Proceedings of NAWTEC16
16th Annual North American Waste-to-Energy Conference
May 19-21, 2008, Philadelphia, Pennsylvania, USA

NAWTEC16-1926

MSW INCINERATION CAPACITY EVALUATIONS FOR THE PROVINCE OF TURIN (NORTHERN ITALY)

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ABSTRACT

This paper assesses the incineration capacity requirement of the Province of Turin through a detailed analysis of the mass streams and the properties of residual Municipal Solid Waste (MSW).
Historical data series were elaborated to study the trend evolution of household generation and separate collection. Residual MSW material compositions were calculated for each year over an observed period and for planned scenarios. A waste properties model was applied to calculate the residual MSW chemical composition and the LHV.

The analysis allows conclusions to be drawn about the design of the planned waste-to-energy plant and to estimate the required size and technology to be used. The results show that the use of grate furnace combustor appears to be more suitable than fluidized bed.

1. INTRODUCTION

Under the pressure of EU directives on landfilling, Italy has been undergoing a transition to integrated systems for the management of Municipal Solid Waste (MSW) since the nineties.
The Province of Turin is an interesting example of this transition. Turin is the fourth largest city in Italy (the second in the north) and the capital of Piedmont, an Italian region near the French border. The Province of Turin is highly populated and productive and it is therefore representative of many other provinces in northern Italy; Table 1 shows some data about the territory.
Local authorities approved a Waste Management Plan (WMP) which defines the organization of MSW separate collection, recycling and disposal [1]. At present the residual waste (after the separate collection) is sent to landfills. The plan provides a separate collection target of nearly 50% for 2010 and the construction of new incineration plants.

Table 1 Province of Turin: key figures

land area (km^2)		
plain	1.844	*27%*
hilly	1.434	*21%*
mountainous	3.552	*52%*
total	6.830	
population (inh.,2004)		
City of Turin	902.255	*40%*
13 medium sized towns (>20.000 inh.)	487.347	*22%*
302 small centres (<20.000 inh.)	847.339	*38%*
total	2.236.941	
end-use energy consumptions (TJ, 2003)		
domestic	63.773	*32%*
agriculture	1.901	*1%*
industry	58.381	*30%*
services	19.456	*10%*
transport	52.842	*27%*
total	196.353	
value added (M€, 2003)		
agriculture	398	*1%*
industry	15.706	*30%*
services	36.315	*69%*
total	52.420	

Household waste is one of the major mixed wastes; because of its heterogeneous nature, the characterization of a MSW requires information about its material composition and the physical properties of each material [2].
The design of waste treatment plants should start with the definition of the input streams; this is true for biological or mechanical treatment and also for incineration [3]. Frequently, waste properties drive the choice among different technology alternatives [4].
On the other hand, a mass and energy analysis of MSW streams

is a key aspect for the technical, economic and environmental evaluation of MSW management options [5,6,7 and 8]

This work examines the MSW generation and collection in the Province of Turin, with the scope of studying the evolution of the waste properties and of estimating the mass and energy input amounts of the planned waste-to-energy plants.

The first step is a mass analysis using the history trends of the MSW household generation and separate collection rates and material compositions. A model of the properties of MSW components is applied to the residual waste characterization.

The study of the evolution of waste composition is fundamental for a Lower Heating Value (LHV) calculation of incineration inputs. The energy analysis therefore then examines the relationship between the heating value and the separate collection mass incidence. The size and technology of the waste-to-energy plant are estimated and finally the mass and energy balance of the MSW management can be calculated.

2. ANALYSIS OF MSW STREAMS

The analysis is focused on mass streams in MSW management: household generation, separate collection materials sent to recycling or composting and residual waste sent to disposal.

Table 2 Province of Turin: MSW streams (10^3 t)

	observed data												*WMP scenarios*	
	1991	1993	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	*2005*	*2010*
household generation														
City of Turin	442.2	427.1	413.4	425.4	438.8	443.7	465.4	473.5	479.0	476.7	469.9	480.7	*465.9*	*449.0*
other centres	465.9	490.4	506.9	521.7	523.0	542.5	579.4	600.9	598.6	613.8	589.6	598.0	*590.5*	*559.0*
total	908.0	917.5	920.2	947.1	961.7	986.1	1,044.8	1,074.4	1,077.6	1,090.5	1,059.5	1,078.7	*1,056.4*	*1,008.0*
separate collection (recycling/composting)														
City of Turin	4.8	10.3	10.8	29.4	51.0	58.3	76.4	95.6	106.1	104.0	108.6	132.2	*167.9*	*229.4*
other centres	11.7	18.1	20.0	24.6	30.2	48.0	65.5	80.7	90.7	110.1	126.9	169.4	*192.6*	*256.5*
total	16.5	28.4	30.8	54.0	81.2	106.3	141.9	176.3	196.8	214.1	235.5	301.6	*360.6*	*485.9*
residual (disposal)														
City of Turin	437.3	416.8	402.6	395.9	387.7	385.3	389.0	377.9	372.9	372.7	361.2	348.5	*297.9*	*219.6*
other centres	454.1	472.2	486.8	497.1	492.8	494.5	513.9	520.2	507.9	503.7	462.7	428.6	*397.8*	*302.5*
total	891.5	889.1	889.4	893.1	880.5	879.8	902.9	898.1	880.8	876.4	823.9	777.1	*695.8*	*522.1*

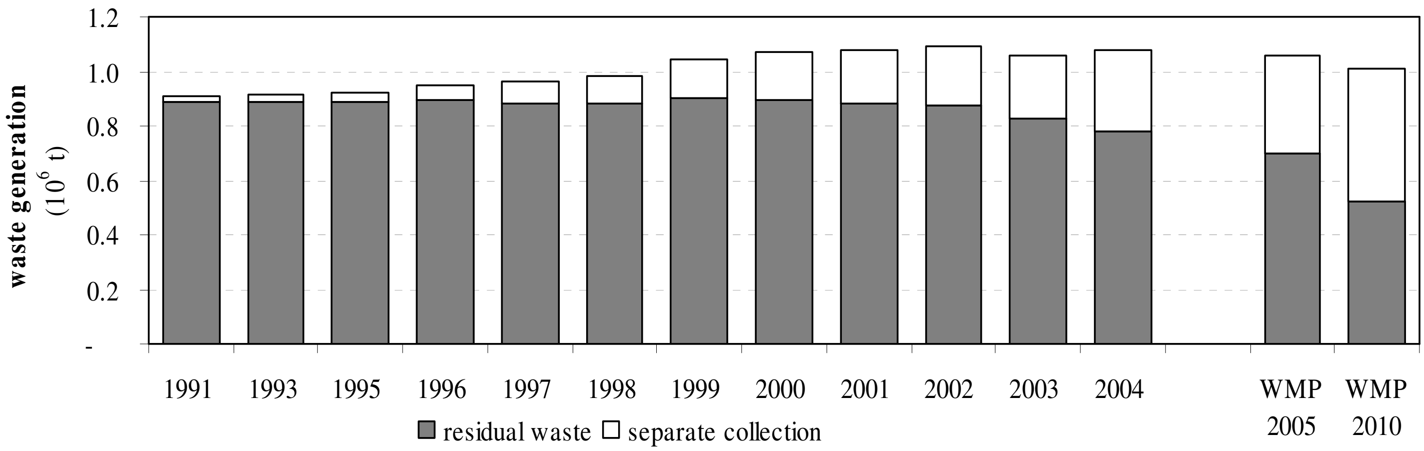


Fig. 1 Province of Turin: MSW management mass streams

2.1 MSW mass stream data source

The MSW data for the Province of Turin can be obtained from the local waste statistical observatory [9]. Its yearly bulletins report data concerning the separate collection and the residual waste streams. The data gives details on each separate collection material and for two observed areas: the City of Turin and the rest of the province. This area distinction is made because they have different evolutions and properties as will be shown later on in this work.

The separate collection data require corrections because they include some materials that may involve several non-domestic waste (i.e. cumbersome waste, demolition waste, metal scraps, old tyres). These materials were excluded from the separate collection data used in this work to avoid overestimate errors in MSW mass streams.

2.2 Household generation

The household generation of MSW is calculated as the sum of the residual waste and all the separate collection mass streams, according to the previous assumptions. The historical data series (Table 2 and Fig. 1) show that the yearly average growth rate of waste generation from 1991 to 2004 is about 1.3%. At present, the MSW generation in the Province of Turin is around 1.1 million tons. Table 2 also shows details of the waste streams for each area: about 45% of the MSW in 2004 was generated in the City of Turin and the rest in the other centres of the province.

WMP provides actions to reduce household waste; the expected target of the yearly average decrease is around 1%. In this way, the WMP 2010 scenario sets the forecast near 1.0 million tons.

The calculation of per capita generation (Fig. 2) draws a better picture of the MSW evolution; it was nearly 400 kg per year in 1991 and was close to 480 kg in 2004; values for the city were generally higher than for the rest of the province. Generally the trends show a rapid growth until 2001; in the last two years small reductions of per capita waste generation (around 2% on yearly average) can be observed, due to new waste collection methods (detailed afterwards).

2.3 Separate collection

EU waste policy states that the first goal of MSW management must be the mass recycling of as many materials as possible (i.e. paper, plastics, glass); household generation should be collected separately in several mass streams and sent to recycling facilities.

Table 2 and Fig. 1 show data series of separate collection in the Province of Turin. If the mass incidence on waste generation is calculated (Fig. 3), it can be seen that very low quantities were involved (less than 5%) in the first half of the nineties; this value only grew from 1995, onwards with different trends in the city from the rest of the province. It can be noted that the increase doubled in 2004 and in both observed areas the separate collection was close to 28%. This increase was mainly due to the progressive setting-up of a new waste collection method. MSW is now collected house-to-house instead of using common waste bins placed on the road. This is more efficient for separate collection and stops the interception of non-domestic waste (i.e. commercial, demolition), preventing the unexpected inflation of household generation amounts. About 20% of the population was already being served by this kind of service at the end of 2004.

Table 3 shows the available data for materials sent to recycling or composting facilities from 1991 to 2004, as reported by the Province of Turin waste statistical observatory [9]. The histories of the separate collections are different for each material and each observed area. Glass and paper were the only relevant quantities in the early nineties. The start-up of plastic, green and food waste there were in following years.

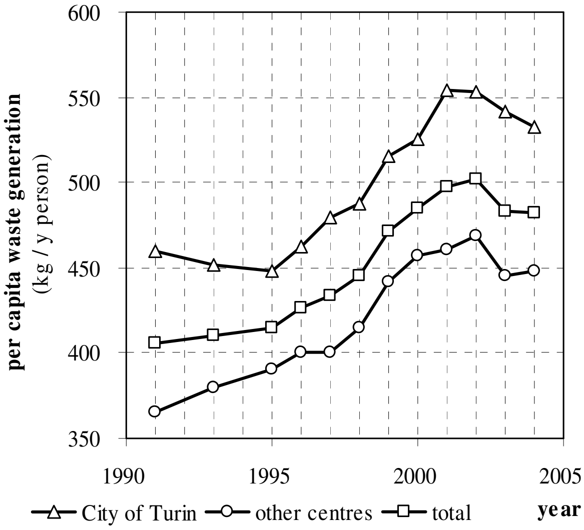


Fig. 2 Province of Turin: MSW separate collection mass incidence

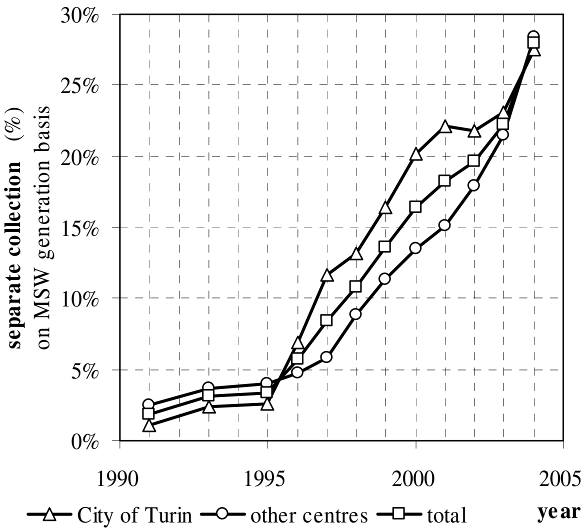


Fig. 3 Province of Turin: per capita MSW generation

The separate collections histories who result to be different as far as each observed area are concerned if the per capita collection (Fig. 4 and 5) and material distributions (Fig. 6 and 7) are calculated.

In the City of Turin the increase is mainly driven by paper, which, in 2004 covered about 60% of the total amount. Wet fractions (food and green waste) has only become relevant in recent years and in 2004 their contribution was limited to about 25% of the total separate collection. In the rest of the Province of Turin, separate collection appears to be more equilibrated than in the city as the growth is similar for all materials. At present the wet fractions are the main contribution: their weight in the material distribution is rather higher than in the city (almost 40% in 2004) but is similar to the paper weight.

Table 3 Province of Turin: material details of the MSW separate collection streams (10^3 t)

	observed data												*WMP scenarios*	
	1991	1993	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	*2005*	*2010*
City of Turin														
food waste	-	-	-	-	-	3,90	8,85	10,56	18,87	15,73	17,50	23,14	*57,39*	*91,46*
green waste	-	-	-	0,51	0,89	9,11	10,05	7,75	7,96	8,41	8,32	10,75	*13,72*	*13,22*
plastic[a]	-	-	0,18	1,26	2,18	2,32	2,46	2,49	2,74	3,12	3,87	5,27	*6,59*	*11,18*
paper[b]	0,21	5,02	5,02	20,35	35,30	31,68	43,01	62,78	64,41	64,31	65,76	79,19	*71,32*	*80,54*
textiles	0,01	0,01	0,01	0,29	0,51	1,32	1,36	1,20	1,25	1,04	1,08	0,64	*- - (d)*	*- - (d)*
aluminium	0,00	0,04	0,03	0,22	0,38	0,31	0,33	0,33	0,34	0,35	0,37	0,41	*0,59*	*1,03*
glass	4,58	5,16	5,49	6,73	11,68	9,57	10,23	10,31	10,37	10,81	11,49	12,51	*18,08*	*31,68*
dangerous[c]	0,02	0,07	0,06	0,08	0,10	0,12	0,14	0,16	0,18	0,20	0,25	0,26	*0,27*	*0,26*
total	4,82	10,29	10,78	29,44	51,04	58,32	76,42	95,58	106,11	103,96	108,64	132,19	*167,95*	*229,37*
other centres														
food waste	-	-	-	-	-	-	2,70	4,84	6,29	8,59	15,64	28,69	*18,47*	*62,67*
green waste	-	-	-	1,43	3,14	8,72	13,38	19,06	20,95	27,44	28,21	37,09	*57,70*	*54,19*
plastic[a]	-	0,45	0,69	1,46	1,93	3,04	3,71	4,05	4,76	5,68	7,16	10,97	*10,54*	*11,84*
paper[b]	1,14	5,94	7,13	9,66	12,30	19,77	25,82	30,42	35,64	43,55	48,40	60,03	*69,30*	*85,16*
textiles	0,01	0,01	0,01	0,64	0,69	1,52	1,79	1,73	1,82	1,73	1,36	1,65	*- - (d)*	*- - (d)*
aluminium	0,00	0,02	0,02	0,37	0,39	1,55	1,88	2,14	2,20	2,40	2,69	3,21	*3,71*	*4,36*
glass	10,49	11,61	12,07	10,83	11,51	13,07	15,86	18,07	18,55	20,19	22,70	27,05	*31,28*	*36,71*
dangerous[c]	0,06	0,11	0,12	0,18	0,24	0,31	0,37	0,43	0,50	0,56	0,72	0,74	*1,65*	*1,62*
total	11,71	18,13	20,03	24,57	30,21	47,99	65,52	80,74	90,70	110,13	126,88	169,43	*192,65*	*256,54*
total														
food waste	-	-	-	-	-	3,90	11,54	15,40	25,16	24,32	33,14	51,83	*75,85*	*154,12*
green waste	-	-	-	1,94	4,03	17,82	23,43	26,81	28,91	35,84	36,52	47,84	*71,42*	*67,41*
plastic[a]	-	0,45	0,87	2,72	4,11	5,36	6,16	6,54	7,50	8,80	11,03	16,25	*17,14*	*23,02*
paper[b]	1,36	10,96	12,15	30,01	47,61	51,45	68,83	93,20	100,05	107,86	114,16	139,22	*140,62*	*165,70*
textiles	0,02	0,02	0,02	0,93	1,20	2,84	3,15	2,93	3,07	2,76	2,44	2,29	*- - (d)*	*- - (d)*
aluminium	0,00	0,06	0,05	0,59	0,77	1,86	2,22	2,48	2,54	2,75	3,07	3,62	*4,30*	*5,39*
glass	15,06	16,77	17,55	17,56	23,19	22,64	26,09	28,37	28,92	31,00	34,19	39,56	*49,36*	*68,39*
dangerous[c]	0,09	0,18	0,18	0,26	0,34	0,43	0,51	0,59	0,68	0,76	0,97	1,00	*1,91*	*1,88*
total	16,53	28,42	30,81	54,01	81,24	106,31	141,94	176,31	196,81	214,09	235,52	301,61	*360,60*	*485,90*

(a) plastic bottles (b) paper and cardboard (c) paints, batteries, drugs and other dangerous household waste (d) not defined in WMP.

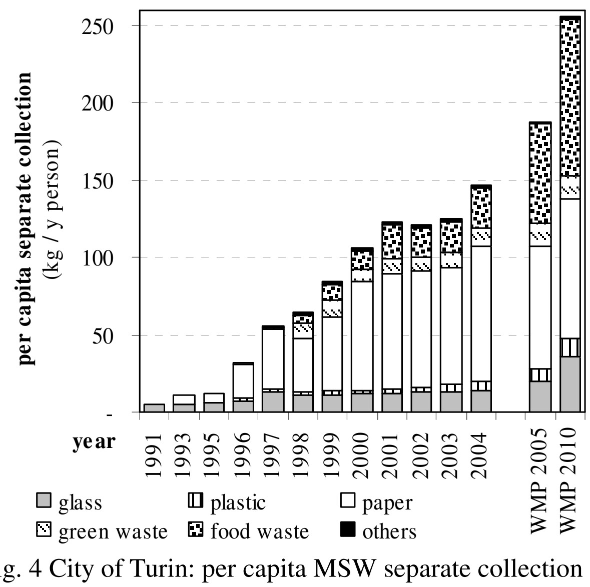


Fig. 4 City of Turin: per capita MSW separate collection

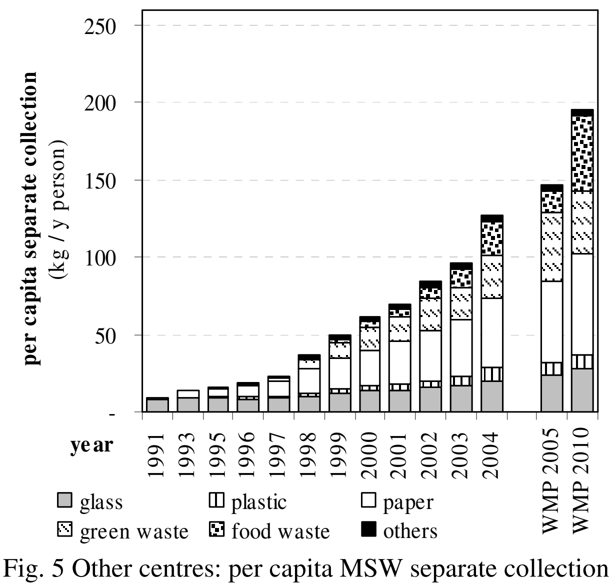


Fig. 5 Other centres: per capita MSW separate collection

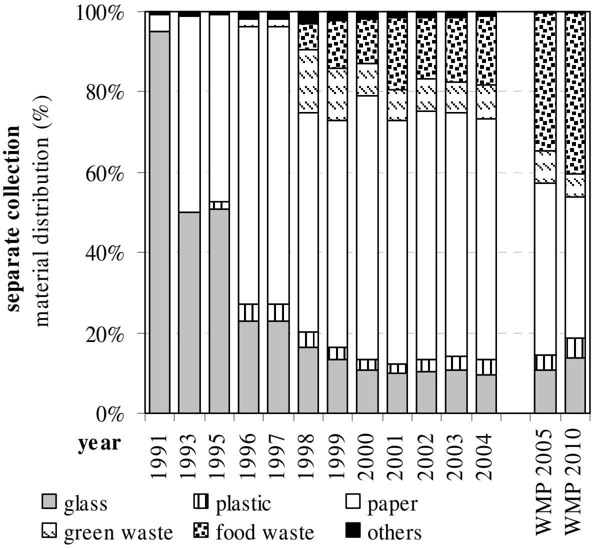


Fig. 6 City of Turin: MSW separate collection distribution

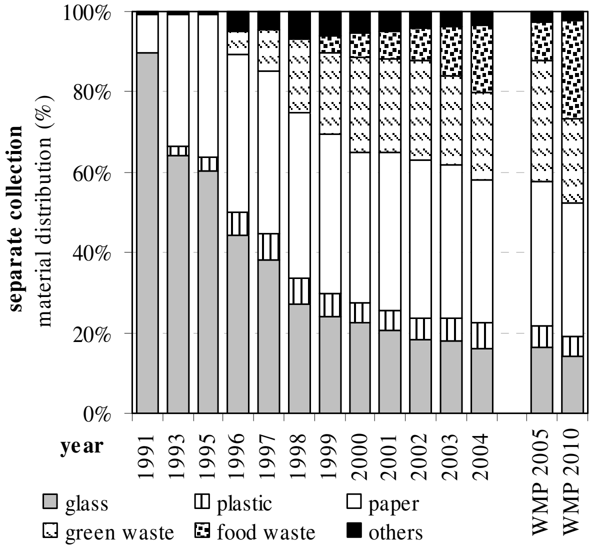


Fig. 7 Other centres: MSW separate collection distribution

Table 4 Province of Turin: standard material composition of MSW household generation

	City of Turin		other centres	
organic	33.7%		35.5%	
food waste	*30.6%*	*90.8%*	*25.3%*	*71.3%*
green waste	*3.1%*	*9.2%*	*10.2%*	*28.7%*
plastic	9.3%		10.4%	
film	*3.3%*	*35.1%*	*4.6%*	*44.6%*
bottles	*2.1%*	*23.1%*	*2.0%*	*19.1%*
others	*3.9%*	*41.7%*	*3.8%*	*36.3%*
paper	27.7%		24.6%	
paper	*17.9%*	*64.8%*	*13.6%*	*55.1%*
cardboard	*6.7%*	*24.1%*	*8.3%*	*33.8%*
diapers	*2.0%*	*7.1%*	*1.8%*	*7.1%*
polylaminates	*1.1%*	*4.0%*	*1.0%*	*4.0%*
wood	3.2%		5.1%	
textiles & leather	3.1%		3.6%	
textiles	*2.5%*	*80.6%*	*2.8%*	*78.0%*
leather	*0.6%*	*19.4%*	*0.8%*	*22.0%*
metals	3.1%		4.7%	
aluminium	*0.4%*	*11.5%*	*0.9%*	*19.3%*
ferrous	*1.2%*	*38.7%*	*2.0%*	*41.6%*
others	*1.5%*	*49.8%*	*1.9%*	*39.2%*
glass	11.0%		7.7%	
inerts	8.6%		7.9%	
dangerous[(a)]	0.3%		0.4%	
total	100.0%		100.0%	

[(a)] paints, batteries, drugs and other dangerous household waste.

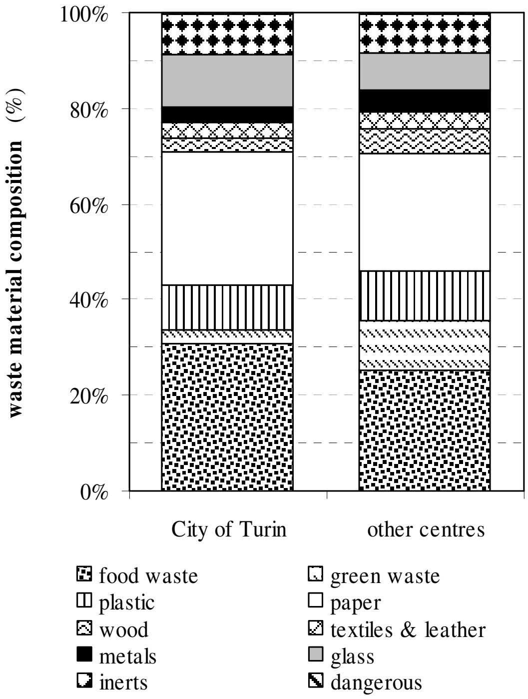


Fig. 8 Comparison of standard material composition of MSW household generation in City of Turin and in the other centres

The first WMP purpose is to reach an overall mass incidence of separate collection close to 50%. WMP has set a transition period from 2005 to 2010 with specific mass collection targets for each material collection (Table 3). The 2005 and 2010 WMP scenarios are quite different from other recent situations (e.g. 2004). If we look at the per capita collection (Fig. 4 and 5), it can be seen that the present food waste collection is lower than the final WMP target, particularly in the City of Turin. If we compare the material distributions (Fig. 6 e 7), it can be noted that the 2010 WMP scenario in the rest of the province is similar to the 2004 situation but quite different are the situations for the city.

3. RESIDUAL MSW PROPERTIES

3.1 Residual MSW material composition

Waste material composition describes the types and proportions of materials contained in MSW; this is the basis for any waste property calculation (proximate and ultimate analysis, heating value). Residual waste composition can be calculated by subtracting the separate collection streams from household MSW.

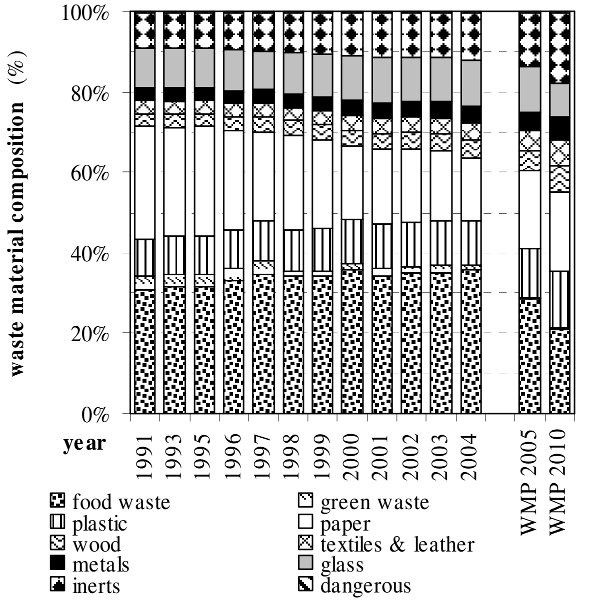


Fig. 9 City of Turin: residual MSW material composition

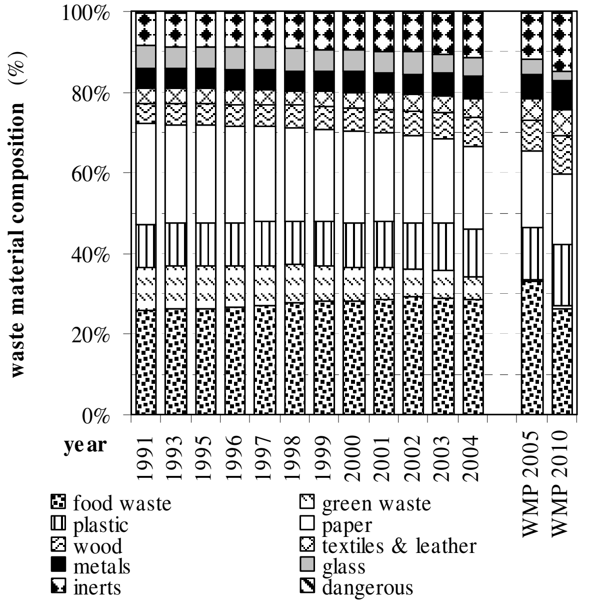


Fig. 10 Other centres: residual MSW material composition

Table 5 Province of Turin: energy contents in MSW streams (GWh)

	observed data												*WMP scenarios*	
	1991	1993	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	*2005*	*2010*
household generation														
City of Turin	1,060	1,024	991	1,020	1,052	1,064	1,116	1,135	1,149	1,143	1,127	1,153	*1,117*	*1,077*
other centres	1,176	1,238	1,280	1,317	1,320	1,369	1,463	1,517	1,511	1,550	1,488	1,510	*1,491*	*1,411*
total	2,236	2,262	2,271	2,337	2,372	2,433	2,579	2,652	2,660	2,693	2,615	2,662	*2,608*	*2,488*
separate collection (recycling/composting)														
City of Turin	1	19	20	90	156	157	206	280	296	296	309	377	*389*	*492*
other centres	4	26	33	53	69	115	151	178	208	253	290	388	*421*	*524*
total	5	45	53	143	225	272	357	458	503	549	600	765	*810*	*1,016*
residual (disposal)														
City of Turin	1,060	1,005	971	930	896	907	910	856	853	847	817	776	*728*	*585*
other centres	1,172	1,212	1,247	1,264	1,251	1,254	1,311	1,339	1,303	1,297	1,198	1,121	*1,070*	*887*
total	2,232	2,217	2,218	2,194	2,148	2,161	2,221	2,194	2,156	2,144	2,016	1,897	*1,798*	*1,472*

The first step is the definition of a standard composition for household waste generation. Unfortunately, waste material analysis campaigns are not frequent and the available data are limited [10,11]. Elaborations of these data in previous works [12,13] produced two waste compositions, one for the City of Turin and one for the rest of the province (Table 4 and Fig. 8) that are adopted as being representative of household generation over the entire analysed period.

The amount of each material in MSW is calculated applying the adopted waste compositions (Tab. 4) to the total household generation. Then residual MSW compositions is obtained subtracting, material by material, the separate collection streams from the household generated amounts.

The results of this methodology are summarised in Figs. 9 and 10. The main evidence concerning city residual waste is that paper is decreasing, organics are quite stable (in spite of growing separate collection rates in recent years) and non-

combustible fractions (metals, glass and inerts) are increasing. Outside the city the variations in paper are smaller and the components have maintained their reciprocal proportions.
The same methodology can also be applied to WMP estimations and targets. The waste compositions that have been obtained are quite different from the actual situation, particularly for the city, where a large reduction of the organic fraction is expected.

3.2 Residual MSW proximate and ultimate analysis

Instead of assuming MSW properties for the overall mass stream, waste properties are better defined as a linear combination based on the waste material composition. This second way is useful to analyse the relationships between waste properties and separate collection and to study the material composition trends of residual waste.
Table 5 shows a model of waste properties which describes each MSW material component using proximate and ultimate analysis and LHV. This model is the result of a wide analysis and comparison of literature data from more than 40 different sources [13,14]

Table 6 Province of Turin : calculation of the residual MSW incineration capacity (according to the 2010 WMP scenario)

yearly input	mass	10^3 t	522
	LHV	MJ/kg	9-11
	energy	GWh	1.472
availability		%	70%
capacity		t/h	85
		MW	240
electrical efficiency		%	25%
electrical power		MW	60,0
electrical production		GWh	368

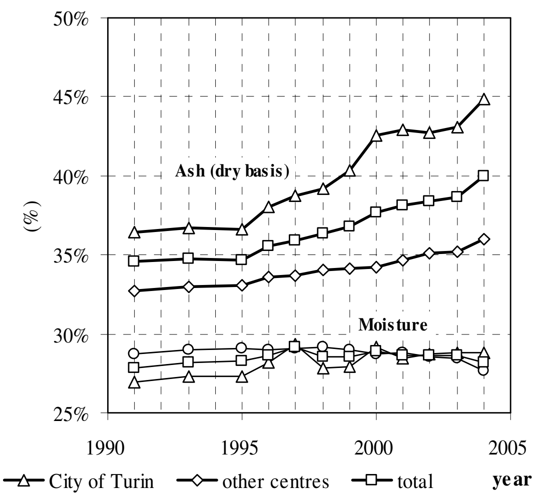


Fig. 11 Province of Turin: residual MSW moisture and ash

The model was applied to previous waste material compositions (paragraph 3.1) to calculate the residual waste proximate and ultimate analysis (Table 6).
Fig. 11 shows the proximate analysis trends for the observed period, which require further discussion.
Moisture is close to 27-29%, both in the City of Turin and in the rest of the province. The moisture in MSW mainly comes from the organic fraction which has been quite stable in recent years. In accordance with the high separate collection targets, the moisture of the total residual MSW is expected to be between 22-23% in the 2010 WMP scenario.
Ash is increasing: in 2004 the residual waste ash content reached to 45% (dry basis) in the city and almost 36% in the rest of the province. Ash in MSW is mainly composed of metals, glass and inerts. Glass and metal collections are growing at a lower rate than paper and organic; inerts are not collected and because of this, non-combustible components incidence is rising. The same trends appear for the WMP scenarios.

3.3 Residual MSW LHV

Table 6 also shows the calculation results for the LHV of residual MSW. The values are quite different for the City of Turin and the rest of the province. If we look at the LHV in the observed period (Fig. 12), it can be seen that the trends in the two areas are completely different. The City of Turin shows a progressive reduction in residual MSW LHV since 1996: from 8.7 to 8.0 MJ/kg. The reasons for this could be due a separate collection unbalance; in recent years, more than half of the total separate collection streams in Turin consist of paper, which accounts for about 35-40% of the total energy contents of household generated waste.
Outside the city, the LHV trend shows a small reduction in the first half of the nineties, but then there is a reversal of trend when green waste collection has started. In this case, the separate collection streams are more balanced than in the city: the wet fractions counterbalance the energy contents subtraction on combustible fractions. The value in 2004 was around 9.4 MJ/kg, which is higher than in the early nineties. In spite of the city and outside stream trends, the LHV of the total residual MSW has been quite stable since 1996 in Province of Turin at around 8.8 MJ/kg, as shown in Fig. 12.
The separate collection has different effects on the waste LHV. The relationship between the LHV of residual MSW and the separate collection mass incidence is shown in Fig. 13 where the calculated data for each year of the observed period (1991-2004) has been plotted. In the City of Turin the mass incidence growth of the separate collection causes a decrease in the LHV. As previously mentioned, this is due to the material distribution of the separate collection which mainly involves high LHV waste fractions. In the rest of the province, there is initially a decrease, but over a 5% mass incidence, the separate collection increase improved the LHV of the residual waste. In this case, there is more equilibrium in the material collection with a good contribution of the wet fractions (food and green waste).

The calculated results of the LHV in the 2010 WMP scenario are much higher than for the present situation (Table 6): 9.6 MJ/kg in the city and 10.6 MJ/kg in the rest of the province (as received basis). The main reason for this is the lower moisture content of residual MSW, as previously mentioned.

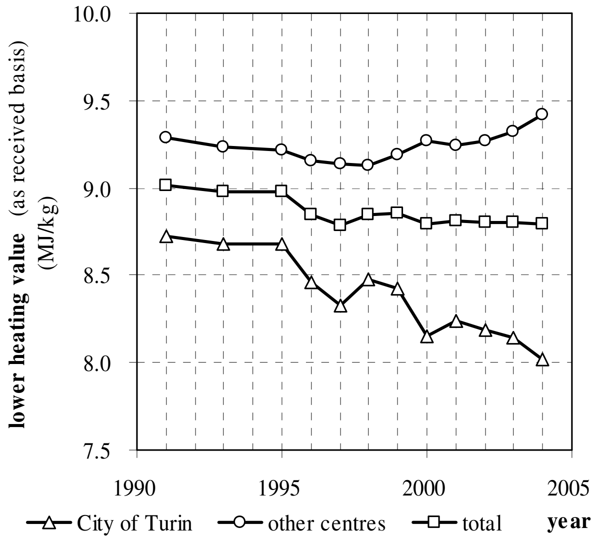


Fig. 12 Province of Turin: residual MSW LHV

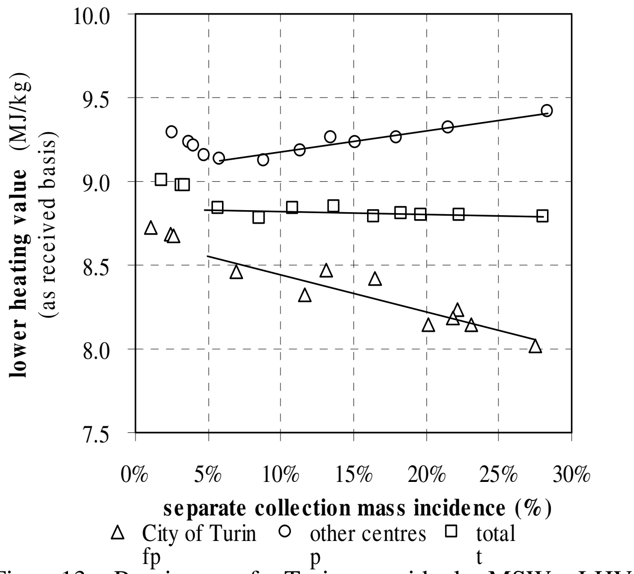


Fig. 13 Province of Turin: residual MSW LHV vs separate collection mass incidence

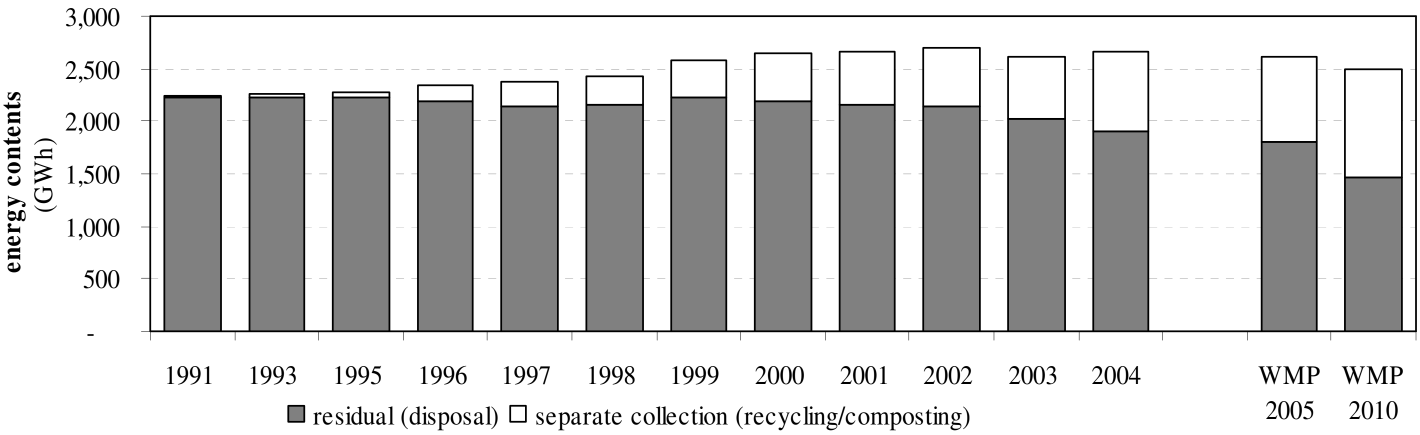


Fig. 14 Province of Turin: energy contents in MSW streams

4. RESIDUAL MSW INCINERATION EVALUATIONS

The size and the technology of the planned waste-to-energy plant should be defined on the basis of the residual MSW stream amount and properties.The size is driven by the evaluations of the energy contents of the residual stream. The choice of combustion technology mainly depends on the LHV of the waste stream to incineration.

In this section, some evaluations are presented concerning these options.

4.1 Incineration capacity

Table 7 and Fig. 14 show the energy contents in MSW streams in the Province of Turin. The total energy content of household generation waste in 1991 was about 2.2 TWh (8.0 PJ); it reached a value of 2.7 TWh (9.6 PJ) in 2004, which is equivalent to about 15% of domestic end-use energy consumption (Table 1).

The subtractions of combustible waste components by the separate collection (particularly paper and plastics) cause a reduction in the energy content in residual waste, as is well known.

Mass and LHV performed analysis allows a comparison to be made between the energy content of household generation and the residual MSW. The calculation results (Fig. 15) show that in

the early nineties, the differences over the different years are very small but from 1995 onwards the separate collection increased in relevance, reducing the energy content. The residual waste energy incidence in 2004 was almost 67% in the City of Turin and close to 75% in the rest of the province. In spite of these reductions, the total amount of energy content in the residual MSW remained quite stable until 2002, as household generation increased; the effect of the separate collection is only evident in the last two years of the observed period. The residual waste stream in 2004 accounted for about 1.9 TWh (6.8 PJ), 15% less than the initial value in 1991. In the same period, the overall energy content of the separate collection streams increased enormously: it was negligible in 1991 but its value was about 0.8 TWh (2.8 PJ) in 2004.
These results allow an estimation to be made of the new incineration capacity for the Province of Turin. The first part of Table 8 shows the calculation, according to the residual MSW stream in the 2010 WMP scenario. The yearly mass stream will be around 522 thousand tons, for an energy input of about 1.5 TWh. The overall plant input capacity can be evaluated (with 70% availability) as 85 t/h and 240 MW.

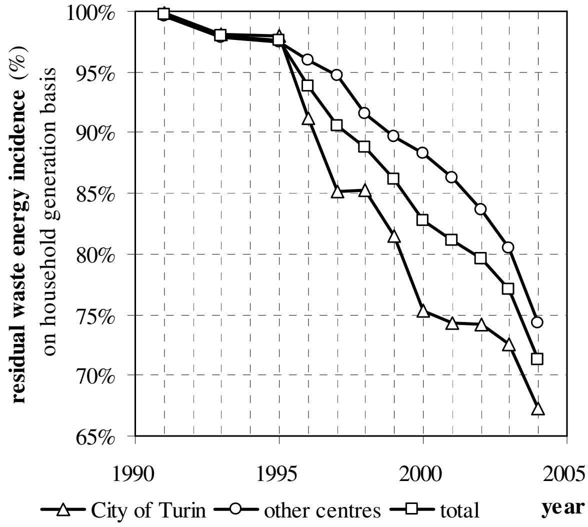
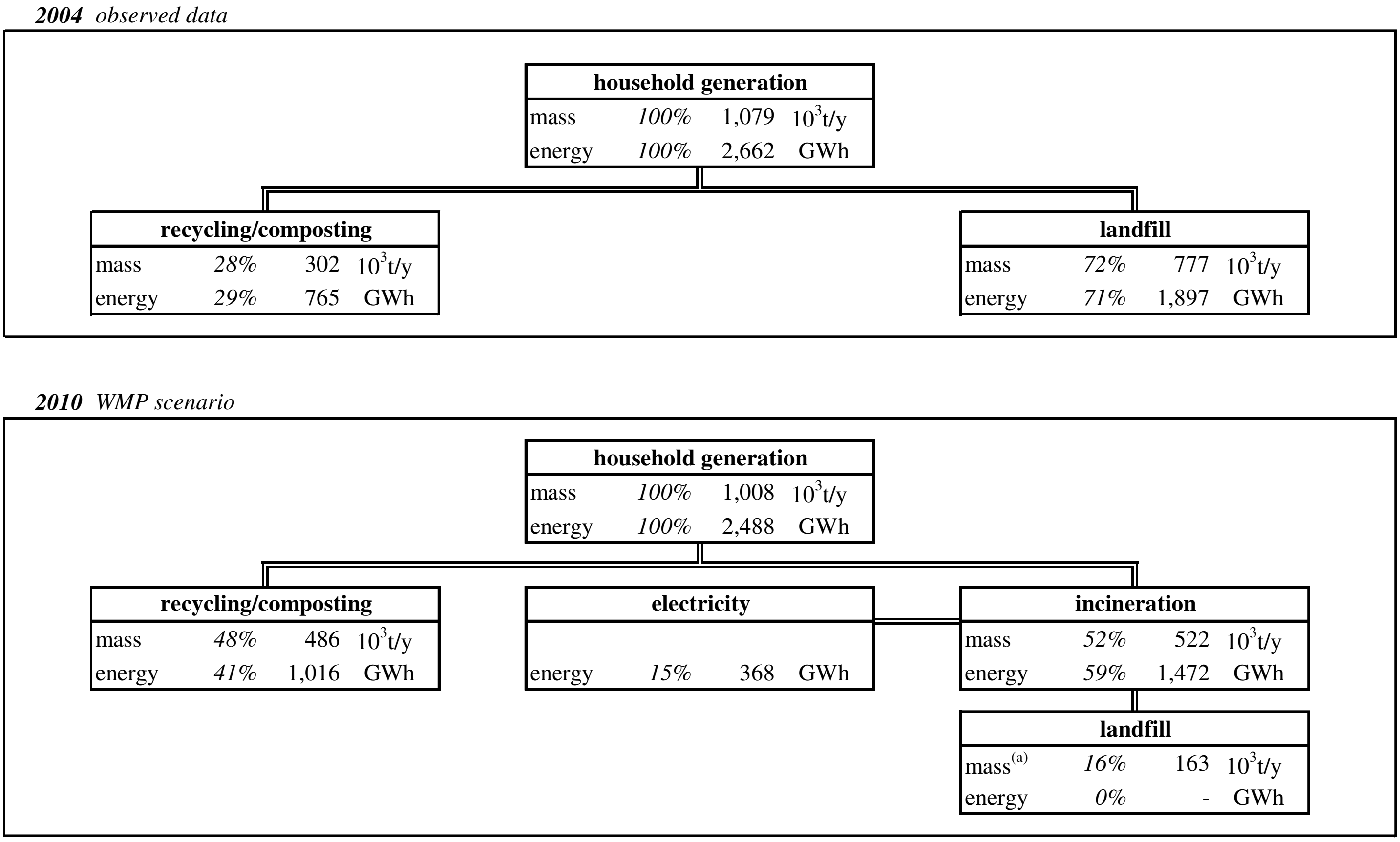


Fig. 15 Province of Turin: residual MSW energy incidenc



a) grate ash only, without fly ash and flue gas treatment residues

Fig. 16 Province of Turin: mass and energy streams of MSW management

4.2 Incineration technology

The analysis of the residual MSW properties offers important indications for the choice of technology, particularly as far as combustion is concerned.

The most important technologies for the combustion of MSW are fluidised bed and grate furnace. Fluidized bed combustors operate with fuels that have higher LHV and lower ash content than typical MSW. For this reason in order to burn residual MSW, they require a pre-treatment of the residual waste to improve the LHV and to remove most of the inert fractions (glass, metals). Non pre-treated residual MSW can be directly incinerated by grate furnace combustors, which are instead not able to burn high LHV fuels [15].

If we examine the residual MSW in the Province of Turin, the present LHV and ash range (as received basis) are respectively 8-9.5 MJ/kg and 26-32%; the expected values, according to the 2010 WMP scenario, are 9-11 MJ/kg and 28-35%. The operating range of a grate furnace better fits the properties of local residual waste; a grate furnace combustor therefore appears to be the best option for the future plant. If a fluidized bed is chosen as the combustion technology, an intensive pre-treatment would be required. Further evaluations are needed concerning additional energy consumption and landfill requirements.

4.3 Energy recovery

Energy production is one of the main goals in a modern MSW incinerator. Plant efficiency mainly depends on the boiler limits such as the steam conditions and the flue gas exit. The temperature and pressure of the steam at the turbine inlet are limited by corrosion of the boiler materials. The flue gas treatment require a strict control of the temperature and water content in flue gas at the boiler exit.

Simulations were conducted in a previous work [12] on state-of-the-art incineration plant configurations with a 450°C, 60 bar steam turbine inlet and dry flue gas treatment; if only electricity generation is considered, the net electrical efficiency was around 24-26%; assuming an average value of 25% and an yearly availability of 70%, the electrical power of the plant could be 60 MW with a yearly electricity production of about 368 GWh (Table 8).

Fig. 16 summarises the mass and energy balance of MSW management in the Province of Turin for the situation observed in 2004 and for the 2010 WMP scenario. The schemes compare the substitution of incineration with the direct landfilling of residual waste. In this way it could be possible to recover about 15% of the energy content of household MSW generation as electricity.

5. CONCLUSIONS

The approach proposed in this work is based on a detailed MSW stream analysis, involving a model of the waste properties, and may be applied to other analyses and planning of MSW management.

The present analysis allows some conclusions to be drawn about the design of waste-to-energy plants in northern Italy, based on the case-study of the Province of Turin.

An elaboration of historical data series has shown that the relevance of separate collection is increasing in MSW management. Consequently, mass and energy amounts of residual waste are decreasing; they represented about 70% of the total household generation in 2004.

The trends of LHV are mainly driven by the residual MSW composition; separate collection incidence on paper and organic fractions are the key drivers. The average values of residual waste LHV has been quite stable since 1996 at around 8.8 MJ/kg.

According to these evaluations, the residual MSW incineration capacity for the Province of Turin is around 0.5 million tons per year. The plant size is estimated to have a waste input of 85 t/h and an electrical power around 60 MW.

The results obtained concerning residual MSW properties (LHV and ash content) show that grate furnace combustion appears to be as more suitable than fluidized bed, which require an intensive pre-treatment.

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