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Full Length Research Paper

Feasibility assessment of investments in waste incineration facilities: Case study of Bucharest-Ilfov region

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The regulators of the waste management sector should pay close attention to the investments made in the field. In addition to environmental impacts, economic analysis can provide policy makers with valuable information for proper decision. Taking into account this requirement, the aim of the present paper is to evaluate the economic efficiency of an incinerator with energy recovery investment, located in Bucharest-Ilfov region, Romania. A detailed investment feasibility evaluation is made using the main economic efficiency indicators in order to reveal the large benefits of this kind of facilities.

Key words: Waste incineration, economic efficiency, waste electrical and electronic equipment, (WEEE), municipal waste*,* energy recovery.

INTRODUCTION

Managing solid waste is a big challenge of municipal areas (Nzeadibe, 2009; Hernández and Crúz-Medina, 2011). Because of rapid urbanization, the quantities of domestic solid waste increased, meanwhile the spaces for disposal decreased. So, the subject of waste treatment is a topical one, as a result of the various difficulties that communities face regarding the limited opportunities for waste disposal.

At present, many waste treatment techniques are used, namely: mechanical treatment, biological treatment, mechanical-biological treatment and thermal treatment. Each of these methods has advantages and disadvantages in terms of economic or environmental efficiency. Incineration is the most important thermal process currently used and is equally applicable to mixed municipal waste and to residual waste fractions.

The incineration of waste is a complex issue and the scientific background behind the various options is still far from clear. Four main dimensions can be identified: technological, environmental, economic and social (Sango, 2010).

Incineration is generally thought to produce fewer externalities, in particular in so-called waste-to-energy facilities (Miranda and Hale, 1997). These facilities do not only reduce final disposal of waste, but also produce electricity and/or heat, saving (energy) resources (Dijkgraaf and Vollebergh, 2004; Joos et al., 1999; Isa, 2008).

The construction of incinerators has an impact on the surrounding environment. Despite the treatment with chemicals and strict guidelines, there is a potential of hazardous gases still escaping and poisonous compounds from ash leaking into the ground, causing effects to both wildlife and people. This is the major factor, which causes a lot of debate.

Municipal solid waste incineration plants tend to be among the most expensive solid waste management options, and they require highly skilled personnel and careful maintenance. For these reasons, incineration tends to be a good choice only when other, simpler, and less expensive choices are not available (World Bank, 1999).

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Abbreviations: WEEE, Waste electrical and electronic equipment; **LCA**, life cycle assessment; **GDP**, gross domestic product; **UN**, United Natisons.

Because these plants are capital-intensive and require high maintenance costs and comparatively higher technically trained operators, they are commonly adopted by developed countries. High capital and maintenance costs may make waste incineration beyond the reach of many of the lesser developing countries.

The cost of incineration across the European Union (EU) is still very variable but is still rising due to the increasingly stringent emission limit requirements. For the modern facilities, costs appear to be stabile. Some European countries have emerged a functioning market for the incineration of wastes in different types of facilities (Bontoux, 1999).

Despite many controversial issues surrounding waste incineration, it seems to be a good solution for the future. It is not the best way to create alternative energy in terms of visibility, public perceptions, potential health and environmental issues, but landfill space is running out, and the incineration represents a solution.

The paper aims to demonstrate the feasibility of waste incineration investments using the main economic efficiency indicators substantiated on the economic and social factors specific to a Romanian region. The research is based on the use of secondary data, observation and interpretation. The collection of information and necessary data was done from the literature, government documents, and national and international statistics.

The paper is organized as follows. We explored first the existing literature in the field of economic efficiency evaluation of waste treatment facilities with accent on incineration. Next we have presented the characteristics of the region and analyzed the economic and social factors that determinate the size of the waste treatment facilities.

Based on the social and economic factors, we estimated the waste in Bucharest-Ilfov region for the horizon time 2040 and analyzed the opportunity of an investment in waste incineration in Bucharest-Ilfov region. The paper continues with the feasibility analysis of municipal waste incinerator proposed for the Bucharest-Ilfov region.

LITERATURE REVIEW

The concerns of scientists on the harmful effects of waste disposal in the environment started in the mid of the previous century. In the late '80s - early '90s several European countries were faced with so-called crisis of disposal capacity, so the diversity and complexity of research undertaken in the field increased. The literature in the field treats, among other topics, is the environmental and economical efficiency of waste treatment facilities.

Across the years, a large number of methods and approaches that can be used for supporting waste management decisions at different levels in society have been developed. Finnveden et al. (2007) present the possibilities and limitations of a large number of methods, namely: environmental impact assessment, strategic environmental assessment, life cycle assessment (LCA), cost—benefit analysis, cost-effectiveness analysis, life-cycle costing, risk assessment, material flow accounting, substance flow analysis, energy analysis, entropy analysis, environmental management systems, and environmental auditing.

Cost-benefit analysis is one of the most relevant methods used in evaluation of the investment efficiency in waste treatment. The cost and benefits of projects must be carefully weighed using a common monetary measuring unit. Yet, many different categories of benefits and cost must be evaluated, such as health impacts, property damage, ecosystem losses and other welfare effects. Furthermore, many of these benefits or damages occur over the long term, sometimes over several generations, or are irreversible (for example, global warming, and biodiversity losses) (Pearce et al., 2006).

Brisson (1997) realized a social cost-benefit analysis of municipal solid waste management for the representative or average EU country. Author analyzed the waste hierarchy of recycling (including composting), incineration and land filling. The calculated private and external costs of different waste treatment options suggest that recycling is the best treatment option from a social cost-benefit point of view. The results shown that incineration is better than a bring system or separate collection of compostable waste.

Döberl et al. (2002) uses a cost-benefit approach to evaluate different waste management scenarios for municipal solid waste and sewage sludge in Austria. The authors include a large number of emissions and nine different waste treatment scenario's, apply shadow prices and add the private costs of the different treatment options to these external costs. They especially focus on the long-term effects as they account for emissions in the next 10,000 years.

Their analysis shows that incineration is the best option, followed by mechanical-biological treatment and land filling is the worst option. That incineration performs better than mechanical-biological treatment follows from the fact that the residues of incineration have a better quality.

In a report prepared for the World Bank, Rand et al. (2000) present the main criteria that incineration should be considered in the use of waste treatment. Moreover, the authors analyze the conditions necessary for successful implementation of thermal waste treatment technologies, the most relevant being considered: the predictability of the energy consumption and of the other residues recoverable from the incineration, the financial guarantees granted for the managers of these facilities, the accurate estimation of quantities of waste incinerated, etc.

EPA (2002) presents a cost-benefit analysis of three recycling options and incineration for plastic bottles. Recycling options differ with respect to collection (only in municipal recycling stations or also local) and the way the bottles are treated after collection (export to Germany or production of granulate in Denmark). On the basis of social costs incineration is much cheaper for society than recycling. According to the authors this stems primarily from the much higher collection costs for recycling.

Vollebergh (1997) calculated the social costs for Waste-To-Energy plant in the Netherlands. He explicitly distinguished between private and environmental costs for both the waste and energy function of this technology. Land filling has been used here as the opportunity option for the waste function and the average Dutch fossil fuel energy reference system as the opportunity option for the energy system. Seven years later, Dijkgraaf and Vollebergh (2004) have applied the same framework to the choice between waste incineration and land filling.

Hellweg et al. (2005) have developed a methodology to compare the advantages and disadvantages of different methods of waste treatment. Their analysis showed that the incineration requires high costs compared with storage and mechanical-biological treatment, but unlike these, ensures the elimination of lower quantities of greenhouse gas emissions and contributes significantly to reducing waste volume.

Other research in the field analyzes the estimated costs and revenues specific to a waste incinerator and the way they are allocated to various categories. According to a study conducted by Zwahr (2004) more than 76% of the revenues of an incinerator with energy recovery come from waste charges for access to the incinerator site and only almost 20% are revenues obtained from recovered energy. Most of the expenditures are covered by operating expenses and maintenance facilities (approximately 44%), but a large share is covered by the costs of decontamination of waste and combustion ash.

Liamsanguan (2007) analyzed the energy balance of a municipal waste incinerator (if the necessary energy for incinerator operation exceeds the amount of produced energy from waste incineration) and concluded that half the energy produced by a waste incinerator can be used for own consumption.

The latest research on waste incineration is focused on the extension of the possibilities of recovery of residual waste from combustion processes. A team of Italian researchers has found an effective method for decontamination of ash resulting from incineration of municipal waste that can be widely used in cement kilns or in the construction of bridges, roads and dams (Bontempi et al., 2010).

The situation is different in terms of waste electrical and electronic equipment (WEEE) as part of municipal waste. With current trend of increasing market of information and communication technologies (for example, office and household electronics, computers, telecommunication and lighting equipments), the amount of WEEE is expected to rise at a rate of at least 3 to 5% per year in Europe (Huisman et al., 2007; Ciocoiu et al., 2011). The identification of the most ecologically suitable treatment option for such specific waste is crucial for effective environmental protection through sustainable waste management.

According to the European waste strategy, if the waste production is unavoidable, as in the case of the EEE, the choice between recycling/re-use or incineration with adequate emission standards should be based on the evaluation of their respective environmental impacts (EC, 2010).

Using a combined approach of material flow analysis and LCA, Hischier et al. (2005) calculated the environmental impacts of the full recycling chain - sorting, dismantling, recycling and disposal or further transformation of the fractions into secondary raw materials - for the annual WEEE derived from two main Swiss recycling systems. The study included the assessment of the environmental impact of each WEEE fraction (for example, batteries, capacitors, screens, plastics, metals, cables) during a complete WEEE treatment. The results were compared to a scenario assuming no recycling with incineration and energy recovery of all WEEE and primary production of raw materials. The resulting environmental impacts were much smaller for the complete WEEE recycling treatment compared to the respective no-recycling and incineration treatment. Even the toxicity caused by recycling resulted of minor importance compared to the incineration scenario. This is due to the combustion of the organic parts and the resulting air emissions. This study concluded that recycling is more ecologically advantageous over incineration. It should be noted that this study was focused on a specific Swiss situation.

The Romanian context

A well-developed and controlled waste management system is considered a prerequisite to a municipal waste incineration plant. The success or failure of an incineration scheme depends also on the attitude of the multiple stakeholders and on the legislative and institutional framework currently in place (World Bank, 1999).

For a better understanding of the context in which this study was carried out, it is useful to recap the main dimensions of waste management in Romania.

In the last 10 years, the Romanian legal framework regarding waste management has undergone numerous changes. Unlike other EU countries, who adapted their waste legislation in more than 20 years, Romania was obliged to bring in line the waste legal framework in a shorter period of time. Thus, the main EU directives on waste have been transposed in the national legislation almost entirely in the period 2000-2003 (Platon et al., 2004). Also, in 2004, Romania has adopted the National strategy on waste and the National plan of waste management, creating in this way the necessary framework for the development and implementation of a sustainable waste management system.

The EU granted Romania transition periods in the waste management field, for: packaging and packaging waste, waste land filling, waste incineration, import, export and waste transit. The need for these transition periods was due to deficiencies recorded in the field, such as: precarious infrastructure for waste collection, transport and disposal, the permissive regime of environmental standards application, the high number of sites damaged by pollution caused by economic activities, unsuitable landfill of waste and so forth (Târţiu and Petrache, 2009).

In April 2007, Romania has adopted the Regional waste management plans. These plans have a key role in the development process of the waste management, promote co-operation between regional and local authorities, citizens and business environment.

The most recent official data available regarding the waste management practice in Romania show the following (BALKWASTE, 2010; Ghergut et al., 2009; Enache, 2010; Ciocoiu et al., 2010): the total amount of solid waste was 320.610 thousand tonnes in 2006 (of which 99.7% is non-hazardous waste) with shares that varied from year to year of around 2.76% for municipal waste and 97.24% for industrial waste. Hazardous waste generated, according to the categories of waste in the European list of waste is about 0.3% of total waste; in 2007, the amount of municipal waste collected by the specialized services of municipalities or sanitation companies was about 6,902 thousand tones.

Municipal waste is managed in different ways, depending on its characteristics and quantities that are generated. Only a small proportion of waste is used as secondary raw materials and recycled. Around 99% of the total municipal waste collected, are eliminated by land filling, Romania currently recycles only 1% of the waste it produces;

1). In the South-East region (municipality of Buzau) there is the largest integrated plant for treating and recycling WEEE (refrigerators, freezers, televisions, monitors, computers, washing machines, small EEE, electric cables and conductors), respecting the most demanding European standards for recovery and recycling (BATRRT). The capacity of processing is 10.000 tones/year and in 2013 it will reach a capacity of 49.000 tones/year. The main recyclable materials are ferrous metals, non ferrous, plastic and glass.
2). There is a need for high levels of investment in physical infrastructure (sorting plants, recycling and treatment facilities, complying landfills);
3). Almost all Romanian counties have elaborated project proposals for getting funds from the Operational Programme for the Environment of the European Union, in order to develop integrate waste management systems;
4). In the almost all Romanian counties have been implemented the selective collection of municipal waste into the following streams: paper and cardboard, plastic and glass;
5). There is a lack of selective collection waste services in communes and villages, excepting those located near the towns;
6). At the national level there are only thirty municipal landfills complying with the EU requirements;
7). In the last three years, the number of educational and informative campaigns has increased. The main aims of this type of actions are to educate people about the sustainable waste management system and to encourage pro-environmental attitudes at all levels.

In conclusion, the waste management practice in Romania has undergone numerous changes but it is still room for further improvements.

CASE STUDY

Evaluation of an investment in a waste incineration with energy recovery for Bucharest-Ilfov region

Incineration, the combustion of organic material such as waste with energy recovery is the most common waste-to-energy implementation. A waste incinerator is a technical plant designed to convert non-recyclable waste into a maximum amount of energy while generating a minimum amount of residues. Modern incineration plants are vastly different from the old types, some of which neither recovered energy nor materials. Modern incinerators reduce the volume of the original waste by 95-96 %, depending upon composition and degree of recovery of materials such as metals from the ash for recycling (Ramboll, 2010).

There are two techniques that involve incineration with energy recovery; Pyrolysis and Thermal treatment. These two techniques are related closely. Pyrolysis is the thermal decomposition of waste material at high temperatures without the presence of gases. This produces combustible gases (methane, hydrocarbons, hydrogen and carbon monoxide), liquids and solid residues. Thermal decomposition differs slightly in that there is a limited amount of oxygen or air involved in the process. The gas that is produced can be used in boilers or cleaned and used to power turbines or generators. However, these techniques are still not perfected and many of the environmental concerns that the world has about incineration remain with energy recovery techniques.

The benefits of energy recovery from incinerators are largest if the heat can be used directly for process heat ordistrict heating systems with sufficiently large constant load. Electricity production brings far lower benefits than heat because of the poor conversion efficiency of incinerator heat (compared to central station power plants) (Rabl et al., 2008).

Incineration is not a usual practice for the treatment/disposal of municipal waste in Romania. Currently in Romania there are no facilities for the incineration of municipal waste because of the properties and the high cost of investment and operation. On the other hand, there are seven incinerators for hazardous waste belonging to four private operators, which incinerate hazardous waste generated in their own activities and 7 cement kilns are authorized for the co-incineration of waste (BALKWASTE, 2010). Furthermore, on a national level there are 6 operators, in the field of energy recovery from packaging waste (Table 1).

The constant increase of the quantities of waste generated and collected requires the identification of concrete solutions for preventing and combating waste disposal. Taking into account the limited waste landfill areas and the possibility of energy recovery, waste incineration seems to be a solution with opportunities from ecological point of view, so in the following we will try to

Table 1. Incinerator units.

Region	Operator	Category of waste recovered				
		PET	Plastic	Paper	Paperboard/Wood	Cork/Textile
Region 1 North East	S.C. Carpatcement Holding S.A.	X	X	X	X	X
Region 2 South East	S.C. Lafarge Ciment Romania S.A		X	X	X	X
Region 3 South Pitesti	S.C. Holcim Romania S.A. Ciment Campulung	X	X	X		X
Region 3 South Pitesti	S.C. Carpatcement S.A.- Sucursala Fieni	X	X	X	X	
Region 6 North-West Cluj	S.C. Holcim Romania	X	X	X	X	X
Region 7 Center	S.C. Lafarge Ciment Romania S.A.	X	X	X	X	

Source: http://www.anpm.ro

demonstrate that incineration with energy recovery is economically feasible.

THE BUCHAREST-ILFOV REGION

The Bucharest-Ilfov region is formed by Bucharest, the capital of Romania, and Ilfov County. Located in the south of the country, in the central part of the Romanian Plane, Bucharest-Ilfov region has a surface of 1,821 km^2, out of which 12.5% represents the administrative territory of Bucharest and 87.5% of Ilfov County (MDRL, n.d.). The region has an economic force and dynamics superior to other Romanian regions, a big level of gross domestic product (GDP) and a social and professional structure with a higher standard.

The localities network of Bucharest-Ilfov region had 9 cities (out of which only Bucharest is municipality), 32 communes and 91 villages. Bucharest is the biggest municipal agglomeration of Romania, its population being of 1,927,559 inhabitants, representing almost 87% from the total region population, over 16% from the total municipal population of the country, respectively 9% from the total Romanian population (MDRL, n.d). Bucharest is the third most dense populated capital in Europe (8,100 inhab/km^2), after Athens (20,287 inhabitants/km^2) and Paris (20,248 inhabitants/km^2) (Ionita, 2010). Regarding the population, the capital is followed by Voluntari (29,910 inhabitants), Buftea (20,564 inhabitants) and Pantelimon (17,084 inhabitants). The other 5 cities within Ilfov County have a population under 15,000 inhabitants, as follows: Popesti-Leordeni, 14,712 inhabitants; Chitila, 12,242 inhabitants; Otopeni, 10,272 inhabitants; Bragadiriu, 8,326 inhabitants; Magurele, 7,792 inhabitants (Ionita, 2010).

There are 9 main providers of the waste service in the region. Almost 90% of all municipal solid waste of region are collected. There is no selection made at source waste. All wastes are buried without being previously treated. The Bucharest-Ilfov region has acknowledged the existent waste problem and therefore have put into practice the idea of the separate recycling waste bins, one for every type (of the three) of waste: paper/ cardboards, plastic or household waste (Ionita, 2010).

The land filling is the main option for the final disposal of the municipal waste. For Bucharest-Ilfov region there are three landfills located in Ilfov County: Chiajna, Glina and Vidra. One significant problem is that the region doesn't have a wastewater treatment plant. Bucharest is the single European capital that does not treat the waste water. The construction works at Glina wastewater treatment station started before 1989, but they have not been finalized yet. When finalized, the Glina plant will treat the sewage waters from the region and is expected to generate 400-500 tonnes of mud per day, which will be turned into biogas, subsequently used for energy production.

Economic and social factors determining the size of waste treatment facilities

The quantity and quality of waste generated in a specific area are closely related to economic and social factors that characterize the level of development in the region. A proper sizing of the treatment and waste recovery facilities must be based on an accurately forecast of the main macroeconomic and demographic indicators, which trends directly and indirectly influence the dynamics of waste (Dhamija, 2006; Bran, 2009). Thus, becomes necessary to analyze and careful estimate the trends of the macroeconomic and demographic indicators for Bucharest-Ilfov region during 2012-2040, the timeframe for which we propose to study the feasibility of building a municipal waste incinerator.

GDP, the final consumption, the rate of inflation, the exchange rate, the annual earnings, the rate of unemployment and the number of employees are indicators that influence directly and indirectly the amount of waste generated annually.

For 2012 to 2014 are relevant the projections made by the Romanian National Commission for Prognosis about the evolution of the main macroeconomic indicators for medium term. The projections show that GDP will register a positive growth between 1.5% and 4.5%, inflation will be 2.8% in 2014, unemployment will decrease gradually to 6.3%, and the final consumption will reach a growth of 3.9% in 2014 compared to 2013. The linearity of the evolution for the macroeconomic indicators is not preserved in the period 2015 to 2020 (National Commission for Prognosis, 2009a). According to the long-term forecast, the real rate of growth for the Romanian GDP will have sensitive variations, from 5.2% in 2015 to 5.7% in 2017, followed to gradually fall to 4.7% towards the end of the period. The growth rate of final consumption has a sinusoidal trend, reaching 5.2% in 2017, dropping to 4.2% in 2019, but increasing again over 4.7% in 2020. The projections made by the National Commission for Prognosis consider the adoption of the Euro in 2014 in Romania, but because of the present evolutions in the country and Europe this becomes more and more unlikely. The forecasts for the employees registered at national level show a 0.6% annual increase and an unemployment rate of 4.4% in 2020. Based on these projections we can conclude that for the 2020 time horizon, the economic and social context is favorable for the increase of municipal waste generated, this trend probably having a slower rate until 2040.

National trends are maintained and for the Bucharest-Ilfov region (National Prognosis Commission, 2009b). Until 2014 it is predicted a linear increase of GDP, both regionally and locally. According to forecasts, the number of employees will increase significantly, with at a higher rate in Bucharest than in Ilfov County. The average monthly net earnings also will record higher annual net value compared with the national average. Such developments in macroeconomic indicators confirm the possibility of increase of the levels of municipal waste generated in the short and medium term.

The dynamics of municipal waste is directly influenced by the evolution of the number of inhabitants, so to obtain a correct sizing of waste treatment facilities for Bucharest-Ilfov region is necessary to achieve a realistic estimation of demographic indicators at local level. From this point of view, the analysis of demographic data indicates two major trends. On the one hand, there is a clear downward trend of the Romanian population as a result of negative natural growth, and on the other hand there is a pronounced internal migration between rural and municipal areas. The decline of Romanian population is confirmed by a series of studies of international bodies such as the United Nation (UN). Experts from the UN population division developed projections until 2050 for the evolution of the Romanian population in several variants of scenarios. All the scenarios reflect a clear trend of decrease for the population of Romania.

In terms of population evolution by urban/rural distribution we believe it will continue the trend of population growth in municipal areas and population reduction in rural areas. The phenomenon is caused by the internal migration, which is more pronounced from rural to urban areas, and the shift of some rural areas in urban areas because of administrative regulation. The estimates made are based on the data collected from the National strategy for sustainable development of Romania. The strategy has the objective to increase the urbanization level of Romania to 70% in 2035, and the transformation of 650 developed rural areas in cities.

Similar phenomena are manifested at regional level. Assuming that Bucharest-Ilfov region will continue to attract labor from surrounding areas and throughout the country, we consider a region's population growth at least similar with the average rate recorded during 2001 to 2010, but differently for Bucharest and Ilfov. For the 2012 to 2040 forecast horizon we estimated a 0.1%/year growth rate for the population of Bucharest, so that at the end of the forecast period the capital's population will reach around 2,000,000 inhabitants. Given the average annual increase of 1.5% for the population in Iflov between 2001 to 2010, we formulated the hypothesis that Ilfov population will continue to grow, but with a lower average annual rate of 1%/year. According to our estimations the population of county will exceed 427,000 inhabitants in 2040, which means that at the end of the forecasted period the population in Bucharest-Ilfov region the population will reach about 2.43 million inhabitants. Table 2 reflects the estimation of population trend in Bucharest-Ilfov region between 2012 to 2040.

Given the fact that 3 big communities around Bucharest, having a population of about 30,000 inhabitants have the potential to be transformed into cities before 2040, we believe that towards the end of forecast the urban population in Ilfov will be approximately 55%.

Given the region's population growth, it is expected that waste in both rural and urban areas will increase. The concentration of population in the Bucharest region will determine major problems concerning the design and implementation of necessary waste treatment and recovery

Table 2. Estimation of population trend in Bucharest-Ilfov region from 2010 to 2040.

Year / Administrative territorial unit	2012	2015	2020	2025	2030	2035	2040
	No. of inhabitants						
Bucharest	1,944,451	1,954,193	1,963,983	1,973,823	1,983,712	1,993,650	2,003,638
Sector 1	224,146	225,269	226,398	227,532	228,672	229,817	230,969
Sector 2	356,679	358,466	360,262	362,067	363,881	365,704	367,536
Sector 3	401,975	403,989	406,013	408,047	410,091	412,146	414,211
Sector 4	300,101	301,605	303,116	304,634	306,160	307,694	309,236
Sector 5	289,778	291,230	292,689	294,155	295,629	297,110	298,599
Sector 6	371,772	373,635	375,506	377,388	379,279	381,179	383,088
Ilfov disctrict	317,247	333,430	350,438	368,314	387,102	406,848	427,601
Urban (%)	43	44	46	49	51	53	55
Rural (%)	57	56	54	51	49	47	45
Bucharest-Ilfov region	2,261,698	2.287.623	2.314.421	2.342.137	2.370.813	2.400.498	2.431.239

Source: Own estimates based on trends in the reference period 2001-2010 and the assumptions made.

Estimation of waste generated in the Bucharest-Ilfov region for time horizon 2040

Based on to the trends registered during 2001 to 2010 and on the assumptions previously made about the dynamics of economic and social environment, we expect that the amount of waste generated will increase considerably in the next period, mainly because of the increase in population of the region,. The hypothesis is confirmed by the fact that beginning with 2007, the coverage of waste services has increased, especially in Ilfov County, arising at around 90% in 2009. In these circumstances, it is expected that a larger amount of waste generated in households in rural and peri-urban areas are to enter in the system of waste collection and management.

The regional waste management plans use different values for the waste generation index in rural and urban areas; the Romanian methodology to develop regional waste management plans recommended the use of the following values: 0.9 kg/capita/day in urban areas and 0.4 kg/ capita/day in rural areas.

The specificity of Bucharest-Ilfov region requires to be taken into account the average annual index recorded during 2001 to 2010, considering that this way can avoid over or under sizing of the waste collection infrastructure. Clearly 0.8 kg/capita/day is an index that does not reflect the extent of waste in Bucharest. During the period 2001 to 2010, the index of waste generation per year recorded values over 1.1 kg/capita/day. Given that over 92% of inhabitants live in a dense urban environment we could make the assumption of 1 kg/capita/day for 2010 reference year, which will increase linearly by 0.8%/year over the forecast period 2012 to 2040. Because urban areas in Ilfov has characteristics of suburban areas, the design of waste generated will start from a rate of 0.8 kg / capita/day for the reference year 2010, with an annual increase of 0 8% /year over the forecasted period. In rural areas we have used a value of 0.4 kg / capita / day for 2010 and an annual increase of 0.4%. Table 3 presents the estimation of municipal waste generation index in Bucureşti-Ilfov region from 2012 to 2040.

The previously hypotheses about the population dynamics and the evolution of the waste generation index in the region were used to identify the quantities of waste that is expected to be generated. Table 4 summarizes estimation of municipal waste generation trend in Bucharest-Ilfov region from 2012 to 2040.

Average composition of municipal waste is different in urban, suburban and rural areas. In 2002 the Research institute for environment and development conducted a study to identify the average composition of waste. The following composition reflects the Bucharest's average of waste: paper/cardboard - 11%, glass - 5%, metal - 5%, plastic - 10%, textile - 5%, biodegradable - 51%, other waste - 13% (Ministry of Environment and Water, 2002). For Ilfov, there were reported the following values: waste paper containing cardboard - 15%, glass - 7%, metals - 4% plastic - 12%, textile - 4%, biodegradable - 34%, other waste - 24% (Ilfov County Council, 2007).

In the absence of any projections for the composition of waste generated in the Bucharest-Ilfov we have realized an own forecast, based on the available statistics for the reference period 2001 to 2010. Table 5 shows estimation of municipal waste composition in Bucharest-Ilfov region from 2012 to 2040.

The composition of municipal waste generated in Bucharest-Ilfov region will undergo significant changes in

Table 3. Estimation of municipal waste generation index in Bucharest-Ilfov region from 2012-2040.

Place of residence	Index of municipal waste generation (kg/cap./day)						
	2012	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**
Bucharest	1.00	1.04	1.08	1.13	1.17	1.22	1.27
Ilfov district – urban	0.80	0.83	0.87	0.90	0.94	0.98	1.02
Ilfov district – rural	0.40	0.41	0.42	0.43	0.43	0.44	0.45

Source: Own estimates based on trends in the reference period 2001-2010 and the assumptions made.

Table 4. Estimation of municipal waste generation trend in Bucharest-Ilfov region from 2012-2040**.**

Place of residence	Amount of municipal waste generated (thousands tons)						
	2012	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**
Bucharest	709.72	742.27	77.631	811.91	849.14	888.08	928.81
Ilfov district – Urban	39.58	44.58	50.97	59.38	67.60	76.84	87.21
Ilfov district – Rural	26.52	27.81	28.75	29.11	29.99	30.84	31.66
Bucharest-Ilfov region	775.83	814.66	856.04	900.41	946.74	995.77	1,047.69

Source: own estimates based on trends of population and municipal waste generation index from 2012-2040.

a differentiated way for Bucharest and Ilfov and for urban waste and waste glass. In urban areas in Ilfov County we also estimate a significant increase in the share of paper, cardboard and plastic waste and a decrease of the share of biodegradable, glass and metal waste, which will go towards the end of projection to values of 45, 5 and 3%. For rural areas we made the assumption of constant share for metal waste and waste glass. As shown Table 5, the share of biodegradable waste will have a downward trend in rural areas, more pronounced than in urban areas.

The opportunity of an investment in waste treatment in Bucharest-Ilfov region

The constant increase of the quantities of waste generated and collected in the region will require the identification of concrete solutions for preventing and combating waste disposal. The estimation of municipal waste composition reflects the need for applying specific methods and techniques for the treatment and recovery of biodegradable waste and waste with combustion potential. All these aspects will be found at the base of the design of an integrated system in which waste incineration has to become a viable alternative to disposal in landfills.

Elimination of municipal waste from disposal in landfills can be done effectively and efficiently by burning it. Waste incineration can reduce the waste by 90% and the products resulted (combustion ash, flue gas residues, metals, etc.) could be recovered or removed in dangerous waste landfill, as appropriate. Waste incineration is considered one of the most expensive methods of treatment of the municipal waste, but using this method could be obtained substantial economic benefits based on energy recovery and recovery of certain categories of waste products.

The categories of waste directed for incineration are: recoverable waste materials (including packaging) that cannot be recovered after sorting, recyclable materials (excepting glass and metal) with a low quality, the sludge resulted from wastewater treatment and other mixed municipal waste. We estimate that approximately 60% of the fraction "other waste" in the composition of municipal waste is waste with combustion potential (wood, textiles, furniture, etc.) that can be directed to incineration. So, the main advantage of the use of incineration with energy recovery as an alternative to land filling, is twofold: once the amount of waste is significantly reduced, and secondly is obtained electrical or thermal energy which can be used for domestic or industrial consumption.

The amount of waste directed to waste incineration can be estimated based on the evolution of the population in urban/rural areas, the dynamic of the waste generation index and the forecast of waste composition. It is estimated that only a part of the waste materials can be recovered after sorting waste in the specific facilities, because of the risk of contamination (higher in the case of paper, cardboard and plastic waste, and lesser for metal and glass waste). For metal and glass waste, we started from the assumption that 100% of the collected and sorted waste can be stored for recovery by recyclers. For paper and cardboard waste, we approximated that only 50% of the amount collected will be available for recovery, after sorting mixed waste. The percentage

Table 5. Estimation of municipal waste composition in Bucureşti-Ilfov region from 2012 to 2040.

Municipality/ Waste	Composition of municipal waste (%)						
	2012	2015	2020	2025	2030	2035	2040
Bucharest							
Paper, cardboard	12	12	13	14	15	16	17
Glass	10	10	9	9	9	8	8
Plastic	9	10	10	10	11	12	12
Metal	5	5	5	5	4	4	4
Biodegradable waste	43	43	43	42	41	41	40
Other waste	21	20	20	20	20	19	19
Total waste	100	100	100	100	100	100	100
Ilfov district– urban							
Paper, cardboard	10	11	11	12	13	14	15
Glass	6	6	6	6	6	5	5
Plastic	7	7	8	8	9	10	11
Metal	4	4	4	4	3	3	3
Biodegradable waste	49	49	48	47	47	46	45
Other waste	24	23	23	23	22	22	21
Total waste	100	100	100	100	100	100	100
Ilfov district – rural							
Paper, cardboard	9	9	10	10	10	11	11
Glass	4	4	4	4	4	4	4
Plastic	8	9	10	10	11	12	13
Metal	2	2	2	2	2	2	2
Biodegradable waste	68	67	66	66	65	64	63
Other waste	9	9	8	8	8	7	7
Total waste	100	100	100	100	100	100	100

Source: own estimates based on trends in the reference period 2001-2010 and the assumptions made.

could rise to 85% after the implementation of selective collection by 2015, and 95% after 2018. For plastic waste, we considered that after sorting we will recover a rate of 60% from 2011-2014. After 2015, the percentage is possible to rise to 80% and after 2018 to 95%. Even in the case of complete and correct implementation of selective collection in four streams, for paper, cardboard and plastic waste remains the risk of contamination due to the emergence of impurities (projected at 5%) caused by the accidental mixing or the presence of food debris in packaging waste. Based on the previous assumptions, we estimated the evolution of amounts of waste incinerated (Table 6).

The waste incinerator with energy recovery must have a working capacity of 160000 tons/year to cover requirements of the region. Basic technical data contained in a report issued by the European Commission (2001), show that an incinerator with a capacity of 150000 ton/year produced a quantity of electricity of 0.35 MWh/ton of waste treated and 0.85 Gcal/ton of waste incinerated, yielding approximately 25 to 30 kg metal/ton of waste incinerated (which can be sold to recyclers) and 180-200 kg of ash (which can be exploited in the construction of roads and cement production). Based on these assumptions, we considered appropriately the location of the waste incinerator in Glina village by 2018. The main reasons for this decision are:

1). Glina is located near the Sectors 3 and 4 which are producing the largest quantity of municipal waste in Bucharest compared to other sectors,
2). To avoid the risk of manifestation of the syndrome "not in my back yard" while the local population knows the effects of improper waste disposal in landfill;
3). The near location with a wastewater treatment plant which in the conditions of a shortage of capacity can remove sludge in the waste incinerator.

Feasibility analysis of municipal waste incinerator proposed for the Bucharest-Ilfov

The calculation of economic efficiency indicators needed

Table 6. Estimation of the capacity of the required municipal waste incinerator proposed for Bucharest-Ilfov region.

Investment objective	Estimated amounts of waste incineration at Glina (tons/year)					Designed capacity (tons/year)
	2018	2025	2030	2035	2040	
Incinerated waste from Bucharest	112,852	122,599	130,344	133,213	140,715	160,000
Incinerated waste from Ilfov district	9,210	10,812	11,881	13,404	14,749	
Total	122,062	133,411	142,225	146,617	155,464	

Source: Own estimates based on trends of population, municipal waste generation index and composition of municipal waste.

Table 7. Estimation of product prices, energy and waste resulting from incineration of municipal waste.

Method of treatment/ recovery	Products/energy/residues resulting from treatment	Price of retail / recovery (€/tonă)					
		2018	2020	2025	2030	2035	2040
Incineration with electrical and thermal energy recovery	Electric energy (0.35 MWh/ton of waste incinerated)	79	80	85	89	93	98
	Thermal energy (0.85 Gcal/ ton of waste incinerated)	32	33	34	36	38	40
	Metal (40 kg/ ton of waste incinerated)	12	12	13	14	14	15
	Ash (180 kg/ ton of waste incinerated)	18	18	19	20	21	22

Source: own estimates based on trends in the reference period 2001-2010 and the assumptions made.

to analyze the feasibility of a municipal waste incinerator is possible by approximating the investment, operating and maintenance costs and the income based on values of similar facilities operating in EU countries.

The investment costs for construction of such facilities include: the average costs for development of the site (estimated at €10,700,000), the costs for acquisition of specific components, tools, equipments and technologies (estimated at €40,880.000) and costs for land acquisition (approximately €420000). To approximate more realistic the investment costs we have considered studies and expert reports prepared by European commission's environment directorate. Also, we have analyzed similar investment in several European countries, and we have identified the costs of investments and operation according to the capacity of the incinerator, the technology used, the types of waste accepted for incineration, the possibility to recover electrical and thermal energy. The annual operating and maintenance costs of the proposed facility were estimated based on approximate unit costs of €45 (specific to a municipal waste incinerator with energy recovery with similar technical characteristics) and the annual amount of waste directed for incineration.

Similarly, it could be estimated the operating income of the incinerator with energy recovery. The incineration of one ton of waste with a minimum caloric combustion of 10000 kJ/kg yields to 0.35 MWh or 0.85 Gcal. Given that the municipal waste incinerator must have a capacity of 160000 tons/year, it is possible from a technical point of view, to recover both electric and thermal energy, depending on seasonal needs. The estimation of the income obtained from electric and thermal energy recovery was based on the assumption of a constant linear growth of 1%/year for the price of kWh Gcal, as shown in Table 7.

The revenues obtained from the sale of energy and waste resulting from incineration is supplemented by funds based on fees of incineration. The incineration fee depends on the size and complexity of technologies used and on the environmental impact. We have considered a constant fee of €25 /ton throughout the forecast period (23 years).

The assumptions made allow the estimation of main economic efficiency indicators. The calculus was using a discount rate of 5%, a rate recommended by the European Commission in the development of feasibility studies in the field on waste management. The results are summarized in Table 8.

With a net present value over €48 million, a payback period of 8 years and 10 months and an internal rate of return much higher than the discount rate, the investment in a municipal waste incinerator with energy recovery could be considered a profitable investment.

Conclusions

Even, it is not a usual practice for the treatment/disposal

Table 8. The investment efficiency indicators of municipal waste incinerator.

Indicator	Estimated value (€)					
	2017	2018	…..	2030	…..	2040
Investment costs	52,000,000					
Operating costs (without depreciation)		2,499,958	…..	3,407,279	…..	4,003,037
Operating incomes		10,200,723	…..	12,932,410	…..	15,208,570
Payback period	8.10 years					
Net present value	€48,485,904					
Internal rate of return	14.37%					

of municipal waste in Romania, the incineration with energy recovery could have an important role in waste management, viewed within the context of the growing range of recycling and re-use options for many waste materials.

The most significant negative outcome of incineration is the emissions that result from combustion. The air pollution has both harmful effects on the local area and on climate. These public concerns are linked to the technologies used in the early waste incinerators. Modern waste incinerators now have greatly reduced emissions due to efficient and effective computer controlled raw-gas treatment facilities and process control.

The problem of waste incineration should be regarded in a much broader context, in which a variety of economic, political, social, technological and ecological factors are implied. Incineration of municipal waste will be truly viable as far as the decision makers, the population, the business and civil society will understand and assume the major opportunities and minor weakness involved in the use of incineration as the main alternative to waste disposal on landfills. We estimate that in 2018 will be the beginning of a new period in the development of waste management systems, when the incineration with electric and thermal recovery will be one of the main pillars in the treatment and recovery of waste in Romania.

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