

Section VI

**Guidance/guidelines by source category:
Source categories in Part III of Annex C**

**Part III Source category (c):
Residential combustion sources**

Table of contents

List of tables.....	i
List of boxes.....	ii
VI.C Residential combustion sources.....	1
Introduction	1
1. Releases of chemicals listed in Annex C of the Stockholm Convention from residential combustion.....	2
1.1 Emissions from the combustion of fossil fuel and biomass	2
1.2. Emissions from the combustion of mixed and contaminated fuels	4
2. Best available techniques	5
2.1 Fuels and appliances: General principles	5
2.2 Cooking and heating appliances.....	6
3. Best environmental practices.....	6
3.1 Combustion appliances and potential problems	6
3.2 Ventilation	7
3.3 Inspection and maintenance.....	8
3.4 Correct use of appliances and fuel.....	8
3.5 Education, awareness and training programmes	9
3.6 Residential combustion management	9
3.7 Management of releases to other media	10
4. Effective implementation of best available techniques and best environmental practices.....	10
References	12

List of tables

Table 1. PCDD/PCDF emission factors for fossil fuel combustion.....	2
Table 2. PCDD/PCDF and PCB emission factors for residential combustion.....	3
Table 3. PCDD/PCDF and PCB emission factors for different fuels	3
Table 4. Comparative PCDD/PCDF emission factors from the combustion of clean and contaminated wood	4
Table 5. Combustion appliances and potential problems.....	6
Table 6. Inspection and maintenance schedules	8
Table 7. Relation of PCDD/PCDF emission factors on PVC content in burned material	9
Table 8. Possible barriers and options for effective implementation of best available techniques and best environmental practices for residential combustion appliances	10

List of boxes

Box 1 Awareness raising and education: Case studies

11

VI.C Residential combustion sources

Summary

This section considers the combustion of wood, coal, gas, as well as other organic matter mainly for residential heating and cooking. Combustion takes place in hand-fired stoves or fireplaces or, in the case of larger central heating systems, in automatically fired installations. Studies have shown that significant levels of chemicals listed in Annex C of the Stockholm Convention are released from residential combustion sources. The amount of chemicals released depends primarily on the fuel used (household waste, sea-salt laden driftwood and treated wood are significant sources of PCDD/PCDF) as well as combustion efficiency. The efficiency of combustion depends upon the combustion temperature, how well the gases are mixed, residence time, sufficient oxygen and the fuel properties. Given their large numbers, residential combustion appliances contribute noticeably to overall releases of chemicals listed in Annex C.

The use of efficient combustion of clean, untreated fuels for cooking and heating is of primary importance for reducing the formation and release of chemicals listed in Annex C. Strategies to minimize releases of chemicals listed in Annex C from residential combustion sources include public education, awareness and training programmes on the proper use of the appliances, use of appropriate fuels and the health impacts from uncontrolled residential combustion. The abatement technologies commonly used in industrial settings are not generally available for smaller residential heating and cooking appliances. However, the use of well-designed stoves with good operation can be effective in reducing chemicals listed in Annex C, with the important added benefit of improving indoor air quality.

Best available techniques include enclosed low emission burners with ducted flues and the use of dry, well-seasoned wood. For countries or regions where these fuels and appliances are not available, best available techniques and best environmental practices for residential combustion include ensuring separation of household waste from fuel to avoid burning of such waste in cooking and heating appliances. In all countries the use of treated wood or sea-salt laden driftwood and the use of plastics as a firelighter or fuel should be avoided.

Cooking and heating with wood is a common and significant practice in all countries of the world. Any action for reducing the emissions of chemicals listed in Annex C from residential combustion will also have to take into consideration local social, cultural and economic factors. Case studies from Australia and New Zealand are provided to highlight this.

Introduction

Because it is cheap and readily available, biomass is used extensively as an energy source by low-income groups. In the developing world 75–80% of the population relies on wood and waste biomass as fuel for cooking and room heating. Furthermore, this dependence of the global rural population on biomass energy is not expected to decrease significantly for at least a century, and some studies indicate it may increase. In most cases waste biomass from agriculture and forests is used as fuel, but in certain regions of the world the demands of the domestic energy sector have put severe pressure on forest resources (Karve 2000).

Cooking stoves using biomass are generally crude in nature. In most cases they are simple structures consisting of three stones (i.e. open fires). There is no chimney or ventilation for smoke and soot, which means that any emission is inhaled directly by the people in the vicinity of the stove. Indoor air pollution (soot and smoke) produced by inefficient combustion of biomass fuels inside homes is an important public health issue. Studies conducted during the last two decades have revealed that poor indoor air quality is one of the major factors contributing to death, respiratory disease and the poor health of rural women and children in developing countries and among low income groups. In India, for example, 1.5% of total deaths among women are attributable to chronic diseases of the respiratory system.

The incidence of blindness and tuberculosis is greater among women using traditional stoves than for any other population group. Several recent studies have indicated a direct correlation between death and disease in infants and children and use of wood and biomass as fuel in the house. (Concern about the relationship between cooking and heating in developing countries, indoor air quality and public health led, in 2003, to the establishment of the Global Partnership for Clean Indoor Air (<http://www.pciaonline.org/> at Nov. 2006), which supports the development of clean and low-cost technologies for residential cooking and heating appliances.) In addition, household waste is being used as a source of fuel for cooking and heating, which can contribute to the formation and release of chemicals listed in Annex C from residential combustion.

1. Releases of chemicals listed in Annex C of the Stockholm Convention from residential combustion

1.1 Emissions from the combustion of fossil fuel and biomass

Residential heating and cooking takes place in a wide array of devices ranging from small, open pit stoves and fireplaces to large highly sophisticated wood-burning stoves and ovens. Because different countries use different terminology (e.g. stove, heater) the term burner is used as a generic description where appropriate.

Fossil fuel is used extensively for domestic heating, especially in developed countries and in countries with economies in transition. Coal, (light fuel) oil and (natural) gas are the main types of fossil fuel used for domestic heating.

Fossil fuel is burnt in devices from small stoker-fired furnaces to large, highly sophisticated boilers for central heat generation in large multi-unit residential buildings. Heat output is maximized when these appliances are well operated and maintained. Two general types of heating system are used and these are distinguished by the way the heat is transported and released. The so-called central heating systems, which usually use oil or gas as a fuel, use one large unit to heat water or air, which is then circulated through the building to release its heat in numerous decentralized radiators or ducts. These modern systems are typically highly efficient and fairly clean burning, leaving little or no residue for disposal.

The second type of heating system is mostly based on solid fuels (coal) and consists of individual stoves, which are located in each room of the building or inside the wall to provide direct access to several rooms at the same time. These stoves consist of fairly small furnaces but provide a system for air to circulate inside the stove and around the furnace. These systems are typically older, less efficient and less clean burning, and can generate bottom ash as a result of the nonorganic content of the fuel, which must be disposed of. Some of these systems are also capable of burning oil.

Polychlorinated dibenzo-*p*-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) may be formed as a result of incomplete combustion and are released primarily to air. In the case of coal combustion, residues may also be a potential release vector. Emission factors derived from studies in Europe are given in Table 1.

Table 1. PCDD/PCDF emission factors for fossil fuel combustion

Appliance type	Emission factors: $\mu\text{g TEQ/TJ}$ of fossil fuel burnt to air ^a	Concentration ng TEQ/ kg ash residue
High chlorine coal fired stoves	15,000	30,000
Coal-fired stoves	100	5,000
Oil-fired stoves	10	NA
Natural gas-fired stoves	1.5	NA

NA Not available.

a. TJ = terajoule = 1×10^{12} joule.

Source: UNEP 2005.

Biomass is a term used to describe natural organic matter such as wood, straw, coconut shell, husks, animal dung, etc. used as fuel in residential heating and cooking. In general, there is substantial variation and uncertainty associated with emission factors derived for residential combustion. The following is a summary of available data at time of publication grouped by fuel type and technology.

PCDD/PCDF emissions testing from home heating was undertaken in Austria (Thanner and Moche 2002). The assessment involved emission measurements from three different types of solid fuel stoves. The appliances included in the experiments were a new low-budget stove suited for all types of solid fuel, a cast-iron stove for coke approximately 20 years old, and a cast-iron stove approximately 10 years old. Measurements were conducted using coal and coke as well as wood, and all fuel was of regularly retailed quality. The samples were taken over a complete heating cycle, starting with the kindling of the fire and concluding when the fire had burnt out. The fumes were analysed for PCDD/PCDF and polychlorinated biphenyls (PCB); the ashes and the chimney soot were sampled after completion of each heating cycle and analysed for PCDD/PCDF and PCB. Emission factors are presented in Tables 2 and 3.

Only small amounts of the PCDD/PCDF and PCB formed during combustion of wood and fossil fuels were found in the ashes and chimney soot; over 90% of these pollutants were present in the gaseous and aerosol by-products. The remainder was mainly accumulated in the soot, while the ashes contained only insignificant amounts.

Measurements in the field with real-life appliances running under normal (i.e., realistic) conditions can yield substantially higher variations using the same type of stove and identical type of fuel. PCDD/PCDF concentrations ranging from 0.09 to 9.0 ng I-TEQ/MJ were recorded in a project surveying seven individual wood-fuelled heating devices conducted by a private institute.

Table 2. PCDD/PCDF and PCB emission factors for residential combustion

Fuel	PCDD/PCDF TEQ (I-TEF) ng/Nm ³ (0% O ₂) ^a	PCDD/PCDF TEQ (WHO) ng/Nm ³ (0% O ₂)	PCB TEQ (WHO) ng/Nm ³ (0% O ₂)
Wood	0.1–2.0	0.1–2.0	0.01–0.08
Coal	7.5–38.7	8.0–41.8	1.7–2.4
Coke	0.9–4.4	0.9–4.6	0.03–0.2

Source: Thanner and Moche 2002.

a. 1 ng (nanogram) = 1×10^{-12} kilogram (1×10^{-9} gram); Nm³ = normal cubic metre, dry gas volume measured at 0 °C and 101.3 kPa.

Table 3. PCDD/PCDF and PCB emission factors for different fuels

Fuel		PCDD/PCDF	PCB	
		I-TEQ ng/MJ ^a	WHO-TEQ ng/MJ	Σ Ballschmitter* ng/MJ
Wood	Median	n=8 0.27	n=3 0.01	n=3 65.2
	Average	0.32	0.01	50.3
Coal	Median	n=8 8.80	n=2 0.51	n=2 64.0
	Average	7.74	0.51	64.0
Coke	Median	n=4 1.53	n=4 0.06	n=4 82.0
	Average	1.47	0.06	81.1

* Source: Thanner and Moche 2002.

a. MJ = megajoule = 1×10^6 joule.

1.2. Emissions from the combustion of mixed and contaminated fuels

The European Emission Inventory reveals residential wood combustion to be one of the largest contributors to air emissions of PCDD/PCDF (Berdowski et al. 1997). Whilst special attention has been paid to the combustion of wood, it should be noted that material burnt often includes not only natural wood but also wood wastes coated and treated with different chemical compounds including organochlorines. Wood residues (waste and industrial) often contain various types of contaminants (chromated copper arsenate, pentachlorophenol, creosote, adhesives, resins, paint and other surface coatings). It is also common practice that any combustible material, including waste, be used as fuel (e.g. textiles, rubber, plastics, printed matter, packaging material, waste oil etc.).

Comparative emission factors were derived from studies carried out in different European countries for the combustion of treated versus untreated wood and is given in Table 4. Emission factors for releases with residues are given on the basis of measured concentrations in the ash and are not related to the heating value of the fuel.

Table 4. Comparative PCDD/PCDF emission factors from the combustion of clean and contaminated wood

Appliance type	Emission factors: $\mu\text{g TEQ/TJ}$ of biomass burnt to air ^a	Concentration: ng TEQ/ kg ash residue
Contaminated wood/biomass-fired stoves	1,500	1,000
Virgin wood/biomass-fired stoves	100	10

a. TJ = terajoule = 1×10^{12} joule.
Source: UNEP 2005.

Studies were conducted in the United States on residential wood combustion to find out whether PCDD/PCDF formation took place (Lavric, Konnov and De Ruyck 2004). Evaluations were made of soot scrapings from the chimneys of wood stoves from the central, eastern and western regions of the country. The average total PCDD/PCDF levels in chimney deposits were 8.3 ng/kg in the eastern region, 42.1 ng/kg in the central region and 10 ng/kg in the west. The wide variability was attributed to the differences in the design of different units and contamination of the fuel wood.

Measurable levels of tetrachlorodibenzo-*p*-dioxins (TCDD) have been found in chimney soot and in bottom ash from wood-burning stoves and fireplaces. Chimney deposits from residential wood burning have been found to have PCDD/PCDF congener profiles similar to those in flue gases from municipal waste incinerators. This indicates that wood used in residential combustion appliances may be highly contaminated, and inappropriate materials such as plastics may also be used as fuel sources.

Soot from two wood stoves in British Columbia, Canada, was analysed for PCDD. The soot from the wood stove burning salt-laden wood in a coastal area was found to have 20 to 90 times greater levels of PCDD than the stoves from non-coastal areas. The concentration of PCDD in fly ash increased when the concentration of chlorine (from sea salt) increased.

According to the data from chemical analysis performed in Poland, residential sources may emit stack gases containing about 3 times higher concentration of PCB than industrial sources (excluding manufacturing industries), about 2 times higher concentration of hexachlorobenzene (HCB) and 25 times higher concentration of PCDD/PCDF. The main reason for these high concentrations of PCDD/PCDF, PCB and HCB is the co-combustion of domestic wastes with hard coal or wood, generally in simple kitchen stoves or heating boilers (Lassen et al. 2002, 2003).

Co-combustion of wood or coal with domestic wastes takes place in rural and suburban areas located close to forests, in recreation houses and also in residential areas. Public statistics data give a value of

95,000 TJ for combined combustion of wood and peat. The contribution of the latter was considered to be small. According to expert estimates, about 15% of the total amount of burnt wood or coal is substituted by domestic wastes. The total amount of contaminated fuel is estimated at 9,500–19,000 TJ. PCDD/PCDF concentrations in stack gases from chimneys of stoves in Poland, where domestic wastes are co-incinerated, ranged widely from 0.32 to 77 ng I-TEQ/Nm³. Emission factors for hard coal ranged from 17 to 570 µg TEQ/Mg. Total annual emission of PCDD/PCDF in Poland from residential sources was estimated at 30 to 85 g I-TEQ. The PCDD/PCDF congener mass distribution profile in stack gas was similar to that recorded for flue gas from waste incinerators.

There is little control over emissions from residential sources. Most stoves and fireplaces are poorly operated with inadequate oxygen levels and low turbulence of burning gases (due to overloading or use of over-large wood feed items). In such circumstances combustion releases not only gaseous pollutants but solid pollutants containing PCDD/PCDF, which constitute releases to land.

2. Best available techniques

High-quality, efficient combustion in cooking and heating appliances is very important for reducing formation and release of chemicals listed in Annex C. For enclosed burners, this primarily depends on the combustion chamber temperature, the turbulence of the burning gases, residence time, excess oxygen and the type of fuel used. These parameters are governed by factors such as:

- Combustion technology (e.g. combustion chamber design, process control technology);
- Operating conditions (e.g. primary and secondary air ratio, distribution of the air nozzles);
- Load condition (full or part load);
- Fuel characteristics (shape, size distribution, moisture content).

Any recommendations made regarding best available techniques and best environmental practices for biomass or wood-burning appliances should take into consideration that dependence on biomass fuel for cooking and heating will remain common practice for many years to come in the low-income and rural communities. The implementation of the guidelines related to such appliances will depend on a range of circumstances, including socio-economic factors. As part of their national implementation plans, countries should undertake assessments to determine the possible socio-economic consequences of applying any new standards or regulations.

Replacing poorly designed stoves with improved stoves that burn fuel more efficiently will be an effective strategy for reducing releases of chemicals listed in Annex C, and has the added benefit of improving indoor air quality. In addition, some studies have indicated that improved designs save 50–80% fuel compared to traditional ones. Optimal designs for improved stoves can save fuel, reduce air pollution, be easy to manufacture, install and operate, and be affordable to rural users. Such designs would also improve safety by reducing direct exposure to flames and heat, and job opportunities through the production, sale and maintenance of improved stoves.

Designs for improved stoves should take into consideration the needs and concerns of the users. For instance, studies have shown that the users of improved stoves are concerned about fuel and fuel economy, pollution emissions, cost, cooking time, convenience of operation and maintenance, adaptability to existing kitchen utensils, fuel and cooking practices, ease of firing and control of heat level, and safety of operation. Efforts to design improved stoves need to take social, cultural, scientific, economic, ergonomic and health aspects into consideration.

2.1 Fuels and appliances: General principles

Best available techniques include enclosed, low-emission burners with ducted flues and the use of dry, well-seasoned wood. For countries with no greenhouse gas reduction requirements the use of cleaner-burning fuels such as liquid petroleum gas, natural gas, oil and kerosene may also be appropriate, although this requires appliances that can use these fuels.

For countries or regions where these fuels and appliances are not available, best available techniques and best environmental practices for residential combustion sources includes ensuring separation of household waste from the fuel used in the appliances to avoid burning of household waste in cooking and heating appliances. In all countries, the use of treated wood or sea-salt laden driftwood and the use of plastics as a firelighter or fuel should be avoided.

Measures to control emissions from waste gases are desirable but not recognized as common for domestic fire and combustion appliances. Large systems comparable to those used for industrial processes should be equipped with cyclones or fabric filters. It is noted that catalytic converters are available in some countries but are not routinely employed.

2.2 Cooking and heating appliances

For individual stoves and furnaces, emissions can be reduced by using optimized heating elements. Different installation types are available, varying by country according to general technical standards, social, cultural and economic background, and climatic conditions.

Optimized combustion technology should have the following characteristics:

- Good mixing quality of gas and air (high turbulence or mixing);
- Sufficient residence time in the hot zone;
- Minimal disturbance of the glow bed and homogeneous distribution of the primary air;
- Minimal residence time in the temperature range between 180 °C and 500 °C and minimal dust deposition ability;
- The emission stack should be kept clean and free of soot by ensuring complete combustion and regular cleaning (at least annually).

3. Best environmental practices

3.1 Combustion appliances and potential problems

Table 5 identifies some typical appliance problems that may cause the release of pollutants. Many of these problems are difficult for a homeowner to identify. This information should be provided by the manufacturer or retailer at the point of sale of these appliances. Public awareness through mass media can also be a good means of disseminating this information.

Table 5. Combustion appliances and potential problems

Appliances	Fuel	Typical potential problems
Central furnaces Room heaters Fireplaces	Natural or liquefied petroleum gas	Cracked heat exchanger Not enough air to burn fuel properly Defective/blocked flue Maladjusted burner
Central furnaces	Oil	Cracked heat exchanger Not enough air to burn fuel properly Defective/blocked flue Maladjusted burner
Central heaters Room heaters	Wood	Cracked heat exchanger Not enough air to burn fuel properly Defective/blocked flue

Appliances	Fuel	Typical potential problems
		Green or treated wood
Central furnaces Stoves	Coal	Cracked heat exchanger Not enough air to burn fuel properly Defective grate Defective or blocked flue Low-quality coal High moisture content of fuel
Ranges Ovens	Natural or liquefied petroleum gas	Not enough air to burn fuel properly Maladjusted burner Misuse as a room heater
Room heaters Central heaters	Kerosene	Improper adjustment Wrong fuel (not K-1) Wrong wick or wick height Not enough air to burn fuel properly
Stoves Fireplaces	Wood Coal	Not enough air to burn fuel properly Defective/blocked flue Green or treated wood Cracked heat exchanger or firebox Inappropriate fuel such as residential refuse
Water heaters	Natural or liquefied petroleum gas	Not enough air to burn fuel properly Defective/blocked flue Maladjusted burner

Source: CPSC 2004.

3.2 Ventilation

To reduce indoor air pollution, movement of air into and out of a residence is very important, helping to reduce the level of harmful pollutants indoors by carrying them up the chimney, stovepipe or flue to the outside. This also ensures adequate air for proper combustion, thereby reducing levels of pollutants.

Ventilation can be improved by:

- Using a hood fan over stoves to assist ventilation;
- Ensuring sufficient airflow into the house when an exhaust fan is used (e.g. by slightly opening a door or window, especially if other appliances are in use);
- For proper operation of most combustion appliances and their venting systems, the air pressure in the house should be greater than that outside. If not, the vented appliances could release combustion pollutants into the house rather than outdoors;
- Ensuring the vented appliance has the vent connected and that nothing is blocking it, and there are no holes or cracks in the vent;
- Opening the stove or heater's damper when adding wood allows more air into the appliance. More air helps the wood burn properly and prevents pollutants from being drawn back into the house instead of going up the chimney. Visible smoke or a constant smoky odour inside the home when using a wood-burning stove are signs that the stove is not working properly,

as is deposition of soot on furniture in the room where the stove is being used. Smoke and soot are signs that the stove is releasing pollutants into the indoor air.

Unvented combustion heaters or stoves should never be used in rooms where people are sleeping as this can result in exposure to dangerous or deadly levels of carbon monoxide.

3.3 Inspection and maintenance

Combustion appliances should be regularly inspected and maintained (Table 6) to reduce exposure to pollutants. It is important to clean chimneys and vents, especially when changing heating systems.

Table 6. Inspection and maintenance schedules

Appliance	Inspection		Maintenance	
	Tasks	Frequency	Tasks	Frequency
Gas hot air heating system	Air filters: clean/change filter Look at flues for rust and soot	Monthly as needed Yearly	Qualified person check/clean chimney, clean/adjust burners, check heat exchanger and operation	Yearly (at start of heating season)
Gas/oil water/steam heating systems and water heaters	Look at flues for rust and soot	Yearly	Qualified person check/clean chimney, clean combustion chamber, adjust burners, check operation	Yearly (at start of heating season)
Kerosene space heaters	Look to see that mantle is properly seated Look to see that fuel tank is free of water and other contaminants	Daily when in use Daily or before refuelling	Check and replace wick Clean combustion chamber Drain fuel tank	Yearly (at start of heating season) Yearly (at start of heating season) Yearly (at end of heating season)
Wood/coal stoves and residential boilers & furnaces	Look at flues for rust and soot	Monthly	Qualified person check/clean chimney, check seams and gaskets, check operation	Yearly (at start of heating season)

Source: CPSC 2004.

3.4 Correct use of appliances and fuel

It is important to understand and follow the operating instructions for all appliances and to use the recommended type of fuel.

Where available, seasoned hardwoods (instead of softwoods) should be used in wood-burning stoves and fireplaces. Hardwoods burn hotter and form less creosote (an oily, black tar that sticks to chimneys and stovepipes, posing a fire hazard).

Green, wet woods or salt-laden (sea) driftwood should be totally avoided. This is because green and/or wet wood burns less efficiently and may result in increased emissions of PCDD/PCDF. Comparative studies of wood from coastal versus non-coastal areas have further shown that sea-salt laden wood has higher chlorine content with increased PCDD/PCDF emissions (see also section 1.2) when burned.

Painted scrap wood or wood treated with preservatives are never to be burnt, because they could release highly toxic pollutants, including chemicals listed in Annex C.

It is important to avoid waste loads containing high chlorine content and/or bromine content, whether inorganic such as salts, or halogenated organics such as PVC (Lemieux et al. 2003). The co-incineration of waste is, however, common practice in solid fuel-fired appliances. It should be strongly discouraged through policies and awareness campaigns (see subsection 3.5 below). Many studies show that combustion of chlorine containing waste such as PVC, leads to increased formation of unintentional persistent organic pollutants as shown in Table 7 (Gullett *et al* 1999). A regulation specifying standard fuels could be implemented. This is also valid for such fuels as treated wood, waste oil, transformer oil, plastics and other combustible waste.

Table 7. Relation of PCDD/PCDF emission factors on PVC content in burned material

PVC content	[%]	0	0.2	1	7.5
Average Emission factor in I-TEQ/kg	[ng]	14	80	200	4,900
Range I-TEQ/kg	[ng]	2 – 28	9 – 150	180 – 240	3,500 – 6,700

Gullett *et al* 1999

3.5 Education, awareness and training programmes

Typically emissions of other pollutants (such as fine particles or carbon monoxide) drive regulatory efforts to improve emissions from residential combustion. Education, awareness and training programmes to improve understanding of best practices related to chemicals listed in Annex C should be a major component of such efforts (see case studies in Box I appended to this section).

Any education and awareness programmes are best developed in conjunction with local communities to ensure they are specific and useful. Key components of effective programmes include:

- Education and awareness on the appropriate use of fuel. Critical factors to include are:
 - Use of dry, well-seasoned wood, which will reduce PCCD/PCDF releases and can also give up to 40% more heat;
 - Use of cleaner-burning fuels such as natural gas for reducing releases of chemicals listed in Annex C;
 - The undesirability of burning of residential wastes in these appliances;
 - Effective operation of appliances to ensure complete combustion of fuel;
- Simple, easy-to-understand information on the effects of chemicals listed in Annex C on human health and the environment, and the significance of releases from residential sources;
- Programmes for those who sell and those who purchase and operate residential combustion appliances, highlighting the issues raised in subsections 3.1 to 3.4.

3.6 Residential combustion management

Complete combustion of fuel is important for ensuring low emissions and efficient operation of the appliance. This can be achieved by ensuring the following:

- Sufficient firing temperature;
- Sufficient airflow to provide enough oxygen for combustion;
- Avoidance of fuel overloading (more than the fire can burn efficiently);
- Sufficient mixing of air and the hot gases given off by the fire.

Specific measures to achieve these desired outcomes are:

- Good-quality, dry fuel;

- Collecting and seasoning wood to ensure it is dry when burnt;
- Ensuring adequate airflow (for example, preventing incoming air from being blocked by pieces of wood);
- Enough space in the firebox for optimal airflow.

3.7 Management of releases to other media

The primary emission of chemicals listed in Annex C from residential combustion is to air. Ash and soot are also released and, when arising from clean wood or biomass combustion, typically contain only small quantities of chemicals listed in Annex C. Minor amounts of ash may be safely used for fertilizer as long as it is not spread in the same place on a regular basis. Larger quantities should be disposed of in a sanitary landfill.

4. Effective implementation of best available techniques and best environmental practices

In most cases end-users of improved combustion appliances will have minimal or no understanding of the adverse health and environment effects of chemicals listed in Annex C. Increased awareness of these concerns can help in encouraging effective operation of these appliances, as well as avoiding such practices as using household waste as fuel. Governments should include in their training and awareness programmes information on the impacts of releases of chemicals listed in Annex C from residential combustion appliances such as stoves, ovens and other devices.

Possible barriers and options for effective implementation of best available techniques and best environmental practices are discussed by Atikullah S.M. and Eusuf M. (2003). These are summarized in Table 8 below.

Table 8. Possible barriers and options for effective implementation of best available techniques and best environmental practices for residential combustion appliances

Barriers	Options for effective implementation of best available techniques and best environmental practices
Mismatch between the appliance design and the types of fuel used and available	Appliance design should be specific to community needs. A detailed assessment of community needs should be undertaken before implementing any particular design
Lack of public awareness about improved technology	Governments and communities should use appropriate means (for example, mass media, awareness campaigns) to publicize and popularize improved appliances. Training programmes at the community level are important to ensure that the appliances are used appropriately and to eliminate the possible use of inappropriate fuel such as household waste
Lack of local capacity to maintain and repair improved appliances	Implementing training programmes to establish capacity for appliance maintenance and repair is important
Lack of resources to purchase, operate and maintain appliances	Those with limited income will only be attracted to improved appliances if they are convinced that such appliances will not be an extra financial burden and will be cost effective to maintain and use
Lack of understanding of the health impacts of chemicals listed in Annex C and other pollutants	Raise awareness on possible health impacts of indoor air pollution (including Annex C chemicals) due to the use of inappropriate household heating/cooking devices and fuels

Additional sources of information for clean burning and improved wood stove design are provided in the references.

Box 1 Awareness raising and education: Case studies

Whilst the regulatory approaches below focus on particles, they have important co-benefits for the reduction of PCDD/PCDF, which may be formed through incomplete combustion. Reduction of particle emissions will at the same time reduce also PCDD/PCDF emissions since PCDD/PCDF are adsorbed on particles.

Case study 1: New Zealand

Urban pollution due to emissions from residential wood combustion is a widespread problem. In New Zealand, many towns and cities suffer from poor air quality in wintertime due to emissions from domestic combustion for heating. Exceedances of the national environmental standard for fine particles of $50 \mu\text{g}/\text{m}^3$ (as a 24-hour average) are not uncommon and in some areas occur on more than 30 days a year. This has the potential to contribute to national PCDD/PCDF emission releases. The problem is largely historical, with a prevalence of uninsulated houses resulting from the plentiful (and in many cases free) wood or coal supply. This has important socio-economic considerations for local authorities charged with reducing air pollution.

An awareness raising campaign on emissions from residential combustion was carried out in four small towns in New Zealand in 2005/06. The key finding from the campaign was the importance of tailoring solutions to each local community (no “one size fits all”). This required engagement with key stakeholders such as community health professionals and trust organizations but was highly successful in creating positive synergies for community action and awareness.

Case study 2: Tasmania, Australia

In many parts of southern Australia, woodheaters are commonly used to heat houses. Launceston, Tasmania (population approximately 10,000) averaged up to 14 exceedances of the Australian fine particle standard per month in winter, primarily due to emissions from woodheaters.

In 2001, a woodheater replacement programme was introduced to improve air quality and since that time approximately 25% of woodheaters have been removed through financial incentives to replace older, polluting woodheaters with cleaner appliances. At the same time a targeted community education campaign was introduced (Launceston Air Quality website) as well as a regulation limiting particle emissions from new woodheaters to 4 g/kg (emission/kilogram of wood burnt).

A 2005 study found that the programme accelerated the existing trend away from older woodheaters and contributed to improved air quality. Although there are no data available there is likely to have been a reduction in dioxin emissions. In the year 2006, for the first time, Launceston did not breach the Australian fine particle standard.

References

- Atikullah S.M. and Eusuf M. 2003. "Biomass Crisis and Improved Stoves in Bangladesh." *Renewable Energy Newsletter* 1:2. Bangladesh Centre for Advanced Studies, Dhaka.
- Berdowski J.J.M., Baas J., Bloos J.P.J., Visschedijk A.J.H. and Zandveld P.Y.J. 1997. *The European Emission Inventory of Heavy Metals and Persistent Organic Pollutants*. Umweltforschungsplan des Bundesministers für Umwelt, Naturschutz und Reaktorsicherheit. Forschungsbericht 104 02 672/03. TNO, Apeldoorn, Netherlands.
- CPSC (Consumer Product Safety Commission). 2004. *What You Should Know about Combustion Appliances and Indoor Air Pollution*. CPSC Document 452. www.cpsc.gov/CPSCPUB/PUBS/452.html.
- Gullet *et al* 1999, Organohalogen and Compounds Vol.41, 157-168, 1999.
- Karve P. 2000. *International Conference on Biomass-Based Fuels and Cooking Systems (BFCS-2000): A Report*. solstice.crest.org/discussiongroups/resources/stoves/Karve_Conference/BFCSrprt.htm.
- Lassen C. *et al*. 2002. *Inventory of Dioxin and Furan Releases in Poland*. Report by Danish Cooperation for the Environment in Eastern Europe (DANCEE) and Ministry of the Environment Poland.
- Lassen C., Hansen E., Jensen A.A., Olendrzyński K., Kołsut W., Żurek J., Kargulewicz I., Dębski B., Skośkiewicz J., Holzer M., Grochowalski A., Brandte E., Poltimae H., Kallaste T. and Kapturauskas J. 2003. "Survey of Dioxin Sources in the Baltic Region." *Environ. Sci. Pollut. Res.* 10:49–56.
- Launceston Air Quality. www.launceston.tas.gov.au/airquality.php.
- Lavric E.D., Konnov A.A. and De Ruyck J. 2004. "Dioxin Levels in Wood Combustion: A Review." *Biomass and Bioenergy* 26:115–145.
- PCIA (Partnership for Clean Indoor Air). www.pciaonline.org/.
- RWEDP (Rural Wood Energy Development Programme in Asia). www.rwedp.org/p-stoves.html.
- Thanner G. and Moche W. 2002. *Emissions of Dioxins, PCBs and PAHs from Domestic Heating*. Monographs Vol. 153. Federal Environmental Agency, Vienna, Austria.
- UNEP (United Nations Environment Programme). 2005. *Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases*. UNEP, Geneva.
- www.pops.int/documents/guidance/Toolkit_2005.pdf.
- Other sources
- Government of Australia. 2004. *Hot Tips for Cleaner Wood Heating*. Natural Heritage Trust, Australia.
- Pfeiffer F., Struschka M., Baumbach G., Hagenmaier H. and Hein K.R.G. 2000. "PCDD/PCDF Emissions from Small Firing Systems in Households." *Chemosphere* 40:225–232.
- Design principles of wood burning cookstoves, PCIA website (Nov. 2006)
http://www.pciaonline.org/assets/20060710-Design_Principles_ES.pdf
- Biomass Energy Technology, http://www.rwedp.org/d_technodc.html (Nov. 2006)