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A new survey to estimate pellet-fired stoves and boilers for residential applications in the province of Turin (Italy)

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Abstract

The use of biomass for energy production is becoming a key factor in order to reach the EU targets of 20% of energy from renewable sources by 2020. The use of wood biomass in residential applications has a significant share in some Italian regions, especially in rural areas. Nevertheless, an accurate estimation of the amount of biomass used for these purposes is not always available and it is not easy to undertake. In this paper a methodology to overcome this lack is proposed. The study has been applied in the Province of Turin, in order to quantify the amount of wood-fired residential heating devices, their fuel consumption and the thermal energy they produce. The data collected from national census and from sales volumes of devices in the province of Turin have been used to perform detailed analyses and assessments.

The results of the present study have been used to improve the local energy balance of the province of Turin for the years 2001-2011 and to implement future scenarios.

This methodology can be extended in any region who needs to estimate the share of energy from biomass in the residential sector.

1 Introduction

An essential requirement in order to define the contribution of biomass to a local energy balance is the knowledge of the number of wood-fired residential heating devices (boilers and room-heaters), their characteristics and main parameters, in terms of heat-output, efficiency and emissions. Further estimations of the consumption of energy and raw materials, the average efficiency in biomass energy conversion and air pollutant emissions can be performed by reconstructing the trends of the number and typology of the heating systems over the years.

The aim of the study is to monitor the trend of the spread of wood-fired heating devices in order to better estimate the contribution of biomass to the production of thermal energy and to improve the Local Energy Balance of the provincial territory.

In Italy the thermal energy production from biomass in residential applications is usually investigated by means of periodical sample surveys, conducted by main trade associations, census institutes and operators in the biomass sector.

The most recent surveys in the Province of Turin area, in the North West of Italy, were carried out in 2006, before the "boom" in pellet-fired device sales. The use of pellet-fired heating devices is quite recent in Italy, beginning on a large scale from 2000, with a strong growth in 2006.

The Energy Department of the Politecnico di Torino has been put in charge of a new survey and of the following analysis for the improvement of the energy balance, within the Interreg Alcotra project named RENERFOR involving the ALPMED Regions of Italy and France.

The study has been developed in three phases:

1. reconstruction of sales of wood-fired residential heating devices through a market survey;
2. assessment of the number of wood-fired residential heating systems at the reference year 2001 from national census data (ISTAT, 2001) and integration with the sales data; definition of average life expectancy of the devices;
3. estimate of the energy produced from wood-fired residential heating systems in the Province of Turin and of the consumption of biomass.

2 Market survey

2.1 Methodology

In 2010, the public administration of the Province of Turin started a census program on wood-fired residential heating systems (based on boilers and room-heaters fired by wood-log and pellet) in its territory, 6.800 km^2 with a population of 2,3 million inhabitants, 52% living in the city of Turin and its neighbourhoods, and about 20% living in rural communities (villages <5.000 inhabitants).

The Companies contacted for the market survey were identified within the member lists of the main trade associations, the members of technical committees, the list of exhibitors in the main expo and events in the biomass sector and through the main technical magazines and journals in the energy and biomass sector.

During the market survey, which took about 10 months, more than 150 companies operating in the provincial territory were contacted and requested to fill in a form about the sales of biomass-fired heating devices over the years from 2001 to 2010.

In the present study, residential biomass-fired heating devices are divided into five categories: boilers, room-heaters with boiler (fireplaces, stoves and cookers with boiler), fireplaces, stoves, cooking appliances. For each category a further distinction based on the fuel (wood log or pellet) has been made.

The market surveys were carried out category by category, defining different panels of companies. Each panel, composed of the companies operating in the provincial territory, were assumed to be a representative sample of the whole market.

The data and composition of panels are complete for the period from 2007 to 2010. Some data is missing in the period from 2002 to 2006, since some companies did not provide consistent sales data, and have been reconstructed by assuming year 2007 as a reference for the market share of the companies under consideration. The data for 2011 was estimated from national sales statistics on the basis of the sales in 2010 and in the previous years.

The sales data of the companies in each panel was used to set four classes of sales volumes, defined as 10th, 30th, 60th and 90th percentile of the set of data. Classes were assigned also to companies that did not provide any data, by estimating sales volumes on the basis of: brand relevance, significant presence in the market (number of dealers, sales and technical branch offices, participation in exhibitions and fairs, advertising), composition and market share of trade associations panels and information from competitors reached on the phone in the frame of the survey. A further category “other companies“ and a correspondent class of sales volume was introduced, in order to compensate the missing data in the census of companies operating in the provincial territory.

The market share of each panel was calculated on the basis of the sales volumes of all the surveyed companies. The accuracy of the assigned classes was continuously verified during the survey, as soon as new data was made available by companies. The organization of the adopted system allows us to minimize errors in the estimation of panel market share, as well as quickly integrating data from new companies, should the survey be extended in the future.

The estimated market shares were compared with statistical data in the sector, where available.

2.2 Results

The market share of the companies participating in the survey analysis is shown in the following table, divided by category.

	Market share
Boilers	48%
Room-heaters with boiler	46%
Fireplaces	57%
Stoves	47%
Cookers	45%

Table 1 - Estimated market share of panels

Figure 1 and Table 2 show the assessments of sales/installations of different typologies of products, divided by fuel (L = wood logs, P = pellets) in the province of Turin territory.

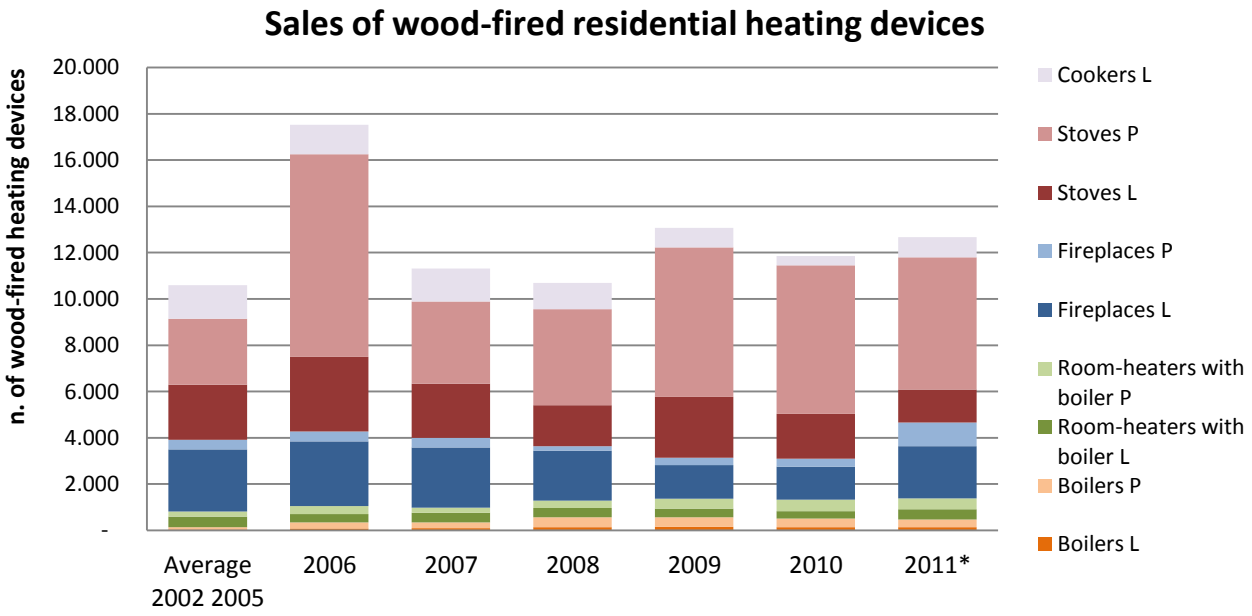

Figure 1 - Sales/installations of biomass-fired residential devices in the province of Turin

	Average 2002 2005	2006	2007	2008	2009	2010	2011*
Boilers L	46	87	97	141	157	134	146
Boilers P	100	259	245	426	415	376	326
Room-heaters with boiler L	457	365	415	408	366	321	447
Room-heaters with boiler P	214	343	224	314	429	492	464
Fireplaces L	2.686	2.798	2.604	2.152	1.461	1.426	2.255
Fireplaces P	411	430	410	194	312	352	1.022
Stoves L	2.380	3.219	2.340	1.777	2.633	1.940	1.431
Stoves P	2.854	8.760	3.561	4.145	6.457	6.412	5.715
Cookers L	1.455	1.267	1.424	1.129	838	400	871
TOTAL	**10.603**	**17.528**	**11.320**	**10.686**	**13.068**	**11.853**	**12.677**
- Wood logs	7.024	7.736	6.880	5.607	5.455	4.221	5.150
- Pellets	3.579	9.792	4.440	5.079	7.613	7.632	7.527

Table 2 - Sales/Installations (number of products) of biomass-fired residential heating devices in the province of Turin

Sales trends of wood-fired heating devices show a constant growth, with an increase of about 10% over the period 2002-2010. The year 2006 is an exception, as an extraordinary peak of sales occurred for several reasons[1].

different trends for wood-log-fired and pellet-fired devices can be distinguished.

An overall significant decline in wood-log-fired room-heater sales (around 30%) occurs over the period under examination, while wood-log-fired boiler sales show a significant increase.

On the other hand, pellet-fired heating device sales show a strong growth (+ 100%), mainly due to the exceptional sales growth of pellet-stoves.

Boilers, both wood-fired and pellet-fired, have a relatively small market share, even if they show a strong rise. It should also be noted that one boiler can heat several houses or apartments, while room-heaters usually cannot heat the whole dwelling.

The sales volumes of biomass-fired heating devices performed a strong growth over the period under examination. Pellet-fired devices went from 35% of the market in 2001 to 60% in 2011. See Figure 2.

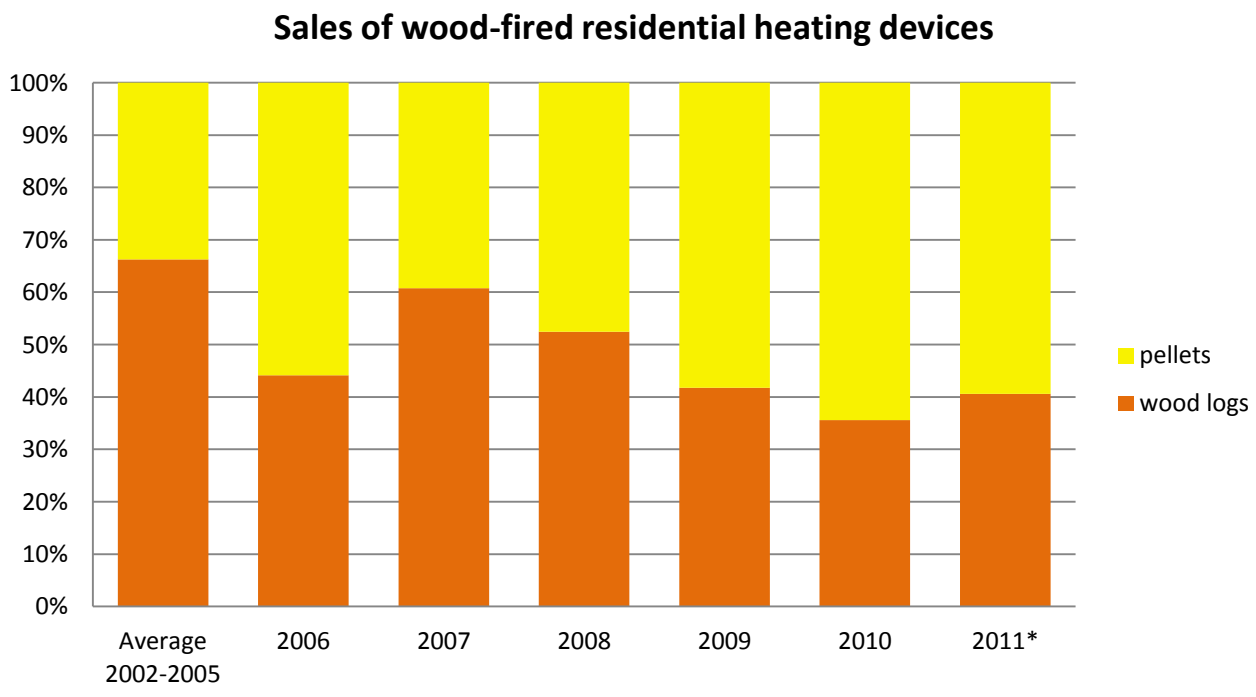

Figure 2 - Wood-fired residential devices sold in the province of Turin: wood log-fired and pellet-fired.

1 The peak sales may be referred to three external factors: significant growth in oil and gas prices, threat of gas supply disruption from Russia, an extraordinary cold winter.

3 Estimation of the number of dwellings with wood-fired heating systems in the province of Turin

3.1 Methodology

In the year 2001 the number of houses with wood-fired heating systems in the province of Turin was assessed from national census data (ISTAT, 2001) at municipal level. It is close to 130.000 units, of which around 90.000 are installed in principle places of residence (PPR) and 40.000 in holiday houses.

The categorization of different types of heating devices was estimated based on the average national and local distribution (as from sample surveys).

Looking at sample surveys carried out in 2005, which showed that pellet-fired devices had less than 10% market share, and at the sales volumes from 2002-2004, we can assume that in 2001 all heating devices were fuelled with wood logs.

The census data were integrated with the sales data, after their conversion into a corresponding number of dwellings according to the following scheme:

	Number of sold heating devices	Number of dwellings with wood-fired heating systems
Boilers ≥ 35kW	from survey	heat power/25
Boilers < 35kW	from survey	equal to nr of sold boilers
Room-heaters	from survey	equal to nr of sold room-heaters

Table 3 – Parameters used in the conversion from number of sold heating devices to number of dwellings

The study is based on the following assumptions:

a) existing devices were replaced according to an estimated average life expectancy (see following table);
b) existing devices in 2001 were equally allocated to each available age-band (from 0 to estimated average life expectancy).

Average life expectancy	Continuous use (PPR)	Occasional use (holiday houses)
Boilers	20 years	25 years
Room-heaters with boiler	20 years	25 years
Room-heaters	25 years	30 years

Table 4 - Average life expectancy of biomass-fired devices

The sales data provided by retailers allowed us to estimate the number of new devices, in fact we assumed in this study that they were installed only in PPR, replacing an existing biomass-fired device or in addition to an existing fossil fuel fired device. New wood log fired devices were allocated amongst the municipalities in the province of Turin according to the same distribution as in 2001 and they appear to be mostly concentrated in rural areas. Pellet-fired devices (easier to install and manage) were allocated amongst the municipalities based on an average between the 2001 distribution and the current resident population pattern.

3.2 Results

The chart in Figure 3 below shows the estimated number of dwellings with biomass-fired heating systems (as main heating systems or in combination with others) in the province of Turin. Table 5 shows the same data filtered by type of device and fuel used.

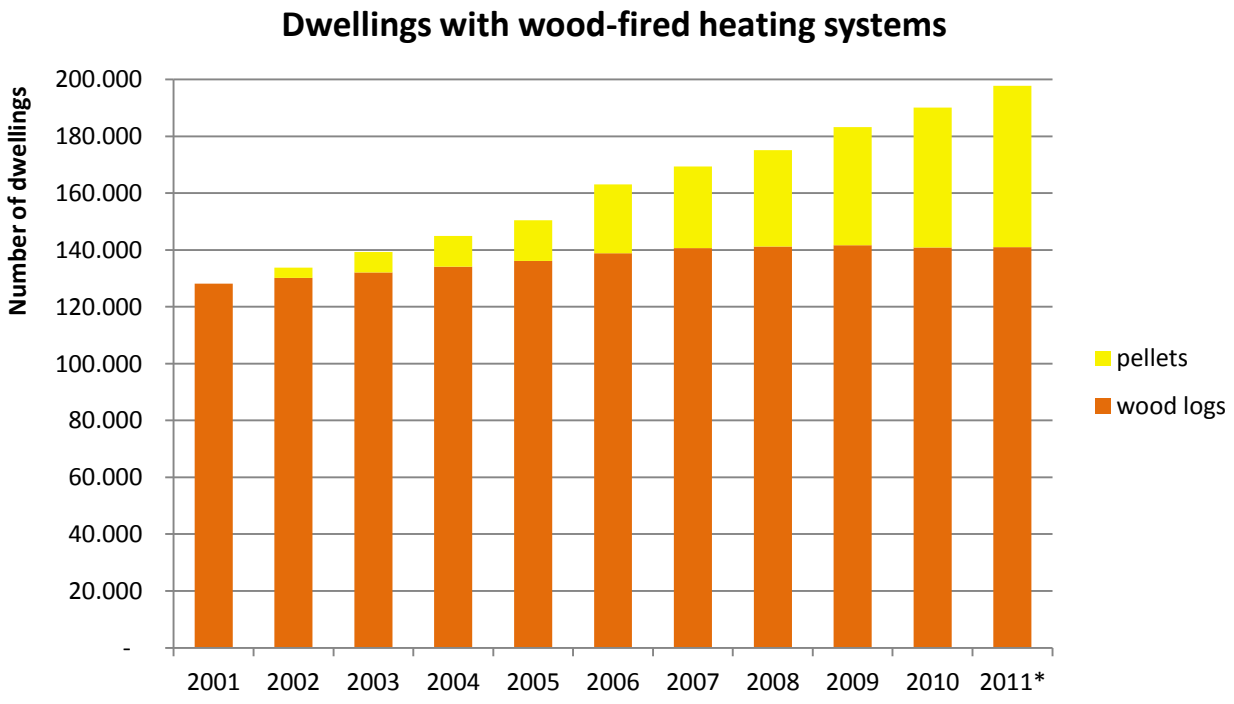

Figure 3 - Estimated number of dwellings with biomass-fired heating systems in the province of Turin

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011*
Boilers L	12.688	12.157	11.626	11.095	10.564	10.097	9.633	9.230	8.824	8.384	7.954
Boilers P	-	108	217	325	434	759	1.026	1.508	2.001	2.426	2.794
Room-heaters with boiler L	9.638	9.632	9.626	9.620	9.614	9.516	9.468	9.413	9.315	9.174	9.158
Room-heaters with boiler P	-	214	428	642	857	1.199	1.424	1.737	2.166	2.658	3.122
Fireplaces L	42.337	43.421	44.505	45.590	46.674	47.870	48.872	49.422	49.282	49.106	49.759
Fireplaces P	-	411	822	1.233	1.644	2.074	2.484	2.678	2.990	3.342	4.363
Stoves L	42.337	43.115	43.893	44.671	45.449	47.066	47.804	47.980	49.011	49.349	49.179
Stoves P	-	2.854	5.708	8.563	11.417	20.177	23.738	27.883	34.340	40.752	46.467
Cookers L	21.168	21.822	22.476	23.130	23.784	24.250	24.873	25.201	25.238	24.837	24.907
TOTAL	**128.168**	**133.734**	**139.301**	**144.869**	**150.437**	**163.008**	**169.322**	**175.052**	**183.167**	**190.028**	**197.703**
- Wood logs	128.168	130.147	132.126	134.105	136.084	138.799	140.651	141.246	141.671	140.850	140.956
- Pellets	-	3.588	7.176	10.764	14.352	24.209	28.672	33.806	41.497	49.178	56.747

Table 5 – Estimated number of dwellings with biomass-fired heating systems in the province of Turin

In the period between 2001 and 2011 the number of dwellings with biomass-fired devices estimated increased by about 50%.

Different trends were identified for wood log or pellet fired devices:

- dwellings with wood log fired devices showed a moderate increase (more than 10%) in the first half of the decade, with about 140.000 units; in the second half of the decade a relative stability was evident, as sales of new devices evened out the number of discarded devices;

- by contrast, dwellings with pellet-fired devices showed a rapid and constant growth. This increase represents almost the total growth in dwellings heated by biomass. The most significant growth was given by the spread of pellet stoves, which in that decade reached similar numbers of units compared to that of wood log fired stoves. Moreover the number of dwellings with pellet-fired boilers and pellet-fired room-heaters with boiler increased by more than 20%. On the other hand, the number of dwellings heated by pellet-fired fireplaces is small if compared to those served by wood log fired fireplaces.

The devices were classified according to the year of installation (up to 2001 and after 2001). An efficiency value and an emission factor value was assigned to each category. The given set of dwellings can be studied according to the classification of the device in use (see Figure 4).

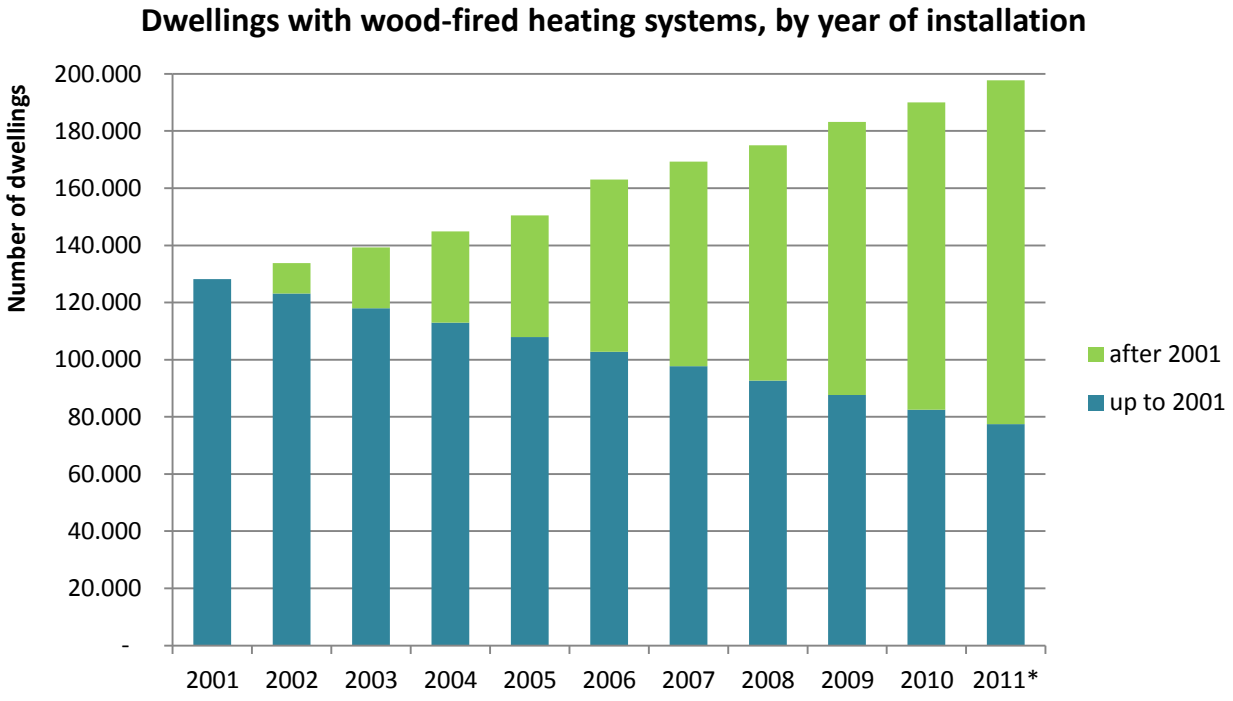

Figure 4 - Number of dwellings with wood-fired heating systems in the province of Turin, by year of installation

New devices play a significant role , with around 120.000 total biomass-fired dwellings in 2011, of which 57.000 with pellet-fuelled devices.

50.000 dwellings had a biomass-fired device installed as a replacement for an old one that had been present in 2001. Based on the initial number of 128.000 dwellings up to 2001, the replacement rate is close to 40% for the period 2001-2011.

4 Estimation of the energy produced from biomass-fired residential heating devices

4.1 Methodology

In order to define the energy contribution of wood biomass in the province of Turin, some assumptions and calculations were made. Primarily the average yearly requirement of useful energy for heating for residential buildings was estimated to be equal to 4,3 kWh per Degree Day per dwelling. This heating requirement was calculated according to the available data for the dwellings heated by fossil fuel fired heating devices: the actual consumption, the number and the average efficiency of the heating systems.

It was assumed that boilers and room-heaters coupled with boilers cover 100% of the thermal needs in dwellings where they are installed. Thus stoves and fireplaces cover 100% of the needs only where there is no other heating system in the dwelling, otherwise their share is assumed to be 55%. In holiday houses it was estimated that the heating needs were equal to 15% of the PPR requirements for the same house size. The thermal energy needs for each dwelling were estimated according to its location (and therefore to Degrees Day), so it was possible to quantify the total amount of useful energy supplied by biomass devices.

It was therefore possible to define biomass consumption assuming some average efficiencies (reported in Table 6), according to the type of device and the year of installation.

	Mean efficiency	
	Until 2001	After-2001
Boilers L	65%	85%
Boilers P	-	90%
Room-heaters with boiler L	55%	75%
Room-heaters with boiler P	-	85%
Fireplaces L	45%	70%
Fireplaces P	-	80%
Stoves L	65%	75%
Stoves P	-	85%
Cookers L	50%	70%

Table 6 - Average values of biomass-fired devices efficiency used in the study (L = wood logs, P = pellets)

The final energy consumption had to be calculated as defined in EU Directive 2009/28/EC (RES Directive). If we consider biomass devices for residential heating, the final energy consumption is equal to the energy content of burned biomass, which is the amount of energy supplied to the user. Therefore biomass consumption should be taken into account in order to achieve European goals in RES production in 2020.

4.2 Results

The total amount of residential energy consumption of wood biomass in the province of Turin (*final energy*, according to Directive 2009/28/EC) is reported in Figure 5 and Table 7, filtered by fuel and type of device used.

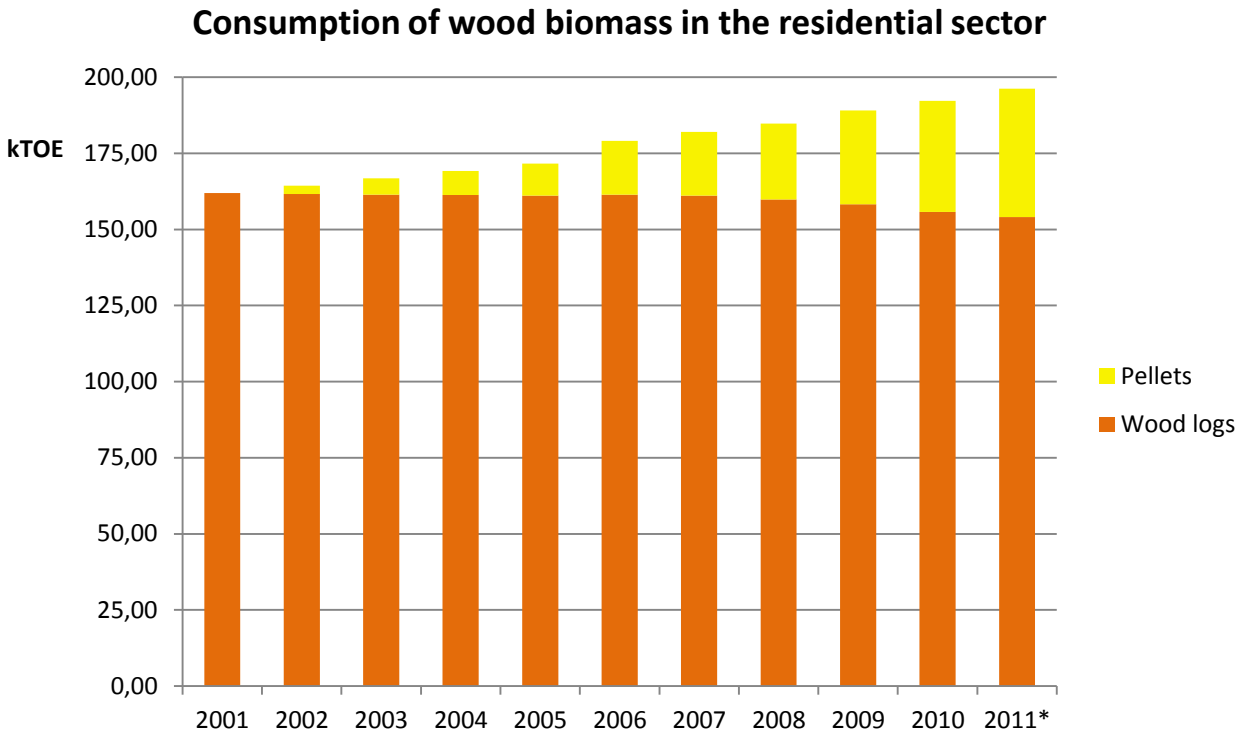

Figure 5 - Consumption of wood biomass in the residential sector in the province of Turin (kTOE)

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011*
Boilers L	18,89	18,03	17,20	16,37	15,54	14,80	14,07	13,42	12,77	12,07	11,38
Boilers P	0,00	0,14	0,28	0,43	0,57	0,99	1,34	1,97	2,61	3,17	3,65
Room-heaters with boiler L	17,60	17,43	17,29	17,15	17,01	16,72	16,51	16,29	16,01	15,65	15,49
Room-heaters with boiler P	0,00	0,30	0,59	0,89	1,18	1,66	1,97	2,40	2,99	3,67	4,32
Fireplaces L	58,55	58,65	58,75	58,85	58,95	59,14	59,17	58,83	57,90	56,95	56,68
Fireplaces P	0,00	0,29	0,59	0,88	1,17	1,48	1,77	1,91	2,13	2,38	3,11
Stoves L	40,53	40,94	41,35	41,77	42,18	43,24	43,62	43,56	44,17	44,23	43,90
Stoves P	0,00	1,91	3,82	5,73	7,65	13,51	15,90	18,67	23,00	27,29	31,12
Cookers L	26,35	26,61	26,86	27,12	27,38	27,48	27,72	27,70	27,45	26,82	26,59
TOTAL	**161,92**	**164,30**	**166,73**	**169,19**	**171,63**	**179,02**	**182,07**	**184,75**	**189,03**	**192,23**	**196,24**
- Wood logs	161,93	161,66	161,46	161,26	161,06	161,39	161,09	159,80	158,29	155,72	154,05
- Pellets	0,00	2,64	5,28	7,93	10,57	17,64	20,98	24,95	30,74	36,52	42,20

Table 7 - Consumption of wood biomass in the residential sector in the province of Turin (kTOE)

The amount of useful energy supplied to dwellings by biomass fired systems is reported in Figure 6 and in Table 8.

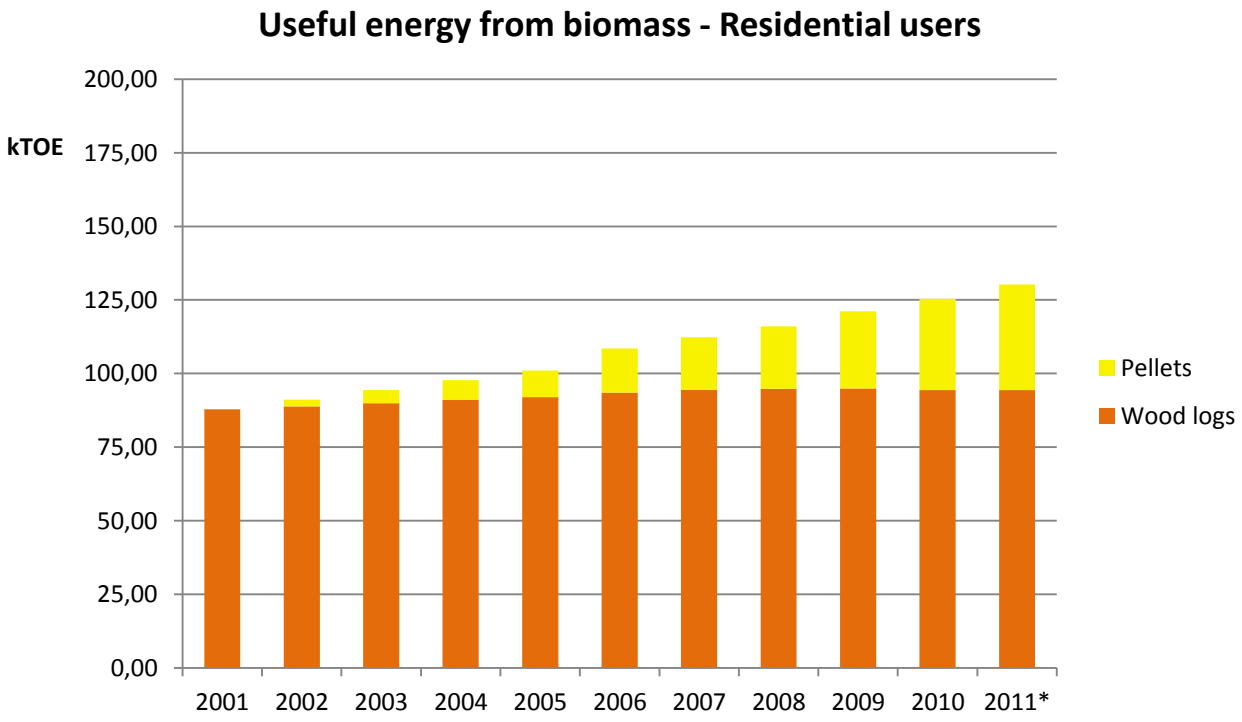

Figure 6 - Useful energy from biomass in the province of Turin – Residential users (kTOE)

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011*
Boilers L	12,28	11,76	11,24	10,72	10,20	9,76	9,32	8,96	8,59	8,18	7,78
Boilers P	0,00	0,13	0,26	0,38	0,51	0,89	1,21	1,77	2,35	2,85	3,29
Room-heaters with boiler L	9,68	9,75	9,82	9,89	9,95	9,91	9,93	9,94	9,90	9,80	9,86
Room-heaters with boiler P	0,00	0,25	0,50	0,75	1,01	1,41	1,67	2,04	2,55	3,12	3,67
Fireplaces L	26,35	26,99	27,64	28,29	28,93	29,65	30,25	30,58	30,51	30,42	30,81
Fireplaces P	0,00	0,23	0,47	0,70	0,94	1,18	1,41	1,52	1,70	1,90	2,48
Stoves L	26,35	26,81	27,28	27,75	28,22	29,18	29,62	29,74	30,35	30,56	30,47
Stoves P	0,00	1,62	3,25	4,87	6,50	11,49	13,51	15,87	19,55	23,20	26,45
Cookers L	13,17	13,56	13,95	14,34	14,73	15,01	15,38	15,58	15,60	15,38	15,42
TOTAL	**87,83**	**91,10**	**94,41**	**97,69**	**100,99**	**108,48**	**112,30**	**116,00**	**121,10**	**125,41**	**130,23**
- Wood logs	87,83	88,88	89,93	90,99	92,04	93,50	94,50	94,79	94,95	94,33	94,35
- Pellets	0,00	2,24	4,48	6,71	8,95	14,97	17,81	21,21	26,15	31,08	35,89

Table 8 - Useful energy from biomass in the province of Turin – Residential users (kTOE)

The useful energy supplied to dwellings by biomass fired systems increased by more than 50% in the years 2001-2011. This growth was proportional to the increase of biomass fired systems (Figure 3 and Table 5).

The biomass consumption increased by a lower percentage, about 20%. This result is related to three main factors:

- the progressive disposal of old systems (installed before 2001), characterized by lower average efficiencies;
- the installation of new wood log systems with higher efficiency;
- the constant increase of the share of pellet fired systems, which has meant better performances compared to wood log systems.

The estimated consumption of log wood decreased slightly in the last years of the decade, due to the steadiness of the number of dwellings heated and the simultaneous increase of the mean efficiency. On the other hand, the pellet consumption increased proportionally to the growing spread of pellet fuelled systems.

In 2011 the total biomass consumption was approximately constituted by 80% of wood logs and 20% of pellets. Nevertheless, the energy produced by pellet fired systems coverd up to 25% of all the residential energy needs, due to the mean higher efficiency of the systems using this kind of fuel.

5 Conclusions

The study undertaken according to the methodology previously described allowed us to estimate the residential energy consumption of biomasses in the province of Turin.

The data collected highlights the importance of biomasses for the local energy production. The biomass energy used for residential heating purposes represents 12% of the total residential consumption for the province of Turin (total final uses: 1.700 kTOE in 2011). Overall, this represents 5% of the total energy consumption in the province of Turin (4.200 kTOE in 2011).

Today wood biomasses represent about one third of the renewable energy sources target for 2020 (15,1% of total final uses) set by the Italian State for the Piedmont region, which encompasses the province of Turin. Moreover, it is important to consider that the final energy from biomasses is a greater order of magnitude than solar thermal and geothermal energy in all sectors in the entire province of Turin (12 kTOE in 2011).

Considering the decrease in consumption forecast for 2020 (-20%) and the growth trend for residential dwellings equipped with biomass fuelled devices, it is possible that the contribution of wood biomasses towards meeting the objectives for 2020 may be even greater than the set target.

In addition to allowing us to quantify the energy consumption pattern at a local level, this study has enabled us to define the market dynamics of the region and to highlight the significant and ever growing spread of pellet fuelled devices.

Sales trends and stability in the number of dwellings supplied by wood log devices highlight a mature market, characterized by a number of installed devices that approach the potential in the field.

On the other hand, the market of pellet devices appears to be dynamic, with strong growth. Pellet devices seem to have a potential customer base that only partially coincides with that of wood log devices. Currently, the ease of installation and use, the limited maintenance needed and the widespread availability of ready-to-use fuel (with the need of reduced storage), makes it possible to reach a wider clientele, beyond the mainly rural demand for wood log devices.

The prospect of an increased residential use of pellet fuelled devices in the province of Turin is high. If the lack of wind and the stagnant air pollution typical of the whole Pianura Padana area (North Italy), limit the possibility of growth for the less advanced wood log devices, the high efficiency and limited emissions of the pellet fuelled devices allow for a broad use of the latter. As a consequence, pellet fuelled devices can in the future not only replace the antiquated wood log fuelled devices, but also replace or complement the individual gas boilers that are so widely spread in Italy (about 15 million nationally and not less than 500,000 in the province of Turin). This would at the same time warrant the use of renewable energy sources and the minimization of emission of polluting agents.