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Evaluation of an alternative Waste Management Scenario on the Greek Prefecture Ilia

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LIST OF ABBREVIATIONS

APC	Air Pollution Control
EU	European Union
EUR	Euro
IP	Internet Protocol
MS	Member State of the European Union
MSW	Municipal Solid Waste
MFA	Material Flow Analysis
OG	Official Gazette of the Hellenic Republic
WM	Waste Management
WFD	Waste Framework Directive

ABSTRACT

Greece is a country where the main way of waste disposal is landfilling. In the Prefecture Ilia, a region that is situated in the South of Greece, the waste management policy does not seem to fulfill adequately the requirements that are set by the EU legislation or to meet the primary goals of waste management, since the common practice is uncontrolled dumping. In order to support more efficient future strategies an alternative waste management system is presented and quantitatively assessed by means of Material Flow Analysis (MFA). This alternative is based on two central EU Directives, the Waste Framework Directive and the Landfill of Waste Directive, and Greek legislation, takes into consideration the waste generation of the region and the present waste treatment infrastructure and introduces the concepts thermal treatment, anaerobic digestion and recycling. By changing the recycling rates two sub-scenarios are formed, evaluated and compared to the status quo. The results show that a waste management system that embraces incineration, anaerobic digestion as well as improved landfilling complies with the EU legislation and attains better the goals of waste management. Following this, a rough economic assessment of the suggested options and of the current waste management system takes place. According to this assessment, the costs of disposing waste in uncontrolled dumpsites are the lowest while the costs for changing the waste management landscape are considerable. However, the picture changes significantly in case the country has to pay fines to the EU for the illegal dumpsites of the region.

This study intends to underline the environmental benefits that come from setting up a completely new waste management system, to indicate how this system, at regional level, could contribute in complying better with the EU Directives and to express the idea that reforming the waste management system cannot be avoided even if it seems expensive, considering that the economic penalties for the uncontrolled dumpsites that function at present are at the gates.

I. INTRODUCTION

1. Background and Motivation

Greece is a country that is heavily dependent on landfilling. Almost all municipal solid waste is driven to landfills or dumping sites, while very little is recycled or recovered. As opposed to most EU member states where waste is seen as a stream consisting of valuable materials with energy potential that should be treated separately for maximizing the benefits that could be obtained, in Greece waste is considered as a stream of unseparated materials that requires common treatment and disposal. The country has to deal with the problem of unauthorized landfills since the 39 existing authorized and controlled landfill sites cover 53% of the population[1]. Even though in the last decade the municipal solid waste management system has been going through significant changes as far as policies and legislation are concerned, shifts in management practices have ended up being more difficult for Greece than for most countries within the European Union. As member state of the European Union since 1981, Greece had to transpose the European environmental acquis and adjust its legislative framework in order to comply with the EU legislation. Although to a certain extent Greek national law incorporated successfully European legislation and the waste management framework is well elaborated, the current EU policy and legislation sets explicit and challenging targets without providing elaborated guidelines on the direction that is necessary for meeting them. Greece, with an apparent lack of infrastructure and management faces additional impediments in implementing the EU legislation. (*Lasaridi*, 2009:266). Along with legal issues come problems that deal with administrative implications, lack of infrastructure and strong public opposition. Meanwhile, the Greek governments have been suffering from lack of coordination and lack of in-house expertise, combined with reluctance to consult outside experts (*Close* 1999:327). At regional level, the Not-In-My-Back-Yard (NIMBY) attitude is amplified and expressed at the local policy-making process as a Not-In-My-Tenure (NIMT) syndrome by the presence of discarded waste and by the absence of any serious attempt by the local authorities to

[1] Information retrieved from: National Report: Waste Management in Greece (A.Sifakis, M.Haidarlis)

educate the public with respect to modern methods and technologies of waste management systems that divert from landfill dumping.

The situation in Ilia, which is one of the 51 prefectures of the country, is characterized by the same issues. The prefecture of Ilia, in Western Greece, occupies the North-West part of the Peloponnese and it is a region that covers 2,618 square Kilometers and has 193.288 inhabitants that produce every day 250-300 tons of waste which is disposed of in 18 semi-controlled dumping sites. After major natural disasters that took place during the last three years, the catastrophic fires in August 2007 and the Peloponnese Earthquake of 6.4 magnitudes in June 2008, the political leaders face multiple challenges setting priorities for the recovery of the area. Since the present waste management system has certain limitations, this study intends to present a more goal-oriented system for this region which, apart from its certain specific characteristics, it can be considered as a typical greek prefecture where representative symptoms caused by the national not so effective Waste Management system can be identified. In fact, the system that is currently implemented consists of three stages: the collection, the transport and the disposal of waste to dumpsites. It succeeds in collecting the waste from the households and transporting it so that it does not constitute danger to public health in inhabited regions. However, there are issues associated with the disposal because the waste is disposed of in 18 dumpsites which functioned till the end of 2008 with temporary permission from the authorities and at present they function illegally. Since there is lack of properly organized facilities for treatment and/or disposal of waste, the following phenomena are observed: uncontrolled and unsafe disposal of waste by citizens and authorities, uncontrolled incineration of waste and negligible conservation of resources.

In this thesis, an integrated solid waste management system at the regional level is presented. At present, many problems occur because of the disposal of waste to dumpsites. At the same time, the current system does not fulfill the requirements that are set by the legislation. This study looks at the potential of an alternative Waste Management system for the Greek Prefecture Ilia as means to attain better the primary goals of waste management as well as to succeed in reaching the targets that are set by the EU legislation. The generally accepted goals of Waste Management are: “protection of men and the environment”, “conservation of resources” and, in addition, based on the precautionary principle, “after-care-free disposal”. Focusing on landfills, this strategy encourages extensive waste pretreatment before landfilling. The emphasis is on the unique problems and limitations faced by the country in general, on the primary goals of waste management and on the standards that are set by European legislation.

2. Research Aims

In view of the information given above it is evident that Greece in general and the Prefecture Ilia in specific are facing problems regarding the Waste Management System based on landfilling and dumping, especially since it is a pressing issue for which the country has been brought before the European Court of Justice. This thesis analyzes the evaluation of an alternative Waste Management scenario on the Prefecture Ilia. More precisely, it aims to describe how a system that includes recycling, incineration, anaerobic digestion and improved sanitary landfilling can better attain the primary goals of waste management protection of human health and the environment, conservation of resources and after care free waste management as well as how this system could better fulfill the targets of the European legislation compared to the current system in Ilia.

3. Structure of the Thesis

In order to get a background on the principle evaluation method that is used, at first place, the method Material Flow analysis will be briefly described as well as its relevance for evaluating an alternative waste management scenario on the Prefecture Ilia and for illustrating and analyzing the current system. After that, the legal framework that has been significant in forming the hypothetical scenario will be described as well as two cases for which the European Commission has taken legal action against Greece for violating the EU legislation. Two crucial EU Directives will be taken into account, the Waste Framework Directive and the Landfill of Waste Directive. In addition to the EU legislation, an important provision of Greek legislation, the Joint Ministerial Decree 50910/2003 and more precisely the National Plan about Solid Waste Management will be taken into consideration. The hypothetical scenario that is evaluated is based on provisions and norms that are set through these pieces of legislation.

Subsequently, in the next part the focus is on the Prefecture Ilia. After giving some general information about the region and describing the present Waste Management system, the alternative scenario for evaluation will be analyzed. Moreover, the criteria for evaluation and their relevance according to the EU legislation and the goals of Waste Management will be scrutinized. After that, the scenario that is to be evaluated will be described. Since this hypothetical scenario is based on more recycling, incineration, anaerobic digestion and improved landfilling, it will be discussed why recycling is only an intermediate and not a final solution for materials management and it will be explained why incineration is a way of treatment that should be introduced in Greece and. Subsequently, two versions (sub-scenarios) will be formed, by changing the recycling rates and evaluated and compared to the status quo scenario that is based on the actual situation. Finally, the costs of the current waste management system and the two sub-scenarios will be approximately estimated, only for illustrating the wide variety of costs for different waste management options and for discussing how the low costs of disposal to dumpsites make choosing another option economically unattractive. In the end, the results of the evaluation as well as the economic assessment will be discussed thoroughly for drawing conclusions.

4. Limitations

The study is based on science and engineering parameters. Therefore, it does not take into account social or political factors but it investigates future directions and draws conclusions about the effectiveness of a new waste management system by taking into account the objectives of waste management and the targets that are set by legislation. Hence, considering that waste management decisions take into consideration multiple sets of criteria from natural as well as social sciences, it is understood that this thesis analyses the problem only from an environmental point of view without considering social or political constraints. The economic estimation of the costs that is made is not intended to provide an accurate calculation of the costs or to serve as the basis for decisions making but its goal is to paint the picture about how the different costs of the available waste management options may end up at the expense of making decisions that are environmentally sound and goal-oriented.

II. RESEARCH METHODOLOGY

Introduction

In the beginning, it should be noted that data or literature about waste management in Greece and particularly at regional level was rather difficult to find. The majority of material was found in English, including legislation of the European Union, studies, reports, articles and analyses. Some crucial material, most notably a study about the alternative solutions for the Periphery of Western Greece and a study about the environmental impact assessment of a sanitary landfill in Ilia that can be obtained through contacts in the authorities of Ilia, as well as some articles were found in Greek.

1. Principle methods used for this study

For the theoretical and legislative basis of the hypothetical scenario primary documents of legislation will be analyzed while for describing and analyzing the status quo as well as for evaluating this scenario, the method *Material Flow Analysis* will be used. The primary documents of legislation include the Waste Framework Directive, the Landfill of Waste Directive and the National Plan about Solid Waste management. Throughout these two key Directives, emphasis will be placed on identifying the challenging areas for the current waste management system as well as the means that could be adopted for reaching the targets that are set. As far as the evaluation method Material Flow Analysis (MFA) is concerned, it is a systematic assessment of the flows and stocks of materials within a system defined in space and time. It connects the sources, the pathways, and the intermediate and final sinks of a material. The rationale of a material flow analysis (MFA) is to follow and quantify the flow of materials in a defined situation and over a set period of time. MFA is a necessary pre-requisite to support the effective planning and management of natural resources. The end product of the MFA will be a detailed input-output table showing all material streams that enter the waste management system. This comprehensive method that describes the metabolism of anthropogenic systems is based on the following definitions:

The term *material* stands for both substances and goods. *Substance* is a chemical element, for example carbon, or a chemical compound, for example carbon dioxide. A *good* consists of one or many substances and has a negative or positive economic value. Waste is a good with negative economic value. *Substance flows* are measured in mass per time units. *Substance fluxes* are measured in mass per time and cross section. *Cross section* can be a house hold, a person, or an entire region, like in this case. A *process* is defined as a transport, transformation or storage (stock) of goods, materials, energy, and information. An *activity* is defined as a set of processes and fluxes of goods, material, energy and information serving an essential basic human purpose, such as to nourish, to clean to reside or to communicate. A MFA can be controlled easily by a material balance comparing all inputs, stocks and outputs of a process, thanks to the law of conservation of matter (*Brunner and Rechberger* 2002:62-64).

MFA is considered to be an excellent tool to support decisions about *waste management* for two reasons. Firstly because in many cases, and in this one as well, waste amounts and waste compositions are often not well known. MFA allows calculating the amount and the composition of wastes by balancing the process of waste generation or the process of waste treatment. Hence, MFA is suitable for cost-efficient and comparatively accurate waste analysis. Moreover, since inputs and outputs are linked in a MFA, if a transfer coefficient is known, it is easy to assess whether a waste management system achieves its objectives. However, frequently, transfer coefficients are not known. Even in these cases, they can be determined by MFA no matter if some inputs or outputs are not known (*Brunner and Rechberger*, 2004:256).

For constructing a Material Flow Analysis, it is necessary to select certain indicator-substances, which are elements or compounds that show a behavior typical for a group of substances. The above mentioned indicators need to correspond to certain criteria that are set in the beginning and they are defined from the aim of the study and from what is attempted to be reached through the Material Flow analysis.

2. MFA for evaluating the scenario on the Prefecture Ilia

In this thesis, the evaluation method Material Flow Analysis will be used for describing the current waste management system (Status Quo) as well as for showing how the hypothetical Waste Management system fulfills better the goals of waste management and reaches better the targets that are set by the legislation compared to the present system of the Prefecture Ilia. The MFA will be used for the evaluation and assessment of two versions (Sub-scenarios) of the hypothetical scenario that will be compared to the Status Quo, which will be based on the actual system. According to the hypothetical system, it will be assumed that waste is separately collected with the aim to separate the biomass and that plastic, paper, metals, and glass are separately collected and sent to recycling. The methods of treatment of restwaste are considered to be incineration and landfilling (in bottom ash landfill) whilst biomass is treated with anaerobic digestion. Considering as boundaries of the system the production of municipal solid waste in Ilia for the year 2009, the following material flows will be quantified: wastes that would be sent to the incineration, treatment residues (in mass and volume) to be diverted to landfills; materials recoverable by recycling processes, biomass that would be sent to anaerobic digestion. The two sub-scenarios will occur by changing the percentages of separate collection. There will be an *optimistic sub-scenario*, according to the percentages set by the European Legislation(Waste Framework Directive), and a *realistic* one, in which the percentages that will be taken into account are considerably lower which seems to be a more feasible goal, regarding to the actual circumstances and given that in the Prefecture Ilia recycling does not take place.

III. THE LEGISLATIVE FRAMEWORK

Introduction

This chapter gives an overview of specific EU and Greek legislation regarding to Waste Management. National waste legislation in Greece, as in most EU-27 member states, is governed by EU policy and legislation. Two decisive EU Directives, the Waste Framework Directive the Landfill of Waste Directive are taken into account for the scope of looking at the provisions that are of importance for the hypothetical scenario for the Prefecture Ilia. The EU waste policy, in the form of the above mentioned Directives has the goal to bring about a significant transformation of the waste management landscape by setting a policy framework at the supranational level with specific targets while leaving the choice of pathways and technological means to individual players, i.e. waste management industry and local authorities. Also, the National Plan about Solid Waste Management that is adopted with the Joint Ministerial Decree 50910/2003 is taken into consideration in order to give a spherical background about the legislation related to Waste Management. After identifying the targets that come from legislation, it is examined how a hypothetical system could in theory better attain these goals, compared to the current system.

1. The EU legislation

i. The Waste Framework Directive

The most important framework Directive of the present EU waste legislation is the Waste Framework Directive. This Directive obliges Member States to ensure that *waste is recovered or disposed of without endangering human health and without using processes and methods that would harm the environment*. With a view to achieving self-sufficiency in waste disposal both at Community and national level, the Directive calls Member States for taking appropriate measures to establish an integrated and adequate network of disposal installations. It also promotes environmental protection through the so-called “Waste Hierarchy” that seeks to prioritize prevention before recycling and disposal. Notably, in the Directive Waste Management is defined as the collection, transport recovery and disposal of waste including the supervision of such operations and after-care of disposal sites.

In the context of this Directive, a better use of resources is promoted by encouraging the use of waste for beneficial purposes, hence recovery operations[2]. Recovery operations result in waste being used instead of primary sources with the aim to conserve natural resources. On the other hand, disposal operations[3] deal with discarding the waste safely with the aim, straightforwardly, to get rid of waste. In the Directive, requirements are set for all waste operations in order to make sure that waste is managed without jeopardizing human health and without using processes or methods which could harm the environment and more precisely without risk to water, air, soil plants or animals, without causing nuisance through noise or odours or without adversely affecting the countryside or places of special interest.

For Greece, the key targets that arise from the Waste Framework Directive are the following: by 2020, Greece reuse/and or recycling rates of paper, metal, plastic and glass have to be minimum 50% while equal to/more than 70% of construction and demolition waste has to be recovered.

ii. The Landfill of Waste Directive

The European Landfill of Waste Directive, also known as the Landfill Directive, is arguably one of the most dominant documents of the portofolio of the EU waste management regulations. Its overall objective is to supplement the requirements of the Waste Framework Directive and *prevent or reduce as far as possible the negative effects of landfilling on the environment as well as any resultant risk to human health.* It seeks to achieve this through specifying uniform technical standards at Community level and sets out requirements for the location, management, engineering, closure and monitoring for landfills. In the Directive, a landfill is defined as a waste disposal site for the deposit of waste onto or into land. Hence, the directive applies only to disposal and not to recovery activities. In the Landfill Directive it is mentioned that only waste that has been treated can be landfilled[4]. As treatment can be considered every physical, thermal, chemical or biological process that changes the characteristics of waste in order to reduce its volume or hazardous nature, facilitate its handling or enhance recovery.

[2] Article 1(f) of the Directive refers to “recovery”.
[3] Article 1(e) of the Directive refers to “disposal”.
[4] Article 6(a) of the Directive.

The diversion of the bio-degradable fraction of municipal solid waste constitutes quite a challenge for all Member States that did not divert a large part of their waste before implementing the Landfill Direction and Greece is one of them (Lasaridi, 2009). More precisely, the Landfill Direction requires a reduction of biodegradable municipal waste going to landfills to 75% of their 1995 baseline levels by year 2006, 50% by year 2009 and 35% by 2016. However, for countries that heavily depend on landfilling for more than 80% such as Greece, the deadline for reaching the targets may be postponed for 4 years maximum. Hence, Greece needs to meet the respective diversion targets by 2010, 2013 and 2020. In addition to these measures, another prerequisite is the closure of non-complying landfills by 2009.

2. Greek legislation

The Joint Ministerial Decree 50910/2727 takes into consideration the environmental acquis communautaire that is incorporated in Greek legislation and adopts in Annex 2 the National Plan about Solid Waste Management (NPSWM). This Plan intends to describe in detail the national directions and choices for achieving an efficient Waste Management System that will take into account the “waste hierarchy”, the replacement of uncontrolled/semi-controlled dumps with sanitary landfills, the “polluter pays principle” that establishes incentives and anti-incentives for achieving the prevention of waste generation and the production of products that can be reused and conserved.

The Plan provides information about the waste, the waste management system and its objectives. As far as the generation of MSW is concerned, according to the NPSWM, it tends to be increased. According to data of the year 2001, the average generation of waste per capita is 1,14 per day. In the generated municipal waste, around 20% w/w comes from packaging waste. The 85% of the country is covered with collection and transportation facilities while the rest corresponds to rural or mountainous, sparsely populated regions. The objectives of municipal solid waste management are defined as: *The prevention or reduction of generation of municipal waste,* that deals with the increasing prevention and continuing reduction of waste generation that comes from packaging or other products through the establishment of systems for the alternative management of packaging and other products. *The extension and modernization of the collection and transportation infrastructure*. This target focuses not only on modernizing the existing system of collection and transportation but also on expanding it to regions where, at present, there is no organized collection of municipal waste. *The exploitation/recovery of various materials that is contained in Municipal Waste and the energy recovery*. Through this objective it is attempted to reach the highest percentage of recovery, so that resources and energy are conserved and the amount of waste that needs disposal is reduced. In case that the generation of waste is inevitable and the reuse in not possible, the generated waste has to be directed to recycling or recovery facilities, whenever that is environmentally and economically sound. There are quantitative targets about the packaging which are set according to the Directive 94/62/EC.

In the provisions of the Plan, the targets that are set by the EU Waste Framework Directive, the Landfill Directive as well as the Amending Packaging and Packaging Waste Directive are referred. The Plan, intends to adjust many objectives of the EU environmental legislation to greek reality. However, it does not succeed to describe the pathway for reaching these objectives. Even it incorporates targets from the Directive, since this takes place in a fragmented way it does not create a solid and integrated background that would provide robust guidelines in the direction of describing how those targets can be reached, especially because even though EU legislation sets a policy framework with well-defined targets the Member States are in charge of finding their individual ways for complying with them. Instead, it mixes the objectives and the means of waste management and confuses about what should be achieved with how it should be achieved. The fundamental objectives of waste management, protection of human health and the environment, conservation of resources and after-care free waste management should not be mixed with measures, such as prevention and recycling since, for example, recycling is a means for reaching conservation of resources, and more specifically materials, and considering it as an objective creates confusion. All in all, this Plan includes objectives, measures and information about the waste management system in Greece without managing to define ways for achieving the objectives or recommending specific means. That is why, even though it is considered to be the most integrated document regarding waste management, it does not succeed in providing an integrated guideline for overcoming the major problems.

3. Infringements of EU legislation and their impact

Major improvements of waste management in Greece are necessary not only for environmental reasons but also for complying with the legislative obligations that are set by the European Community. With 1,453 illegal or uncontrolled waste dumps, receiving waste from 47% of the population operating in 2005, the deviation from key requirements of the Waste Framework Directive, the central pillar of EU waste management legislation, is obvious. There have been several cases in which the country has been accused of failing to adjust to the requirement of legislation about waste management. In one of them, the Commission took Greece to the European Court of Justice over the country's failure to clean up an illegal waste dump[5], a case that reveals the country's limits in complying with the Waste Framework Directive, while in another occasion, the European Commission sent a final warning about the malfunction of a new landfill and issues that have to be faced concerning the implementation of the Landfill Directive.

In 2000, the European Court of Justice fined Greece a daily penalty of EUR 20,000 for violations of the Waste Framework Directive in Crete *(IP/05/1644).* The main focus of the case was the operation of an illegal dumpsite in Chania Prefecture. Greece paid a fine totaling Euro 4.72 million until the closure of the dump in 2001. Following the closure, the waste was diverted to a temporary storage site. Two years later, in 2003, this temporary solution seemed to be more permanent than it was supposed to be, creating instead a new dumpsite. The European Commission in a report pointed to the problems posing threats to human health and the environment concerning the temporary storage and the implications that occurred after the closure of the first dumpsite. After that, in the same year, the European Commission brought Greece before the European Court of Justice declaring that the country did not succeed in transposing certain requirements under the Waste Framework Directive as it failed to take all the measures necessary in three areas[6]. Firstly, the country failed in ensuring that waste is disposed without endangering human health and without harming the environment. Moreover, Greece did not manage neither to prohibit the abandonment, disposal and uncontrolled treatment of waste, nor to ensure that any

[5] Case C-502/3

[6] The Court held that by failing to transpose the requirements of Article 4, 8 and 9 of Directive 75/442/EEC, Greece had failed in its obligations under the Directive.

holder of waste has it handled by a private or public waste collector or by an undertaking which carries out disposal, or disposes of it himself. Finally, it was not guaranteed that the establishments or undertakings which carry out disposal operations operate under a permit from the competent authority or under a permit which meets the legal requirements. It has become common practice that the closure of a dumpsite is followed with the opening of a new one. An extreme example is what happened on the island Samothrace during the summer of 2008, when the inhabitants of the island pursued legal action against the illegal disposal of waste. The authorities started closing down old dumpsites and subsequently opening new ones and as the citizens continued blocking the opening of almost every new dump, in the end, since there was no space on the island left for the disposal of waste, it remained uncollected for months. This jeopardized the public health and devastated economically the island whose economy is substantially based on tourism through promoting an unattractive image during the most touristic months of the year.

Apart from the Waste Framework, the European Commission condemns Greece about infringements concerning the Landfill of Waste Directive. Many operational problems are identified in a new waste landfill at Fyli *(IP/08/1825)* in Western Attica, representing a danger to human health and the environment. Due to major shortcomings, the permitting authorities have turned down the authorization that is required, however, the national authorities carry on tolerating its operation, even though according to inspections the situation of the landfill violates[7] several requirements of the Landfill Directive about the safe operation of landfills and of the Waste Framework Directive as well, as it establishes basic guidelines about waste management across the EU. In this case, the Commission has sent a final written warning to Greece about the inadequate operation of the landfill. So, it is quite likely that the country will be brought again before the European Court of Justice

The common denominator of the problematic situation is the disposal of waste at illegal dumps. The inefficiency of the current waste management system and the need to end illegal landfilling, put in place adequate networks of regulated waste

[7] Four inspections by the permitting authorities between October 2007 and July 2008 revealed several ongoing operational problems which include waste not being adequately covered in the landfill, the lack of security at the site which allows people and animals to gain access, the absence of rainwater collection, and the risk of fires and of waste slippage in the landfill.

facilities and intensify public awareness of the goals of preventing, reusing and recycling waste is not an abstract goal that Greece will have to reach eventually but a prerequisite for meeting specific targets under European environmental legislation. The 31st December 2008 was the last deadline for closing down the unauthorized dumps. Hence, a shift in the waste management policy is necessary not only because the current system is unsustainable and the environmental costs are high, but also because eventually and taking into consideration that there has been already a case in which the country had to pay it is likely that paying high fines[8] will not be avoided.

4. The legislative foundation of the hypothetical Scenario

As it has been already mentioned, the current waste management system of Ilia is based on the disposal of waste in dumpsites. The waste is not treated before disposal and there is no recycling or energy recovery. Hence by now, this system does not succeed in the quantitative targets that the Waste Framework Directive and the Landfill Directive set. For constructing a scenario that reaches the goals of the EU legislation, it is necessary to take into account the context of Directives itself.

Due to the fact that the Waste Framework Directive encourages recovery operations and sets specific recycling targets, in the hypothetical scenario, these concepts are introduced. Consequently, in the hypothetical scenario it is assumed that energy is recovered with anaerobic digestion of biomass and that waste separation and recycling take place. It has been already mentioned that recycling rates of paper, metal, plastic and glass have to be minimum 50% by year 2020 and that is why two different rates of recycling define two Sub-scenarios, the *optimistic* and the *realistic*. So, the Optimistic Sub-scenario is differentiated from the Realistic in this: the recycling rates for the Optimistic Sub-scenario are set following the target of the EU Waste Framework Directive while for the Realistic they are considerably lower reflecting more down-to-Earth expectations, thinking that in the present waste management system they are negligible.

[8] The minister of Environment and Climate Change on 30/04/2010, referring to the fines concerning waste management, explained that they could reach EUR 4 bill.

In addition, according to the provisions of the Landfill of Waste Directive, the gradual diversion of the bio-degradable fraction is necessary and only waste that has been treated can be landfilled. At present, in the current system, no waste pre-treatment takes place and the dumpsites should have been closed down more than one year ago[9] because they do not comply with any requirements. On the other hand, the alternative Scenario for fulfilling the above obligations is based on pre-treating the restwaste and disposing the residues safely in a sanitary landfill. Also, by 2010 it is required that Greece reduces the amount of biodegradable municipal waste going to landfills to 75% of their 1995 baseline levels. Even if the 1995 baseline levels of biodegradable waste for Ilia are unknown and it cannot be argued with certainty, after building the Scenario and the Status Quo system and quantifying the mass flows of waste, it is evaluated how the alternative Scenario fulfills this target compared to the current system.

[9] The dumpsites were operating with temporary permission till the end of 2008, when they were supposed to close.

IV. THE WASTE MANAGEMENT IN THE PREFECTURE ILIA

1. Short Profile of the Prefecture

The prefecture Ilia, in Western Greece, occupies the North-West part of the Peloponnese and it is a region that covers 2.618 square Kilometers 60% of which is plain and has 193.288 inhabitants that generate every day 250-300 tons of waste. Ilia is divided into 8 municipalities and 215 communities with the capital city of Pyrgos being the major urban centre. The population tends to be concentrated in urban and semi-urban centres in the plain regions of the Prefecture. The main economic activity of the population comes from the primary sector and more specifically from agriculture. The secondary sector is not significantly developed and it is restricted mainly in small agricultural and livestock companies. The tourism industry is not particularly developed either, with the exception of the region of Ancient Olympia and the coastal zone of Kyllini. According to data from the national authorities, the population of the Prefecture tends to diminish from the year 1981 to 2001. It is likely that this phenomenon has been reinforced after the fires of 2007. Finally, it has been observed that the last three years part of the population has moved to the urban centres due to the impacts of the fires on the economy and on the environment. The fires that took place in August of 2007 affected grossly a big part of the natural environment, almost 50%, of Ilia. Apart from the natural environment, the fires affected severely the infrastructure and the economic activities of the region. According to data from Ministry of Environment, Planning and Public Works, 524 houses were absolutely burnt, while 238 were partially burnt. This region, apart from economic and environmental challenges, faces substantial difficulties regarding waste management not only because of shortcomings in infrastructure but also due to the fact that it is sparsely populated which makes the collection and transport of waste more complicated and this might seem to be one of the reasons why at present in a relatively small geographically area exist 18 dumpsites for disposal of waste in proximity of inhabited areas.

2. Analysis of Status Quo of Waste Management in Ilia

It can be stated that regarding waste management, Greece is divided in three categories of different regions, according to their special characteristics. At first place, major urban centers that are densely populated and high material turnover can be found. For this category, since the total generation of waste is high and the scarcity of space for the disposal of waste is a pressure factor, it is evident that setting priorities for waste management is urgent. The second category includes the islands. Even though the permanent inhabitants of the islands are few, due to tourism the waste management capacity needs are multiplied during summer and spring. The islands face several constraints, compared to the mainland. Firstly, the geographical space available for landfilling is more restricted and due to the few permanent inhabitants on most of them large-scale organized waste management facilities do not correspond to the situation since the waste management capacity needs change dramatically from the one season to the other, they are economically unattractive and do not have the public support. Finally, there are areas in the mainland of Greece that are sparsely populated and finding land for landfills or dumpsites does not seem to constitute a limit that the population will have to deal with in the very near future. Many of their communities are not only small (less than 2000 people) but also remote. For this kind of communities, it is not easy to engage economically in recycling or incineration with energy recovery on their own (*Vigileos and Powel* 1997:51). Most of these regions are rural, the public awareness towards waste management is limited and since potential problems concerning the disposal of waste do not constitute a direct concern if the collection and transport take place regularly and waste is removed away from the households, changes in waste management do not seem to be an emergent priority. The prefecture Ilia is one of them. The current waste management system consists of three stages: *the collection, the transport and the disposal of waste*. Every day, the waste is collected from the households and transported to the dumpsites where it is disposed. Waste is collected daily in general in Greece as opposed to weekly or twice weekly in Northern European countries, as the higher temperatures mean that food waste begins to degrade quickly. The overall production of municipal solid waste in Ilia in 2009 as estimated by data from the authorities was about 100.400 tons. The production of 250-300 tons per day is directed to 18 semi or uncontrolled dumpsites.

As far as those dumpsites are concerned, they have the following characteristics: uncontrolled disposal area, no operation control, no technical isolation from the environment. The gas emissions coming from the dumpsites are not prevented technically because they do not have landfill covers and the leachate generated from waste can easily find its waste as there is no leachate collection. They have no construction barriers, as there is no base liner to constitute a technical barrier between the landfill and the environment, no waste treatment takes place, thus, in this case the waste itself does not function as a barrier and it is possible that they have no geological barrier to prevent from polluting the groundwater because there have been no studies about the areas where the dumpsites are situated. Generally in Greece, the lack of a centralized administration and the absence of a strict legislation to stimulate action towards environmentally sound directions have resulted in the stagnation in the gathering of information related to waste generation (*Koufodimos et al* 2002:48). It is accepted that the Greek MSW have a higher organic fraction compared to the MSW of other developed countries which increases during summer months due to the high consumption of fruits and vegetables. Due to the lack of official data, the quantitative composition of waste is estimated according to the qualitative characteristics of MSW in other cities in Greece and according to the official data from the Join Ministerial Decision 50910/2727/2003. Taking into consideration that the average daily production is 275 tons, 137.5 tons per day are biowaste, 55 tons per day are paper, 27.5 tons per day are plastic, 11 tons per day are metal, 11 tons per day are glass and 33 tons per day are restwaste.

The current waste management system has serious shortcomings that make the reaching of targets that are set by the European Union quite unlikely. At first place, the so-called waste hierarchy “prevention”, “recycling”, and “disposal” that it considered as a background principle for waste management decisions is ignored as there is no separate collection or recycling. Apart from that, there is no pretreatment of waste before its disposal or biological treatment plants. Thus, it is clear that changes are necessary for making the system more goal-oriented and effective. For defining the hypothetical system that is suggested, it is analyzed which goals are achieved by the present system and which are the potential challenges.

i. **Goals achieved**

In general, the present waste management system succeeds in achieving several goals. At first place, it makes sure that waste is transported far from inhabited regions and this way health risks are minimized. Since the main purpose of waste management is to provide a service which aims to remove waste from human habitat for ensuring hygienic living conditions it can be said that this basic task is attained with the current waste management system. Hence, from that perspective, and in the short-run, the primary goal of waste management which is the protection of human health is fulfilled. The waste that is produced is collected and transported away from the households.

ii. **Future challenges**

Even though the collection and the transportation of waste take place successfully, there are many issues regarding the disposal of waste. Considering that the central objectives of waste management are *protection of human health and the environment, conservation of resources such as materials, energy and space and the after-care free waste management, meaning that landfills, incineration, recycling or other treatments do not leave problems to be solved by future generations* (precautionary principle), there are many challenges that the current waste management system has to deal with. Taking into account that waste disposal requires management and control, there are many phenomena that are associated with open dumping, such as contamination of ground and surface water, uncontrolled fires, potential dangers for human health and diseases via food chain that indicate that the present system is inadequate in fulfilling all the objectives of waste management.

The current waste management system does not sufficiently reach the *goal protection of human health and the environment* because during disposal there is no isolation from the environment. The lack of isolation can lead to many implications as leachate and gas emissions are not prevented from getting out of the landfill. Consequently, there are many potential dangers for human health coming mainly from hazardous materials such as heavy metals or persistent and organic substances. Furthermore, the potential dangers of the way that waste is disposed increase considering that no waste pretreatment takes place and the reactivity of waste is high. In addition, the goal *conservation of resources* is not reached either, due to the fact that, at present, no separate collection or recycling takes place. As a result, the waste hierarchy is not followed even though the country in general is obliged to establish this order under EU legislation. However, apart from materials, energy is not conserved either, as there are no waste-to-energy plants. Also, the scarcity of space has not been taken into consideration. At present, the scarcity of space has not been a problem for waste management as it has not been difficult finding unpopulated areas for the disposal of waste. This might have to do with the fact that the cost of landfilling per ton of waste is significantly low in Greece. However, sooner or later the issue of finding space will come up since the space for dumping in the future will become inevitably less and less. So, the existence of open dumpsites where untreated waste is simply disposed of is problematic for attaining the objective conservation of resources due to the following reasons: the scarcity of space and lack of recovery of materials or energy. Finally, the waste management system is far from reaching the goal *of after-care free waste management*. Due to the fact that the waste is not pretreated before disposal, there is a large fraction of biodegradable constituents in waste that result in landfill leachate which is not treated. With the present system, all hazardous organic and inorganic substances are landfilled and stored with unknown future consequences.

Moreover, as it has been already mentioned, the current waste management system does not comply with the obligations coming from the European Legislation and more precisely with the provisions of the European Waste Framework Directive and the European Landfill of Waste Directive. So, apart from the primary goals of waste management, two central Directives address the issues of pre-treating waste before landfilling, reducing the volume of biodegradable waste going to landfills, introducing separate collection and recycling as well as energy recovery, processes that do not take place with the current waste management system in Ilia. Obviously, for building a system that complies with the EU legislation, the above mentioned parameters have to be included.

All in all, it can be said that even if the present waste management system fulfills the primary task of waste management, which is removing the waste from the households, it is inadequate in attaining the principal goals of waste management and in reaching the targets of the European legislation. Thus, for forming an alternative waste management system, it is necessary to take into account the shortcomings of the current one.

3. Criteria for the definition of a new waste management system

For constructing a waste management system that fulfills the objectives of waste management and complies with the EU Directives, there are many factors that it is necessary to take into account. At first place, according to the waste hierarchy that is included in the Waste Framework Directive of the EU, prevention of waste is an indispensable element for a more goal-oriented approach and it should be the number one priority. In the scenario, it is assumed that in the specific region the necessary measures are taken to prevent waste generation but due to the augmenting effect, the waste amount stays the same regardless of the growth in waste generation that was observed during the last years. Secondly, recycling is a parameter that has to be included in a new system. Apart from that, for avoiding landfill after-care, the mineralization of organic substances in non-recycled waste can be introduced along with the disposal of the treatment residues in appropriate sanitary landfills. Hence, the above aspects are taken into consideration in developing a new waste management system. The alternative solution has been defined in accordance with the following criteria:

- To minimize the use of landfill. This criterion focuses on the conservation of space as a scarce resource and the pretreatment of waste before disposal to landfills.
- To maximize the recovery of materials. Materials can be recovered through recycling and incineration.

- To introduce energy recovery. Energy recovery from waste leads to less consumption of fossil fuels and emissions from all energy conversion systems.

So, the suggested alternative aims to give an end to the problematic aspects of the current system. At the same time, it attains better the primary goals of waste management and is compatible with the standards that are set by the European legislation.

4. The defined waste management Scenario

According to the suggested solution, wastes are separately collected with the objective of separating as far as possible the organic fraction that can be suitable for biological treatment. The biological treatment that is used is the anaerobic digestion. During anaerobic digestion, methane gas is produced that can be captured and used for energy generation. Plastic, paper, and metals are separately collected. The restwaste is treated with incineration. The products of the incineration process are flue gas, waste water, air-pollution-control residues and bottom ash the last of which is directed to a sanitary landfill. The engineering design of this landfill is quite complex. Firstly, there are mechanisms for isolating waste from the environment. Apart from the base liner, there is leachate collection system and treatment plant and the landfill gas is controlled and utilized. Also, there is operational control and emission monitoring. This suggested alternative is subdivided in two sub-scenarios which differ only in the percentage of waste that is collected separately and recycled. For the first sub-scenario, the rate of recycling is defined according to the recycling targets that are set by the EU in the Waste Framework Directive. In the Directive it is mentioned that the following goals of recycling have to be achieved: by 2020 in Greece recycling rates of paper, metal, plastic and glass have to be minimum 50%. These rates are taken into account for the optimistic sub-scenario while the realistic sub-scenario is based on the 20% of the above percentages, i.e. 10%. These rates are considerably lower but as a goal it is more feasible considering the actual circumstances and infrastructure. As far as biowaste is concerned, in the Waste Framework Directive it is mentioned that member states are encouraged to collect it separately without defining the extent. In the hypothetical alternative solution it is assumed that 50% of biowaste is separately collected in the optimistic case while for the realistic one the percentage of separate collection is 20% of the initial percentage, hence 10%.

The hypothetical waste management system *differs* from Status Quo, which is based on the current system, in the following points:

- *Recycling* is introduced. In the Status Quo, recycling rates are equal to zero. In contrast, the hypothetical system takes into account at first place recycling rates according to the targets that are set by the European Framework Directive and secondly lower recycling rates that adjust more realistically to the actual situation.
- *The biomass is separately collected.* This separately collected biomass is treated in anaerobic digestion plants. The residues from anaerobic digestion are assumed to be used as compost.
- *The way of landfilling differs substantially*. In the Status Quo, waste is disposed of in dumpsites, which, apart from the environmental costs, is anyway against European legislation. In the hypothetical scenario, the residues that come from incineration are landfilled in a sanitary landfill for pre-treated waste.

5. Options of Waste Management used in the Scenario

In the hypothetical scenario, specific means of waste management have been chosen for maximizing the overall efficiency of the system. More precisely, it is assumed that materials are separately collected and recycled, biomass that is separately collected is sent to anaerobic digestion while incineration is chosen for the treatment of restwaste and the residues of incineration are disposed of in a sanitary landfill. The mentioned processes as well as the material streams that emerge from them are briefly described below:

i. Incineration

According to the alternative waste management Scenario, incineration is the option for treating restwaste. For long time periods, MSW incineratiors polluted the environment harshly and with long-lasting effects. However, today’s technology for APC allows meeting emission values that are one to three orders of magnitude below existing advanced emission regulation limits (*Brunner et al.*2004:789). The purpose of thermal treatment of waste is to reduce the bulk of waste needing ultimate disposal in landfills to an inert inorganic ash residue. Organic carbon compounds are oxidised to CO_2 and water vapour, which are discharged to the atmosphere in the stack gas. Incineration of fossil carbon in residual organic matter remaining in the ash residue should be reduced to a very low level if the combustion process is carried out efficiently. The ash will therefore have virtually no capacity to form organic leachates or gas after disposal in landfills. Heat, power or both can be recovered from thermal treatment. The most common form of incineration in use at present, which is also assumed to be the form that takes place in the Scenario, is large scale mass burn incineration, with annual throughputs usually in excess of 100,000 tons per year.

In *mass burn incineration*, during combustion, the waste is burnt in the presence of a good supply of air, so that organic carbon is essentially completely oxidised to CO_2, which, along with water vapor and trace products of combustion, is discharged to the atmosphere. Energy can be recovered in the form of steam, which is used to drive turbines for electricity generation. Mass-burn incineration is currently the most widely deployed thermal treatment option, with about 90% of incinerated waste being processed through such facilities. As the name implies, waste is combusted with little or no sorting or other pre-treatment. Because of the large scale of operation, such facilities may effectively ‘lock-in’ supplies of waste that could otherwise go for recycling. Since in the Optimistic Sub-scenario, separate collection rates of 50% are considered in the analysis, mass-burn incineration corresponds more to the Realistic Sub-scenario that assumes much lower rates, which is closer to the present situation of the region, given that recycling does not take place.

Several material streams emerge from mass-burn incineration. The greatest of these is the ash residue discharged from the combustion chamber, which may represent between 20 – 30% of the mass of waste consumed. The ash may be processed by stabilising and grading to form a useful secondary construction material that can be used for low-grade applications such as road or car-park base layers. Ash which cannot be re-used is landfilled. Metals can also be recovered from the bottom ash. In plants with an ash-processing facility, nearly all of the ferrous metal can be recovered, otherwise up to 90% can be recovered. Non-ferrous metal can also be recovered in plants with ash processing. Residue is produced from the air pollution control system, representing about 2-4% by weight of the incoming waste. This material consists of salts and surplus alkali from acid gas neutralisation, although some plants using wet scrubber systems currently discharge the scrubber residues to water as a salts solution. In addition, fly ash containing dioxin and heavy metals is produced. This material requires disposal at hazardous waste landfills, usually after some form of stabilisation or immobilisation in an inert medium such as cement has taken place (*Smith et al,* 2005).

ii. Anaerobic digestion

In the hypothetical Scenario, it is assumed that anaerobic digestion is introduced for managing biomass and releasing energy. Anaerobic digestion involves the biological decomposition of waste in air-tight vessels under anaerobic conditions to produce a methane-rich biogas. The temperature, pH and moisture content are controlled to optimize methane production and the gas produced is collected and burnt for heat or electricity production.

Incoming source-segregated waste is first screened and then mixed with previously digested material or liquor to inoculate it with bacteria and achieve the correct consistency. This mixture is then pumped in to the air-tight digester vessel where is held for 2-3 weeks. Whilst inside the digester the material is mixed and the biogas evolved (containing 55 – 65% methane by volume) is taken off and burnt for energy recovery. The solid residue extracted from the digester, termed digestate, is then de-watered in a screw press to achieve a moisture content less than 50% and the press water is returned for mixing with fresh feedstock.

Control over temperature is very important since methane formation decreases markedly below about 30 deg C. Systems are available that operate up to 65 deg C, but although the methane yields tend to be higher and the process goes to completion faster, the higher temperature creates additional on-site energy demand for biogas and the process may be harder to control.

The liquid from the process is generally disposed of to sewer, although it could be used to manufacture a liquid fertilizer if the quality was high enough. The solid digestate is usually ‘cured’ by composting aerobically for one to two weeks to stabilize the waste, release free ammonia and to allow the moisture content to reduce through passive drying. This reduces odour and produces a compost-like material. If the composted digestate quality is sufficiently high, it can be used for agriculture (*Ostrem et al.* 2004).

iii. Separate collection and Recycling

There is an increasing recognition of the benefits of collecting waste in separate fractions, allowing easy diversion of glass, metal and paper for recycling, and biodegradable waste for composting or anaerobic digestion. This approach has been adopted in the suggested Scenario, as it is assumed that different flows of glass, paper, metal, and plastic are separated manually at a centralised sorting plant. In reality, separate collection of waste tends to have an important effect on the awareness of householders of the impacts of the waste that they create. Many times, this can lead to reduction of waste at source but this effect has not been taken into account in this analysis.

The reason for separate collection is of course for leading the collected materials to recycling. Recycling of materials from the municipal solid waste stream, after collecting the separated materials from individual households and transporting to a place for further treatment generally, involves the following steps: At first place sorting, baling and bulking for onward transfer to reprocessors (e.g. at a Materials Recycling Facility) and in the end reprocessing to produce marketable materials and products. The costs of reprocessing depend largely on the material to be processed, the scale of the process used, the complexity of the reprocessing technology, and the quality of the input materials.

In general, it is recognized that recycling decreases the amount of primary material needed. However, recycling is an intermediate and not a final solution for materials management. Recycling is a process that prolongs the residence time but for thermodynamic reasons, it does not prevent the need for future disposal (*Brunner and Rechberger*, 2002:16). Regarding the objective conservation of resources, recycling is a means that reduces the overall impact of materials which require a lot of energy and produce wastes and emissions during primary consumption. Nonetheless, the materials that have been used are not decreased and these materials will inevitably need disposal in the future. By no means does that realization undermine the importance of recycling as a key process in waste management which diverts an important fraction of the total waste stream back to consumption (*Brunner et al.* 2004:805) and there is no doubt that the extension of recycling means that higher amounts of metals and organic substances are treated and disposed safely.

6. Criteria

For the evaluation, a few criteria that represent the objectives of waste management are selected. As it has been already mentioned, the objectives of waste management are the protection of human health and the environment, the conservation of resources and the after-care free waste management. As far as the first objective is concerned, it basically refers to preventing hygienic risks by organizing the collection and disposal of waste and in advanced economies where this primary goal is reached in ensuring that hazardous substances within waste is disposed without jeopardizing public health. Thus, for this objective, it is necessary to check the presence of specific substances in wastes. So, for the analysis, it is necessary to address to the level of substances. The same applies for the conservation of resources, for looking at substances that have a resource potential. The objective after-care free waste management implies that materials in waste are either directed towards clean cycles or that they are eliminated and directed towards final sinks. That means that hazardous substances have to be eliminated from cycles when waste is recycled into new products, and the eliminated hazardous substances need to be disposed of in final sinks. (*Mastellone et al*. 2008:70)

Hence, the criteria that are selected have to correspond to these objectives and to manage to describe whether those goals are reached and how. Firstly, for examining how the objective protection of human health is reached, hazardous materials are considered useful indicators. Through following the path of a substance from its import in to its export out of the waste management, it is observed whether this substance can affect human health as well as the environment. When referring to the goal conservation of resources, the emphasis is on energy and materials. If energy and materials such as glass, paper or plastics can be conserved through recycling, there is an obvious positive environmental impact on the environment which occurs not only by exploiting the already existing materials but also from avoiding to use new ones. The same applies for energy. The conservation of energy does not only mean that waste can produce valuable resources but also that the produced energy can replace other non-environmentally friendly sources of energy. Thus, the positive effect on the environment is double. Finally, in the hypothetical system it is assumed that the flows that incineration yields are treated and disposed safely and that is how the last objective, the after-care free waste management is reached. This way, future concerns are prevented.

In consideration of the reasons given above, the following *criteria* are selected for evaluation: mass flow, volume, carbon and cadmium. The reasons for this selection are the following:

Mass flow is a criterion of importance because it determines the amount and capacity of waste collection, treatment and disposal. The way that mass flows change in a waste management system defines to which extent, separate collection, recycling, waste treatment and disposal take place. Therefore, a mass flow approach apart from giving the general picture about the plant capacity that is needed, it also depicts which means of waste management synthesize the system and how they work.

Volume is a crucial parameter for all stages of waste management, from collection to treatment and disposal. It also corresponds to the objective conservation of resources, considering that the volume of waste defines the space for landfilling and space is a scarce resource that has to be conserved.

Carbon is an important indicator that someone can look at when assessing a waste management system, since its role is double: it is an indicator of resource potential and of environmental hazard. So, as an indicator of resource potential, carbon in biodegradable waste can be used for producing energy or as an indicator of environmental hazard it can be found in hazardous organic compounds that require special treatment. When carbon flows out of the boundaries of waste management, the primary goal is to transform hazardous organic compounds to undisruptive substances, such as CO_2.

Cadmium is a major hazardous element that has to be taken into account in waste management evaluation. From that perspective, it makes sense investigating if in a defined waste management system this element is concentrated in a fraction where it cannot cause harm either to public health or to the environment.

In summary, the criteria *mass flow, volume, carbon, and cadmium* have been selected for investigation due to the fact that they represent prerequisites that should be taken into consideration for observing if and how a waste management system reaches the primary goals of waste management.

7. Evaluation

As it has been described above, the approach that has been chosen for evaluation takes into account specific indicators and substances with the aim to describe how the goals of waste management and of EU legislation are better attained with the hypothetical waste management system compared to the Status Quo. Three layers of analysis have been formed for the evaluation with the STAN software (*Cencic and Rechberger, 2008*): *the layer of goods, the layer of Carbon and the layer of Cadmium.*

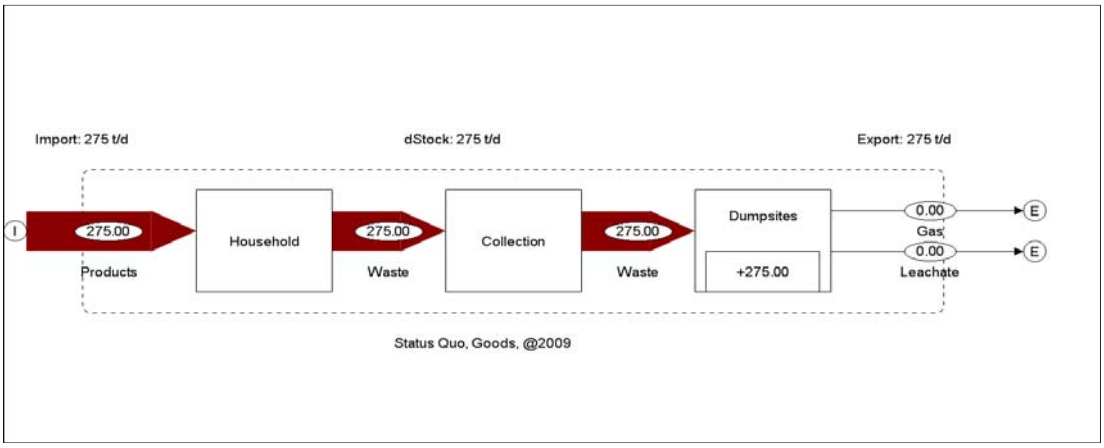
Layer of Goods

When the focus is on the *layer of goods*, then what is depicted in the Material Flow Analysis is how different flows of waste move to processes that are included in the waste management system, how their mass is influenced and which products are generated by the different processes in the system.
In the tables below, it is described the input of waste in the three different cases:

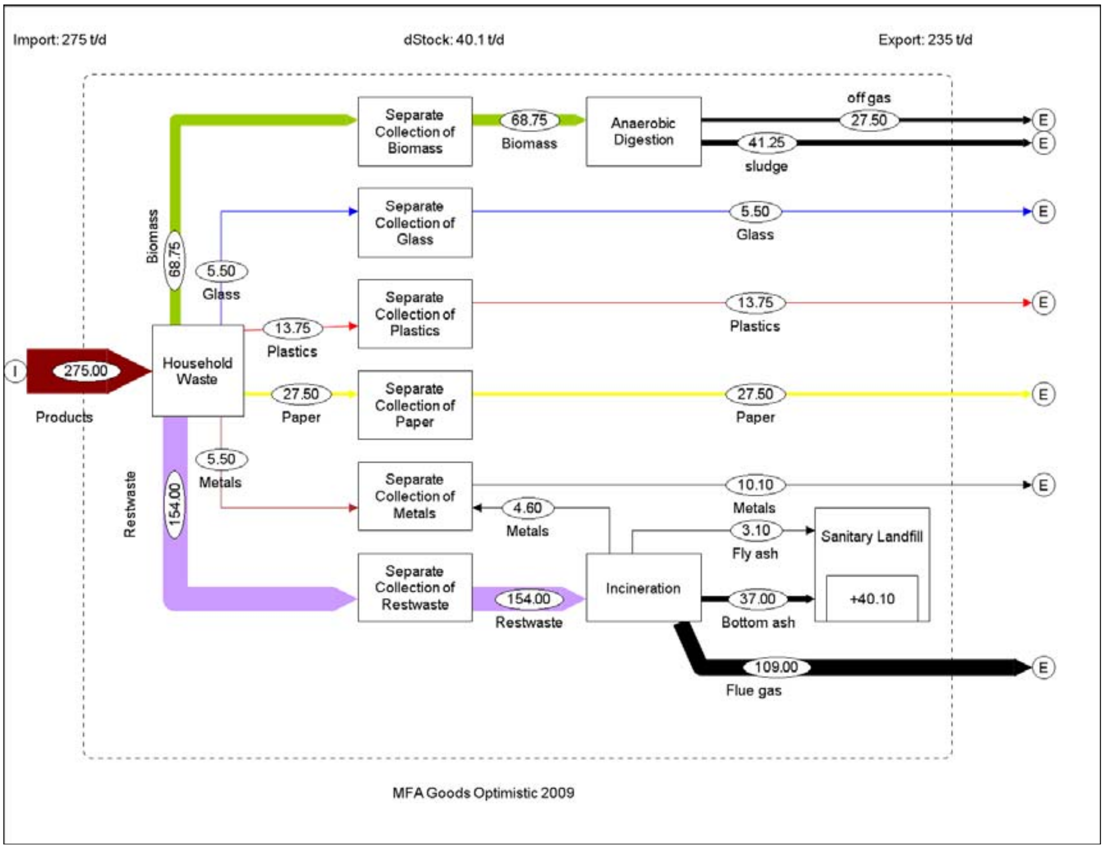
- For the Scenario Status Quo, the total waste is one stream that is directed from the households to the collection process and then it is disposed to the dumpsites.
- For the Optimistic Sub-scenario of the Alternative Solution there are different waste streams as separate collection and recycling are assumed. 50% of Glass, Paper, Plastics and Metals are collected separately and recycled while 50% of Biomass goes to anaerobic digestion. The rest of the

waste is incinerated and the bottom ash from the combustion is landfilled in a sanitary landfill.

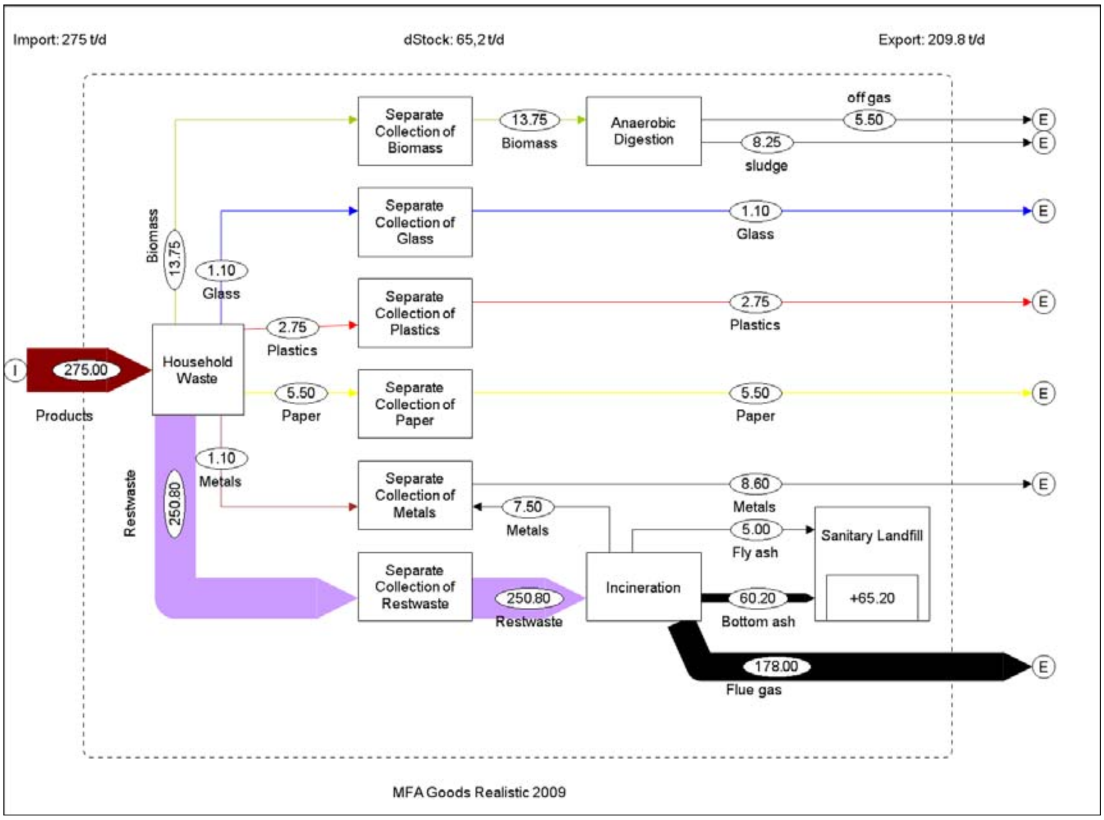
- For the Realistic Sub-scenario of the Alternative Solution there are different waste streams but in this case 10% of Glass, Paper, Plastics and Metals are collected separately and recycled while 10% of Biomass goes to anaerobic digestion. The fraction of total waste that is incinerated is much higher as well as the amount of bottom ash that needs landfilling.



1.1 Material Flow Analysis for the Status Quo



1.2 Material Flow Analysis for the Optimistic Sub-scenario



1.3 Material Flow Analysis for the Realistic Sub-scenario

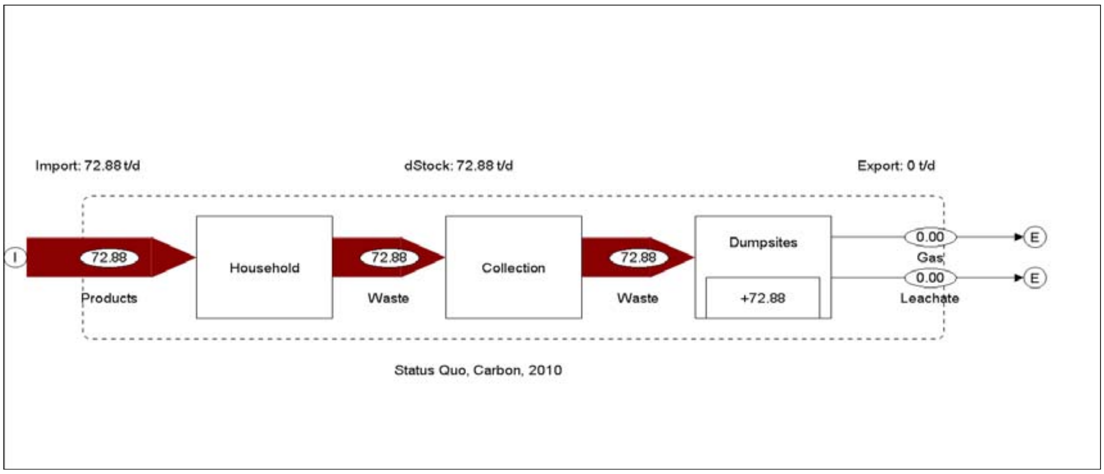
Layer Carbon

Regarding this layer of analysis, the MFA (Figures 2.1-2.3) paint the picture about how the flows of Carbon that are found in different waste streams move in the system.

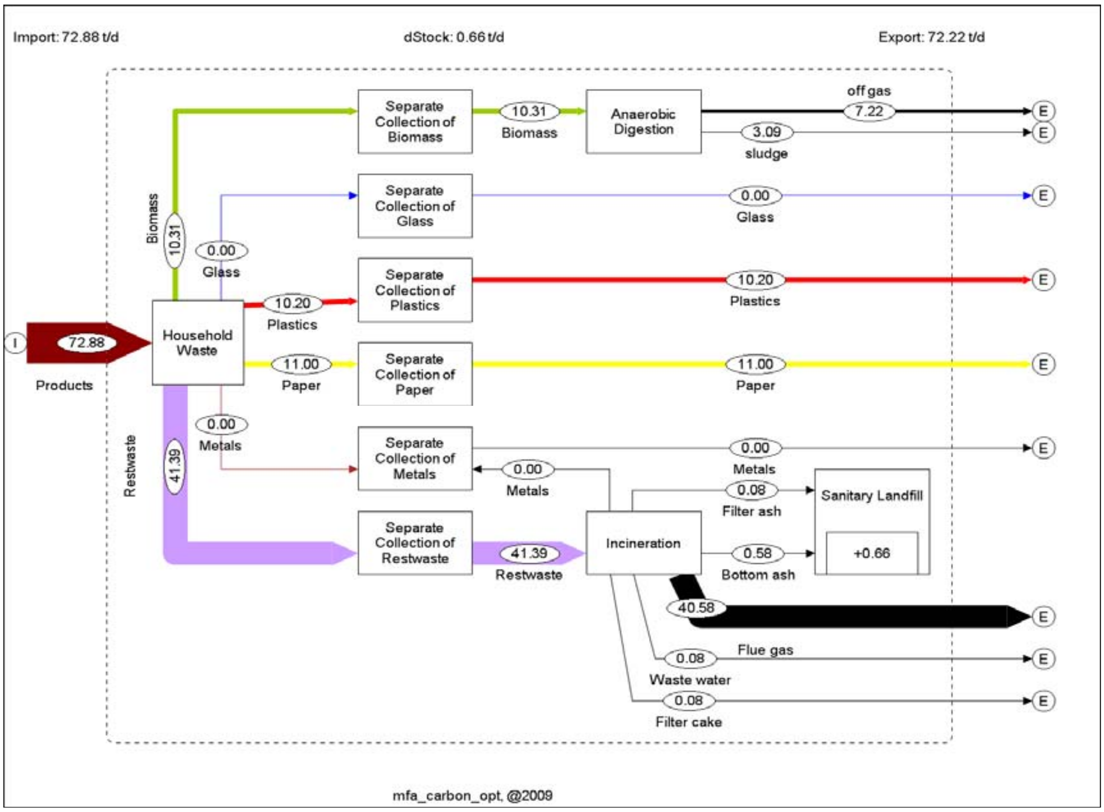
- For the Status Quo, there is only one waste stream, since neither separate collection nor recycling takes place. Hence, the almost 73 tons of Carbon that are contained in the average generation of waste which is 275 tons end up in the dumpsites. After a century, most of this quantity is transformed to landfill gas which ends up in the atmosphere since there is on gas collection system.
- For the Optimistic Sub-scenario, Carbon is divided in different waste streams, due to the fact that separate collection takes with rates equal to those that are set by the EU Waste Framework Directive, i.e. 50%. 30% of the total amount of Carbon that is contained in paper and plastics is directed to recycling after separate collection and 14% is treated with anaerobic digestion. What is rest

in restwaste is incinerated. After incineration, 98% of Carbon is transferred to flue gas.

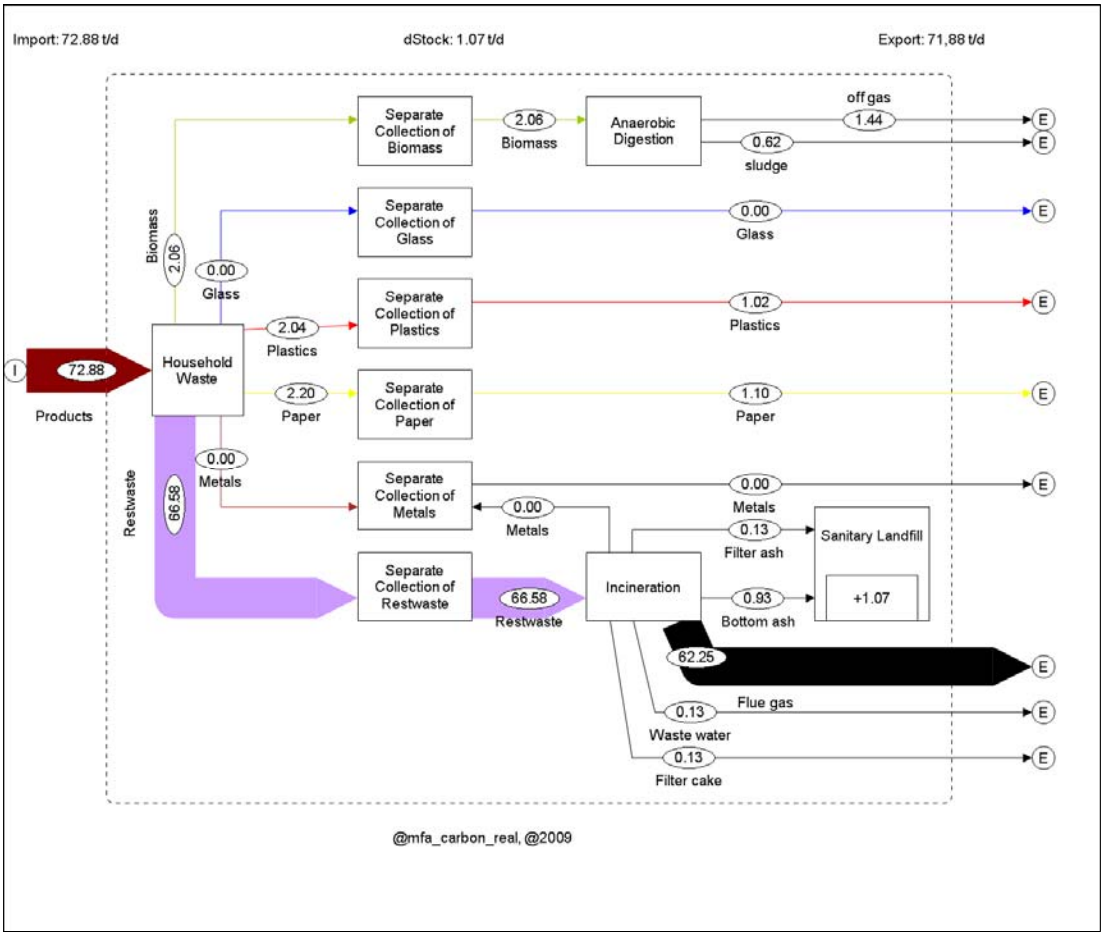
- For the Realistic Sub-scenario, separate collection with rates 10% takes place and as a result the total amount of waste is split. Due to the lower rates of separate collection more Carbon, actually 91%, ends up to restwaste and subsequently to incineration.



2.1 Material Flow Analysis for the Status Quo



2.2 Material Flow Analysis for the Optimistic Sub-scenario



2.3 Material Flow Analysis for the Realistic Sub-scenario

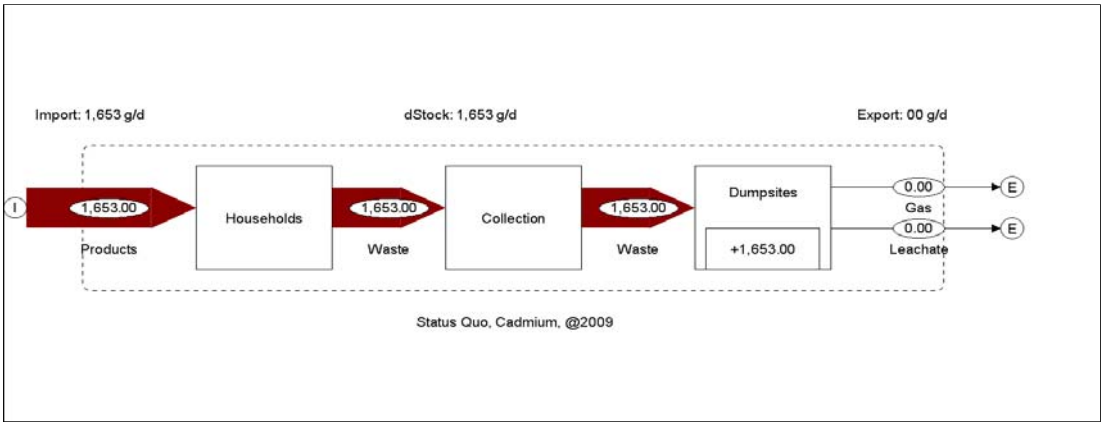
Layer Cadmium

At this point, the focus is on the path that the toxic element Cadmium follows within the waste management system and especially where its way ends for observing whether it is concentrated safely in a fraction for making sure that public health is not jeopardized. In the waste that is generated every day, more than 1600 grammars of Cadmium are contained.

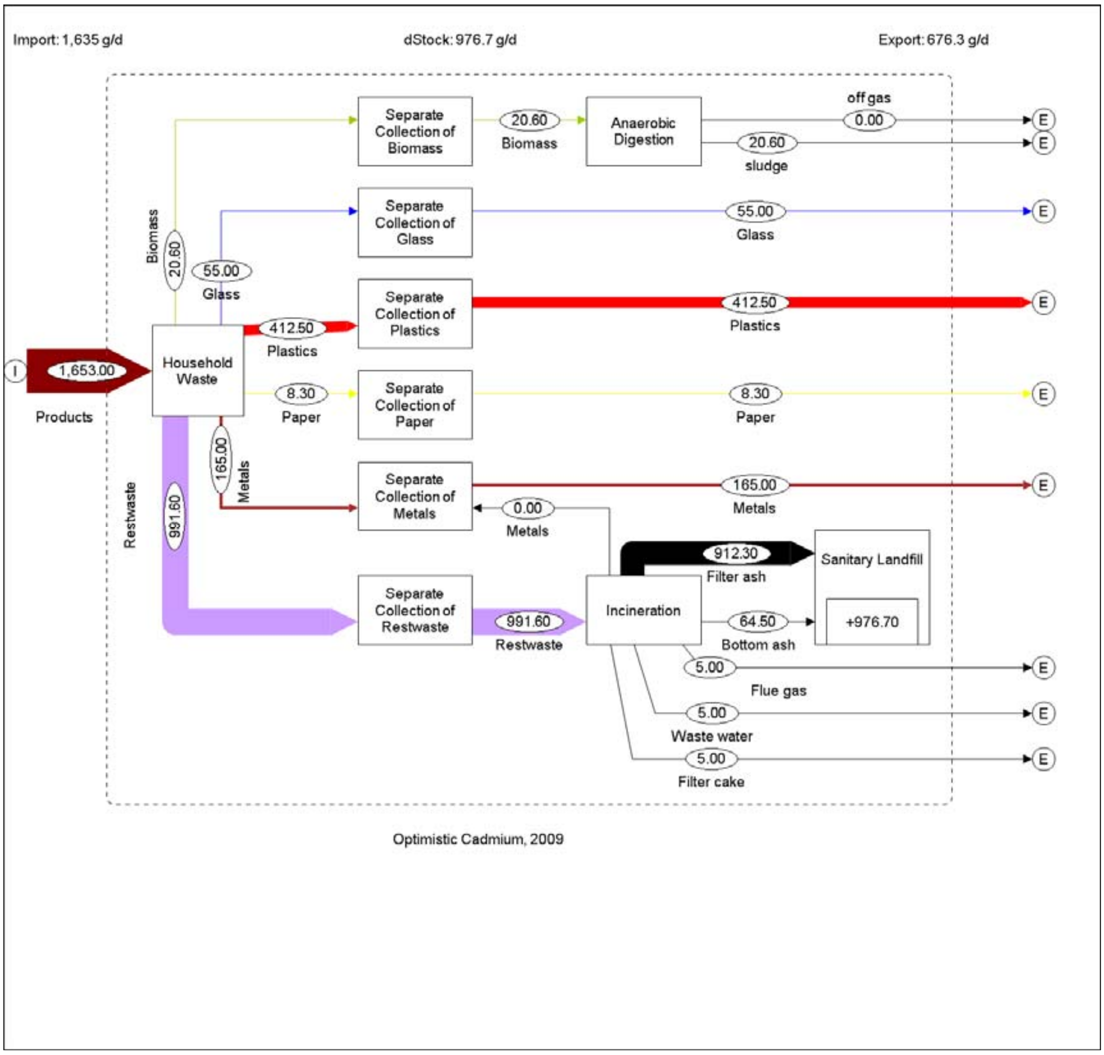
- For the Status Quo, as it can be seen in the respective MFA, the route of Cadmium from the households to disposal is straight. The total amount of Cadmium follows the same way with the mass flow of the unseparated and untreated waste and ends up in the dumpsites. Almost all of this quantity that includes organic material is disposed of in dumpsites that are characterized by the absence of control of the disposal operations and lack of management.

- In the Optimistic Sub-scenario, 39% of Cadmium is lead to recycling, around 1% to anaerobic digestion and the rest 60% to incineration. Inorganic Cadmium is present in residues after incineration. The residues are disposed of in a sanitary landfill where they are isolated from the environment with hydrogeological control that ensures that leachate is minimized.
- In the Realistic Sub-scenario, the less waste is separately collected, the less Cadmium goes to recycling, in fact, almost 8% of the total Cadmium content in the waste. In addition, less than 1% is contained in the biomass stream that is treated with anaerobic digestion. More than 90% that is rest is in the waste that is treated with incineration and the residues.

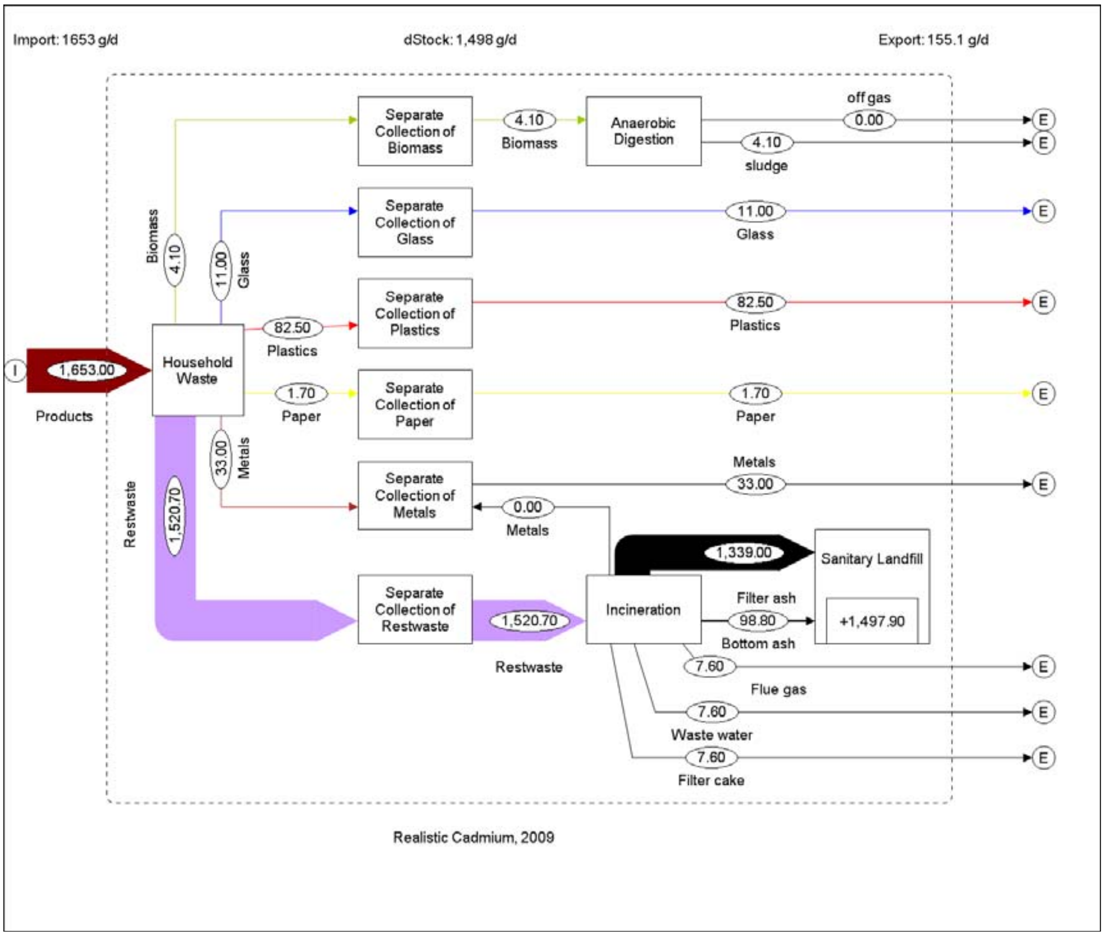
Above were synoptically described the pathways of mass flows of waste, Carbon and Cadmium as they were estimated and depicted with the evaluation method Material Flow Analysis. In the figures in the Appendix, it can be easily observed how different flows of waste moved after their import in the waste management system and where they ended.



3.1 Material Flow Analysis for the Status Quo



3.2 Material Flow Analysis for the Optimistic Sub-scenario



3.3 Material Flow Analysis for the Realistic Sub-scenario

8. Results

After constructing the reference scenario Status Quo and the hypothetical Sub-scenarios and quantifying the mass flows of waste, Carbon and Cadmium in the waste management system, the criteria *Mass Flows of Materials, Volume, Carbon and Cadmium* that represent the primary objectives of waste management are used for describing whether and how these goals are better attained through the alternative Sub-scenarios.

Mass Flows of Materials

Looking at the mass flows of materials, the most remarkable difference between the Status Quo and the hypothetical Scenario is the total amount of waste being landfilled. In the Status Quo 100% of the total waste is disposed of in dumpsites while the mass of residues after incineration is for the Optimistic Sub-scenario almost 15% of the total waste input 275 tons per day and for the Realistic Sub-scenario around 24%, since the total waste flow to landfill increases for a lower separate collection rate. Hence, the difference between the separate collection rate for the Optimistic Sub-scenario, which is 50% according to the targets that are set from the European Waste Framework Directive, and the Realistic Sub-scenario, which is 10%, results in increasing the need for landfilling 9%. The objective *conservation of materials* is reached through separate collection of different waste streams which takes place to a larger extent in the Optimistic Sub-scenario due to the higher separate collection rates. Also, energy is conserved from biomass, because it is assumed that it is treated with anaerobic digestion. In the Status Quo neither recycling nor anaerobic digestion takes place. Regarding the objective of *after-care-free waste management,* both sub-scenarios are effective as they prevent the most serious future concerns with incineration and sanitary landfilling, while in the Status Quo the waste management bequeaths many problems and uncertainties which future generations will have to deal with.

Volume

Volume is an important parameter for all the stages of waste management and it is taken seriously into account for landfilling, because landfill space is an inevitably scarce resource. Before the analysis, it should be mentioned that according to data, the density of municipal solid waste that was taken into consideration for calculating the volume is 1,100 kg/m^3 while the density of residues and filter ash a after incineration is 1,900 kg/m^3 due to an increased mass as a consequence of processes necessary for the stabilization of bottom ash and the immobilization of fly ash. According to the Status Quo, the volume of waste going to the dumpsites every day is 250 m^3. Respectively, the volume of bottom ash and fly ash for the Realistic Sub-scenario is less than 35 m^3 while for the Optimistic Sub-scenario only 21 m^3. The fact that the volume of waste that needs to be landfilled in both sub-scenarios is much less than the volume of waste in the Status Quo means that landfill space is conserved. In percentages, that means that the volume of waste that needs to be landfilled in the Optimistic Sub-Scenario reaches more or less 8% of the space that the whole amount of waste needs in the Status Quo while even for the Realistic Sub-scenario which assumes feasible recycling rates, the volume of residues after thermal treatment is less than 14% compared to the volume of total waste that is disposed of in dumpsites. Hence, the space that is needed for landfill is reduced drastically. Consequently, the *goal conservation of resources* is attained through the reduction of the use of landfill space.

Carbon

Carbon is an indicator of resource potential when regarding to biomass and of environmental hazard when it is seen as a greenhouse gas component or when considering persistent and toxic organic substances. The prevention of accumulation of carbon in the storage sites constitutes a major target for waste management. The Carbon flow of the two sub-scenarios is evidently different from the Status Quo since following the hypothetical scenario no organic carbon is landfilled and the amount of inorganic carbon that can be found in incineration residues going to sanitary landfills is significantly small. According to the Status Quo, every day more than 72 tons of carbon that are contained in the unseparated stream of waste are collected from the households and they are transported to the dumpsites where they are disposed of. As time goes by, the Carbon that is concentrated in the landfill body is gradually transformed to landfill gas and, as a result, after one hundred years, 54% of the total Carbon is in the landfill body while 46% is in the gas that is emitted from the landfill. In the long run, almost all of the Carbon will be transformed to landfill gas that has a high content (60-80%) of methane and carbon dioxide. Thus, for centuries, carbon emissions are expected in leachates as well as in off gas. According to the Status Quo which is based on the current waste management system, there is neither gas nor leachate management.

In contrast, for the hypothetical alternative scenario that includes incineration, anaerobic digestion and sanitary landfilling, the flows of Carbon are much different. In the scenario, readily biodegradable compounds are directed to anaerobic digestion while complex compounds with environmental externalities to incineration. According to the Optimistic Sub-scenario that takes into account recycling rates equal to the recycling targets that are set from the European Waste Framework Directive for the year 2020, i.e. 50%, the mass flow of Carbon that needs to be landfilled is less than one ton per day in the form of residues coming from the incineration process which is actually less than 1% of the amount of Carbon that is disposed of in open dumpsites in the Status Quo. During incineration, hazardous organic carbon compounds are degraded efficiently as modern plants can mineralize more than 99% of all carbon, yielding in carbon dioxide, water and energy. In addition, incineration can destroy substances in products that can damage the ozone layer, such as CFCs, or that have a high greenhouse gas potential, such as SF_6. As far as the Carbon mass flow of biomass that ends up to anaerobic digestion is concerned, from the 5 tons per day, the 1.5 roughly ends up to off gas and 3.5 to sludge. In this process, biodegradable compounds are degraded much faster compared to landfills. Even if in the Optimistic sub-scenario the recycling rates that are taken into consideration are quite high and it is expected that it is differentiated a lot compared to the Status quo, the results that occur from much lower recycling rates in the Realistic Sub-scenario underline the benefits from a waste management system that embraces pretreatment and safe disposal. In this case, a bigger mass flow of Carbon goes to incineration and around 1 ton per day is landfilled in a sanitary landfill, which is less than 2% of the Carbon mass flow that is unsafely disposed of in the Status Quo.

All in all, according to the result from the MFAs, both Optimistic and Realistic Sub-scenarios attain better the primary goals of waste management compared to the current system when Carbon is the point of reference. The objective *protection of human health and the environment* is achieved through the mineralization of hazardous carbon compounds that takes place during incineration. Moreover, *conservation of resources* is realized, more in the Optimistic Sub-scenario and less in the Realistic, with the generation of energy through anaerobic digestion where the fraction of biomass ends up. This way, not only energy is produced through Carbon exploitation but also biodegradable waste is rapidly degraded under anaerobic circumstances, a process needs much more time in landfills. Finally, the goal *after-care free waste management* is accomplished through the disposal of the Carbon flow that is contained in the residues in a sanitary landfill whilst in the Status quo the total organic and inorganic Carbon flow goes to the dumpsites, leaving many problems to be solved in the future.

Cadmium

Cadmium is a toxic heavy element that enters the municipal solid waste stream as components of a variety of consumer products. Cadmium is intentionally added to major categories of products where it imparts distinct performance advantages, such as batteries, cadmium stabilizers, cadmium pigments, and it is also present as impurity in other classes of products, such as non-ferrous metals (zinc, lead, copper) iron, steel, cement and phosphate fertilizers. The use of Cadmium is under severe pressure due to its toxicity.

In the Status Quo as well as in the alternative scenario most of the Cadmium in the end is in landfills. However, in the Status Quo, it is obvious that every day more than 1,600 gr Cadmium end up to the dumpsites within the untreated waste with organic material while, in both sub-scenarios, most of the Cadmium in landfilled waste is comparatively immobile. During incineration a high percentage of Cadmium, 92%, is concentrated in the filter ash while 6.5% is in the bottom ash. These two mass flows after incineration need to be landfilled. As far as the Cadmium content in the bottom ash is concerned, since it is relatively immobile, after pretreatment it can be landfilled with minor risks. Yet, Cadmium in the incineration residues is mobile and for this reason it is necessary that residues from filter ash are pretreated and immobilized before being landfilled.

In the alternative waste management scenario, source separation for recycling results in continually decreasing inputs of cadmium into municipal solid waste incinerators. This is evident when comparing the two sub-scenarios with each other. For the Optimistic Sub-scenario, 39% of the total Cadmium input is recycled and 8% for the Realistic Sub-Scenario. Since the recovery of cadmium from cadmium products through recycling programs not only ensures that cadmium will is kept out of the waste stream and out of the environment, but it also conserves valuable natural resources, high recycling rates mean higher conservation of resources and at the same time less future implications are likely to happen. Higher recycling rates mean apart from clean packaging plastics, long-lasting non-packaging plastics containing Cadmium are to be collected and recycled too. Since the amount of these plastics is growing and with long residence times, extracting cadmium and other hazardous additives from plastics is an emerging duty to be introduced into waste management for achieving clean cycles.

In terms of waste management goals, clearly the hypothetical scenario is more successful in achieving them. The objective *protection of human health and the environment* is reached best through the sub-scenario with the highest recycling rates, in which a big amount of cadmium is going out of the waste management system thanks to the assumed separate collection of materials. However, in the realistic sub-scenario in which the recycling percentages are more modest and feasible, human health is better protected from this toxic substance, since its flow within the waste management system is predictable and in the end it can be found mainly in the sludge of anaerobic digestion, in the filter ash and in the bottom ash after incineration. In contrast, in the Status quo, Cadmium is accumulated in the dumpsites and stays almost all there and even after one century 99.9% of Cadmium is still found in the landfill body. Nevertheless, in the very-long run (after ten thousand years) it is expected that a significant amount of Cadmium, 42%, will be in the leachate. The goal *conservation of resources* is reached with the separate collection and subsequent recycling of Cadmium that differentiates the alternative scenario from the Status quo. Finally, drawing conclusions about how the objective *after-care free waste management* is reached is more complicated, because in all cases, in the Status Quo as well as in the two Sub-scenarios, most of the Cadmium is in the end in a landfill. In the Sub-scenarios it is in the form of inorganic Cadmium and in the Status Quo it includes organic material. It is beyond the scope of this study to investigate in greater detail how these two different flows evolve as time goes by but this issue could be analyzed in depth in another study

V. ECONOMIC ASSESSMENT OF THE STATUS QUO AND THE ALTERNATIVE SUB-SCENARIOS

1. Introduction

In this chapter, an economic assessment of the Status Quo and the two Sub-Scenarios is attempted. This economic assessment is intended to inform about the "gap" between several and different waste management options and to highlight that, even if there is available technology, the enormous economic difference between the costs of waste management options that attain the goals of waste management and the disposal to landfills can simply make other solutions seem economically unattractive. The estimation of the costs of the current waste management system and of the two hypothetical sub-scenarios is based on average figures and by no means is it meant to provide an absolutely accurate calculation of the costs of the different options that have been analyzed for the Prefecture Ilia. Finally, the arithmetic data representing the costs for each option that have been taken into consideration for this estimation are found in the Waste Management Options and Climate Change, Final report to the European Commission (*DG Environment*).

2. Costs of Different Waste Management Options

The costs of different waste management services do not form a continuum. The discontinuity in costs of waste treatments, i.e. the "gap" between the costs of landfills and the costs of the "next cheapest" treatment has been one of the reasons that explain why Greece is depended on landfills. In Greece, landfill constitutes by far the cheapest waste management option. The costs of landfill per ton of waste are 9-30 EUR, costs that it is likely to increase in coming years due to Landfill Directive. This will, amongst other things, require most landfills accepting biodegradable wastes to implement gas collection by 2013 for states currently highly dependent on landfill. It is not surprising that the disposal to Dumpsites is even cheaper with costs 5-10 EUR/ton. The cost will inevitably increase with the requirement for higher environmental standards and the consumption of void space as existing sites fill up and close. In a given area, like the Prefecture Ilia, dumpsites tend not to exist in abundance. However, in the absence of other treatment facilities, and as long as dumpsites remain economically attractive, the shift to other waste management options seems to be difficult. Something that would make a difference would be the imposition of fines. Before, it was mentioned that Greece had to pay for the operation of a dumpsite in Crete EUR 20,000 per day. If that kind of fines were imposed for the operation of unauthorized dumpsites in Ilia, the cost for disposal of waste in dumpsites would be considerably higher and eventually the authorities in Ilia would be forced to close them and to think about ways that would enable the waste management system to comply with the EU legislation.

However, it is quite clear that sound waste management requires in general a high level of technology and a significant budget. What Germany and Austria can afford today, Greece and Portugal will have to wait a long time for. In the alternative Scenario, it is assumed that the following waste management options take place: *incineration, anaerobic digestion,* and *recycling.*

Incineration: At present, no thermal treatment of municipal solid waste takes place anywhere in Greece. For decades, the administration and the public opinion have been against incineration, with the exception of incineration of clinical waste (*Mavropoulos:2*). Up until present day, there have been two unsuccessful attempts to introduce incineration in Greece. The first one took place in the beginning of 90's in Zakynthos Island. In this case, a small, old-fashioned incinerator was installed and after a while it had to shut down due to high operational and environmental cost. The second endeavor was realized in the middle of 90's when it was tried to establish a small incineration plant with a total capacity of 15,000 tones/year in Thira Island. This plant would work for 6-7 months per year and during the rest of the year the waste would be stored till the next operational period. This project was unfortunate because it was backed neither by the local municipalities nor by the government (*Mavropoulos et al.*:9). Even though there was a financial support from the European Union, there were doubts for the feasibility of this project due to its high operational costs and the lack of technical experience. Concerning the costs of incineration, the average fee for in the EU-15[10], weighted by the waste arisings in each country, is 64 EUR/ton (including taxes) with energy recovery and 66 EUR/ton without energy recovery. The highest gate fee is in Austria (148 EUR/ton) and the lowest in Sweden (31 EUR/ton). The costs in EUR per ton that have been included in the present

[10] No data were found for Greece, Portugal and Ireland.

economic assessment are EUR 100 since the latest incinerators fulfilling all legal requirements operate in this range.

Anaerobic digestion: At present, no anaerobic digestion of the organic fraction of municipal solid waste takes place anywhere in Greece. Hence, the average of the costs of anaerobic digestion in the EU-15 is taken into account for estimating the costs of this method, which is 65 EUR/ton.

Recycling: As it has been already mentioned, recycling of materials from the municipal solid waste stream generally involves the collection of the separated materials from individual households and transporting to a place for further treatment, the sorting, for onward transfer to reprocessors (e.g. at a Materials Recycling Facility [MRF]) and, in the end, the reprocess to produce marketable materials. The route of waste is linear and schematically it could be reproduced like that:

Household →Collection point→Materials recovery facility (MRF)→reprocessor

As far as *collection* costs are concerned, broadly speaking they are common to all treatment options. Costs are particularly significant for recyclable plastics, because of their very low density and the need for a high degree of sorting. The collection costs are 80 EUR/ton of waste.

Sorting takes place in a Materials Recycling Facility and this operation employs manual and/or semi-automatic processing for sorting recyclables from waste and preparing them in a form suitable for use by a materials reprocessor. In the Scenario it has been assumed that the recyclables are well separated and, as a result, demand less processing. Hence, the Scenario assumes a 'clean' MRF that receives source-separated recyclable materials. In general, total costs per ton of waste processed at a MRF which include capital and operating costs have been estimated as 51 EUR/ton and 128 EUR/ton respectively for a manual processing and semi-automatic processing plant. According to the Scenario, the MRF facility operates with manual processing, so the costs that are taking into consideration for sorting are 51 EUR/ton. Finally, the costs of *reprocessing* depend largely on the material to be processed, the scale of the process used, the complexity of the reprocessing technology, and the quality of the input materials. In the Scenario, the materials that are recycled are Glass, Paper, Metals, Plastics.

- For Glass, current costs for reprocessing are 0-17 EUR/ton for green glass, 25-37 EUR/ton for brown glass and 37-45 EUR/ton for clean glass. An average price of 30 EUR/ton is taken into consideration in this study.
- For Paper, the costs are highly volatile, starting from 70 to 475 EUR/ton. This price includes 46 % was operating costs, 40% capital charges and 14% raw material costs. In this price, collection and sorting are included.
- For Metals, there is a differentiation between aluminium metal that can be found in cans, aluminium foil and containers and ferrous metal which is in tin-plated food cans in households waste. The average price paid for used beverage cans in the EU is 945 EUR/ton while for used steel scrap it is 22 EUR/ton. In these prices, collection and sorting are included.
- Costs are particularly significant for recyclable plastics, because of their very low density and the need for a high degree of sorting.The direct costs are 706 EUR/ton and this figure is much higher than 610EUR/ton which is the market price for recycled plastics. The price706 EUR can be broken down as: 90 EUR for collection, 90 EUR for sorting, 40 EUR for baling, 28 EUR for transport, 207 EUR for wash and dry, Euro180 EUR for melt process, 28 EUR for additives and 43 EUR for bagging and warehousing.

The costs that have been taken into account for a rough economic assessment of the Status Quo and the two Sub-scenarios can be seen in the Tables below:

Table 5.1: Costs for different Waste Management Options

WM Option	EUR/ton
Collection	80
Collection and Disposal to Dumpsites	80-90
Incineration	120
Anaerobic digestion	65

Table 5.2: Costs for recycling of different materials

Recycling	Costs (€/t)
Glass	30
Paper	70-475
Metals (aluminium)	945
Metals (ferrous)	22
Plastics	706

3. Economic assessment of the Status Quo and the two Sub-scenarios [11]

Economic Assessment of the Status Quo

In the Status Quo which is based on the current waste management system of Ilia every day the total amount of waste, i.e. 275 t/d, is disposed of in open dumpsites. Hence, since the price for collection and disposal to dumpsites is 80-90 EUR/ton of waste, it is easy to estimate that the present waste management system costs 22,000-25,750 EUR/day.

Optimistic Sub-scenario

For estimating the costs of the Optimistic Sub-scenario, the costs for each waste stream have been calculating separately according to the way of treatment that is assumed. From the following table it can be seen that the total costs of the waste management system that is described in the Optimistic Sub-scenario would be between 35,000 and 46,000 EUR/day.

[11] The tables with the calculationsn of the Costs can be found analytically in the Appendix 5 (p.69).

Realistic Sub-scenario

The costs of the Realistic Sub-scenario, in which the recycling rates are considerably lower and the percentage of restwaste going to incineration is higher, have been estimated to be between 33,000 and 37,000 EUR/day and they can be seen analytically in the table below

4. Results

As it has been estimated above, the costs of the current waste management (Status Quo) which is based on the waste disposal in dumpsites are much lower than the costs of a system that embraces high recycling rates (Optimistic Sub-scenario) or of a system in which most of the waste is treated with incineration (Realistic Sub-scenario). The costs of the Optimistic Sub-scenario are higher than the costs of the Realistic Sub-scenario without having taken into consideration revenues coming from selling the recycled products. In general, the hypothetical system seems to be significantly more expensive compared to the costs of the current waste management system. The major differences among the three cases remind that usually the solutions that are the most environmentally sound are at the same time the most expensive while, on the other hand, the cheapest solution from an economic perspective has the highest costs in environmental terms. What could reverse this trend would be the imposition of fines. Since the present waste management system in Ilia clearly does not comply with the EU legislation, if the European Commission decided to compel financial penalties, it would become economically unsustainably to maintain it.

VI. SUMMARY-CONCLUSIONS

In this thesis an alternative waste management system was compared to the present system and evaluated on the Prefecture Ilia. The suggested waste management system was formed according to the provisions of the Waste Framework Directive and the Landfill Directive and it was aiming at fulfilling better the primary goals of waste management compared to the current system. The present waste management system was depicted by MFA using software STAN. The suggested alternative waste management scenario was divided in two sub-scenarios, in the one the recycling rates that were taken into consideration were those that were set as targets by the European Framework Directive whilst in the other one they are much lower, corresponding to more reasonable expectations. Apart from enhancing recycling rates, anaerobic digestion and incineration were compared to the current system of the region.

According to the results of the study, the benefits coming from the introduction of the above mentioned elements in the waste management system of Ilia are quite clear. Both sub-scenarios fulfill the objectives of waste management significantly better than the actual waste management system that is based on disposal of waste to dumpsites. Moreover, as it is expected, a higher rate of separate collection is more effective and expensive too. However, comparing the two sub-scenarios with each other, it should be mentioned that, looking at the volume of waste that needs to be landfilled after incineration, the difference between the two sub-scenarios is not that unbridgeable. So, even through the adoption of low and feasible recycling rates that seem to be a more realistic plan in practice, no matter if they are lower than the targets of the EU Waste Framework Directive, it is possible to have noteworthy advantages, given that the waste management system includes separate collection, anaerobic digestion and incineration as they have been described for the alternative scenario that is suggested. Also, it should be recognized that the fact that in the EU Waste Framework Directive the recycling rates that are set are 50% might lead to different directions, according the existing situation in each member state. For example, for Northern European countries this 50% might seem to be a reasonable and doable aim, on the other hand, for Greece, the things are different quite different. Unless dramatic changes take place in the waste management landscape within the next years, it does not seem that possible that this target will be reached. And looking at the fact that changes in waste management have ended up being more complicated and time-consuming than it was expected, it seems difficult that this target will be reached by Greece. So, considering that this target is rather ambitious, in fact, instead of motivating for changes it is regarded as unfeasible at first place and does not encourage for changes the way it would be expected.

This study concludes that from an environmental and economic perspective incineration is a way of waste pre-treatment that should be introduced in the waste management mix for a number of reasons. In particular, because it diverts the largest part of the MSW stream away from landfill combined with the potential of delivering carbon dioxide neutral energy. In Greece, authorities, public opinion and other stakeholders tend to focus on the environmental issues that were associated with thermal treatment in the past, as for a long time it has been believed that incinerators were polluting the environment with long lasting effects. However, the progress in air pollution control technology can guarantee that the pollutant flows from MSW incinerators in smaller than those from other sources (*Brunner et al.*2004:798). Since incineration is a realistic way to process hazardous and non-hazardous waste which with the suitable technology can generate emissions smaller than the most advanced standards, it is a way of treatment that could be introduced in future waste management strategies, in case barriers and prejudices against this method are left behind. However, it should not serve as an "end-solution" ignoring prevention and recycling, even though it is recognised that preventing the generation of waste in small-scale, i.e. households is quite challenging. Attempts to prevent the generation of waste or increase recycling through changing people's behaviour are not as effective as people's awareness must be created first in order to tackle the problem and it is understood that this takes a lot of time. It is understood that increasing people's awareness about waste management is a parameter that should be introduced in Greece and in Ilia in particular, since in Ilia most of the people ignore how waste is disposed of and that kind of effects this way of disposal might cause. But given that shifts in people's attitude requires time and it cannot be expected that recycling rates will increase significantly from the one day to the other, incineration seems to be an effective way for treating large amounts of mixed waste.

All in all, it is recommended to transform the present waste management system in Ilia which is mainly based on uncontrolled disposal of waste in dumpsites. It was shown that the goals of waste management along with the targets that are set by the EU legislation will be much better fulfilled if the recycling rates reach 10%, biomass is anaerobically treated and incineration is introduced for the treatment of restwaste. Also, it was also analyzed how this system would be with 50% recycling rates, knowing that this system would be rather optimistic compared to the actual situation for showing how the waste management system in Ilia that complies with the EU Legislation would function and which would be its benefits.

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http://europa.eu/rapid/pressReleasesAction.do?reference=IP/08/1825&format=HTML&aged=0&language=FR&guiLanguage=en

Environment: Commission to pursue legal action against Greece over infringements (IP/05/1644), EUROPA Press Releases RAPID

http://europa.eu/rapid/pressReleasesAction.do?reference=IP/05/1644&format=HTML&aged=1&language=FR&guiLanguage=en

The online portal for material flow data

http://www.materialflows.net/

Hellenic Solid Waste Management Association

http://www.eedsa.gr/default.aspx?lang=en

VII. APPENDIX

1. Layer Goods

1.1: Table for mass flows for the MFA for the two Sub-scenarios for the Layer Goods

	Total	Biomass	Glass	Paper	Plastics	Metals	Restwaste
Production of MSW (t/d)	275	137.5	11	55	27.5	11	33
Composition of MSW (%)	100	50	4	20	10	4	12
Status Quo							
Fraction of Separate Collection (%)	*		0	0	0	0	*
Separate Collection (t/d)	*	*	0	0	0	0	*
Alternative System. optimistic Sub-scenario							
Fraction of Separate Collection (%)	*	50	50	50	50	50	*
Separate Collection (t/d)	*	68.75	5.5	27.5	13.75	5.5	*
Mass Flow (t/d)	275	68.75	5.5	27.5	13.75	5.5	154
Alternative System. realistic sub-scenario							
Fraction of Separate Collection (%)	*	10	10	10	10	10	*
Separate Collection (t/d)	*	13.75	1.1	5.5	2.75	1.1	*
Mass Flow (t/d)	275	13.75	1.1	5.5	2.75	1.1	250.8

Status Quo

1.2.1Mass of waste in dumpsites after 100 years:

TC leachate	TC landfill gas	TC landfill body
0.10%	25%	74.90%
Mass of Waste	Mass of Waste	Mass of Waste
0.275 t	68.75 t	205.98 t

1.2.1: Mass of waste in dumpsites after 1000 years

TC leachate	TC landfill gas	TC landfill body
0.30%	35%	64.70%
Mass of Waste	Mass of Waste	Mass of Waste
0.825 t	96.25 t	177.93 t

1.3: Mass Flows per day for the Optimistic and Realistic Sub-scenario after Anaerobic Digestion

Anaerobic Digestion	Optimistic	Realistic
Mass Flow of Waste (t/d)	68.75	13.75
TC off gas (%)	40	40
TC sludge (%)	60	60
Mass Flow of Waste in off gas (t/d)	27.5	5.5
Mass Flow of Waste in sludge (t/d)	41.25	8.25

1.4: Mass flows per day for the Optimistic and Realistic Sub-scenario after Incineration.

Incineration	Optimistic	Realistic
Mass flow of restwaste (t/d)	154	250.8
TC filter ash (%)	2	2
TC bottom ash (%)	24	24
TC flue gas (%)	71	71
Mass flow of fly ash	3.1	5.0
Mass flow of bottom ash	37.0	60.2
Mass flow of flue gas	109	178
TC Scrap Iron	3	3
Mass Flow of Iron (t/d)	4.6	7.5
Mass flow for Landfill	40.0	65.2
% of Total Amount (275)	14.6	23.7

2. Layer Carbon

Status Quo

2.1.1Carbon Content in 275 tons of waste containing 72.88 t of Carbon in dumpsites after 100 years:

TC leachate	Landfill gas	Landfill Body
0.30%	46%	54%
C quantity	C quantity	C quantity
0.22 t	33.5 t	39.4 t

2.1.2: Carbon Content in 275 tons of waste in dumpsites after 1000 years:

TC leachate	Landfill gas	Landfill body
0.90%	70%	29%
C quantity	C quantity	C quantity
0.66 t	51.016 t	21.14 t

2.1.3: Carbon Content in 275 tons of waste in dumpsites after 10000 years:

TC leachate	Landfill gas	Landfill body
2.80%	92%	5%
C quantity	C quantity	C quantity
2.04 t	67.05 t	3.64 t

Sub-scenarios

2.2: Mass flows of Carbon per day in different waste streams for the Optimistic and Realistic Sub-scenario.

Type of Waste	Mass (t/d) Fraction of Waste	Tranfer Coefficient for Carbon	Carbon Content(t/d)	Optimistic Sub-scenario (50%)	Realistic Sub-scenario (10%)
Biomass	137.5	15%	20.63	10.31	2.06
Glass	11	0	0	0	0
Paper	55	40%	22	11	2.2
Plastics	27.5	74%	20.35	10.2	2.04
Metals	11	0%	0	0	0
Restwaste	33	30%	9.9	*41.39*	*66.58*

Total	275	*	72.88	72.88	72.88

2.3: Mass flows of Carbon per day to and from the process Anaerobic Digestion for the Optimistic and Realistic Sub-scenario.

Anaerobic Digestion	Optimistic	Realistic
Carbon in Biomass (t/d)	10.31	2.06
TC off gas (%)	70	70
TC sludge (%)	30	30
Carbon Content in off gas (t/d)	7.22	1.44
Carbon Content in sludge (t/d)	3.09	0.62

2.4: Mass flows of Carbon per day to and from the process Incineration for the Optimistic and Realistic Sub-scenario.

Incineration	Optimistic	Realistic
Carbon in Restwaste (t/d)	41.39	66.58
TC flue gas (%)	98	98
TC bottom ash (%)	1.4	1.4
TC waste water (%)	0.2	0.2
TC filter cake (%)	0.2	0.2
TC Filter ash (%)	0.2	0.2
Carbon in flue gas (t/d)	40.56	65.25
Carbon in bottom ash (t/d)	0.58	0.93
Carbon in waste water (t/d)	0.08	0.13
Carbon in filter cake (t/d)	0.08	0.13
Carbon in filer ash (t/d)	0.08	0.13

2.5: Stock, Import and Export of Carbon per day for the Optimistic and Realistic Sub-scenario.

	Optimistic	Realistic
Carbon in bottom ash (t/d)	0,58	0,93
Carbon in filter ash (t/d)	0,08	0.13
d Stock (t/d)	0.66	1.07
Import	72.88	72.88
Export	72.22	71.81

3. Layer Cadmium

Status Quo

3.1: Mass Flow of Carbon per day for the Status quo.

Status Quo	
Total Cadmium in Waste(g/d)	1,653
TC Landfill Gas %	0
TC Landfill Body %	100
TC Leachate %	0
Cadmium in Landfill Gas(g/d)	0
Cadmium in Landfill Body (g/d)	1,653
Cadmium in Leachate (g/d)	0

3.2.1: Cadmium Content in 275 tons of waste in dumpsites after 100 years

TC Leachate	TC Landfill Gas	TC Landfill Body
0.10%	0%	99.90%
Cd quantity	Cd quantity	Cd quantity
1.653 gr	0 gr	1,651.347 gr

3.2.2: Cadmium Content in 275 tons of waste in dumpsites after 1000 years

TC Leachate	TC Landfill Gas	TC Landfill Body
2.10%	0%	0.98
Cd quantity	Cd quantity	Cd quantity
34.713 gr	0 gr	1,619.94 gr

3.2.3: Cadmium Content in 275 tons of waste in dumpsites after 10000

TC Leachate	TC Landfill Gas	TC Landfill Gas
42%	0	58%
Cd quantity	Cd quantity	Cd quantity
694.26 gr	0 gr	958.74 gr

3.3: Mass flows of Cadmium per day in different waste streams for the Optimistic and Realistic Sub-scenarios.

Type **of Waste**	**Mass (t/d) Fraction of Waste**	**Content of Cadmium ppm**	**Mass Flow of Cadmium(g/d)**	**Optimistic Sub-** **scenario (50%)**	**Realistic Sub-scenario (10%)**
Biomass	137.5	0.3	41	20.6	4.1
Glass	11	10	110	55.0	11.0
Paper	55	0.3	17	8.3	1.7
Plastics	27.5	30	825	412.5	82.5
Metals	11	30	330	165.0	33.0
Restwaste	33	10	330	991.6	1520.7
Total	275		1,653	1,653	1,653

3.4: Mass Flows of Cadmium per day to and after the process Incineration for the Optimistic and Realistic Sub-scenario.

Incineration	Optimistic	Realistic
Cadmium in Restwaste (g/d)	991.6	1520.7
TC flue gas (%)	0.5	0.5
TC bottom ash (%)	6.5	6.5
TC waste water (%)	0.5	0.5
TC filter cake (%)	0.5	0.5
TC Filter ash	92	92
Cadmium in flue gas (g/d)	5.0	7.6
Cadmium in bottom ash (g/d)	64.5	98.8
Cadmium in waste water (g/d)	5.0	7.6
Cadmium in filter cake (g/d)	5.0	7.6
Cadmium in filter ash (g/d)	912.3	1399.0

3.4: Stock, Import, Export of Cadmium for the Sub-scenarios.

	Optimistic	Realistic
Cadmium in bottom ash (g/d)	64.5	98.8
Cadmium in filter ash (g/d)	912.3	1,399.0
d Stock (t/d)	976.7	1,497.9
Import (t/d)	1,653	1,653.0
Export (t/d)	676.3	155.1

3.5: Mass flows of Cadmium to and from the process Anaerobic Digestion for the Optimistic and Realistic Sub-scenario.

Anaerobic Digestion	Optimistic	Realistic
Cadmium in Biomass (g/d)	20.6	4.1
TC off gas (%)	0	0
TC sludge (%)	100	100
Mass Flow of Cadmium in off gas (g/d)	0	0
Mass Flow of Cadmium in sludge (g/d)	20.6	4.1

4.Volume

4.1: Volume of waste going to Landfill for the Optimistic and Realistic Sub-scenario.

	Optimistic	Realistic
Mass Flow to Landfill (t/d)	40	65.2
Initial Mass flow of Rest waste (t/d)	154	250.8
Total Waste Mass Flow (t/d)	275	275
Volume of Residues to Landfill (m3/d)	21.05	34.32
Volume of Initial Restwaste (m3/d)	140	228
Volume of Total Waste (m3/d)	250	250

4.2: Densities taken into account for calculating the Volume.

Densities	
Density of MSW (kg/m3)	1100
Density of Residues (kg/m3)	1900

5. TABLES FOR THE ECONOMIC ASSESSMENT OF THE STATUS QUO AND THE TWO SUB-SCENARIOS

5.1: Costs of Recycling for different materials.

Recycling	Collection	Sorting	Reprocess	Total
Glass	included	Included	Included	30
Paper	included	Included	Included	70-475
Metals (5% aluminium)	included	Included	Included	945
Metals (95% ferrous)	included	Included	Included	22
Plastics	included	Included	Included	706

Table 5.2: Costs for different Waste Management Options

WM Option	EUR/ton
Collection	80
Collection and Disposal to Dumpsites	80-90
Incineration	120
Anaerobic digestion	65

Economic Assessment of the Status Quo

The average production of waste per day is 275 tons and the costs are 80-90 EUR/ton

5.3: Calculated minimum and maximum costs of the current waste management system.

Status Quo Costs €/d
(275*80)22,000
(275*90)24,750

Table 5.4: Economic Assessment of the Optimistic Sub-scenario

Optimistic			
Mass Flow	t/d	Costs €/t	Costs for each flow
Biomass	68.75	65	4,468.75
Restwaste	154	120	18,480
Glass	5.5	30	165
Paper	27.5	70-475	1,925-13,062.5
Metals (Al) 5%	0.27	945	255.15
Metals (Fe) 95%	5.23	22	115.06
Plastics	13.75	706	9,707.5
		Total Costs EUR	35,100-46,300

Table 5.5: Economic Assessment of the Realistic Sub-scenario

Realistic			
Mass Flow	t/d	Costs E/t	Costs for each flow
Biomass	13.75	65	893.75
Restwaste	250.8	120	30,096
Glass	1.1	30	33
Paper	5.5	70-475	385-
Metals (Al) 5%	0.05	945	47.25
Metals (Fe) 95%	1.05	22	23.1
Plastics	2.75	706	1,941.5
		Total Costs EUR	33,619.6-35,647.1