 2005	SE	backyard burning - barrel					510[5)]
2006	Enviros 2006	UK	Uncontrolled burning					100 – 2400[6)]
2006	Enviros 2006	UK	bonfire					10

Table 1-17: Range of PCDD/PCDF concentrations and EF in solid residues from open burning of waste in EU Member States

1) combustion of garden waste (1 sample)
2) combustion of garden waste + plastic (1 sample)
3) combustion of garden waste + RDF (refuse-derived fuel) (1 sample)
4) combustion of garden waste + PE (1 sample
5) combustion of garden waste + PVC (1 sample)
6) combustion of domestic waste (4 samples)

1.2.5 *Dioxin concentrations in solid residues from landfill fires and accidental fires*

Year	Short reference	Type of appliances	Type of fuel	POP		bottom ash ng TEQ/kg
~1995	Nakao et al. 2002	house accidental fires	ash from wood scrap	PCDD/F + dl-PCB (I-TEQ)	min	442
					max	541
		shoe-making factory (accidental fire)	ash from wood scrap	PCDD/F + dl-PCB (I-TEQ)		859
		electric appliances stores (accidental fire)	ash from wood scrap	PCDD/F & PCB (I-TEQ)		22,800
~1995	Alawi et al. 1996	landfill fire	waste	PCDD/F (TEQ-BGA)	min	8.2
					max	1,470
					max	0.047

Table 1-18: Dioxin emissions from landfill fires and accidental fires

1.3 Additional information on heating value and chemical composition of fuels

year	Short reference	MS	fuel	heating value [MJ/kg d.m.]	elemental analysis of the fuel		
					chlorine [mg/kg d.m.]	sulphur [mg/kg d.m.]	Cl/S-ratio in fuel
~1998	Launhardt & Thoma 2000	DE	spruce wood - chipped		43	104	0.41
~1998	Launhardt & Thoma 2000	DE	wheat straw - pelleted, chopped		1,778	1236	1.44
~1998	Launhardt &., Thoma 2000	DE	hay (set aside land) - pelleted, chopped		2,286	1520	1.50
~1998	Launhardt & Thoma 2000	DE	Triticale (whole crop) - pelleted, chopped		983	1176	0.84
~1994	Thuß et al. 1995 & 1997	DE	"salt" coal briquettes (2,000 ppm w/w Cl)	20.50	2,000	45,000	0.04
~1994	Thuß et al. 1995 & 1997	DE	"normal" coal briquettes (300 ppm w/w Cl)	21.40	300	27,000	0.01
~1997	Launhardt et al. 1998	DE	pieces of beach w=15-20% luftrocken	18.27	16	123	0.13
~1997	Launhardt et al. 1998	DE	pieces of spruce w=>30% humid	18.86	41	160	0.26
~1997	Launhardt et al. 1998	DE	conifers briquettes w<10% typ A	18.67	43	63	0.68
~1997	Launhardt et al. 1998	DE	conifers briquettes w<10% typ B	18.71	27	103	0.26
~1997	Launhardt et al. 1998	DE	pieces of conifers w=15-20% air dry	18.69	10	124	0.08
~1997	Launhardt et al. 1998	DE	pieces of spruce w=>30% humid	18.86	41	160	0.26
~1997	Launhardt et al. 1998	DE	Grobhackgut of spruce air dry	18.84	31	77	0.40
1994/1995	Erken et al. 1996	DE	Braunkohlenbriketts Rheinisches Revier 2	18.86	0.02%	0.22%	0.09
1994/1995	Erken et al. 1996	DE	Braunkohlenbriketts Mitteldeutsches Revier 2	20.57	0.02%	2.84%	0.01
1994/1995	Erken et al. 1996	DE	Braunkohlenbriketts Lausitzer Revier 1	19.52	0.02%	0.72%	0.03
1994/1995	Erken et al. 1996	DE	Anthrazit 1	34.10	0.09%	0.64%	0.14
1994/1995	Erken et al. 1996	DE	Anthrazit 3	33.35	0.10%	0.84%	0.12
1994/1995	Erken et al. 1996	DE	Steinkohlenbriketts	31.87	0.09%	1.24%	0.07

year	Short reference	MS	fuel	heating value [MJ/kg d.m.]	elemental analysis of the fuel		
					chlorine [mg/kg d.m.]	sulphur [mg/kg d.m.]	Cl/S-ratio in fuel
1994/1995	Erken et al. 1996	DE	Steinkohlenkoks	29.75	0.06%	0.88%	0.07
1994/1995	Erken et al. 1996	DE	Buchenscheitholz	15.78	0.01%	0.04%	0.25
2004	Hedman et al. 2005	SE	garden waste		0.14%		
2004	Hedman et al. 2005	SE	garden waste		0.12%		
2004	Hedman et al. 2005	SE	garden waste		0.09%		
2004	Hedman et al. 2005	SE	garden waste (4), paper pack (1.7), plastic pack (0.3)		0.14%		
2004	Hedman et al. 2005	SE	garden waste (4), plastic pack		0.28%		
2004	Hedman et al. 2005	SE	garden waste (4), RDF		0.36%		
2004	Hedman et al. 2005	SE	garden waste (4), RDF		0.31%		
2004	Hedman et al. 2005	SE	garden waste (4), waste motor oil (0.5 l)		0.13%		
2004	Hedman et al. 2005	SE	garden waste (4), silage film (polyethylene)		0.41%		
2004	Hedman et al. 2005	SE	garden waste (4), PVC		19%		
2004	Hedman et al. 2005	SE	papers and magazines (4), paper pack (1.7), plastic pack (0.3)		0.08%		
2004	Hedman et al. 2005	SE	RDF (4.5), paper pack		0.68%		
2004	Hedman et al. 2005	SE	RDF (4), paper pack		0.55%		
2004	Hedman et al. 2005	SE	RDF (3.4), paper pack (2.65), car tire (0.95), waste motor oil (0.5 l)		0.38%		
2004	Hedman et al. 2005	SE	RDF (4), paper pack (2), computer scrap		1.20%		
2004	Hedman et al. 2005	SE	straw		0.34%		
2004	Hedman et al. 2005	SE	straw		0.29%		
2004	Hedman et al. 2005	SE	straw (4), silage film (polyethylene)		0.53%		
2004	Hedman et al. 2005	SE	garden waste - open fire		0.11%		
2004	Hedman et al. 2005	SE	garden waste (4), RDF - open fire		0.35%		
2000	Lee et al. 2005	UK	wood	34-42	0.04%	0.04%	1.00
2000	Lee et al. 2005	UK	House coal	43-45	0.35%	1.33%	0.26

year	Short reference	MS	fuel	heating value [MJ/kg d.m.]	elemental analysis of the fuel		
					chlorine [mg/kg d.m.]	sulphur [mg/kg d.m.]	Cl/S-ratio in fuel
2000	Raventos et al. 2000	FR	Wood fibre board, hard	18.10	17	108	0.16
2000	Raventos et al. 2000	FR	Wood particle board, melaminated	16.20	65	116	0.56
2000	Raventos et al. 2000	FR	Wood particle board (non-chloride hardener)	16.40	53	150	0.35
2000	Raventos et al. 2000	FR	Plywood (with non-chloride phenolic resine)	18.10	27	43	0.63
2000	Raventos et al. 2000	FR	Wood particle board (chloride based hardener)	16.50	878	141	6.23
1999	Deroubaix 1999	FR	bark	15.08	86	189	0.46
1999	Deroubaix 1999	FR	wooden pallets	16.40	102	98	1.04
1999	Deroubaix 1999	FR	wooden pallets	15.81	102	98	1.04
1999	Deroubaix 1999	FR	wooden pallets	16.23	102	98	1.04

Table 1-19: Overview on information on heating value and chemical composition in studies on dioxin emissions from domestic sources

1.4 Measurement data for dl-PCB

1.4.1 Output concentrations and EFs for dl-PCB from coal combustion

year	Short reference	MS	heating systems	Year of manu-facture	fuel	comment	dl-PCB concentration output			EF dl-PCB			
							flue gas	soot	ashes	air		soot	ashes
							ng TEQ/Nm³	ng TEQ/kg	ng TEQ/kg	µg TEQ/t	µg TEQ/TJ	µg TEQ/t	µg TEQ/t
1999	Thanner & Moche 2002	AT	Stove type 1 6 kW, ~1996 low priced multi-fuel stove	~1996	coal Poland	TEQ (WHO) at 0% O_2	1.65 2.39	5.2 7.04 24.16 19.12	0.80 0.25 0.68 0.29	12.02 16.40	430 590	n.a. 0.24 0.09 0.06	0.05 0.02 0.05 0.02
1999	Thanner & Moche 2002	AT	Stove type 2 6 kW, ~1976 cast iron stove for coke	~1976	coal Poland	TEQ (WHO) at 0% O_2		10.82 n.a. 20.62	0.23 0.38 0.17			0.04 n.a. 0.14	0.01 0.06 0.01
1999	Thanner & Moche 2002	AT	Stove type 3 5 kW, ~1991 danish style cast iron wood stove	~1991	coal Poland	TEQ (WHO) at 0% O_2		38.02	0.28			0.22	0.02
2000	Lee et al. 2005	UK	open fire		house coal	TEQ (WHO 1998)				0.2			
1999	Thanner & Moche 2002	AT	Stove type 2 6 kW, ~1976 cast iron stove for coke	~1976	coke Czech Republic	TEQ (WHO) at 0% O_2	0.09 0.030	19.82 18.32	0.19 0.17	1.54 0.89	50 30	0.12 0.11	0.02 0.03

year	Short reference	MS	heating systems	Year of manu-facture	fuel	comment	dl-PCB concentration output			EF dl-PCB			
							flue gas	soot	ashes	air		soot	ashes
							ng TEQ/Nm³	ng TEQ/kg	ng TEQ/kg	µg TEQ/t	µg TEQ/TJ	µg TEQ/t	µg TEQ/t
1999	Thanner & Moche 2002	AT	Stove type 1 6 kW, ~1996 low priced multi-fuel stove	~1996	coke Czech Republic	TEQ (WHO) at 0% O_2	0.17 0.19	11.51 12.52	0.25 0.22	2.05 2.44	70 90	0.71 0.21	0.03 0.02

Table 1-20: Range of EF for coal/coke combustion in different appliances in the EU

1.4.2 Output concentrations and EFs for dl-PCB from wood and biomass combustion

year	Short reference	MS	heating systems	Year of manu-facture	fuel	comment	dl-PCB concentration output			emission factor			
							exhaust gas/air/flue gas	soot	ashes	air		soot	ashes
							ng TEQ/Nm³	ng TEQ/kg	ng TEQ/kg	µg TEQ/t	µg TEQ/TJ	µg TEQ/t	µg TEQ/t
1999	Thanner & Moche 2002	AT	Stove type 1 6 kW, ~1996 low priced multi-fuel stove	~1996	beech wood	TEQ (WHO) at 0% O_2	0.04 0.01 0.08	n.a. n.a. 15.45	0.23 0.23 0.16	0.14 (0.21) 0.03 0.41	10 2 30	n.a. n.a. 0.06	0.002 0.002 0.003
1999	Thanner & Moche 2002	AT	Stove type 2 6 kW, ~1976 cast iron stove for coke	~1976	beech wood	TEQ (WHO) at 0% O_2		15.67 9.41 16.04	0.23 0.34 0.19			0.04 0.02 0.02	0.003 0.005 0.002

year	Short reference	MS	heating systems	Year of manu-facture	fuel	comment	dl-PCB concentration output			emission factor			
							exhaust gas/air/flue gas	soot	ashes	air		soot	ashes
							ng TEQ/Nm³	ng TEQ/kg	ng TEQ/kg	µg TEQ/t	µg TEQ/TJ	µg TEQ/t	µg TEQ/t
~2005	Hedman et al. 2006	SE	boiler for pellet fuel or oil	?	wood pellets	TEQ (WHO) at 10% O2	0.12		4.9	0.4			n.a
~2005	Hedman et al. 2006	SE	boiler for pellet fuel or oil	?	wood pellets	TEQ (WHO) at 10% O2	0.022		1.6	0.1			n.a
~2005	Hedman et al. 2006	SE	boiler for pellet fuel or oil	?	wood pellets	TEQ (WHO) at 10% O2	0.07		2.2	0.4			n.a
~2005	Hedman et al. 2006	SE	boiler with two separate fireplaces one for oil, one for solid fuels (wood or coke)	~1975	birchwood	TEQ (WHO) at 10% O2	0.24						
~2005	Hedman et al. 2006	SE		~1975	birchwood	TEQ (WHO) at 10% O2	0.21		0.3	1.3			0.0021
~2005	Hedman et al. 2006	SE		~1975	coniferous wood	TEQ (WHO) at 10% O2	0.016						
~2005	Hedman et al. 2006	SE		~1975	coniferous wood	TEQ (WHO) at 10% O2	0.004		0.9	0.7			0.0049
~2005	Hedman et al. 2006	SE		~1975	birchwood + paper	TEQ (WHO) at 10% O2	0.013						
~2005	Hedman et al. 2006	SE		~1975	birchwood + paper	TEQ (WHO) at 10% O2	0.016		<0.3	0.7			0.0036
~2005	Hedman et al. 2006	SE		~1975	birchwood + paper + plastic	TEQ (WHO) at 10% O2	0.68						
~2005	Hedman et al. 2006	SE		~1975	birchwood + paper + plastic	TEQ (WHO) at 10% O2	1.1		49	23.0			0.87

year	Short reference	MS	heating systems	Year of manu-facture	fuel	comment	dl-PCB concentration output			emission factor			
							exhaust gas/air/flue gas	soot	ashes	air		soot	ashes
							ng TEQ/Nm³	ng TEQ/kg	ng TEQ/kg	µg TEQ/t	µg TEQ/TJ	µg TEQ/t	µg TEQ/t
~2005	Hedman et al. 2006	SE	modern wood boiler	?	birchwood	TEQ (WHO) at 10% O2	0.004		<0.1	0.2			0.31
~2005	Hedman et al. 2006	SE		?	birchwood	TEQ (WHO) at 10% O2	0.002						
~2005	Hedman et al. 2006	SE		?	birchwood	TEQ (WHO) at 10% O2	0.003		0.6	0.1			4.2
~2005	Hedman et al. 2006	SE		?	coniferous wood	TEQ (WHO) at 10% O2	0.002						
~2005	Hedman et al. 2006	SE		?	coniferous wood	TEQ (WHO) at 10% O2	0.004		0.1	0.1			0.23
~2005	Hedman et al. 2006	SE	modern wood stove	?	birchwood	TEQ (WHO) at 10% O2	0.005		0.1	0.4			3.6
~2005	Hedman et al. 2006	SE		?	birchwood	TEQ (WHO) at 10% O2	0.008		0.1	0.6			n.a.
2000	Lee et al. 2005	UK	open fire	?	wood	TEQ (WHO 1998)				0.02			
2000	Lohman et al. 2006	UK	Modelling	?	wood	TEQ (WHO-1998)-				0.02			
2001/2002	Gullett et al. 2003	USA	Free standing steel woodstove	?	Oak	Mean	0.0001			0.0014	1.1		

Table 1-21: Range for EF for wood combustion in different appliances in the EU

1.4.3 *Output concentrations and EFs for dl-PCB from open burning of waste*

year	Short reference	MS	heating systems	Fuel	no. of samples		comment	EF	
								air	ashes
								µg TEQ/t	µg TEQ/t
~2004	Hedman et al. 2005	SE	steel barrel	garden waste	2	min	TEQ (WHO 1998)-	2.0	0.02
						max		2.1	
				garden waste + other wastes	7	min	TEQ (WHO 1998)-	0.02	0.02
						max		250	2.6
				Paper waste + other wastes	6	min	TEQ (WHO 1998)	0.5	
						max		2.5	
				Straw	3	min	TEQ (WHO 1998)	0.3	
						max		2.3	
			open fire	Garden waste + RDF	2	min	TEQ (WHO 1998)	0.3	
						max		3.3	
2003	Collet 2004		simulated burning in open air	mixture of forest litter, cones, small branches etc. (from South-West FR, inland)	7	min		0.35	
						max		16.6	

Table 1-22: Range of EF for dl-PCB from open burning of waste in different appliances in the EU

2 Annex Emission estimation

2.1 Transposition Table relevant SNAP-IPCC categories

	CORINAIR / SNAP classification		IPCC classification
01	COMBUSTION IN ENERGY AND TRANSFORMATION INDUSTRIES		
01 01	**Public power**		
	Items 01.01.01 to 01.01.05	1A1a	Electricity and heat production
01 02	**District heating plants**		
	Items 01.02.01 to 01.02.05	1A1a	Electricity and heat production
01 03	**Petroleum refining plants**		
	Items 01.03.01 to 01.03.06	1A1b	Petroleum refining
01 04	**Solid fuel transformation plants**		
	Items 01.04.01 to 01.04.07	1A1c	Manufacture of Solid Fuels and Other Energy Industries
01 05	**Coal mining, oil / gas extraction, pipeline compressors**		
	Items 01.05.01 to 01.05.05	1A1c	Manufacture of Solid Fuels and Other Energy Industries
01 05 06	Pipeline compressors	1A3e	Transport-Other transportation
02	NON-INDUSTRIAL COMBUSTION PLANTS		
02 01	**Commercial and institutional plants**	1A5a	(*)
	Items 02.01.01 to 02.01.06	1A4a	Other Sectors-Commercial/Institutional
02 02	**Residential plants**		
	Items 02.02.01 to 02.02.05	1A4b	Other Sectors-Residential
02 03	**Plants in agriculture, forestry and aquaculture**		
	Items 02.03.01 to 02.03.05	1A4c	Other Sectors-Agriculture/Forestry/Fishing
03	COMBUSTION IN MANUFACTURING INDUSTRY		
03 01	**Combustion in boilers, gas turbines and stationary engines**	1A2	Industry
	Items 03.01.01 to 03.01.06		When relevant economic sector split data are available in CORINAIR, data can be allocated to sub-categories a to f.
03 02	**Process furnaces without contact**		
03 02 03	Blast furnace cowpers	1A2a	Industry-Iron and steel
03 02 04	Plaster furnaces	1A2f	Industry-Other
03 02 05	Other furnaces	1A2f	Industry-Other by default

(*) stationary military sources are not differenciated in SNAP 02 01. This item cannot be allocated twice; military emissions representing generally minor contributions within this category, figures are allocated to IPCC 1A4a only to avoid double counting.

	CORINAIR / SNAP classification		IPCC classification
07	**ROAD TRANSPORT**		
07 01	**Passenger cars**		
	Items 07.01.01 to 07.01.03	1A3b	Transport-Road (1-Cars)
07 02	**Light duty vehicles < 3.5 t**		
	Items 07.02.01 to 07.02.03	1A3b	Transport-Road (2-Light duty trucks)
07 03	**Heavy duty vehicles > 3.5 t and buses**		
	Items 07.03.01 to 07.03.03	1A3b	Transport-Road (3-Heavy duty trucks and buses)
07 04	**Mopeds and Motorcycles < 50 cm3**	1A3b	Transport-Road (4-Motorcycles)
07 05	**Motorcycles > 50 cm3**		
	Items 07.05.01 to 07.05.03	1A3b	Transport-Road (4-Motorcycles)
07 06	**Gasoline evaporation from vehicles**	1A3b	Transport-Road
07 07	**Automobile tyre and brake wear**	-	Not allocated
08	**OTHER MOBILE SOURCES AND MACHINERY**		
08 01	**Military**	1A5	Other
08 02	**Railways**		
	Items 08.02.01 to 08.02.03	1A3c	Transport-Railways
08 03	**Inland waterways**		
	Items 08.03.01 to 08.03.04	1A3d	Transport-Navigation
08 04	**Maritime activities**		
08 04 02	National sea traffic within EMEP area	1A3d	Transport-Navigation / 2-National navigation
08 04 03	National fishing	1A4c	Small combustion-Agriculture/Forestry/Fishing
08 04 04	International sea traffic (international bunkers)	1A3d	Transport-Navigation / 1-International marine(bunkers)
08 05	**Air traffic**		
08 05 01	Domestic airport traffic (LTO cycles - <1000 m)	1A3a	Transport-Civil aviation (2-Domestic)
08 05 02	International airport traffic (LTO cycles - <1000 m)	1A3a	Transport-Civil aviation (1-International)
08 05 03	National cruise traffic (>1000 m)	1A3a	Transport-Civil aviation (2-Domestic)
08 05 04	International cruise traffic (>1000 m)	1A3a	Transport-Civil aviation (1-International)
08 06	**Agriculture**	1A4c	Small combustion-Agriculture/Forestry/Fishing
08 07	**Forestry**	1A4c	Small combustion-Agriculture/Forestry/Fishing
08 08	**Industry**	1A2f	Industry-Other by default
08 09	**Household and gardening**	1A4b	Small combustion-Residential
08 10	**Other off-road**	1A3e	Transport-Other

CORINAIR / SNAP classification		IPCC classification	
09	**WASTE TREATMENT AND DISPOSAL**		
09 02	**Waste Incineration**		
	Items 09.02.01 and 09.02.02	6C	Waste-Incineration
	Items 09.02.03 and 09.02.06	1B2c	Fugitive emissions from fuels-Oil and natural gas/Flaring
	Items 09.02.04 to 09.02.05 and 09.02.07 to 09.02.08	6C	Waste-Incineration
09 04	**Solid Waste Disposal on Land**		
09 04 01	Managed Waste Disposal on Land	6A1	Waste-Solid waste disposal on land-Managed Disposal
09 04 02	Unmanaged Waste Disposal Sites	6A2	Waste-Solid waste disposal on land-Unmanaged Sites
09 04 03	Other	6A3	Waste-Solid waste disposal on land-Other
09 07	**Open burning of agricultural wastes (except 10.03)**	6C	Waste-Incineration
09 09	**Cremation**		
	Items 09.09.01 to 09.09.02	6C	Waste-Incineration
09 10	**Other waste treatment**		
09 10 01	Waste water treatment in industry	6B1	Waste-Wastewater treatment/Industrial
09 10 02	Waste water treatment in residential and commercial sect.	6B2	Waste-Wastewater treatment/Domestic and commercial
09 10 03	Sludge spreading	6D	Waste-Other
09 10 05	Compost production	6D	Waste-Other
09 10 06	Biogas production	6D	Waste-Other
09 10 07	Latrines	6B2	Waste-Wastewater treatment
09 10 08	Other production of fuel (refuse derived fuel,...)	6C	Waste-Incineration
10	**AGRICULTURE**		
10 01	**Cultures with fertilizers**		
	Items 10.01.01 to 10.01.02 and 10.01.04 to 10.01.06	4D	Agriculture-Agricultural soils
10 01 03	Rice field	4C	Agriculture-Rice cultivation
10 02	**Cultures without fertilizers**		
	Items 10.02.01 to 10.02.02 and 10.02.04 to 10.02.06	4D	Agriculture-Agricultural soils
10 02 03	Rice field	4C	Agriculture-Rice cultivation
10 03	**On-field burning of stubble, straw,...**		Agriculture-Field burning of agricultural wastes
10 03 01	Cereals	4F1	Agriculture-Field burning of agricultural wastes-Cereals
10 03 02	Pulse	4F2	Agriculture-Field burning of agricultural wastes-Pulse
10 03 03	Tuber and Root	4F3	Agriculture-Field burning of agric. wastes-Tuber and Root
10 03 04	Sugar Cane	4F4	Agriculture-Field burning of agric. wastes-Sugar Cane
10 03 05	Other	4F5	Agriculture-Field burning of agricultural wastes-Other
10 04	**Enteric fermentation**		
10 04 01	Dairy cows	4A1a	Agriculture-Enteric fermentation/Cattle/Dairy
10 04 02	Other cattle	4A1b	Agriculture-Enteric fermentation/Cattle/Non-dairy
10 04 03	Ovines	4A3	Agriculture-Enteric fermentation/Sheep
	Items 10.04.04 and 10.04.12	4A8	Agriculture-Enteric fermentation/Swine
10 04 05	Horses	4A6	Agriculture-Enteric fermentation/Horses
10 04 06	Mules and asses	4A7	Agriculture-Enteric fermentation/Mules and asses
10 04 07	Goats	4A4	Agriculture-Enteric fermentation/Goats
	Items 10.04.08 to 10.04.10	4A9	Agriculture-Enteric fermentation/Poultry
	Items 10.04.11 and 10.04.15	4A10	Agriculture-Enteric fermentation/Other
10 04 13	Camels	4A5	Agriculture-Enteric fermentation/Camels and llamas
10 04 14	Buffalos	4A2	Agriculture-Enteric fermentation/Buffalos

CORINAIR / SNAP classification		IPCC classification	
10 05	**Manure management regarding Organic compounds**		
10 05 01	Dairy cows	4B1a	Agriculture-Manure management/Cattle/Dairy
10 05 02	Other cattle	4B1b	Agriculture-Manure management/Cattle/Non-dairy
	Items 10.05.03 and 10.05.04	4B8	Agriculture-Manure management/Swine
10 05 05	Sheep	4B3	Agriculture-Manure management/Sheep
10 05 06	Horses	4B6	Agriculture-Manure management/Horses
	Items 10.05.07 to 10.05.09	4B9	Agriculture-Manure management/Poultry
	Items 10.05.10 and 10.05.15	4B13	Agriculture-Manure management/Other
10 05 11	Goats	4B4	Agriculture-Manure management/Goats
10 05 12	Mules and asses	4B7	Agriculture-Manure management/Mules and asses
10 05 13	Camels	4B5	Agriculture-Enteric fermentation/Camels and llamas
10 05 14	Buffalos	4B2	Agriculture-Enteric fermentation/Buffalos
10 06	**Use of pesticides and Limestone**		
	Items 10.06.01 to 10.06.04 (CO2 from liming only)	5D	CO2 Emissions and removals from soil
10 09	**Manure management regarding Nitrogen compounds**		
10 09 01	Anaerobic	4B10	Agriculture-Manure management-Anaerobic
10 09 02	Liquid Systems	4B11	Agriculture-Manure management-Liquid Systems
10 09 03	Solid Storage an dry lot	4B12	Agriculture-Manure management-Solid Storage
10 09 04	Other	4B13	Agriculture-Manure management-Other
11	OTHER SOURCES AND SINKS		
11 01	**Non-managed broadleaf forests**	-	Not allocated
11 02	**Non-managed coniferous forests**	-	Not allocated
11 03	**Forest and other vegetation fires**	-	Not allocated
11 04	**Natural grassland and other vegetation**	-	Not allocated
11 05	**Wetlands (marshes - swamps)**	4D	N2O from Leakage of N into Waters
11 06	**Waters**	4D	N2O from Leakage of N into Waters
11 07	**Animals**	-	Not allocated
11 08	**Volcanoes**	-	Not allocated
11 09	**Gas seeps**	-	Not allocated
11 10	**Lightning**	-	Not allocated

2.2 Information sources for estimation of dioxin emission on MS level

MS	Information sources	Specification
AT	Austria´s Informative Inventory Report (IIR) (2007): Submission under the UNECE Convention on Long-range Transboundary Air Pollution. http://www.umweltbundesamt.at/fileadmin/site/publikationen/REP0082.pdf	Information on pollution and methodology: page 197, 202 Information on EF: page 206, 207
BE-BR	Annual Energy Balance (2006): Bilan Énergétiue de la Région de Bruxelles-Capitale le Bilan Énergétique Global de L'année 2004. Document de synthèse – avril 2006. IBGE www.bruxellesenvironnement.be http://documentation.bruxellesenvironnement.be/documents/BAB060419Synthese_bilan_final_2004_1223.PDF	Source for activity data Balance of 2005 will be available soon
BE-WA	Bilan Energétique de Wallonie 2005 - Consommations du secteur logement 2005. Ministry of the Walloon Region (DBTRE) http://energie.wallonie.be/xml/doc-IDC-5138-.html	Source for activity data
BE-FL	http://www.milieurapport.be/Upload/main/miradata/MIRA-T/02_themas/02_02/AG_POVs.pdf	
BG	Bulgarian Informative Inventory Report (IIR) (2007): Emissions Data reporting for year 2005. Submission under the UNECE Convention on Long-Range Transboundary Pollution (CLRTAP/EMEP) http://cdr.eionet.europa.eu/bg/un/copy_of_UNECE_CLRTAP_BG/envrdqegg	Information on methodology: page 4, 5, 8
CY	Excel spreadsheet used to prepare emission inventories for all pollutants, the Cyprus's National Implementation Plan required by the Stockholm Convention on POPs and Cyprus's annual emission inventory reports. Including data from 1990 to 2010 Provided by the Department of Labour inspection	Information on EF and specifications to activity rate
CZ	Czech Hydrometeorological Institute, Department of emissions and Sources (2003): "Emission inventory for domestic heating by small sources since 2001" Provided by the Ministry of the Environment	Information on methodology and specification on activity rate
DE	Nationaler Durchführungsplan unter dem Stockholmer Abkommen zu persistenten organischen Schadstoffen (POPs), Forschungsvorhaben im Auftrag des Umweltbundesamtes, FKZ 205 67 444, O. Rentz, U. Karl, M. Haase, M. Koch, Deutsch-Französisches Institut für Umweltforschung, Universität Karlsruhe (TH), 01. Dezember 2007 In German http://www.umweltbundesamt.de/uba-info-medien/mysql_medien.php?anfrage=Kennummer&Suc	Information on methodology: page 1-2 Data on activity rate: page 40-42 Data on EF: page 42, 43

MS	Information sources	Specification
	hwort=3354	
DK	NERI (National Environmental Research Institute) technical report No. 602: Dioxin Air Emission Inventory 1990-2004. December 2006 http://www2.dmu.dk/Pub/FR602.pdf	Information on methodology and EF: page 20-25
EE	Air emission annual data reporting under UNECE CLRTAP http://cdr.eionet.europa.eu/ee/un/UNECE_CLRTAP_EE	Information on total emission
ES	No information available	
FI	Air Pollution Emissions in Finland 1990 - 2006. Informative Inventory Report. 15th March 2008. Part 2 Annexes. http://cdr.eionet.europa.eu/fi/un/UNECE_CLRTAP_FI/envr9u3ya/FI_IIR2008_15032008_partII.pdf	Information on methodology: page 18-19, 102-104 Information on EF: 110
FR	CITEPA: Inventaires des émissions de polluants atmosphériques en france au titre de la Convention sur la Pollution atmosphérique transfrontalière à longue distance et de la directive européenne relatives aux plafonds d'émissions nationaux- December 2007 In French http://www.citepa.org/publications/UNECE_FRANCE_dec2007.pdf	Information on methodology, EF and activity data
GR	No information available	
HU	Air emission annual data reporting under UNECE CLRTAP http://cdr.eionet.europa.eu/hu/un/UNECE_CLRTAP_HU/envr7qqsq/NFRHU2006.xls	Information on total emission
IE	http://www.epa.ie/downloads/pubs/research/air/name,12128,en.html	
IT	No information available	
LT	EMEP/CLRTAP emission inventory report and Informative inventory report (IIR) http://cdr.eionet.europa.eu/lt/un/UNECE_CLRTAP_LT/envrdrnkg/LRTAP_Emission_data_2005_LT.zip/manage_document	Information on methodology and EF: page 14-16
LU	No information provided	
LV	No information available	
MT	No information available	
NL	D.S. Nijdam & WWR Koch (2007) Methodenbeschrijvingen Emmissiergistratie. Productgebruik, Consumenten, Bouw en HDO. Emissies van de taakgroep WESP, werkvelden 12, 19 en 20. Versie 1.0 In Dutch www.emissieregistratie.nl	Information on methodology

MS	Information sources	Specification
PL	Institute of Environmental Protection (2005): Emission Inventory of SO_2, NO_2, NH_3, CO, PM, NMVOC, HMs, and POPs in Poland in 2003. http://emisje.ios.edu.pl/kcie/Download/report_EMEP2003.pdf	Information on methodology: page 30, 31, 36 Information on activity data and EF: page 31-34, 36-39
RO	Studiu privind elaborarea Inventarului Naţional anual de emisii de poluanţi organici persistenţi în conformitate cu prevederile Convenţiei Stockholm privind poluanţii organici persistenţi (POP) In Romanian Provided by National Reseyrch and Development Institute for Environmental Protection	Information on methodology, EF and activity rate
SE	Swedish Environmental Protection Agency: Survey of sources of unintentionally produced substances. Report 5503. March 2005 http://www.naturvardsverket.se/Documents/publikationer/620-5503-8.pdf In Swedish: “Kartläggning av källor till oavsiktligt bidade ämnen” http://www.naturvardsverket.se/Documents/publikationer/620-5462-7.pdf	Information on methodology, EF and activity rate: page 21-33
SI	National Emission Inventory from years 1990 to 2006 of POPs http://cdr.eionet.europa.eu/si/un/UNECE_CLRTAP_SI/colr4iwfq/envr4iwpq	Information on total emission
SK	Informative Inventory Report to LRTAP Report (IRR) 2008 http://cdr.eionet.europa.eu/sk/un/UNECE_CLRTAP_SK/envr7knyq/Informative_Inventory_Report_UNECE_2008.DOC	Information on methodology: page 8, 20, 21 Information on EF: page 9-11
UK	AEA Energy and Environment: UK Emissions of Air Pollutants 1970 to 2005. November 2007 http://www.airquality.co.uk/archive/reports/cat07/0801140937_2005_Report_FINAL.pdf	Information on activity data: page 120, 124

2.3 Allocation of specific appliances in National reporting on "residential" sources in EU Member States

MS	Category	Appliances
AT	NFR 1A4b i	SNAP 020202: Central and apartment heating
		SNAP 020205: Stoves
	NFR 1A4b ii:	Fuel combusted in non commercial mobile machinery such as for gardening and other off road vehicles
BE-FL	SNAP 0202	Domestic and residential facilities; schools, hospitals, rest homes, offices, restaurants, etc
BE-BCR	SNAP 020202; NFR 1A4b	Central heating, singles stoves, etc
BE-WA	NFR 1A4bi; SNAP 020202 & 020205:	Fireplaces, stoves and boilers
	NFR 1A1a/SNAP 010203: Small installations in district heating NFR 1A4a/SNAP 020103: Commercial / institutional NFR 1A4ci/SNAP 020302 & 020305: Agriculture/ Forestry / Fishing NFR1A5a/SNAP 020106: Other stationary (including military)	Coal, gas, oil and wood boilers with capacity between 50kW and 1MW and from 1MW to 50MW
BG	SNAP 020202	Combustion plants < 50 MW (boilers)
	NFR 1A4b ii	Included in SNAP 0809
CY	NFR 1A4b: Residential plants	Barbecue charcoal, residential fireplaces and boilers for central heating
	NFR 4F: Field Burning of Agricultural Wastes	Open burning of agricultural wastes
	NFR 6 C: Waste incineration	Open burning of domestic/ municipal wastes, aircraft waste, construction waste, agricultural waste, bonfires, accidental fires buildings and vehicles
CZ	1 A 4 b i: Residential plants	Individual heating of households with significant share of solid fuels and wood combustion; larger apartment buildings with external heat supply not included.
	1 A 4 b ii:	Annual total
DE	1 A4b i	Domestic combustion sources: Households and other small consumers (boilers, stoves and open fire places)
	1 A4b ii	Mobile sources in households and gardening (emergency power units, gardening tools)
	??	Open burning (accidental fires, on-field burning of gardening/agriculture/forestry, illegal waste burning
DK	SNAP 020200: Residential plants	020202, Combustion plants < 50 MW (boilers)
		020204, Stationary engines
	SNAP 080900	
EE	NFR 1 A 4 b I /SNAP 0202	Fuel combustion in households. Emission from the household machinery
FI	NFR 1 A 4 b i: Residential plants	All releases from domestic small combustion activities are included, also emissions from sauna stoves. We do not at the moment have a technique based calculation for small combustion sources in our inventory system. However, in the coming years, also the small combustion inventory will be technique based
	SNAP 0809	not estimated separately, owing to lack of activity data Covered by sector 07 – Road transport
FR	SNAP 0202	No further differentiation
HU	NFR 1 A 4 b i: Residential plants	No information so far

MS	Category	Appliances
IE	SNAP 0202	Natural Gas and Oil fired (kerosene and gasoil) boilers rated 20–50 kW. All solid fuel stoves and ranges (peat products, coal/lignite/pet coke/anthracite and wood) and open fireplaces (peat products, coal/lignite/pet coke/anthracite and wood)
	SNAP 0809	mostly petrol driven garden equipment: reported under the road transport sector as no split of the activity data (gasoline consumption) is currently available
IT	SNAP 0202	No further differentiation
IT (Lombardy Region)26		The 2005 PCDD/Fs emission inventory is ongoing and will be published in late 2008. Burning of wood has been considered and differentiated in 5 categories: Open fireplace, traditional stove, closed fireplace or insert, innovative low emission system and boiler, pellets plant or BAT system burning wood; BAT pellets plant; the average emission factor considered for the five categories, based on a literature survey, are respectively 170, 170, 30, 3, 3 µg TEQ/TJ.
LT	NFR 1 A 4 b i: Residential plants	Fuel combustion in households (boilers, gas turbines, stationary engines and other stationary equipments in commercial/ institutional, household and agriculture sectors)
LU	NFR 1 A 4 b i: Residential plants	No information so far
NL	NFR 1 A 4 b i	Open fireplaces/ stoves; barbecues, PCP treated building construction
PL	SNAP 0202	Households
	SNAP 080900	Included in 0810 (Other off road)
RO	SNAP 0202	Household heating using fossil fuels, wood and other biomass fuels
SE	SNAP 0202	Small-scale burning of wood (also for dl-PCB); allocation 020202 and 020205 not clear
SI	SNAP 0202 / IPCC 1A4b	Households; the specific sources are not reported
SK	NFR 1A4b: Residential plants	No specific emission factors for different appliances only for different fuels
UK	SNAP 0202: Residential plants	Burning of solid fuels to provide heat in domestic homes. Also have a category for small scale waste burning and for accidental fires including homes and vehicles. No estimation from off road machinery such as is covered by SNAP Code 0809
	NFR 1A4a, NFR 1A4bi, NFR 1A4ci, NFR 1B1b	No separation of sectors is made in the “UK Emissions of Air Pollutants 1970 to 2005” report.
		Emissions from open agricultural burning and accidental fires are included in the agricultural sector.

26 inventory for the year 1997 and 2001 (Caserini and Monguzzi, 2000; Caserini et al., 2003)

2.4 Charcoal consumption in EU Member States

	MS	HH	HH+OC	capita (mio.)	cc per capita [kg per capita]
1	Austria	10	10	8.3	1.2
2	Belgium	17	17	10.5	1.6
3	Bulgaria			7.7	
4	Cyprus	0	11	0.76	11
5	Czech Republic			10.3	
6	Denmark		23	5.4	4.3
7	Estonia			1.3	
8	Finland		2	5.3	0.4
9	France-Monaco			62.9	
10	Germany			82.5	
11	Greece	48	48	11.1	4.3
12	Hungary	2	2	10	0.2
13	Ireland			4.2	
14	Italy + San Marino			58.8	
15	Latvia			2.3	
16	Lithuania			3.4	
17	Luxembourg			0.46	
18	Malta			0.4	
19	Netherlands	9	9	16.3	0.6
20	Poland			38.2	
21	Portugal		37	10.6	3.5
22	Romania		9	21.6	0.4
23	Slovakia	43	43	5.4	8.0
24	Slovenia		1	2	0.5
25	Spain			43.8	
26	Sweden			9	
27	United Kingdom			60.4	
	EU 27			492.92	3.1

Hh households

OC other consumers

mt = metric tons

cc = Charcoal

2.5 State of estimation of dioxin emissions from illegal burning of waste in EU Member States

MS	Estimate	Comment
AT	NO	High uncertainty on emissions of illegal waste co-incineration in domestic heating and backyard burning; but in general this seems to be a minor source. Illegal co-incineration of waste in domestic stoves is estimated to occur in 2% of the possible cases (manually fed stoves and boilers) Combustion of gardening wastes is prohibited but known to occur.
BE-FL	YES	Based on a 2001 study and the available literature data, EF were determined for open fires and the burning of garden waste. The amounts of burned (garden) waste are based on data from a single inquiry in 2000
BE-WA	NO	Open burning waste is forbidden in the Walloon Region; therefore it is not reported in the inventory even if it occurs.
BE-RBC	NO	Open burning waste is forbidden in RBC; therefore it is not reported in the inventory.
BG	PARTLY SNAP 1003	Only emissions from stubble-(field) are estimated. National CORINAIR methodology
CY	YES NFR 6C	Burning of waste is prohibited but known to still occur
CZ	NO	Open burning of waste is generally prohibited; specific exceptions can be set for certain garden wastes
DE	YES	**Subcategories:** accidential fires (buildings, vehicles), forest fires, open burning of waste in agriculture and forestry, illegal burning of waste Generation of **AR:** -Accidential fires: Statistic from fire fighters with information on type and size of fire, statistics of forest fires; -Open burning of biomass: assumed as 0.1- 1% of total production -Illegal burning of waste: assumed as 0.01-0.1 % of annual waste generation
DK	NO	Backyard burning of kitchen waste is not anticipated to be a big problem in Denmark. On the other hand burning waste wood is regarded as a main source for dioxin emissions in the residential sector.
FI	NO	Open burning of waste not allowed.
FR	NO	Open burning of household waste is forbidden. “backyard burning” is not considered in the inventory as no concrete statistics exist on the amount of waste burned.
IE	YES SNAP 090108.	Backyard/open burning of waste is illegal in Ireland. Nevertheless in 2005 it was estimated that approximately 38,000 tonnes of waste was burned (11.4 kg TEQ PCDD/PCDF; figure was assumed as 40% of uncollected waste (see also “Inventory of Dioxin and Furan Emissions to Air, Land and Water in Ireland for 2000 and 2010” http://www.epa.ie/downloads/pubs/research/air/name,12128,en.html
IT	PARTLY	Open burning of agriculture waste is estimated and reported in the waste and agriculture sectors while open burning of municipal waste is not estimated. Although existing, it seems that household burning of waste is a minor source of dioxin if compared to the large amount of waste burned in the streets in some Italian areas. Has to be considered that in the Campania region (Naples province in particular) in the year 2007-2008 hundreds of tonnes of waste have been burned along the road due to the “Naples garbage crisis” (see http://news.bbc.co.uk/2/hi/europe/7174987.stm or http://www.spiegel.de/international/europe/0,1518,528501,00.html)

MS	Estimate	Comment
LU	NO	Open burning of waste is not allowed but often tolerated with respect to garden waste
PL	YES SNAP 1003 SNAP 11	Commercial fuels are frequently co-combusted with household waste; this is taken into consideration via the EF applied (based on national measurements); Open burning of waste is reported under SNAP 1003 (agricultural waste, landfill fires) and SNAP 11 (forest fires)
RO	NO	Backyard burning is a problem, but there is not data about quantity available and measures so far are not taken.
SI	NO	Open burning of waste is prohibited; emissions are not estimated due to lack of statistical data
SK	NO	Open burning of waste is prohibited, but considered to still be a problem and used practice. Not only gardening waste is burned, but also waste, especially plastics. No estimates are available.
SE	NO	No official estimates but rough estimates for backyard burning are available
UK	YES SNAP 0902	Calculated by summing estimates of emissions from waste burning from domestic fires, commercial small scale waste burning, industrial small scale waste burning, construction and demolition waste and bonfires. These are estimated from what waste disposal statistics are available and calculated with emission factors from a range of sources, principally using US EPA AP-42 Principal material disposed of in this way is probably garden waste, virtually no data available. Since legislation and hence the types of waste burnt differ between countries, it is difficult to use the few EF that have been calculated internationally.

2.6 Current methodologies for estimation of PCDD/PCDF emissions in EU Member States

Member States	Description
AT	The CORINAIR methodology is applied. Own national study to specify EF of wood and coal ovens was realized in 1999/2000. EFs for mobile sources based on study on off-road emissions in Austria (Pischinger 2000); calculation via ratio power of the engine and EF; engine type, performance, age, and operating time taking into account
BE-FL	The emission inventory for dioxins to air for Flanders is updated once a year. The results are presented in the MIRA publication (Flanders Environmental Report edited by the Flemish environment Agency (VMM)) (http://www.milieurapport.be/Upload/main/miradata/MIRA-T/02_themas/02_02/AG_POVs.pdf) (Dutch) The calculation of the release of dioxins to air for heating facilities is based on emission factors and masses of fuel burned. These calculations are performed for domestic as well as residential (SNAP 0202) heating facilities Source for EF: Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases. 2nd edition, February 2005, Prepared by UNEP Chemicals Geneva, Switzerland. (http://portalserver.unepchemicals.ch/Publications/StToolkitIdQuantDFRel2005_2e.pdf) In 2001 VITO performed a study to estimate the emissions of PCDD/F from open fires, barrels for garden waste. Based on this study and the available literature data, EF were determined for open fires and the burning of garden waste
BE-RBC	**EF for coal**: national data from ICEDD : Collecte des données sur les émissions atmosphériques en Région de Bruxelles Capitale, décembre 1997) **EF for liquid and gaseous fuel:** EMEP/CORINAIR Emission Inventory Guidebook - 2004.
BE-WA	Guidebook – 2006; Group 2 Non-industrial combustion plants Methodology: p.28; Calculation via estimated share of type of installations and EFs from detailed methodology tables
BG	Application of the national CORINAIR - 94 methodology together with SNAP-94 in relation with EMEP grid, which is adapted to Bulgarian conditions (activities, technologies, equipment) and approved by the MoE. National measurements and studies though are only used for verifying and specifying the EF of standard air pollutants (SO2, dust, NO2)
CY	The methodology of CORINAIR is applied.
CZ	Own national model for emission inventory for domestic heating based on CHMI project's data (Emission inventory for domestic heating by small sources since 2001 (P. Machalek, J. Machart, CHMI, 2003). The difference in the fractions of the various means of heating between family homes (FH) and apartment buildings and other buildings (AB+OB) are used as basis for calculation. Apartments in apartment buildings are mostly heated from sources outside of the building, while heating using home heating units is mostly employed in family homes. On the basis of the energy employed for heating, almost 40% of apartments are heated from remote medium-sized and large sources. The fraction of heating oil and propane-butane is negligible. Only 20% of all dwellings are heated with fossil fuels, mostly coal. Average furnace efficiency is calculated by fuel as is the caloric value. This is regionally differentiated for coals, 12.6 for wood, 44 for oils and 34 for gases." **EF for domestic heating (brown and hard coal) and coke**: National data on the base of measurements within the framework of projects of the Ministry of Environment. **EF for wood and liquid fuel:** M-SCE Belarusian contribution, annual report 2002, Preparation of additions and refinements to the EMEP/CORIAIR Atmospheric Inventory Guidebook
DE	Own national EFs based on evaluation of relevant scientific literature.
DK	The methodology for the Danish emission inventory for dioxin follows the EMEP/Corinair methodology; choice of factors and methodology see www2.dmu.dk/Pub/FR602.pdf
EE	For the estimation of the emission the CORINAIR handbook is used. For Identification and Quantification of Dioxin and Furan Releases "Standardized Toolkit for Identification and

Member States	Description
	Quantification of Dioxin and Furan Releases, UNEP Chemicals", Geneva. January 2001
FI	The EMEP/CORINAIR Guidebook methodology as well as national methods is used. PCDD/PCDF emissions are calculated using EFs from UNEP Toolkit (1999) except for wood combustion for which EFs are taken from USEPA 1997 and for peat for which EFs are domestic (Ruuskanen 2000). For the 1A4b sector 4 boilers <50 MW are included in the VAHTI database
FR	CITEPA - National inventories of air emissions in France : organisation and methodologies February 2008 (§ B,1,3,4,1,5) http://www.citepa.org/publications/Inventaires.htm#inv3
HU	Estimations are based on the "Emission factors manual PARCOM- Atmos". p 92-235, Report Nr. 112322-24285 study, the TNO Technical Paper to the OSPARCOM-HELCOM_UNECE emission inventory of heavy metals and Persistent Organic Pollutants. R95/247 (1995).
IE	The preparation of this emission inventory was based on the UNEP-Toolkit 2001. http://www.epa.ie/downloads/pubs/research/air/name,12128,en.html
IT	Air Emissions are estimated on the basis of default emission factors by fuel as reported in "The European Emission inventory of HM and POP for 1990" published by TNO/UBA Berlin in June 1997 The results of a survey done with CATI (Computer Assisted Telephone Interviewing) techniques, that allow a quantification of a larger use of wood in the domestic sector (see 3.9), has not been considered for the inventory because the latter is based only on "official" statistics made by the National Energy Balance. It seems that reasons for discrepancies are due to the large portion of wood that is not recorded in official statistics. Only about 20% of wood burnt in the domestic sector in Italy comes from sales channels, as invoiced or purchased. Moreover, there are thus great discrepancies between fuel-wood consumption and the amounts of production (removals) and imports. For the emission inventory of the Lombardy Region 1999 EFs from USEPA 1998 have been used for oil, coal and wood For emission inventory see http://nfp-it.eionet.eu.int:8980/Public/irc/circa-it/reportnet/home . For water and land there is not sufficient information is available to produce a national inventory.
LT	Emission factors used are either country specific (Energy sector) or internationally recommended default factors, mainly those provided in EMEP/CORINAIR Emission Inventory Guidebook **EF for PCDD/Fs**: Institute of Environmental Protection (2004): Emission Inventory of SO_2, NO_2, NH_3, CO, PM, NMVOC, HM's, and POP's in Poland in 2002. **EF for PCB's**: TNO (1995): Technical Paper to the OSPARCOM-HELCOM-UNECE Emission Inventory of Heavy Metals and Persistent Organic Pollutants. TNO-MEP Nr. 95/247
LU	For the estimation of the emissions the methodology given in the CORINAIR Handbook 1994 is used.
NL	**EF for wood stoves**: Hulskotte et al. (1999): Monitoring systematiek open harden en houtkachels, TNO report R99/170. **EF for dioxin emissions from PCP treated wood:** H.J.Bremmer et al. (1993): Emissies van dioxins in Nederland', April 1993, RIVM/TNO, RIVM Report Nr 770501003, chapter 19. **EF from crematories**: H.J.Bremmer et al. (1993): Emissies van dioxins in Nederland', April 1993, RIVM/TNO, RIVM Report Nr 770501003
PL	A mixture of emission factors from national measurement campaigns and from literature is used to estimate PCDD/F and PCB emissions. **1. EF for coal and lignite**: Country specific EFs: Grochowalski A (2001): Estimation and analysis of EFs of PCDD/F from selected types of sources for the national inventory purpose, Krakow University of Technology. Not published, Only in Polish **2. EF for fuel oil and fuel wood** Berdowski J.J.M., Veldt C., Baas J., Bloos J.J., Klein A.E... (1995) Technical Paper to the OSPARCOM-HELCOM-UNECE Emission Inventory of Heavy Metals and Persistent Organic Pollutants. TNO Institute of Environmental Sciences, Energy Research and Process Innovation, The

Member States	Description
	Netherlands; **3. EF diesel oil and gasoline** Quass. U., Fermann, M. Bröker G. (2000): The European Dioxin Emission Inventory, Stage II, Volume 2. Desktop studies and case studies. Landesumweltamt Nordrhein-Westfalen for European Commission DG XI. The same factors are also quoted in: Pacyna, J.M. (ed.). (1999): Environmental cycling of selected persistent organic pollutants (POPs) in the Baltic Region. Technical Report. Appendix I to Executive Final Summary Report. (POPCYCLING - Baltic). Norwegian Institute for Air Research, Kjeller **4. EF for coke** Quass. U., Fermann, M. Bröker G. 2000. The European Dioxin Emission Inventory, Stage II, Volume 2. Desktop studies and case studies. Landesumweltamt Nordrhein-Westfalen for European Commission DG XI (data for Germany for SNAP 0202).
RO	The methodology is based on Emission Factors Manuals from. CORINAIR and UNEP. Study on developing national annual emission inventory on POPs from Stockholm Convention – includes the Methodology on the inventory development.
SE	Emissions are estimated on the basis of international EFs (e.g. UNEP) and Swedish measurement data.
SI	Estimations are based on the Technical Paper to the OSPARCOM-HELCOM UNECE Emission Inventory “Emission Factor Manual PARCOM-ATMOS” **EF default factor:** → CORINAIR Inventory → Default Emission Factors Handbook, Jan. 1992, → EU EMEP/CORINAIR Atmospheric Emission Inventory Guidebook, Feb. 1996 → Pacyna et al., 1993. **EF for SNAP 0202**: Pacyna et al. (2003): European atmospheric emissions of selected persistent organic pollutants, 1970 – 1995, Atmospheric Environment 37, Supplement No. 1, p. 119-131, page 121). **EF for emissions to water and land**: Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases (where possible)
SK	**EFs for wood and natural gas:** CORINAIR 2004 - Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases, UNEP Chemicals, December 2005 **EFs for coal:** based on expert estimation according to measurements in CZ and PL
UK	The inventory is in terms of the sum of the weighted emissions expressed as ‘ITEQs’ which are widely used in UK and European legislation. However, the WHO published a modification to the values used to calculate the toxic equivalents for some of the PCDDs and PCDFs in 1997 which was revised using updated information in 2006. They have also suggested that there is value in using a similar approach for the PCBs which have dioxin-like toxicity and combining the PCDD/F and PCB TEQs together.

2.7 Specific default EFs for different types of domestic appliances in the UNECE Guidebook

UNECE Guidebook Default EF ng I-TEQ/GJ	1A4bi Residential	Fireplace	Domestic stoves	Advanced stove	Small boiler (<50 kWth)	Advanced manual boiler <1 MW	Medium size boiler (50 kW-1 MW)	Pellet stove <1MW	Medium size boiler (1-50 MW)	Advanced automatic boiler
Coal	800	500	1000	500	500	200	400		100	40
Coal Briquettes			300*		200		100		2	
Wood	700	800	800	300 (and fireplace)	500	300	500	50	200	30
Liquid fuels*	10	NA	10		10		10		10	
Gaseous fuels	0.5	1.5	1.5		NA		2		2	

Coal: All raw coals as well as derived fuels such as patent fuels, coke and other manufactured coal fuels

Coal briquettes: including patent coal, coke, other manufactured

Wood: = Wood, peat, wood wastes and agricultural wastes (straw, corn cobs, etc)

Liquid fuels = Gas oil (gas/diesel), fuel oil (residual oil, residual fuel oil)

Gaseous fuels* = Natural gas, liquefied petroleum gas (LPG), othe

2.8 Original EFs for coal reported by MS in µg TEQ/ton

Coal		1A4bi Residential µg TEQ/ton
POP Protocol Annex IV	Charcoal	0.23 – 1.3
BG	Anthracite/hard coal	1.6
	Brown coal/lignite	4.37
CZ	Hard coal and coke	4.45
	Brown coal/lignite	6.39
IT (Lombardy 1999)		2.1
NL	Coal (stoves)	1.6
	Briquette (stoves)	0.5
	Charcoal for barbeque µg TEQ/ton meat	0.27
PL	Hard coal	10 mg/Gg
	Coke	0.6
	Brown coal	18
SK	Hard coal	3.5
	Brown coal	4.5
UK	Hard coal	2.1
	Coal	2.9
	Coke, petroleum coke	2.4
	SSF	2.7

2.9 Original EFs for wood reported by MS in µg TEQ/ton

Wood		Residential µg TEQ/ton
CZ		5 µg TEQ/ton
NL	Wood (domestic stove)	2.2 µg TEQ/ton
	wood for barbeque	0.27 µg TEQ/ton meat
	Waste (domestic stove)	50 µg TEQ/ton
PL		5 µg TEQ/ton
SK		1.4 µg TEQ/ton
UK		2.4 µg TEQ/ton

2.10 Sources and methodologies for generation of activity data in EU Member States

MS	Source and methodology for generation of activity data
AT	**Data sources**: Information about type of heating: Micro census surveys, energy statistics supplier Energy consumption by type of fuel and by type of heating: Statistical evaluation of micro census (STATISTIK AUSTRIA 2002) Share of natural gas and heating oil condensing boilers on central and apartment heating and new biomass boilers: Estimated by means of projected boiler change rates from (LEUTGÖB et al. 2003). Pellets: Survey of the Provincial Chamber of Agriculture of Lower Austria, Austrian association of pellets manufacturers ‘ProPellets’ Wood chip consumption: Calculated by subtracting pellet consumption from biomass consumption taken from energy statistics. **Methodology:** Condensing oil and gas boilers, controlled pellet boilers, wood gasification boilers, wood chip fired boilers considered from 2000 onwards Pellet boilers considered to have lower POP emissions than wood chips fired boilers. Research study 1999/2000: Monitoring of emission from 30 solid fuel heating installations under realistic-like conditions. Up-dating monitoring project currently planned. Results: No major difference in EF between wood and coal stoves, because both in practice are not heated with one fuel exclusively. The emissions from automatic wood chip and pellet stoves are generally lower as the individual firing behaviour of the users does not have such an influence.
BE-FL	The energy consumption by residential and domestic heating installations is updated yearly by VITO. For this purpose VITO organizes written inquiries (by mail or e-mail) for industrial companies and energy producers in cooperation with the confederations. For the burning of wood in domestic stoves it is assumed (based on an inquiry in 2000) that 11% of the total amount of burned wood is treated wood and 89 % is untreated wood
BE-WA	Data source: 2005 energy balance of the region of Wallonie; Socio-economic survey conducted by the DGISE Energy consumption derived from regionalized data for natural gas (CWAPE and ICEDD calculations). For oil-derived products and coal, the sales evolutions for Belgium (published by SPF EPMECME, apart from butane-propane for which sales evolution comes from FEBUPRO) are taken into account. For wood, regional data are considered (source: DGISE – 2001) **Methodology** Top-down methodology to estimate the energy balance. Determination of the total consumption of households. Then this total is split between the different types of dwelling as well as between the various equipments. This precise approach requires additional data. Socio-economic survey data are gathered for: 1. Type of dwellings; apartments or houses 2. Type of heating: centralized heating system, decentralized heating system 3. Type of energy vectors : wood, coal, electricity, butane/propane, natural gas, heat pumps, others The data collected allow determining 2 different repartitions for each fuel: a repartition between the different types of dwelling, and a repartition among the different types of heating systems. The number of dwellings is estimated by dividing the number of inhabitants by the average number of inhabitant by dwellings. The share of fireplaces, stoves and boilers fuelled by solid coal fuels, biomass and gaseous

MS	Source and methodology for generation of activity data
	fuels was assumed as 5%, 65% and 30%, respectively and the emissions factors were taken from the detailed methodology tables. Within solid coal fuels a figure of about 5% was assumed for briquettes. For liquid fuels the share of stoves was assumed as 10% and boilers as 90%. Because the share of biomass and coal advanced stove and boilers was assumed to be currently lower than 5% in most of the countries they haven't been taken into consideration.
BE-BR	**Data sources** : Evolution of the use of natural gas in the dwellings and equipments: "Collectivité du gaz" Regional consumption of liquid fuel and coal: SPF EPMECME Evolution of regional consumption of butane/propane: Published by Febupro **Basic Methodology:** The 2001 socio-economic survey by DGIS provides the 2001 split of the energy vectors (coal, fuel oil, natural gas, butane/propane, electricity, heat pumps) for each type of dwellings (houses and apartments) and each type of heating systems (central heating and decentralized heating). This 2001 repartition is used as a basis to derive the 2005 repartition. The number of dwellings is estimated by dividing the number of inhabitants (published by DGSIE) by the average number of inhabitant by dwellings. Assumed 10% houses in 2001 (the value provided by the 2001 DGSIE is supposed to vary with time proportionally to the size of the private households). Data from the "Collectivité du gaz" are used to estimate changes in shares of fuels via rates of constructions that switch from coal to natural gas use, and rate of new constructions that are connected to the urban gas network, rate of dwellings switching from a liquid fuel to natural gas when changing their boiler. The evolution of the share central heating system/decentralized heating system is assumed to be the same as the one between 1991 and 2001 (centralized heating system replacing progressively the decentralized one)
BG	**Data source:** National Statistical Institute. No division within the domestic source sector is made.
CY	**Data source:** Activity data are generated from information of the Statistical Service of Cyprus and annual reports submitted by operators of industrial installations. Local production of wood for fireplaces is available in "Agricultural Statistics", Table 48: production of wood. The imported quantity is found in "Imports/Exports", Code 4401 1000 **Methodology open burning of waste:** Construction waste such as plastic, wood, cartons etc. (estimation 0.5 t/construction site from start to completion of building). The number of construction sites was taken to be equal to the number of building permits issued every year. For the last 15 years open burning of waste contributed to about 80% of the total dioxin emissions in CY, due to recent measures this should reduce significantly Domestic waste (estimation 10 kg/inhabitant/yr) burned in open landfills
CZ	**Data sources**: Czech Statistical Office **Methodology:** Census of persons, buildings and apartments in 2001 (Census 2001), average total area of the apartment for the manner of heating and the energy used to heat permanently occupied apartments Data collected for individual municipalities and city wards in statutory cities Overall data and separate data for family homes, apartment buildings and other buildings with up to 20 apartments in the building. Only apartments with apartment central heating and stoves were included in the model, while apartments heated by building furnaces (45,570 apartments) were included under non-local

<table>
<tr><th>MS</th><th>Source and methodology for generation of activity data</th></tr>
<tr><td></td><td>heating (corresponds to the output of medium-sized and large building furnaces).
On the basis of the energy employed for heating, almost 40% of apartments are heated from remote medium-sized and large sources
Apartments in apartment buildings mostly heated from sources outside of the building. A total of 3,800,000 apartments, of which 1,600,000 are in family homes with an average total area of 96.7 m2
Heating using home heating units is mostly employed in family homes.
Specifications for methodology are described for:
Average annual fuel consumption per apartment
Fractions of the individual kinds of coal solid fuels
Annual consumption of fuel in a municipality
Amount of heat produced per annum</td></tr>
<tr><td>DE</td><td>Data sources:
Activity data for domestic and other small combustion sources are centrally generated and stored by type of fuel at the Federal EPA (UBA) in the ZSE (Zentrales System Emissionen) a database for management of all emission data in Germany.
• Energy consumption and installation registers;
• Fire-fighters statistics
• Agriculture and Forestry statistics
• Waste statistics
Mobile sources can be emergency power generators, gardening tools or similar appliances using diesel, 2-or 4-stroke engines
Methodology:
Consumption of peat and raw brown coal is allocated to briquettes
The differentiation by type of appliance (stoves, open fire places and boilers) is made via data for the total energy consumption of solid fuels by type of appliance (data 2000) and via the register of installed appliances (data 2003)
Accidental fires are estimated via the fire-fighter statistics, data for forest fires are available in the Ministry of Agriculture, Estimation of open burning of biomass can only be roughly performed using the data for separately collected biomass from households and assuming an open burning of 0.1-1%; the amount of residues from forestry is estimated via the amount of wood cut annually (54.5 Mio m^3; estimated residual biomass 10%; open burning 0.1-1%);
For illegal burning of household waste (generation ~460 kg/inhab/year) an share of open burning of 0.01-0.1% has been estimated due to the fact, that public waste services and collection sites are at disposition</td></tr>
<tr><td>DK</td><td>Consumption data are taken from energy statistics
Calculation of the consumption of wood is based on interviews of randomly chosen users of wood stoves or boilers. This showed that approximately 50% of the wood consumption comes from private felling of trees. Only 25% comes from registered suppliers and is included in the statistics for firewood (wood pellets not included)
It was also disclosed that 3.2% of the wood is used wood, e.g., pellets, packaging, demolition wood, furniture etc.,</td></tr>
<tr><td>FI</td><td>No information</td></tr>
<tr><td>FR</td><td>Data source :
Energy consumptions and fuel repartitions : « Observatoire de l'Energie »
Activity data : "Bilan énergétique de l'année 2006 de la France" http://www.industrie.gouv.fr/energie/statisti/pdf/bilan2006.pdf</td></tr>
<tr><td>GR</td><td>No calculations have been made up to now to estimate dioxin emissions from non-industrial sources. But it is certain that the non-industrial dioxin emissions are more severe than the industrial ones mainly due to landfill and forest fires and on-field burning of agricultural</td></tr>
</table>

MS	Source and methodology for generation of activity data
	wastes. Heating and cooking is not regarded as important
HU	No information
IE	Illegal waste combustion is assessed via waste generation and waste collection data (oral communication)
IT	Data sources/Methodology: National statistics on production and import In 2006 a survey on domestic wood use was carried out. The survey allowed the quantification of wood used in the different types of appliances used, i.e. open and close fireplaces, stoves, pellets burner, etc. (Caserini et al., 2007). The study provided evidence that there is an important discrepancy between wood consumption and the official statistics for production and imports.
LT	**Emissions from large point sources:** Annual emission questionnaires submitted to the MoE. **Emissions from area sources**: Statistical fuel consumption data
LU	**Data sources**: National Statistical Office.
NL	Dioxin emissions from domestic sources are calculated for open fireplaces and barbeques Information on calculation of activity rates for fireplaces has not yet been provided but might be added For barbeques activity rates are based on the average annual meat consumption per person estimated by the Dutch statistical office (CBS); the emission factor used is 0.02 µg TEQ/ton meat with an annual per capita consumption of 85 kg For dioxin emissions from PCP treated wood used in building construction estimations are performed on an extrapolation basis without use of an EF. Estimations are based on a 1993 report using amounts of preservative used and physico-chemical characteristics to calculate an annual emission of 25 g for 1993 and assuming that zero emissions are reached in 2040. Hence current reporting is on linear interpolation between these two figures.
PL	Data sources: Fuel statistics.
SE	Methodology and data sources domestic combustion: to be added Methodology open burning of waste: Estimated as 0,1 % of all waste incineration; Combustion experiments have been conducted to generate EFs (14 in drums, 2 as open bonfires) Since legislation and hence the types of waste burnt differ between countries, it is difficult to use the few EF that have been calculated internationally.
SI	Data sources: SNAP 0202 (IPCC 1A4b – residential sector): Statistical Office For other activities the following additional sources are relevant. Ministry of Environment and Spatial Planning Environmental Agency (obtains much of its data through other activities, which are performed under the Environmental Protection Act).
SK	Data sources/Methodology Activity data for fossil fuels are based on sales statistics of fuel providers; consumption of wood is extrapolated from this figures via its energetic value and the estimated "heat deficit" resulting from fossil fuel consumption and inhabited areas There is no information about changes of heating systems which could be used for a more detailed estimation PCDD/PCDF emissions from small sources decreased in the 1990ties due to decreased use of coal but increase in last years due to increased use of wood

MS	Source and methodology for generation of activity data
UK	Data source: Digest of UK Energy Statistics http://www.berr.gov.uk/energy/statistics/publications/dukes/page39771.html

2.11 Annual PCDD/PCDF emissions and fuel consumption in the residential sector in EU MS

MS	year	EMEP (CEIP) Annual emissions g TEQ/a	MS answer Annual emissions g TEQ/a	AR	Wood, Biomass, Fuelwood, Charcoal	Peat	Coke, coal petroleum coke Briquettes	Hard coal, anthracite	Brown coal	Fuel oil, Gas oil, LPG	Natural gas	Electricity	District heat heat pumps	Source
AT	**2006**	**27.08**		**TJ/a**	63,862	4	3,307	1,038	58	62,927	54,779	53,620	28,514	Energy Balance 2006 Statistik Austria
BE-FL		**---**	**32.00**											
BE	**2006**	**36.38**		**TJ/a**	8,777		5,183			156,197	146,580			CRF BE 2008
BG	**2006**	**70.75**	**59.00**	**TJ/a**	32,270		8;030			76	3;020			Transformed *4)
CY	**2006**	**0.7**	**7.9**	**TJ/a**	24			220		3720				Transformed *4)
CZ	**2006**	**14.12**	**14.20**	**TJ/a**	10;276		36;784			160	51;920			Transformed *4)
DE	**2006**	**14.40**	**22.10**	**TJ/a**	194,579		5,162	1,838	15,000	725,323	1,070,000			
DK	**2006**	**14.46**		**TJ/a**	32,695*3		679			23,366	30,148	5,951	67,773*2	
EE	**2006**	**1.26**		**TJ/a**	11,945	150	622			292	1,907			
ES	**2006**	**28.55**		**TJ/a**	113,000									
FI	**2006**	**0.89**		**TJ/a**	41,240*1	470	13		1,328	28,624		69,282	70,001	
FR	**2006**	**20.60**												
GR	**?**	**?**		**TJ/a**	11,397									IRR GR 2007
HU	**2006**	**16.28**		**TJ/a**	200,000 (not differentiated)									NIR HU 2008
IE				**TJ/a**	712	11,890	6,615	2,386	167	47,813	26,461	29,098	---	Transformed from ktoe

MS	year	EMEP (CEIP) Annual emissions g TEQ/a	MS answer Annual emissions g TEQ/a	AR	Wood, Biomass, Fuelwood, Charcoal	Peat	Coke, coal petroleum coke Briquettes	Hard coal, anthracite	Brown coal	Fuel oil, Gas oil, LPG	Natural gas	Electricity	District heat heat pumps	Source
IT²				TJ/a	16,142		361			12,000				Transformed *4)
IT	2006	31.39												
LT	2006	9.38	9.10											
LU	?	?		TJ/a	184	---	21	---	6	4,222	5,365	?	?	NIR LU 2008
LV	2006	3.18												
MT	?	?												
NL	2006	4.22												
PL	2006	199.4	186.00	TJ/a	101,542		195,822			14,040				Transformed *4)
PT	2006	4.94		TJ/a	49,149	---	---	---	---	27,829	7,688	---	---	NIR PT 2008
RO	2006	75.8		TJ/a	107,639	---	11	---	398	19,394	107,740	36,036	58,810	NIR RO 2008
SE	2006	2.78	<5	TJ/a	39,736	----	----	-----	----	17,082	1,193	----	----	NIR SE 2008
SI	2006	5.91	5.90		13,573									
SK	2006	3.65	3.65	kt/a	1,606		316		0.27		1,569			
SK				TJ/a										Transformed *4)
UK	2006	4.41		kt/a	854.5		647	212.3						
UK				TJ/a	11,963		18,904							Transformed *4)
UK	2006			TJ/a	8,114		26,167			133,773	1,181,112			CFR GB 2008

Table 2-1: Overview on annual fuel consumption in the domestic sector in EU Member States (2005-2006)

*1) = including recycled fuels;

*2) Emissions are reported in SNAP 0102 (energy production) and thus not included in domestic sources;

*3) includes straw

*4) used energetic value: Wood: = 14 TJ/kt, Coal (mixed) = 22 TJ/kt, gas and liquid fuels = 40 TJ/kt

*5) includes Coke Oven Gas, Blast Furnace Gas

[2] = Lombardy Region

Annual Dioxin emissions

No current information (2006) for GR, LU, MT; no Data since 2003

Fuel consumption

Only 1A4 in FR, NL, IT, ES, SI, LT, LV - no differentiation in 1A4b (residential); no NIR from MT

2.12 Deficits in and proposals for emission estimation from domestic sources as identified by EU Member States

MS	Deficits, data gaps and proposals for improvement in the field of emission estimation from domestic sources
AT	Correspondence between inventory EF for POPs and real world emissions should be better: - Current measurements from modern domestic boilers and stoves are missing, - Extent and effect of incorrect operation of coal and wood boilers and stoves difficult to assess, - Wood fired stoves without type approval might be imported and used High uncertainty of emissions from manually loaded domestic heating (coal, biomass). Emissions of illegal waste co-incineration in domestic heating are not estimated but could be a key source (according to a Swiss estimate). Uncertainties concerning the applied EF and AR are high. The used EF based on the CORINAIR Handbook are uncertain and domestic heating processes are not divided deeply enough (e.g. for wood stoves the quality of wood is very different and emissions are highly dependent from the consumer behaviour)
BE-FL	EFs have a broad uncertainty range, sometimes with a factor of more than 100. EFs are dependent on the property (quality) of the fuel, oxygen supply, burning facility…. The amounts of burned fuel ((garden) waste, wood….) are based on single inquiries. The composition of the wood (% of treated, untreated, dry …) is uncertain. The results of the inquiries give only an approximate indication of the present situation. The group of inquired people may be not completely representative for Flanders.
BE-BCR	EFs need to be updated
BE-WA	The main obstacles are the lack of statistical data concerning the types of appliances in the dwellings and the lack of activity data. The lack of activity data is more important for fuels like wood that has no regulated market.
BG	In order to eliminate methodological and data gaps in the currently used CORINAIR 94, a new Emission Inventory Methodology (EIM) was established by MoE/EEA (end 2005), adapting the Third edition of EMEP/CORINAIR to Bulgarian conditions (activity, technologies, equipment). Implementation of the new methodology is planned for 2007 reporting (in 2009). Until then both methodologies will be used.
CY	The main obstacle in Cyprus in addressing domestic sources is the difficulty in finding the

MS	Deficits, data gaps and proposals for improvement in the field of emission estimation from domestic sources
	right EF for each of the various types of equipment that are available on the market. The main difficulty is how to classify each type of activity especially open burning and also how to estimate activity data Missing EF for different types of equipment (e.g. wide array of fireplaces and central heating boilers using wood / biomass) Difficult to check whether the wood / biomass used are not contaminated Difficult to estimate activity data According to Commission's Biomass Action Plan, a need to increase the amount of biomass used for heating in order to reduce greenhouse gas emissions. On the other hand biomass, if is burnt without proper controls, can be a major source of pollution. What is therefore needed is a variety of EF for various types of equipment so that the MS can promote the use of biomass without increasing the emissions of dioxins and other POPs.
CZ	Lack of information, lack of measurement results, insufficient verification of EFs; Local authorities have data on energy efficiency of domestic heating appliances (CO emissions and thermal efficiency) which however, are highly incomplete as many owners use legal exceptions
DE	To be added
DK	Especially regarding wood combustion in the residential sector, both the activity data and emission factors are uncertain. The different technologies, e.g. new versus old stoves are also an important aspect. A study on the distribution of technology in the residential wood burning sector was conducted in 2004.
EE	The data is highly estimated and not very exact, e.g. on the basis of population. Expert estimates by sector are not available. National measurements for adapting the EF are missing, as measurements are difficult to realise and measurement equipment is too expensive
FR	Lack of monitoring results according to different type of equipment and different combustion conditions. Identification of domestic sources and assessing EF for different equipment type Evaluation of dioxin emission factors representative for French reality and robust statistically speaking. Lack of knowledge on the fleet of equipment in use (energy efficiencies, technical characteristics, number of equipment sold each year, the number of old equipment disappearing and the technical characteristic of equipment sold). Such assessment is particularly difficult in terms of data generation and collection and economical stakeholders involvement. Specific R&D programs would be needed (as the US-EPA did on backyard barrel burning). An EU network on that topic may be helpful The dioxin emission factors in SNAP 020201 (combustion plants (boiler) >50 MW) and SNAP 020202 (combustion plant (boiler)<50 MW) or 020203 (gas turbines) are defined for a type of fuel but not a type of equipment, except for wood for which the emission factor is different from one type of equipment to another one. It would be welcome to have emission factors for the different types of equipment and on the effect of the increase in energy efficiency on dioxin emissions. A synthesis of monitoring results would be welcome.
GR	Lack of data
HU	No information provided so far
IE	Quantification of waste refuse that is illegally burned by domestic households. The uncertainty associated with the amount of waste refuse burned by domestic households is

MS	Deficits, data gaps and proposals for improvement in the field of emission estimation from domestic sources
	very high Quantification of different types of domestic sources (e.g. Stoves, ranges, open fires, pellet burners etc.) Estimating the amount of gasoline in the national energy balance which is used by householders in non-mobile machinery (garden maintenance equipment) SNAP 0809. Development of national specific emission factors by measurement for typical sources in Ireland for dioxin emissions from domestic oil & gas boilers, solid fuel burners and open fireplaces would increase robustness of estimation It is possible that figure for biomass underestimates the actual wood usage due to private felling of trees, etc.
IT	National studies and emission factors are only available for incinerators and iron and steel industry. No measurements are available for other sectors. No statistics are available regarding the amount of waste burned without control in open air. A project on emission measurement from wood combustion (including PCDD/Fs) will start in September 2008, managed by ENEA (Agency for New Technology, Energy and the Environment) and ARPALombardia (Lombardy Environmental Protection Agency) and funded by the Italian ministry of the environment.
LT	No answer
LU	It is difficult to get reliable activity data for small combustion plants as a variety of different types exist especially when it comes to wood stoves. Activity data is scarce as information about numbers of chimneys, heating methods is missing.
NL	No information so far
PL	High uncertainty in data for waste combustion and burning of agricultural and domestic waste Insufficient data for non-point sources (residential heating small appliances like stoves, small boilers, cars) Landfill fires was estimated a main source for PCDD/F (in year 2003), but emission estimate is very uncertain. Difficult to estimate mass of burned waste and number of spontaneous fires
RO	Emissions from stubble burning are not known because the surface area where this burning is practiced is not inventoried; Some EFs are not determined Some incoherencies between the classifications in Romanian Standards and ISIC, SNAP, NACE, NOSE, etc
SE	Large uncertainties in data available/produced Uncertainties due to monitoring methodology and too few samples for each sector. Since emissions/concentrations vary considerably due to operating conditions (especially abnormal operating conditions) it is difficult to pull together a good “average estimate”, based on just a few samples. The high cost for sampling/monitoring is an important limiting factor here.
SI	Substantial uncertainties in estimates. Major scientific challenge to develop useful approaches to quantify the uncertainty. This mitigates the potential for conducting a sensible statistical uncertainty analysis. In spite of the problems of quantifying the uncertainty it is evident that the uncertainty of the EF is more significant than the uncertainty of the activity data. Development of national emission factors is needed for better estimation of dioxin emissions from domestic sources. Specific sources with belonging EF and activity data should be developed.

MS	Deficits, data gaps and proposals for improvement in the field of emission estimation from domestic sources
	Missing activity data. In some cases it was not feasible to obtain information (i.e. activity data, EF) needed to construct better inventory
SK	Lack of measured emission factors Lack of methodology for emission estimation from backyard burning
UK	Lack of data on emission estimates (work ongoing to improve) Lack of annually updated and accurate waste combustion data. Hence it is hard to estimate the effectiveness of policy measures as the data to support the effectiveness is not collected annually Poor knowledge of the extent of household fires; fire brigades only record the number of incidents and the potential scale of the incident hence a small fire in a block of flats will lead to several engines being called out even though only 1 fireperson was required as if they are slow to get their they may need to evacuated the building. Hence estimating the amount of material burnt is very difficult. Wood combustion statistics are subject to large uncertainty as a result of the untreated nature of the fuel. Current emission factors do not reflect the range of combustion characteristics being based on open fire measurements. Inadequate numbers of measurements under appropriate conditions mean the emissions estimates are uncertain. Supplement information derived from Phone interview: The (inadequate) numbers of measurements of dioxin emissions from wood burning were less than 10. Some were from very old degraded plants. In order to improve data on dioxin emission from domestic waste combustion the following measures have been taken, without achieving real improvement of data: 1. Efforts for improving the estimate of the amount of waste burned in domestic appliances and in bonfires. From questioning 30 of the 400 Local Authorities in UK, about figures for domestic waste burning only one had some figures. 2. Improving knowledge about the EF for dioxin emission from different type of domestic waste burning, but it implies knowledge about the amount and type of the waste burned, how it is burned, and which EF is relevant for different sources, Current studies are inadequate to achieve this. Wood is not in common use in UK. Cheap natural gas is distributed widely over the country, but increasing prices, and government policy to reduce CO2 emissions, enhance the installation of wood stoves and wood boilers. Lack of widespread distribution systems for high quality wood fuels, e.g. wood pellets, hinder the spreading of such boilers.

3 Annex Reduction measures

3.1 Legislative measures and standards

MS	Legal requirements and standards
AT	1. Regulations on domestic heating at the level of federal provinces ("Länder"): - Installation of boilers and stoves without type approval is forbidden - Only regular fuels may be used - (Multi)annual inspections of certain types of boilers required 2. New: Formal agreement about standards and emission limit values for CO, NOx, TOC, PM for boilers and stoves <= 400 kW. The new agreement under Art. 15a of the federal convention for the installation and control of small combustion plants (Vereinbarung gemäß Art. 15 a B-VG über das Inverkehrbringen und Überprüfung von Kleinfeuerungsanlagen) is expected to be ratified mid 2008. The regional authorities "Bundesländer" have to implement the agreement as fast as possible into federal law. It is assumed that in average it will be implemented in about 3 years
BE-BR	1. Royal ordinance regulating NOx and CO emissions from central heating boilers < 400 kW (7 June 2007 — "Ordonnance relative à la performance énergétique et au climate intérieur des bâtiments" transposes the Energy Efficiency Directive 2002/91/EC 2. Regional plans http://www.bruxellesenvironnement.be
BE-WA	1. Royal ordinance regulating NOx and CO emissions from central heating boilers and burners fuelled by liquid or gaseous fuels, and having nominal output up to 400 kW sets ELV for the two pollutants (Federal Service for Public Health, Food Safety and Environment, 8 January 2004) setting norms for boilers 2. Regular inspections for boilers: foreseen by the decree transposing the EPB Directive was voted by the Parliament of Wallonia 17/04/2007 (it should come into force in September 2008). 3. Arrêté du Gouvernement wallon portant programme de réduction progressive des émissions de SO2, NOx, COVphot et NH3, 25.03.2004 : Regional action plan "Plan air climate" to reduce progressively SO2, NOx, VOC and NH3 emissions. - Fixes the emission ceilings for the above-mentioned air pollutants for the Wallonie - mentions the installations of condensing boilers and proper maintenance of heating installations as measures to reduce energy consumption and emissions. - provides a list of measures of « good practice », including installation of low NOx burners, information on the choice of domestic heating solutions, and encourage the replacement of the boiler park.
BG	The National Bulgarian Environmental Strategy identifies priority sectors for dioxin emissions reduction: 1. Waste incineration; 2. Metallurgical industry; 3. Solid fuels in residential heating Ministry has a National program for implementation of natural gas in the domestic sector.
CY	1. Reduction of dioxin emission from small boilers burning biomass (especially olive seeds) by introducing low emission limit values for CO (200 mg/Nm³) (recent amendment of the Air Pollution Control Law by the Ministry of Labour and Social Insurance) 2. National Implementation Plan prepared according to the provisions of the Stockholm Convention

MS	Legal requirements and standards
CZ	1. Operators of small combustion sources (thermal output <200 kW) must comply with permissible smoke blackness 2. CO emission measurement is performed in some cases too
DE	Currently the First Ordinance on the Federal Emission Control Act (1. BImSchV) covers combustion sources > 15 kW. With this measure the “average” heating installation (boiler) of a house has to comply with limit values for CO (0,5-4 g/m³ depending on the thermal input) and dust (150 mg/m³) already by now. As Dioxin emissions are somehow correlated with CO and namely dust emissions this measure has an expected reduction effect, even though the correlation is not linear. **Implementation of the regulation** and the legal provisions is enforced by chimney sweepers who are authorised and empowered to do control measurements. The Ordinance foresees regular emission measurements (annual) performed by the chimney sweepers for automatic pellet and wood chips driven boilers. For hand operated installations an analysis is performed once after the start of operation.
DE	In the planned amendment of the First Ordinance on the Federal Emission Control Act, (1. BImSchV), currently under discussion, it is foreseen to further lower the capacity threshold for inclusion of heating facilities to 4 kW for boilers, to include single stoves and to request regular emission measurements for both automated and hand operated pellet boilers (biannually). Control of compliance of single stoves will be performed prior to putting in operation (“test-bench limits”). Emission control is not possible for open fireplaces, however, pursuant to 1. BImSchV emission there is a restriction on operation level (only occasional operation permitted), that has a reducing effect on overall emissions.
DK	Introduction of strict mandatory environmental standards for residential wood burning appliances based on limits for particle emissions with reduction of PAHs is planned. New Statutory Order approved by EU, into force end 2007, effect in 2008
EE	General measures are taken generally to apply energy saving technologies in the residential sector.
FI	Currently no legislation in force for domestic heating appliances but work underway to set limit values and efficiency targets wood fed heating boilers (<50 kW, 50-150 kW, >150 kW)
FR	1. Decree n° 98-8 17 - 11 septembre 1998 relatif aux rendements minimaux et à l'équipement des chaudières de puissance comprise entre 400 kW et 50 MW Minimum energy efficiency is regulated for boilers which can be used in 020201. 2. Decree n° 98-833 - 16 septembre 1998 relatif aux contrôles périodiques des installations consommant de l'énergie thermique : boilers have also to be controlled regularly. 3. All UN standards: EN303.5 of 1999, EN 13229; EN 13240; EN 12809 are applied.
IE	The ban on sale of smoky coal products in large urban areas (Dublin 1990, Cork 1995, remaining cities 1998, all towns with population >15,000, 2002)
IT	No specific measures have been taken except the reduction of sulphur content in the fuels as established by the European Directives. In some municipality coal heating boilers have been banned, but the use of coal for heating is very limited in Italy.
LU	Small combustion plants are not covered by a Regulation in Luxembourg and the burning of wood is not regulated.
PL	1. Development and implementation of National programme on the reduction of emissions of POPs, including PCCD/F: - Short-term priority within II State Environmental Policy for air protection but focussing mainly on the industry. 2. Executive Programme for the II State Environmental Policy: - Including advanced air protection control measures, implementation of BAT, extension of the scope of emission

MS	Legal requirements and standards
	standards and product standards. 3. Environmental Protection and Act on Waste27 (4. Several Regulations that regulate PCCD/F emissions directly or indirectly28: - Regulation on emission standards from installations ; including emission standards for SO2, NOx, particulate matter (dust) depending on the thermal capacity of boilers and type of fuel used; – Regulation on detailed requirements concerning air protection programmes (detailed scope, starting point for local, regional and national level preparation of appropriate legislation)-
RO	1. Law no 261/2004 for the ratification of the Stockholm Convention on POPS, Inclusion of the action plan in the National Implementation Plan for Stockholm convention *2.* Law no 271/2003 for the ratification of the LRTAP Convention Protocol on POPs, 3. EU Regulation no 850/2004 on POPs 4. Regulation (EC) No 166/2006 on E-PRTR Implementation measures: 1. Elaboration of NIP (support of GEF and UNIDO), NIP impelementation 2004 to 2029 2. Elaboration of the "Study on developing national annual emission inventory on POPs from Stockholm Convention", for years 2004-2006 – includes the dioxin inventory from domestic sources
SE	1. Limit values for CO and particles in energy sector (>500kW) 2. BAT requirements for dust and installations in line with IPPC-requirement (>10MW). 3. Limit values for "minimum performance" in new small scale installations (<300kW). www.boverket.se/upload/publicerat/bifogade%20filer/Boverkets%20byggregler/bbr12/Avsnitt_6_hygien_halsa_miljo.pdf
SI	1. National Implementation Plan on POPs (still needs governmental approval, Ministry of Health/ National Chemicals Bureau) 2. Action plan for identification, determination and reduction of emissions of POPs (still needs governmental approval, Ministry for the Environment and Spatial Planning, Environmental Agency of the Republic of Slovenia)
UK	1. Clean Air Act 1956 Defra (Ban for "smoky" solid fuels in smoke protection areas) 2. UK waste strategy

Table 3-1: Detailed information on legal measures to reduce dioxin emission in EU Member States

27 Act of 27 April 2001,Dz. U of 2008, No. 25, item 150; Act of 27 April 200, Dz. U of 2007, No. 39, item 251, as amended)

28 DzU of 2005, No. 260, item 2181, DzU of 2008, No. 38, item 221, DzU of 2008, No. 47, item 281, DzU of 2004, No. 168, item 1762, as amended in 2005, 2006 and 2007, DzU of 2007, No. 69, item 457

3.2 Legal measures to prevent burning of waste

MS	Legal Bans on the burning of waste
AT	Regulations on domestic heating (level of federal provinces (“Länder”): Waste burning is prohibited
BE-FL	Legal framework addressing domestic burning of waste (Flemish environmental legislation, implemented on 01/06/1995)
BE -BR	Open burning of waste is forbidden
BE -WA	Open burning of waste is forbidden; BE-WA: a distinction is made between vegetable wastes and household wastes. Under certain conditions, vegetable waste burning in gardens is allowed. A minimum distance of 100 m from houses has to be respected. It is forbidden to burn household wastes.
CY	Recent amendment to the Municipalities Law: Prohibition of burning of any kind of waste in municipal areas New law (May 2008) restricting burning of agricultural waste
CZ	Clean Air Act No. 86/2002 Coll: Open burning of waste is prohibited. Local authorities can set conditions for open burning of dry vegetable material only. . The vegetal waste (dry leaves, braches, grass etc.) is burnt in the open air only, but local authorities can prohibit this activity. It is assumed, that some waste is burnt in domestic sources (boilers, stoves), but it is difficult to force household to keep the prescribed requirements (prescribed kind of fuel only),
DE	Burning of waste in small combustion appliances is generally not permitted in Germany, however enforcement is difficult in the field. Awareness of citizens is the instrument currently used and managed at local level. Chimney sweepers are the competent bodies for control. The control of burning of garden waste is regulated at local level and is specified in the municipal statutes. In consequences “burning days” in autumn may be permitted in single communities, whereas the majority of cities has already banned this practice
DK	Burning of any types of waste in domestic heating appliances or in bonfires is forbidden in Denmark. A mandatory standard order the municipality to collect household waste regularly from all households in Denmark, and there is consequently no economic pressure to get rid of waste. Nevertheless burning of waste wood is regarded as a main source for dioxin emission from domestic sources. According to an investigation on the consumption of wood in Denmark (Brændeforbrug i Danmark, FORCE Technology 2006), 3,2 % of the Danish wood stoves and boilers is mainly or partly burning waste wood, as used wood, pallets, demolition wood, furniture etc.
EE	General law for waste combustion and the Waste Act: Backyard burning of waste is forbidden or authorized only for certain types and under certain conditions. First Regulations regulating waste management (including burning of waste in household sector) on the local level established (e.g.Tallinn region and Märjamaa region).
FI	Open burning of waste not allowed Open burning of garden waste is allowed on scattered settlement areas and also in some municipalities in planned areas during certain times. The municipal ordinances give detailed instructions and vary between municipalities
FR	It is forbidden to burn wastes, neither in open air nor in a fireplace or boiler. In case of violation of this rule, fines can reach 450 euros (article 84 of the local health rule). However in some cases dispensations are possible, when destruction is made thank to an incinerator. They are granted by the prefect, with the authorisation of the health authority, after notice from the local hygiene council.

MS	Legal Bans on the burning of waste
GR	No information so far
HU	No information so far
IE	Backyard burning of waste is illegal
IT	No information so far
LT	No measures have been taken
LU	It is not allowed to burn waste, but the burning of gardening waste is tolerated in many cases. The burning of wood is not regulated.
NL	Open barrel burning and open burning of waste is forbidden
PL	Uncontrolled individual burning of household waste is prohibited, unless it is carried out in specially designed for that purpose installations complying with requirements regarding the incineration process and emission standards. Plant residues, certain types of agricultural waste are allowed to be burned off in areas where separate collection of biowaste is not organised. Preparation of national, regional and local waste management plans is required regularly including measures.
RO	On legislative and political level the problem is not addressed so far
SE	Private burning of household waste is illegal. Local authorities can issue local relegations on what private individuals are allowed to burn (e.g. garden waste) Based on a questionnaire to local authorities most local authorities permit burning of non-compostable garden wastes (e.g. large branches and twigs), whereas private burning of household waste is not permitted. Nevertheless complaints have been received about illegal burning (e.g. plastics and other types of waste; few cases of on-site burning of silage plastic)
SI	Open burning is forbidden (Environment Protection Act (OJ RS 41/2004)
SK	The burning of waste is prohibited.
UK	It is allowed and widespread in UK to burn own garden waste in the garden. Other domestic wastes, e.g. furniture's may be burned in the garden, because of cost of transportation and disposal; demolition waste may be burned in open fires at the place of demolition. Planned Change of Paragraph 2 of Waste Management (England and Wales) Regulations 2006 SI No 937 and modification of Section 33 of the Environmental Protection Act 1990Remove exemption for households to pollute the environment with their own controlled waste

Table 3-2: Legal requirements regarding the open burning of waste in EU Member States

3.3 Awareness raising activities

MS	Description of awareness raising approaches	Webpages
AT	Various measures are taken in the field of energy efficient use of heating systems, for example by "Die Umweltberatung".	http://www.umweltberatung.at
BE-FL	Information campaign and brochure on proper heating with solid fuels	
BG	The problem of backyard burning and the burning of waste have been addressed to the population.	
CY	Information about reducing emission by avoiding uncontrolled backyard burning of waste in the form of FAQ It aims at raising public awareness about emissions of POPs during the burning of waste.	FAQ on web page of Department of Labour Inspection

MS	Description of awareness raising approaches	Webpages
	Brochure is planned for distribution end of 2008. Information campaign from Department of Labour Inspection to inform about waste burning and the combustion of biomass in small inefficient boilers.	
DE	The UBA has published a brochure on proper domestic combustion of solid fuels including appropriate disposal of resulting residues and manages a website with recent information on emissions from domestic combustion (e.g. dust) and latest developments Furthermore it is foreseen to include in the amendment of the 1. BImSchV the obligation to perform an expert consultation by the chimney sweeper, prior to putting into operation and changing of operator of any solid fuel driven heating installation. It is probable although not yet decided that a related information brochure will be developed for and distributed at this occasion as well.	Brochure, webpage, oral instructions
DK	National information campaign by Danish EPA to improve the firing habits (in winter, including local initiatives, leaflets, homepages and national TV-spots). The current campaign is strengthened considerably compared to previous. Awareness development and demonstration of new technologies including flue gas cleaning technologies for retrofitting on existing wood burning stoves and boilers	http://www.groentansvar.dk/Default.aspx?ID=417
EE	1. Guidance "Good practice in residential combustion" published in 2006 especially to reduce PM2.5 and PAH emission from domestic combustion. 2. "Guidance for energy saving in residential sector" published 2000 by Ministry of Economic Affairs.	
FI	Guidelines for wood burning	http://www.ytv.fi/NR/rdonlyres/0A8F7C38-4549-46D8-95D4-F48715868199/0/roksignaler.pdf
FR	ADEME implements communication campaigns **« Faisons vite. Ca chauffe ! »** and is present in internet to distribute information. "Practical guidelines" on the website of ADEME such as “Heating with wood” and “Heat and comfort without waste” give advice to the selection of heating appliances and good practice. Since 2004 the ADEME carried out numerous actions for awareness raising in the general population of their fundamental role for energy control and renewable energy sources development. With this campaign, the agency gives to the public information about wood heating, Flamme Verte, “NF wood for heating” mark and tax credit	http://www2.ademe.fr/servlet/KBaseShow?sort=-1&cid=96&m=3&catid=14288) http://www.ademe.fr/particuliers/fiches/chauffage_reg_eau/rub3.htm http://www.ademe.fr/particuliers/Fiches/chauffage_bois/index.htm http://www.faisonsvite.fr
IE	Several campaigns regarding illegal collection of waste and backyard burning using high profile media releases on television, radio and newspapers, advertisements, hotline, leaflets: 1. Race Against Waste campaign (MoE - DoEHLG) 2. EPA media campaign on backyard burning and illegal waste collection. 3. ‘Dump the Dumpers’ phone hotline 4. See something say something’ campaign	
IE	**Race Against Waste campaign** Department of the Environment, Heritage & Local Government’s campaign to raise awareness of waste issues	http://www.raceagainstwaste.ie/

MS	Description of awareness raising approaches	Webpages
	and change behaviour among people at home and at work in order to reduce the amount of waste being produced and increase recycling and composting. The campaign involved high profile media releases on television, radio and newspapers. Backyard burning was also covered under this campaign to highlight the risk of dioxin emissions from this activity.	
IE	**EPA media campaign on backyard burning and illegal waste collection** EPA's Office of Environmental Enforcement (OEE) ran two high profile media campaigns in the autumn of 2005 and 2006 regarding illegal backyard burning/dioxin releases and illegal waste collection. Advertisements were placed in 23 regional newspapers. Also, radio adverts were placed on 15 local stations. In the summer of 2007 the EPA ran amalgamated advertisements for backyard burning and illegal waste collection. The aim of these campaigns is to increase public awareness of the dangers of illegal burning and the problems of illegal waste and hence reduce the emissions from these practices	http://www.raceagainstwaste.ie/learn/backyard_burning/
IE	**Dump the Dumpers' phone hotline** The EPA launched this phone hotline in June 2006 to enable the public to call a lo-call phone number and report illegal waste activities. The phone line is operate don 24 hour basis to a lo-call number 1850 365121. Information received during phone calls is followed up and checked by the enforcement authorities – local authorities, the EPA's Office of Environmental Enforcement and the Gardaí through the Environmental Enforcement Network. A total of 2184 calls were taken between June 2006 and June 2007. A review of the operation of the phone service indicated that 70% of the calls are resolved. Approximately 75% of calls received during this period related to fly tipping and burning of waste.	Dump the Dumpers: http://www.epa.ie/whatwedo/enforce/report/illegaldumping/#d.en.23767
IE	**See something say something' campaign** A leaflet produced by the Environmental Enforcement Network (operated by the Office of Environmental Enforcement within the Environmental Protection Agency), to make it easier for members of the public to make an environmental complaint. The leaflet was launched by the Minister for the Environment, Heritage and Local Government in April 2007. Instances such as illegal burning of waste, illegal dumping and water pollution are examples of where the public can assist by informing the relevant authorities of the problem	See something say something: http://www.epa.ie/downloads/pubs/other/corporate/
IT	Public information and awareness for residential devices, in order to improve plant efficiencies, guide to the use of dry wood and prevent burning of plastics and painted wood.	(i.e. see http://www.provinz.bz.it/Umweltagentur/2902/FAP/herd_d.htm)
NL	Public information and awareness in the case of residential open fireplaces (in order to prevent for instance burning of plastics and painted wood).	
PL	GEF Project in the period of 2001-2004: leaflet on "Dioxins – human and environmental threats"; 2. PHARE 2003 in 2005/2006: "Clean energy for my house. Clean and cheap heat from coal"; 3. The project "Coal and clean energy" financed in 2007 by the Regional Fund for Environmental Protection and Water Management in Katowice 4. Project "Don't release pollutants – protect your health. Individual Heating versus the Environment and Human Health – pilot programme for selected municipalities of the Upper	Brochure "Good heat production practice in individual and municipal heating – solid fuels": ISBN: 83-918298-7-1 published in 2006 and 2007 http://www.polskiklubekologiczny.org

MS	Description of awareness raising approaches	Webpages
	Silesian Region" co-financed in 2008 by the UE funds; 5. Brochure "Good heat production practice in individual and municipal heating – solid fuels 6. **a brochure "Efficiency and environment friendly heat source – reduction of *low level emission*"; http://www.czestochowa.energiaisrodowisko.pl/** **TOPTEN contest– www.topten.org** **Means used: workshops, seminars, conference, leaflets, folders, brochures, educational films, questionnaire campaign, contest for producers of appliances"**	
SE	Regional and local authorities have arranged information campaigns on "good practice" for small scale wood combustion. 1. Measures for replacement of old small boilers by modern ones (fitted with accumulator tanks) proposed by the Swedish EPA, but not yet carried out. (would reduce also emissions of PCDD/Fs by improving combustion efficiency by avoiding smouldering fires to keep up temperature during the night etc.) 2. Campaigns to improve drying of fire wood and better operation of boilers. Both issues are overlapping and probably covered in the most of the campaigns.	exemplary and not exhaustive http://www.naturvardsverket.se/sv/Klimat-i-forandring/Minska-utslappen/Energieffektivisera-i-ditt-hem-bli-energismart/ http://www.naturvardsverket.se/Documents/publikationer/620-8028-8.pdf http://www.energimyndigheten.se/sv/Hushall/Din-uppvarmning/Biobransle---ved-och-pellets/Ved/Vedpannor-kaminer-och-kakelugnar/ http://www.skogsvardsstyrelsen.se/forlag/rapporter/1712.pdf http://www.vastragotaland.se/natur_miljo/miljosamv98/ved1.htm http://www.norsjo.se/PDF/PDF/Styrdokument/Klimatinvesteringsprogram%20f%C3%B6r%20Norsj%C3%B6%20kommun%202004-2006.pdf http://www.umea.se/samhallsservice/miljoochhalsoskydd/boendelokalerbyggnader/informationforhushall/atteldamedved.4.183d59c103d4d349c380003568.html http://www.t.lst.se/t/amnen/Miljoskydd/policydokument/vedeldning.htm http://www.miljosamverkanf.se/download/Projekt/Sammanst_atgarder_reg_miljomal_kommuner.pdf http://www.f.lst.se/NR/rdonlyres/2EAEC2F4-A953-435E-A261-7FA84EB85FEF/0/2007_37.pdf http://www.vallentuna.se/content.asp?menu=3&sidid=23&subsidid= http://www.hylte.se/admin2/files/20061128112318.pdf
SK	There exist a Biomass Strategy and energy saving campaigns, coordinated by the Ministry of Economy and the Air Protection Department of the Ministry of Environment.	

Table 3-3: Detailed information to awareness raising approaches to reduce dioxin emission in EU Member States

3.4 Research & development measures related to dioxins

MS	Description of research measures
AT	1. Study about emission values of wood stoves and coke oven 2. Project aiming at a new measuring campaign is planned. Financing issues have to be solved as measuring campaigns for POPs are depending on expensive measuring technology.
CZ	**Research project for evaluation of EF for dioxins and their relation with mass pollutants** (SO2, NOx, CO, PM and O2ref) **and energy efficiency in different common heating appliances** Four year project (Technical University of Ostrava) has started. Some most representative boilers have been selected and the measurement will be carried out at the test laboratory of the University of Ostrava. The project will be completed in 2010 and the Ministry expects first at the end of the year 2008.
DE	The FNR (Fachagentur Nachwachsende Rohstoffe) supports and subsidises the development of **abatement technologies and process optimisation for biomass combustion.** (www.fnr.de). The following results in this field could be achieved: 1. Development of a fabric filter for the application within small combustion installations which has meanwhile been tested with problematic fuels (e.g. straw, lopping) by "Oskar Winkel" GmbH. The results seem to be encouraging, but the costs are not insignificant. http://www.koeb-holzfeuerungen.com/kus_tree/powerslave,id,1.html) 2. Development of a small electric separator by Swiss EMPA (interdisciplinary research and service institution for material sciences and technology within ETH-Domain) which suits for single room combustion installation and small boilers. In Germany the device is currently distributed by "Kutzner and Weber" http://.kutzner-weber.de/deu/produkte/zumikron.htm 3. Prototypes for electro filters for boilers are tested by the company Spanner. http://www.spanner.de/?p=elektrofiler 4. Development of a wet scrubber "Schräder Hydrocube", which serves for heat recovery and up to a certain decree for dust separation. An increase of efficiency by electrostatic charging is currently tested http://www.schraeder.com/pdf/probe/HydroCube_AWT.pdf
DK	Development and demonstration of new technologies. 1) One 0,3 million € project on testing flue gas cleaning technologies, which can be mounted on existing stoves and boilers will start up next month by FORCE Technology in cooperation with the National Environmental Research Institute and Danish Technological Institute. 2) For the rest of the money, 0,9 mill. €, there will be an invitation for submitting tenders for any projects within the aim.
PL	1. Research study with Institute for Chemical Processing of Coal http://www.ichpw.zabrze.pl/ 2. Seminars and conferences organised, e.g. IX Scientific Conference on Dioxins in the Industry and in the Environment (June 2007 in Tomaszowice) http://www.dioksyny.pl/
UK	Work ongoing to improve lack of data on emission estimates

Table 3-4: Detailed information on approaches in the field of research and development

3.5 Labelling schemes

Eco-labelling of wood boilers and stoves in Austria

The guideline UZ 37 for woodstoves sets criteria for wood boilers and stoves in the framework of the Austrian eco-labelling scheme (Österreichisches Umweltzeichen). The guideline was updated in January 2008.

The following criteria are included:
1. Limit values for automatically and manual operated wood stoves heated with wood, wood pellets or wood chips.
2. Emission limit values for CO, NOx, TSP and TOC
3. Requirements for proper installation, operation, regular maintenance and for the use of appropriate fuels
a) The distributor has to provide information material about correct operation and maintenance
b) Regular and professional maintenance and control have to be provided by the selling company or information from which such maintenance can be obtained has to be given.

Consumer information on companies receiving the eco-label for wood stoves and additional information are provided on a separate webpage, being constantly up-dated.

Campaigns to inform stove/boiler producers about the possibility of eco-labelling have been realized
http://www.umweltzeichen.at

Applicance (automatically fed)	ELV [mg/MJ]		
	CO	NOx	Dust
Boiler (pellet)	60 (n), 135 (p)	100	15
Boiler	150 (n), 300 (p)	120	20
Roomheating (pellet)	120 (n)	100	30
Roomheating (wood chips)	255 (p)		

(n): at nominalload, (p): at partial load

Applicance (manually fed)		ELV [mg/MJ]	
	CO	NOx	Dust
Boiler	250 (n), 750 (p)	120	30
Roomheating	700 (n)	120	30

Box 3-1: Eco-label of wood boilers and stoves in Austria

The Blue Angel label in Germany

The Blue Angel environment label is sponsored and administered by the German Federal Environmental Agency and the quality assurance and product labelling institute RAL Deutsches Institut für Gütesicherung und Kennzeichnung e.V.

The Blue Angel was founded in 1978 and is the oldest environmental label. It involves more than 80 product categories and provides the following criteria for wood pellet stoves (RAL-UZ 111) and wood pellet boilers (RAL-UZ 112):

Emission limit values for CO, NOx, dust and organic substances/total carbon

Appliance	ELV[mg/Nm3]			
	CO	NOx	Organic substances Total carbon	Dust
Wood-Pellet Stoves (RAL-UZ 111)	180 (r), 400 (p)	150 (r)	10(r), 15 (p)	25 (r)
Wood-Pellet Boilers (RAL-UZ-112)	90 (r), 200 (p)	150 (r)	5 (r), 5 (p)	20 (r)

(r): at rated load, (p): at partial load

The energy efficiency for both types of heating systems has to be equal to or exceed 90% at rated and partial load.

http://www.blauer-engel.de/

Box 3-2: Details on requirements for heating installations in the official eco-label in Germany

DIN-Plus mark in Germany

In addition the quality mark DIN-Plus has been established for single stoves and very small appliances. This certification scheme "Wood Pellets for Use in Small Heating Systems" combines the requirements of the German standard DIN 51731 and the Austrian standard ÖNORM M 7135. In this way certification criteria are combined from two most recognized test specifications that currently exist for this product.

The certification scheme involves

Product test according to combustion requirements

Monitoring of quality assurance measures conducted at the production plant in the course of annual factory inspections, including sampling.

Applicance	ELV		
	CO	OGC	Dust
	at 13% O2; nominal load [mg/m³ dry gas]		[g/kg fuel]
Slow heat release applicance (manually feed)	150	2000	1 (nominal load)
Stove (manually feed)	150	2500	< 5 (3 low; nominal) < 10 (for each individual test)
Stove (automatically feed)	50	1000	< 5 (2 low loads; nominal) < 10 (for each individual test)
Inset (manually feed)	150	2500	< 8 (3 low; nominal) < 15 (for each individual test)
Sauna stove (manualyl feed)	1000	5000	< 8 (3 low; nominal) < 15 (for each individual test) < 8 (if only fired at nominal load)

Applicance	minimum efficiency [%]
Slow heat release fireplaces	≥ 78
Sauna stoves	≥ 60
Wood stoves and inset appliances	≥ 73
Pellet stoves	≥ 5

http://www.dincertco.de/en/competencies/products/solid_fuels_barbeque/wood_pellets_for_central_heating_boilers/index.html

Box 3-3: DIN eco-label for heating appliances in Germany

The Nordic Swan

The Nordic Ecolabel has been established in 1989 by the Nordic Council of Ministers and is locally implemented by the governments of Sweden, Norway, Iceland, Denmark and Finland. It is the official ecolabel in the Nordic countries.

Over 1000 licenses were provided just in Sweden alone, for a total of 66 product areas.

All Danish producers of wood stoves have eco-labelled all of their products, which is more than 150 models. The Danish EPA recommends to by eco-labelled stoves ever since the first stoves was eco-labelled in 2006

For heating systems it provides criteria for closed fireplaces (such as stoves, tiled stoves, inset fireplaces and even sauna stoves) and solid biomass boilers.

Criteria for closed fireplaces consist of limit values on air emission, limit values on noise and minimum requirements for efficiency.

Criteria for solid biofuel boilers consist of limit values on air emission and minimum requirements for efficiency.

Applicance	ELV			
	CO	NO2	OGC	dust
	at 13% O2 [mg/m3 dry gas]			
Automatic feed boiler (≤ 300 kW)	400	340	25	40
Manual feed boiler (≤ 100 kW)	2000	340	70	70
Manual feed boiler (< P ≤ 3000 kW)	1000	340	50	70

Particles and NOx emissions are only tested at nominal load

http://www.svanen.nu/Default.aspx?tabName=StartPage

Box 3-4: Details on requirements for domestic heating appliances in the official eco-label from the Nordic countries (Nordic Swan)

Swedish P marking system

The P-mark is a certification marking owned by SP (Technical Research Institue of Sweden) and SITAC (Swedish Institute for Technical Approval in Construction). This certification scheme not only includes requirements on emission and energy efficiency but also on construction, safety and operational reliability. Covers: pellet fuelled burners and boilers; pellet stoves; wood-fired room heaters.

http://www.sp.se/en/Sidor/default.aspx, http://www.sitac.se/eng/p-marking.asp

Appliance	ELV at 10% O2 [mg/m3 dry gas]			
	minimum energy efficieny [%]	CO	OGC	dust
Pellet burner		1500	50	
Pellet boiler	86/80	1500	50	
Pellte stove	75	2000	75	100
Wood-fired room heater	70	0,30%	200	

Eco-labelling of wood combustion installations in France

“Flamme verte” (Green Flame) is a voluntary agreement created in 2000 by French public authorities and manufacturers of wood combustion installations (closed fireplaces, inserts, stoves, cookers and boilers), in the purpose of improving the performances of these appliances. Currently, more than 50 European companies sell appliances with the “Flamme Verte” label.

Performance criteria to be “Flamme verte” labelled are continuously brought up: see table below presenting the evolution of the minimum efficiency and the maximum CO rate.

Continuing improvements of performances	2004	2005	2006	2007	2008	2009
Minimum efficiency [%]	60	65	65	70	70	70
Maximum CO rate* [%]	1	0.8	0.6	0.6	0.6	0.3
*percentage of smoke volume						

To be “Flamme Verte” labelled, wood heating appliances must be comply with established standard, respect the threshold of minimum efficiency and not exceed a maximum pollutants rate. Requirements for boilers are presented below

Boiler type		Efficiency [%]	Emission limit values [ppm]		
			CO [ppm]	VOC [ppm]	dust [mg/m3]
Manual	Pn < 50 kW	70	6 500	225	165
	50 kW < Pn < 70kW		3 750	150	
Automatic	Pn < 50 kW	75	4 000	150	
	50 kW < Pn < 70kW		3 500	115	
Pn = Nominal Power					

See http://www.flammeverte.org

Box 3-5: Details on requirements for domestic heating appliances in the official eco-label from France

Industry organisations: EFA, HETAS

EFA is the European association of fireplace-manufacturers. It has introduced a voluntary labelling scheme to ensure high-quality fireplaces in Europe, including requirements for emission and efficiencies. http://www.efa-europe.com/

The Heating Equipment Testing and Approval Scheme (HETAS) is an independent organisation for setting standards of safety, efficiency and performance for testing and approval of solid fuels, solid mineral fuel and wood burning appliances and associated equipment and services for the UK solid fuel domestic heating industry. http://www.hetas.co.uk/

Box 3-6: Details on requirements for domestic heating appliances in voluntary industrial labelling schemes

Parameter	Boiler type	
	Batch	Automatic
Heat efficiency:		
for 30-60% loading	>65	>70
for 100% loading	>75	>78
Emission factors [g/GJ]		
CO	<2000	<1000
NO2	<150	<200
SO2	<400	<400
Dust	<120	<100
Organic pollutants:	<80	<50
16 PAHs	<1.2	<0.8
B-a-P	<0.08	<0.05

Box 3-7: Details on requirements for domestic heating appliances in voluntary labelling in Poland **Environmental Safety Certificates of ICCPC" granted since 1999 by the Institute for Chemical Processing of Coal in Zabrze**

3.6 Subsidies for purchase of heating appliances

Financial energy assistance in France

Wood combustion appliances which comply with some efficiency and emissions criteria can benefit from the following financial assistance:

- VAT reduction from 19.6% to 5.5%.

- Tax credit of 50% of the cost of the appliance (from 2005)

These two conditions apply only if the appliance is being installed by an accredited supplier (and not by the consumer himself) in the main residence of the consumer ("residence principale"), and if the consumer is a French taxpayer. In practice the consumer needs to pay all of the costs (with VAT at 5.5%) and claim the tax credit against the next tax submission. The stove supplier should provide the necessary paperwork.

The tax credit is granted from 2005 and is valid until 31st December 2009.

All "Flamme Verte" labelled appliances can benefit from these subsidies.

NB: a grant from the ANAH (National agency for improvement of habitat) is also possible when renovating or installing appliances. It is attributed to homeowners of dwellings older than 15 years.

Box 3-8: Details on subsidy programme for domestic heating in France

Subsidy programme for small biomass combustion in Germany

Introduced by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) and managed by the Federal Office of Economics and Export Control (BAFA).

The programme is announced via press releases and then spread due to advertisement and articles in professional journals and newspapers. Further information channels are associations, installer, mechanics and manufacturer for which the subsidy programme is a good selling argument.

Detailed information and application forms can be downloaded at the webpage of BAFA, which manages a hotline for information purposes as well.

http://www.bafa.de/bafa/de/energie/erneuerbare_energien/biomasse/index.html;

hotline: +49 616 908 625

Since the year 2000, 158,000 biomass installations could be supported. The most of the installations are very small appliances. The majority of the installations are operating with wood pellets, but the installation of wood chips and manually operated split log installation are supported as well. The number of subsidised installations generally increased within the last years and conditions for subsidies have been changing several times. Up to now a budget of 42 Million Euro was spend within the programme. Specifications to the programme are as follows:

1. Basic funding

1.1 Automatically fed biomass installation from 5 kW to 100 kW nominal power

The funding of automatically fed biomass installation with power and heating regulation and automatic ignition to the combustion of solid biomass (with the exception of wood chips) for heat generation with an installed nominal power of 5 kW to 100 kW (also combination boiler) amounts to € 36 per kW of established installed nominal power.

The following minimum funding amount applies: pellet ovens: € 1,000, pellet boilers: € 2,000

For pellet boilers with new installed buffer vessel with a storing volume of minimum 30 l/kW: € 2,500

Airs fed pellet ovens are only fundable from 8 kW on.

1.2 Automatically fed biomass installation from 5 kW to 100 kW nominal power for heating with wood chips:

The funding consists of € 1,000 as a lump sum. Only installations are fundable which dispose of a buffer vessel with a storing volume of minimum 30 l/kW.

1.3 Split log gasification boiler from 5 kW to 100 kW nominal power:

The funding is € 1,125. Only installations are fundable which dispose of a buffer vessel with a storing volume of minimum 55 l/kW.

2. Bonus funding

Particularly innovative or efficient biomass installations can be subsidized in addition to the above mentioned basic funding by bonus funding.

2.1 Regenerative combination bonus: In addition to the basic funding for a solar installation, a bonus of € 750 can be granted if coevally a fundable biomass installation is established.

2.2 Efficiency bonus: A precondition for granting the efficiency bonus is that the biomass installation is established in a building which shows a very low need for primary energy verified by a pursuant attestation.

2.3 Bonus for particular efficient circulation pumps: If coevally with the establishment of a fundable biomass installation a particular efficient circulation pump is integrated a bonus of € 200 per heating system can be granted.

3. Heat from renewable energies in schools and churches

In the context with the establishment of a fundable biomass installation in schools, universities, professional schools, public career development centres and similar institutions as well as churches, additional educative measures (such as display panels) can additionally be funded with a maximum of € 2,400.

Box 3-9: Details on subsidy programme for domestic heating in Germany

3.7 Information on effectiveness of taken measures

MS	Information on effectiveness
AT	Information may be available on Länder level; evaluation of subsidies done primarily with respect to GHG mitigation. In respect to the subsidy programme for wood chip and pellet stoves the following data is available: - The “Pro-Pellet Verband Austria” has available data for the amount of sold pellets, this being an indication for the increasing use of such boilers and stoves over the last years. - The “Landes-Landwirtschaftskammer Niederösterreich” has available such data for small biomass heatings ("Biomasse - Heizungserhebung 2006) - Also data for the sold pellet stoves are available with the “Kesselverband ÖROK”, but data is confidential. In 2007 the amount of sold pellets boilers decreased after showing an increase in the last years. There are two explanations: 1. The price of pellets raised in 2006 having an effect on the usage in 2007. 2. Users who wanted to renew their heating systems to pellet stoves have already done this in previous years. http://www.energieklima.at/fileadmin/user_upload/pdf/Biomasseheizungserhebung.pdf
DE	Since the year 2000, 200,000 end-users applied for a financial subsidy and 158,000 biomass installations could be supported. The most of the installations are very small appliances. The majority of the installations are operating with wood pellets, but the installation of wood chips and manually operated split log installation are supported as well. The number of subsidised installations generally increased within the last years and conditions for subsidies have been changing several times. Up to now a budget of 42 Million Euro was spend within the programme. http://www.bafa.de/bafa/de/energie/erneuerbare_energien/biomasse/index.html
DK	According to the evaluation of last years public awareness and behaviour has improved due to national information campaign
FI	Information on effectiveness available
FR	Dioxins and furans emissions from combustion are in 2005 57% smaller than in 1990. This is due to the decrease in wood use (-11% on the 1990-2005 period) and the decrease of coal consumption (0% in 2005). Improvement of equipments fuelled by wood has contributed to the reduction of dioxin emissions.
PL	The pilot programme on “low emission abatement in the peripheral districts of the Tychy city”, realised in 2002-2004, is one of the projects financed by Regional Fund for Environment Protection and Water Management under the programme on emission abatement through the use of low emissive heat sources, fuelled with coal, realised in the Silesian Region, which resulted in the 90 % reduction of annual sum of CO, SO2, NOx and coal dust emission. Dr. Krystyna Kubica (kkubica@interia.pl) from the Silesian University of Technology
RO	Emission reduction effect (calculated data) In air: 5.140 mg TEQ/TY (2000) to 5.106 mg TEQ/TY (2005) In residues: 0.136 mg TEQ/TY (2000) to 0.130 mg TEQ/TY (2005)
SE	No
UK	1. Clean Air Act 1956 improved the efficiency of appliances hence reducing domestic solid fuel use for the same energy output and prevented the use of bituminous coal on domestic open fires. This has led since 1994 to a requirement that fuels used in smoke control areas – predominantly the urban areas of the UK have less than 2% sulphur on a dry basis. 2. UK waste strategy improved recycling rates and increased public awareness of

MS	Information on effectiveness
	environmental issues with waste disposal hence hopefully reducing illegal burning of waste.

Table 3-5: Detailed information on effectiveness of reduction measures taken by EU Member States

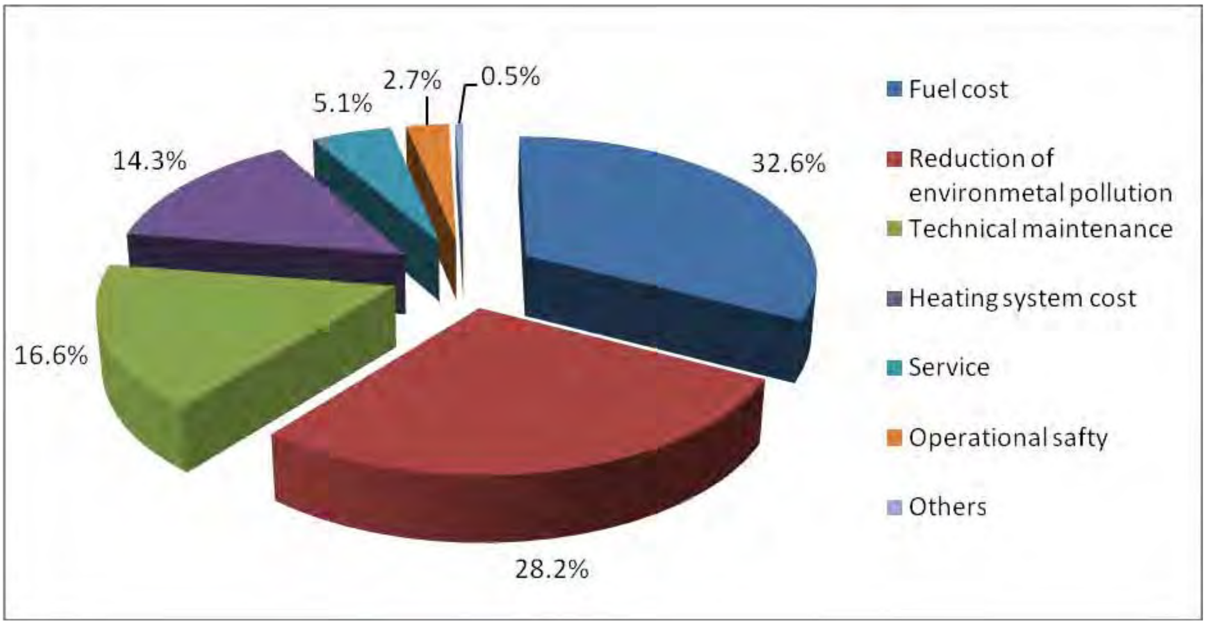

Figure 3-1: Effectiveness evaluation of awareness raising measures related to domestic combustion in Poland (presentation Kubica)

3.8 Major problems and obstacles for emission reduction

MS	Major problems and obstacles for emission reduction
AT	Any regulations have to be adopted by nine Länder; details of the regulations are usually different if not covered by a formal agreement between the Länder; no jurisdiction of the Federation on this issue.
BE-WA	1. Essential competencies regarding emission abatement have been transferred in exclusive manner to the federal entities. So, it is necessary to negotiate and coordinate action even within Belgium. 2. Lack of information of the public on the role of domestic sources and what they can do to minimise them 3. Difficulty in enforcing the interdiction of backyard burning of waste
BG	Main problem is lack of central heating in many populated places and the use of solid and liquid fuels in the domestic sector. In many populated places there are distribution networks for natural gas but for single family house to build this kind of installation is very expensive.
CY	1. Too many domestic sources to control 2. Need of alternative options to dispose of waste instead of backyard burning of waste 2. Heating systems in Cyprus mainly operated with Diesel. Due to the climate, household heating is not a big issue in Cyprus. However, there is concern in Cyprus about the increasing use of biomass in boilers for central heating. Using biomass eliminates cost and CO2 emissions, but increase POPs emissions, especially PAH if boilers are not very efficient.
CZ	1. Obligation (Operators of small combustion must comply with permissible smoke blackness) is not applied to operators of small sources (family houses, apartments, buildings for individual recreational purposes). 2. Insufficient inspection of domestic combustion sources operation and type of used fuels. It is difficult to force the operators (owners) of the domestic sources to burn the prescribed fuel only and to respect the proper operation conditions (prescribed by boilers producers)
DE	1. No emission limit values for POPs in small scale residential combustion yet (planned amendment of 1. BImSchV expected reductions are expected by lowering the minimum capacities to comply with emission

MS	Major problems and obstacles for emission reduction
	limits and reduction of emission thresholds for CO and dust which correlate to certain extend with POPs emission) 2. Widespread small and diffuse sources 3. Existing facilities with limited potential for retrofitting 4. Awareness raising of high importance for emission reduction or prevention
DK	Difficult to control if population is following advises. It is also very difficult to control if the population is obeying the ban on burning waste, including waste wood etc.
IE	The promotion of biomass in the domestic sector as part of climate policy may increase emissions.
IT	Notwithstanding wood limitation due to concern for local air quality (PM and VOCs) the use of wood in the domestic sector is expanding due to the low price of wood energy and the constant increase of gas and liquid fuel cost.
NL	1. Sources are domestic - legal measures difficult to take 2. Measures are taken on voluntary basis by public information and awareness 3. Some measures may be possible through product policy. This is considered to be more an EU task than a national one (common market issue).
PL	1. Estimated that around one third of emissions of dioxins to the atmosphere are due to non-industrial sources. Many of their sources are non-point sources, which are difficult to monitor and control. 2. Economic and financial obstacles.
RO	Lack of measuring equipment and public education.
SE	Firewood, wood chips and wood pellets used as domestic fuel mainly in rural areas. Rising prices on electric power started replacement by pellets and geothermal heating by heat pumps for small houses also in densely built-up areas. Old small boilers have since identified as significant source of PAHs (measures of replacement proposed) Main obstacle is costs: Elder people in rural areas are not financially, physically mentally strong enough to carry out modernising their heating systems as long as they can provide enough heat. It is politically not attractive to raise demands on elder people. Younger people can see advantages of reducing costs in long run, improve air quality, reduce CO2 emissions by efficiently using bio-fuels. Subsidies one way. Forbidding existing systems more difficult.
SI	Domestic sources equally treated as other dioxin sources (e. g. public power/heat plants, industrial combustion, production processes, road transport, waste treatment). Programs are ready but need approval by government.

Table 3-6: Specifications of information on effectiveness of measures

4 Annex exemplary oven standards

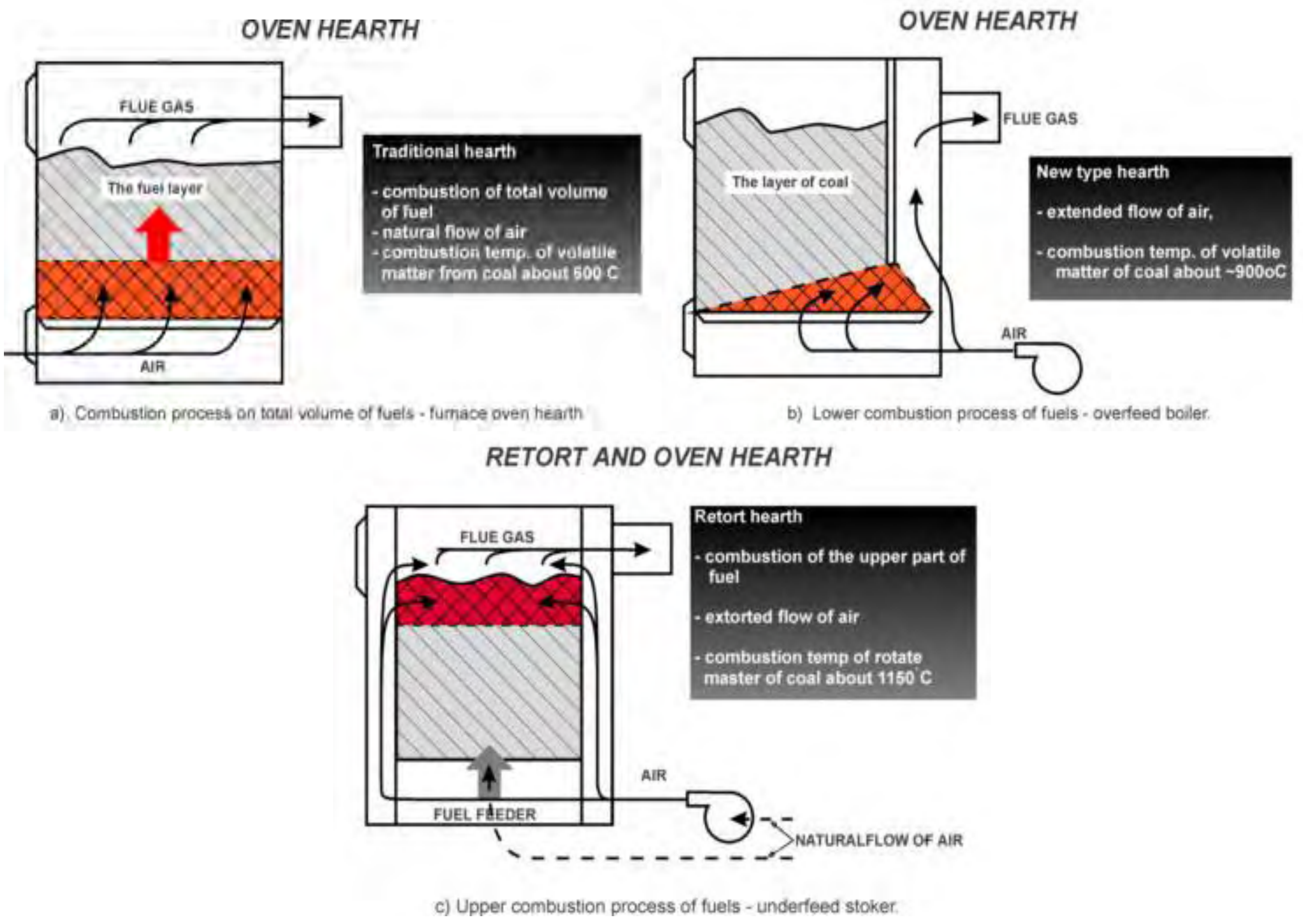

Figure 4-1: Standard and advanced types of solid fuel fired domestic ovens in PL (Ref.: Kubica K., (2003/1); "Environment Pollutants from Thermal Processing of Fuels and Biomass, *in* Thermochemical Transformation of Coal and Biomass; pp 145-232, ISBN 83-913434-1-3, Publication, Copyright by IChPW and IGSMiE PAN; Zabrze-Kraków; 2003, (in Polish)

5 Annex Exemplary legislation for emission reduction from wood fired appliances (DK)

Regulation for the use of solid fuel appliances in Hvidovre Municipality

Background and legal authority
Improper use of stoves, firewood boilers, fireplaces and other solid fuel stoves often leads to smoke nuisances for the neighbours, as well as increased emissions of harmful particles into the environment.

Several national campaigns launched by the Danish Environmental Protection Agency (last www.fyrfornuftigt.dk) and local campaigns launched by the Hvidovre Municipality (Fire Properly) has submitted the correct use of solid fuel appliances. The municipality, however, still receives a large number of complaints about smoke nuisances from solid fuel appliances in residential areas.

This regulation is based on section 12 § 1 of the Environment Ministry Order No. 1432 of 11 December 2007 on regulating air pollution from solid fuel burning furnaces and boilers and other fixed installations for energy production (The Wood Burner Order).

The regulated area

§ 1. The regulation is in force for the following types of residential areas in Hvidovre municipality (according to the municipal scheme):

- Open and low residential areas
- Dense and low residential areas
- Allotment garden areas

Subsection 2. The regulation sets rules for the use of solid fuel stoves for the in § 1 mentioned residential areas.

Subsection 3. Owner and/or the user of a solid fuelled appliance are responsible for the observation of the regulation.

§ 2. In case of doubt, Hvidovre municipality decides whether a solid fuelled appliance or the use of a solid fuelled appliance, is covered by this regulation.

Definitions

§ 3. In the document, the terms
1) *solid fuelled appliance*, means any form of combustion appliance for solid fuels, including wood stove, wood boiler, fireplace, solid fuel boiler, masonry stove, stoker boiler, pellet boiler and the like.

2) *waste wood*, means any type of treated wood, e.g. impregnated wood, painted wood, painted an lacquered wood, glued wood, particle boards, MDF boards, laminated boards, sawdust and Wooden pallets.
3) *household waste*, means any type of waste generated in an ordinary household, e.g. milk carton, cardboard, plastics, coloured and glossy circulars and magazines.

Firewood Types

§ 4. Only clean wood is allowed fuel in solid fuel appliances, e.g. firewood, wood pellets and wood briquette.
Subsection 2. Only in the fuel types mentioned in § 1 as the producer of the appliance recommend, may be used.
Subsection 3. Coal, coke, waste wood or household waste is not allowed to burn in solid fuel appliances.

§ 5. The Wood must be adapted to burn chamber and the size, as the producer of solid fuel stove recommend.

Humidity and storage

§ 6. Only dry firewood with moisture content (water content) of less than 20% is allowed.

§ 7. The firewood shall be stored in a dry, well-ventilated place, for example, in a woodshed, in a carport or under lean-to, to avoid the dryness and quality to deteriorate.

Subsection 2. Newly felled and chopped wood shall be kept dry at least 1 year, before it may be used in solid fuel appliances.

Use

§ 8. Lightning up a solid fuelled appliance may be conducted only with dry brushwood, kindling wood, firelighter, crumpled newspaper or the like.
Subsection 2. Lightning up shall be made with plentiful air supply.
Subsection 3. Lightning up must last for maximum 15 minutes.

§ 9. The burn chamber must not be overfilled according to the manufacturer's instructions.

§ 10. Firing over night is not allowed. That is to fill up with firewood, and reduce the air supply to a minimum, in order to still have embers the next morning.

Chimney and smoke nuisances
§ 11. The smoke from solid fuel appliances may not give visible or smelling flue gas falling down at the neighbours.
Subsection 2. The current stack height should be increased if necessary in accordance with instructions from the municipality of Hvidovre.

§ 12. It must be ensured that the use of a solid fuelled appliance doesn’t give significant smoke

nuisances for the neighbours.
Subsection 2. The Hvidovre municipality decides in case of doubt whether a smoke nuisance is significant.

Physical conditions

§ 13. Hvidovre municipality may prohibit the use of a solid fuelled appliance if the local situation as terrain, location and height of buildings, trees, chimney, etc. is not suitable.

Subsection 2. In individual cases, the Hvidovre municipality can ban the use of solid fuel appliances during specific weather conditions.

Administrative decisions

§ 14. Hvidovre municipality may temporarily or permanently ban the use of solid fuel appliances that do not comply with the regulations or decisions under the regulation.

§ 15. Hvidovre municipality may, in exceptional cases give exemption from the rules in this regulation. Requests for exemption must be accompanied by a special justification.

§ 16. Decisions under this regulation shall be taken by the Hvidovre municipality.

§ 17. Decisions taken according to the regulation cannot be appealed to another administrative authority.

§ 18. The provisions of this regulation do not prevent, that the Hvidovre Municipality may require additional pollution control measures the stated in the regulation, according to Environmental Protection Act, § 42, subsection 1-4.

Penalty provisions

§ 19. Unless higher penalty is in force after other legislation, punishment is a fine for:
• burn anything other than clean wood in solid fuel appliances, according to § 4, subsections 1-3.
• burning of wet wood in solid fuel appliances, according to § 6, subsection 1.
• not storing the firewood appropriate, according to § 8, subsection 1-4.
• firing a solid fuel appliance over night, according to § 10.
• not increasing a chimney after an order from Hvidovre municipal, according to § 11 subsection 2.
• emitting significant smoke nuisances to neighbours, according to § 12 subsection 1.

Effectuation provisions
§ 20. The regulation comes into force on 1st December 2008.

Adopted by the Hvidovre Municipal Council meeting on the 25th November 2008.

Milton Graff Pedersen	Anders Thanning
Mayor	Technical Manager

6 Annex Questionnaire

Questionnaire on dioxin releases from domestic sources **Related to "Information exchange on reduction of dioxin emissions from domestic sources"** **Project on behalf of the European Commission, DG Environment (Ref: 070303/2007/481007/MAR/C4)** 08 January 2008		
1	**Please provide name and contact data of answering expert:**	
Name of Institution		
Country		
City/ CIP Code		
Street		
Competent contact person		
e-mail		
Tel		
Remark		
2	**Did you establish a national emission inventory on dioxins?**	
☐ yes	☐ no	☐ unknown
3	**If yes, does it contain domestic emission sources (SNAP 0202, 0809; IPCC 1A4b)?**	
☐ yes	☐ no	☐ unknown
4	**If yes, please provide the corresponding information sources** **e.g. a report including information on methodology applied, emission factors and activity data used (please attach the document (preferably English version)** **or provide a web link (preferably English version):**	
Please answer here:		
4a	**If possible, please specify the methodology, emission factors (air, water, land) and activity data applied for SNAP 0202, 0809; IPCC 1A4b**	
Please answer here:		
4b	**If possible, please specify the specific sources (appliances) included in your reporting under SNAP 0202, 0809; IPCC 1A4b**	
Please answer here:		
4c	**If possible, please specify whether and how you address and estimate open burning of waste (backyard burning) in your national emission inventory**	
Please answer here:		
5	**Please specify major data gaps, problems and obstacles encountered in your country in estimating dioxin emissions from domestic sources:**	
Please answer here:		

6	**Please provide name and contact data of the expert(s)/institution(s) responsible for emission calculation and familiar with the methodologies used for domestic sources SNAP 0202, 0809; IPCC 1A4b (please copy the following lines if you provide contact data of several experts/institutions):**
Name of Institution	
Country	
City/ CIP Code	
Street	
Competent contact person	
e-mail	
Tel	
Remark	

7	**Have measures been taken in your country to reduce emissions from domestic sources? (e.g. legal measures addressing CO, dust (e.g. specific limit values), specific measures for mercury, chlorine, sulphur content, educational measures (information brochure on proper heating with solid fuels, information brochure on domestic burning of waste), incentives to change either heating appliance or fuel (e.g. eco-label, subsidies for purchasing new heating appliances), etc.)**	
☐ yes	☐ no	☐ unknown
7a	**If yes, please list each measure with date of implementation, responsible institution and contact data.**	
Please answer here:		
8	**Do you have information on the effectiveness of measures?**	
☐ yes	☐ no	☐ unknown
8a	**If yes, please specify with data (emission reduction effect, scope, costs) by measure if possible.**	
Please answer here:		
9	**Please specify any obstacles in your country in better addressing domestic sources:**	
Please answer here:		

7 Annex Workshop results and participant list

EU Project
Information exchange on reduction of dioxin emissions from domestic sources
Monday 7 July 2008, from 10:00-17:00
Brussels

MINUTES

1. Participants

The workshop was attended by 34 participants from DG Environment, Member States, UNECE task force, UNEP Chemicals, industry, research and the project team (see annex).

The workshop discussed results on emission estimation and reduction measures and aimed at identifying good practice and options for further action.

Presentations covered project results as well as exemplary practice of emission estimations and emission reduction in MS. In addition one presentation focused on recent developments in the framework of the current UNECE Guidebook review process.

2. Results and conclusions on current knowledge and emission estimation

2.1. Measurements

- Results from dioxin measurement studies vary over large ranges. The workshop identified the following reasons:
  1. The generation processes of dioxins are still not fully understood.
  2. Emissions vary largely in the course of a combustion process. Combustion processes consist of distinct phases and each phase has its specific dioxin emission profile
  3. Insufficient specification of the fuel employed. Participants stated that combustion of wood with bark results in higher dioxin emissions than combustion of wood without bark. The need to further distinguish biomass with respect to EF was deliberated but was not finally agreed upon.
  4. Besides different types of boilers, furnaces, etc. post-combustion events strongly influence the quantity of dioxins measured in the exhaust fumes. Condensation processes in the chimney and adsorption to soot reduce the dioxin concentrations in the exhaust gas (length of chimney as important parameter). Memory effects from previous combustions are strong and may result in elevated dioxin concentrations for days or weeks.
  5. Study design, sampling points and sampling conditions influence measured dioxin concentrations and thus are an important parameter for comparability of

results. In order to facilitate the interpretation of results a scientific participant recommended to generally use the following approach: first measure history, measure simultaneously at 400° and at the top of the chimney

- A number of MS are planning measurement campaigns. In this context it was stated that a close cooperation might be very helpful to produce comparable results and to allow to cover a broader spectrum of conditions. Critical parameters for comparability are sampling and design. It was discussed, without reaching a conclusion, whether measurements should be performed under experimental conditions (disadvantage: link to real situation missing) or real life conditions (disadvantage: memory effect, adsorption of dioxins to soot). Future measurements should comprise additional POPs such as dl-PCB or HCB. The need for joint research action for improvement of EFs was highlighted and stressed. This activity could be performed under FP7.

- The workshop participants discussed whether the quality of the combustion process in a household stove or boiler as indicated by CO and PM levels in exhaust gases is correlated with dioxin emissions. In this context there was an agreement that CO and PM are useful indicators as to the quality of the combustion process but that they are inadequate to predict PCDD/PCDF concentrations in the exhaust gas.
  On the one hand, new ovens that are typically of high energy efficiency tend to emit less dioxin than old ones. On the other hand, low CO or PM levels in exhaust gases can still be associated with high dioxin concentrations. This issue is complicate by the fact that the formation of PCDD and PCDF follow different chemistries. Emissions of dibenzofurans show some correlation with the quality of the combustion process, whereas the formation of dibenzodioxins depends largely on the chlorine content of the fuel. Automated combustion processes are more stable concerning emissions. However, it does not necessarily result in a lower EF when compared to manual feeding. In conclusion, measures towards energy efficiency do not automatically imply reduced dioxin emissions.

2.2. Emission factors

- The EF applied by the MS for the determination of national dioxin emission inventories differ by at least one order of magnitude. An example is Belgium, where Flanders applies an EF of 100 µg TEQ/TJ for the combustion of coal in households whereas the Region of Brussels Capital applies a factor of 2150 µg TEQ/TJ for the same process. The workshop did not find a solution to reduce or further clarify the range of EFs applied in MS. Amendments in the emission reporting under EMEP in order to better highlight underlying EFs and activity data is envisaged but dioxins are not a specific focus of the work. The difference in applied units for reporting of EF was shortly addressed as a problem. It was concluded that reporting on PCDD/PCDF and dl-PCB should be on the basis of TEQ and caloric value of the fuel than on mass, i.e. in Terajoule and not in tonne.

- The development of appropriate EFs is a need for parties to the Stockholm Convention in order to be able to fulfil their reporting obligations. Under the international estimation tools work is ongoing to review EFs although changes of EFs cannot be expected for the near future. MS are very much welcome to participate in the intersessional work. The installation of an additional working group or exchange platform between involved MS authorities is not required. Existing international fora (UNECE, UNEP) offer sufficient possibilities for exchange and further work. Besides releases to water, residues and land (UNEP Toolkit) further information is deemed to be needed for estimation of activity data (UNECE task force). The UNEP representative stressed the need of improved reporting on releases to water and waste as obligation pursuant to Stockholm Convention requirements.

2.3.Activity data

- The need for accurate activity data (annual consumption) and the difficulties with generation of such data were highlighted as second major problem for generation of national emission inventories. Deficits in this field have even been considered as important as lacks of emission factors by certain participants. Biggest problems arise in the field of wood combustion and with respect to calculation of shares of specific types of appliances (stoves versus ovens and boilers; simple old fashioned versus modern advanced; manually fed versus automated) which would be needed to make use of the default emission factors provided in the UNECE Guidebook. An intensified information exchange on determination of these data and related costs would be desirable.
- In this context annual sales figures for specific appliances and census data were presented as appropriate tools for differentiation of the equipment pool and the evaluation of trends in composition of the pool. Comparison of waste generation and collection data were reported as means to generate consumption estimates for illegal waste burning.
- Increased prices for pellets and reduced quality are expected by a number of participants due to a strong request for pellets also from the industry sector.

3. Results and conclusions on reduction measures

The second part of the workshop discussed measures to reduce dioxin emissions from domestic sources. In order to meet EU policy objectives, MS are facing the need to raise energy efficiency and increase the use of renewables for energy production. These policy needs can cause a conflict towards the goal of reducing overall dioxin emissions. In this context increased wood combustion is an issue of major concern. In addition it has been reported that it was observed in work performed by JRC Ispra that insulation of chimneys seems to increase dioxin emissions due to a prolonged cooling down phase of the exhaust gases.

- **Change of fuel**. Switching to natural gas or oil as fuel for domestic heating would result in a major reduction of dioxin emissions. However, fuel prices and infrastructural problems prevent the general application of this measure. In particular, it can be expected that the combustion of wood and other biomass will increase. Consequently research and activities are directed towards improving combustion conditions for solid fuels in order to reduce the EFs. In this context improved standards for boilers were called for.
- **Regional bans of solid fuels**: like being applied in e.g. the UK, Italy and Ireland were shortly addressed. Based on the example of the UK it could be shown that dioxin emissions from small scale coal combustion have declined in association with a strong decrease of the consumption of different types of coal and a strong increase of use of natural gas. A direct correlation or quantification of effects however, was not provided.
- **Education on proper heating habits**. Associated problems with the combustion of biomass are acids, PM and PAHs, even more than dioxins. This is addressed besides limit values and labelling schemes, mainly by education on proper heating habits (such as sufficient air supply, proper storage of wood, operation at full load and installation of heat reservoir, etc.).
- **Elimination of combustion of waste or treated wood** in domestic appliances. Incineration of waste and waste wood in domestic heating appliances or as back-yard burning is generally seen as a potential major problem with respect to dioxin emissions but has not yet been quantified in the majority of Member States. The related measure taken in the majority of Member States is a ban of waste combustion, but it was agreed upon that enforcement is difficult in this field. Development of rapid testing methods to be able to detect illegal behaviour in ash samples is consequently a priority in Austria. The high costs for dioxin measurements are a general problem in this context.
- **Abatement technology** for private households was presented but it could not be clarified which would be the implications on waste management. The problem of management of filter ashes after installation of filters in small appliances has been questioned and might need to be further clarified.
- **Shift towards district heating**. Due to the lower dioxin emissions of large boilers or power plants and the established practice of flue gas treatment in this type of facilities, it was discussed whether a shift towards district heating could be an appropriate solution. In addition, district heating would avoid the illegal combustion of contaminated wood and waste. The UK is consequently planning to focus subsidy programmes on district heating facilities. With respect to Northern countries, participants pointed out that private households combust wood despite a well established infra structure for district heating. This is motivated by the free availability of wood that is used in order to save on the energy bill in peak times in winter.

Participants called for an evaluation of the reduction potential of geothermal energy as well as district heating with biomass versus decentralised heating.

- Strengthening the role of **chimney sweepers**. Chimney sweepers can play an important role in control of emissions, education and detection of illegal behaviour and so far only few MS take advantage of their potential. For this purpose development of a quick test for dioxin analysis in ashes is a priority measure in Austria. However, forcing citizens to change appliances is generally seen as politically difficult. Preparedness and possibilities to bear higher costs for heating in order to protect the environment is expected to be limited.

*****

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