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New insight into the role of wood combustion as key PM source in Italy and in Lombardy region

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ABSTRACT

The work provides new evidence of the importance of wood combustion as a key source for PM2.5 and toxic emissions (i.e. PAH) both at national (Italy) and at local (Lombardy Region) level. A specific survey, based on CATI (Computer Assisted Telephone Interviewing) and TELEPANEL techniques, has been undertaken. Data were statistically analyzed in order to allow an estimate of wood consumption for domestic use in different Italian regions. The research confirms and updates previous assessments of the entity and patterns of the use of wood for domestic heating in Italy and in Lombardy, highlighting its large use, in particular in the sub-Alpine and Apennine area. Details on used types of combustion installations and temporal split of wood use are provided.

Collected data allow a better estimation of wood combustion emissions from old residential equipments, that represent an important share of primary PM10 emissions in Italy and in Lombardy Region. Domestic appliances for wood combustion are responsible for up to 90% of the primary emitted fine particulate from non-industrial combustion in Italy. This share increases when natural gas, characterized by very low primary PM emissions, represents the only alternative fuel used.

Although the large variability of PM emission factors for wood combustion (depending on type of wood, combustion devices, etc.) is an important source of uncertainty for PM emissions, this work stresses the importance of technological improvements as well as new policy for emission reduction in this sector.

INTRODUCTION

In several areas in Italy atmospheric pollutant levels are problematic and anthropogenic PM2.5 levels are responsible for a loss of more than one year of life expectancy (1). In Lombardy, and generally in the whole Po-Valley, specific geographical characteristics, such as poor ventilation and a surrounding mountain chain (the Alps) as well as high density urbanization and motorized traffic, lead to high pollutant levels, particularly during the winter time, observed not merely in city centers but also dispersed all over the territory.

Latest atmospheric emission inventory have confirmed the weight of wood combustion as a key source for particulate emissions (2), and the importance of having a more accurate assessment of its share. Recently, a survey carried out by the Lombardy Foundation for the Environment has provided first details on how wood use for domestic heating is spread in the Lombardy region (3).

Due to the need of more information regarding the diffusion of this practice a specific survey has been undertaken, in order to get data of wood consumption, type of burning system, supplying means, type of wood, storage, frequency of use, reasons, in different Italian regions.

METHODOLOGY

A survey has been carried out combining two methods: part of the sample has been contacted by phone with the CATI (Computer Assisted Telephone Interviewing) technique while other families were part of the TELEPANEL, a representative panel of the Italian population (individuals and households, distributed across over 700 municipalities) connected to the data center via personal computer. A questionnaire was elaborated to collect information concerning amount and methods of wood consumption for domestic heating during the 2005/2006 winter. CATI and TELEPANEL interviews were done in October, 2006. Data on wood use could be considered representative for the consumption in the year 2006.

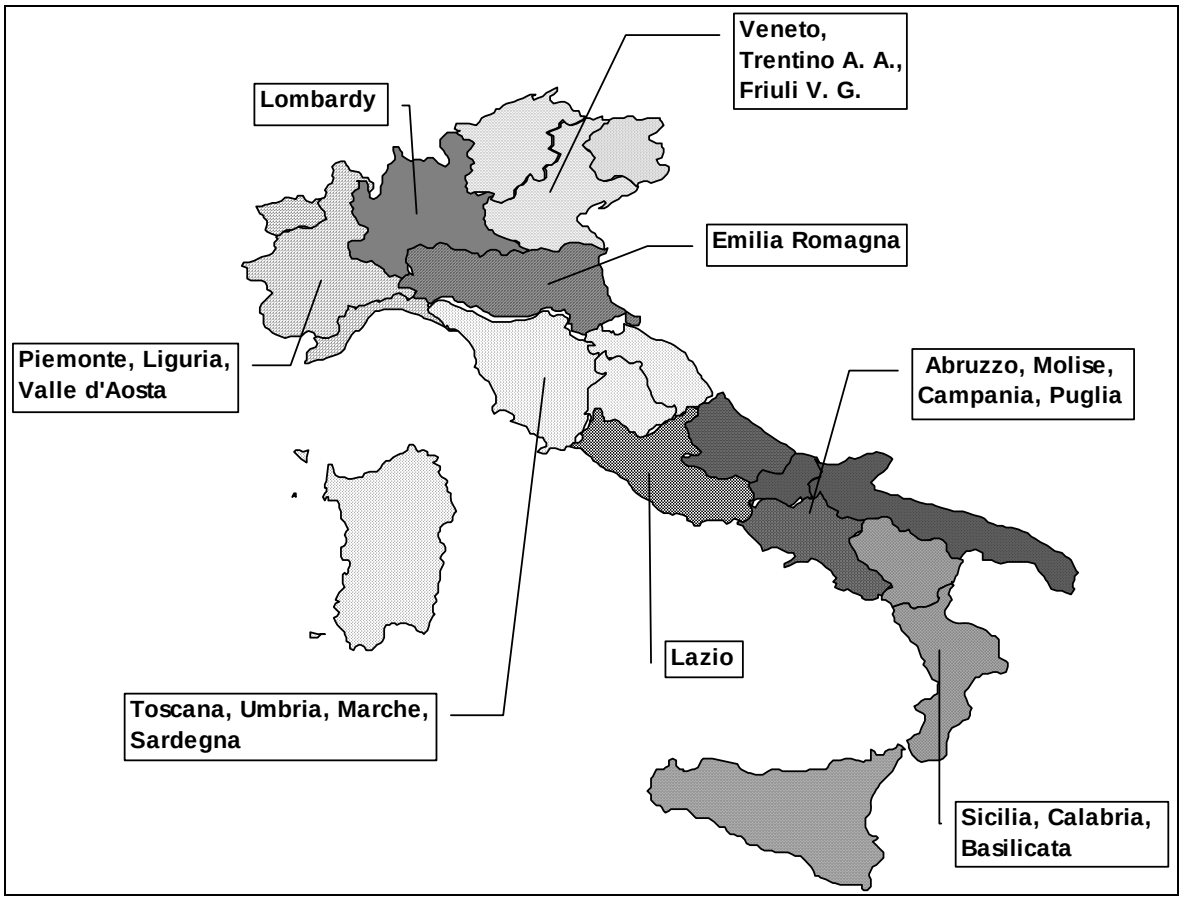
Questions were aimed to determine quantities of consumed wood, used types of combustion systems, frequency of supplying, storage conditions and the reasons to have a preference for wood as a fuel for domestic heating. These data have been gathered with other features concerning the family (number of members, etc.), the house (building type, heated surface) and its location (height, position, town size). The same information has been obtained for holiday homes.

The statistical elementary unit is the family; the sample has been chosen with the aim to split the universe in different layers in which the number of interviews was proportional to the number of represented families, in order to reduce the error of sampling (Table 1). The sample has been divided into four layers: macro-regions (Figure 1), size of the settlements, number of family members, altimetrical zone. The two techniques used for the survey have permitted to build a sample of 5,000 families spreaded all over the Italian territory.

Table 1. Distribution of the sample of the survey into the four layers.

	SAMPLE	UNIVERSE (families)	%
Basis	**5,000**	**21,810,676**	**100 %**
Macro-regions			
Piemonte + Liguria + Valle d'Aosta	591	2,576,236	11.8 %
Lombardia (Lombardy)	836	3,646,028	16.7 %
Veneto + Trentino A. Adige + Friuli V.G.	591	2,576,236	11.8 %
Emilia Romagna	380	1,659,270	7.6 %
Toscana + Marche + Umbria + Sardegna	651	2,838,226	13.0 %
Lazio	455	1,986,758	9.1 %
Abruzzo + Molise + Campania + Puglia	876	3,820,689	17.5 %
Sicilia + Calabria + Basilicata	621	2,707,232	12.4 %
Size of settlements			
Up to 5,000 inhabitants	944	4,118,100	18.9 %
5,001 – 20,000 inhabitants	1,424	6,209,833	28.5 %
20,001 – 50,000 inhabitants	849	3,704,111	17.0 %
50,001 – 100,000 inhabitants	539	2,353,200	10.8 %
More than 100,000 inhabitants	1,244	5,425,433	24.9 %
Altitude			
Mountain (over 600 m)	699	3,050,433	14.0 %
Hill (300 – 600 m)	1,918	8,366,933	38.4 %
Plain (up to 300 m)	2,383	10,393,300	47.7 %
Number of family members			
One member	1,244	5,425,433	24.9 %
2 members	1,354	5,904,788	27.1 %
3 members	1,079	4,706,400	21.6 %
4 members	949	4,139,889	19.0 %
5 members and more	375	1,634,167	7.5 %

Figure 1. Macro-regions used in the sample.



RESULTS

Diffusion of wood use

Results show that 25.6% of Italian families use wood for domestic uses, the greater part of them (84.5%) in the residence house, 10.1% in the holiday home and only 5.4% in both of them. By geographical level, regions that use more wood are in the central and southern Italy: its use is more common in mountains and hills, in single buildings, and in towns below 5,000 inhabitants. With reference to the altitude of the house location, values are quite different from the national average of 25.6%: in fact, more than 4 families out of 10 use wood in the mountain (over 600 m above sea level), followed by 26.4% of people living in the hills and 21.1% on the plain.

In order to obtain the total annual consumption over Italy only families that use wood regularly, that is more than four times a year, have been considered: the percentage is in that case about 20% of the total, more than 4 million houses in Italy.

Distribution of wood combustion systems

Utilized combustion systems add up to 5,697,631 units, an average of about 1.28 appliance for each household: differences persist from mountain (1.40) to hills (1.30) and plain (1.17).

As regards the types of device, as shown in Figure 2, open fireplace is the most widespread type in Italy (44.7%), followed by the traditional stove (27.6%); this point is of a great importance because, as shown later, “traditional” systems are characterized by much higher emission levels than “innovative” ones, due to bad combustion conditions in the furnace determined by temperature and air availability conditions. Innovative systems represent instead the remaining 27.7% of wood combustion devices, with the closed fireplace (20.2%) at the top, followed by the innovative stove at 4.4% and finally by the automatic pellet stove at 3.1%.

With reference to the altitude (Figure 3) the traditional stove is moderately above the national average in the mountain (38.2%) whereas the open fireplace is more common in the hill (51.2% instead of 44.7% as national average). It must be noted that innovative stove is leading in the mountain, with 7.4% of the devices, rather than the 3.7% in the hill and only the 2.7% in the plain.

Figure 2. Distribution of wood combustion systems by type.

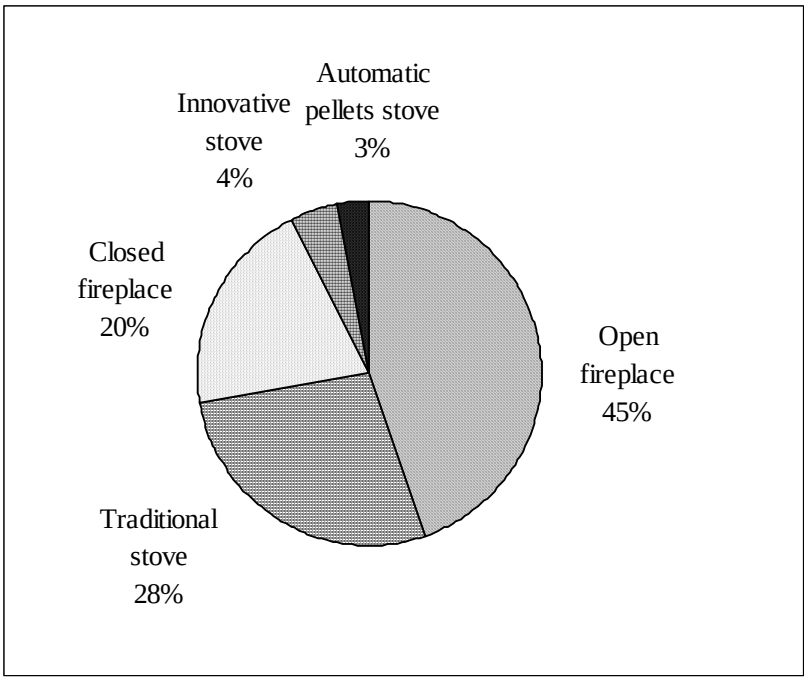
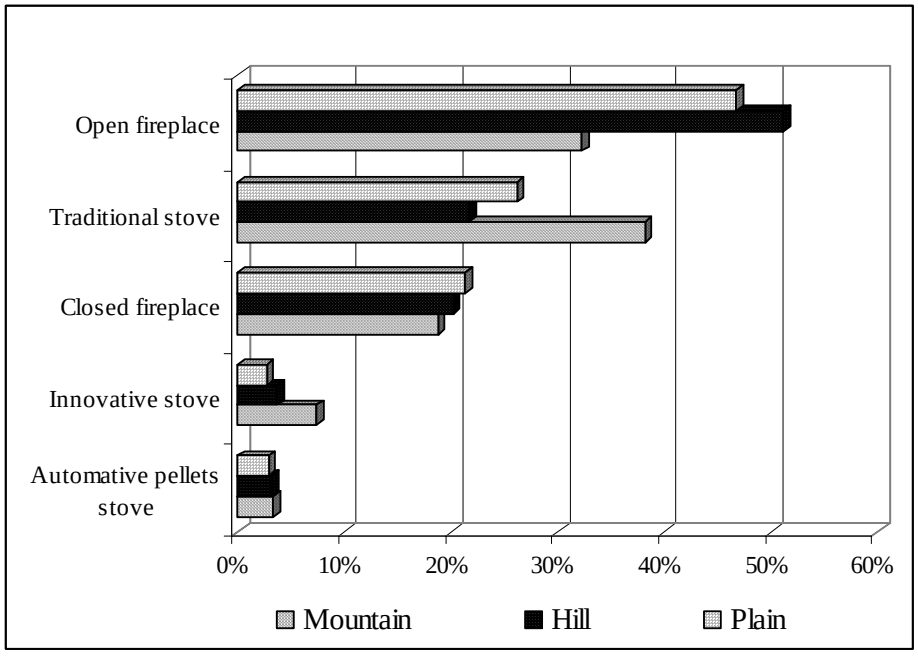


Figure 3. Distribution of wood combustion systems by altitude.



The distribution of wood combustion systems by type and by geographical area is represented in Table 2: in central and southern Italy can be observed the predominance of traditional systems (open fireplace and traditional stove); innovative systems are therefore not very common yet, although in Lombardy they represent an increasing share (46% on the regional subtotal).

Table 2. Distribution of wood combustion systems by geographical area.

Wood combustion system	MACRO REGIONS – FAMILY RESIDENCY							
	Piemonte + Liguria + Valle d'Aosta	**Lombardy**	**Veneto + Trentino A. A. + Friuli V. G.**	**Emilia Romagna**	**Toscana + Marche + Umbria + Sardegna**	**Lazio**	**Abruzzo + Molise + Campania + Puglia**	**Sicilia + Calabria + Basilicata**
Open fireplace	19%	27%	16%	36%	66%	55%	72%	49%
Traditional stove	46%	27%	55%	36%	18%	19%	6%	22%
Closed fireplace	27%	35%	19%	19%	11%	19%	16%	20%
Innovative stove	4%	5%	7%	7%	1%	5%	3%	6%
Automatic pellets stove	3%	6%	3%	1%	3%	2%	2%	3%
TOTAL	100%	100%	100%	100%	100%	100%	100%	100%

Wood consumption

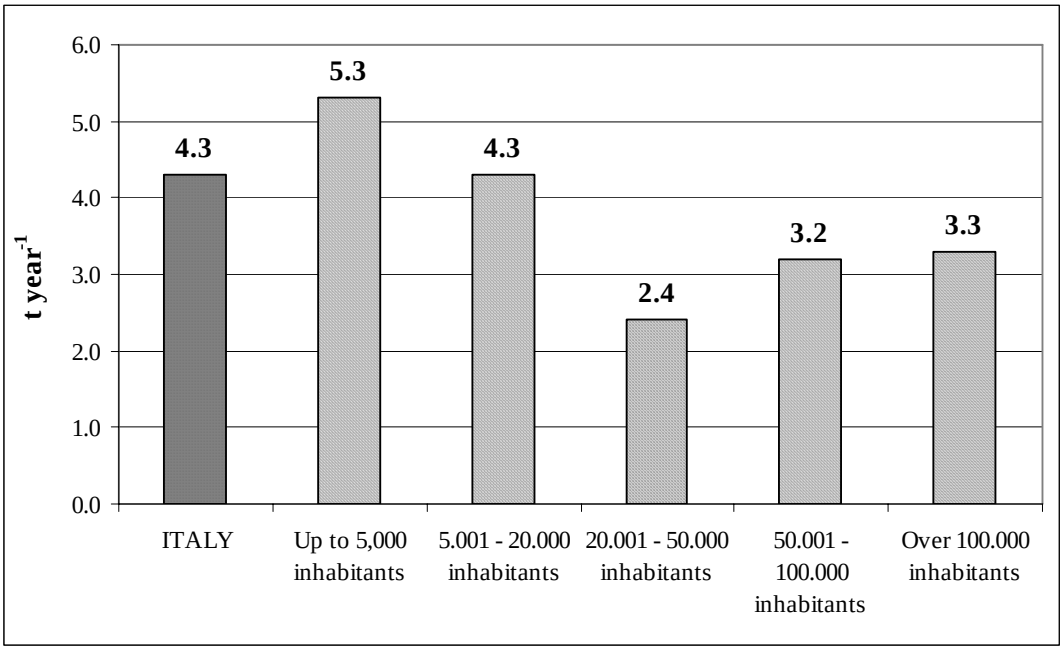
The survey has allowed to estimate a domestic wood consumption of about 19 million tons, used in 4,432,419 households, with an average consumption of 4.3 tons of wood per household per year. The use of wood, or wood derived fuels, is characterized by significant differences over the territory, due to the different morphologies and climates, as stressed in Table 3. The geographical area at the top is the central Italy (Toscana, Marche, Umbria and Sardegna), that consumes 18.1% of the total amount in Italy, followed by the macro-region Abruzzo-Molise-Campania-Puglia with a consumption of 17.5%.

Table 3. Distribution of wood consumptions by geographical area.

	Households	**%**	**Wood consumptions** t	**%**	**Wood consumptions per household** t
ITALY	**4,432,419**	**100 %**	**19,119,481**	**100 %**	**4.3**
Piemonte + Liguria + Valle d'Aosta	480,115	10.8 %	2,268,662	11.9 %	4.7
Lombardy	594,396	13.4 %	2,034,035	10.6 %	3.4
Veneto + Trentino A. A. + Friuli V. G.	656,140	14.8 %	3,112,048	16.3 %	4.7
Emilia Romagna	271,260	6.1 %	932,336	4.9 %	3.4
Toscana + Marche + Umbria + Sardegna	752,458	17.0 %	3,461,665	18.1 %	4.6
Lazio	404,453	9.1 %	1,707,416	8.9 %	4.2
Abruzzo + Molise + Campania + Puglia	782,329	17.7 %	3,350,698	17.5 %	4.3
Sicilia + Calabria + Basilicata	491,269	11.1 %	2,252,622	11.8 %	4.6

As regards the average consumption per household, values are close to the national average, corresponding to 4.3 tons of burnt wood per household for the year 2006. Besides, consumptions can be read also on the basis of other variables: for instance, in Figure 4, with reference to the size of the settlements the main consumptions are in towns below 5,000 inhabitants, with 5.3 tons burnt per household.

Figure 4. Wood consumptions by size of settlements.



Concerning distribution of wood consumptions by altimetrical zones, in the mountain the averages are about 5.2 t whereas the type of house which presents the highest consumptions, equal to 5.3 t, is the villa (Table 4).

Table 4. Wood consumptions by altitude and building type.

	Wood consumptions t	**%**	**Wood consumptions per household** t
ITALY	**19,119,481**	**100 %**	**4.3**
Altitude			
Mountain	6,120,079	32.0 %	5.2
Hill	7,552,451	39.5 %	4.3
Plain	5,446,951	28.5 %	3.7
Building type			
Flat in multi-story building	1,560,038	8.2 %	3.0
Semi-detached house	2,519,937	13.2 %	3.6
House in row	10,001,885	52.3 %	4.4
Villas	5,037,621	26.3 %	5.3

Finally, considering the subdivision between residence and holiday home, the weight of wood consumption in residence house is notably higher and adds up to 92.6% while for the holiday home is 5.4%; average consumption per household is similar to the national average (4.3 t) and it is equal to 4.4 t for the residence house and to 3.1 t for the holiday home.

Use of wood combustion systems

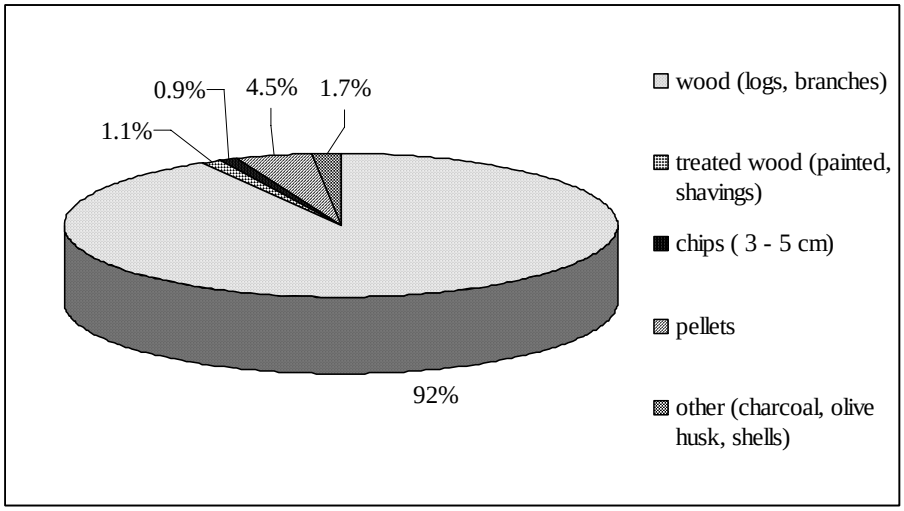
The main use of the wood combustion systems is domestic heating; more than 70% of households is heated by traditional devices whereas only one third of Italian houses uses sometimes wood for cooking. Analysis of the diffusion of fuels employed for domestic heating (Table 5) shows that wood is used as a unique fuel particularly in Southern Italy (Sicilia + Calabria + Basilicata) while in the rest of the peninsula more than 80% of the households is heated with other fuels (mainly natural gas). As shown in Figure 5, the wooden material most used in combustion systems is wood

(logs, branches) with values above 90% all over Italy; pellets share (4.7%) is small although increasing, whereas other wooden materials represent less than 2% each.

Table 5. Percentages of diffusion of fuels used for domestic heating.

	TOTAL	Piemonte + Liguria + Valle d'Aosta	Lombardy	Veneto + Trentino A. A. + Friuli V. G.	Emilia Romagna	Toscana + Marche + Umbria + Sardegna	Lazio	Abruzzo + Molise + Campania + Puglia	Sicilia + Calabria + Basilicata
Only wood material	16.1 %	17.9 %	16.8 %	10.1 %	16.9 %	13.1 %	13.8 %	18.1 %	24.5 %
Other:	83.9 %	82.1 %	83.2 %	89.9 %	83.1 %	86.9 %	86.2 %	81.9 %	75.5 %
natural gas	*56.4 %*	*53.1 %*	*70.2 %*	*56.4 %*	*58.9 %*	*53.1 %*	*60.9 %*	*56.7 %*	*42.8 %*
gas oil	*8.7 %*	*14.8 %*	*4.6 %*	*20.5 %*	*7.1 %*	*7.6 %*	*6.0 %*	*6.6 %*	-
LPG	*11.0 %*	*6.5 %*	*7.7 %*	*10.2 %*	*8.4 %*	*16.0 %*	*14.6 %*	*9.7 %*	*13.6 %*
solar panels	*1.4 %*	*0.9 %*	*0.7 %*	*3.2 %*	*1.8 %*	*1.1 %*	*2.2 %*	-	*1.8 %*
electrical energy	*9.8 %*	*8.5 %*	*2.2 %*	*7.6 %*	*10.6 %*	*13.2 %*	*4.7 %*	*11.4 %*	*19.2 %*
other	*1.2 %*	*1.0 %*	-	-	*1.7 %*	*0.6 %*	*4.9 %*	*1.2 %*	*1.9 %*

Figure 5. Wooden materials used in wood combustion systems.



Reasons and supplying means

Another aim of the survey was to know the reasons to prefer a wood combustion system: the multiple choice question has permitted to find out that besides economic savings, which are prevalent, there is also a mere "aesthetic" reason that drives wood use: the answer "because it is beautiful to see it burning" has been chosen by 42.3% of the interviewed (Table 6). It is notable that the same reason results exclusive for the 17% of the families.

Table 6. Main declared reasons of using wood for domestic heating (percentage on the total number of interviews, multiple choices were possible).

	TOTAL	Piemonte + Liguria + Valle d'Aosta	Lombardy	Veneto + Trentino A.A. + Friuli V. G.	Emilia Romagna	Toscana + Marche + Umbria + Sardegna	Lazio	Abruzzo + Molise + Campania + Puglia	Sicilia + Calabria + Basilicata
it's cheap	31.0 %	37.8 %	30.3 %	39.7 %	37.7 %	20.9 %	29.3 %	28.2 %	31.0 %
it's ecologic	16.2 %	22.3 %	18.2 %	18.9 %	13.6 %	15.6 %	13.4 %	12.1 %	15.4 %
I don't buy it	32.0 %	35.3 %	26.4 %	37.9 %	30.9 %	31.9 %	19.2 %	32.6 %	38.1 %
it warms better	24.0 %	24.1 %	36.1 %	31.9 %	25.7 %	19.2 %	19.8 %	14.8 %	23.0 %
I don't know	6.4 %	1.9 %	5.3 %	3.4 %	5.1 %	8.8 %	12.4 %	6.1 %	9.0 %
it's beautiful to see	42.3 %	35.0 %	41.9 %	31.5 %	39.3 %	53.0 %	53.4 %	49.4 %	29.1 %
tradition/country life	1.8 %	3.0 %	-	0.7 %	2.0 %	3.7 %	1.3 %	1.8 %	1.7 %
it's better for cooking	1.1 %	1.8 %	0.7 %	1.3 %	3.6 %	1.2 %	1.2 %	-	1.0 %
other	0.9 %	-	3.1 %	-	-	0.6 %	-	1.9 %	0.9 %
it's beautiful to see (sole answer)	*17.0 %*	*14.6 %*	*16.0 %*	*6.8 %*	*19.0 %*	*21.2 %*	*20.5 %*	*25.4 %*	*9.9 %*

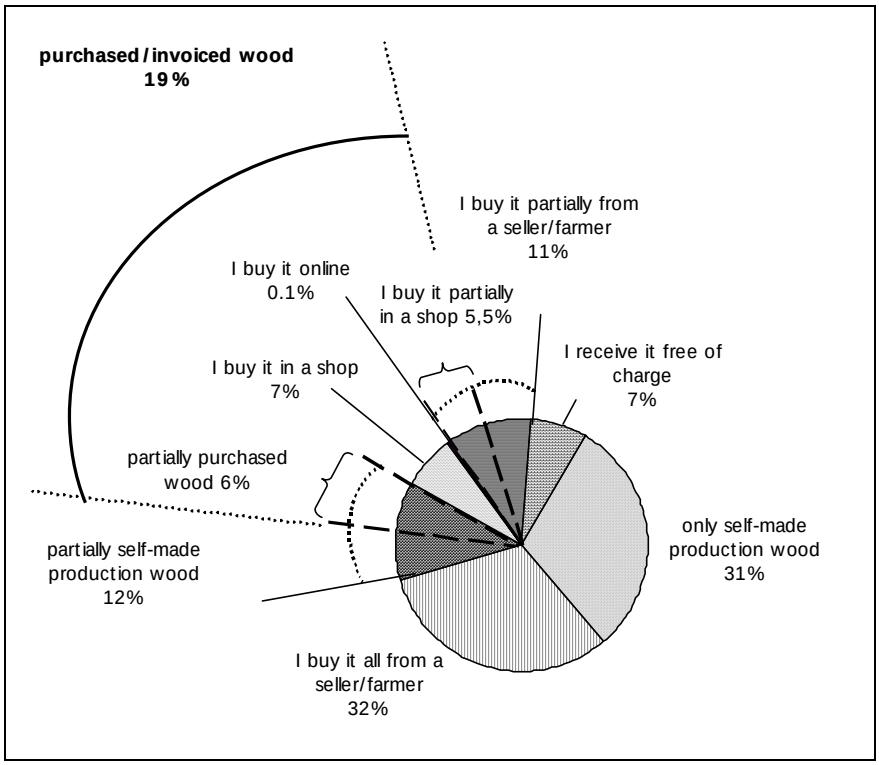
As regards the supplying means there is approximately a balance between self-made production and purchase on a national average, although some differences result among regions: Table 7 illustrates how the North-West and Southern Italy have the biggest fractions for self-made production, whereas purchase is instead more disseminated in the Central Italy and in Lombardy. Frequency of supplying is commonly one or twice a year in most case, with percentages decreasing as frequency rises. Storage is usually outdoor, repaired by a roof (45.7%) or in a shed or other closed shelter (27.5%). Materials used to light the fire are commonly little branches, newspapers or other products.

Table 7. Supplying means for wood (percentages on the total number of interviews, multiple choices were possible).

	TOTAL	Piemonte + Liguria + Valle d'Aosta	Lombardy	Veneto + Trentino A. A. + Friuli V. G.	Emilia Romagna	Toscana + Marche + Umbria + Sardegna	Lazio	Abruzzo + Molise + Campania + Puglia	Sicilia + Calabria + Basilicata
only self-made production wood	34.6 %	44.8 %	27.1 %	38.4 %	34.4 %	29.5 %	27.7 %	33.9 %	43.7 %
partially self-made production wood	14.0 %	11.2 %	13.4 %	13.6 %	10.1 %	16.1 %	10.7 %	13.9 %	20.0 %
I buy it all from a seller/farmer	36.0 %	30.2 %	40.9 %	24.8 %	41.7 %	40.7 %	48.3 %	35.6 %	31.0 %
I buy it partially from a seller/farmer	12.4 %	14.3 %	7.4 %	18.3 %	12.0 %	7.0 %	12.1 %	16.3 %	11.7 %
I buy it in a shop	8.0 %	6.4 %	11.7 %	9.6 %	3.3 %	10.2 %	9.5 %	7.2 %	2.7 %
I buy it online	0.1 %	-	-	-	-	-	-	-	0.9 %
I receive it free of charge	8.1 %	3.7 %	15.1 %	10.9 %	10.2 %	8.3 %	2.4 %	5.3 %	8.1 %

It is possible to estimate wood consumptions "recorded" in official statistics, as invoiced and purchased by the common trading exchanges. Answers to the questionnaire do not allow an accurate identification of the flows; therefore it has been assumed that for whom declaring to use wood only "partially self-made" or "partially purchased", a share about 50% of the total amount is purchased with an invoice and so included in the official statistics. Adding up the percentages it can be noted in Figure 6 that about 20% of wood consumptions derive from the trading exchanges (about 3.6 Mt) whereas the remaining 80% is from non commercial sources.

Figure 6. Percent distribution of supplying means (purchase/other).



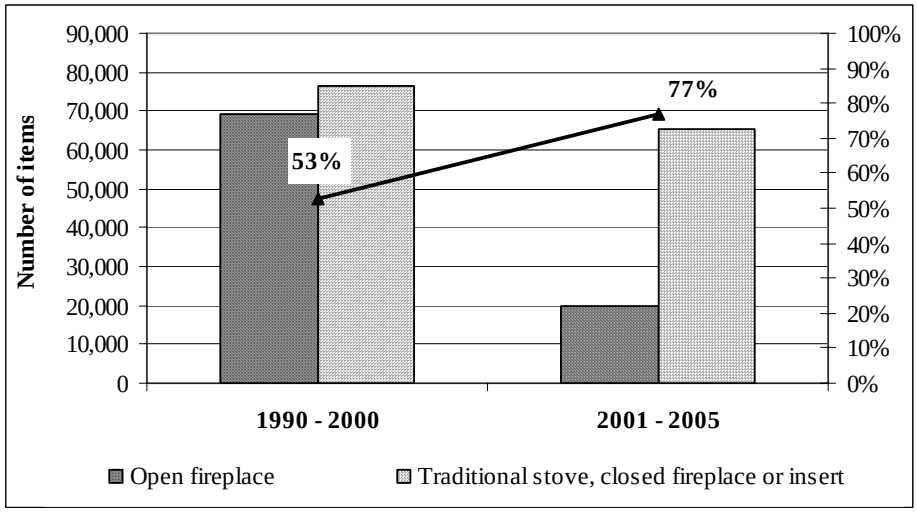
Tendency to purchase new wood combustion systems

Another goal of the survey has been to analyze the family tendency to substitute the present wood combustion system for domestic heating with an innovative one, using incentives offered by institutions; in particular two replacements have been considered, with an innovative stove and with an automatic stove, and for both of them different increasing incentives have been proposed.

The 5.1% of the sample affirm the intention of changing their combustion system with an innovative stove (total cost about € 2,000) if an incentive of € 500 would be provided (17.1% has considered probable the purchase); with an incentive of € 1,000 this percentage rises to 6.6%. The tendency to purchase an automatic stove, a system where pellets or chips are automatically fed, has been analyzed instead through incentives of € 300, € 500 and € 1,000: in the first two cases the sure answer to the purchase resulted in 3.3%, raising to 4.3% for the last incentive.

The interest in the renewal of wood appliances is confirmed by information gathered from producers of the wood combustion system (4), demonstrating an increasing trend for new technologies in Lombardy, as illustrated in Figure 7 where is shown the evidence for the rising percentage of the innovative devices for the most part of the sales.

Figure 7. Trend in sales of wood combustion systems in Lombardy (number of appliances and percentage on the total sold).



Comparison with previous surveys

Available information on domestic use of wood has been extremely scarce and fragmentary until a few years ago. In the years 1997 and 1999 two surveys have been conducted by ENEA (5, 6) which have allowed to carry out a sufficiently accurate estimation of wood consumptions for domestic heating at national level. According to the period and the size of the sample, a comparison could be made on the total wood consumption assessed, at the national and regional level, for altimetrical zones, residence/holyday home, fuels and wood combustion systems. For instance, a comparison among the different estimates of the national and average wood consumptions is shown in Figure 8, while consumptions by altimetrical zones are illustrated in Figure 9.

Figure 8. Comparison of national (t year^{-1}) and average wood per household (t household^{-1}) consumptions among three surveys.

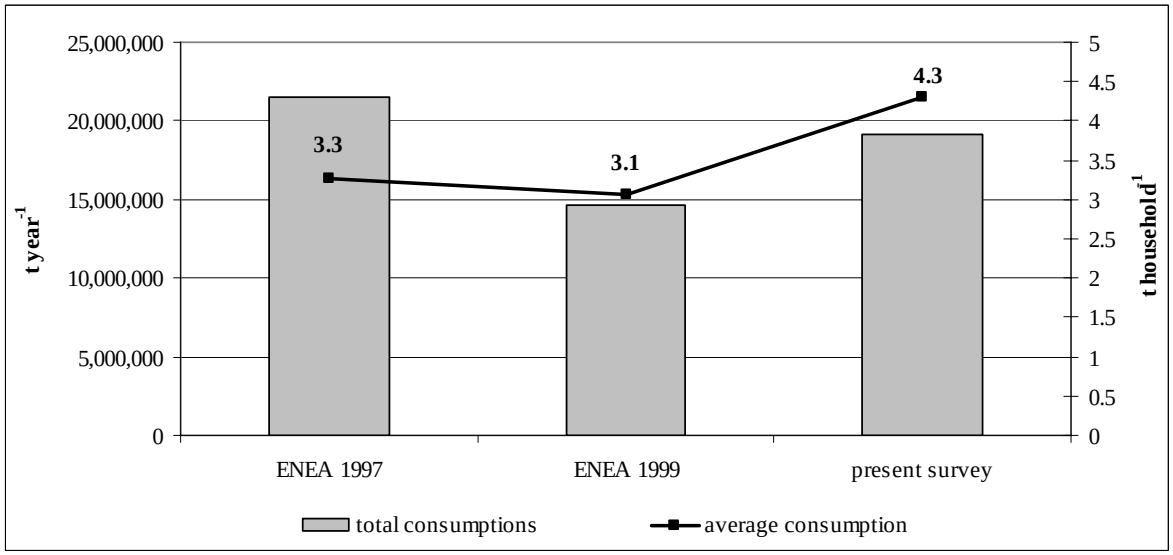
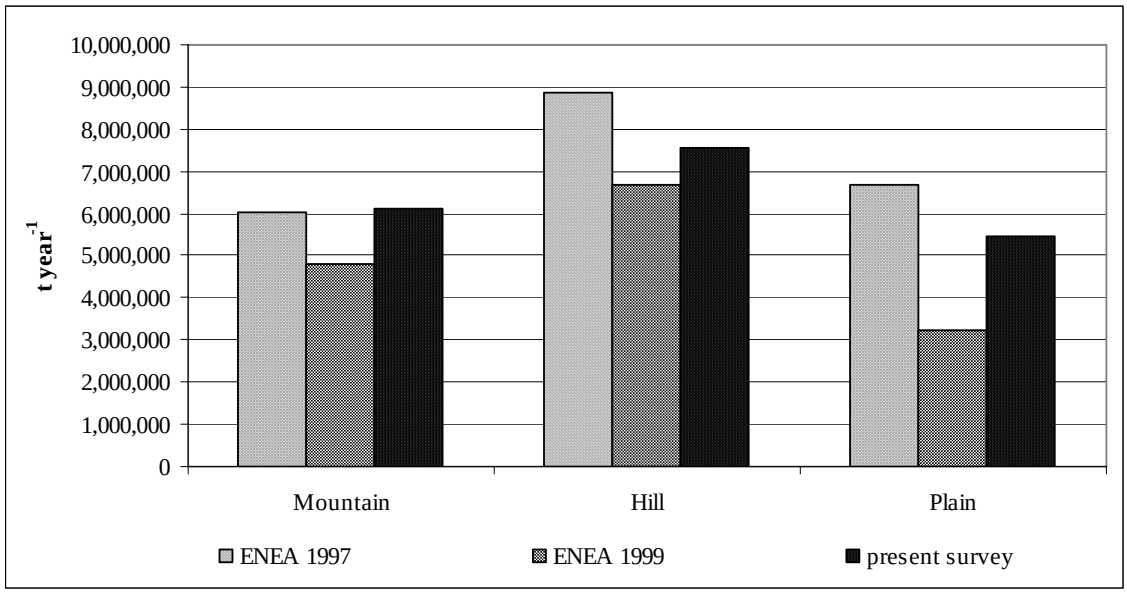
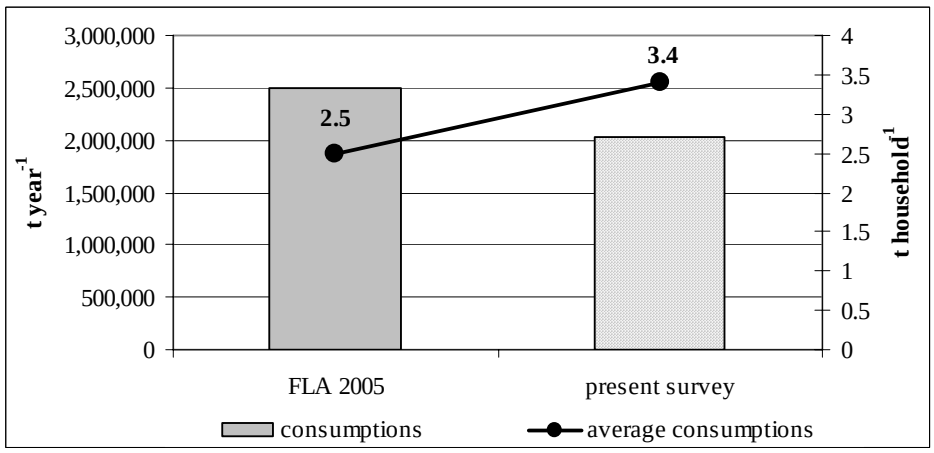


Figure 9. Comparison of wood consumptions by altimetrical zones among three surveys.



With reference to Lombardy region a specific survey has been conducted in 2005 among the middle school students (2): results seem close to those of the present survey, as shown in Figure 10 where results from (2) are expressed as "FLA 2005", both for the average consumption per household and for the total use.

Figure 10. Comparison of Lombardy wood consumptions between two surveys.



Atmospheric emissions assessment

In recent years wood as an energy source has received a considerable attention for both its cheap supplying costs and its minor environmental impact due to CO_2 emissions. Wood is actually a renewable and carbon-neutral source of energy, as CO_2 emitted during its combustion is equal to that absorbed throughout its vegetative life because of the photosynthesis process. A Life-cycle analysis for seven strategies of biomass combustion has shown important environmental advantages in terms of reduction of greenhouse gas emissions, but has also highlighted the significant contribution of domestic biomass burning to fine particulate and toxic emissions (7, 8).

Results of present survey have been used to assess implied atmospheric emissions, on the basis of average emission factors derived from literature (Table 8). Wood consumptions, converted in GJ by a 12.5 GJ t^{-1} LHV (lower heating value) and split into the combustion systems (Table 9), have allowed an estimate of emissions from wood combustion in Italy and in Lombardy (Tables 10 and 11). PM10 emissions in Italy, assessed by this methodology in 84,000 tons per year, are more

than 90% of emissions previously estimated from domestic heating and 50% of the total emissions in 2003 in Italy from all sources (9), whereas in Lombardy this share represents 94% of the residential combustions and almost a third of the overall emissions (10).

On the other hand, with regards to CO_2 savings, a thermal energy production of 131 PJ (PJ = 10^{15} J) by the national consumption of 20 Mt of wood has been assessed assuming an average efficiency of 55% for the combustion systems and a 12.5 GJ t^{-1} LHV. If the same energy would have been produced by natural gas boilers, with a 75% efficiency and a CO_2 emission factor of 55.5 kg GJ^{-1}, the estimate of the CO_2 emissions would have been about 9.7 Mt. This amount is almost 2% of the CO_2 emitted in Italy in 2005 (9).

Table 8. Emission factors of the main pollutants from domestic use of different technologies for several fuels (7, 8).

	PM10 g GJ^{-1}	**NOx** g GJ^{-1}	**VOCNM** g GJ^{-1}	**SO2** g GJ^{-1}	**CO** g GJ^{-1}	**PAH** mg_{TEQ} GJ^{-1}	**Dioxins** ng_{TEQ} GJ^{-1}
Open fireplace	500	70	5,650	13	5,650	280	170
Traditional stove, closed fireplace or insert	250	70	1,130	13	5,650	280	170
Innovative low emission system and boiler	150	60	560	13	2,260	280	30
Pellets plant or BAT system burning wood	50	65	85	13	800	0.2	3
Average EF*	**351**	**69**	**3,093**	**13**	**5,351**	**271**	**159**

*estimated by the total wood consumptions by system in Italy.

Table 9. National and Lombardy wood consumptions by combustion system.

	Italy TJ	**Lombardy** TJ
Open fireplace	106,849	6,959
Traditional stove, closed fireplace or insert	114,251	15,779
Innovative low emission system and boiler	10,426	1,265
Pellets plant or BAT system burning wood	7,468	1,422
Total consumptions	**238,994**	**25,425**

Table 10. Emissions of the main pollutants estimated from domestic combustion of wood (t y^{-1}).

	PM10		NOx		VOCNM		SO2		CO	
	Italy	**Lombardy**	**Italy**	**Lombardy**	**Italy**	**Lombardy**	**Italy**	**Lombardy**	**Italy**	**Lombardy**
Open fireplace	53,425	3,479	7,479	487	603,697	39,318	1,389	90	603,697	39,318
Traditional stove, closed fireplace or insert	28,563	3,945	7,998	1,105	129,104	17,830	1,485	205	645,518	89,152
Innovative low emission system and boiler	1,564	190	626	76	5,839	709	136	16	23,563	2,859
Pellets plant or BAT system burning wood	373	71	485	92	635	121	97	18	5,974	1,138
Total estimated emissions	*83,924*	*7,685*	*16,588*	*1,760*	*739,274*	*57,978*	*3,107*	*331*	*1,278,750*	*132,467*
Total emissions (9, 10)	168,094	25,293	1,245,343	210,629	1,463,363	346,145	528,156	52,430	4,381,230	561,105
% on total	50%	30%	1.3%	0.8%	51%	17%	0.6%	0.6%	29%	24%

Table 11. Annual emissions estimated of PAH and dioxins.

	PAH kg		Dioxins mg_{TEQ}	
	Italy	**Lombardy**	**Italy**	**Lombardy**
Open fireplace	29,918	1,948	18,164	1,183
Traditional stove, closed fireplace or insert	31,990	4,418	19,423	2,682
Innovative low emission system and boiler	2,919	354	313	38
Pellets plant or BAT system burning wood	1.5	0.3	22	4.3
Total estimated emissions	*64,829*	*6,721*	*37,922*	*3,908*

CONCLUSIONS

Statistical analysis of data collected from 5,000 families has permitted to estimate the Italian wood consumption for domestic heating in about 20 Mt, with an important use frequency (more than 4 times a year) for about 20% of the Italian population. Results confirm and better characterize previous assessment on the entity and patterns of domestic use of wood in Italy and in Lombardy.

Results highlight a large use of wood in mountain areas, followed by the hills; biomasses are utilized commonly in residence houses, in small settlements below 5,000 inhabitants, and in single buildings.

Wood is typically the most used fuel, mainly for domestic heating and hardly ever for cooking; reasons that lead to have a preference for wood as a fuel are closely related to its economic saving, even if in some cases there is also an "aesthetic" component.

Results of the present research compare well with previous surveys, and allow to conclude that:

- wood consumption for domestic use is widespread throughout the national territory;
- biomasses are utilized generally more in residence house than in the holiday home;
- altimetrical zones where wood is more common are the mountain followed by the hills;
- consumption is higher in little settlements, below 5,000 inhabitants, and in single buildings;
- biomasses are typically used for domestic heating rather than cooking;
- wood logs and branches are the most common fuel whereas other wooden materials add up to a little percentage;
- traditional wood systems are widespread on the national territory but trend in sales for innovative devices is growing.

Traditional combustion systems (open fireplace, traditional stove) represent more than 70% of the total and are the most common appliances throughout Italy; the remaining 30% corresponds to the innovative devices (closed fireplace, innovative and automatic stove) that, thanks to more advanced technologies, have reduced pollutant emissions. The information on the use of different appliances are of great importance because wood as a fuel has an environmental cost in terms of PM and toxic emissions, directly linked to combustion technologies and higher for old stoves and fireplaces.

Environmental benefits from the use of wood are otherwise related to its photosynthetic origin, as wood is nearly neutral for greenhouse gas emissions; the assessment of CO_2 savings in Italy from the wood consumptions in household heating is quantified by the present survey in about 2 % of the total CO_2 emitted in Italy.

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