

**Final Background Document
on the sector**

Wood Combustion in Domestic Appliances

Prepared in the framework of EGTEI

Prepared by CITEPA, Paris

Summary

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- Total activity (GJ/year) has to be estimated from 2000 to 2020 and distributed according to the different installations.
 - If no prevision on the structure of this sector is available (for 2005 to 2020), the proportions used in 2000 can be used. But total activity (GJ/year) should evolve.

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*The default data mean can be modified in a range of $\pm 10\%$.
 If a measure is missing in the document, national experts have to contact the Secretariat to add it in the background documents.*

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WOOD COMBUSTION IN DOMESTIC APPLIANCES

SNAP 02 02 02 + 02 02 05 or NFR 1 A 4 b i Residential plants

This sector covers the combustion of wood in domestic appliances with the use of furnaces, stoves, fireplaces, inserts, residential cooking and boilers. Thermal capacity of these installations ranges from 4 kW to about 75 kW. Primary emissions from this sector include particulate matter (PM), nitrogen oxides (NO_x), sulphur dioxide (SO₂), volatile organic compounds (VOC) and heavy metals (HM).

ACTIVITY : GJ of wood (GJ / year)

POLLUTANT CONSIDERED : VOC, NO_x, TSP, PM10, PM2.5

1 Data from the bibliography

1.1. Data currently used in the RAINS model [14] [21]

In all RAINS modules (PM, NO_x, SO₂ or VOC) the same activity data is included. However, in the PM module, additional distinction is made for fireplaces, stoves, etc.

The RAINS model developed by CIAM uses different values across European countries reflecting different operating practices, age of installations, etc. Two principal regions (country groups) are distinguished: Eastern and Western Europe, however, allowing for country specific values to be used. The control options considered in the RAINS model include two types (stages) of modern boilers/stoves to simulate the gradual replacement of old facilities and for fireplaces, an option of installing a catalyst or non-catalyst insert is added.

Wood combustion in domestic appliances is included in the RAINS category "Residential, commercial, institutional, agricultural use" and a distinction is made in sub-sectors: fireplaces, stoves, manual single house boilers and automatic single house boilers.

Activity unit used in RAINS: PJ of wood consumed.

1.1.1. Control options

ü *Particulate Matter:*

PM control options are considered for wood stoves and fireplaces while for boilers no add-on controls are included, instead a gradual replacement with newer/more efficient installations is taken into account.

Control options taken into account in RAINS for wood appliances are as follows:

- Measure 01: replacement with new domestic stove, non-catalytic with an efficiency of 63 percent.
- Measure 02: replacement with new domestic stove, catalytic with an efficiency of 65 percent.
- Measure 03: addition of an insert, non-catalytic with an efficiency of 44 percent.
- Measure 04: addition of an insert, catalytic with an efficiency of 47 percent.

For boilers no add-on controls are considered, however, a gradual replacement with newer/more efficient installations is taken into account.

The applicability of these control options depends on the country considered.

Ü VOC:

Two categories of control options are currently included in RAINS:

- Oxidation **catalysts** with an efficiency of 50 percent.
- **New boilers** with accumulator tank with an average efficiency of 80 percent.

These control options are only applied to boilers.

Ü NO_x:

No NO_x control options are taken into account for wood combustion in RAINS.

Ü SO₂:

No SO₂ control options are taken into account for wood combustion in RAINS.

1.1.2. Abatement measure costs

Examples for three countries are given:

*No comments are made on the figures displayed bellow because no further information is available.
Data at a country level are downloadable on
http://www.iiasa.ac.at/~rains/voc_review/single.html*

Ü Particulate Matter :

Table 1.1.2.1: PM abatement costs taken into account in the RAINS model

	control option	EF PM _{2.5} (t/PJ)	Technical eff. %	Unit cost k€ ₁₉₉₀ /t	EF PM ₁₀ (t/PJ)	Technical eff. %	Unit cost k€ ₁₉₉₀ /t	EF TSP (t/PJ)	Technical eff. %	Unit cost k€ ₁₉₉₀ /t
France										
Fireplaces	no control	279	0	0	288	0	0	300	0	0
	non - catalytic insert	156,24	44	585,01	161,28	44	566,73	168	44	544,06
	catalytic insert	147,87	47	884,61	152,64	47	856,96	159	47	822,68
stoves	no control	186	0	0	192	0	0	200	0	0
	new domestic stove, non-catalytic	68,82	63	142,5	71,04	63	138,05	74	63	132,53
	new domestic stove, catalytic	65,1	65	231,06	67,2	65	223,84	70	65	214,88
Small domestic boilers manual	no control	77	0	0	89	0	0	100	0	0
	cyclone	53,9	30	11,16	57,5	35,39	8,18	58,6	41,4	6,22
	Small domestic boilers automatic	77	0	0	89	0	0	100	0	0
Small domestic boilers automatic	no control	77	0	0	89	0	0	100	0	0
	cyclone	53,9	99	2,41	57,5	99,12	2,08	58,6	99,22	1,85
	bag house	0,77	30	2,76	0,78	35,39	2,02	0,78	41,4	1,54
Germany (New & Old Landers)										
Fireplaces	no control	77,19	0	0	79,68	0	0	83	0	0
	non - catalytic insert	43,23	44	2114,51	44,62	44	2048,43	46,48	44	1966,49
	catalytic insert	40,91	47	3197,37	42,23	47	3097,45	43,99	47	2973,55
stoves	no control	66,96	0	0	69,12	0	0	72	0	0
	new domestic stove, non-catalytic	24,78	63	395,84	25,57	63	383,47	26,64	63	368,13
	new domestic stove, catalytic	23,44	65	641,83	24,19	65	621,77	25,2	65	596,9
Small domestic boilers manual	no control	77	0	0	89	0	0	100	0	0
	cyclone	53,9	30	11,16	57,5	35,39	8,18	58,6	41,4	6,22
	Small domestic boilers automatic	50,05	0	0	57,85	0	0	65	0	0
Small domestic boilers automatic	no control	50,05	0	0	57,85	0	0	65	0	0
	cyclone	35,03	99	3,7	37,38	99,12	3,19	38,09	99,22	2,84
	bag house	0,5	30	4,23	0,51	35,39	3,1	0,51	41,4	2,36
Hungary										
Fireplaces	no control	279	0	0	288	0	0	300	0	0
	non - catalytic insert	156,24	44	585,01	161,28	44	566,73	168	44	544,06
	catalytic insert	147,87	47	884,61	152,64	47	856,96	159	47	822,68
stoves	no control	279	0	0	288	0	0	300	0	0
	new domestic stove, non-catalytic	103,23	63	95	106,56	63	92,03	111	63	88,35
	new domestic stove, catalytic	97,65	65	154,04	100,8	65	149,23	105	65	143,26
Small domestic boilers manual	no control	154	0	0	178	0	0	200	0	0
	cyclone	107,8	30	5,6	115,01	35,39	4,1	117,2	41,4	3,12
	Small domestic boilers automatic	77	0	0	89	0	0	100	0	0
Small domestic boilers automatic	no control	77	0	0	89	0	0	100	0	0
	cyclone	53,9	99	2,41	57,5	99,12	2,08	58,6	99,22	1,85
	bag house	0,77	30	2,76	0,78	35,39	2,02	0,78	41,4	1,54

ü VOC:

Wood combustion is included in the RAINS category "Commercial and residential combustion". No distinction is made between equipments. They are all taken into account under the term "boiler".

The costs of control options included in the RAINS model are derived from the NUTEK study [22] and are currently not country-specific. Unit costs defined by RAINS are presented in table 1.1.2.2.

Table 1.1.2.2: VOC abatement costs taken into account in the RAINS model

	control option	EF VOC (t/PJ)	Applicability %	Technical eff. %	Unit cost €/1990/tVOC
France, Hungary					
Small domestic boilers	no control	600	0	0	0
	improved boiler with accumulation tank	264	70	80	133
	oxidation catalyst	360	80	50	2475
	new boiler and oxidation catalyst	192	100	68	3127
Germany (New & Old Landers)					
Small domestic boilers	no control	600	0	0	0
	improved boiler with accumulation tank	456	30	80	133
	oxidation catalyst	510	30	50	2475
	new boiler and oxidation catalyst	438	100	27	2968

ü NO_x:

Wood combustion is included in the RAINS category "domestic, commercial and agricultural use". No distinction is made between equipments. They are all taken into account under the term "boiler". As no control option is taken into account in RAINS for NO_x, there is no abatement cost data available.

Table 1.1.2.3: NO_x emission factors used in RAINS model for wood combustion

	control options	EF NO _x (t/PJ)
France		
Small domestic boilers	no control	53
Hungary		
Small domestic boilers	no control	50
Germany		
Small domestic boilers	no control	75

ü SO₂:

Wood combustion is included in the RAINS category "domestic, commercial and agricultural use". No distinction is made between equipments. They are all taken into account under the term "boiler". As no control option is considered in RAINS for SO₂, there is no abatement cost data available.

Table 1.1.2.4: SO₂ emission factors used in RAINS for wood combustion

	control options	EF SO ₂ (t/PJ)
France, Hungary		
Small domestic boilers	no control	40
Germany New Laender		
Small domestic boilers	no control	30

1.2. Other data available in the bibliography

Costs presented in this study result from a bibliography survey and expert advices [1].

2 Short technology description

Various combustion devices are used in the residential sector. They are as follows:

Ü Domestic open fireplaces

This heat production device has low energy performances. The combustion quality is bad and the production of unburned gases important. Moreover, the suction due to the thermal draught of the fireplace leads to important thermal losses and to a bad distribution of produced heat. Domestic open fireplaces are essentially used for aesthetic reasons. It is not possible to distinguish them according to technical criterions like power, efficiency or autonomy.

Ü Stoves

Several types of wood stoves exist. They are more or less energy efficient. It is possible to distinguish the following ones:

- Conventional stoves:

They have low energy efficiency and the poor combustion control leads to significant pollutant emissions. Low prices and robustness are their main interest for public. Their thermal efficiency ranges from 40 to 50 % and their autonomy from 3 to 6 hours.

- Masonry stoves:

This equipment is made of materials able to accumulate heat (ex: faience, fire brick or certain volcanic rocks (Finish stove for example)). A rapid heating in large thermal mass of masonry materials is achieved. Heat is slowly released by radiation to the surrounding area, according to the needs. Their combustion efficiency ranges from 70 to 80 % and their autonomy from 8 to 12 hours.

- Stoves with advanced combustion:

These stoves are less polluting and have higher thermal efficiencies than masonry stoves. The main innovation is the multiplication of air inlets. Secondary pre-heated air (heat exchange with hot waste gases) insures a more complete combustion. Their thermal efficiency is quite high (near 70%) at full charge. However this combustion efficiency decreases at reduced charge and the autonomy is medium.

- Classic energy efficient stoves:

Their combustion efficiency is improved by the use of secondary air in the combustion chamber. Moreover, thermal retention is increased by the use of special materials for the fireplace covering. Their combustion efficiency ranges from 60 to 80 % and their autonomy from 6 to 12 hours depending on models and operating temperatures.

- Energy efficient stoves also called "fireplace stove":

These stoves are very similar to the former ones at a technical level. Their main characteristic consists in the use of hot plate zones and a space for wood storage. Their combustion efficiency ranges from 60 to 80 % and their autonomy from 6 to 12 hours depending on models and operating temperatures.

- Pellet stove:

These stoves clearly differ from typical stoves by the type of fuel used and by the performances obtained. Pellet stoves reach high combustion efficiencies by providing the proper air/fuel and mixture ratio in the combustion chamber at all times. Pellets burn providing a very good

combustion quality (less pollutants). Their combustion efficiency ranges from 80 to 85 % and their autonomy is important (one to several days).

Ü Domestic cooking

These appliances were used for meal preparation, for heating a room where it was standing. They have been slowly replaced by butane cooker and central heating with other fuel. However, they are still found on the market. They are distributed in two categories:

- "Simple" residential cooking:

They are equipped with a fireplace making possible food cooking and room heating due to a cast-iron plate and to an oven.

- "Boiler cooking":

They have the same functions as the former ones.

These two types of wood residential cooking are usually made of iron or steel and the combustion chamber is often covered with fire bricks. Their combustion efficiency ranges from 50 to 70 % depending on the type and quality of the installation and also the operation mode. Their autonomy is of few hours. Pollutant emissions are quite high in old installations while in the most recent ones, the use of secondary or tertiary air insures a better combustion control.

Ü Closed fireplaces

In closed fireplaces combustion temperature is 400 °C. The connection of a closed fireplace on hearth without caution can lead to disasters. This type of installation provides a circulation of ambient air which is heated at the device contact.

A closed fireplace is composed of :

- a hot-air outlet on the boot,
- a fresh-air inlet to be heated between the device and the lagging,
- a secondary air admission,
- a primary air admission for the combustion control,
- a fresh-air inlet to heat in the double lagging,
- a fresh-air inlet to heat by the sub foundation,
- a discharge of smokes,
- a hot-air flow system.

Their combustion efficiency ranges from 50 to 70% and even more for some of the most recent devices. This efficiency is better than insert's one.

Ü Inserts

Like closed fireplaces, the combustion temperature is about 400°C. Inserts are designed to be installed in existing open fireplaces. They can be embedded and are originally equipped with a system which ensures the circulation of ambient air around the device for its heating.

An insert is composed of:

- a hot-air outlet by the front of the edifice,
- a hot-air outlet frontal,
- a secondary air admission,
- a hot-air flow system around the insert,
- a primary air admission for the combustion control,
- a fresh-air inlet to heat ,
- a discharge pipe of smokes,
- a smoke circuit.

Their thermal efficiency ranges from 50 to 70% and even more for some of the most recent devices. This efficiency is worse than the closed fireplace's one.

Ü Boilers

Boilers have the best wood combustion efficiency of all domestic appliances. Several types of log wood boilers exist with various efficiencies. They generally differ by the type of combustion:

- boilers with overfire combustion and natural draught :

Their combustion mode is similar to those of common stoves and cooking. The fuel, piled up in the fireplace, ignites simultaneously without great distinctions of combustion phases. The

combustion is generally of medium quality, incomplete and irregular. Only low performances are obtained and pollutant emissions are high. It is impossible to keep the nominal charge steady during several hours. Finally the smoke temperature is very high. This can represent a risk. The combustion efficiency at nominal output is about 55% and the autonomy ranges from 4 to 8 hours.

- Boilers with underfire combustion and natural draught :

Their combustion mode is characterized by the spread of flames through and below the grating of the wood support. Wood can be dried before combustion. That leads to a slight improvement of performances and to less pollutant emissions. The combustion efficiency is in the order of 60% and the autonomy is reduced due to the small volume of the fireplace.

- Boilers with down draught and natural draught :

The particularity of this combustion mode is the spread of the flames through the grating of the wood support. With this combustion mode, wood can be dried above the fireplace before combustion. The location of primary and secondary air inlets is an important parameter. Good quality combustion is achieved, the pollutant emissions are limited except during reduced charge operations. Wood with higher moisture content can be used without high decrease of performances. The combustion efficiency reaches 65% and the autonomy is improved.

- Boilers with inverted combustion and forced draught also called "turbo" :

They are the most recent on the market. Their combustion mode is similar to the former ones. These contain a fan which improves the draught either by blowing the air of combustion or by sucking the combustion waste. This device improves the combustion and enlarges the range of thermal capacity. Forced draught gives more important exchange areas and increases heat recovery. Pollutant emissions are reduced. The combustion efficiency at nominal output is higher than 70%, the autonomy can reach 12 hours and the ash quantity is reduced. These boilers can be equipped with fans which work at the hit-or-miss mode or at variable speed. At low output, frequent starting can damage the combustion. This boiler type often presents higher energy efficiency than the former ones. They often need to be associated with hot water tank to secure their optimal work.

- Automatically stoked boilers :

They can only work with two types of fuels: wood chips or pellets. Pellets give a very good combustion quality. By-products from wood industry can be recovered with this type of wood fuel. Pellet costs are higher than wood chips or wood log costs and depend on their conditioning modes. Automatic boilers are the most recent on the market. They generally have a high level of autonomy. Inverted combustion is generally used with forced draught providing the best performances. The combustion efficiency ranges from 85 and 90% and the autonomy depends on the type of fuel used but ranges from 24 hours to all the heating season.

3 EU regulation

At a European level, there is no regulation for wood domestic appliances. However, European standards exist for boilers, stoves, residential cooking, inserts and fireplaces.

Boiler:

Boilers can be certified according to three classes if they meet some standards in VOC, CO and particle emissions and thermal efficiency.

Norm EN 303.5 from August 1999

Heating boilers – Part 5: boilers for solid fuel, hand stoked or automatically stoked, output ≤ 300 kW. The EN 305.5 norm defines 3 classes of boilers, from 1 to 3, by implementing minimum thermal efficiency as well as emission limits from boilers burning solid fuels.

Table 3.1 presents emission values for the various classes.

Table 3.1: Emission values not to be exceeded defining the various boiler classes burning biomass

	Output kW	CO			Organic components			Particles		
		mg / n m ³ at 10 % of O ₂								
		Class 1	Class 2	Class 3	Class 1	Class 2	Class 3	Class 1	Class 2	Class 3
Hand stoked boilers	< 50	25000	8000	5000	2000	300	150	200	180	150
	50 to 150	12 500	5000	2500	1500	200	100	200	180	150
	150 to 300	12500	2000	1200	1500	200	100	200	180	150
Automatically stoked boilers	< 50	15000	5000	3000	1750	200	100	200	180	150
	50 to 150	12500	4500	2500	1250	150	80	200	180	150
	150 to 300	12500	2000	1200	1250	150	80	200	180	150

Other domestic appliances:

Concerning closed fireplaces, stoves, boilers (< 50 kW) and residential cooking, four new European norms (respectively **EN 13229**, **EN 13240**, **EN 12809**, **EN 12815**) are currently being adopted. For closed fireplaces, the norm is in place since January 2003. The norm for stoves is planned for June 2003 and the norm for residential cooking will follow.

Table 3.2 to 3.4 present respectively the classification of the different appliances, emission values and thermal efficiencies defining in the various classes.

Table 3.2: Classification of appliances

Classification of appliances by categories	Independent appliances or embedded without functional modification	Independent appliances or embedded with functional modification	Embedded appliances for niche and enclosure
Appliances with closed doors	NF EN 13 240 (stoves)	NF EN 13 229 (closed fireplaces)	
Open fireplaces without doors	NF EN 13 229 (open fireplaces)		

NOTE: The expression «without functional modification " means modification of an appliance envelope, which changes only the heat transfer and has no effect on combustion.

Table 3.3: Emission values of CO for the different classes of appliances

Classification of appliances	CO emission limit values (at 13% O ₂)			
	13 229 Closed fireplaces, insert (Appliances with closed doors)	13 240 Stoves (Appliances with closed doors)	12 815 (residential heating cooking)	12 809 (boiler P<50 kW)
Class 1	< 0,3			
Class 2	> 0,3 et < 1,0		> 0,3 et ≤ 0,8	

Class 3		> 0,8 et ≤ 1,0
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Table 3.4: Thermal efficiency for the different classes of appliances

Classification of appliances	Thermal efficiency limits of classes (%)			
	13 229 Open fireplaces, insert (Appliances with closed doors))	13 240 Stoves (Appliances with closed doors)	12 815 (residential heating cooking)	12 809 (boiler P<50 kW)
Class 1	≥ 70		≥ 75	
Class 2	≥ 60 et <70		≥70 et < 75	
Class 3	≥ 50 et < 60		≥ 65 et < 70	
Class 4	≥ 30 et < 50		≥ 60 et < 65	

4 Definition of reference installations

Five categories of domestic appliances are distinguished to take into account large differences in PM and NMVOC emission factors and in thermal efficiencies (thermal efficiency influences operating costs through a more or less important wood consumption for the same heat delivery), (tables 5.3.1 and 5.3.2):

- domestic open fire places with a combustion efficiency of 10 % [1],
- stoves and residential cooking which are considered together because their emission factors, combustion efficiencies and investment costs are very similar,
- Closed fireplaces and inserts which are considered together because their emission factors, combustion efficiencies and investment costs are very similar,
- Hand stoked log wood boilers with a combustion efficiency of 50 to 75 % [1],
- Automatically stoked boilers with a combustion efficiency of 85 to 90 % [1].

Table 4.1: Reference installation

Reference Installation Code	Equipment	Combustion efficiency [%]	Autonomy [hours]	Lifetime [year]
01	Domestic open fireplaces	10	Few hours	25
02	Stoves and residential cooking	30 to 80	5 to 12	15
03	Closed fireplaces and inserts	30 to 85	5 to 12	15
04	Hand stoked log wood boilers	50 to 75	4 to 8	15
05	Automatically stoked boilers	85 to 90	24 hrs to all the heating season	15

5 Emission abatement techniques and costs

5.1 Definition of primary measures

Pollutant emission reduction and energy efficiency increase can only be obtained via replacement of old appliances by new ones with higher energy efficiency and better combustion conditions. Accumulator tanks are used in new boilers to maintain performance during the firing cycle and limit the boiler's operation time. Accumulator tanks can also be added in existing domestic boilers.

These replacements can take place either at the equipment lifetime end or during its lifetime. In the first case, the appliance replacement is planned by the user. The lifetime being about 15 years, the new equipment is evidently more energy efficient. Additional investment costs are considered however the case of a replacement of the equipment before its life end is presented in chapter 7.

An insert can be added to a domestic open fireplace. Stoves, closed fireplaces, residential cooking can replace domestic open fireplaces but for simplification reasons, these changes of equipment are not considered in the document. Stoves, closed fireplaces, residential cooking and boilers can be replaced with more efficient appliances of the same type only.

There are numerous control options available in this sector but considering the data availability, differences in performances and costs, it has been decided to distinguish only five categories of techniques. They are the most common and already used: advanced stoves or residential cooking, advanced closed fireplaces or inserts (equivalent to class 1), advanced manual or automatic boilers (equivalent to class 3), accumulator tanks.

Consequently, emission factors and costs presented in the document are mean values.

Table 5.1.1: Primary measures

Primary Measure Code	Description
00	Conventional
01	Replacement with advanced insert or closed fireplaces (equivalent to class 1)
02	Replacement with advanced stove or residential cooking (equivalent to class 1)
03	Replacement with hand stoked log wood boiler (equivalent to class 3)
04	Replacement with automatically stoked log wood boiler (equivalent to class 3)
05	Addition of an accumulator tank on existing installation
06	Replacement with boilers (equivalent to class 3) with an accumulator tank

NB: For inserts, stoves, residential cooking and closed fireplaces, the most energy efficient appliance corresponds to class 1 and the less energy efficient to class 3 (tables 3.3 and 3.4).

For boilers, an opposite classification is used: the most energy efficient boiler corresponds to class 3 and the less energy efficient to class 1 (table 3.1).

5.2 Definition of secondary measures

Presently few secondary measures for wood combustion in domestic appliances exist: oxidation catalyst, post combustion, catalytic filter. These abatement techniques have similar removal efficiency. These techniques are essentially efficient for reducing PM, VOC and CO. They can be applied in existing as well as in new appliances such as stoves, closed fireplaces, residential cooking or boilers.

Table 5.2.1: Secondary measures

Secondary Measure Code SMC	Description
00	None
01	Oxidation catalyst, post combustion, catalytic filter

5.3 Emission factors and costs data for the different abatement techniques

Table 5.3.1: Emission factors of NO_x and VOC and abatement efficiencies for applied emission abatement techniques.

Combination code	EF NO _x [g/GJ]	Abatement efficiency [%]	EF NO _x CI %	Q	EF VOC [g/GJ]	Abatement efficiency [%]	EF VOC CI %	Q
01 00 00	50	0	20	3	1700		30	4
01 01 00	50	0	20	3	60	96	15	4
01 01 01	50	0	20	3	30	98	50	2
02 00 00	50	0	20	3	1600	0	15	4
02 02 00	50	0	20	3	60	96	30	4
02 02 01	50	0	20	3	30	98	60	2
03 00 00	50	0	20	3	1600	0	15	4
03 01 00	50	0	20	2	60	96	30	4
03 01 01	50	0	20	2	30	98	60	2
04 00 00	50	0	20	3	400	0	10	4
04 03 00	50	0	60	3	40	90	50	3
04 04 00	50	0	60	3	20	95	50	2
04 05 00	50	0	60	2	80	80	50	3
04 06 00	50	0	60	2	40	90	50	3
04 03 01	50	0	60	3	20	95	60	3
04 04 01	50	0	60	3	20	95	60	2
04 05 01	50	0	60	2	40	90	60	3
04 06 01	50	0	60	2	20	95	60	3
05 00 00	50	0	60	3	80	0	60	1
05 04 00	50	0	60	3	20	75	60	2

Q: data quality from 1 to 5 (see methodology)

Sources: [3, 4, 5, 6, 7, 8]

Table 5.3.2: Emission factors of PM and abatement efficiencies for applied emission abatement techniques.

Combination Code	EF PM2.5 [g/GJ] mean	Abatement efficiency [%]	EF PM2.5 CI %	Q	EF PM10 [g/GJ] mean	Abatement efficiency [%]	EF PM10 CI %	Q	EF TSP [g/GJ] mean	Abatement efficiency [%]	EF TSP CI %	Q
01 00 00	698	0	40	2	713	0	35	2	750	0	30	2
01 01 00	72	90	20	2	73	90	15	2	77	90	10	2
01 01 01	25	96	50	2	26	96	50	2	27	96	50	2
02 00 00	288	0	40	3	295	0	35	3	310	0	30	3
02 02 00	158	45	50	2	162	45	45	2	170	45	40	2
02 02 01	56	81	40	2	57	81	35	2	60	81	30	2
03 00 00	288	0	20	2	295	0	15	2	310	0	10	2
03 01 00	72	75	50	2	73	75	45	2	77	75	40	2
03 01 01	25	91	25	2	26	91	20	2	27	91	15	2
04 00 00	233	0	40	2	238	0	35	2	250	0	30	2
04 03 00	19	92	25	2	19	92	20	2	20	92	15	2
04 04 00	9	96	30	2	10	96	25	2	10	96	20	3
04 05 00	233	0	50	2	238	0	50	2	250	0	50	1
04 06 00	19	92	50	2	19	92	50	2	20	92	50	1
04 03 01	19	92	50	2	19	92	50	2	20	92	50	2
04 04 01	9	96	50	2	10	96	50	2	10	96	50	2
04 05 01	82	65	50	2	84	65	50	2	88	65	50	2
04 06 01	19	92	50	2	19	92	50	2	20	92	50	2
05 00 00	19	0	40	2	19	0	35	2	20	0	30	2
05 04 00	9	50	30	2	10	50	25	2	10	50	20	3

Q: data quality from 1 to 5 (see methodology)

Sources: [4, 7, 9, 10, 11, 12, 19]

No fugitive emissions in the combustion process are considered.

Table 5.3.3 presents investments and operating costs of the different appliances.

It has been assumed that fixed operating costs represent 5% of the investments of the secondary measure (fixed operating costs are only associated with the secondary measure. It is assumed that fixed operating costs are the same for the different domestic appliances). For oxidation catalyst, an additional variable cost (added to wood consumption cost calculated in table 7.6) is taken into account since the filter must be changed each year with a cost around 250 € (Refer to chapter 7 for explanations).

New appliances considered as reduction techniques are more energy efficient. Wood consumption is reduced with the increase of combustion efficiency. Fuel saving depends on the progress made and on the rate of use of the domestic appliances.

Wood domestic appliances can be used just for auxiliary purposes (just some hundred of hours per year) or wood is consumed as the main fuel and domestic appliances run a large number of hours per year.

Operating costs and unit costs are provided for these two cases in chapter 7, based on average fuel consumptions observed in France for the different types of uses of domestic appliances. Costs are significantly different. For EGTEI, only one average case is presented. The average wood consumption per domestic appliance is country specific since it can be different from country to country and highly influences total costs (savings are observed and can be larger and larger with the increase in the rate of use of the domestic appliance).

Table 5.3.3: Investments, fixed operating costs (OC), variable operating costs and total annual costs for abatement techniques in wood domestic appliances

Combination code	Average additional investment [€]	Q	Fixed OC [€/y]	Q	Variable OC [€/y] wood consumption	Variable OC [€/y] catalyst replacement	Total annual cost [€/y]
01 00 00		-		-			
01 01 00	3300	5	0.0	-	-157.0		139.8
01 01 01	4400	5	55.0	4	-157.0	250.0	543.8
02 00 00	0	-		-	0.0		0.0
02 02 00	1100	5		-	-154.5		-55.6
02 02 01	2200	5	55.0	4	-154.5	250.0	348.4
03 00 00	0	-		-	0.0		0.0
03 01 00	1775	5		-	-124.1		35.6
03 01 01	2875	5	55.0	4	-124.1	250.0	439.5
04 00 00	0	-		-	0.0		0.0
04 03 00	2250	5		-	-285.0		-82.6
04 04 00	6100	5		-	587.6		1136.2
04 05 00	1400	5		-	-244.3		-118.4
04 06 00	2600	2		-	-352.1		-118.2
04 03 01	3350	5	55.0	4	-285.0	250.0	321.3
04 04 01	7200	5	55.0	4	587.6	250.0	1540.1
04 05 01	2500	5	55.0	4	-244.3	250.0	285.6
04 06 01	3700	2	55.0	4	-352.1	250.0	285.7
05 00 00	0	-		-	0.0		0.0
05 04 00	2725	5		-	-84.9		160.2

Q: data quality from 1 to 5 (see methodology)

Sources: [1, 2, 15]

Table 5.3.4: Unit costs for abatement techniques in wood domestic appliances

Combination code	Unit cost €/GJ	Unit cost €/t NMVOC abated	Unit cost €/t TSP abated
01 00 00			
01 01 00	31.74	2888	6616
01 01 01	123.44	11201	25462
02 00 00			
02 02 00	-1.46	-573	-4364
02 02 01	9.13	3552	20574
03 00 00			
03 01 00	1.16	457	2719
03 01 01	14.34	5581	30083
04 00 00	0.00		
04 03 00	-0.94	-1677	-2646
04 04 00	15.50	22139	35221
04 05 00	-1.26	-2616	-12557
04 06 00	-1.52	-2379	-3760
04 03 01	3.65	6297	10288
04 04 01	21.01	30010	47743
04 05 01	3.03	5826	11563
04 06 01	3.68	5577	9088
05 00 00	0.00		
05 04 00	2.19	33777	4967

6 Data to be provided by national experts

The following tasks are required:

6.1 Validation work

For representing costs in this sector, the national expert can use the default values provided in this report or use other costs data if justified.

- Validation of the default investment cost data provided for his own country, and
- Validation of the method of derivation of operation cost data for his country.
- Or
- Provide other costs data for the same combination of techniques and justify these cost data.

Comments have to be sent to the secretariat in the two weeks after electronic publication of the document.

6.2 Provision of country specific data

Tables to be filled in with country specific data by national experts

- Determination of country specific economic parameter to calculate variable costs (*Specific values for energy, man power...are valid for all emitting sectors and have to be entered in ECODAT only once. Some parameters have to be collected on a case by case basis depending on sectors*).

Table 6.2.1: Country and sector specific economic parameters

Parameters	Default costs provided by EGTEI	Country specific costs
Wood log [€/GJ]	6.48	To be provided by national expert
Wood chips [€/GJ]	19.68	To be provided by national expert

- Respective shares (GJ wood consumed/year) of the total activity level carried out on each reference installation in 2000, 2005, 2010, 2015, 2020.

Table 6.2.2 must be completed. Some default values for the confidence interval are provided. They can be used by one Party if no data is available.

The future consumption of wood must be defined in line with the national energy scenario.

Table 6.2.2: Activity levels on reference Installations (GJ of wood / year)

RIC	2000	CI%	2005	CI%	2010	CI%	2015	CI%	2020	CI%
01										
02										
03										
04										
05										
Default values proposed for CI		10		20		50		100		100

For explanation on the confidence interval refer to the methodology chapter.

- Average wood consumption in the different appliances (GJ wood consumed/year).

Table 6.2.3 must be completed. Default values are provided. They can be used by one Party if no data is available.

Table 6.2.3: Wood consumption per appliance (GJ of wood / year)

RIC PMC SMC	Default consumption provided by EGTEI GJ /unit/year	Country specific wood consumption GJ/unit /year
01 00 00	28.63	
02 00 00	49.80	
03 00 00	62.01	
04 00 00	131.97	
05 00 00	131.97	

- Respective percentage of combinations of reduction measures in 2000 for each reference installation as well as if possible, the percentage of use in 2005, 2010, 2015, 2020 due to national regulations and applicability according to the definition used in the RAINS model.

Some default values for the applicability factor are provided in table 6.2.5. They can be used by one Party if no data is available.

Table 6.2.4: Percentage of use and applicability factor for each combination of reduction measures

RIC PMC SMC	Percentage of use in 2000 [%]	Percentage of use in 2005 [%]	Applicability factor [%]	Percentage of use in 2010 [%]	Applicability factor [%]	Percentage of use in 2015 [%]	Applicability factor [%]	Percentage of use in 2020 [%]	Applicability factor [%]
01 00 00									
01 01 00									
01 01 01									
Total RIC 01	100	100		100		100		100	
02 00 00									
02 02 00									
02 02 01									
Total RIC 02	100	100		100		100		100	
03 00 00									
03 01 00									
03 01 01									
Total RIC 03	100	100		100		100		100	
04 00 00									
04 03 00									
04 04 00									
04 05 00									
04 06 00									
04 03 01									
04 04 01									
04 05 01									
04 06 01									
Total RIC 04	100	100		100		100		100	
05 00 00									
05 04 00									
Total RIC 05	100	100		100		100		100	

Table 6.2.5: Default values for applicability factor for each combination of reduction measures

RIC PMC SMC	Applicability factor 2005 %	Applicability factor 2010 %	Applicability factor 2015 %	Applicability factor 2020 %
Reference installation 01				
01 00 00	100	100	100	100
01 01 00	50	70	85	100
01 01 01	50	70	85	100
Reference installation 02				
02 00 00	100	100	100	100
02 02 00	100	100	100	100
02 02 01	70	80	80	80
Reference installation 03				
03 00 00	100	100	100	100
03 01 00	100	100	100	100
03 01 01	70	80	80	80
Reference installation 04				
04 00 00	100	100	100	100
04 03 00	100	100	100	100
04 04 00	100	100	100	100
04 05 00	80	80	80	80
04 06 00	100	100	100	100
04 03 01	70	80	80	80
04 04 01	70	80	80	80
04 05 01	70	80	80	80
04 06 01	70	80	80	80
Reference installation 05				
05 00 00	100	100	100	100
05 04 00	100	100	100	100

If detailed information is available, table 6.2.4 can be filled in.

If only sparse information is available, table 6.2.4 can be filled in with the same "Application rates" for all RI (this corresponds to the filing of table 6.2.6).

Table 6.2.6: Aggregated table (this table does not appear in the tool)

RIC PMC SMC	Percentage of use in 2000 %	Percentage of use in 2005 %	Applicability factor 2005 %	Percentage of use in 2010 %	Applicability factor 2010 %	Percentage of use in 2015 %	Applicability factor 2015 %	Percentage of use in 2020 %	Applicability factor 2020 %
Aggreg. 00 00									
Aggreg. 01 00									
Aggreg. 01 01									
Aggreg. 02 00									
Aggreg. 02 01									
Aggreg. 03 00									
Aggreg. 03 01									
Aggreg. 04 00									
Aggreg. 05 00									
Aggreg. 06 00									
Aggreg. 07 00									
Aggreg. 04 01									
Aggreg. 05 01									
Aggreg. 06 01									
Aggreg. 07 01									
Total aggreg.	100	100		100		100		100	

Aggreg. : Aggregation

The total of percentages of uses of combinations or reduction techniques must be 100 since the combinations are assumed to represent all the different situations in this activity.

In ECODAT, the absolute terms are directly entered (% for a given combination multiplied by the total activity).

Table 6.2.7: Unabated emission factor [g /GJ]

Combination code	Default NO _x EF [g/GJ]	User NO _x EF [g/GJ]	Default VOC EF [g/GJ]	User VOC EF [g/GJ]	Default TSP EF [g/GJ]	Default TSP EF [g/GJ]
01 00 00	50		1700		750	
02 00 00	50		1600		310	
03 00 00	50		1600		310	
04 00 00	50		400		250	
05 00 00	50		80		20	

The “default emission factor” can be modified in a range of ± 10%.

7 Explanatory notes

7.1 Derivation of emission factors

CITEPA has carried out a survey for CTBA (Technical Centre for Wood and wood Furniture) and ADEME (Agency of Environment and of Energy Management) aiming at compiling the most recent studies providing emission monitoring results or emission factors from domestic wood combustion appliances and small boilers in industry and district heating.

Pollutant emissions in domestic appliances depend on combustion conditions (air excess, combustion temperature...), the wood type used (moisture content, wood nature, wood form (logs hand stoked in appliances, pellets in automatically stoked in appliances)), the configuration of the combustion chamber, the type of appliances.

Analytical protocols and monitoring periods (inclusion or not of the appliance start up periods in the monitoring period, monitoring during steady combustion...) are also important factors. Different monitoring protocols on the same appliance would result in different emission factors.

For VOC, emission factors have been derived as follows:

Conventional stoves:

The emission factor of 1.6 g eq. C₃H₈/MJ is the average value derived from the following data:

1.45 g VOC /MJ provided by US EPA (3).

1.3 g VOC /MJ provided by Mac Donald (6),

2.86 g eq. C₃H₈/MJ resulting from measurement carried in France (4).

Advanced wood stoves:

The emission factor derives from data presented by reference (5): 0.030 g VOC/MJ.

Inserts and closed fireplaces:

Emission factors from INERIS (4) are used. These emission factors range from 1.57 g eq. C₃H₈/MJ for inserts, to 1.75 g eq. C₃H₈/MJ for closed fireplaces discontinuously operated and to 2.65 g eq. C₃H₈/MJ for continuous operated closed fireplaces. An average emission factor of 1.6 g eq. C₃H₈/MJ is taken into account.

Non-certified boilers:

Measurements have been carried out by CETIAT (7) in 1995. Emissions are estimated to 1.5 g eq. C_3H_8 /MJ. Measurements carried out in Sweden (8) give 1.7 to 1.8 g eq. C_3H_8 /MJ. An average emission factor of 1.65 g eq. C_3H_8 /MJ is taken into account.

Advanced boilers from class 1:

Measurements have been carried out by CETIAT in 1995 (7). Emissions are estimated to 0.4 g eq. C_3H_8 /MJ.

Advanced boilers from class 3:

Measurements have been carried out by CETIAT in 1995 (7). Emissions are estimated to 35 mg eq. C_3H_8 /MJ. Measurements carried out in Sweden (8) give 25-80 mg eq. C_3H_8 /MJ and 13-40 mg eq. C_3H_8 /MJ for the most advanced boilers with a zircon probe for controlling the excess air. An average factor of 40 mg/MJ is taken into account.

Open fireplaces: emissions have been estimated at least equal to those of conventional stoves and inserts: 1.7 g eq. C_3H_8 /MJ.

According to CIAM (14), oxidation catalysts used with boilers enable a VOC reduction of 50%. This technical efficiency reaches 68% if the oxidation catalyst is applied to a new boiler with an accumulator tank. CIAM (14) also gives a technical efficiency of 80% for a boiler improved by an accumulator tank.

These values are taken into account by default for boilers and they are also applied for the other domestic appliances.

NOX

The most recent studies carried out in France (4), (7) and some other papers make possible to estimate NO_x emissions to 50 mg/MJ. However, gathered data do not make it possible to tell if there is a representative difference between the diverse domestic appliances or not. Results from Sweden present higher emission factors for the most recent boilers compared with conventional boilers (80-95 mg/MJ compared with 60 mg/MJ for conventional boilers). This result has not been taken into account.

TSP:

For TSP, emission factors derive from a large number of measurements.

Open fireplaces: average of 750 mg/MJ.

Conventional stoves and cooking: 310 mg/MJ deriving from data ranging from 146 (4) to 910 and 1350 mg/MJ (21).

Advanced stoves: 170 mg/MJ

Conventional closed fireplaces and inserts: 310 mg/MJ deriving from data range from 77 to 89 (4) to more than 330 mg/MJ (21).

Hand stoked log wood boilers: data examined range from 27 (7) to 1500 mg/MJ (9). The value of 1500 is very high and has not been retained by CITEPA. It has been assumed that due to better combustion efficiency, TSP emissions from the oldest boilers are lower than in conventional stoves but not so much.

Hand stoked log wood boilers class 3: 20 mg/MJ deriving from data range from 11 (7) to 50 (20).

The PM emission reduction due to oxidation catalyst is of 65% for stoves (19). This value is also used by default for closed fireplaces and boilers (equivalent to class 1). It has been assumed that oxidation catalyst has low impact on modern boilers (equivalent to class 3, hand and automatically stoked) and then, by default, the same emission factors are used with or without oxidation catalytic for this class of boilers.

A catalytic insert applied on conventional open fireplaces permits a PM emission reduction of 95% (19).

It has been assumed that the addition of an accumulator tank on existing boilers has no effect on PM emissions so the same emission factor is considered for boilers (equivalent to class 3) with accumulator tank and boilers (equivalent to class 3) without.

By default, the emission factor used for automatically stoked log wood boilers is the same than for hand stoked log wood boilers.

The distribution size (PM10, PM2.5) is an average value between IIASA distributions and several other references which are quite similar (10), (11), and (12): PM10 represents 95% of TSP and PM2.5 represents 93% of TSP.

7.2 Derivation of cost data

Cost data have been derived from reports of ADEME (13), (2) and discussions with M. Jean-Christophe POUET (1). For boilers with accumulator tank and for oxidation catalyst, IFARE (16) and EVA (17) data are used. Wood domestic appliance costs are expressed from the less energy efficient to the most energy efficient equipment as described in the table 7.2.1 below:

Table 7.2.1: Cost ranges of wood domestic appliances

Wood domestic appliance	Ranges of cost (€)
Domestic open fireplaces	500 to 2300
Stoves / Residential cooking	600 to 2300
Closed fireplaces/inserts	750 to 2300
Hand stoked log wood boilers	1500 to 4500
Automatically stoked boilers	4500 to 12 200
Accumulator tank	800 to 1500

Costs for a replacement with the most efficient appliance are expressed as investments corresponding to the maximum or near to the maximum (depending on the performance of the appliance required) of the appliance cost range (available in table 7.2.1). The installation cost has to be added to the investment cost. The following investments and installation (on the site) costs are considered for the replacement of old installations.

Table 7.2.2: Investment costs for wood domestic appliances taken into account

Combination code	Wood domestic appliance	Investment cost (€)	Installation cost (€)
01 00 00	Open fireplace*	1400	
01 01 00	Inserts/closed fire places class 1	2300	1000
02 00 00	Stoves / Residential cooking*	1450	
02 02 00	Stoves / Residential cooking class 1	2300	250
03 00 00	Inserts/closed fire places*	1525	
03 01 00	Inserts/closed fire places class 1	2300	1000
04 00 00	Hand stoked log wood boilers*	3000	
04 03 00	Hand stoked log wood boilers class 3	4500	750
04 04 00	Automatically stoked wood boilers class 3	8350	750
04 05 00	Addition of an accumulator tank on the existing appliance	1150	250
04 06 00	Hand stoked log wood boilers class 3 with accumulator tank incorporated	4800	800
05 00 00	Wood ships automatically stoked boilers	6375	
05 04 00	Wood ships automatically stoked boilers class 3	8350	750
SMC 01	Oxidation catalyst/post combustion/...	1100	-

* The average figure from the range provided in table 7.2.1 has been taken into account conventional appliances.

Thermal efficiencies taken into account are as follows:

Table 7.2.3: Improved thermal efficiency

Wood domestic appliance		No control		Improved appliances	
		PMC	Thermal efficiency (%)	PMC	Thermal efficiency (%)
01	Domestic open fireplaces	00	10	01	65
02	Stoves / Residential cooking	00	40	02	65
03	Closed fireplaces / Inserts	00	40	01	65
04	Hand stoked log wood boilers	00	50	03	75
				04	90
				05	70
				06	85
05	Automatically stoked boilers	00	85	04	90

Operating costs:

It has been assumed that fixed operating costs represent 5% of investment costs for secondary measures.

The following energy costs / unit have been used:

- wood log: 40 €/stere (typical French unit representing one m³ of wood logs. Average mass 0,5 t) or 6.48 €/GJ
- wood chips : 255 €/t or 19.68 €/GJ

The following energy content has been used:

- wood log : 1 stere à 0.147 tep x 42 = 6,174 GJ/stere
- wood chips : 1 t à 3600 kWh or 12,96 GJ/t of wood chips

Variable operating costs depend on the consumption of wood. The increase in appliance combustion efficiency results in reduction of wood consumption (a more efficient device uses less wood to provide the same heat). Variable operating costs can be derived from (15) following the methodology described below:

Approximate annual heating cost for a house is calculated by using the formula:

$$[(\text{Energy cost/unit}) / (\text{Energy content})] \times [\text{heat load (in GJ)} / \text{system efficiency}] \times 100\,000$$

However, wood is not always used as the main fuel for insuring heating of houses. Some types of domestic appliances are just used as auxiliary appliances. According to these cases, wood consumption per appliances is different.

The average fuel consumption considered to calculate default wood consumption cost per appliance, is based on French data. Table 7.2.4 presents the annual wood consumption per appliance in case of main use of wood and in case of auxiliary use [24]:

Table 7.2.4: average wood consumption according to the use of domestic appliances

		Number of appliances	% of wood consumption per type of use and domestic appliances	Wood consumption per appliance GJ/unit/year	Total wood consumption per type of appliances PJ/year
Main use of wood	Boilers	366000	1.000	131.97	48.30
	Cooking	397000	0.882	92.04	36.54
	Stoves	474000	0.807	77.97	36.96

	Inserts	981000	0.620	79.16	77.66
	Open fire places	181000	0.308	73.09	13.23
Auxiliary use	Boilers	Not used as auxiliary appliances			
	Cooking	89000	0.118	45.53	4.87
	Stoves	203000	0.193	33.44	8.86
	Inserts	992000	0.380	31.03	47.63
	Open fireplaces	596000	0.692	22.54	29.78
Total and Weighted average	Boilers	366000		131.97	48.3
	Cooking	504000		82.17	41.412
	Stoves	739000		62.01	45.822
	Inserts	2516000		49.80	125.286
	Open fireplaces	1502000		28.63	43.008
	Total	5627000		53.99	303.828

The table 7.2.5 presents the annual wood consumption costs and annual additional costs according to the different appliances and uses.

Table 7.2.5: Default annual wood consumption costs and default annual costs according to the different appliances and uses

Combination code	Annual wood consumption			Cost of wood consumption		
	Auxiliary use	Full use	Weighted average	Auxiliary use	Full use	Weighted average
	GJ/unit/year	GJ/unit/year	GJ/unit/year	€/year	€/year	€/year
01 00 00	22.54	73.09	28.63	146.0	473.6	185.5
01 01 00	3.47	11.25	4.41	22.5	72.9	28.5
01 01 01	3.47	11.25	4.41	22.5	72.9	28.5
02 00 00	33.44	77.97	62.01	216.7	505.2	401.7
02 02 00	20.58	47.98	38.16	133.3	310.9	247.2
02 02 01	20.58	47.98	38.16	133.3	310.9	247.2
03 00 00	31.03	79.16	49.80	201.0	512.9	322.6
03 01 00	19.09	48.72	30.64	123.7	315.6	198.5
03 01 01	19.09	48.72	30.64	123.7	315.6	198.5
04 00 00		131.97	131.97		855.0	855.0
04 03 00		87.98	87.98		570.0	570.0
04 04 00		73.32	73.32		1442.5	1442.5
04 05 00		94.26	94.26		610.7	610.7
04 06 00		77.63	77.63		502.9	502.9
04 03 01		87.98	87.98		570.0	570.0
04 04 01		73.32	73.32		1442.5	1442.5
04 05 01		94.26	94.26		610.7	610.7
04 06 01		77.63	77.63		502.9	502.9
05 00 00		77.63	77.63		1527.4	1527.4
05 04 00		73.32	73.32		1442.5	1442.5

For oxidation catalyst, an annual variable cost is considered: it has to be added to wood consumption costs. The catalytic filter must be indeed changed each year for a cost around 250 €

The table 7.2.6 presents how costs presented in table 5.3.3 for the average use of domestic appliances have been derived. Tables 7.2.8 to 7.2.11 present costs in case of auxiliary use of domestic appliances and in case of main use of wood as fuel.

Table 7.2.6: additional investments, additional operating costs and total annual costs for abatement techniques in case of an average use of domestic appliances

Combination code RIC PMC SMC	Additional Investment [€]	Q	Fixed OC [€/y]	Q	Variable OC wood consumption [€/y]	Variable OC catalyst replacement [€/y]	Total annual cost [€/y]
01 00 00		-		-			
01 01 00	3300	5	0.0	-	-157.0		139.8
01 01 01	4400	5	55.0	4	-157.0	250.0	543.8
02 00 00	0	-		-	0.0		0.0
02 02 00	1100	5		-	-154.5		-55.6
02 02 01	2200	5	55.0	4	-154.5	250.0	348.4
03 00 00	0	-		-	0.0		0.0
03 01 00	1775	5		-	-124.1		35.6
03 01 01	2875	5	55.0	4	-124.1	250.0	439.5
04 00 00	0	-		-	0.0		0.0
04 03 00	2250	5		-	-285.0		-82.6
04 04 00	6100	5		-	587.6		1136.2
04 05 00	1400	5		-	-244.3		-118.4
04 06 00	2600	2		-	-352.1		-118.2
04 03 01	3350	5	55.0	4	-285.0	250.0	321.3
04 04 01	7200	5	55.0	4	587.6	250.0	1540.1
04 05 01	2500	5	55.0	4	-244.3	250.0	285.6
04 06 01	3700	2	55.0	4	-352.1	250.0	285.7
05 00 00	0	-		-	0.0		0.0
05 04 00	2725	5		-	-84.9		160.2

Q: data quality from 1 to 5 (see methodology)

Sources: [1, 2, 15]

Table 7.2.7: Unit costs for abatement techniques in case of an average use of domestic appliances

Combination code RIC PMC SMC	Wood consumption [GJ/unit/year]	Unit cost [€/GJ]	NM VOC emissions abated [kg NM VOC/year]	Unit cost [€/t NM VOC abated]	TSP emission abated [kg TSP/year]	Unit cost [€/t TSP abated]
01 00 00	28.63					
01 01 00	4.41	31.74	48.4	2888	21.1	6616
01 01 01	4.41	123.44	48.5	11201	21.4	25462
02 00 00	62.01				0.0	
02 02 00	38.16	-1.46	96.9	-573	12.7	-4364
02 02 01	38.16	9.13	98.1	3552	16.9	20574
03 00 00	49.80				0.0	
03 01 00	30.64	1.16	77.8	457	13.1	2719
03 01 01	30.64	14.34	78.8	5581	14.6	30083
04 00 00	131.97	0.00			0.0	
04 03 00	87.98	-0.94	49.3	-1677	31.2	-2646
04 04 00	73.32	15.50	51.3	22139	32.3	35221
04 05 00	94.26	-1.26	45.2	-2616	9.4	-12557
04 06 00	77.63	-1.52	49.7	-2379	31.4	-3760
04 03 01	87.98	3.65	51.0	6297	31.2	10288
04 04 01	73.32	21.01	51.3	30010	32.3	47743
04 05 01	94.26	3.03	49.0	5826	24.7	11563
04 06 01	77.63	3.68	51.2	5577	31.4	9088
05 00 00	77.63	0.00			0.0	
05 04 00	73.32	2.19	4.7	33777	32.3	4967

The unit cost expressed in €/GJ is obtained by dividing the total annual cost (table 7.2.6) by the wood consumption (table 7.2.7).

The unit cost expressed in €/t NMVOC abated is obtained by dividing the total annual cost (table 7.2.6) by the amount on NMVOC abated per year (table 7.2.7).

The unit cost expressed in €/t TSP abated is obtained by dividing the total annual cost (table 7.2.6) by the amount on TSP abated per year (table 7.2.7).

7.2.3 Uncertainties on costs

Unit costs per GJ or per tonne of NMVOC abated or tonne of TSP abated for the replacement of domestic appliances may vary significantly according to the type of domestic appliance, the rate of use of this appliances (unit costs increase with the decrease of the appliance use). It is why the average wood consumption on the five appliances defined as reference for calculating emissions and costs has to be known. The consumption may vary significantly from country to country.

Tables 7.2.8 and 7.2.9 present costs in case of auxiliary use of wood domestic appliances. Fuel saving being less important, unit costs are higher than for the use of wood as main fuel. This demonstrates that in this sector, costs strongly depend on the use of the domestic appliance.

Table 7.2.8: Additional investments, additional operating costs and total annual costs for abatement techniques in case of auxiliary use of domestic appliances

Combination code RIC PMC SMC	Additional Investment [€]	Q	Fixed OC [€/y]	Q	Variable OC wood consumption [€/y]	Variable OC catalyst replacement [€/y]	Total annual cost [€/y]
01 00 00		-	-	-			
01 01 00	3300	5	-	-	-123.6		173.2
01 01 01	4400	5	55	4	-123.6	250.0	577.2
02 00 00	0	-	-	-			0.0
02 02 00	1100	5	-	-	-83.3		15.6
02 02 01	2200	5	55	4	-83.3	250.0	419.5
03 00 00	0	-	-	-			0.0
03 01 00	1775	5	-	-	-77.3		82.3
03 01 01	2875	5	55	4	-77.3	250.0	486.3
04 00 00	Not used		Not used		Not used	Not used	Not used
04 03 00	Not used		Not used		Not used	Not used	Not used
04 04 00	Not used		Not used		Not used	Not used	Not used
04 05 00	Not used		Not used		Not used	Not used	Not used
04 06 00	Not used		Not used		Not used	Not used	Not used
04 03 01	Not used		Not used		Not used	Not used	Not used
04 04 01	Not used		Not used		Not used	Not used	Not used
04 05 01	Not used		Not used		Not used	Not used	Not used
04 06 01	Not used		Not used		Not used	Not used	Not used
05 00 00	Not used		Not used		Not used	Not used	Not used
05 04 00	Not used		Not used		Not used	Not used	Not used

Q: data quality from 1 to 5 (see methodology)

Sources: [1, 2, 15]

Table 7.2.9: Unit costs for abatement techniques in case of an auxiliary use of domestic appliances

Combination code RIC PMC SMC	Wood consumption	Unit cost	NM VOC emissions abated	Unit cost	TSP emission abated	Unit cost
	[GJ/unit/year]	[€/GJ]	[kg NM VOC/year]	[€/t NM VOC abated]	[kg TSP/year]	[€/t TSP abated]
01 00 00	22.54					
01 01 00	3.47	49.95	38.1	4545	16.6	10411
01 01 01	3.47	166.43	38.2	15102	16.8	34329
02 00 00	33.44		0.0		0.0	
02 02 00	20.58	0.76	52.3	299	6.9	2272
02 02 01	20.58	20.39	52.9	7932	9.1	45941
03 00 00	31.03		0.0		0.0	
03 01 00	19.09	4.31	48.5	1698	8.1	10104
03 01 01	19.09	25.47	49.1	9909	9.1	53417
04 00 00						
04 03 00						
04 04 00						
04 05 00						
04 06 00						
04 03 01						
04 04 01						
04 05 01						
04 06 01						
05 00 00						
05 04 00						

Tables 7.2.10 and 7.2.11 present costs in case of main use of wood domestic appliances. Fuel saving are higher, unit costs are consequently lower than for the use of wood as auxiliary fuel. This demonstrates that in this sector, costs strongly depend on the use of the domestic appliance.

Table 7.2.10: Additional investments, additional operating costs and total annual costs for abatement techniques in case of main use of domestic wood appliances

Combination code RIC PMC SMC	Additional Investment	Q	Fixed OC	Q	Variable OC wood consumption	Variable OC catalyst replacement	Total annual cost
	[€]		[€/y]		[€/y]	[€/y]	[€/y]
01 00 00		-	-	-	0.0		
01 01 00	3300	5	-	-	-400.7		-103.9
01 01 01	4400	5	55	4	-400.7	250.0	300.0
02 00 00	0	-	-	-	0.0		0.0
02 02 00	1100	5	-	-	-194.3		-95.4
02 02 01	2200	5	55	4	-194.3	250.0	308.6
03 00 00	0	-	-	-	0.0		0.0
03 01 00	1775	5	-	-	-197.3		-37.6
03 01 01	2875	5	55	4	-197.3	250.0	366.3
04 00 00	0	-	-	-	0.0		0.0
04 03 00	2250	5	-	-	-285.0		-82.6
04 04 00	6100	5	-	-	587.6		1136.2
04 05 00	1400	5	-	-	-244.3		-118.4
04 06 00	2600	2	-	-	-352.1		-118.2
04 03 01	3350	5	55	4	-285.0	250.0	321.3
04 04 01	7200	5	55	4	587.6	250.0	1540.1
04 05 01	2500	5	55	4	-244.3	250.0	285.6
04 06 01	3700	2	55	4	-352.1	250.0	285.7
05 00 00	0	-	-	-	0.0		0.0

05 04 00	2725	5	-	-	-84.9	160.2
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Q: data quality from 1 to 5 (see methodology)

Sources: [1, 2, 15]

Table 7.2.11: Unit costs for abatement techniques in case in case of main use of domestic wood appliances

Combination code RIC PMC SMC	Wood consumption	Unit cost	NMVOC emissions abated	Unit cost	TSP emission abated	Unit cost
	[GJ/unit/year]	[€/GJ]	[kg NMVOC/year]	[€/t NMVOC abated]	[kg TSP/year]	[€/t TSP abated]
01 00 00	73.09				54.0	
01 01 00	11.25	-9.24	123.6	-841	54.5	-1926
01 01 01	11.25	26.68	123.9	2421	0.0	5504
02 00 00	77.97		0.0		16.0	
02 02 00	47.98	-1.99	121.9	-782	21.3	-5955
02 02 01	47.98	6.43	123.3	2502	0.0	14492
03 00 00	79.16		0.0		20.8	
03 01 00	48.72	-0.77	123.7	-304	23.2	-1809
03 01 01	48.72	7.52	125.2	2926	0.0	15773
04 00 00	131.97	0.00	0.0		31.2	
04 03 00	87.98	-0.94	49.3	-1677	32.3	-2646
04 04 00	73.32	15.50	51.3	22139	9.4	35221
04 05 00	94.26	-1.26	45.2	-2616	31.4	-12557
04 06 00	77.63	-1.52	49.7	-2379	31.2	-3760
04 03 01	87.98	3.65	51.0	6297	32.3	10288
04 04 01	73.32	21.01	51.3	30010	24.7	47743
04 05 01	94.26	3.03	49.0	5826	31.4	11563
04 06 01	77.63	3.68	51.2	5577	0.0	9088
05 00 00	77.63	0.00	0.0		32.3	
05 04 00	73.32	2.19	4.7	33777	54.0	4967

Investments presented in table 5.3.3 and in all tables above, are additional costs compared to the reference appliances of each category. This is only valid when the replacement takes place at the end life of the equipment. If the replacement occurs during the life time, full investment costs can be taken into account for estimating unit costs.

In this case, costs are as follows (tables 7.2.12 and 7.2.13):

Table 7.2.12: Additional investments, additional operating costs and total annual costs for abatement techniques in case of average use of domestic wood appliances and replacement of the domestic appliance before its life end

Combination code RIC PMC SMC	Additional Investment	Q	Fixed OC	Q	Variable OC wood consumption	Variable OC catalyst replacement	Total annual cost
	[€]		[€/y]		[€/y]	[€/y]	[€/y]
01 00 00		-	-	-			
01 01 00	3300	5	-	-	-157.0		139.8
01 01 01	4400	5	55	4	-157.0	250.0	543.8
02 00 00		-	-	-			0.0
02 02 00	2550	5	-	-	-154.5		74.8
02 02 01	3650	5	55	4	-154.5	250.0	478.8
03 00 00		-	-	-			0.0
03 01 00	3300	5	-	-	-124.1		172.7
03 01 01	4400	5	55	4	-124.1	250.0	576.7
04 00 00		-	-	-			0.0
04 03 00	5250	5	-	-	-285.0		187.2

04 04 00	9100	5	-	-	587.6		1406.0
04 05 00	1400	5	-	-	-244.3		-118.4
04 06 00	5600	2	-	-	-352.1		151.6
04 03 01	6350	5	55	4	-285.0	250.0	591.1
04 04 01	10200	5	55	4	587.6	250.0	1810.0
04 05 01	2500	5	55	4	-244.3	250.0	285.6
04 06 01	6700	2	55	4	-352.1	250.0	555.6
05 00 00		-	-	-			0.0
05 04 00	9100	5	-	-	-84.9		733.6

Q: data quality from 1 to 5 (methodology)

Sources: [1, 2, 15]

Table 7.2.13: Unit costs for abatement techniques in case in case of average use of domestic wood appliances and replacement of the domestic appliance before its life end

Combination code RIC PMC SMC	Wood consumption	Unit cost	NM VOC emissions abated	Unit cost	TSP emission abated	Unit cost
	[GJ/unit/year]	[€/GJ]	[kg NMVOC/year]	[€/t NMVOC abated]	[kg TSP/year]	[€/t TSP abated]
01 00 00	28.63					
01 01 00	4.41	31.74	48.4	2888	21.1	6616
01 01 01	4.41	123.44	48.5	11201	21.4	25462
02 00 00	62.01					
02 02 00	38.16	1.96	96.9	772	12.7	5877
02 02 01	38.16	12.55	98.1	4882	16.9	28276
03 00 00	49.80				0.0	
03 01 00	30.64	5.64	77.8	2219	13.1	13208
03 01 01	30.64	18.82	78.8	7322	14.6	39472
04 00 00	131.97	0.00				
04 03 00	87.98	2.13	49.3	3800	31.2	5994
04 04 00	73.32	19.18	51.3	27397	32.3	43586
04 05 00	94.26	-1.26	45.2	-2616	9.4	-12557
04 06 00	77.63	1.95	49.7	3052	31.4	4823
04 03 01	87.98	6.72	51.0	11585	31.2	18927
04 04 01	73.32	24.69	51.3	35268	32.3	56108
04 05 01	94.26	3.03	49.0	5826	24.7	11563
04 06 01	77.63	7.16	51.2	10843	31.4	17671
05 00 00	77.63	0.00				
05 04 00	73.32	10.01	4.7	154642	32.3	22741

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9 Modifications made to the draft document

Correction made in December 2003

Information, data and comments on this sector have been formulated by Mr Pouet from ADEME (French Agency for Environment and Energy Management).

Information on future European norms for domestic wood appliances has been provided: these information has been included in this document (chapter 3).

Modification made in chapter 5

Fixed operating costs have been corrected in table 5.3.3 for combination code that includes both primary and secondary measures: the 5% of investment is only applied to secondary measure.

Modification made in chapter 7

The percentage for fixed operating costs given in this chapter, was corrected to be in coherence with the document. Errors have been detected in table 7.2.5 for the fiftieth case and have been corrected.

Correction made in September 2005

Corrections were made on:

- Efficiency and emission factors of the primary measure 01 “use of an insert on open fireplace” have been modified. This insert has in fact the same characteristic as the previous measure 03. Previous measures 01 and 03 have been merged in the new primary measure 01. The codes of the other primary measures have been changed consequently.
- Only additional investment costs are considered in this new version. In the previous document, total costs were taken into account considering that for reducing rapidly emissions, the appliances have to be replaced before their end of life. This case is still presented in the document.
- Domestic appliances with wood as fuel are used differently. Open fire places are used as auxiliary appliances often for esthetical reasons. They work a low number of hours per year. Wood boilers on contrary are used as main domestic appliance. The default wood consumption used to calculate wood consumption cost has been modified and takes presently into account the average uses of each domestic appliance considered. Average wood consumption per domestic appliance becomes a country specific parameter. Default values are provided.

Abbreviations

ADEME	French Environment Agency
n.a.	not available
-	not existing
CETIAT	Centre Technique des Industries Aérauliques et Thermiques
CIAM	Centre Integrated Assessment Modelling
CITEPA	Centre Interprofessionnel Technique d'Etude de la Pollution Atmosphérique
CI%	Confidence interval

CO	Organic Components
CTBA	Centre Technique du Bois et de l'Ameublement
EF	Emission factor
EPA	Environmental Protection Agency
EU	European Union
GJ	Giga Joules
HM	Heavy Metals
IFARE	Institut Franco-Allemand de Recherches sur l'Environnement
IIASA	International Institute for Applied Systems Analysis
INERIS	Institut National de l'Environnement industriel et des RISques
NFR	New Format Reporting
NO _x	Nitrogen Oxides
PM	Particulate matter
PM ₁₀	Particulate matter with an aerodynamic diameter less than 10 µm
PM _{2.5}	Particulate matter with an aerodynamic diameter less than 2.5 µm
PMC	Primary Measure Code
Q	Quality
RAINS	Regional Air pollution Information and Simulation model
RIC	Reference Installation Code
SMC	Secondary Measure Code
SNAP	Selected Nomenclature for Air Pollution
SO ₂	Sulphur Dioxide
TSP	Total suspended particulate matter
VOC	Volatile Organic Compounds