A municipal solid waste management assessment guide for waste management plans and reporting

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Abstract

The proposed Municipal Solid Waste (MSW) management guide can contribute to a local MSW management plan and also be useful for the design and monitoring of MSW management. In this guide, data concerning the municipality and the solid waste management are imported as input parameters. These parameters are the municipality's surface, the amount of solid waste produced per year and its composition, data about the used equipment, financial data, etc. Different scenarios such as the percentage of separation at source can be examined and results concerning equipment requirements and the total project cost are calculated by the guide. The guide produces reports and diagrams, so that results can easily be presented without any specialized knowledge required. Since the guide can easily be modified, supplementary reports can be produced. The guide was applied to the municipality of Kallithea; however it can be used for all municipalities of Greece.

Keywords: *solid waste management guide; recycling; waste management in Greek municipalities; separation at source*

1. INTRODUCTION- OVERVIEW OF THE CURRENT STATE OF MUNICIPAL SOLID WASTE MANAGEMENT

1.1. Solid waste management methods

Human activities produce municipal solid waste. Solid waste effective management is essential in order to avoid environmental, social and economic impacts (air/ water pollution, solid contamination, solid waste management cost, etc).

There are several Municipal Solid Waste (MSW) treatment methods. Each of these methods has advantages and disadvantages. The current trend is not the juxtaposition of alternative methods, but their combination. More common treatment methods are separation at source, mechanical sorting, recycling, (aerobic) composting, anaerobic digestion, incineration and landfilling.

According to the waste management hierarchy, waste must be prevented, recycled or composted. If these options aren't feasible, then waste- to- energy treatment and landfilling in modern landfills with methane recovery must be used, as presented in the next picture (Figure 1). [1], [2]

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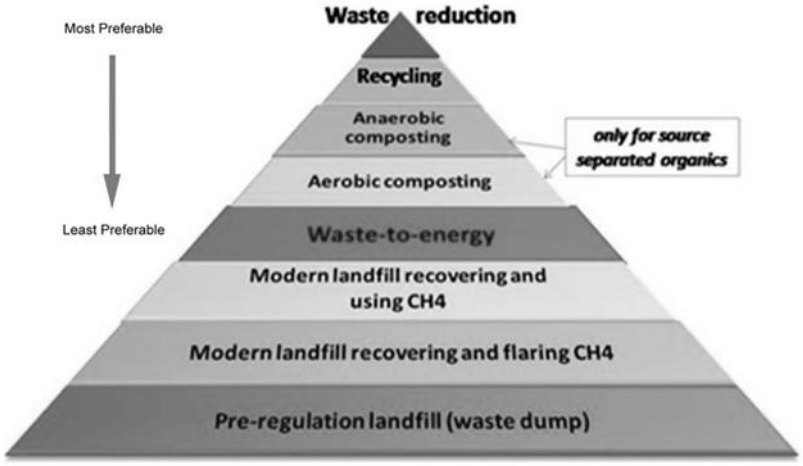

Figure 1: Waste management hierarchy [1]

1.2. Legal framework in EU

Biodegradable waste is responsible for many environmental impacts caused by landfills. For this reason, the EU has established the Landfill Directive 99/31 EC. The article 5 of the Landfill Directive defines that Member States should set up a national strategy for the implementation of the reduction of biodegradable waste going to landfills. This strategy should ensure that biodegradable municipal waste disposed at landfills must be reduced to 75% of the total amount of biodegradable municipal waste produced in 1995, in no longer than five years after the date of implementation. After 15 years this percentage must be reduced to 35% of the amount. Member States that landfilled more than 80% of their collected municipal waste in 1995 may postpone the attainment of these targets by a period not exceeding four years [3], [4].

According to the Waste Framework Directive 2008/98 EC, member states shall reach the following specific objectives [2], [4]:

- (a) by 2020, the preparing for re-use and the recycling of waste materials such as at least paper, metal, plastic and glass from households and possibly from other origins as far as these waste streams are similar to waste from households, shall be increased to a minimum of overall 50 % by weight.
- (b) by 2020, the preparation for re-use, recycling and other material recovery, including backfilling operations using waste to substitute other materials, of non-hazardous construction and demolition waste, excluding naturally occurring material defined in category 17 05 04 in the list of waste, shall be increased to a minimum of 70 % by weight.
- (c) The Directive requires that Member States adopt waste management plans and waste prevention programs that cover the whole State alone or combined.

1.3. Quantitative data

In Europe and in the rest of the industrialized world, people use an increasing amount of materials. In 2015, the average annual municipal solid waste production was about 477 kg per European capita [5]. There are considerable recycling efforts undertaken. Composting, incineration and landfilling are also used in Europe. About 42

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% of municipal solid waste was recycled and composted (27% recycled, 15% composted), 31% was landfilled and 26% was incinerated in 2013. Recycling and composting together accounted in 2013 for nearly two-thirds (65%) of waste treatment in Germany and for more than half in Slovenia (62%), Austria (59%) and Belgium (55%). On the other hand, more than 80% of MSW going to landfills in countries like Romania (99%), Malta (87%), Croatia (85%), Latvia (84%) and Greece (81%) [5], [6], [7].

2. MUNICIPAL WASTE MANAGEMENT IN GREECE

In Greece, the municipalities are responsible for municipal solid waste management. Habitants throw solid waste in bins. In most cases, there are (green) bins for mixed solid waste, and (blue) bins for mixed recyclable materials (mainly packaging waste and paper). There are also some bins for specific recyclable streams (paper, glass). Waste is collected with garbage trucks and moved to treatment areas.

In 2010, about 5900000 tons of Municipal Solid Waste (MSW) were produced in Greece. Of these, approximately 4.6 million tons were disposed in sanitary landfills, and approximately 300000 tons in uncontrolled landfills. About 140000 tons were composted (52000 tons in the Mechanical Recycling & Composting Plants) and 870000 tons recycled. The total amount of MSW utilized / recovered is calculated at 1010000 tons, which amounts to approximately 18% of the total. Based on more recent data, the annual waste production in Greece for the year 2013 was 506 kg per inhabitant per year, or 5.5 million tons. 16% of this amount was recycled, 4% was composted and about 81% was landfilled [6], [8], [9], [10]. The quantities and the percentage of recycling and recovery of packaging waste for the year 2013 are presented in table 1. The total recovery was 51.2% (the goal was 60%) [11], [12]

Table 1: Quantities and percentage of recycling and recovery packaging waste for year 2013 [11], [12]

Material		Produced packaging waste	Recycling	Energy Recovery	Total recycling and energy recovery	Recycling Goal (%)	Recycling (%)
Glass		99527	27094	0	27094	60	27.2
Plastic		184915	58621	0	58621	22.5	31.7
Paper and carton		337088	259327	600	259927	60	76.9
Metals	Aluminum	19430	6506	0	6506		
	Steel	86339	40018	0	40018		
	Total	105769	46523	0	46523	50	44.0
Wood		40850	1103	2.674	3777	15	2.7
Other		5196	0	0	0		
Total		773345	392668	3274	395942	55	50.8

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The major recycling system is organized by the Hellenic Reuse Recycling Company (HERRCO). The company was created with the participation of municipalities. In 2014, about 87% of the population (9.4 million inhabitants) had access to the blue bins. In cooperation with more than 270 municipalities (about 85% of municipalities of Greece), HERRCO has placed more than 164000 bins and has allocated 430 garbage trucks [9], [12], [13], [14]. The materials from recycling bins are transferred to sorting centers of recyclable materials (KDAY). There are about 30 sorting centers, which are operating under the responsibility or with the funds of HERRCO. In sorting centers the materials are separated in stream categories like paper-carton from packages, printed paper, plastic packages, plastic film, mixed plastic, glass, packages from aluminum and tinplate etc. After sorting, materials are sold in secondary markets [11], [12], [13], [14], [15].

The recycling industry in Greece is also characterized by the operation of informal waste collection networks. [14]

3. WASTE MANAGEMENT ASSESSMENT GUIDE

3.1. General information

Local plans are composed in accordance with the national waste management plan. They can contribute to an effective waste management, reducing landfilling while supporting prevention, recycling and composting. The presented MSW management guide can contribute to a local MSW management plan, while it can also be useful for the design and monitoring of solid waste management.

The guide is based on waste management practices that are used in Greece. Treatment methods include separation at source, recycling, composting and landfilling. Municipal solid waste is separated by the habitants, in different waste bins. Four types of waste bins are proposed in this guide: one for mixed recyclable materials (plastic, paper, glass, and metals), one for paper, one for compostable organic waste and one for mixed solid waste. Waste bins for other streams (glass, plastic, etc.) can also be used with proper modification.

The guide includes a description and data about the existing municipal waste management system, its effectiveness (rates of separation at the source, etc.). It produces reports and can be used in the evaluation of proposals for the improvement of the waste management. It can contribute to the development and evaluation of alternative investment proposals, aimed towards both the economical and environmentally sensible operation of the waste management system; in line with the objectives of Greek and European legislation. The proposals for improvement may include purchase of new equipment (vehicles, containers, etc), construction of mechanical sorting and composting plants, awareness campaigns, home composting programs, etc.

The guide was based on data from the municipality of Kallithea (Attica). The municipality was used as an example only in fields of waste management that were considered satisfactory. The remaining fields were based on the literature review including studies of other countries' municipalities' cases which were adapted to waste management in Greece. As a result, the guide can be used for all Greek municipalities, with small modification. [16]

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The programs used to import data and export the results are Microsoft Excel 2007 and Microsoft Word 2007. These are widely used programs and don't require any specialized skills. Additional files in MS Excel 2003 and MS Word 2003 are also available, in case that these editions are used. Moreover, the guide uses simple functions of MS Excel and has a description in a pdf file, so it can be easily understood and used by people with basic knowledge of computing and waste management. The guide uses two files. The data are imported in the Excel file. In the same file results are calculated and reports are exported. The MS-Excel file is the source file. The MS-Word file adjusts the parameters and the results from the Excel file in the text. [16]

3.2. Imported data and produced reports

The majority of the required data is usually available and can be provided by Greek municipalities. However, the guide was developed independently from the available data. If accurate data is unavailable, estimates can be used. The guide includes suggested values when data are not available. It is also possible for some cells to be left empty. Given that the guide can easily be modified, additional data can be imported and further reports can be produced.

The guide uses the imported data for the municipality to create reports and automatically fills in the corresponding cells. These data include the total surface of the municipality, demographics such as the total population, data from previous censuses as well as the dividing units and sectors of the municipality.

Outturn data about solid waste management are also required as input parameters. These data include the amount of municipal solid waste that is generated every year in the study area. If the total amount of waste isn't available, it can be estimated by the routes of garbage trucks or the average waste production per capita. The composition of solid waste is also used by the guide. The composition can be measured specifically for the municipality, can be obtained from studies for the administrative region to which the municipality belongs, or entire Greece. The (average) density of solid waste is also needed. If accurate data aren't available, the guide has suggested values, which can be used. Forecasting for future waste production may additionally be introduced.

Data concerning the equipment used are also required, such as the number and the capacity of waste bins and garbage trucks. Financial data, related to the cost of solid waste management, wages, cost of fuel, maintenance costs etc, can also be added. Furthermore, especially if relative reports are required, balance sheet data, municipality incomes, indirect costs and similar data can be imported.

The aforementioned data about the production of solid waste is used for the calculation of the required equipment, like waste bins and garbage trucks. If additional equipment is necessary, the guide calculates the total cost, based on the amount and the cost per unit. Additionally, the guide calculates the cost of construction or the extension of a municipal composting plan and the required equipment. In case of a home composting program, the amount of composted organic waste and its cost can be estimated, based on the amount of households that will obtain a composting bin, and the cost of each bin. If there is a home composting campaign, the relevant cost can be added. The waste management assessment guide calculates partial and total cost.

The guide produces reports and diagrams, so that results can easily be presented, without any specific knowledge required. Financial data are processed and the total income and the total cost are calculated. The investments are evaluated with economic

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data and the results are described. Thus, the guide informs the user if the investment is economically viable. Different scenarios including the percentage of separation at source can be examined using the guide, and results about the amount of waste, equipment requirements and the total project cost are produced.

The current guide can easily be modified to a more proper form for each municipality. Moreover, it can easily be adapted to changes in municipal waste management. For example, more data can be added if there are available.

Moreover, the guide includes data and a questionnaire and produces a report about a Pay As You Throw system, in case the municipality installs or extends one.

Note that streams of waste like used tires, waste batteries and accumulators, waste oils, vehicles at the end of life cycle, waste electrical and electronic equipment, construction and demolition waste are collected separately and managed by alternative management systems.Their management isn't included in the guide. However, if data are available and the management of these streams is examined, the guide can be easily modified and relevant reports can be created.

Some input and output data which were described above are shown in the following table (table 2).

3.3. Application examples

As mentioned, the guide was applied in the municipality of Kallithea (Athens). Examples from the imported data and the produced reports are presented below (screens from sheets of the Excel file).

The municipality is divided in 13 sectors (sectors 14, 15 and 16 that are noted were abolished and their garbage bins were incorporated in the other sectors). For each sector an average of daily waste production is presented. The total amount per day, the average amount per month and per year are noted. There is also the current number of waste bins and the suggested number of waste bins, which is calculated automatically, based on the average density of waste, the completeness (percentage) and the capacity of the bins (in liters). The total number of bins is also calculated in both cases (existing and suggesting) and so is their difference. The results for the municipality of Kallithea are showed in figure 2.

An example of cost calculation is shown in the next picture (figure 3). The required equipment for a composting plan and its cost are presented. In case there are no available data, suggested prices for the equipment are also available. If additional equipment is required, more data cells can be added. The sheet includes also data about home composting. Specifically, the required bins and their cost are calculated (based on the cost per unit).

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Table 2: Input and output data of municipal solid waste guide

Input parameter	Output parameter
Demographics such as the total population, data regarding the municipality, obtained from previous censuses	Population change
Total surface of the municipality	Population density
Amount and composition of municipal solid waste	Amount of recyclable and compostable waste that can be recovered
Average density of waste	Amount of required bins and garbage trucks
Amount of existing garbage trucks and garbage bins	Total volume of waste that can be stored/moved, required garbage trucks/ garbage bins (an approach based on the amount of waste and their density and the difference from existing equipment)
Dividing units and sectors of the municipality.	Waste bins required for each sector (an approach based on the amount of waste and their density)
Data concerning the equipment used and its cost (number and the capacity of waste bins and garbage trucks, cost of garbage trucks such as fuel cost, maintenance cost etc.)	Total cost of used equipment
Number of types of garbage bins/ amount of streams that collected in separation at source programs (existing or planned) and cost of each garbage bin. Purchase cost of garbage truck.	Cost of extra equipment needed
Financial data, related to the cost of solid waste management, wages, cost of fuel, maintenance costs, indirect costs etc	Total solid waste management cost
Cost of equipment used in composting plan (that already exists or needs to be purchased	Total cost of composting
Balance sheet data, municipality incomes, indirect costs etc	Total solid waste management cost, total cost per capita

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	A	B	C	D	E	F	G
1	**Sector**	**APW (kg/day)**			**Sector**	**Suggested number of bins**	**Number of bins**
2	1	10200.8			1	155	178
3	2	9634.1	10539.89		2	146	176
4	3	9319.3			3	141	169
5	4	14671.6			4	222	263
6	5	13160.3			5	199	227
7	6	11208.3			6	170	201
8	7	11586.1			7	176	205
9	8	9949.0			8	151	176
10	9	7367.3			9	112	133
11	10	11586.1			10	176	201
12	11	12152.8			11	184	214
13	12	7745.1			12	117	134
14	13	8437.7			13	128	148
15					14,15,16	-	544
16	SUM	168.64			Total	2620	2970
17		5059.15	60709.76			350	
18	**Waste density (kg/m^3)**	**100**					
19	**Completeness factor**	**0.6**					
20	**Capacity (l)**	**1100**					

Figure 2: Existing and suggested amount of waste bins as an example of use of the guide (adjusted from [16])

	A	B	C	D	E	F	G	H	I	J
19										
20			**INITIAL CAPITAL**							
21	**Equipment**	**Price**	*Suggested price*	Depreciation rate			**HOME COMPOSTING BINS**			
22	Windrow turner	90,000 €	*90,000 €*	*0.1*			**Composting bin**	**Amount**	**Bin price**	**Total**
23	(Wood) shredder	55,000 €	*55,000 €*	*0.1*			Residence	*50*	80.00 €	*3,400.00 €*
24	Trommels	40,000 €	*40,000 €*	*0.1*			Block of flats	*100*	315.00 €	*26,775.00 €*
25	Measure instuments, sensors etc	3,000 €	*3,000 €*	*0.1*			Shops	*100*	315.00 €	*26,775.00 €*
26	Equipment for separation	15,000 €	*15,000 €*	*0.09*			Total	*250*		*56,950 €*
27	Roof	15,000 €	*15,000 €*	*0.06*						
28	Earthworks	6,000 €	*6,000 €*				**AMOUNT OF BUILDINGS THAT PARTICIPATE**			
29	Infrastructure	8,000 €	*8,000 €*	*0.07*			**Building type**	**Amount**		
30	Building (office)	10,000 €	*10,000 €*	*0.07*			Residence	50		
31	Compost bagging machine	13,000 €	*13,000 €*	*0.08*			Block of flats	100		
32	Other equipment	1,000 €	*0 €*	*0.08*			Shops	100		
33										
34	**TOTAL**	*256,000 €*	*255,000 €*	*23,430 €*			**PURCHASE OF ADDITIONAL GARBAGE TRUCKS (IF NEEDED)**			
35							**Amount of trucks**	**Price**	**Cost**	
36							1	50,000.00 €	*50,000.00 €*	

Figure 3: Calculation of cost of composting plan and home composting program (adjusted from [16])

In the following example (figure 4), an economic evaluation of the scheme of 4 types of garbage bins (one type for mixed waste, one for mixed recyclable waste, one for paper and one for organic waste) is presented. The results are automatically calculated from the imported data, like the cost of garbage bins etc. Initial cost, inputs, other income and net cash flows are calculated. Furthermore, net present value and internal rate of return are automatically calculated, based on the imported interest rate.

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	A	B	C	D	E	F	G	H
28	Four bins scheme							
29	Year	Outflows	Incomes	Operating costs	EBIDA	Depreciation	Remaining value	Net cash flow
30	0	637,040 €						-637,040 €
31	1		263,339 €	163,264 €	100,074 €	30,900 €		100,074 €
32	2		349,662 €	165,322 €	184,340 €	30,900 €		184,340 €
33	3		510,589 €	176,412 €	334,177 €	30,900 €		334,177 €
34	4		823,916 €	190,595 €	633,321 €	30,900 €		633,321 €
35	5		951,021 €	201,391 €	749,630 €	30,900 €	195,500 €	945,130 €
36	Discount rate			0.075				
37	Net Present Value			1,017,137 €				
38	Internal Rate of Return			39%				

Figure 4: Costs and income of a scheme of 4 type garbage bins (adjusted from [16])

4. CONCLUSIONS

The proposed municipal solid waste management guide was successfully applied to the municipality of Kallithea (Attica). It was a helpful tool for solid waste management and for Kallithea's local waste management plan. The guide produces reports and can also be used in the evaluation of proposals for the improvement of the waste management. The municipality of Kallithea was used as guide only in fields that were considered satisfactory. The remaining fields were based on Greek and national literature. As a result, the guide can be applied in any Greek municipality, with small modifications. The modifications are necessary in order to adjust the guide to the municipality's waste management and the available data.

The guide is easy to use, doesn't have special requirements and doesn't require special trained employees. To import data and export the results it uses the widely used programs Microsoft Excel 2007 and Microsoft Word 2007. Thus, simple waste management and MS Excel knowledge is necessary. It automatically produces reports and diagrams, so that results can be easily presented without any specialized knowledge required. Since the guide can easily be modified, additional data can be imported and supplementary reports can be produced. Moreover, the guide can easily be adapted to changes in municipal waste management (more data, purchase of equipment, import of new management method etc.).

We note that the guide can be easily used for a quick calculation of the needed equipment and its cost, of the total waste management cost, etc. If precise calculations are needed, the guide must be used with caution. The results may need further examination, especially when non-accurate data, average values or suggested numbers are used.

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