A dissertation submitted to the Department of Environmental Sciences and Policy of Central European University in part fulfilment of the Degree of Doctor of Philosophy

Environmental assessment and policy options for solid waste systems and technologies in Budapest with EASEWASTE

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Author's declaration

No portion of the work referred to in this thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

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ABSTRACT OF DISSERTATION submitted by:
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for the degree of Doctor of Philosophy and entitled: Environmental assessment and policy options for solid waste systems and technologies in Budapest with EASEWASTE.

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The waste management system in Hungary has been fundamentally changed in the last two years. A new Waste Law which in full compliance with the EU Waste Framework Directive will come into force in 2013. A state-owned National Waste Management Agency Nonprofit Ltd. was established to control the flows of specific waste types and to contribute to building a stricter, controllable and more transparent waste management system.

Parallel to these national changes, FKF Zrt., the waste management company of Budapest also has reviewed its activity and examined possibilities for more efficient and environmentally friendly waste management. In this thesis the solid waste management of Budapest has been evaluated focusing on selective waste collection, which must be increased in coming years according to new legislation. The key stakeholders of FKF Zrt. are specifically interested in the impact of waste management on the environment.

This thesis therefore provides numerical answers to the research question of what the nature and capacity for recycling in Budapest is, and what impacts recycling can have on environmental pollution and climate change. This issue had been analyzed with life cycle assessment, which in the new legislation is regarded as a very important tool for decision-making. This thesis applies the EASEWASTE model for life cycle assessment, which hasf authjor never been applied before in Hungary. By request of the author, laboratory samples of three waste generation types (multi family, single family and business units) in Budapest were recorded and classified into 48 categories in a process that represents the most detailed waste composition study to date in Budapest and very likely in Hungary. In most cases life cycle assessment is based on yearly data. In this thesis, however, the analysis was prepared based on the data for each month from 2008-2011 illustrating the trend in selective waste collection and its related changes in environmental impacts.

The interpretation of the results are discussed at the end of the dissertation, and in the conclusion important recommendations have been outlined which suggest pathways for development of the present system to becoming a more efficient and controllable waste management network with lower environmental impacts.

Keywords:
Life cycle assessment, global warming potential, recycling, EASEWASTE, municipal solid waste, environmental impacts, Budapest, FKF Zrt.,

To Flóra

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List of abbreviations

CO_2 - Carbon dioxide

CH_4 – Methane

DTU – Danish Technical University

EASEWASTE - Environmental Assessment of Solid Waste Systems and Technologies

EC - European Commission

EDIP - Environmental Design of Industrial Products (LCA methodology developed by the Danish EPA and DTU, Denmark)

EIA –Environmental Impact Assessment

EU - European Union

EPA – Environmental Protection Agency

FKF Zrt. –Fővárosi Közterület-fenntartó Zrt. (Municipal Public Services Co. Ltd.)

GHG – Greenhouse Gas,

GWP - Global Warming Potential (of greenhouse gases, relative to CO2, over a specified time horizon)

HIR - Hulladék Információs Rendszer (waste information system)

ISPA - Instrument for Structural Policies for Pre-Accession

ISO - International Organization for Standardization

IPCC - Intergovernmental Panel on Climate Change

IWM – Integrated Waste Management

KSH - Központi Statisztikai Hivatal – Central Statistical Office

LCA - Life Cycle Assessment

LCIA - Life Cycle Impact Assessment

LFG – Landfill Gas

LULUCF - Land Use, Land-Use Change and Forestry

MBT - Mechanical Biological Treatment

MF – Multi family

MSW - Municipal Solid Waste

MRF - Material Recovery Facility

NO_x – Nitric Oxide and Nitrogen Dioxide

NH_3 – Ammonia

OHÜ Nonprofit Kft. – Országos Hulladékgazdálkodási Ügynökség Nonprofit Kft. (National Waste Management Agency Nonprofit Ltd.)

OGyHT – Országos Gyűjtési és Hasznosítási Terv (National Collection and Utilization Plan)

RFID – Radio Frequency Identification,

RDF - Refuse Derived Fuel

SCBU – Small commercial and business units

SETAC - The Society of Environmental Toxicology and Chemistry

SF – Single family

SO_2 – Sulfur Dioxide

SWMS – Solid Waste Management System

UNFCCC – United Nations Framework Convention on Climate Change

1 Introduction

"Earth provides enough to satisfy every

man's needs, but not every man's greed."

Mahatma Gandhi

The management of municipal solid waste and the associated environmental impacts are the subject of growing attention in industrialized countries. The European Union has recently strongly emphasized the use and the role of life cycle assessment in its waste and resource strategies. (Bhander *et al.*2010) The development of sustainable solid waste management systems requires readily understandable and user friendly tools for modeling the environmental impacts of different waste management systems. Life cycle assessment – as Hauschild (2006) – emphasizes is a holistic tool because it models all relevant environmental impacts from the global (like climate change and ozone depletion) to the local (like land use) and also the loss of resources. Some LCA analysis has been prepared for a broad scope of waste types such as paper waste (Merrild *et al.* 2008.) or garden, kitchen, or food waste (Bernstad and Jansen, 2011; Boldrin *et al.* 2011. and Hansen *et al.* 2006.) or even specifically for waste management technologies which are mostly focused on incineration (Riber *et al.* 2008.,) or landfills (Manfredi 2010 and Manfredi *et al.* 2010). Several PhD studies have also focused on this issue, such as environmental assessment and LCA of contaminated site remediation (Lemming 2010.). The life cycle assessment of solid waste management systems has never been used before in Hungary and in the light of the argumentations mentioned above it is considered as highly interesting and spotlight topic nowadays.

This thesis focuses on Budapest municipal solid waste, as in the Hungarian capital selective waste collection rates are fairly low and not compliant with EU requirements. First the selective waste collection system must be analyzed and evaluated in detail due to the reason that selective waste collection rates must be dramatically increased and will be compulsory from 2015. One of the main paths of the present changes in the waste management sector is to avoid waste landfilling and support recycling. This thesis therefore discusses the environmental pollution of the present municipal waste management system in Budapest with high regard to the selective waste collection. During the LCA evaluation the thesis numerically answers the research question: what is the nature and capacity for recycling in Budapest and its impacts on environmental pollution including climate change.

For the analysis, by request of the author, a detailed waste composition study was made for 48 waste fractions, which have never been prepared in Budapest so far. The research data is unique because they author has obtained data for the total waste amounts as well as the selective waste amounts for every month between 2006 and 2011. As a consequence, the comparison of the selectively collected and not selectively collected waste and the waste LCA analysis for the different months is also possible. This is the proper way to demonstrate the trends in the selective waste collection and to show the consequences of the different decisions. Through this format it becomes possible to draw correlation between the rate of the selective waste collection and the environmental impacts including global warming.

The structure of the research is the following: a short background describes the originality of the research and the introduction of the EASEWASTE model as well as basic information on the present municipal solid waste management legislation in the EU as well as in Hungary. Later, the document shows the research question and the research objectives that include qualitative policy and quantitative measures as well.

Naturally, every waste management system has a significant adverse impact on the environment and through the proposed environmental assessment it can be quantified which technological elements have impacts and also what type of impacts the elements have on the environment. The main research objective therefore is to prepare an environmental assessment analysis of Budapest waste management system both for the current system and for different scenarios, and to discuss the findings with the key stakeholders. The research then continues with the theoretical framework and a description of the methodology that is necessary to reach the objectives. The Budapest waste management LCA research discusses later the present system with high attention to the selective waste collection and its impact on the environmental issues. The results of the research are also discussed in detail, along with a short description of the conclusions, followed by limitations and recommendations.

In Hungary the waste management system has been utterly changed since 2010. Hungary implemented a new Waste Law beginning on 1 January 2013, and additionally the new

National Waste Management Plan is under preparation at the moment. In Hungary the newly established National Waste Management Agency Nonprofit Ltd. is taking over the tasks from the coordinating companies and among other responsibilities this state owned agency controls common waste flows such as packaging waste, tires, WEEE, car batteries etc. This research is highly important and relevant for developing a more transparent and controllable system which can be initiated in the new waste management system in Hungary.

The purpose of this paper is to help local decision-makers and strategy planners by enlightening them regarding the environmental impact results of potential higher selective waste collection rates. Although during LCA case studies in other countries several waste management scenarios have been analyzed and compared (Koci V. and Trecakova T. 2011; Güereca *et al.* 2006; Merrild *et al.* 2012. and Miliūtė 2009.) this research does not particularly focus on different scenarios but rather focuses on scenarios based on a number of different selective collection rates. The paper reveals several methodology-related issues and discusses what waste-related policy intervention is necessary to improve the present management system.

2 Background of the research

Hungary is part of the European Union, and because of this it is expected that legislation is shared. This premise is the basis for the environmental protection improvements, acknowledging the fact that the European Union takes waste management and global warming very seriously. The waste management system has gone through a history of shifting problems, demands, and strategies over the years and now waste is viewed as a problem ranging from local to global concern. Increased environmental consciousness as well as the more regional or global focus on the waste management sector highlights the potential possible solutions for this complex issue. It is commonly accepted in the international and Hungarian waste management legislative systems that waste can cause serious environmental and human damage, and because of this proper treatment is mandatory. Nowadays there are many technologies in which waste production is minimal or even some production arrangements where at the processing stage the waste itself is circulated back to the technology so actually no waste is produced.

In Hungary to date this study would be the first life-cycle-assessment (LCA) research focusing on solid waste management of a public service provider in this detailed level covering several years. The environmental assessment is based on the obtained data, and highlighting the selective waste collection. Meanwhile the LCA will be prepared by the EASEWASTE model. Life cycle assessment methods are becoming more integrated to waste management research and decision making. In the majority of European countries, particularly in Scandinavian countries as well as in Germany, Austria and the

Netherlands, LCA is expected to be regarded as a supporting tool for decision making (Helias A. 1999.). The EU has introduced this concept in the Thematic Strategy on the prevention and recycling of waste (EC, 2005a), the Thematic Strategy on sustainable use of resources (EC, 2005b) and more recently in the European Waste Framework Directive (EC, 2008), which all have been fully transposed in Hungarian legislation. LCA-modeling is now used for decision support in terms of the waste management systems in several countries.

Life-cycle assessment (LCA) models are becoming important decision support tools of waste management systems. This paper describes our experience with the use of EASEWASTE (Environmental Assessment of Solid Waste Systems and Technologies), a new computerized LCA-based model for analyzing the Budapest waste management system. Our findings provide a quantitative evaluation of the environmental impacts of the different selective waste collection methods within the waste management systems and may reveal consistent approaches for improving their environmental performances.

2.1 Originality of the research – the EASEWASTE model

The correlation between the waste management sector and greenhouse gases has been analyzed by several studies already. Hungary has already reported GHG emissions from solid waste management to the UNFCCC and emissions of SO_2, NH_3, etc. emissions to Convention on Long-range Transboundary Air Pollution and made a study on GHG emissions from landfills. However, in spite of these reports, a comprehensive analysis has not been prepared which would be able to quantify the different environmental impacts (such as global warming) from the current solid waste management system. The Danish Technical University recently developed the EASEWASTE software and this technology has only been applied in a few countries to date. The aim of the EASEWASTE model is to provide an understanding of the ecological (environmental) issues involved in waste management systems, and the capacity of life cycle assessment techniques. As Bhander *et al*. (2010.) claimed, the model reports data at all of the LCA stages and an overall sensitivity analysis, weighting, normalization and material balances for all substances found in the system. The EASEWASTE model consists of a number of modules that reflects the real waste management system, and these modules altogether represent a scenario. EASEWASTE includes data on emissions of each chemical (inventory), and as a result of serious laboratory measurements these characteristics are translated and aggregated into different environmental impact categories, e.g. the global warming, acidification, and toxicity. As Kirkeby (2007) mentions the model is a framework in which the individual user can define all necessary data for waste composition, collection, treatment, recovery and disposal and through this process the user can establish a new database. The model also requires life cycle inventory data for materials and energy used in the waste management system. EASEWASTE provides a versatile system modeling facility, and in addition to the traditional impact categories it addresses toxicity-related categories as well. New categories such as stored ecotoxicity and spoiled groundwater resources have been integrated. EASEWASTE has been applied in several studies, including full-scale assessments of waste management in Danish and other municipalities worldwide. This scientific research has led to numerous modeling areas of focus such as the importance of waste prevention, recycling versus incineration, and analyzing the recycling efficiency of different waste types.

According to Bhander *et al.* (2010) this model was developed because to date, no other existing solid waste LCA models have achieved the following at the same time:

- flexibility to model and modify the different waste management processes,
- to describe and document data and calculation methods,
- to be transparent in calculations and assumptions,
- to be user-friendly and make results easily comprehendible and
- to include a full life cycle impact assessment method to calculate potential environmental impacts and resource consumption.

By using the model it is easy to identify the most important pollution sources in the different impact categories. The model calculates waste flow, resource consumption and environmental emissions from waste management systems and provides a complete life cycle assessment with the following environmental impacts: global warming, ozone depletion, photochemical ozone formation, acidification, nutrient enrichment, ecotoxicity and human toxicity. The model furthermore has introduced two impact categories: Spoiled Groundwater Resources and Stored Toxicity. (Christensen *et al.* 2007)

Potential impact categories included in EASEWASTE are the following:

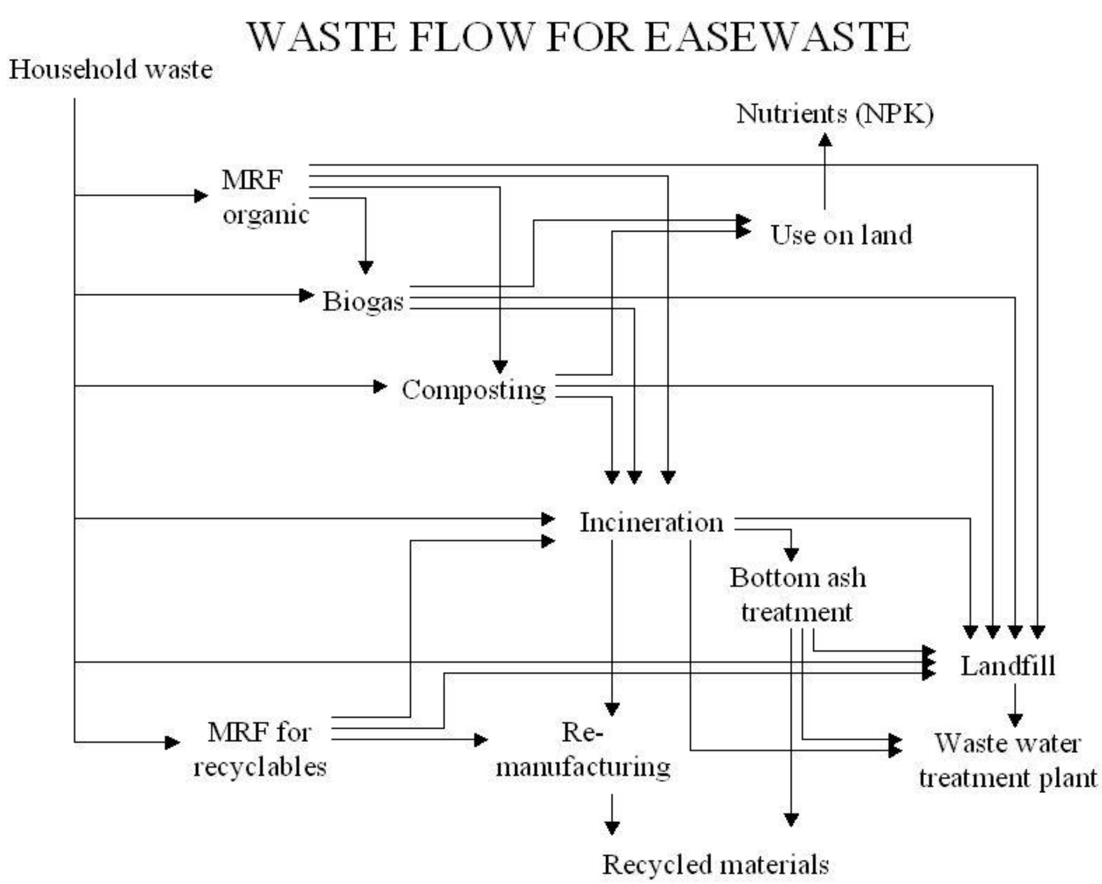
Potential Impact Category	**Acronym**	**Unit**	**Physical basis**
Global Warming, 100 years	GW100	kg CO_2-eq. /person/yr	Global
Photochemical Ozone Formation	POFI	kg C_2H_4-eq. /person/yr	Regional
Ozone Depletion	OD	kg CFC-11-eq./person/yr	Global
Acidification	AC	kg SO_2-eq. /person/yr	Regional
Nutrient Enrichment	NE	kg NO_3^--eq. /person/yr	Regional
Human Toxicity, soil	HTs	m^3 soil /person/yr	Regional

Human Toxicity, water	HTw	m^3 water /person/yr	Regional
Human Toxicity, air	HTa	m^3 air /person/yr	Regional
Ecotoxicity, soil	ETs	m^3 water /person/yr	Regional
Ecotoxicity, water chronic	ETwc	m^3 water /person/yr	Regional
Spoiled Groundwater Resources	SGWR	m^3 water /person/yr	Local

1. Table Potential environmental impact categories in EASEWASTE

Source: Christensen. T.H *et al.* 2007.Experiences On The Use Of LCA-Modeling (EASEWASTE) In Waste Management and Research

Figure 1.shows the possible routes in EASEWASTE for treatment, recovery and disposal of the different municipal solid waste types (Kirkeby et al 2006).



1. Figure Possible waste flows in EASEWASTE

Source: own contribution based on Kirkeby *et al.* 2006

Besides the waste processes (collection, transport, treatment, recovery and disposal) the model also includes external energy and raw materials that are consumed in the system. In case of the material recycling the replaced external production of similar material or energy is also taken into account in the calculations. Therefore, the avoided external productions are presented as negative pollution leading to avoided emissions.

The EASEWASTE software includes 48 different types of waste fraction (Kirkeby *et al.* 2006.) and these can be seen in Table 2. It is a very detailed category compared to Hungary whereas we generally use 11-12 general waste types (see more detailed at the discussion of the Hungarian and Budapest solid waste management system).

No.	Material fraction	No.	Material fraction
1	Vegetable food waste	25	Wood
2	Animal food waste	26	Textiles
3	Newsprints	27	Shoes, leather
4	Magazines	28	Rubber etc.
5	Advertisements	29	Office articles, plastic products
6	Books and phonebooks	30	Cigarette buts
7	Office paper	31	Other combustibles
8	Other clean paper	32	Vacuum cleaner bags
9	Paper and cardboard containers	33	Clear glass
10	Other cardboard	34	Green glass
11	Milk cartons and alike	35	Brown glass
12	Juice cartons with aluminium foil	36	Other glass
13	Other dirty paper	37	Aluminium containers
14	Other dirty cardboard	38	Aluminium trays and foil
15	Kitcen tissues	39	Metal foil (Al)
16	Soft plastic	40	Metal containers (Al)
17	Plastic bottles	41	Other of metal
18	Other hard plastic	42	Soil
19	Non-recyclable plastic	43	Rocks, stones and gravel
20	Yard waste, flowers etc.	44	Ash
21	Animals and excrements	45	Ceramics
22	Napkins and tampons	46	Cat soil
23	Cotton stick etc.	47	Other non-combustibles
24	Other cotton etc.	48	Batteries

2. Table: **The 48 different waste fractions in EASEWASTE**

Source: own contribution based on Kirkeby et al 2006

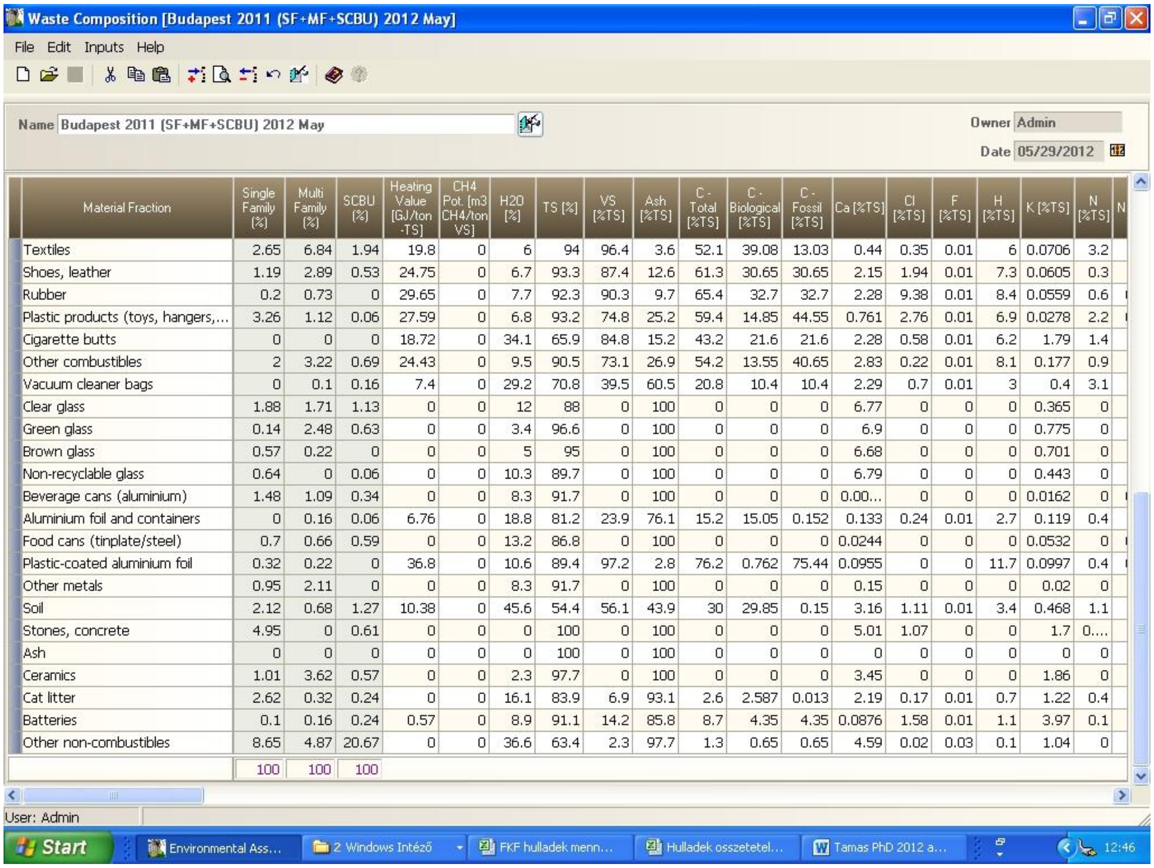
EASEWASTE was developed after several years of laboratory research at the Danish Technical University and is the product of the high level expertise and experience of the Danish faculty. Waste composition is limited to 48 material fractions and to these waste types 40 physical and chemical properties are connected (Kirkeby *et al.*2006.) which adds to this format's acceptance as a very detailed and unique analysis.

No.	Parameter	No.	Parameter
	Heating value [MJ/kg TS]	19	Al
	Methane potential [Nm3 CH4/ton VS]	20	As
1	H2O	21	Br
2	TS	22	Cd
3	VS	23	Cr
4	COD	24	Cu
5	fat	25	Fe
6	protein	26	Hg
7	fibers	27	Mg
8	C-tot	28	Mn
9	Ca	29	Mo
10	Cl	30	Ni
11	F	31	Pb
12	H	32	Sb
13	K	33	Se
14	N	34	Zn
15	Na	35	DEHP
16	O	36	NPE
17	P	37	PAH
18	S	38	PCB

3. Table: **Chemical composition for each material fraction in EASEWASTE**

Source: own contribution based on Kirkeby *et al.* 2006

The chemical properties of the material fractions can be followed in the model during the steps of the waste management scenario evaluation. The chemical characteristics have been developed through several years of detailed laboratory analyses.



Material Fraction	Single Family [%]	Multi Family [%]	SCBU [%]	Heating Value [GJ/ton -TS]	CH4 Pot. [m3 CH4/ton VS]	H2O [%]	TS [%]	VS [%TS]	Ash [%TS]	C - Total [%TS]	C - Biological [%TS]	C - Fossil [%TS]	Ca [%TS]	Cl [%TS]	F [%TS]	H [%TS]	K [%TS]	N [%TS]
Textiles	2.65	6.84	1.94	19.8	0	6	94	96.4	3.6	52.1	39.08	13.03	0.44	0.35	0.01	6	0.0706	3.2
Shoes, leather	1.19	2.89	0.53	24.75	0	6.7	93.3	87.4	12.6	61.3	30.65	30.65	2.15	1.94	0.01	7.3	0.0605	0.3
Rubber	0.2	0.73	0	29.65	0	7.7	92.3	90.3	9.7	65.4	32.7	32.7	2.28	9.38	0.01	8.4	0.0559	0.6
Plastic products (toys, hangers,...	3.26	1.12	0.06	27.59	0	6.8	93.2	74.8	25.2	59.4	14.85	44.55	0.761	2.76	0.01	6.9	0.0278	2.2
Cigarette butts	0	0	0	18.72	0	34.1	65.9	84.8	15.2	43.2	21.6	21.6	2.28	0.58	0.01	6.2	1.79	1.4
Other combustibles	2	3.22	0.69	24.43	0	9.5	90.5	73.1	26.9	54.2	13.55	40.65	2.83	0.22	0.01	8.1	0.177	0.9
Vacuum cleaner bags	0	0.1	0.16	7.4	0	29.2	70.8	39.5	60.5	20.8	10.4	10.4	2.29	0.7	0.01	3	0.4	3.1
Clear glass	1.88	1.71	1.13	0	0	12	88	0	100	0	0	0	6.77	0	0	0	0.365	0
Green glass	0.14	2.48	0.63	0	0	3.4	96.6	0	100	0	0	0	6.9	0	0	0	0.775	0
Brown glass	0.57	0.22	0	0	0	5	95	0	100	0	0	0	6.68	0	0	0	0.701	0
Non-recyclable glass	0.64	0	0.06	0	0	10.3	89.7	0	100	0	0	0	6.79	0	0	0	0.443	0
Beverage cans (aluminium)	1.48	1.09	0.34	0	0	8.3	91.7	0	100	0	0	0	0.00...	0	0	0	0.0162	0
Aluminium foil and containers	0	0.16	0.06	6.76	0	18.8	81.2	23.9	76.1	15.2	15.05	0.152	0.133	0.24	0.01	2.7	0.119	0.4
Food cans (tinplate/steel)	0.7	0.66	0.59	0	0	13.2	86.8	0	100	0	0	0	0.0244	0	0	0	0.0532	0
Plastic-coated aluminium foil	0.32	0.22	0	36.8	0	10.6	89.4	97.2	2.8	76.2	0.762	75.44	0.0955	0	0	11.7	0.0997	0.4
Other metals	0.95	2.11	0	0	0	8.3	91.7	0	100	0	0	0	0.15	0	0	0	0.02	0
Soil	2.12	0.68	1.27	10.38	0	45.6	54.4	56.1	43.9	30	29.85	0.15	3.16	1.11	0.01	3.4	0.468	1.1
Stones, concrete	4.95	0	0.61	0	0	0	100	0	100	0	0	0	5.01	1.07	0	0	1.7	0....
Ash	0	0	0	0	0	0	100	0	100	0	0	0	0	0	0	0	0	0
Ceramics	1.01	3.62	0.57	0	0	2.3	97.7	0	100	0	0	0	3.45	0	0	0	1.86	0
Cat litter	2.62	0.32	0.24	0	0	16.1	83.9	6.9	93.1	2.6	2.587	0.013	2.19	0.17	0.01	0.7	1.22	0.4
Batteries	0.1	0.16	0.24	0.57	0	8.9	91.1	14.2	85.8	8.7	4.35	4.35	0.0876	1.58	0.01	1.1	3.97	0.1
Other non-combustibles	8.65	4.87	20.67	0	0	36.6	63.4	2.3	97.7	1.3	0.65	0.65	4.59	0.02	0.03	0.1	1.04	0
	100	100	100															

2. Figure Sample for the chemical properties of the waste types

From these chemical characteristics which are connected to the individual waste composition several features clearly can be seen, for instance that glass waste has no C content at all.

As it is illustrated in this figure, the waste amount and waste composition as well as the technological data together with the relevant chemical characteristics of the waste influences the output data including the environmental emissions.

As Kirkeby *et al.* (2007.) pointed out the model includes the following processes:

- Source separation

- Collection and transport
- Mechanical treatment and MRF’s
- Biological treatment (aerobic and anaerobic)
- Use of compost and biomass on land
- Thermal treatment
- Bottom ash treatment
- Landfilling
- Remanufacturing of paper, glass, plastic, metals etc.

The model uses life-cycle assessment and thus includes potential environmental impacts from internal as well as external processes, which are the following:

External processes

- Electricity generation
- Fuel combustion for thermal energy,
- Materials, input and output

Scenarios

According to the given data for waste amount and composition, waste collection, waste transportation and waste treatment and disposal, various scenarios can be made. As Kirkeby (2006) describes in the User Manual (2011) for the EASEWASTE model the preparation and running of a scenario usually involves the following background steps:

1. Life cycle inventory of substances, resources and emissions

2. Material flow: The model calculates all solid waste masses entering and leaving the process, which will be products or residues.
3. Output composition: The model calculates the composition of the outputs from each treatment process. These environmental impacts are expressed in equivalents or m3 water, soil or air.
4. Impact Potentials can be related to substances or to processes and can be sorted according to magnitude. A sensitivity ratio can be calculated at this level.
5. All categories of environmental impact and resource consumption are assigned the same unit (Person Equivalents, PE) and thereby made comparable. Furthermore, the user can choose to assign a weight to each category if they are of unequal importance. Environmental impacts are weighted by political reduction targets, and resources are weighted by their supply horizon.
6. Normalization converts the Impact Potentials into person-equivalents. The normalized impacts can be related to substances or to processes and can be sorted according to magnitude. Person equivalents are defined as the impact of one person in a reference year.
7. A sensitivity ratio shows the sensitivity of the model according to one small variable.
8. Weighting introduces a political weight on the normalized impact potentials, so this step expresses person equivalents defined as the politically targeted impact of one person in a year. These weighted values can be related to substances or to processes and can be sorted according to magnitude.

9. The final results may be expressed graphically or can be transported into an Excel table.

Before starting an LCA it is very important to define the "functional unit," which is related to the function that a product or service will deliver. The definition of a functional unit is actually very much linked to the question asked, as there may be several functional units depending on the type of questions we want to answer. Energy and raw materials consumption as well as associated environmental emissions are calculated on the basis of this functional unit.

Impact assessment

The impact assessment method aggregates inventory data into a select number of environmental impact categories which quantifies the environmental burdens as well as resource consumption. In the results the positive value means pollution, whereas negative potential impacts means savings to the environment, as it is represented in every LCA evaluation.

As Christiensen *et al.* (2007) pointed out EASEWASTE has already been applied in the following areas:

- several full scale assessments of waste management in Danish municipalities (Herning, Århus) as well as in other countries,
- in comparison of technologies (landfill, incineration),
- in assessing material fraction management (paper, wood waste) and
- in comparison of models for specific applications (for example land-use of compost).

The model includes process-specific as well as in-put-specific emissions, as Christiensen *et al.* (2007) emphasized, so not only the emissions that occur due to the waste management process can be counted but also the in-put-specific emissions which are originating directly from substances in the waste (e.g. ammonium volatilization during composting or mercury in the flue gas from incineration).

EASEWASTE is designed to compare different waste management strategies, technologies, methods, and identify significant pollution sources. It can be used to optimize waste management systems and for setting guidelines and regulations and to evaluate strategies for handling of waste.

Comparison with other waste management LCA models

Naturally, there are varying models which are suitable for the LCA evaluation of waste management models in addition to EASEWASTE. Waste LCA tools have been developed in previous years and during this time consequent models have benefited from the lessons learnt from those previous. Some of these models are outdated currently, or some were developed for use by private companies, or were proven to have utilized bad hypotheses. The ORWARE model was designed for organic waste, the WRATE model uses 150 waste management technologies therefore its value is really significant. The following models were developed by different countries throughout the past few decades. The solid line next to the name of the model means the active development phase and launch of subsequent versions of the same model, whereas the dotted line indicates the research which leads to the development phase or the phase meaning not too active development, such as use of the model as a research tool.

Name	Country	1994	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09
MIMES	Sweden																
ORWARE	Sweden																
LCA-LAND	Denmark																
MSWI	Germany																
ARES	Germany																
EPIC-CSR	Canada																
ISWM DST	USA																
WISARD	UK, Fr, N.Z,																
IWM2	UK																
SSWMSS	Japan																
LCA IWM	EU																
WAMPS	Sweden																
HOLIWAST	EU																
WRATE	UK																
EASEWASTE	Denmark																

4. Table Different waste management LCA models in the last years

Source: Gentil *et al.* 2010. Models for waste life cycle assessment: Review of technical assumptions

In some models information is not really adequate or has not been presented in English (pl. ARES, WAMPS, HOLIWAST, SSWMSS, LCA-LAND, MIMES and MSWI).

The EASEWASTE model – Environmental Assessment of Solid Waste Systems and Technologies represents a high level of credibility, has a large number of scientific publications supporting its findings.

Unlike most other models available, EASEWASTE provides a very detailed analysis for the following status: landfilling, use-on-land, utilization of materials and recycling. Landfilling is also one of the most difficult parts of the system because landfills can have long time pollutants while unfortunately significantly lack data representing these prolonged time horizons.

Above all it consists of several options, is user friendly, and can be used in different languages. It is also of note that the technical calculations are transparent and explained in the technical manual.

Potential users

EASEWASTE can be used for many different purposes for the following potential users (EASEWASTE webpage 2009) for instance:

Municipalities and waste management authorities

- Evaluate new waste management options, new technologies or new collection systems, etc.
- Test improvements in the different technologies such as better leachate treatment,
- Assess environmental consequences of new public services.
- Greenhouse gas accounting, showing environmental loads as well as savings, from energy recovery and material recycling.

Consultants

- Environmental assessment of different waste management options.
- Improvement potentials of the environmental aspects in existing waste management systems.

Technology providers

- Assessment of development potentials such as increased electricity consumption versus improved flue gas cleaning.

Service providers

- Present the more comprehensive structure of the environmental data of services provided.
- Assessment of recycling schemes, collection systems etc.

Researchers

- Analysis on which waste management technologies contribute to environmental loads and savings.

The LCA methodology and a model like EASEWASTE are very suitable for evaluating the overall environmental consequences and can be used for decision support and strategic planning as well. This decision support tool can specifically be used in a country like Hungary where pollution control has become increasingly important with respect to the terms of the European Union legislation. In Budapest, the amount of waste generation has been significant in the past years and the waste management system can be developed with stricter environmental policy and the increasing public awareness.

3 Research question, assumptions, objectives and outcomes

The aim of this research is to contribute to a more efficient waste management system in Budapest with high regard to the waste hierarchy defined in the Waste Framework Directive. In the waste hierarchy, waste prevention, re-use, and recycling are supported activities while thermal treatment is an acceptable solution. Waste landfilling is accepted to be the least appropriate disposal method. Therefore, in this thesis the present selective waste collection system is evaluated in detail which will be compulsory from 2015 in Hungary.

This research aims to analyze the impact of solid waste management on the different environmental impact categories, including global warming potential, as this was desired by the main stakeholders of FKF Zrt. Through a life cycle assessment, a determination of the exact numerical values of the different environmental impacts which are generated by the potential higher waste recycling rates is provided.

3.1 Key research question

For the detailed analysis of the selective waste collection and its related environmental impacts this study has identified the following research question, according to the discussion with the environmental leaders of FKF Zrt.:

What is the nature and capacity for recycling in Budapest and its impacts on environmental pollution including climate change?

This research therefore analyses the characteristics of waste recycling in Budapest and includes higher potential recycling rates and so determines related environmental impacts, particularly global warming potential. In Budapest, the rate of the selective waste collection is relatively small (around 1-2% by waste types in the years of 2006-2011, whereas in some other EU countries reaching 50% for some fractions is not unrealistic). As it is described in this thesis this rate has not been increased significantly since 2006, which is the earliest date where relevant data was provided to this research. However, due to an EU co-financed project the door-to-door collection of selective waste will be increased from 2013 gradually in Budapest and collection will be mandatory in Hungary from 2015. Based on the above, the improvement areas for the selective waste collection is accepted to be more important than comparing the present system with any other technological option (gas motor, second incinerator or transfer station) which implementation is not in the agenda for the near future.

3.2 Research assumptions

Assumption 1.

It is assumed that environmental pollution can be evaluated in more detail if several months and years are analyzed instead of one year.

Assumption 2.

This research assumes that the data and information given to prepare the EASEWASTE model is sufficient, proper, correct and realistic. However, for many cases if possible, it is necessary to double check them.

Assumption 3.

It is assumed that the waste generation per capita is different in the case of multi family, single family and small commercial and business units (SCBU) cases. During the discussion of waste amount and waste composition it has been described in detail.

Earlier the No. 1 assumption was that Hungary is eager to reach European Union targets (particularly in terms of the packaging waste). However, later changes in the Hungarian structure and legislation resulted in the preparation of the National Waste Collection and Utilization Plan, so obligatory recycling rates are included in this official document. Therefore, during preparation of this thesis this assumption has been changed.

3.3 Research objectives

Overall aim: To prepare the environmental assessment and policy options for the present and expected municipal solid waste management systems of Budapest. This research will use the EASEWASTE model for this assessment. According to the results of the different scenarios in the environmental assessment, a discussion with the key stakeholders about their perspective and preferred options will be made.

Objective 1.

To acquire the necessary inputs which are required for modeling the Budapest solid waste system. Based on the necessary data, the author is able to prepare the LCA evaluation for the different months and observe the trend in related environmental impacts, whereas other LCA research focuses on a single year individually. During the collection of the necessary inputs a detailed waste composition was provided at the request of the author for 48 waste types, an analysis which has never been analyzed in such detail in Budapest previously. In addition the author's own contribution is a draft map of Budapest waste collection points.

Objective 2.

Determine the major desirable alternatives acknowledging higher recycling, rates and run the EASEWASTE model for them.

Earlier former objective 2 was to determine the major desirable alternatives from both technological and managerial standpoint of the current system and to run the EASEWASTE model both for the alternatives and for the present system. However, after the discussions with the main decision-makers this objective was modified as the research focuses on the selective waste collection, so alternatives were chosen to be the different imaginary higher recycling rates. Accordingly, the related environmental impacts and not the technological alternatives were calculated.

Objective 3.

Discuss the findings with the key stakeholders, aiming to determine their perspectives and preferred options. When discussions occurred the key stakeholders identified that the preferred options are higher recycling rates, so according to their request these options had been evaluated.

In spite of the unfolding transnational debates on environmental pollution (including toxicity, acidification, global warming, and waste management) and as a result of the concentrated European Union policy making the diminishing role of nation-states in policy making, the role of national levels and states in policy translation has been found to be highly influential. States remain the main actors, and the legislative activity is directed by the state in Hungary. Therefore the policy decisions which determine the direction of Budapest solid waste management are not only depending on the Budapest Council, but strongly affected by the European Union and the Hungarian Government. Apart from the national level, the role of individuals has also been crucial in order to comply with the strict European Union regulations in terms of waste management.

3.4 Expected outcomes

Based on the above research assumptions and aims, this research is expected to produce the following outcomes. Outcomes of the research can be divided into theoretical as well as practical outcomes. The most important result of this research is produced by the fact that life cycle assessment modeling of solid waste systems has never been prepared in Hungary and it is Budapest who will have this waste LCA evaluation first. The research may help to understand the basic waste collection, transport, and treatment and disposal system of the FKF Zrt. The research results will contribute to understanding what factors motivate Budapest waste management system policy.

<u>Theoretical outcomes shall be:</u>

The research is expected to contribute to our understanding of

- How the deeper analysis of environmental and resource impacts will support identification of the main sources of impact and the main sources of resource loss.
- How the evaluation contributes to assess and to identify focus points for improvement of the existing system from an environmental perspective.
- With the developed model it will also be easier to assess the improvement achieved by different alternative system layouts that may be developed to improve the current level of impacts.
- Based on the result the environmental life cycle assessment we can determine the main pollution sources and the causing factors respectively.

This research will have practical outcomes as well. The waste amount, composition, as well as the waste collection system will be analyzed in detail with high regards to the importance of the selective waste collection. The rate of the selectively collected and not selectively collected waste fractions will be evaluated in detail at every single waste type. The operation of the collection vehicles and its consumption will also be analyzed.

<u>Practical outcomes shall be:</u>

The research will include the environmental assessment analysis of Budapest's waste management systems with life cycle assessment. An analysis of this type has never been performed, and it gives answers to the following questions:

- The comparison of the selectively collected waste and the potentially collectable waste fractions, which are unfortunately disposed of

- How recycling operates in Budapest, and which method collects the most recyclable waste
- My own contribution (for instance special waste composition, which has not been prepared to date in Budapest as well as the analysis for the consecutive months which is also unique. Additionally a map on the waste islands and waste yards)
- What is the environmental assessment both of the current system and the proposed alternatives
- Which environmental impact is the highest and from what waste management technology

Based on this research important policy and technological options are suggested, which have already been discussed with the main key stakeholders and decision makers regard to the FKF Zrt. waste management system. Finally in the conclusion, the limitations as well as even recommendations for future research will be discussed.

4 Literature review

The main aim of this chapter is to disclose the essential scientific background and interlinkages of environmental assessment and solid waste management processes from the relevant literature in order to provide a selection of the life cycle assessment publications and to prove that these are significant issues to tackle for the future.

Key insights include the variety and diversity of successful waste management models – there is no ‘one size fits all’ solution. As the scientific articles in the literature review have warned and Wilson *et al.* (2012.) points out, it can be determined that during the evaluation of a solid waste management system one of the major constraints is the lack of reliable and consistent data.

4.1 Introduction

The literature review gives a short picture on the main characteristics of the waste management system, while a proper, integrated and sustainable waste management system will be evaluated in this thesis. From the literature review it can be clearly determined that the EASEWASTE model has proved to be a suitable, flexible and robust tool to support decision-making in the waste management sector.

If waste becomes a resource which can be used as a raw material again within the economy, then much higher priority needs to be given to re-use and recycling. A combination of policies would help create a full recycling economy, such as product design integrating a life-cycle thinking approach, better collection processes, appropriate regulatory framework, and incentives for waste prevention and recycling, as well as public awareness.

4.2 Life cycle assessment in the EU regulation

Life cycle assessment has become more important in decision making processes and strategy planning. Recently, there has been a major attention given to LCA computer-aided tools, because LCA provides a holistic approach that is increasingly utilized nowadays for solid waste management, as it can compare the environmental impacts of different scenarios. As Abeliotis *et al*. (2009) stated:”LCA can be categorized as a hybrid approach since it utilizes equations for inventory analysis and recycling loops on the one hand, while on the other it requires expertise input for impact assessment and characterization”.

The European Commission has revised the Waste Framework Directive and as a consequence of this revision life cycle thinking become much more important. There are several tools for analyzing environmental effects of waste systems and from these tools one has to determine the field of interest and the type of system to be studied. Thinking in global terms and through the comparison and analyzation of different waste management systems have much attention has been directed towards the development of waste management in the recent years.

The Waste Framework Directive (2008/98) states the following:

- par 8. “necessary to introduce an approach that takes into account the whole life-cycle of products and materials and not only the waste phase, and to focus on reducing the environmental impacts of waste generation and waste management,”

- par 9. „the environmental impacts of waste generation and waste management more sharply into focus throughout the life-cycle of resources”
- par. 27 „The introduction of extended producer responsibility in this Directive is one of the means to support the design and production of goods which take into full account and facilitate the efficient use of resources during their whole life-cycle including their repair, re-use, disassembly and recycling without compromising the free circulation of goods on the internal market.”

This is illustrated in the European Union’s thematic waste strategies in which life-cycle thinking and life-cycle analyses are mentioned as really important tools (EC 2005d). This concept is emphasized in the Thematic Strategy on the prevention and recycling of waste (EC, 2005a), and the Thematic Strategy on sustainable use of resources (EC, 2005) and more recently in the European Waste Framework Directive (EC, 2008).

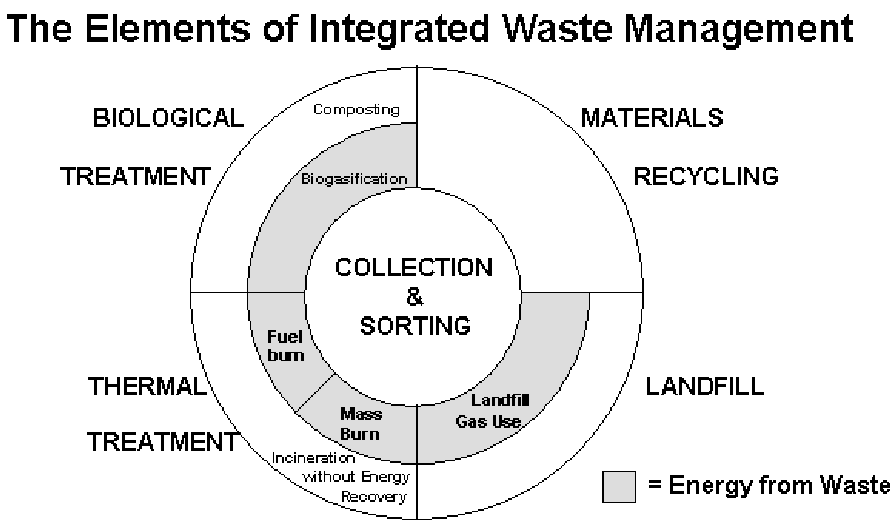
As Gentil (2011) claimed, the fundamental objective of these thematic strategies is to help Europe to become a “recycling society” through increased waste prevention and the sustainable use of natural resources. These two interlinked European strategies have basic implications for the evolution of the European waste management, as they are the driving forces behind the simplification and modernization of existing waste legislation. These strategies have already introduced life-cycle thinking into waste policy.

4.3 Integrated waste management

In the past, waste management systems consisted primarily of waste collection and disposal at a local landfill, however the waste management systems today are often complex and highly integrated systems that include raw material savings, prevention, material recovery, recycling, composting, combustion, and other processing steps as well as landfilling at the end.

Integrated Waste Management (IWM) represents a holistic approach to the entire solid waste system. Integrated Municipal Solid Waste (MSW) management is a tedious task requiring the simultaneous fulfillment of technical, economic and social constraints, meaning that it combines the environmentally effective, economically affordable and socially acceptable methods of waste treatment (McDougall *et al.* 2001).

The following figure represents the concept and the elements of the Integrated Waste Management (IWM). The IWM picture demonstrates that proper collection and sorting are at the center of any successful waste management system. The four main waste management technologies – such as materials recycling, biological treatment, thermal treatment and landfilling - are shown as equally important. Data based decision support using Life Cycle Assessment tools facilitates the selection of the most appropriate waste management technologies which are needed to deliver an environmentally optimized IWM system. The elements of the integrated waste management are as follows:

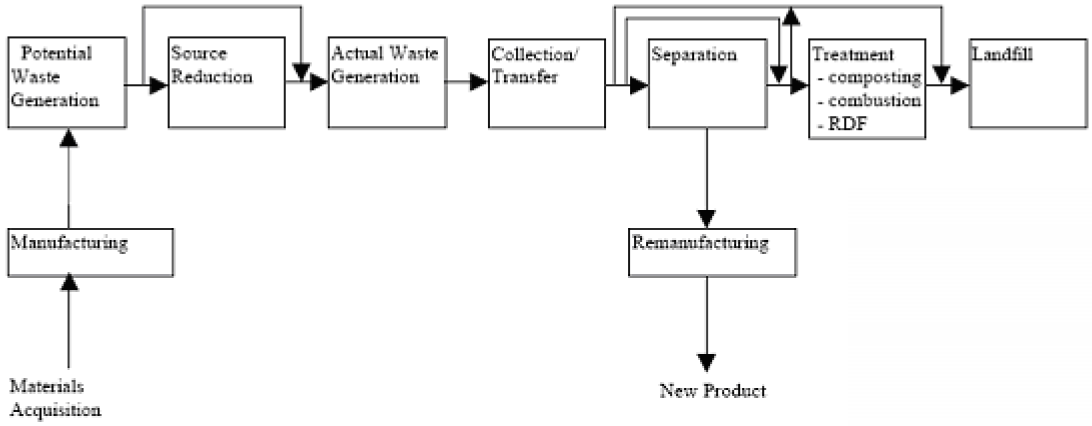


3. Figure The elements of the integrated waste management

Source: McDougall *et al.* 2001

As McDougall (*et al.* 2001) emphasizes, along with the overall requirement for sustainable waste management, it is clear that a single treatment method is not sufficient to manage all materials in Municipal Solid Waste (MSW) in an environmentally effective way. Following a suitable collection system, a range of treatment options is necessary.

A waste management system includes different technological processes and all of them must be taken into account in the life cycle system. Therefore the functional elements of the life cycle assessment of municipal solid waste management alternatives according to Barlaz M.A. and Weitz K.A. (1995) can be followed in the following figure:



4. Figure Functional elements of the Life Cycle Assessment of municipal solid waste management alternatives.

Source: Barlaz M.A. and Weitz K.A. 1995

All of them together form an Integrated Waste Management (IWM) system. IWM systems can be optimized using the tool of Life Cycle Assessment. In summary, to ensure sustainable development regarding solid waste management three areas of focus have been identified (Francke and McDougall, 1999; Kirkeby 2005):

1. Environmental sustainability
2. Economical sustainability
3. Social acceptance

Waste managers need to create systems that are economically affordable, socially acceptable and environmentally effective.

- Economic affordability means that the costs of waste management systems are acceptable to all key stakeholders including the inhabitants (waste fee), commerce, industry, institutions and government.

- Social acceptability occurs when the needs of the local community are fulfilled, and the waste management system reflects the values and priorities of the community.
- Environmental effectiveness requires that the environmental load of the waste management system is mitigated, in resource consumption as well as in environmental emissions to air, water and land.

Only the issue of environmental sustainability is analyzed in this PhD thesis. Environmental sustainability has been defined by the Brundtland report as: ”*…development that meets the needs of the present without compromising the ability of future generations to meet their own needs*” (World Commission on Environment and Development, 1987).

The total LCA for a waste management system according to (Clift *et al.*, 2000) can be calculated as the following:

+ means environmental emission from the waste management activities

– avoided emission associated because of production of materials and energy.

Negative burdens indicate an avoided impact, when the benefits of production of materials and energy are stronger than the environmental load from the waste management system. (Kirkeby 2005).

However, it is very important to reinforce that LCA analysis does not take into account the social acceptance, nor the economic background, so life cycle assessment predominantly concentrates on the environmental assessment. Economic, social and political point of views, however, must be taken also into account in the decision making itself.

The sustainable development concept also emphasizes these areas as the three main pillars which are regarded as highly important (UN 2005):

- environmental,
- social equity and
- economic demands.

Both economy and society are constrained by the environmental conditions. The three overlapping ellipses indicate that the three pillars of sustainability are not mutually exclusive and can be mutually reinforcing.

4.4 Life cycle assessment in other countries and cities

During the evaluation of a solid waste management system it is very important to obtain good and reliable data, as well as focusing on the harmony of governance and technology, and the need to build on the existing strengths of the different cities. For the present research the case studies for different cities that have been prepared with Life Cycle Assessment modeling have been analyzed. The first example was the waste management system of Aarhus, and since then there are several other studies for example in countries such as France and China have been prepared. Much of this research used different LCA models, and not only the EASEWASTE model. Hereby in brief, the main findings of the LCA analysis of different cities are summarized, which are divided according to location:

EU country – West Europe

Aarhus, Denmark

Kirkeby (2005) analyzed the life cycle of Aarhus, Denmark in his PhD thesis. The municipality of Aarhus consists of approximately 300,000 inhabitants and 140,000 dwellings. The inhabitants generate about 81,000 tons of municipal solid waste per year. The source separation of organic waste in plastic bags started in 2001. Kirkeby conducted the LCA for the following options:

Scenario A. included an incineration and a biogas alternative for organic material. Scenarios B. consist of the case when the organic waste was sorted correctly in the green bags. Several sensitivity scenarios were prepared in order to observe more precisely the differences in environmental impacts. Scenario C was the case when the separated organic household waste was directed to the optic sorting plant and pretreatment facility for subsequent anaerobic digestion. Scenario D considers the organic household waste that potentially could have been source separated, but was combusted at the incineration plant.

Results showed that - with regard to the present dissertation - the most important environmental impacts are the saved global warming potential which took place due to energy recovery. Kirkeby (2005) showed that the potential human toxicity via soil was because of the arsenic content in organic waste and the potential human toxicity via water is caused by the air emission of mercury from the incineration plant, as the mercury settles down on soil and surface waters and so contributing to human toxicity potentials via soil and water. Acidification, photochemical ozone formation and nutrient enrichment are environmental impacts that have a smaller amount and differences.

Kirkeby (2005) emphasized, however, that Aarhus municipality closed the optic sorting plant and prohibited all organic household waste going to incineration due to financial and environmental reasons in spring 2004.

Salzburg, Austria

The environmental impacts of a few rural areas in the Salzburg regions were analyzed by Beigl & Salhofer (2004) with the IMW model. There were three alternatives in the research:

1. recycling with waste yards,
2. recycling with sack (door-to-door) collection,
3. no recycling.

The functional unit was accepted as the waste amount per year.

Impact categories are the following: global warming potential, acidification potential and net energy consumption. The main consequence was that the door-to-door collection is the most favorable in terms of the environmental aspects, and even better than the selective collection with waste yards, as the fuel consumption of the collecting vehicles is lower in the case of the municipal cleaning vehicles that are collecting the waste and not the inhabitants transporting them individually. Regarding the acidification and net energy consumption the metal recycling has a serious role.

Switzerland, waste of electrical and electronic equipment

The life cycle assessment research in Switzerland was prepared by Hischier *et al. (*2005) for waste of electrical and electronic equipment –WEEE for the year 2004. In his comparison the SWICO Recycling Guarantee and the S.E.N.S system was included which is an operational collection systems in Switzerland. During the WEEE collection it was possible to separate 11 kg of collected products from the traditional waste collection stream per capita in 2004, therefore recycling them. This accomplishment exceeds the 4 kg standard, set by the European WEEE Directive. Hischier *et al.* (2005) pointed out that the WEEE collection and recycling has a serious environmental advantage against incineration.

LCA studies have been made in East and West European countries also.

EU country – East Europe

The Czech Republic

Koci V. and Trecakova T. (2011) presents the results of a life-cycle assessment (LCA) study for integrated solid waste management systems in the Czech Republic. The seven scenarios were as the following: (a) incineration with slag recovery, (b) incineration without slag recovery, (c) landfills with incineration of the landfill gas by flaring, (d) landfills with recovery of the landfill gas, (e) mechanical–biological treatment (MBT) with aerobic treatment, (f) MBT bio drying with co-incineration of refuse-derived fuel, and (g) MBT bio drying with incineration of refuse-derived fuel from a monosource. The treatment of 1 ton of municipal solid waste was the functional unit. In the Czech Republic there have been several reoccurring debates including a mechanical–biological treatment plant, and without this plant the necessary data for this facility were provided from abroad. In this study the researchers derived the pollution from diesel consumption to electric production data from the GaBi 4 Professional database, which also justifies that the lack of the proper data is common in other countries as well, because GaBi 4 is not a waste management model. As a research result they concluded that the integrated system of mixed municipal waste management of landfills without landfill gas recovery and the aerobic MBT causes the greatest environmental burden. Alternatively, the lowest environmental impacts were caused when the MBT bio drying technology with RDF co-incineration was used. In the conclusions it is declared that a comparison of the environmental impacts of landfills to the other scenarios should be made, using both a detailed and long-term inventory including the future environmental impacts after closures of the landfill sites. It would also be appropriate to include several additional aspects (such as social, technical, and economic factors) for a fully objective assessment and to compare the different scenarios in a more detailed analysis. After evaluating this literature it can be stated that unlike other LCA analyses, this one concerns the entire Czech Republic and not a single city.

Lithuania - Alytus municipality

In Baltic countries the WAMPS (Waste Management Planning System) model was applied by Miliūtė (2009) for Alytus municipality. It is reasonable that she used this model as it was designed by the Swedish Environmental Research Institute (IVL), tested and calibrated in collaboration with the Institute of Environmental Engineering APINI (Lithuania) and Stockholm Environment Institute SEI (Estonia). Miliute and Kazimieras (2009) identified the following five scenarios: (1) landfilling, (2) recycling, composting and landfilling, (3) recycling, composting, MBT and incineration, (4) recycling and incineration and (5) recycling, MBT and incineration. Similarly to the Czech case study the mechanical biological treatment was included in their scenarios. Since waste incineration facilities are planned to be built later than the European deadline for landfilling of bio-degradable waste in Lithuania, this facility represents one of the possible solutions. Concerning the research results in terms of the global warming impact potential (GWP) expressed as CO2-equivalents, scenarios 1 and 2 involving landfilling show poor performance, mainly due to the fact that landfilling of untreated waste releases a significant amount of greenhouse gases. Scenarios 3, 4 and 5 show larger greenhouse gas emissions caused by transportation because the incineration plants demand longer transport distances than landfill. Nevertheless, Miliute and Kazimieras (2009) highlight that the differences caused by transport distances are insignificant in changing prioritization of the scenarios. The composting process (especially in scenario 2) does not have a considerable influence on the results, because biogenic CO2 is not considered to be contributing to global warming, which is justified by other researchers as well (Christensen *et al.*, 2009; Gentil *et al.*, 2009). In terms of the acidification and the eutrophication impact categories, the results are similar, so most of the emissions originate from landfilling, and a positive effect of recycling results in an ecological benefit. The most likely explanation is that the production of materials from virgin material resources requires considerable amounts of raw energy such as coal and crude oil.

One of the main targets of her study was to establish a decision-making system through the LCA process, which also justifies that LCA is a suitable tool for strategic decisions. She also urges the introduction of a mandatory deposit system to a wider range of beverage packaging (PET bottles, other glass bottles, aluminum cans) as it would be would be a significant factor reducing landfilling and extending reuse and recycling. This economic incentive was also highlighted in the Hungarian legislation mentioned earlier, which would result in a reduced environmental burden. Comparing again with Hungary, Miliute (2009) emphasized that alongside the landfill tax, the introduction of incineration tax (e.g. tax on CO2 emissions) should be considered too.

Located in Europe but not EU country

Ankara, Turkey

Özeler *et al.* (2005) showed the results of the Ankara research, utilizing the results of the IWM Model-1 model. Özeler pointed out that in the research the following 5 scenarios were used for Ankara life cycle assessment:

1. Collection - transport – landfilling
2. Selective collection – transport – landfilling
3. Collection - transport – recycling - landfilling
4. Collection - transport – recycling – incineration - landfilling
5. Collection - transport – recycling – composting - landfilling

The research showed that the most recommended and feasible waste management system is No. 3. Depending on the amount and density of the waste, Ankara was divided into different regions, and taking into consideration the logistic aspects three waste transfer stations were recommended. In versions number 3, 4, and 5, recycling centers were planned for the waste transfer stations whereas in the versions No. 1. and 2. no transfer stations were planned. The result of the life cycle assessment was that the energy consumption was less in scenario 2, but in every scenario the waste collection accounted for the biggest energy consumption. Version No. 5 contributed the least to global warming as a result of the composting while No. 1 contributed most significantly. In terms of the acidification and eutrophication, No. 2 scenario was the most favorable. Concerning the human toxicity the worst scenario was No. 4.because of the incineration and No. 2 was the most favorable.

Outside Europe

There are even several LCA evaluation studies in cities outside the European Union.

Shanghai, China

Hong *et al.* (2006) in China used the following 5 solid waste management scenarios:

1. Landfilling
2. Incineration
3. Biological and mechanical treatment – composting
4. Biological and mechanical treatment – incineration

5. Biological and mechanical treatment – landfilling.

The functional unit was 2200 t/day waste treatment in Pudong area, Shanghai. The environmental impact categories were the following: global warming, acidification and eutrophication potentials. The main result of the research was that incineration contributes to the highest level to the acidification and landfilling accounts for the largest global warming and eutrophication potential.

State of Kuwait

Al-Salem and Lettieri (2009) examined the life cycle assessment of Kuwait municipal solid waste. As it is written in their study the average citizen in Kuwait produces 1.4 kg/day of Municipal Solid Waste (MSW), which exceeds the major Western countries, e.g. UK (0.95 kg/day), Belgium (0.93 kg/day), France (0.89 kg/day), Italy (0.95 kg/day) and Spain (0.88 kg/day) in 2008. This amount can be justified with the fact that in Kuwait, environmental awareness is much lower than in Western European countries. The common practice is landfilling, which poses a serious threat in terms of water and air pollution and public health problems. The three scenarios in the study were the following:

1. collection- transport- landfilling,
2. collection- transport- materials recovery facility-incineration -landfilling,
3. collection- transport- materials recovery facility-anaerobic digestion –landfilling.

The main tool used in the LCA evaluation was the IWM-2 model, which is a modified version of the IWM-1 model. This model was run for each scenario based on the data gathered at the life cycle inventory stage.

In the conclusion it was concluded that Scenario 3 was best, in terms of Global Warming Potential (GWP), and Scenario 1 came in second, although it was the least fuel consuming option. Scenario 2 was the worst in terms of acidification potential. Scenario 3 reached the least impact and was the most favored waste management option as a result of the life cycle assessment.

Hungarian studies

In Hungary there several studies have been made since 2005 (Szita K. pers.comm. 2012) on different aspects of solid waste management, among others: Life-cycle assessment of gasoline and diesel products, when authors analyzed the environmental aspects of these fuels. (Sándor R. and Molnár T.) covered the Life cycle assessment of polystirol (Szita K. T. and Szabó B.P.). There are several other studies on WEEE, and construction and demolition waste as well. These can be found at the webpage of LCA Center.

According to Zsolt István (pers. comm. 2012), the leader of LCA Association in Hungary the Association developed the LCA database in the Hungarian sector including waste management within a GVOP tender (GVOP 3.1.1.-2004-05-0248/3.0) between 2004-2007. Clara Szita Tóthné is also an internationally recognized expert in LCA research, and additionally she is a university teacher at Miskolc University in Hungary. Such research in Hungary has typically used GaBi or SimaPro software, which are not specialized for waste management. Koneczny (et al. 2007) included the analysis of several options for the Hungarian Kökény landfill site.

As István (pers.comm 2012) stated during personal communication, they have made analysis for selective waste collection and compared them with other treatment methods, however as far as he is aware no research was made in Hungary for a waste service provider nor for consecutive months as was performed in this thesis.

Several other LCA studies had been prepared in the recent years, the list above only summarizes a few relevant studies. Naturally, the results of the LCA have been adjusted to the desired targets. In many cases the aim is to decrease the energy consumption and the GHGs but there are some cases when LCA has focused on different environmental, social and economic factors. LCA analysis can even investigate the recycling of paper and plastic waste types or the replacement of fuel by biomass. The reduction of the transport distances and the increased rate of the selective waste collection increase recycling efficiency (Moberg A. 2006.)

Life cycle assessment had been widely used to analyze the environmental impacts of solid waste management systems in either whole countries or select cities. It is common to evaluate greenhouse gas emissions from solid waste management systems, and it has been proven by Miliūtė (2009) that landfilling of untreated waste releases a significant amount of greenhouse gases, which is also the case in Hungary, as landfill sites do accept organic waste and operate only with flaring. Miliūtė (2009) also suggests implementing not only the landfill tax but the incineration tax also, which is again useful in Hungary taking into account the waste hierarchy.

As a conclusion, these studies can prove that LCA of solid waste management systems have drawn high attention worldwide. The LCA research, however, were mainly produced when new waste treatment technology was being introduced (for instance in case of the Czech Republic for MBH treatment) or the environmental aspects of different options had to be assessed. Most of the LCA results proved that according to the waste hierarchy, the landfilling disposal method is the worst in terms of the environmental impacts and it is highly important to promote the diversion of the waste that is to be landfilled and to promote waste prevention, re-use and recycling. Good advice can be drawn from these studies which has relevance to Budapest such as the introduction of incineration tax. All studies have not been reviewed, but it can be concluded that LCA studies have been applied to all stages of waste hierarchy. More analysis and a descriptive summary of these studies will be evaluated at the end of this topic, in chapter 4.6 when the gaps in the literature are discussed.

Based on the above studies it can be observed that the LCA evaluation of Budapest solid waste management system is really timely particularly in the light of the new Hungarian Waste Law which considers it highly important. Several LCA studies abroad have been made for waste service providers analyzing their solid waste management system, and in Hungary this thesis would be the first of them. Compared with the above assessed studies the present thesis on Budapest solid waste LCA goes beyond previous research as it analyses the environmental impacts of the different selective rates in consecutive months. Presumably following this work solid waste LCA studies can be made for additional Hungarian cities as well.

4.5 Waste management and its impact on GHG emission

Climate change is a serious international environmental concern and the subject of much research and debate. Global warming (GW) is today one of the highest priorities on the public agenda so it is highly recommended to evaluate the connection of waste management and global warming. In Hungary the waste management decisions are often made locally without taking into account quantified measures on the environment (including GHG mitigation). Strict strategies and financial incentives, however, can have the consequence that waste management options can achieve lower environmental load. Local decisions are the function of many competing variables, including waste quantity and characteristics, cost and financing issues, social issues, optimized collection and transport, as well as regulatory constraints. As a result of these factors life cycle assessment (LCA) can provide decision-support tools. However, as mentioned before, LCA generally focuses on environmental issues.

As it is discussed in this thesis the product life cycle includes the following steps:

1. extraction and processing of raw materials;
2. manufacture of products;
3. transportation of materials and products to markets;
4. use by consumers; and
5. waste management.

Virtually every step along this life cycle series impacts GHG emissions. As USEPA (2002) describes in the field of waste management the GHGs can be reduced by affecting one or more of the following processes:

1. Energy consumption, specifically, combustion of fossil fuels. It may take place when making, transporting, using, and disposed of the product or material which becomes a waste.

2. Non-energy-related manufacturing emissions. For instance when CO_2 released in the case when limestone is converted to lime. Lime is needed for use in aluminum and steel manufacturing or concrete production.
3. CH_4 emissions from landfills – this is the most significant GHG release.
4. Carbon sequestration. It is associated with natural or man-made processes that remove carbon from the atmosphere and store it for long periods.

It can be summarized that the first three mechanisms *add* GHGs to the atmosphere and contribute to global warming. The fourth—carbon sequestration—*reduces* GHG concentrations by removing CO_2 from the atmosphere. An evident example for sequestering carbon is forest growth, because in this case more biomass is grown than is removed, so the amount of carbon stored in trees increases, and thus carbon is sequestered. But this is really only the case in expanding forest areas, while uptake and tree removal should be accepted as constant.

Different waste types and different waste management options can have various implications for energy consumption, CH_4 emissions, and carbon sequestration. For instance source reduction and recycling of paper products reduce energy consumption, decrease combustion and landfill emissions, and increase forest carbon sequestration.

It must be also repeated that it is important to precisely define the waste types which have effect on GHG emission. In the EASEWASTE there are 40 waste types analyzed in the EPA research the waste types were shortlisted to the following 16 items:

1. Aluminum Cans;
2. Steel Cans;
3. Glass;

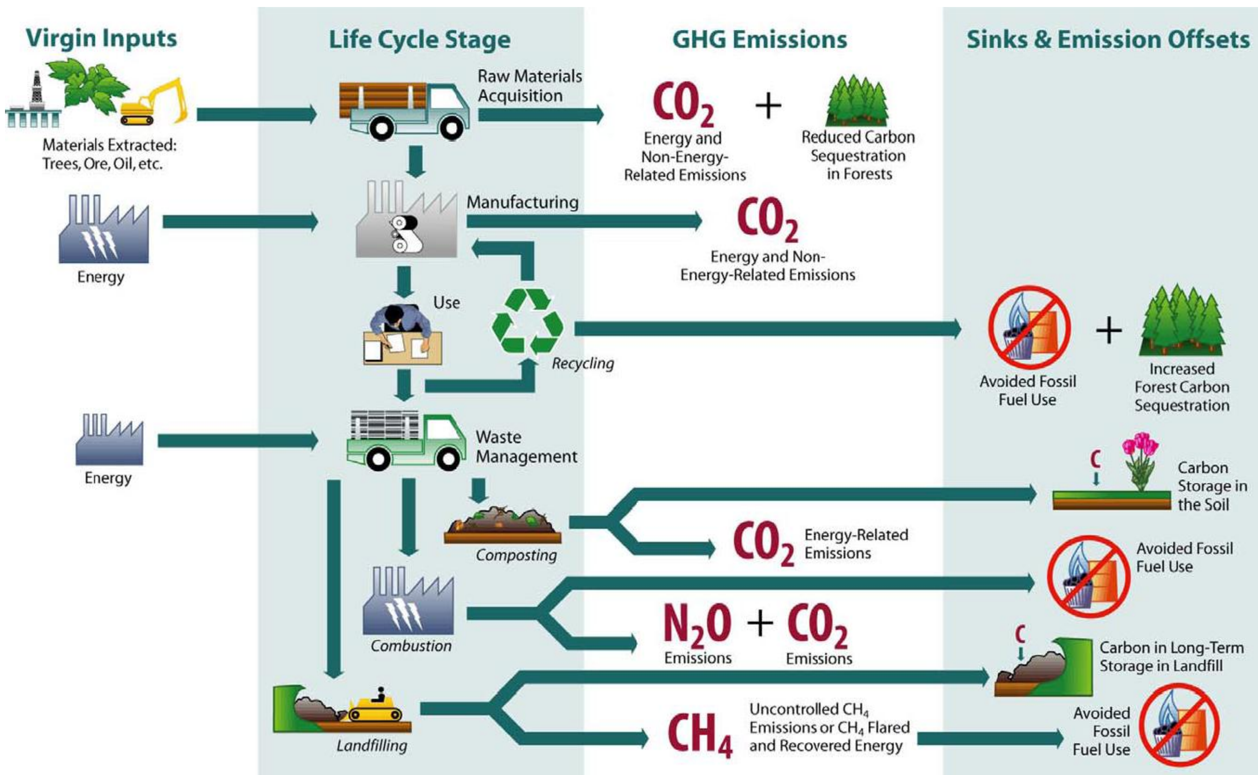
4. HDPE (high-density polyethylene) Plastic;
5. LDPE (low-density polyethylene) Plastic;
6. PET (polyethylene terephthalate) Plastic;
7. Corrugated Cardboard;
8. Magazines/Third-class Mail;
9. Newspaper;
10. Office Paper;
11. Phonebooks;
12. Textbooks;
13. Dimensional Lumber;
14. Medium-density Fiberboard;
15. Food Discards; and
16. Yard Trimmings.

Obviously this list varies from the EASEWASTE waste fractions, but it justifies that the different sub-categories of paper, plastic, aluminum cans, glass and kitchen waste are the main objects of every study which evaluates LCA from waste management. USEPA (2002) research has examined the potential for these effects at the following points in a product's life cycle:

- Raw material acquisition (fossil fuel energy and other emissions, and changes in forest carbon sequestration);
- Manufacturing (fossil fuel energy emissions); and
- Waste management (CO_2 emissions associated with composting, non-biogenic CO_2 and nitrous oxide (N_2O) emissions from combustion, and CH_4 emissions

from landfills); these emissions are offset to some degree by carbon storage in soil and landfills, as well as avoided utility emissions from energy recovery at combustors and landfills.

In the USEPA study the following picture can be found which illustrates the impact of waste management on GHG emission within the LCA steps.



5. Figure Greenhouse gas sources and sinks associated with the material life cycle

Source: U.S. Environmental Protection Agency. 2002.

This picture shows how GHG sources and sinks are affected by each waste management strategy. For example, the top row shows that source reduction, selective collection at the source of the waste generation influences the greenhouse production in the following ways:

1. reduces GHG emissions from raw materials acquisition and manufacturing;
2. results in an increase in forest carbon sequestration; and
3. does not result in GHG emissions from waste management.

From this diagram it is again proven that selective waste collection decreases the waste management impact on GHG emission.

The sum of emissions (and sinks) across all steps in the life cycle represents net emissions (USEPA 2002).

MSW management strategy	**GHG sources and sinks**		
	Process and transportation GHGs from raw materials acquisition and manufacturing	**Forest carbon sequestration or soil carbon storage**	**Waste management GHGs**
Source Reduction	Decrease in GHG emissions, relative to the baseline of manufacturing	Increase in forest carbon sequestration (for organic materials)	No emissions/sinks
Recycling	Decrease in GHG emissions due to lower energy requirements (compared to manufacture from virgin inputs) and avoided process non-energy GHGs	Increase in forest carbon sequestration (for organic materials)	Process and transportation emissions associated with recycling are counted in the manufacturing stage
Composting (food discards, yard trimmings)	No emissions/sinks, because these materials are not considered to be manufactured.	Increase in soil carbon storage	Compost machinery emissions and transportation emissions
Combustion	Baseline process and transportation	No change	Non-biogenic CO2, N2O emissions,

	emissions due to manufacture from the current mix of virgin and recycled inputs		avoided utility emissions, and transportation emissions
Landfilling	Baseline process and transportation emissions due to manufacture from the current mix of virgin and recycled inputs	No change	CH4 emissions, long-term carbon storage, avoided utility emissions, and transportation emissions

5. Table Components of net emissions for various MSW management strategies and their impact on GHG sources and sinks

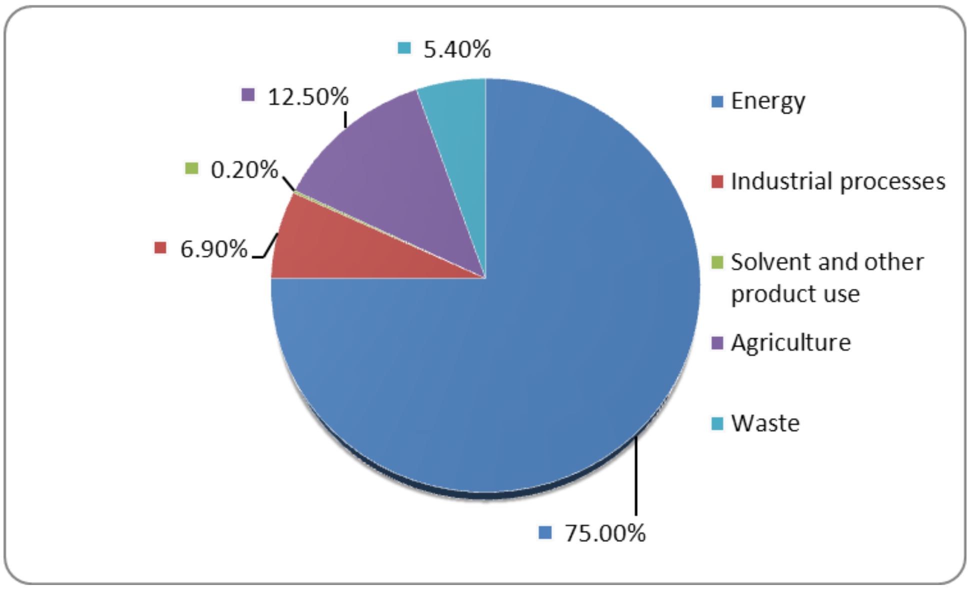
Source: US Environmental Protection Agency. 2002.

The table summarizes that source reduction and recycling decreases GHG emission, whereas landfilling is the biggest CH_4 emitter source and composting causes CO_2 emission. During incineration CO_2 and NO_2 are generated, but the avoided fossil fuel use must be recorded as well, which is required to produce the same amount of energy.

Gentil (2011) identified that globally, atmospheric CO_2 ranged from 339 ppm in 1980 to 386 ppm in 2009, which accounts for a 14% increase. Anthropogenic global methane emissions which are the most relevant GHG sources in the waste management sector originating from landfill emissions. The amount of global landfill methane emissions have increased from 550 $MtCO_2$-eq in 1990 to 700 $MtCO_2$-eq in 2010, which equates to a 27% increase in 20 years. The direct contribution of post-consumer waste is less than 5% of the total GHG emissions, and its amount is 1300 $MtCO_2$-eq in 2005.

In spite of the fact that the waste sector contributed only 5,4% to the total GHG emission in Hungary in 2007, it is important to analyze this process and attempt to find a solution for its reduction taking into account the principles of the sustainable development.

It is also justified due to the fact that in the waste management sector it is much more difficult to measure and control the environmental benefit contra for instance taxes on cars or airlines in order to avoid CO_2 emission.



6. Figure Emissions by sectors in 2007excluding LULUCF, Gg CO_2 eq

Source: National Communication to UNFCCC Hungary, 2009.

By far, the biggest emitting sector was the energy sector contributing, 75% to the total GHG emission in 2007. Carbon dioxide from fossil fuels is the largest item among greenhouse gas emissions, while agriculture was the second (12.5%) in 2007. In this sector CH_4 and N_2O emissions are taken into account. 77 % of the total N_2O emissions are generated in agriculture. Industrial processes was the third largest sector contributing 6,9% to total GHG emissions in 2007. The waste sector represented 5.4% of the total national GHG emissions. The Land Use, Land-Use Change and Forestry (LULUCF) sector is a net sink of carbon. In 2007, the net removal was -4.1 million tons CO_2, which was determined largely by Forest Land.

Existing waste-management practices can provide effective mitigation of the environmental loads from this sector: a wide range of mature, environmentally-effective technologies (such as selective waste collection, landfill gas recovery) are available to mitigate the environmental load and provide public health, environmental protection, and sustainable development. In addition, waste minimization, recycling and re-use represent an important and increasing potential for indirect reduction of the pollution emission through the conservation of raw materials, improved energy and resource efficiency and fossil fuel avoidance.

The GHG data reported to the UNFCCC contain estimates for direct greenhouse gases, such as:

i. CO_2 - Carbon dioxide
ii. CH_4 – Methane
iii. N_2O - Nitrous oxide
iv. PFCs – Per fluorocarbons
v. HFCs – Hydro fluorocarbons
vi. SF6 - Sulphur hexafluoride

as well as for the indirect greenhouse gases such as SO_2, NOx, CO and NMVOC (UNFCCC 2012).

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change of Working Group III includes a separate chapter on waste management (Chapter 10) The coordinating lead author of this chapter was Jean Bogner. According to Bogner *et al.*, (2007) post-consumer waste is a small contributor to global greenhouse gas (GHG) emissions (<5%) with total emissions of approximately 1300 MtCO_2-eq in 2005. The largest source is landfill methane (CH_4), followed by wastewater CH_4 and nitrous oxide (N_2O); in addition, minor emissions of carbon dioxide (CO_2) result from incineration of waste containing fossil carbon (C) (plastics; synthetic textiles). A part of this is due to the fact that the benefits of this are allocated in the energy sector, so the waste management sector only gets the negative impacts.

In the 2006 IPCC Guidelines for National Greenhouse Gas Inventories at Chapter 5: Incineration and Open Burning of Waste it can be seen that such practices are sources of greenhouse gas emissions, like other types of combustion.

Relevant gases emitted include CO_2, methane (CH_4) and nitrous oxide (N_2O). Normally, emissions of CO_2 from waste incineration are more significant than CH_4 and N_2O emissions. (Guendehou *et al.* 2006).

The calculation for the estimated emitted CO_2 on the total amount of waste incinerated is the following way (USEPA 2002):

Equation:

$$CO2\ Emissions = \Sigma i\ (SWi \bullet dmi \bullet CFi \bullet FCFi \bullet OFi) \bullet 44/12$$

Where

- CO2 Emissions = CO2 emissions in inventory year, Gg/yr
- SWi = total amount of solid waste of type i (wet weight) incinerated or open-burned, Gg/yr
- dmi = dry matter content in the waste (wet weight) incinerated or open-burned, (fraction)
- CFi = fraction of carbon in the dry matter (total carbon content), (fraction)
- FCFi = fraction of fossil carbon in the total carbon, (fraction)
- OFi = oxidation factor, (fraction)
- 44/12 = conversion factor from C to CO2
- i = type of waste incinerated/open-burned specified as follows:
- MSW: municipal solid waste (if not estimated using Equation 5.2), ISW: industrial solid waste,
- SS: sewage sludge, HW: hazardous waste, CW: clinical waste, others (that must be specified)

In case of a municipal solid waste the CO_2 emission can be estimated as follows (USEPA 2002):

Equation:

CO2 Emissions = MSW • Σi (WFj • dmj • CFj • FCFj • Oji) • 44/12

Where

- CO_2 Emissions = CO_2 emissions in inventory year, Gg/yr
- MSW = total amount of municipal solid waste as wet weight incinerated or open-burned, Gg/yr
- WF_j = fraction of waste type/material of component j in the MSW (as wet weight incinerated or open burned)
- dm_j = dry matter content in the component j of the MSW incinerated or open-burned, (fraction)
- CF_j = fraction of carbon in the dry matter (i.e., carbon content) of component j
- FCF_j = fraction of fossil carbon in the total carbon of component j
- OF_j = oxidation factor, (fraction)
- 44/12 = conversion factor from C to CO_2

with: $1 = \Sigma_j$

WF_j

- j = component of the MSW incinerated/open-burned such as paper/cardboard, textiles, food waste, wood, garden (yard) and park waste, disposable nappies, rubber and leather, plastics, metal, glass, other inert waste.

Biogenic CO_2 emission

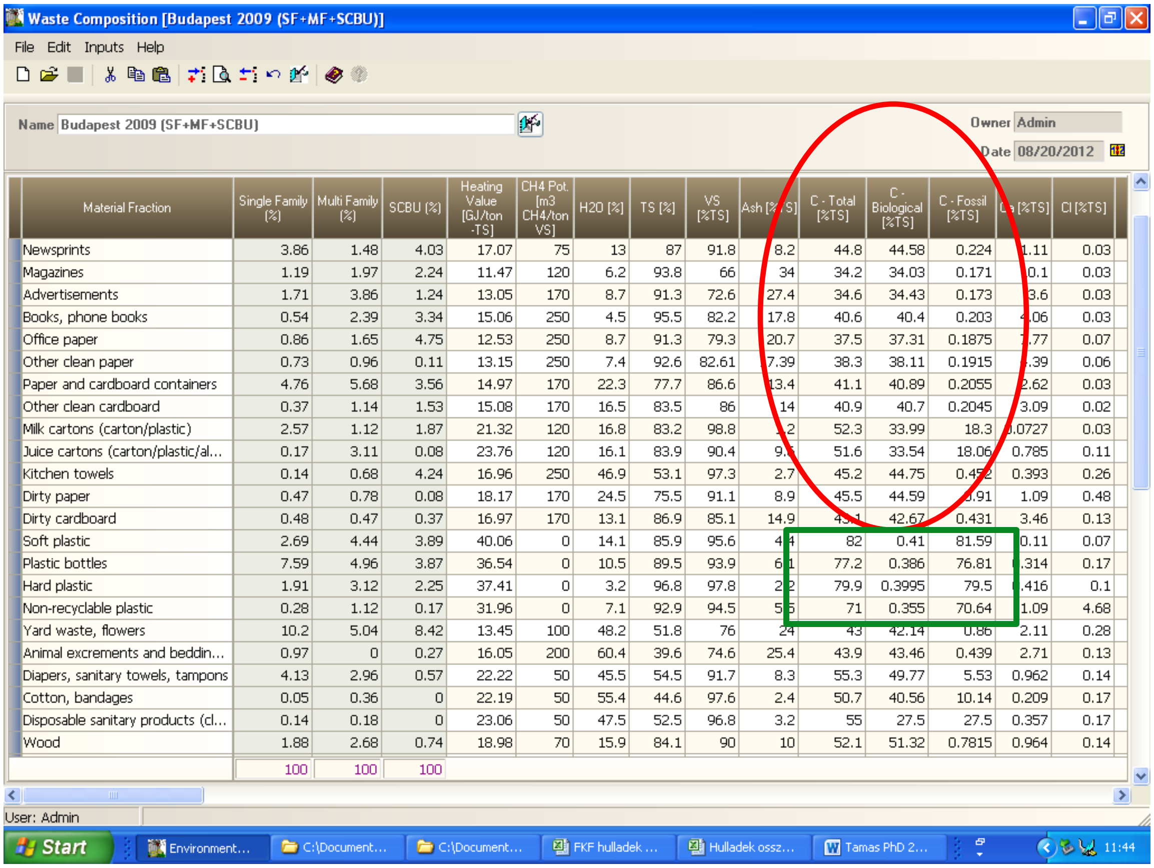
There has been a debate over the inclusion of biogenic CO_2 emission into the calculation taking into consideration whether the biogenic CO_2 emission can be regarded as neutral with respect to GW. This question needs to be discussed as the quantity of carbon that these natural processes cycle through the Earth's atmosphere, waters, soils, and biota is much greater than the quantity added by anthropogenic GHG sources (USEPA 2002.). The carbon in paper and grass and other biomass waste was originally removed from the atmosphere by photosynthesis, and under natural conditions, it would cycle back to the atmosphere through the CO_2 degradation processes. Nevertheless, there is still not full agreement on the method and calculation for the carbon remaining in the landfill at the end of the LCA time horizon.

One school of thought accepts that in a life cycle assessment, biogenic CO_2 emissions should be considered as neutral to GW (GWP=0) because they originate from organic matter. In this case the CO_2 is generated by the same biological uptake of CO_2 during plant growth. As Manfredi (2009) emphasized one should make distinctions between the overall CO_2 emission and the following two parts:

- biogenic CO_2 emission and
- fossil CO_2 emission.

In the EASEWASTE model in the case of the waste composition chemical characteristics the C- total, the C-biological and the C- fossil are distinguished.

It is important to state this difference, as it can be observed in the screenshot picture of waste composition for 2009 in Budapest that the C biological is nearly as much as C total and C fossil is minimal, (or at least for paper and most of the waste types – see red circle), however in case of plastic, the C fossil is much higher than C biological, nearly as much as C – total (see in the green square of the screenshot picture).



Material Fraction	Single Family [%]	Multi Family [%]	SCBU [%]	Heating Value [GJ/ton -TS]	CH4 Pot. [m3 CH4/ton VS]	H20 [%]	TS [%]	VS [%TS]	Ash [%TS]	C - Total [%TS]	C - Biological [%TS]	C - Fossil [%TS]	Ca [%TS]	Cl [%TS]
Newsprints	3.86	1.48	4.03	17.07	75	13	87	91.8	8.2	44.8	44.58	0.224	[illegible].11	0.03
Magazines	1.19	1.97	2.24	11.47	120	6.2	93.8	66	34	34.2	34.03	0.171	[illegible]0.1	0.03
Advertisements	1.71	3.86	1.24	13.05	170	8.7	91.3	72.6	27.4	34.6	34.43	0.173	[illegible]3.6	0.03
Books, phone books	0.54	2.39	3.34	15.06	250	4.5	95.5	82.2	17.8	40.6	40.4	0.203	[illegible].06	0.03
Office paper	0.86	1.65	4.75	12.53	250	8.7	91.3	79.3	20.7	37.5	37.31	0.1875	[illegible].77	0.07
Other clean paper	0.73	0.96	0.11	13.15	250	7.4	92.6	82.61	[illegible]7.39	38.3	38.11	0.1915	[illegible].39	0.06
Paper and cardboard containers	4.76	5.68	3.56	14.97	170	22.3	77.7	86.6	[illegible]3.4	41.1	40.89	0.2055	[illegible].62	0.03
Other clean cardboard	0.37	1.14	1.53	15.08	170	16.5	83.5	86	14	40.9	40.7	0.2045	3.09	0.02
Milk cartons (carton/plastic)	2.57	1.12	1.87	21.32	120	16.8	83.2	98.8	[illegible]	52.3	33.99	18.3	[illegible].0727	0.03
Juice cartons (carton/plastic/al...	0.17	3.11	0.08	23.76	120	16.1	83.9	90.4	[illegible]	51.6	33.54	18.06	0.785	0.11
Kitchen towels	0.14	0.68	4.24	16.96	250	46.9	53.1	97.3	2.7	45.2	44.75	[illegible]	0.393	0.26
Dirty paper	0.47	0.78	0.08	18.17	170	24.5	75.5	91.1	8.9	45.5	44.59	[illegible].91	1.09	0.48
Dirty cardboard	0.48	0.47	0.37	16.97	170	13.1	86.9	85.1	14.9	[illegible]	42.67	0.431	3.46	0.13
Soft plastic	2.69	4.44	3.89	40.06	0	14.1	85.9	95.6	[illegible]	82	0.41	81.59	[illegible]0.11	0.07
Plastic bottles	7.59	4.96	3.87	36.54	0	10.5	89.5	93.9	[illegible]	77.2	0.386	76.81	[illegible].314	0.17
Hard plastic	1.91	3.12	2.25	37.41	0	3.2	96.8	97.8	[illegible]	79.9	0.3995	79.5	[illegible].416	0.1
Non-recyclable plastic	0.28	1.12	0.17	31.96	0	7.1	92.9	94.5	[illegible]	71	0.355	70.64	[illegible]1.09	4.68
Yard waste, flowers	10.2	5.04	8.42	13.45	100	48.2	51.8	76	24	43	42.14	0.86	2.11	0.28
Animal excrements and beddin...	0.97	0	0.27	16.05	200	60.4	39.6	74.6	25.4	43.9	43.46	0.439	2.71	0.13
Diapers, sanitary towels, tampons	4.13	2.96	0.57	22.22	50	45.5	54.5	91.7	8.3	55.3	49.77	5.53	0.962	0.14
Cotton, bandages	0.05	0.36	0	22.19	50	55.4	44.6	97.6	2.4	50.7	40.56	10.14	0.209	0.17
Disposable sanitary products (cl...	0.14	0.18	0	23.06	50	47.5	52.5	96.8	3.2	55	27.5	27.5	0.357	0.17
Wood	1.88	2.68	0.74	18.98	70	15.9	84.1	90	10	52.1	51.32	0.7815	0.964	0.14
	100	100	100											

7. Figure Biological and fossil CO2 in the EASEWASTE model for some waste types

Some fractions are highlighted below:

Material fraction	C –total (% TS)	C – biological (% TS)	C – fossil (% TS)
Newsprints	44.8	44.58	0.224
Magazines	34.2	34.03	0.171
Book, phone books	40.6	40.4	0.203
Paper and cardboard containers	41.1	40.89	0.2055

6. Table Biological and fossil CO2 content of paper fractions

It can be clearly seen that for the paper products, the C total is nearly as much as C biological (red circle).

Material fraction	C –total (% TS)	C – biological (% TS)	C – fossil (% TS)
Soft plastic	82	0.41	81.59
Plastic bottles	77.2	0.386	76.81
Hard plastic	79.9	0.3995	79.5
Non-recyclable plastic	71	0.355	70.64

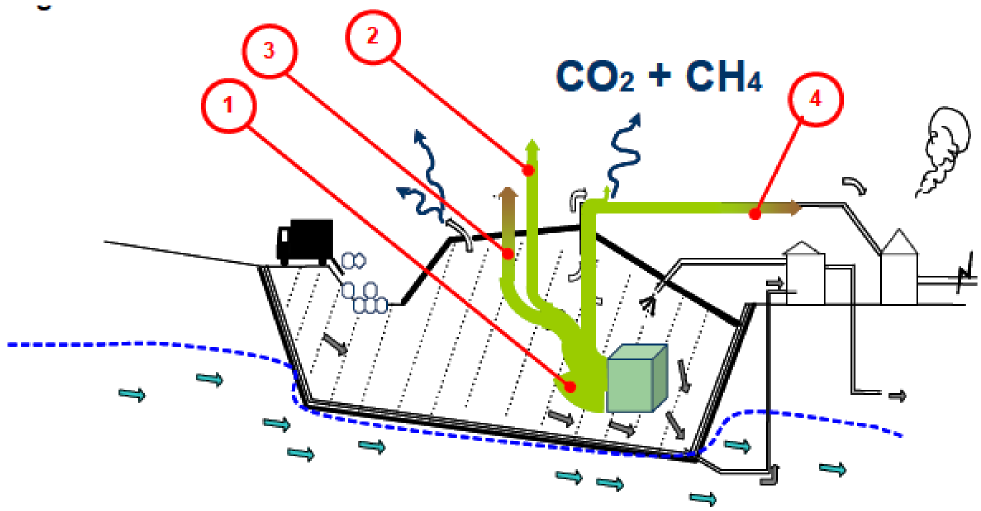
7.Table Biological and fossil CO2 content of plastic fractions

For plastic, nevertheless, it is evident that C fossil is nearly as much as C total (green square).

Biogenic materials are included paper, yard trimmings, and discarded food. If emissions of biogenic CO_2 are neutral to GW, then the biogenic carbon which can be found in the landfill should be considered as an avoided CO_2 emission; which means saving should be indicated as a negative contribution to GW. (Christensen *et al.*, 2009; Gentil *et al.*, 2009). This school of though is represented by the Danish professors, who developed the EASEWASTE model and also performed most of the recent studies on LCA modeling of carbon-rich waste (for instance: Grant *et al.*, 2001; Raymer, 2006; Schmidt *et al.*, 2007). However, different accounting principles are taking place in these studies which acknowledge the biogenic carbon which is stored in landfills and soils amended with compost, and also it affects the whole waste industry and the energy industry as well as forestry (Christensen *et al.*, 2009).

The emission of CO_2 from combustion of fossil carbons are counted, GW (GWP=1) because this release is not counter-balanced by a recent uptake of CO_2 so these emissions would not enter the cycle were it not for human activity. Likewise, CH_4 emissions from landfills are counted.

However, as USEPA (2002) highlights the anthropogenic emissions are resulting from human activities and have the potential to alter the climate by disrupting balances in carbon's natural cycle. Even though the source of carbon is primarily biogenic, CH_4 would not be emitted were it not for the human activity of landfilling the waste, which creates anaerobic conditions conducive to CH_4 formation. EASEWASTE covers this as well, and there is not discrepancy in how this is assessed. It must be noted that this approach does not make any difference between the timing of CO_2 emissions, so it records them as long as the biogenic carbon would eventually be released as CO_2, even during a combustion process or over several decades (e.g., decomposition on the forest floor). In this respect, carbon storage means that landfilled organic materials result in landfill carbon storage, as carbon is moved from a product (e.g., furniture) to the landfill. The same is true for composted organics that lead to carbon storage in soil. Carbon sequestration, nevertheless, differs from carbon storage because it represents a transfer of carbon from the atmosphere to a carbon pool. For instance, trees in a forest undergo photosynthesis, converting CO_2 in the atmosphere to carbon in biomass. USEPA (2002) analysis considers the impact of waste management on forest carbon sequestration. Although source reduction and recycling are associated with forest carbon sequestration, composting—in particular, application of compost to degraded soils—enhances soil carbon storage.



8. Figure Sources of carbon emission in a landfill

Source: European Environmental Agency 2011a.

As it can be seen in this picture in the landfill the following GHG emissions may occur USEPA (2002):

1. Direct emission of CO_2 from anaerobic biodegradation
2. Direct emission of CH_4 from anaerobic biodegradation
3. Emission of CO_2 from CH_4 oxidized in the top layers
4. Emission of CO_2 from recovered CH_4 which is oxidized by flaring (with or without energy generation).

Emissions 1. and 3. are biogenic and thus not included in the model. These four sources are illustrated in Figure 9. No methodology is provided for N_2O emissions from landfills due to their small significance.

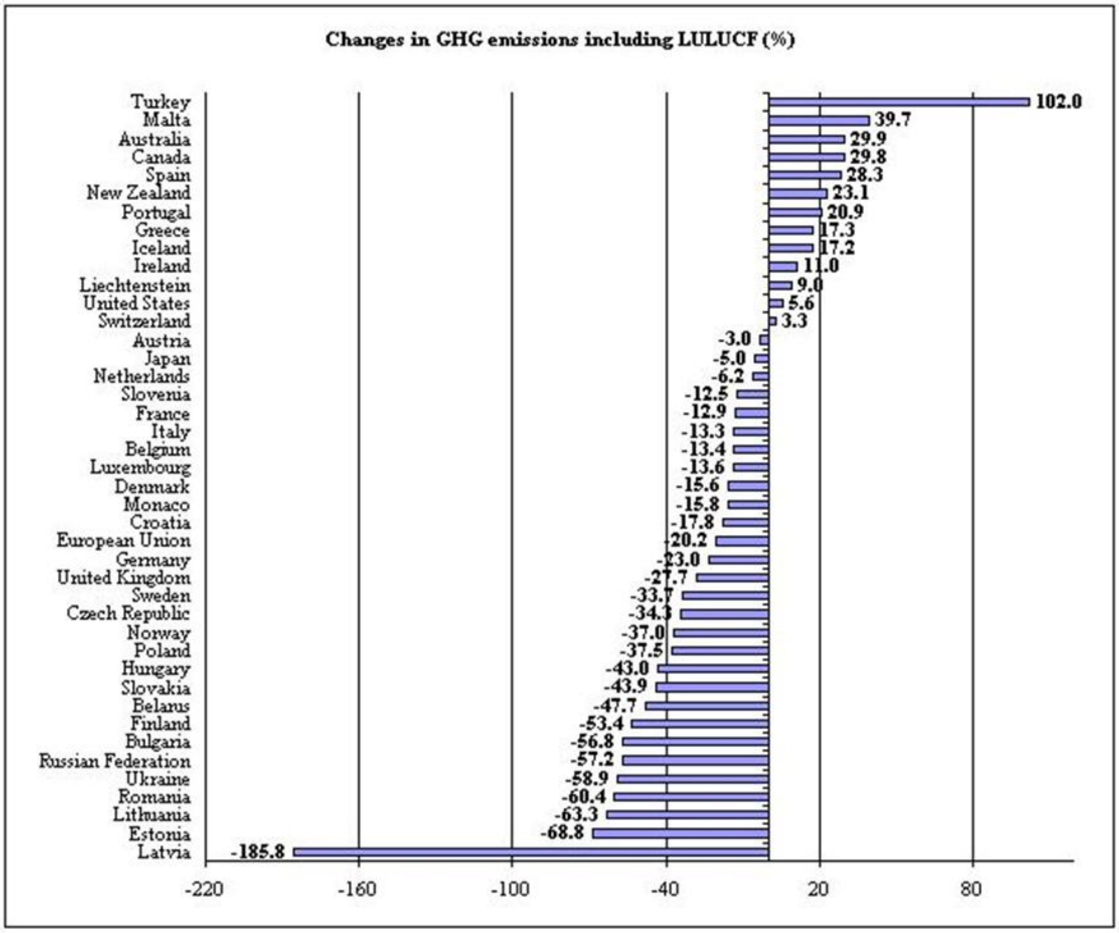
The study on the methane gas production of the Hungarian regional waste landfills Green-Con (2007) calculates the GHG emission according to the IPCC Tier 1.

methodology. However this study focuses only on methane production and does not include other environmental impacts.

In the present European Union co-financed Cohesion Fund for regional solid waste management systems in Hungary, there is no life cycle assessment used to calculate the different environmental impacts of solid waste management. For example, one of the most intensely scrutinized recent projects, The Mecsek Dráva waste management system Feasibility Study, during its submission phase in 2005 included the following in chapter of 2.5 "Emission indicators: There is no data for the climate change so we are not able to calculate it, but the following statements can be determined:

- CO_2: All of its volume is emitted to the air (no collection and treatment).
- Methane: All of its volume is emitted to the air (no collection and treatment).
- Biogas treatment: Not solved."

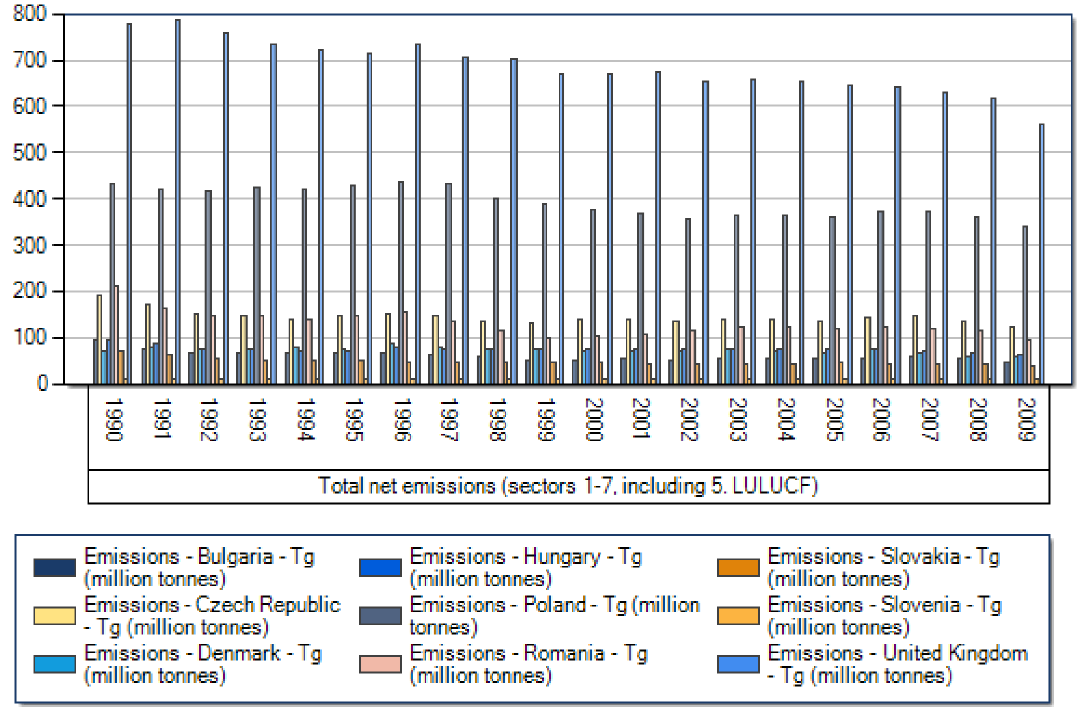
It can be observed that GHG emissions have been generally decreasing between 1990 and 2007 in most EU countries. The following table shows the total aggregate GHG emission in these years between the countries participating in the UNFCCC report.



9. Figure Total aggregate greenhouse gas emissions of Annex I Parties 1990-2009

Source: United Nations Framework Convention on Climate Change 2012

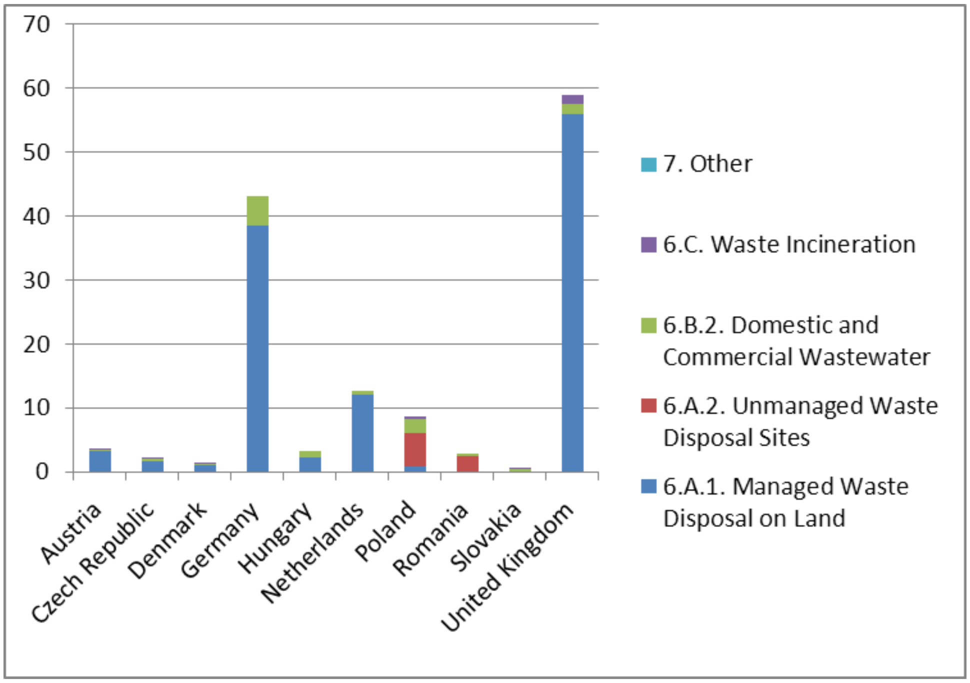
Although the impacts of waste treatment on the environment have been considerably reduced, there is still potential for further improvement. Development opportunities are listed as follows: a transition to full implementation of existing regulations, and also through the extension of existing waste policies in order to encourage sustainable consumption, and production practices in connection with more efficient resource use.



10. Figure Greenhouse gas net emission (CO2 equivalent) in selected countries 1990-2009

Source: European Environmental Agency 2010b. EEA greenhouse gas data viewer.

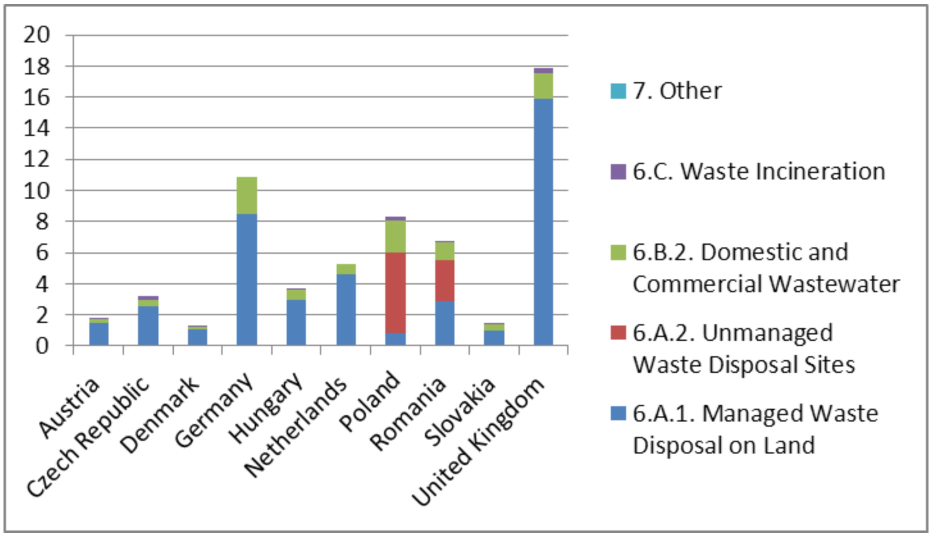
The table shows that when comparing Hungary with other Eastern or Western European Union countries it can be observed that Poland is the largest source of emissions, secondly United Kingdom, while the emissions levels of Hungary, Denmark and Bulgaria are relatively low in comparison. The smallest emissions totals are produced in Slovenia, and Slovakia. The graph shows that generally the amount of the GHG net emission between 1990 and 2009 is steadily decreasing. The graph should be applied on a per capita basis for a more accurate comparison between the different countries, but trend can be seen extracted here.



11 Figure All GHG emission from the waste sector, selected countries, (million tons) 1990

Source: author own contribution based on EEA 2010b

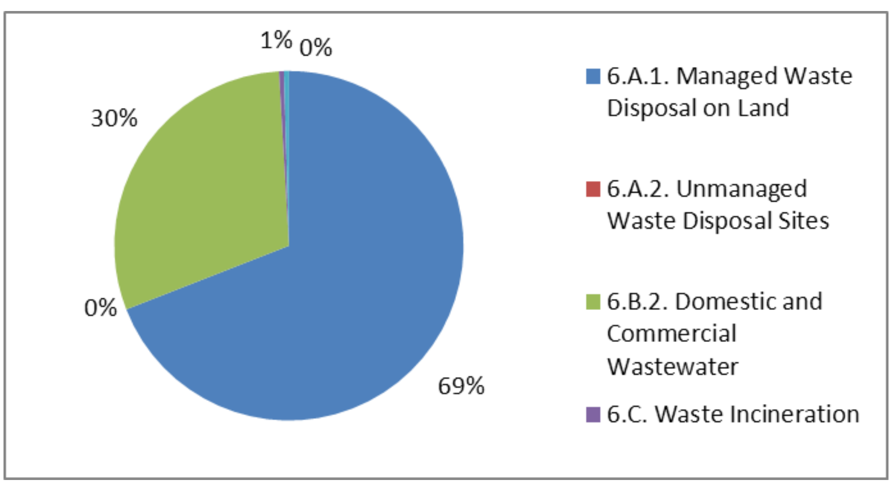
These figures also should be based on per capita basis in order to compare the different countries with each other. There are 19 years differences between the data of these two figures. During this nineteen year period (1990-2009) the following consequences can be drawn from these figures: the GHG emission from the waste sector has drastically decreased (in UK it was 58 million tons whereas in 2009 this value is around 17.6 million tons) due to the reason that the GHG emission from managed waste disposal on land has been dropped. Also, the rate of domestic and commercial waste water is increasing in all of the represented countries. The rate of GHG emission from unmanaged waste disposal sites is still high in case of Poland and Romania, whereas there is no visibly seen value like this at other countries, including Hungary.



12. Figure All GHG emission from the waste sector, selected countries, (million tons) 2009

Source: author own contribution based on EEA 2010b

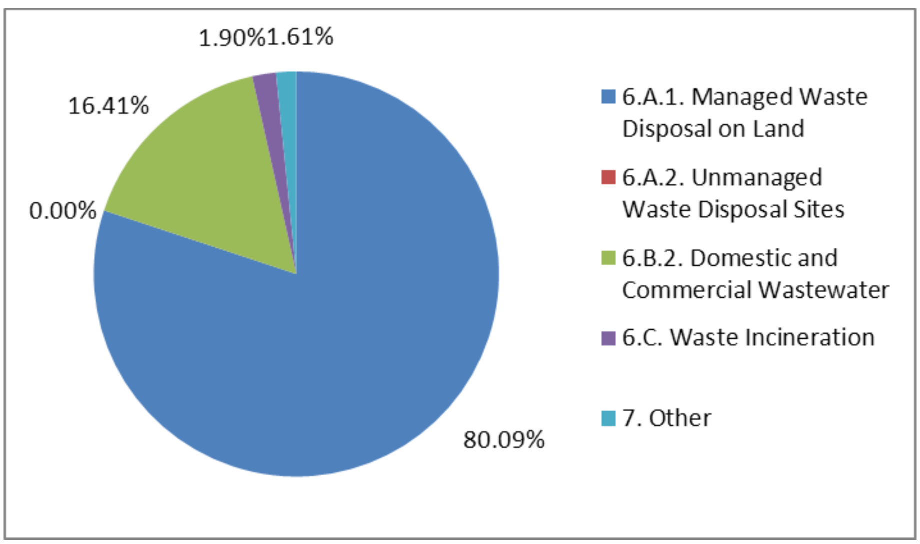
In all the years, the largest category was solid waste disposal on land. In recent years, waste incineration gained importance while emissions from wastewater treatment decreased further.



13. Figure All Greenhouse gas emission in the waste sector, Hungary, 1990

Source: author own contribution based on EEA 2010b

Focusing on Hungary we can conclude the following tendencies in these 19 years: GHG contributions were increased due to managed waste disposal on land. However, a very interesting picture can be drawn from the years after 2009 when several landfill sites not compliant with EU requirements were shut down. Managed waste disposal needs further definition. GHG emissions from incineration increased, which is a natural result as the capacity of the incineration was increased during these years. An interesting picture can be drawn by analyzing the GHG emission from the Budapest incineration (the only MSW waste-to-energy facility in Hungary) between and after the renovation. It is not clear whether hazardous waste incineration is included or not. As a conclusion of the comparison of these two graphs it must be stated that the GHG emission from waste incineration and managed waste landfilling has increased between 1990 and 2009 in Hungary, while domestic and commercial wastewater has dropped.



14. Figure All Greenhouse gas emission in the waste sector, Hungary, 2009

Source: author own contribution based on EEA 2010b

This figure takes into account only direct contributions, and does not factor in avoided use of conventional electricity production due to the waste incineration, which is however, considered in the LCA evaluations. European Environmental Agency (2010a) pointed out that greenhouse gas (GHG) emissions from landfills and waste incinerators in the EU 27 have decreased by 34 % since 1990, the highest reduction rate of all GHG-emitting sectors.

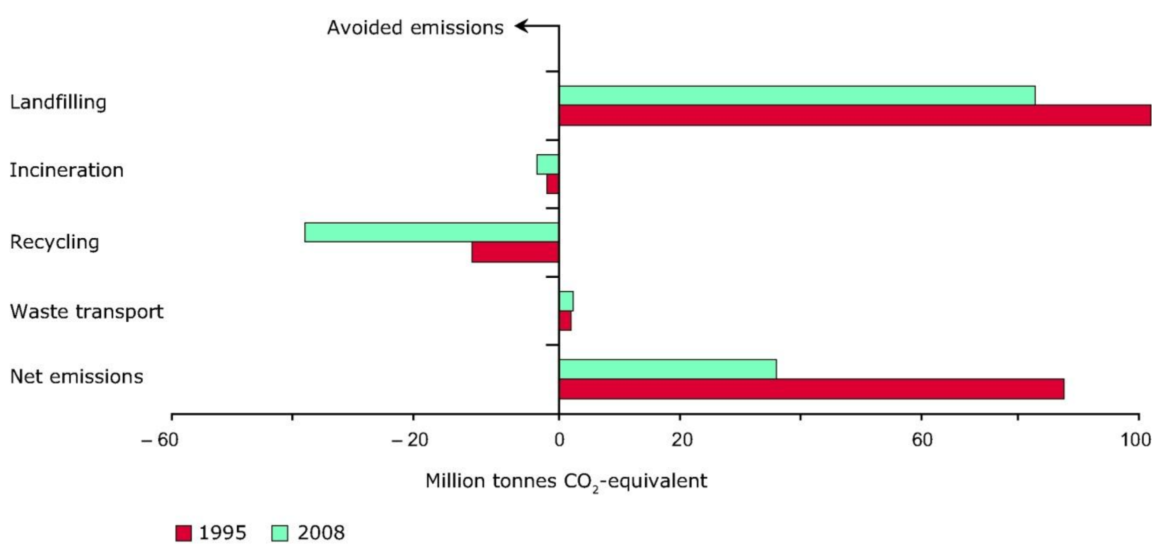
Context of recycling and GHG emission

Waste policies can primarily reduce three types of environmental pressures: emissions from waste treatment installations such as methane from landfills; impacts from primary raw materials extraction; and air pollution and greenhouse gas emissions from energy use in production processes. Although recycling processes also have environmental impacts, in most cases the overall impacts avoided by recycling and recovery are greater than those incurred in the recycling processes.

Waste prevention can help reduce environmental impacts during all stages of the life-cycle of resources. Although prevention has the highest potential to reduce environmental pressures, policies to reduce waste generation have been sparse and often not very effective. Waste recycling (and waste prevention) is closely linked to material use. On the basis of European Environmental Agency (2010a.) data in average, 16 tons of materials are used annually per person in the EU, much of which is sooner or later turned into waste. However, it is difficult to set up direct links between resource use and waste generation due to the inaccuracy in the different methodological guides but mostly due to the lack of long-term time-series data. (European Environmental Agency 2010a.) The increases in overall resource use and waste generation in Europe are closely linked to economic growth and increasing affluence. In absolute terms, Europe is using more and more resources.

Re-use, recycling and recovery follow waste prevention in the EU Waste Hierarchy as presented in the EU Waste Framework Directive, therefore good waste management typically results in lower resource use and less emissions. In addition, the recycling of municipal waste in the EU27 is estimated to have avoided around 47 million tons of CO_2-equivalent emissions in 2008 by reducing the demand for virgin materials. (European Environmental Agency 2010a).

Recycling means savings on GHG emission as the need for the virgin materials is much lower. In Hungary recycling rate is rather low, compared to the developed Western European Union countries, such as Denmark, Germany respectively.

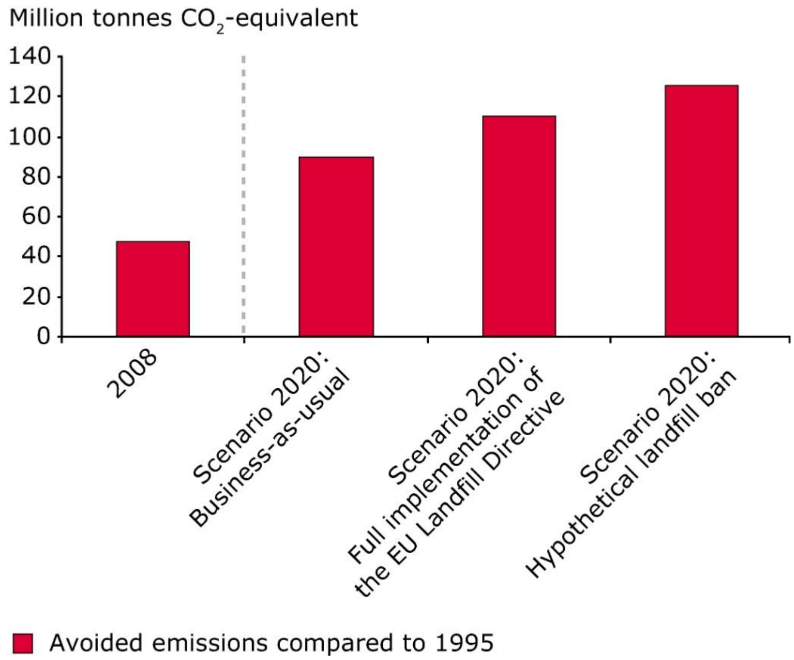


15. Figure Impact of the waste processes on the CO_2 equivalent, EU, 1995, 2008

Source: European Environmental Agency 2011b.

This figure shows that the rate of recycling has been increased in an enormous amount between 1995 and 2008 which is by far the biggest net GHG savings followed by incineration. Landfilling had been decreased due to the stricter waste management policies. These directions resulted in decreasing net GHG emission in 2008. Taking into account the EU-15 countries for the year 2005, we can state that landfills account for about 2/3 of the overall GHG emissions from waste management, which are mainly caused by the fugitive methane emissions (Gugele *et al.*, 2007; Skovgaard *et al.,* 2008).

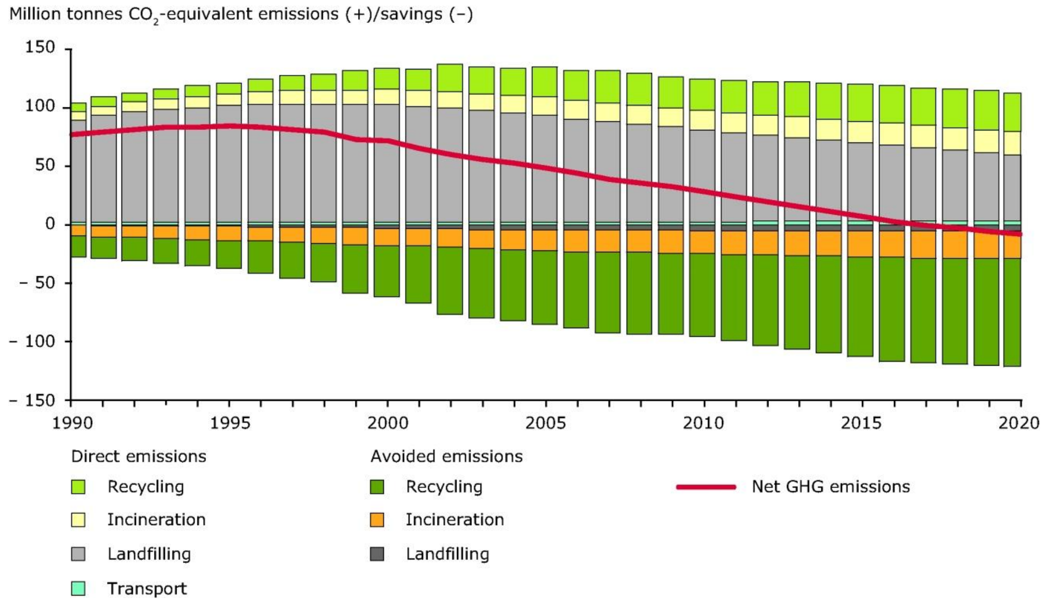
The present trend in the waste management sector and related policy, to shift from a singular dependency on landfilling to integrating more recycling and prevention, has been realized in some Western European countries in the last 10–15 years. This shift has clearly mitigated the pressures of waste on the environment. According to national reports to the United Nations Framework Convention on Climate Change (UNFCCC), the potential GHG emissions from the waste management sector in the EU 27 plus Norway and Switzerland dropped by 37 % between 1995 and 2008, mostly because of the reduced methane emissions from landfills.(USEPA 2002.)



16. Figure Impact of the different waste policies on GHG emission, EU

Source: European Environmental Agency 2011b.

The figure clearly shows that waste management policies have a significant impact on GHG emissions. It is visualized that due to the increased sternness of EU policies, namely the Waste Framework Directive, the landfill ban will result in less greenhouse gas emissions. The present Hungarian legislation is in full compliance with the Waste Framework Directive, and in Hungary the landfill tax will be implemented, as described earlier in this study.



17. Figure Impact of the different waste treatment methods on GHG emission

Source: European Environmental Agency 2011b.

Following the results of the previous figures, this figure clearly shows that net GHG emissions have decreasing since 1990 and are projected to decrease in the future due to the higher rate of recycling. Net GHG emission is still a positive value; however, it might eventually reach negative values resulting in net savings.

Varying levels of separation rate and different approaches to separate collection have been considered in this research while focusing on the separate collection of organic waste, paper and cardboard, metal, plastic, and glass respectively. In a recent study made by Calabro (2009) the list of the separate collected different waste types are similar, however instead of glass he evaluated wood and textiles. In Hungary wood and textiles are not collected separately and the recycling of these waste fractions is also poor. Because of this the current study evaluates glass waste, which is collected separately in the waste islands of Budapest. Calabro's opinion is that in terms of the plastic the produced secondary raw material is hardly attractive for the industry because its quality and cost are often not competitive with virgin plastic. It is obvious that the increase in the separation rate has led to a decrease in the percentage of combustible materials in the residual waste.

Based on the literature review it has been proven that recycling, and the production of secondary raw materials, significantly reduces GHG emissions (see for example Skovgaard *et al.*, 2008; Choate *et al.*, 2005; USEPA, 2002). It takes place not only due to the reduction of the energy needed in the production process but also because of the avoidance of other process emissions (for example during steel and aluminum manufacturing lime is needed and CO_2 is emitted when limestone is converted to lime).

In summary, it must be taken into account that this research focused predominately on the LCA studies which were made by the EASEWASTE model, not only because of the reason that the author is familiar with this model, but also this method is widely used in the contemporary scientific journal publications. In addition, several studies have been made with the EASEWASTE model, not only focusing on different levels of the municipal solid waste treatment (prevention, recycling, incineration, landfilling etc.) phases but also for other waste types such as organic or hazardous waste.

4.6 Gaps in the literature

The above literature review helped identify gaps in the literature both in terms of theoretical as well as practical aspects. Based on the literature review it can be stated that most of the environmental impacts, including global warming potential are influenced by the waste treatment facilities (landfill and incinerator) while the transport distances do not make big difference in the environmental results (Moberg 2006). However, during reviewing the literature the following gaps were identified:

1. it was identified in the literature that exact data were not provided but only at the conclusion chapters, lack of proper data or data inaccuracy seems to takes place often,
2. the scientific publications hardly included Eastern European countries,
3. the direct analysis between greenhouse gas and selective waste collection is rare,
4. policy issues are neglected, as in the LCA evaluations mostly the methodology and the scenarios are discussed and interpreted
5. LCA evaluations are made from yearly data. There were no studies in the literature which analyzed the LCA for different months, showing the trends and respectively the environmental impacts.

These gaps are explained in detail as follows:

1. Exact numbers were not determined for this dependency, due to the reason that every single research project is unique and based on different data. Literature review documents warned that the researcher must remain skeptical on the obtained data and lack of proper data gathering may occur.
2. Furthermore, while most of the relevant studies focus on Western research, or even that performed outside Europe, literature on the experience of the life cycle assessment of the Eastern European waste management systems, especially in a metropolitan city, is relatively rare. The study conducted by Miliūtė (2009) and Koci and Trecakova (2011) are an exception, focusing

their studies on Lithuania and the Czech Republic respectively. Nevertheless, these studies would be relevant for the present research as the waste management structure and technologies are similar that of other Eastern European countries. In the Czech Republic landfilling was 75% in 2006 (Koci and Trecakova 2011) which is very similar to the Hungarian situation. The Czech research claims that the country is considering the establishment of the first mechanical-biological treatment plant, technology which is presently located in some Hungarian cities. In the research elaborated by Miliūtė (2009) the same economic incentives are recommended which are on the political and legislative agenda in Hungary, namely: landfill tax and product fee. In addition Miliūtė (2009) suggest an incineration tax as well.

3. Gaps were also present in the literature specifically focusing on the connection of GHGs and selective waste collection (USEPA2002; Gentil 2011) which is a distinguished topic in my research. More research and analysis would be needed both on the importance of waste segregation and the selective waste collection encompassing waste prevention and landfill diversion related issues. Moreover, the crucial question of the biogenic CO2 is discussed in detail in some studies (Christensen *et al.*, 2009; Gentil *et al.*, 2009). The interactive maps of the European Environmental Agency also provided up-to-date results.
4. Policy issues are hardly included in the reviewed literature. Publications mostly focus on the methodology and some scenarios without mentioning whether that specific scenario is realistic or impossible to implement.

5. Finally, it is required to emphasis that there was no literature which included the analysis of LCA based on different months. It seems to be standard practice that the LCA is elaborated for a yearly basis, therefore the present research seems quite unique work in terms of the elaboration of the different months data and as a consequence their environmental impact.

After the identification of the mentioned gaps in the literature, the current research aims to provide a comparative approach, addressing the trends in the different months between the years 2006-2011. The author conducted an LCA evaluation of a metropolitan city with appr. 1.7 million inhabitants. The environmental impacts, particularly the greenhouse gas emission are evaluated in detail in the present thesis. The mentioned research gap regarding the policy issues is also discussed as in general the point of view of the author is that in several cases there are no explanations whether the listed scenarios are real scenarios or just theoretical. In the case of the present research, only those scenarios are listed and analyzed which have been consulted with the decision-makers.

Generally from the literature review it has been proven that life cycle assessment of waste management systems is a necessary and desirable process. Such a study can provide solutions to decision makers as well as policy planners, municipal leaders or technological experts. This approach is necessary especially in the Hungarian context, as most cities do not engage in any kind of life cycle assessment. Budapest is the front runner in this field and also the capital provides an opportunity to gain insight into the attitude of other large municipalities.

5 Theoretical framework

The aim of the research is to analyze the environmental impacts of different waste management systems and technologies in Budapest through the EASEWASTE model. To reach this aim, a theoretical framework will be used which includes the relevant environmental policies and their interaction. The theoretical framework for the present research can be evaluated while taking into account its compliance with the following policies: it includes sustainable development, environmental impact assessment and also life cycle assessment.

5.1 Sustainable development

Before discussing the main topic and the research problem, it is necessary to define the different definitions in order to clearly locate the ideology and practice in the complex system. The first major international meeting on the human environment, was the UN Conference on 'Human Environment' in 1972 in Stockholm, which brought developed and developing nations together to discuss the future of the global environment. The idea of "sustainable development" was first published in the Bruntland report in 1987, when the United Nations Commission on Environment and Development (the Bruntland Commission) drew attention to the fact that economic development often leads to deterioration, not an improvement, in the quality of people's lives.

The Commission therefore called for

„a form of sustainable development which meets the needs of the present without compromising the ability of future generations to meet their own needs."

There are two key issues as part of this:

- development is not just about bigger profits and higher standards of living for a minority. It should be about making life better for everyone and
- this should not involve destroying or recklessly using up our natural resources, nor should it involve polluting the environment. (Seafield Research)

This is highly important in the case of waste management systems, as the sustainable waste management approach takes into account natural resources, mainly by the first priority of the waste hierarchy, which is waste prevention.

Basiago (1995) defines that sustainability can be "regarded as tantamount to a new philosophy, in which principles of futurity, equity, global environmentalism and biodiversity must guide decision making." It is a far reaching concept and has particular meanings in different disciplinary settings:

- “In biology, sustainability has come to be associated with the protection of biodiversity. It concerns itself with the need to save natural capital on behalf of future generations
- In economics it is advanced by those who favor accounting for natural resources. It examines how markets, as conventionally conceived, fail to protect the environment
- In sociology it involves the advance of environmental justice in situations where some groups make decisions over the use of natural resources and other groups are affected in their daily lives.
- In planning, it is the process of urban revitalization where there is a pursuit of a design science that will integrate urbanization and nature preservation.

- In environmental ethics, it means alternatively preservation, conservation or 'sustainable use' of natural resources. This probes the domain where humans ponder whether they are part of, or apart from, nature, and how this should guide moral choice."

The next meeting in this issue was the Rio Earth Summit in 1992 that proclaimed sustainable development to be the most important policy of the 21st century. This meeting has often been referred to as the first global declaration on sustainable development. The three priority areas indicated in the strategy were:

- Maintenance of essential ecological processes
- Preservation of genetic diversity
- Sustainable utilization of species and ecosystems.

If the Stockholm Conference in 1972 may be considered as the official start of international environmental awareness; the 1992 Rio Earth Summit represented a partial 'coming of age' of the international environmental movement.

This meeting was a milestone in the development of sustainability, however many declarations have not met with the promised results following. More than a decade later it can be said that since then there has been hardly any major results.

The enthusiasm that was generated during the Rio Conference 1992 diminished at the New York Conference 1997. The conference at New York reviewed the progress since the Rio Summit 1992, and found that the environmental quality of our planet's oceans, forests and atmosphere has not been increased significantly. The following international conference in this issue was in Johannesburg for the World Summit on Sustainable Development, in September 2002. This approach called for auditing our efforts for meeting national or global agenda of environmental and sustainable development strategy as it can be easily determined that the previously set targets have not been met. (Anil K.G. and Yunus M. 2004). The latest conference in this issue was the Rio +20 United Nations Conference on Sustainable Development between 20-22 June 2012. This conference is regarded as a failure and ended up only with wishes without any strict obligations. The protection of oceans, and over fishing was blocked by USA and Canada, and demand from the EU for a continuous negotiation at least in ministry's level stayed in minority (Hargitai 2012).

According to the mentioned literature, it seems that between the period of 1972 and 2002 the „sustainable development" principle has been reached only in theory but not in practice. The basic principles, set by Basiago (1995.), are considered to be very influential as in many publications and documents mentioned these as the basic definitions of sustainability. Such 'sustainability' criteria outlines that humanity will only succeed if it finds a way to meet human needs, and at the same time maintaining the integrity of biological systems, accounting for the loss of natural resources from the economy, working social equity, regenerating human settlements and conserving natural capital.

In case of planning the sustainable waste management systems this theory applies to

- biological systems (to save the present flora and fauna etc.),
- economic viability (not cost-effective projects, affordable waste fee, market driven prices etc.)
- social equity (working power, decrease the unemployment, democratic decision-making etc.),

- technical aspects (for example best available technology not entailing the excessive cost)
- and environmental aspects (waste principles, waste prevention etc.) must always be taken into consideration.

According to different studies and common practice sustainable waste management means that waste is treated in the most environmentally friendly way possible, which also takes into account pollution avoidance for the present and for the future generation.

5.2 Environmental impact assessment

The environmental assessment is a process that can describe the likely significant environmental impacts of a project.

As the Environmental Impact Assessment Directive (EC 1985) states: "This Directive shall apply to the assessment of the environmental effects of those public and private projects which are likely to have significant effects on the environment." The environmental impact assessment will identify, describe and assess the direct and indirect effects of a project on the following factors:

- human beings, fauna and flora,
- soil, water, air, climate and the landscape,
- their interaction listed above in the first and second indents,
- material assets and the cultural heritage.

As the Environmental Impact Assessment Directive (EC 1985) mandatory EIA have to be applied to all projects listed in Annex I., whereas screening must be used for projects listed in Annex II.

Environmental assessment of a product can be defined as: "*to define and quantify the service provided by the product, to identify and quantify the environmental exchanges caused by the way in which the service is provided, and to ascribe these exchanges and their potential impacts to the service*" (Wenzel et al. 1997).

Environmental assessment exists in two main forms:

- Environmental impact assessment (EIA) of individual projects (e.g. road construction, power plants etc.)
- Strategic environmental assessment (SEA) of policies, plans and programs (e.g. an energy policy, waste management policy, water resource development plan, road construction program (Bellinger *et al.* 2000)

The stages of the EIA and SEA are the following:

- Screening,
- Scoping,
- Prediction,
- Mitigation,
- Preparation of the Environmental Impact Statement,
- Consultation and public participation,
- Decision making,
- Monitoring.

Instruments of environmental policy within the EIA are:

- Anticipatory: their purpose is to anticipate the adverse environmental impacts and to mitigate them,

- Integrative: they consider all environmental impacts not only those occurring in one environmental medium,
- Technical and participative: they use both scientific and technical analysis and consultation and public participation methods when undertaking the assessment (Bellinger *et al.* 2000).

The life cycle assessment includes similar stages and as a result also shows the environmental load to different environmental mediums, and in this way is similar to the EIA process.

The main differences between EIA and the life cycle assessment are as follows:

EIA is assessment of environmental impacts from an installation or local operation. It is normally highly site-specific in contrast to LCA and it normally does not take a life cycle perspective on the operation but only looks at the immediate local impacts. Generally EIA is an assessment of the environmental impacts caused by major construction works or industrial plants, while LCA is mostly for comparison of several options. EIA takes into account all relevant environmental impacts and often has strong focus on different forms of physical disruption, whereas the model output in LCA is restricted. Normally, EIA is highly site-specific and predicts actual effects on humans and ecosystems in the environment surrounding the installations, while LCA is not site-specific. EIA involves public participation and is legally required in many parts of the world, while in case of LCA public participation is not needed. Several other impact categories are different in case of the LCA and the EIA, such as global warming potential, eutrophication or even impacts on human or cultural heritage.

5.3 Life cycle assessment

Life cycle assessment is a tool for evaluating the environmental impacts and consumption of resources and was initially developed for evaluating the whole life cycle of products including extraction of resources, production, distribution, use and disposal. Life-cycle-assessment (LCA) methods are becoming more integrated to waste management research and decision making.

A part of the waste framework directive allows the member states to shift away from waste hierarchy if through LCA, they can prove that other versions are more environmentally friendly. LCA can be used to make explorative studies in this field.

Within the LCA, quantitative estimations and evaluation of the environmental impacts are elaborated with Life Cycle Impact Assessment (LCIA) process. As Benkő (2009) highlighted, within environmental analysis LCA is likely to be the most common analysis tool in environmental planning, and among several reasons one of the most important is that LCA is the only environmental management system in which frames are defined in ISO standards.

The development of international standards for life cycle assessment (ISO 14040:1997, ISO 14041:1999, ISO14042:2000, ISO 14043:2000) was an important step in consolidating procedures and methods of LCA. The regulations of the LCA begin in 1997, and this standard has been revised by ISO 14040: 2006. This ISO 14040:2006 describes the principles and framework for life cycle assessment (LCA) including: definition of the goal and scope of the LCA, the life cycle inventory analysis (LCI) phase, the life cycle impact assessment (LCIA) phase, the life cycle interpretation phase, reporting and critical review of the LCA, limitations of the LCA, the relationship between the LCA phases, and conditions for use of value choices and optional elements.

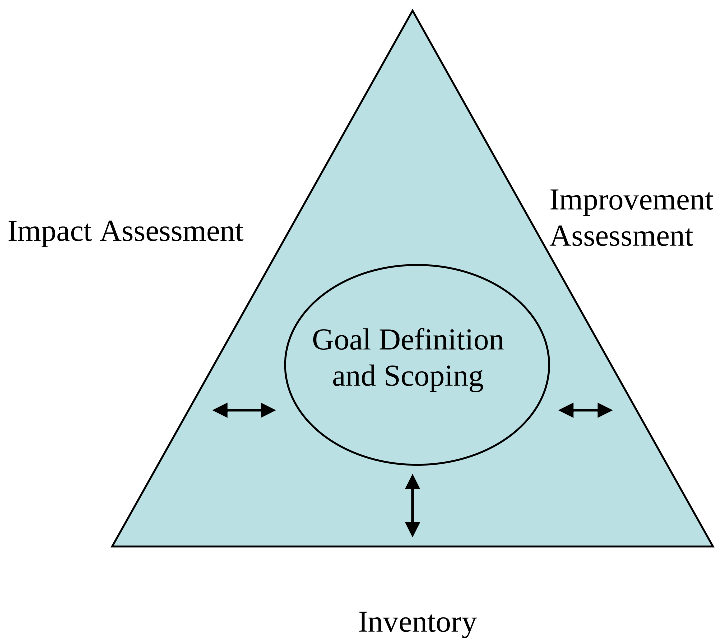
Environmental life cycle assessment (LCA) developed rapidly during the 1990s and has reached a certain level of harmonization and standardization. LCA has mainly been developed for analyzing material products, but can also be applied to services, e.g. treatment of a particular amount of solid waste. Life cycle assessment (LCA) is becoming an important tool in assessing solid waste management systems. The Waste hierarchy has long governed waste management in major parts of the world, but the increasing complexity of waste management and the increasing demand for renewable energy has created the need for more detailed and accurate models for assessing resource conservation and environmental emissions from waste management.

The LCA has been defined as comprising three interrelated components: (Curran 1996)

- Inventory: a data-based process of qualifying the environmental releases throughout the life cycle of the process
- Impact assessment: a quantitative process to characterize and assess the effects of the different environmental load
- Improvement assessment: a systematic evaluation of the need and opportunities to reduce the environmental burden throughout the whole life cycle of the product. It may include both quantitative and qualitative measures of improvement.

Some added a fourth element called initiation or scoping, which precedes the activity and defines the purpose of the study.

According to these components the LCA conceptual model is the following:



18. Figure The LCA conceptual model

Source: Curran, Mary Ann 1996

According to the ISO 14040 standard the Life Cycle Assessment has the following 4 steps (together with the addendums from Abeliotis 2010 and Moberg A. 2006.):

1. Goal and scope definition

   In this case not only the goal and scope must be defined but as well as the system objectives and the functional units also

2. Life cycle inventory -LCI

   This step focuses on all of the required input data

3. Life cycle impact assessment - LCIA

In this case the size and the significance of the potential environmental impacts must be determined. Its main points are the following:

- Determining the impact categories,
- Classification,
- Characterization,

4. Life cycle interpretation

The evaluation of the results is the important task in this phase.

In Hungary attempts have been made to use the normal LCA software for analyzing waste management systems, but such software (such as GaBi) has been developed for different purposes therefore the structure of the model is not detailed enough for waste management systems as they were established for product life cycle assessment. It has not proven to be properly adapted for evaluating the characteristics of different waste management systems.

If we consider LCA within the sustainable development framework it must be stated that the total LCA analysis includes the cost and the social analysis as well according to the following formula: Sustainable LCA = LCA+LCC+SLCA (Szita 2010) meaning: Sustainable LCA= life cycle assessment (LCA) + life cycle cost (LCC) + social life cycle assessment (SLCA). The initial phase of the process is the environmental LCA, while the cost analysis and the social LCA follows, therefore sustainable development can be described. In this research, however, only the environmental part is analyzed, as the cost and the social evaluation of Budapest selective waste is out of scope of this research.

The indicators for life cycle assessment are different from the carbon footprint (CFP) and the ecological footprint (EFP). As Biczó (2012.) pointed out the comparison table of the life cycle assessment, the ecological footprint and the carbon footprint is the following:

	LCA	Carbon footprint (CFT)	Ecological footprint (EFP)
Considered environmental impacts	Emissions	Emissions	Area occupation impact
Climate change	+	+	+
Acidification	+		
Changes in land use	+		++
Eutrophication	+		
Global warming potential	+		
Energy demand	+	+	+
Resource use	+		

8 Table Comparison of LCA, carbon footprint and ecological footprint

Based on Biczó 2012.

Regarding the international standards ISO is relevant to LCA and CFT but not for EFT. For the LCA and the EFT special software and knowledge are necessary. In summary among all, LCA is considered as the most reliable and thorough evaluation.

Life cycle assessment of solid waste management systems

The levels of result are similar to a life cycle assessment, which basically includes the following steps:

1. Life-cycle inventory (of substances, all resources and emissions)
2. Characterization to environmental impacts (g equivalents or m3water, soil or air)
3. Normalized environmental impacts (person equivalents - defined as the impact of one person in a reference year)
4. Weighted environmental impacts (targeted person equivalents -defined as the politically targeted impact of one person in a year)

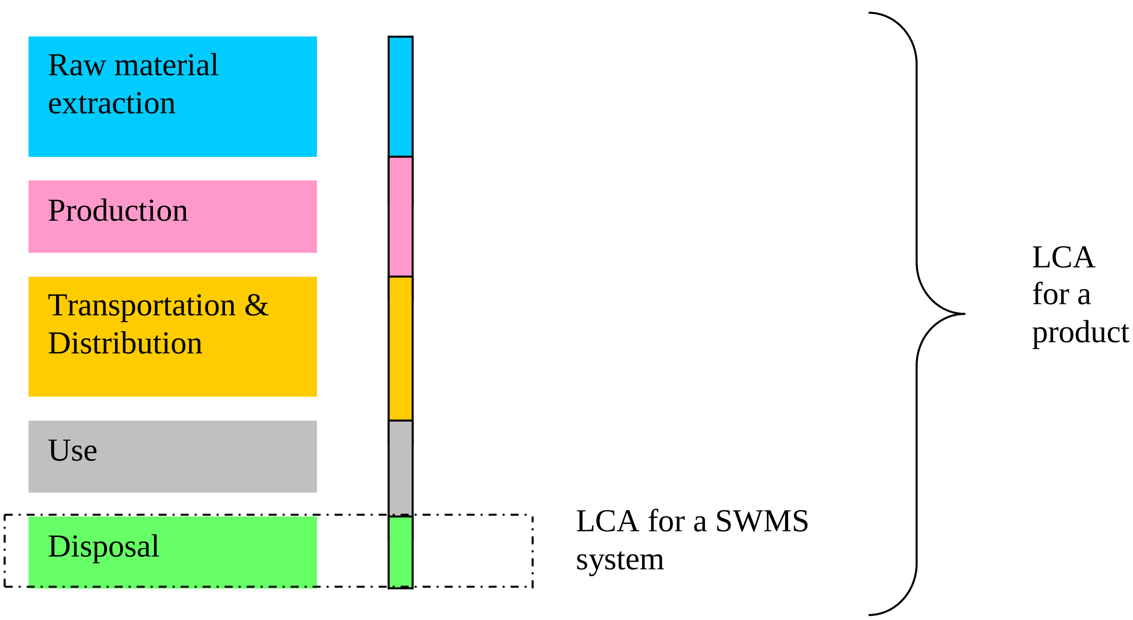
The procedure for conducting an LCA on a waste management system is very similar to an LCA on a product. In the EASEWASTE model a holistic and systematic approach is used to evaluate the environmental impacts when using life cycle assessment on integrated solid waste management systems (Kirkeby 2006). The software takes into account the consumption of resources and potential impacts on human health and on the environment as well as recycling and energy balances (Damgaard 2006).

Life Cycle Assessment has typically been used for waste management evaluations as it plays a very important role in decision making and strategical planning. Güereca (*et al.* 2006) pointed out that LCA in the waste management sector has been used since 1995.

In a waste management system, it would involve all activities which take place in the whole waste management system such as collection, treatment, recycling and disposal. The technical units could include collection vehicles, material recovery facility (MRF), a composting plant, an incinerator etc. For a waste management system, the following aspects may be relevant to consider in the scoping of the different life-cycle stages of the product:

- Raw material extraction
- Manufacture – production
- Transportation and distribution
- Use
- Waste management - disposal of the product

A normal product LCA is said to be a cradle-to-grave analysis where the raw material extraction is the cradle and the disposal stage is the grave. For a solid waste management system which starts at the disposal stage this is called a bin-to-grave analysis. Where the waste is followed from the point where it is disposed by the user in the waste bin, until its final disposal site (e.g. a landfill, incineration residues from a waste combustion plant which is placed in an inert landfill etc.). But, a waste management system goes a bit further as it also looks at the remanufacturing of recycled material where the offset from recycling is compared with the use of virgin material in manufacturing (Damgaard 2006)



19. Figure Comparison of a product and a waste management LCA

Source: based on McDougall *et al*., (2003) This figure shows the system boundaries of the waste management system and compares it to a life-cycle assessment of a product. The five stages mean the system boundary in LCA of products, whereas the last stage represents the system boundary in LCA of waste management.

Main purposes of the solid waste management system LCA are the following:

- Collect and organize data,
- Comparing alternatives,
- Evaluating the future impacts,
- Determine the biggest environmental load in the system,
- Evaluating the technologies (landfill, incinerator, composting and biogas systems),
- To find solutions depending on the results (negative or positive environmental impacts),
- To find the best environmental solution,
- In summary: life cycle assessment modeling of solid waste management systems.

The LCA can be a solution for choosing and applying the suitable technologies, programs and strategies in a solid waste management system in order to reach the special waste management objectives. Therefore several studies have been made by using solid waste management LCA modeling. (Barton *et al.*, 1996; Barlaz *et al.*, 1999).

The EASEWASTE model is using life cycle assessment. According to the LCA standards, ISO 14040 (ISO 14040, 1997 and together with the description of Technical University of Denmark. 2008), LCA consists of the following four phases:

- Definition of the goal and scope of the study (ISO 14041, 1998)
- Inventory analysis: preparing an inventory of inputs and outputs from all processes that form part of the product's life-cycle (ISO 14041, 1998)
- Impact assessment: Using the results of the inventory analysis to prepare environmental impact and resource consumption profiles for the product system (ISO 14042, 2000)
- Interpretation of the impact profile and resource consumption according to the defined goal and scope of the study including sensitivity analysis of key elements of the assessment (ISO 14043, 2000)

These four phases are in line with the above mentioned LCA conceptual model. Although LCA consists of four consecutive phases, LCA is an iterative procedure where experience gathered in a later phase may serve as feedback leading to modification of one or more earlier phases.

Hauschild and Barlaz (2008) developed the specific description of these steps in the waste treatment sector as the following activities:

Goal and scope definition

As in any evaluation, an LCA study should start with an explicit declaration of the goal and scope.

Goal

The goal of the research means the purpose of the study, therefore it is very important to exactly determine the types of questions that can be addressed by the LCA and also to which the LCA can not answer.

In a waste management context the goal of an LCA could be to compare different waste treatment methods in order to define which treatment process contributes the least to the overall impact on the environment and the resource base. Another goal may be to compare different flue gas cleaning technologies or other technological process, so generally it is stated that LCAs are used for comparisons. The waste amount and composition, existing legislation on waste treatment, available waste treatment technologies etc. are crucial and should be considered in interpreting the outcome of the study. The interpretation phase of the LCA could be used to determine what contributes to the environmental impact of technology and use this information for improving the technology.

Scope

The scope definition of an LCA study must address the following issues by Hauschild and Barlaz (2008):

- The object of the study - the functional unit
- The boundaries of the system and exchange over boundaries
- The assessment criteria to be applied
- The time scale of the study
- The technologies representing the different processes
- Allocation for processes entering into other systems as well

The detailed descriptions of these are the following:

The object of the study – the functional unit

The functional unit of a waste management LCA could include:

- Quantity of the waste to be managed
- Waste composition
- Duration of the waste management service
- Quality of the waste management (legal emission units, requirements for residual products)

For example, for a packaging study comparing cartoons and reusable glass bottles for milk the functional unit was defined as "packaging of 1000 liters of milk" (Lundholm and Sundström 1985). In the assessment for example 1000 liters cartons versus 40 liters glass bottles are represented, provided that the bottles are reused 24 times.

System boundaries

If we take into account the life cycle thinking perspective, we must be aware that decisions should be based on clear definition of the system boundary, and the identification and quantification of mass and energy flows through the boundary. The technical units among others can be the composting plant, material recovery facility, incinerator or even landfill site. Therefore this part means the elaboration of a thorough definition and delineation of the waste management system including:

In a solid waste management system the system boundaries include the upstream and downstream processes of the core system, representing all solid waste processes. Upstream processes can be regarded as the different activities related to input material and energy to the core system, while downstream processes include activities related to the final use of products as well as the displacement of external material and energy production (Björklund & Bjuggren, 1998). The core system is also known as the foreground system where the upstream and downstream processes make up the background system. (Kirkeby 2005)

Assessment criteria

The assessment criteria must be specified before the inventory analysis starts in order to ensure collection of the relevant data. SETAC has identified an overview of potential environmental impact categories for the LCA. (Udo de Haes (ed.) 1996, Udo de Haes *et al.,* 2002). In addition the model includes the consumption of natural resources as well. There have been attempts to include the socio-economic and ethical aspects as assessment criteria, as well as working environment impacts, but these are not used generally. Most LCA's should cover the following impacts: (Hauschild and Barlaz 2008):

- Global impacts:
    - Global warming,
    - Ozone depletion
- Regional impacts:
    - Photochemical ozone depletion
    - Acidification
    - Terrestrial and aquatic eutrophication
    - Human toxicity
    - Ecotoxicity
- Local impacts:
    - Land use

- Odor
- Division of habitats
- Radiation
- Accidents

The resource issues may be assessed in terms of:

- Consumption of non-renewable resources, for example:
    - Oil
    - Natural gas
    - Iron
    - Aluminum
- Consumption of renewable resources, for example:
    - Forest biomass
    - Agricultural biomass
    - Groundwater
    - Freshwater

The main purpose of LCA is to analyze and optimize scenarios. Some people may be interested in whether the values are under health limit values, but in this case the risk assessment area is also considered. It must be highlighted that LCA is just one of the tools for decision making and should not stand alone, and should be supported by other tools as well. LCA is appropriate for the initial screening when choosing between different scenarios. For instance if the emissions are lower in scenario A than in scenario B, then it matters from a health stand point that A will always be better than B, but they might both be below the safety limit. It is important to understand that the emissions from the waste management system are just a part of the daily release, so they can not be converted directly to concentrations, as there are several other sectors releasing emissions and its aggregated value what is required for the complex risk assessment.

Time scale

The time scale practically means the period until the conclusions of the study will be valid. It depends on the waste management technologies and the data that is collected during the inventory analysis. For landfilling the latest studies take into account 100 years (Gentil *et al.* 2010)

Technological scope

This issue involves the identification of the relevant technology in the waste management system. At national level average technologies and the best available technologies for future development may be considered.

Allocation

The application of multiple output processes is necessary in the waste management system where the waste generates a number of material or energy streams like glass, paper, plastics, metals, and electricity, thermal energy or energy carriers like methane. It can be stated when recyclables are used for the production of new raw products, then the production of virgin materials are avoided, so the environmental impact may be negative, resulting in savings.

Inventory analysis

After the goal and scope of the waste management system, the emissions and resource information are listed in the input and output for the relevant processes.

Data collection

In general, data collection is crucial in order to obtain an average functional unit of the process. However, data collection is a crucial step, and in many cases data is inaccurate, and there are contradictions in the data, consequences which can be realized through the literature review (USEPA 2002). In the inventory, exchanges of the different individual waste management processes will be summed up. Some of the data originate from the composition of the input waste while other data are generated from the technology of the facility, meaning the difference between the process-specific and waste-specific emission types. For instance the dioxin emission from an incinerator is not directly linked to the composition of the waste but the flue gas cleaning technology and the operation of the incinerator, so it can be regarded as technology process emission.

Data quality

The quality of the collected data in the inventory is crucial to the outcome of the LCA. The collection of process data should be guided by a sensitivity analysis focusing on the data that has the greatest influence on the overall outcome. The LCA report should contain a thorough documentation of data sources.

Use of computer tools and databases

The use of the existing databases with environmental process data is a prerequisite for performance and public review of LCAs. A number of software tools are available to the modeling of the system, both in the inventory and the impact assessment stages, these have been discussed when the different waste LCA models are described.

Impact assessment

The complex impact assessment typically includes a large number of inputs and emissions. Today the following protection areas of life-cycle assessment are accepted (Udo de Haes *et al.*, 1999):

- Human health,
- Natural environment,
- Natural resources,
- Man-made environment.

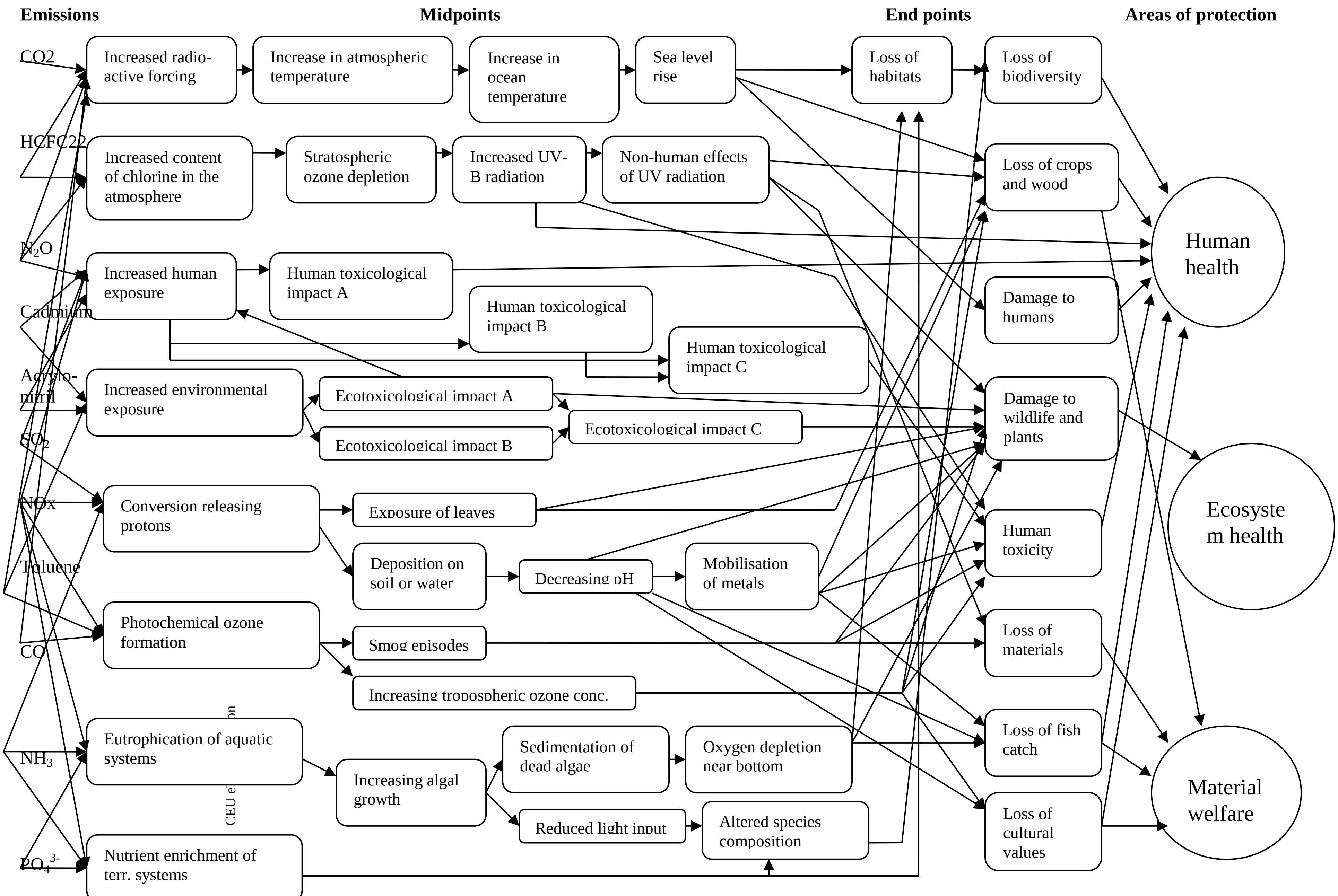
The goal of the impact assessment is to interpret the emissions into their potential impacts on the areas of protection by applying the relations between emissions and their effect on the environment as illustrated in the following figure.

In the life cycle impact assessment two approaches exists to model the impacts:

- Midpoint modeling, where impacts are modeled until a midpoint is developed, which is as close to the areas of protection as possible. The relation of the midpoint to the area of protection is considered in the weighting. This is the traditional approach to life cycle impact assessments. Experts in this field are Wenzel *et al.* (1997), Hauschild and Potting (2005.) and Guinée *et al.* (1996). .

- Endpoint modeling or damage modeling represents where impacts are modeled all the way to effects on the areas of protection using the best available models. The only weighting here is the weighting between the areas of protection. This school of thought considers that the uncertainty in the LCA is improved by the developed interpretation of the results. This method is represented by Goedkoop and Spriensma (2000) and Steen and Ryding (1992.)

The present research tries to combine the two approaches with the dominance of the midpoint modeling. The figure was drawn based on EASEWASTE User's Manual (2008). Today the discussion takes place whether to analyze the uncertainty on interpretation (stopping at midpoint) versus uncertainty in going from mid to endpoint, which could result in easier endpoint interpretation.



20. Figure Causality web linking emissions of environmental mechanisms on the areas of protection Source: EASEWASTE User's Manual (2008)

The life cycle assessment has four steps which are the following; each of which will be further described later:

- Selection of impact categories and classification,
- Characterization,
- Normalization and
- Weighting.

According to ISO 14040 the classification and the characterization are mandatory while the normalization and the weighting are optional.

Classification

In this step an identification of the impact categories that were chosen as assessment parameters at the beginning in the goal and scope definition is performed. When determining the impact categories it should be taken into consideration that in the causality web there is no overlap between the elements of the web. It is also important to go observe that for the inventory for each emission we need to identify potential effect on the impact categories. Naturally, there are several substances which influences more than one impact category; for instance NOx which has effect on acidification, nutrient enrichment or eutrophication, photochemical ozone formation and human toxicity.

Characterization

Characterization occurs when the impact potentials of emissions are aggregated; therefore the impacts are thought of as a total sum of the contributions from each emission which are released over several years in the different locations. The analysis of landfills are difficult due to the fact that emissions result over a time, even longer than in any other waste management method (Manfredi 2009).

Normalization

The aim of normalization is typically two-fold

- to place LCIA indicator results into a broader context and
- to adjust the results to have common dimensions.

As Pennington *et al.* (2004).pointed out the sum of each category indicator result is divided by a reference value.

Equation:

Nk=Sk/Rk

where

- k denotes the impact category,
- N is the normalized indicator,
- S is the category indicator from the characterization phase and
- R is the reference value.

The reference system is generally chosen using overall indicator results for a specific region, for example a country, and for a specific year, such as the annual national US contribution to climate change in terms of GWPs. Spatial scale, temporal scale, a defined system (e.g. a region or an economic sector) and a per capita basis are all examples of attributes that could be taken into account when choosing the reference value. Normalization results can provide input to grouping or weighting, as described in the next subsections, or can help directly judge the relative importance of different impact categories within an LCA study. However, it should be noted that direct application implies acceptance of the ratios of different impacts as they exist today, meaning that, for example, the total current effects of global warming and ecotoxicological effects in Europe would be considered to be of equivalent importance.

Weighting

Weighting results in numerical factors which are based on value choices to determine the comparison across impact category indicators (or normalized results). Weighting is often applied in the form of linear weighting factors (Pennington *et al.* 2004):

Equation:

$$EI = \sum V_k N_k$$

or

$$EI = \sum V_k S_k$$

where

- EI is the overall environmental impact indicator,

- Vk is the weighting factor for impact category k,
- N is the normalized indicator and
- S is the category indicator from the characterisation phase.

Weighting remains a controversial element of LCA, as in other assessments - mainly because weighting involves social, political and ethical value choices In the EDIP methodology a weighting method for impacts based on political reduction targets for either Denmark or EU is available (Wenzel *et al.*, 1997; Stranddorf *et al.*, 2005). Not only are there values involved when choosing weighting factors, but also when choosing which type of method to use, and even in the choice of whether to use a weighting method at all. However, all weighting methods include scientific aspects - not only from natural sciences, but also from social and behavioral sciences as well as from economics.

Interpretation

During the interpretation phase the results are discussed taking into account the defined goal of the whole research. The output of the interpretation can be recommendations to policy makers in order to help them in decision-making. Naturally, decision-makers require additional information in terms of the economic and social impacts and not only the environmental impacts, which is only one part which is necessary to make a decision. Interpretation may result in reviewing the goal of the study, as the whole LCA itself is an iterative process. Interpretation includes **sensitivity analysis** which is an indispensable part of this phase. The sensitivity analysis identifies the key figures of the LCA, the model assumptions, processes and environmental impacts possessing the greatest importance on the final results. As there may be uncertainty in the data inputs, the sensitivity analysis helps to vary the results in their estimated range. For this the most usual technique is the Monte Carlo method, which can be easily implemented and used by several LCI studies. (McCleese and LaPuma 2002; Sonnemann *et al.* 2003. and Kaplan *et al.* 2005).

Limitations

The complexity of the LCA evaluation and the large amount of required data lead to some limitations (Hauschild and Barlaz 2008.) First, it must be mentioned that uniform data is necessary. Secondly, the inventory stages do not include emissions with spatial resolution, therefore an aggregated net emission may result from an emission increase from one location and emission decrease from a totally different location. The third point is that only total emissions are presented and not emission rates. Finally, the results must be presented with many caveats. Political and regulatory decision-makers often require a "bad" or "good" answer; however LCA is a comparative study.

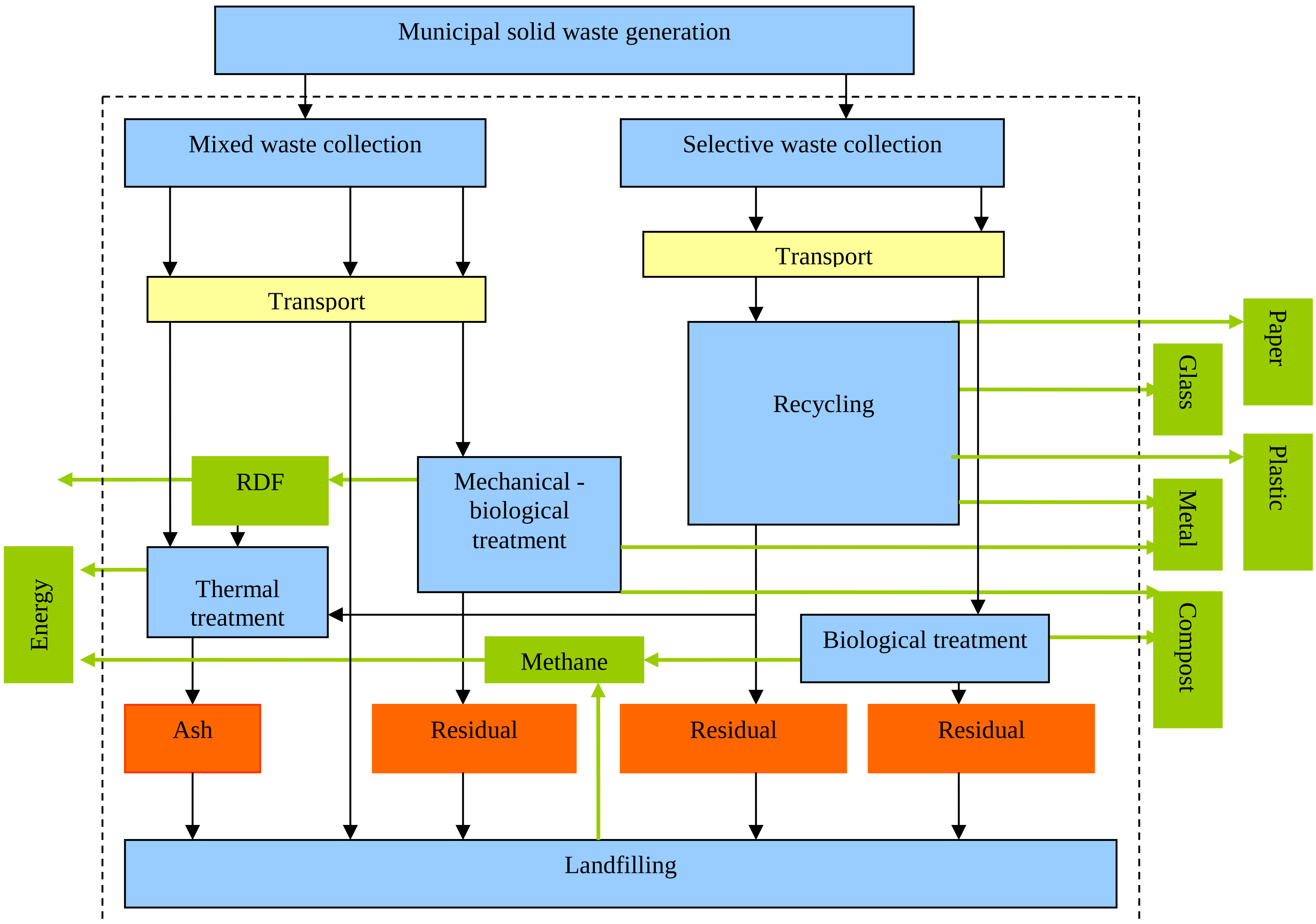
Elements of the waste LCA

Abeliotis (2010) has a broader view on the different elements of the LCA on waste management systems. The detailed characteristics of the following waste management treatment methods are required:

- Collection and transport
- Recycling after selective waste collection
- Mechanical biological treatment
- Composting

- Incineration
- Landfilling

The structure of the solid waste management LCA can be seen in the following figure:



21. Figure Whole life cycle of the municipal solid waste

Source: Abeliotis, K. (2010) Life Cycle Assessment in Municipal Solid Waste Management

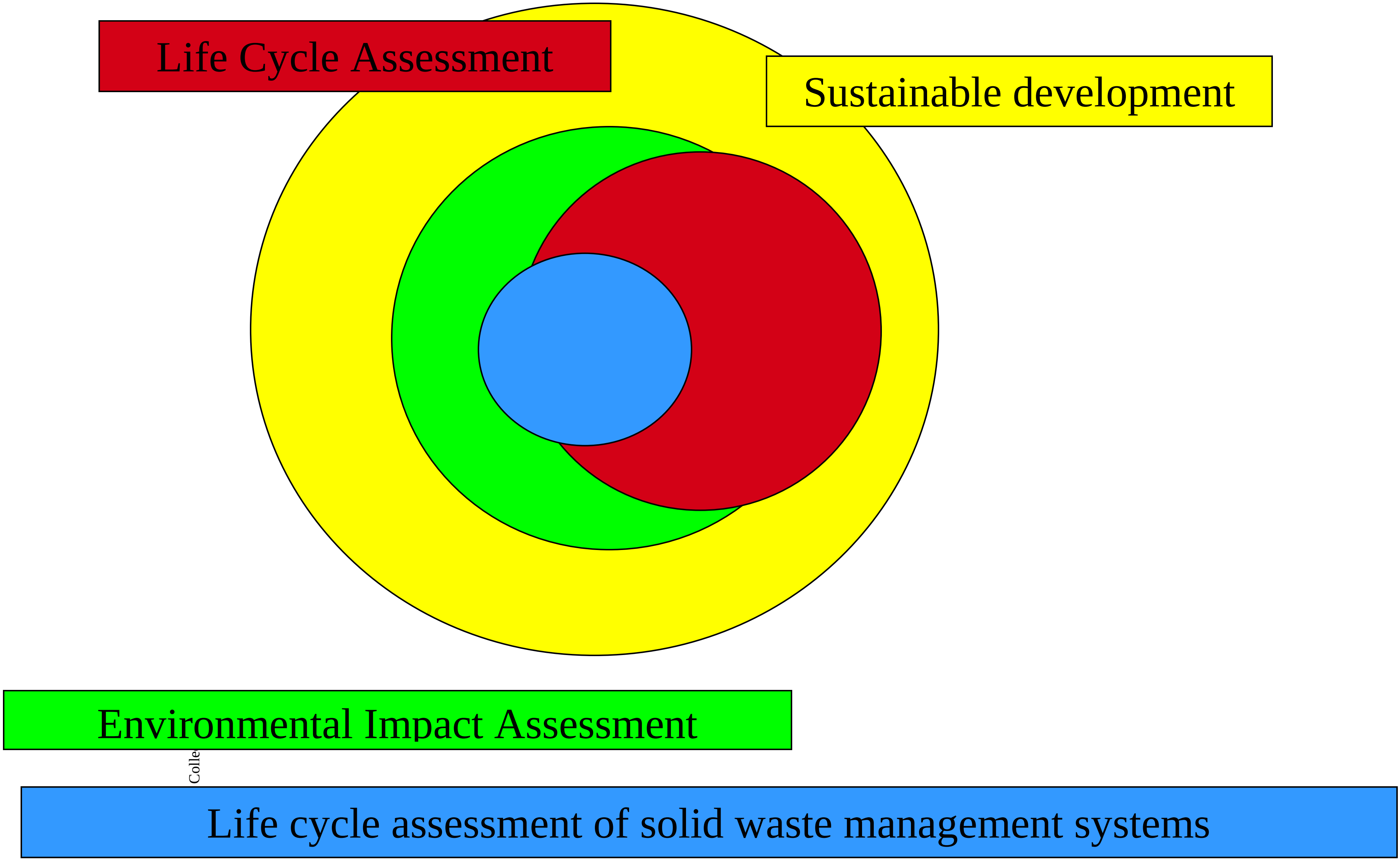
This figure does not contain the used resources and the emission. The structure shows a general picture, as not all of the waste treatment facilities occur in all of the waste management systems. Ideally the selectively collected waste is recycled and further reprocessed. At many cases metal is collected after incineration.

The collections of the methane gas from the landfills are highly important as it has more serious implications on GHG than CO_2. At many places it is done by flaring, but the best solution is the use of the gas motor, as it can use much more CH_4 for energy production. In Budapest the use of the gas motor has been planned for the Pusztazámor landfill site for several years.

According to author the life cycle assessment of the solid waste management systems is part of the following concepts:

- Sustainable development and
- Environmental impact assessment.

The integrated waste management is also included in the system, but it is part of the EU waste management system. The interaction of these policies and the life cycle assessment of the solid waste management systems can be described in a picture. Therefore according to the mentioned policies the policy background of this research can be illustrated in the following figure.



22. Figure Theoretical framework of the research within the environmental policies - own theory

The detailed description of this picture is the following:

All of these policies are part of the **sustainable development** system, as they promote the mitigation of the environmental load. However, sustainable development is a much broader theory as it includes not only waste management but also climate change, energy efficiency, waste water treatment, air protection, sustainable agriculture, genetically modified orgasms, nature protection, biodiversity, consumer protection etc.

Environmental Impact Assessment includes waste management and several other aspects of an environmental activity such as the impact on flora and fauna, soil and groundwater, nature protection, etc.

Life cycle assessment, nevertheless, is also used for a product, but the present research uses it for a waste management system. In some cases life cycle assessment is more detailed than the environmental impact assessment and the EIA is mainly focused on site operations, unlike LCA which the scope is broader in terms of the territory.

The **life cycle assessment of waste management systems,** however, is part of the environmental impact assessment as it evaluates the impact on the different environmental elements. Therefore according to author's opinion, the life cycle assessment of the solid waste management systems can be located within these environmental policies.

6 Methodological approach

This chapter aims to describe the whole dissertation research process from a methodological point of view. It explains of the type of research methods, why, and how they were used to achieve the research objectives. It also includes assumptions, and discusses the main modeling related methodology issues highlighting data collection and includes also validity and reliability issues. The research utilizes qualitative methods for the policy field as well as quantitative method for some research stages, e.g. for the data collection and evaluation. As Patton (1990) emphasizes such a combined approach gives a greater understanding of the nature and behavior of the research phenomenon – the environmental assessment of Budapest waste management including an LCA and benefits the research by enhancing its validity, providing a general picture, and facilitating interpretation.

The research utilizes qualitative methods with quantitative methods employed only in the later stages. The combination of these two methods seems to be the most appropriate to answer to the main objective and the three sub-objectives of the research - which have been discussed in the “Research questions, assumptions, objectives and outcomes” chapter.

The research question, objectives and assumptions are the following:

Research question	**Comment**
What is the nature and capacity for recycling in Budapest and its impacts on environmental pollution including climate change?	Research question was formulated according to the desirable perspectives of the key stakeholders

9. Table Research question of the present thesis

Research assumptions	**Comment**
• **Assumption No. 1.** It is assumed that the environmental pollution can be evaluated in more detail if several months and years are analyzed instead of one year.	This is a unique method in LCA evaluation, and by analyzing the results of the different months and years the trend can be visibly demonstrated.
• **Assumption No. 2.** The research assumes that the data and information that are given to prepare the EASEWASTE model are sufficient, proper, correct and realistic.	The data which was given for the model are proper, and discussed several times. However, general data inaccuracy is significant in Hungary.
• **Assumption No. 3.** It is assumed that the waste generation per capita is different in case of multi family, single family and SCBU cases.	It has been discussed in the Evaluation of Budapest solid waste management system chapter at the waste composition. This assumption requires more detailed research in the future.

10 Table Research assumptions of the present thesis

Research objectives:	
To prepare the environmental assessment and policy options for the present and expected municipal solid waste management systems of Budapest. This research will use the EASEWASTE model for this assessment. According to the results of the different scenarios in the environmental assessment a discussion with the key stakeholders about their perspective and preferred options will be made.	Correct
• **Objective No. 1.** To acquire the necessary inputs which are required for modeling the Budapest solid waste system.	A highly significant output of this objective is a very detailed waste composition for 48 waste types, which was provided by the request of author and had never prepared before. In addition author's own contribution is a draft map on the Budapest waste collection points which can be a base for future maps.
• **Objective No. 2.** Determine the major desirable alternatives taking into account higher recycling rates and run the EASEWASTE model for them.	Modified as originally technological and managerial alternatives were determined, however the research focused on the different selective recycling rates. In the policy options and conclusion chapters several recommendations are discussed which are relevant to the original objective.
• **Objective No. 3.** Discuss the findings with the key stakeholders, aiming to determine their perspectives and preferred options.	Correct and helped to formulate the research question

11. Table Research objectives of the present thesis

The modifications compared to the original assumptions and objectives are the following:

- **Assumption No. 1.**

Originally assumption No. 1.was the following:

Hungary is eager to reach the European Union targets (particularly in terms of the packaging waste).

However, the organizational structure of the new waste management system drove me to the new research path. There have been several fundamental changes in the Hungarian waste management sector since the beginning of writing the present research. A new state-owned company, the Országos Hulladékgazdálkodási Ügynökség Nonprofit Kft. (OHÜ Nonprofit Kft. - the National Waste Management Agency Nonprofit Ltd.) was established and started to operate from January 2012. This company controls the waste collection and utilization of some waste types, including packaging waste. OHÜ Nonprofit Kft. has to determine the planned (mandatory) collection and utilization rates on the OGyHT (National Collection and Utilisation Plan) for some waste types, including packaging waste. Therefore this assumption has been revised and removed out of the scope of the present research.

As present research focuses on the correlation of the selective waste collection, waste recycling and their impact on greenhouse gases the new assumption become has been changed and literature review and also my present research will find answers to this assumption.

- **Objective No. 2.**

Originally objective No. 2.was the following:

Determine the major desirable alternatives both technological and managerial to the current system and to run the EASEWASTE model both for the alternatives and to the present system

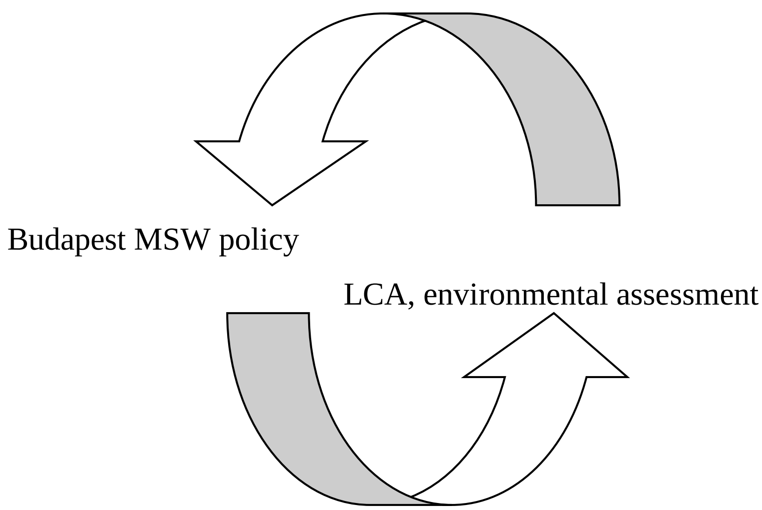
In the case of Budapest there is no point in setting up unrealistic alternatives which will are unlikely to be implemented in the near future due to the lack of political, financial and environmental support. A good example can be that some leaders considered that a second waste-to-energy plant or a transfer station can be useful for Budapest. Nevertheless, a waste-to-treatment plant is not at the priority of the waste hierarchy, but preferably waste prevention, waste re-use and waste recycling are the preferred options, which are also supported by the present Hungarian government. Concerning the transfer station, the plans have been prepared and will be built in Ipacsfa street in the following years (in XVIII. district, down in Pest side), but there are no detailed information about it. Therefore the scenario options will not be the analysis of the environmental impacts of a new incineration plant or a transfer station.

The present dissertation – according to the revised assumption –analyses the selective waste collection and their impact on the greenhouse gases. Different rates of the selective waste collection either in the months of 2006-2011 or in the rates (three time, five times higher recycling rates) was proposed for evaluation by the Head of the Environmental Department, Attila Olgyay-Szabó (pers.comm. 2012) as different scenarios.

During the discussion of the main key decision-makers of FKF Zrt. their desirable alternative was the analysis for the higher rate of selective waste collection.

Qualitative methods are chosen because they provide detailed information with increased depth of understanding about processes and policies and quantitative methods are necessary to calculate the results of the life cycle assessment.

Life cycle assessment is an iterative process.



23. Figure Interaction of environmental assessment and the Budapest waste management policy

Since there are different policy plans to improve the municipal solid waste management system of Budapest it can affect the environmental assessment and so the results of the environmental assessment can affect the policy, which are described above.

The EASEWASTE software is available to give feedback on the present waste management policy hence „the model can be used either at a regional or national level for the purpose of setting guidelines for solid waste treatment" (Kirkeby *et al.* 2006).

Therefore the results of the model are definitely useful in order to prepare a strategy that describes the most suitable technology within a waste management system.

6.1 Methodology for LCA modeling

Before discussing the research methods it is important to describe how author was able to get in contact with the EASEWASTE model.

The author was eager to analyze the impact of waste management sector, particularly the solid waste management on the climate change. It can be seen that the waste management sector contributes to GHG emission at a rate around 4 % (EEA 2010b), a value which can be diminished. The majority of the emissions originate from the landfill sites, and in Hungary the common practice for waste disposal is landfilling. There were several landfill sites which were even in operation before July 2009. After this date only those which fulfill EU requirements are allowed to operate. Waste incinerators also contribute to global warming in terms of CO_2, (even taking out the biogenic CO_2) but in a smaller extent. In order to follow the waste hierarchy in the Waste Framework Directive (EC 2008) waste prevention, preparing for re-use and recycling are the top priorities. These activities need to be promoted by a more sophisticated public awareness campaign which means that waste management policy issues are also emphasized.

The author carefully considered the Waste Management sector in the Climate Change 2007: Mitigation plan which was in the Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. (Bogner *et al.* 2007.) After reading this chapter author was looking to form a relationship with some contributors in order to obtain some more information and contacted Katarina Mareckova from Slovakia who was a lead author and from the contributing authors Peter Kjeldsen from Denmark and Suvi Monni from Finland. Out of these respected scientific researchers, Suvi Monni from the European Commission - DG JRC, Institute for Environment and Sustainability, Climate Change Unit, TP290, I-21027 Ispra (VA), Italy, accepted my invitation and contributed to a great extent to my Prospectus Defense which took place in February 2009. Peter Kjeldsen forwarded my letter to Thomas H. Christensen, who is the Head of the Department of Environmental Engineering at the Technical University of Denmark. Thomas H. Christensen informed me that they have developed the EASEWASTE model which is suitable to analyze the impact of the waste management sector on the global warming and recommended take part in their training. The author organized his travel to Denmark through the financial support of Central European University and so took part in the EASEWASTE training for PhD students in June 2008. Today author represents the only Hungarian who had the opportunity to obtain this knowledge. Since 2008 the author has been in continuous correspondence with the Danish Professors in relation to his LCA research for Budapest, mostly Anders Damgaard but also with Thomas H. Christensen and Michael Hauschild.

Specialty of this research compared to other LCA studies in terms of scenarios

In other LCA studies – which have been described even in the literature review chapter- several waste management scenarios have been analyzed and compared to each other. In the case of Budapest, nevertheless, the author mainly focuses on the state of the selective waste collection in the different months from 2006-2011. The reasons for this unique analysis are the following:

1. In the LCA framework it is not appropriate to evaluate different scenarios in which are not considered as real options. In many cases different technological elements are included in a system, however there are not enough feasibility conditions available for the designed system. In the case of project planning of the former ISPA or the present Cohesion Fund, in waste management systems three obligatory options have to be prepared, however two of them were only „designed" when the already accepted third version have been drawn. According to the author's opinion sometimes this is artificial planning, and not realistic.
2. In Hungary as well as in Budapest the selective waste collection rates are relatively low and also not yet compliant to the EU requirements. First, the selective waste collection system must be analyzed and evaluated in detail. There is a likelihood that the rate of the selective waste collection will increase in Hungary partly because this is one of the most important mandates of the recently established National Waste Management Agency Nonprofit Ltd. and also an obligation in the Hungarian legislation.
3. Another reason for the increase of the selective waste collection rate is that several municipalities, including Budapest, received EU support in order to develop door-to-door collection system, which is expected to result in a higher selective waste collection rate in the forthcoming years.
4. The author obtained the exact figures for the total waste amounts as well as the selective waste amounts for every month between 2006 and 2011, which is different from other studies where waste analysis for the different months was not possible. In other studies only yearly data was used for the discussion. The

monthly analysis is a better way to demonstrate the trends and to show the environmental impact consequences of the different decisions in terms of the selective waste collection. In this format it becomes easy to draw correlation between the rate of the selective waste collection and the environmental impacts including global warming.

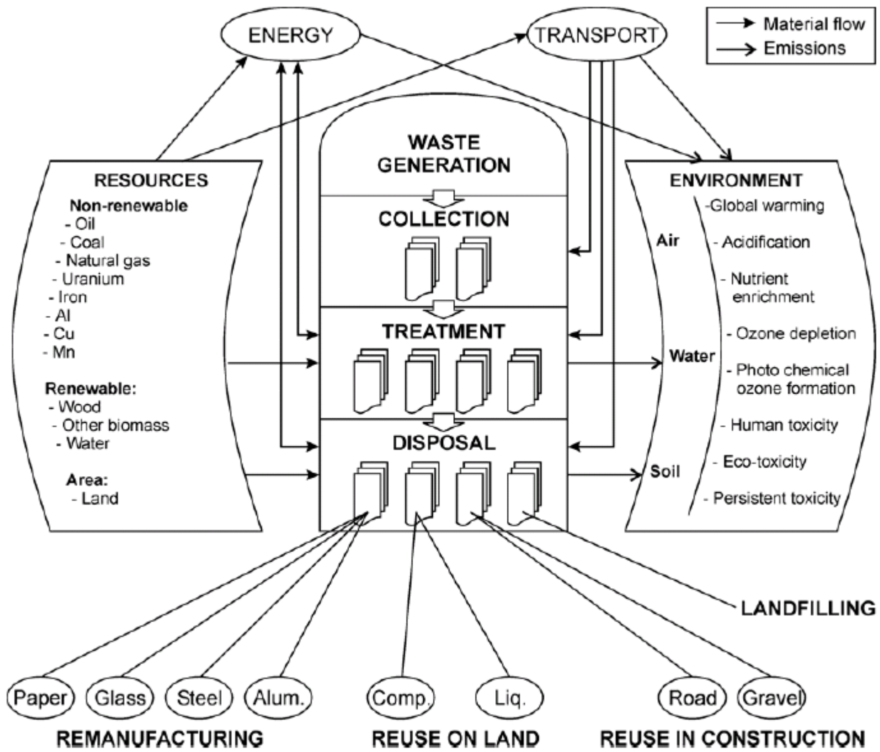
5. One of the assumptions of the research is that the increasing selective waste collection causes less pollution, including global warming potential and this hypothesis is analyzed thereof.
6. The disadvantage of this method is that it takes much more time as instead of running the model for one year, one time, and author ran the model for every month between 2008 and 2011 respectively and summarizes the output results.

The paper reveals several methodology-related issues and discusses what implications waste-related policy intervention would have on the environmental outcomes of different waste management scenarios in the last years in Budapest.

Methodology of modeling of waste management processes

EASEWASTE was developed in order to create a user-friendly, well documented and flexible model that evaluates the impact of the given municipal solid waste management system on resource consumption and the environmental emissions. In the model is a framework where the user can define all the necessary data regarding the waste characteristics as well as the life cycle inventory data for materials and energy use. The

EASEWASTE model takes into consideration the following waste management processes:



24. Figure Conceptual framework in the EASEWASTE model

Source: Damgaard 2006

The methodology is called EDIP97 (Environmental Design of Industrial Products) and is in compliance with the ISO standards. As Laurent *et al.* (2011.) emphasizes the EDIP97 methodology is the most widely used LCA methodology in Denmark.

In the following description it can be seen that LCA modeling was applied to every step of the waste hierarchy, extracted from the Waste Framework Directive, which is discussed in detail in the relevant chapter on the EU legislation.

Waste prevention

Waste prevention is the most important part of the waste hierarchy, however in many cases it is not regarded as important in practice. Waste prevention programs emphasize PR campaigns which aim to increase the environmental awareness and explain how and where appliances can be repaired, or where products and services can be rented. The Waste Framework Directive sets the following definition for waste prevention, so in Article 3 Clause 12 and 13 declares that ‘prevention’ means measures taken before a substance, material or product has become waste, that reduce:

a) the quantity of waste, including through the re-use of products or the extension of the life span of products;
b) the adverse impacts of the generated waste on the environment and human health; or
c) the content of harmful substances in materials and products.

According to the Waste Framework Directive in Hungary the National Waste Management Plan has to include waste prevention programs. Robust and easily understandable indicators will be necessary to provide signals and measure progress in improving waste prevention. As Bartus (2010.) wrote there are three main types of indicators:

- qualitative,
- quantitative and
- environmental impact indicators.

For the waste prevention program a short pre-study was made by Dienes (2011) on the waste prevention indicators. He analyses 34 available indicators and categorized all of them according to the following aspects: relevant, accepted, credible, easy and robust. He highlighted that apart from the listed 34 indicators some new indicators are also recommended which are the following: CO_2 emission, CH_4 emission, diversion from landfill sites and raw material consumption. He pointed out that presently in Hungary the waste prevention indicators are in scientific, preparation phase, so it has not been used in practice and therefore not known by the key players.

Waste prevention can have a regulatory side but the public awareness is highly important in this phase either. Public behavior may have the most important aspect among other stages in the waste hierarchy. A number of authors have used behavior change theories either to explain or predict waste prevention behavior (Tonglet *et al.* 2004, Gray and Toleman 2006). One of the most widely analyzed is the theory of planned behavior, which proposes that three factors influence one intention to act: a person’s attitude, whether they feel able to act and wider social norms. (Cox *et al.* 2011) Under the proper external conditions, intention is expected to translate into action. In waste prevention the economic factors can also be highlighted, as naturally the consumer will choose waste prevention if it means less expenditures for the occurred costs.

Preparing for re-use

Re-use has been partly discussed in the description of the Hungarian legislation, as the refillable packaging materials were compared according to the work which was made by Vámosi (2011). So it is not repeated here again. Re-use has a limited literature as the LCA analysis mainly compares options which are real (such as recycling, or disposal) and re-use systems has not that exact result such as recycling.

Platt and Rowe (2002.) emphasizes that life-cycle analysis (LCA) studies revealed that refilling reduces most of the environmental impacts and mitigates the exploitation of the natural resource of beverage packaging. In fact, refilling can bring environmental benefits without requiring economic sacrifices.

Recycling

As Tyskeng and Finnveden (2010) declares recycling saves more energy than combustion in general. This is emphasized by Björklund and Finnveden (2005), Finnveden and Ekvall (1998), Villanueva and Wenzel (2007), and WRAP (2006), among others. We can take into account the pro and con justifications in terms of recycling versus incineration for the different waste types based on the literature of different solid waste management life cycle assessments.

- **Paper, Cardboard, and Newsprint**

There are several factors which play an important role in the energy savings, such as the type of paper. Finnveden and Ekvall (1998) state that more energy can be saved when mechanical pulp is used for recycled newsprint; for example the chemical pulp used in cardboard. Profu (2004) emphasizes that the substitution factor matters as some cases large quantities of recycled material must be used to replace a certain amount of new raw material. He also highlighted that recycling of newspaper shows savings in terms of climate effect, acidification, eutrophication, and production of photo oxidants. For newsprint, in the studies summarized by WRAP (2006), the average savings of greenhouse gases is 1.25 kg CO_2 equivalents/kg waste when recycling is compared to incineration. If we take into account the mixed paper and office paper, the figure is 1.2 kg/kg and for corrugated board and cardboard it is 0.35 kg/ kg. It can be stated that the savings are usually larger for newsprint than for cardboard. The range in the different studies ranges from 3.5 kg/kg to −1.5 kg/kg; so it looks like that a number of key aspects can determine the results.

If we reduce the consumption of new raw materials than we save biomass, thereby increasing the environmental benefits of material recycling. If the saved biomass can be used to replace fossil fuels for energy, recycling will have a clear advantage over combustion in terms of lesser environmental impact (WRAP 2006, Merrild *et al.* 2008).

Obviously, the energy recovery efficiency of the thermal incineration plant determines the level of energy savings as well in case of paper recycling versus incineration.

- **Plastic**

The literature indicates that taking into account the total energy use from recycling of plastic, we can state that recycling does produce an energy savings (Beigl and Salhofer 2004; Björklund and Finnveden 2005; Finnveden *et al.* 2005; WRAP 2006). However, there seems to be only three exceptions when incineration may be more advantageous.

One exception is if the recycled plastic does not replace other plastic but is used instead of wood in cases such as sitting bench in kindergartens (Mølgaard 1995; Finnveden *et al.* 2005). Another exception concerns highly soiled packaging containers such as the mayonnaise tubes which contains leftover mayonnaise, an undesirable case for incineration, as the energy in the mayonnaise itself may be used, whereas in recycling the mayonnaise would go out with the wastewater. A third exception may be situations in which a high substitution factor is assumed, e.g., 1:0.5, so that 2 kg of recycled plastics are required to replace 1 kg virgin plastics. In such cases, combustion may be more energy efficient (WRAP 2006 and Tyskedng 2010). The literature also indicates that in most cases the recycling of plastic provides clear advantages as far as other environmental impacts such as climate change, acidification, eutrophication, and production of photo oxidants. Björklund and Finnveden (2005) show that both total energy use and climate impact are generally lower for recycling than for combustion of non-renewable materials such as plastic. For the studies included in WRAP (2006), the average savings of gases contributing to climate change was 1.45 kg CO_2 equivalents/kg waste for recycling compared to incineration.

- **Metal**

It is obvious that recycling is more environmental friendly in the case of metal, as it is not an efficient material to burn. This statement is justified in the literature as well because recycling provides a general gain both in terms of energy use and other environmental impacts (Björklund and Finnveden 2005; WRAP 2006). Beigl and Salhofer (2004) also declare that the most environmentally advantageous outcome for metal packaging is if collected and recycled, as recycling of metals plays an important part in lowering acidification and energy use. Edwards and Schelling (1996) show that recycling of metals (aluminum) reduces environmental burden by 80% over new production of raw material and disposing of waste.

The average savings when recycling as compared to combustion in the studies included in WRAP (2006) concerning gases contributing to climate change was 10.5 kg CO_2 equivalents/kg waste for aluminum and 0.9 kg/kg for steel. It can be interesting in a further study to analyze the recovery efficiencies of metal in the slag after incineration.

- **Glass**

According to literature glass recycling provides positive environmental gains in terms of energy use (WRAP 2006) and other environmental impacts. This study showed a reduction of gases contributing to climate change with an average savings of 0.8 kg CO_2 equivalents/kg waste.

The authors maintain that the collection systems and the transports conditions have limited effect on the environmental impact results. In the study from Tyskeng (2010) we can read that in general, just as for plastic, paper and cardboard, transport distance does not have a significant effect on ranking between recycling and energy extraction from waste.

Energy recovery

Recycling of materials from municipal solid waste is commonly considered to be superior to any other waste treatment alternative. For the material fractions with a significant energy content this might not be the case if the treatment alternative is a waste-to-energy plant with high energy recovery rates. The environmental impacts from recycling and from incineration of six material fractions in household waste have been compared through life cycle assessment assuming high-performance technologies for material recycling as well as for waste incineration. The results showed that there are environmental benefits when recycling paper, glass, steel and aluminum instead of incinerating it. For cardboard and plastic the results were more unclear, depending on the level of energy recovery at the incineration plant, the system boundaries chosen and which impact category was in focus. Further, the environmental impact potentials from collection, pre-treatment and transport was compared to the environmental benefit from recycling and this showed that with the right means of transport, recyclables can in most cases be transported long distances. However, the results also showed that recycling of some of the material fractions can only contribute marginally in improving the overall waste management system taking into consideration their limited content in average Danish household waste. (Merrild *et al.* 2012)

Landfilling

Landfilling of waste has a great effect on the different environmental impacts and, above all, landfills account for most of the greenhouse gas (GHG) emissions from the waste management sector. Landfilling is the last step of the waste hierarchy mostly because emissions from landfills typically last for very long periods.

In Budapest we use the conventional landfilling method, where waste is simply buried. However, there are several types of landfill sites besides the conventional landfill which aim is to decrease the environmental impacts.

As Manfredi (2009) pointed out the optimization of the waste degradation during the landfill site results higher amount of landfill gas (LFG) production early in the life of the landfill or other objective can be to decrease the time frame of active landfill operation to 10-15 years. Bioreactor landfills for example use recirculation of the collected leachate to the waste mass, which increases the waste density up to 1–1.2 ton/m3 (wet) and therefore allows a better utilization of the landfill capacity (Benson *et al.* 2007).

The semi-aerobic landfill technology was developed in Japan (Hanashima, 1999) and in this process the degradation mechanism is anaerobically driven by the leachate recirculation operation, while afterwards aerobic step is initiated by injecting air flow from the bottom of the landfill.

As Manfredi (2009) summarized the LCA models allow usually a time horizon of 100 years for the landfill, as beyond this time-span emissions from landfills are hardly foreseeable. For example EPIC/CSR, LCA-IWM and ORWARE models assume a 100-year time horizon while WISARD allows 100 years for LFG emissions and 500 years for leachate emissions and WRATE assumes 150 years for LFG and 20,000 years for leachate. (Gentil *et al*. 2010)

Currently, the regulations allow less and less waste to be landfilled and the Council Directive 1999/31 on the landfill of waste determines a gradual reduction of organic waste to be landfilled, with the target of maximum of 35% organic waste being landfilled by 2014.

Today, some EU member states have already banned the landfilling of organic waste (e.g. the Netherlands as of 1996, Denmark as of 1997, and Germany as of 2005). By 2012 some EU countries have moved even further and banned the landfilling of some waste types in their country (Dawkins and Allan 2010)

- Austria: ban on waste with the exception for mechanical-biological treatment waste with a calorific value > 6.600 KJ/kg dry substance, 2008,
- Belgium: ban on plastic waste landfilling, 2007,
- Denmark: ban on waste suitable for incineration, 1997,
- Estonia: ban on unsorted waste, 2008,
- Finland: ban on biodegradable waste, 2011,
- France: ban on everything but 'residual' wastes, 2002,
- Germany: 2001, ban on
  - Any municipal waste that can be recovered
  - Untreated municipal waste
  - All biodegradable municipal waste to be separately collected and composted
  - Waste wood
- Hungary: ban on
  - tires - 2003,
  - rubber scrap - 2006 and
  - non pre-treated waste – 2015.
- Netherlands: ban on 35 categories of waste, 1998,
- Norway: ban on all waste with > 10% TOC, 2009

- Sweden: ban on
    - sorted combustible waste – 2002,
    - organic waste (including plastics) > 10% TOC – 2005,
- United Kingdom, ban on: (for UK source is: Environment Agency 2010.)
    - liquid waste;
    - waste which in a landfill would be explosive, corrosive, oxidising, flammable or highly flammable;
    - hospital and other clinical wastes – from medical or veterinary establishments – which are infectious;
    - chemical substances from research and development or teaching activities (such as laboratory residues) which are not identified or which are new, and whose effects on man and/or the environment are not known;
    - whole and shredded used tyres – apart from tyres used as engineering material, bicycle tyres, and tyres with an outside diameter of more than 1,400 mm.

In the EASEWASTE model the overall amount of gas generated is based on the overall amount of methane generated. Therefore the relative importance of the overall emission of gas is compared to the emission of methane generated. It can be calculated according to the following fraction (User Manual 2012):

Equation:

$$Tot\_gas\_gen = \frac{Tot\_CH4\_pot}{\dfrac{\sum_{i=1}^{i=4}\left(\dfrac{Gas\ gen\ tpi}{100} * \dfrac{CH4\ tpi}{100}\right)}{\sum_{i=1}^{i=4}\dfrac{Gas\ gen\ tpi}{100}}}$$

where:

- Tot_gas_gen – is the overall amount of gas generated throughout the time horizon of the assessment (m3)
- Tot_CH4_pot – is the total methane potential in landfill waste (m3 CH_4)
- Gas_gen_tpi - is the percent of gas potential generated in time period “i”, (%)
- CH4_tpi – is the percent of methane in the generated gas period “i”(%)
- i = 1,2,3,4 (%)

Collected landfill gas can be divided into four different landfill gas treatment options:

i. vent (no energy recovery),

ii. flare (no energy recovery),

iii. combined heat and power plant (CHP) and

iv. to an electricity producing gas engine.

Landfilling has posed a problem in preparing precise LCA studies, as during several years as there was no exact measurements available for the long time effect of the toxic metals or highly persistent organic compounds within the landfill, as the slow release meant a dilution in time, stated by Hauschild *et al.* (2011). Therefore the long-term emissions from landfills which take place over thousands of years are often neglected. However, all future emissions (even over thousands of years) in the inventories are included. When calculating the emissions from landfills, leachate and gas treatment must be taken into account. Conventional municipal landfilling, which can be found in Hungary, generally produces a highly contaminated leachate and a significant amount of landfill gas. As Damgaard (2011) emphasized leachate controls may include bottom liners and leachate collection systems as well as leachate treatment. The gas control system can include oxidizing top covers, collection systems with flares or gas utilization systems for production of electricity and heat. The importance of leachate and gas treatment in reducing the overall environmental impact of a conventional landfill was assessed by life-cycle-assessment (LCA) and included in the EASEWASTE model.

Taking into consideration the long-time effect of the pollutants in the landfill, Christiensen *et al.* (2007) highlighted that in the EASEWASATE model two new impact categories are introduced: the stored ecotoxicity and stored human toxicity of the contaminants, which are called ‘stored’ (eco) toxicity. It is relevant for the remaining contaminants in the landfill after a time period of 100 years. As presented by Hauschild et al (2011), less than 1% of the content of metals is leached within the first 100 years. Several landfill examples were modeled with the waste LCA model EASEWASTE. Among the results Damgaard (2011) showed that global warming went from an impact of

0.1 person equivalents (PE) for the open dump to −0.05 PE for the best design. The same improvements were calculated for photochemical ozone formation (0.02 PE to 0.002 PE) and stratospheric ozone formation (0.04 PE to 0.001 PE). Leachate collection can result in a slight increase in eco-toxicity and human toxicity via water (0.007E to 0.013PE and 0.002 to 0.003 PE respectively), because in spite of the fact that the leachate is treated, slight amounts of contaminants are released through emissions of treated wastewater to surface waters.

6.2 Research methods

This chapter describes the different research methods which were used during the preparation of present thesis. It discusses the methodology and time schedule for data collection, the necessary data input and data output of the model. Also, conferences and interviews which were inevitable for the thesis preparation archival research and validity and reliability issues are covered.

Methodology for this thesis

This research includes data collection (which took place from 2008 until 2012) and data evaluation (mainly in 2012) as it is described in detail. Case studies were elaborated only at the literature review level, as the present research did not require any case studies. Archival research was also necessary in order to review the available official documents. Interviews are made with the key stakeholders in relation to the Budapest solid waste management system which helped to discuss the research results and to identify their desirable options.

The reasons why I chose Budapest are the following:

- Budapest has a large scale of waste management system, as it treats the waste of 1.7 million people, which is nearly 20% of the country.
- Budapest has a Waste-to Energy Plant, which makes it unique as this is the only MSW thermal treatment in Hungary,
- landfilling here is not as common as in other parts of Hungary,
- from 2013, a new EU funded project will be launched to increase door-to-door collection during three years, representing itself a big project,
- Budapest has bigger chance to receive EU funds than other small cities
- there will be changes in the Budapest MSW system as there are plans for implementing a biogas treatment at the Pusztazámor Landfill site or even a transfer station which later can be evaluated in the EASEWASTE software
- the author has personal connections to leaders in the Budapest waste management arena, which helped during the information gathering period.

Data collection and analysis

The detailed data requirement and its evaluation are described in the "Evaluation of Budapest solid waste management system" at Chapter 8. (page 199.) as the whole individual research work is exposed in that chapter, so in this chapter author focuses on the data collection and analysis from the methodological point of view.

For Objective 1 and Objective 2 the methodology related to data analysis was the most crucial for this research. In general, it must be stated that the data collection process took place over four years (2008-2012), which is far more that it was expected at the onset of the project. Reasons for this delay can be attributed to the economic crisis of the last years, but the biggest likelihood for this serious delay is connected to the political change in Hungary as well as in Budapest in 2010.

It was only at the end of 2010 when the new Head of the Environmental Department at the Budapest Municipality realized that my research represented a high interest for the company he was in charge of, and he initiated the processes to provide the required data, which took place from the second half of 2011.

The author studied the EASEWASTE model in Denmark in June 2008 and afterwards during a meeting with FKF Zrt. In September 2008 it was offered that a life cycle assessment for the solid waste management system can be elaborated. It can be seen that from the first meeting with FKF Zrt. plenty of years have passed until they sufficient amount of data were provided. From the autumn of 2010 the new environmental leader of the FKF Zrt. found our research very interesting and as several studies and results were submitted to them they provided additional data to us.

Therefore the first valuable data – the waste composition for the 48 fractions – was collected in November 2011. For the data requirement mentioned above author received the following data from 2008 from the FKF Zrt.:

- October 2009. (total waste amount and selective waste collection – waste islands, waste yards and door-to-door collection for the years of 2006, 2007 and 2008),
- July 2010. (total waste amount for 2009)

- October 2010. (waste composition of 24 waste collection routes in Budapest for 2009)
- November 2010. (technology: technical data for the waste-to-energy plant 2009)
- November 2011. (48 fractions waste composition for single family, multi family for 2008, 2009, 2010 and 2011 and SCBU for 2011- which is the basics waste composition for my research),
- November 2011. (technology, technological data for the landfill until 2010),
- December 2011. (total waste amount and selective waste collection – waste islands, waste yards and door-to-door collection for the years of 2006, 2007 and 2008, 2009, 2010 and partly 2011),
- January 2012. (fuel consumption for 2008-2011),
- March 2012. (clarifying the data personally at FKF Zrt. meeting room)
- April 2012 (standards for the waste composition analytical analysis)
- Today there is still missing some data (5-7% technical data), which mostly does not exist in Hungary due to the lack of measurements.

Since beginning work in 2008 we provided the following to FKF Zrt:

- appr. 170 written pages plus this thesis,
- 7 studies, and from them several studies were uploaded on their webpage
- 9 presentations,
- 23 meetings,
- 8 interviews,
- visited the environmental laboratory,

- carried out methodology for the input data,
- waste composition in detail,

According to the data collection which took several years generally it can be stated that

- FKF Zrt. has no uniform database for the data which means they do not possess uniform measurement units, (some of them were in kg, some in tons, etc.),
- the data was originated from different departments so it happened that they sent me the same data in certain occasions
- in many cases it was necessary to clarify the exact amount,
- however, in spite of these difficulties the decision makers and the employees proved to be kind and helpful to me.

In this chapter the required data as well as the available data are discussed in detail, followed by the introduction of the methodology for data evaluation and the interpretation of the LCA result.

For evaluating the Budapest waste management system life cycle assessment it took several years for author (from 2009-2012) to obtain the necessary data from Fővárosi Közterület-fenntartó Zrt. (Municipal Public Services Co. Ltd.). The data obtained must be double-checked and consulted with the representatives of FKF Zrt. in order to clarify them. I also discussed the data with the Danish Professors, who developed the software.

Data input and output for my research

During the research the data obtained was double checked and analyzed carefully ton ensure a high quality, therefore several meetings were initiated in order to clarify the obtained data. The necessary data can be divided into three categories that are distinctive from each other:

- Statistical data:
    - for instance residential structure, (single family houses, multi family houses and SCBU – small commercial and business units)
- Measurable data:
    - for example transported distances in kilometers, waste amount, waste composition of the 48 waste types, selective waste amount,
- Technological data:
    - for instance the technological data of the recycling, composting, waste-to-energy plant as well as landfilling.

In order to carry out the Life Cycle Assessment modeling of the Budapest solid waste management system in the EASEWASTE model, it was necessary to obtain the following input data:

Input data

Waste generation

- Number of generation units
    - For single family housing

    - For multi family housing (the two housing types are distinguished as collection schemes and waste composition differs between them)
    - For SCBU (small commercial and business unit)
- People/unit type
- Waste amount kg/person/year

Waste composition

- Waste composition for the different waste fractions
    - For single family housing collection types
    - For multi family housing collection types
    - For SCBU housing collection types
- The chemical speciation of these waste types (H_2O, TS, Ash, C-biological, C-fossil, Ca, Cl, H, N, Na, Cd, Mg etc. content – it does not exist in Hungary, so the data are therefore based on the Danish laboratory calculations)

Sorting efficiencies at the household for the different waste fractions

- For single family housing
- For multi family housing
- For SCBU (small commercial and business unit)

Collection and transportation for the different waste types

- Collection vehicle, fuel combustion technology, (e.g. EURO 3 engine, 4.5 liter/ton truck),

- Transportation distances (km) for the different treatment facilities

Waste technologies for the different waste types and amounts (waste flow)

- Biotechnology (anaerobic digestion and composting)
- Energy utilization
- Landfill mixed waste (landfill type)
- MRFs (material recovery facility) – (e.g. glass sorting, paper sorting)
- Ash treatment
- Material recycling
- Thermal treatment (incineration type)

The functional unit is the waste amount per year in Budapest.

According to these data entries the software calculates an inventory of emissions associated with solid waste management system, and thus the different potential environmental impacts.

The collected data for waste amount and waste composition and its evaluation are described in detail in the "Evaluation of Budapest solid waste system" in Chapter 8.

Output data of the environmental impact assessment[1]

- Global warming potential (CO_2-equivalents)
- Acidification (SO_2-equivalents)

[1] aggregated based on an inventory of emissions contributing to these impact categories

- Eutrophication (nutrient enrichment, NO_3--equivalents)
- Ozone depletion (CFC11-equivalents)
- Photochemical ozone formation (C_2H_4-equivalents)
- Ecotoxicity (m^3 soil, water or air)
- Human toxicity (m^3 soil, water or air)
- Resource consumption of Al, Cu, Fe, coal, oil, natural gas,
- water, wood, etc.

From the input data the following research can be carried out:

- general analysis of the Budapest waste treatment, with strong emphasis on the evaluation of the selectively collected – non selectively collected waste types in each months between 2006-2011 (for this the EASEWASTE model is not necessary)
- collection and utilization of the necessary input data for the EASEWASTE model for each months between 2006-2011,
- interpreting and evaluating the results.

By the evaluation the following analysis can be elaborated:

- data collection and data organization, evaluation in terms of the waste management,
- determine the optimal waste collection routes,
- calculate the waste composition of an area depending on the collection routes and the population,

- comparing the environmental impacts in the different options,
- flow chart of the selective waste collection system with the exact amounts and the connected financial values, by means of this analysis it can be calculated to what extent the disposed recyclable waste would be beneficial,
- modeling the environmental impacts in the different months for the years between 2006-2011,
- to determine which technology contributes to the environmental emission in the biggest degree,
- increasing the utilization rate,
- comparison of the fuel consumption at the different technologies and different waste types,
- extension the landfill lifespan by the diversion of the landfilled waste due to the increased selective waste collection,
- revision of former decisions in terms of the collection and technology, taking into account a specific objective (such as decreasing GHGs), etc.

Archival research

Archival research is a valuable method for studying policy. It includes the collection and analysis of public records, documents, legislation background and governmental documents (Esterberg 2002). It also includes information on the collection of secondary data, which provides information on the content and quality of the output and how it was negotiated and agreed. Archival research has been used to explore the existing documents containing rules and environmental performance indicators in the case of Budapest and partly on national level. Document analysis had a significant contribution to understanding the life cycle assessment as well as the structure of the Budapest solid waste management. Strategic, legislative, program and policy documents, and web pages had been reviewed to obtain information about the present and planned waste management policies, instruments and processes, as well as institutional structures. Secondary data sources are used to enrich the primary information and strengthen the validity and reliability of research findings.

Frankfort-Nachmias and Nachmias (1996) suggest that secondary data can also display and explain changes. By including a combination of data sources including archival research, interviews and event attendance, information was gathered for the research that contributed to answering the research objectives and the assumptions.

For the necessary background information among other documents author have reviewed the following documents:

- Waste Framework Directive
- Hungarian new Waste Law
- Waste Management Plan for Budapest
- Budapest Environmental Development Plan,
- National Waste Management Plans
- Documents from the Budapest Waste-to Energy Plant (its technical parameters, emission etc.)
- Documents from the landfill site (its technical parameters, proposed improvement etc.)
- National official documents (such as the National Development Plan etc.)

- Documents from the environmental inspectorates,
- Reporting papers,

However, data validity is very important, therefore the data was double-checked. The author requested to obtain the composition for the 48 waste categories which have never been sampled in Budapest before in that detail. Following this a comparison of this data with the data in other documents was performed, and also with other Eurostat statistics or other official documents for instance from the European Environmental Agency.

Interviews

For the elaboration of Objective 1 and Objective 3, interviews were necessary. In order to undertake this research some semi-structured, open-ended interviews were conducted with the key stakeholders in the waste management area. The interviews were guided by the "snowball effect" which directed me to follow-up with other respected respondents. This process included formal personal interviews, email communications as well as some conference meetings with the following key stakeholders: The time resources of the interviewees were respected. They were asked beforehand about their time availability. However, in many cases the interviewees became involved in the conversation and answered all questions. To comply with the principles of confidentiality and anonymity (e.g. Trochim 2006b), the respondents were asked if they would like to keep anonymity, but none of them asked for this, however, if they wanted to reveal some sensitive issues, the dictaphone was switched off and the relevant point was not presented in this research. As part of the semi-structured interviews, opportunity was provided for the informants to talk freely about topics they found important, which greatly contributed to the identification of emerging issues, for instance the sampling, waste composition or waste management options. The interviews were conducted on a face-to-face basis mostly at the meeting room of the informant. Some personal communication took place via email correspondence or conducted on the telephone, however, they did not contribute to the research in a great extent. Attendance at conferences and workshops provided the opportunity for participant observation and further data collection or personal communication. It was possible to join relevant mailing lists, which enabled the continuous monitoring of the development of solid waste management issues throughout Europe, which justified the present trend which is shown in this research document. Continuous engagement with the Danish professors and also other former PhD students at the EASEWASTE course helped the author's precision and punctuality in the model preparation and result interpretation stages.

The first interviews were conducted in November 2009 after receiving the primary data for the waste amount and the waste composition, which were however in the preparation stage for my research. An interview took place with Zsuzsanna Pfeiffer Koltainé, former Head of the Environmental Department. She talked about the history and main purpose of the environmental laboratory. She emphasized that although that there was a large difference between the waste composition of the countryside and Budapest, by today the aggregated waste composition of Budapest's solid waste has become similar to the other bigger cities and rural areas in Hungary due to the dominancy of the packaging materials. Later in 2010 and 2011 several interviews were conducted with Zsuzsanna Borsi, the environmental manager of the waste-to-incinerator plant, and Gábor Mile, the chief engineer of the Pusztazámor landfill site. Besides the history and the importance of their waste treatment plants, they provided the main technological data for these facilities. From the beginning to the end Mihály Siklóssy, former technical advisor also supported my research. Later when the research progressed, Attila Olgyay-Szabó, the Head of the Environmental Department communicated with me several times and Gábor Király, the Head of the Environmental Laboratory provided invaluable data. When finishing the research the results and the desirable options were discussed at the end of May 2012 with the key stakeholders. Naturally, there were several personal communications with experts who were not members of the FKF Zrt., for instance Henrik Balatoni, who is the general manager of Fe-Group Zrt., the company what receives the collected selective waste of Budapest.

Interview data is also integrated for purposes that are related to issues of social reality and used to determine the policy options and recommendations for further development of the present waste management sector.

The main actors, within FKF Zrt., whom author had personal communication with are the following respectable experts:

- Lajos Klug, Director of Budapest Municipal Public Services Co. Ltd.
- Attila Olgyay-Szabó, present Head of the environmental department of Budapest Municipal Public Services Co. Ltd.
- Gábor Mile, technical main engineer of the Regional Waste Management Centre in Pusztazámor
- János Bánhidy, former director of the Budapest Waste-to Energy Plant,

- László Sámson, present director of the Budapest Waste-to Energy Plant,
- Zsuzsanna Borsi, environmental manager of the Budapest Waste-to Energy Plant,
- József Halász, Head of the economic department,
- Gábor Király, Head of the environmental laboratory of Budapest Municipal Public Services Co. Ltd.
- Mihály Siklóssy, former chief engineer of Budapest Municipal Public Services Co. Ltd.
- Zsuzsanna Pfeiffer, former Head of the environmental department of Budapest Municipal Public Services Co. Ltd.

The required data therefore were obtained from the following sources:

Waste generation	Zsuzsanna Pfeiffer, Gábor Király, József Halász
Number of units • For single family housing • For multi family housing (the two housing types are distinguished as collection schemes and waste composition differs between them) • People/unit • Waste amount kg/person	
Waste composition	Gábor Király
• Waste composition for the different waste fractions • For single family housing • For multi family housing collection types • The parameters of these waste types (H2O, TS, Ash, C-biological, C-fossil, Ca, Cl, H, N, Na, Cd, Mg etc. content)	
Sorting efficiencies for the different waste fractions	József Halász, Gábor Király, Mihály Siklóssy
• For single family housing • For multi family housing	
Collection and transportation for the different waste types	Mihály Siklóssy, József Halász, Henrik

• Collection vehicle, fuel combustion technology, (e.g. EURO 3 engine, 4.5 liter/ton truck), • Transportation distances (km) for the different treatment facilities	Balatoni (he is not FKF Zrt. employer)
Waste technologies for the different waste types and amounts (waste flow) • Biotechnology (biogas and composting) • Energy utilization • Landfill mixed waste (landfill type) • MRFs (material recovery facility) – (e.g. glass, paper sorting) • Ash treatment • Material recycling • Thermal treatment (incineration type)	Gábor Mile (landfill) and Zsuzsanna Borsi (Budapest Waste-to Energy Plant). For recycling Mihály Siklóssy.

12. Table The required input and their proposed sources

With the required inputs provided, the environmental assessment and the life cycle assessment can be prepared. According to the research objectives, the interpretation of results can be discussed with the main decision-makers in terms of the Budapest solid waste management system.

We have discussed our results with the following key stakeholders within FKF Zrt.:

- Zsolt Elter, Vice-director of FKF Zrt.
- Attila Olgyay-Szabó, Head of the Environmental Department,
- Mihály Siklóssy, chief engineer of Budapest Municipal Public Services Co. Ltd.
- Gábor Mile, director of the Regional Waste Management Centre in Pusztazámor
- Bánhidy János, director of the Budapest Waste-to Energy Plant,
- Gábor Király, Head of the environmental laboratory,

For Objective 3 the mentioned interviews were necessary to compare the results with the opinions of the main decision makers and discuss their desirable path in order to analyze the LCA of the solid waste management of Budapest.

Conferences and seminars

The author participated in the “The twenty-third international conference on solid waste technology and management” between March 30 - April 2 2008. in Philadelphia, PA, U.S.A. from the financial support of the Central European University and the National Research and Technology Authority. At this event a conference presentation of the paper, called `Use of biomass in the light of $CO_2$ emission and sustainable development` was performed, which was did not directly focus on life cycle assessment but related to the topic within the context of focusing on solid waste management and global warming. The second conference was the CEEweb Academy on Biomass, 9-10 May 2008 Esztergom, Hungary where a discussion was held, titled ‘Solid biomass and the Washington renewable energy conference’.

CEEweb Academy on Biomass, 9-10 May 2008 Esztergom, Hungary.

Between 14-22 June 2008, the author participated in a Summer University, where EASEWASTE software was taught to the software which is available to evaluate the life cycle assessment for solid waste management systems. The training took place at the Danish Technical University, Copenhagen, Denmark. This was the most important seminar in this research project, and represents the “turning point” in terms of this thesis, where the direction and the topic of the present research was finalized. In Denmark the EASEWASTE model was observed, the model that would prove to serve as the foundation of this dissertation. This work continuously discusses and interprets the results of the LCA for the Budapest solid waste management system with the representatives and professors at the EASEWASTE model. This is true for 2012, as the first valuable data for his research from Budapest was obtained first in the autumn of 2011.

The author's third conference presentations focused on the Hungarian waste management policy in the ECENA (Environmental Compliance and Enforcement Network for Accession) Training on Waste Landfill and Waste Incineration Directive conference, between 30 June-2 July 2008 Gellért Hotel, Budapest.

Shortly afterwards the second Summer University, Climate Change: An Interdisciplinary Inquiry, 30 June – 6 July, held at Central European University, Budapest, Hungary was organized. This session was attended by key players in the field of climate change and the high level lectures were held on this comprehensive issue.

The author's fourth conference presentation was made at the SETAC 17th Life Cycle Assessment Case Study Symposium, focusing on Sustainable Lifestyles on 1 March 2011. at the Gellért Hotel, in Budapest, Hungary. SETAC (The Society of Environmental Toxicology and Chemistry) is a non-profit, world- wide, professional society engaged in the analysis of environmental problems, the management and regulation of natural resources as well as research and development. This society played a great role in developing the LCA methodology and creating an international forum for scientific discourse. This conference produced a rigorous debate on the different aspects and results of the life cycle assessment and the different LCA evaluations at this conference had been discussed. Important presentations were recorded and contacts were made which are still functional, therefore the conversations and results were used to this research paper. The conversation with other participants at this event served as an additional means for theme identification and information gathering.

Later, the author published a journal article on the waste management transport at Közép-Európai Közlemények 2010/4. and further publications are expected based on this thesis results.

Later the author joined the Research Gate network, which is a website which follows and presents related research by others concerning similar research topics. Through Research Gate the author was informed when a desired publication has been issued, and in this format several scientific publications were obtained by the author for this research.

Several conferences were also attended without being a speaker or poster presentation. The most important among them was the VII. LCA conference in Miskolc, Hungary on 13. March 2012. During this conference there was the opportunity to discuss the possible waste management LCA models in Hungary. This conference was organized by LCA Center, which was established on 20 May 2008. in Budapest. On this day author as a member of the foundation associations, along with other private individuals signed and initiated the foundation of the professional association before attending the training in Denmark.

Validity and reliability

For the purposes of this dissertation the objectivity and validity of research findings were pursued to the best possible extent within the boundaries of understanding. Credibility involves understanding whether the results of qualitative research are credible or believable from the perspective of the participants in the research (Trochim 2006a). This is closely connected to the ability of the research to verify its results. Reliability or dependability deals with the consistency and explicitness of the research process in terms of procedures, methods or connectedness to theory (e.g. Miles and Huberman 1994; Trochim 2006a).

Credibility of the research (and researcher) has been maintained by iterative research design (with inter-active empirical and theoretical research steps) and corresponding/consulting with professionals/researchers in the same field. The design of the research strategy and methods took place in congruence with the needs of the research and the nature of the research topic.

Whereas rigor deals with correct methods, ethics focuses on correct moral conduct (Ezzy 2002). Transparency and respect accompanied all activities during the field research and the interviews during the writing of this dissertation. While conducting interviews the goal was to inspire trust and confidence in respondents. Direct quotations from the interviewees were not incorporated into the text. Recording techniques during interviewing were deployed in a manner that has not caused personal harm.

7 Short description of Hungarian waste management systems

Before evaluating the Budapest solid waste management system and showing the results of my environmental research as well as the results of the LCA model for the different years, it is necessary to receive information about the present trends in the European and Hungarian solid waste management. It is required to briefly summarize the current changes and legislation as well as to foresee the expected trends in the near future as these national processes have serious consequences on the Budapest solid waste management system as well.

7.1 The EU regulation on waste management

When taking into the waste management legislation of the European Union we have to consider the following principle regulations related to this thesis:

- Waste Framework Directive
- Packaging and Packaging Waste Directive

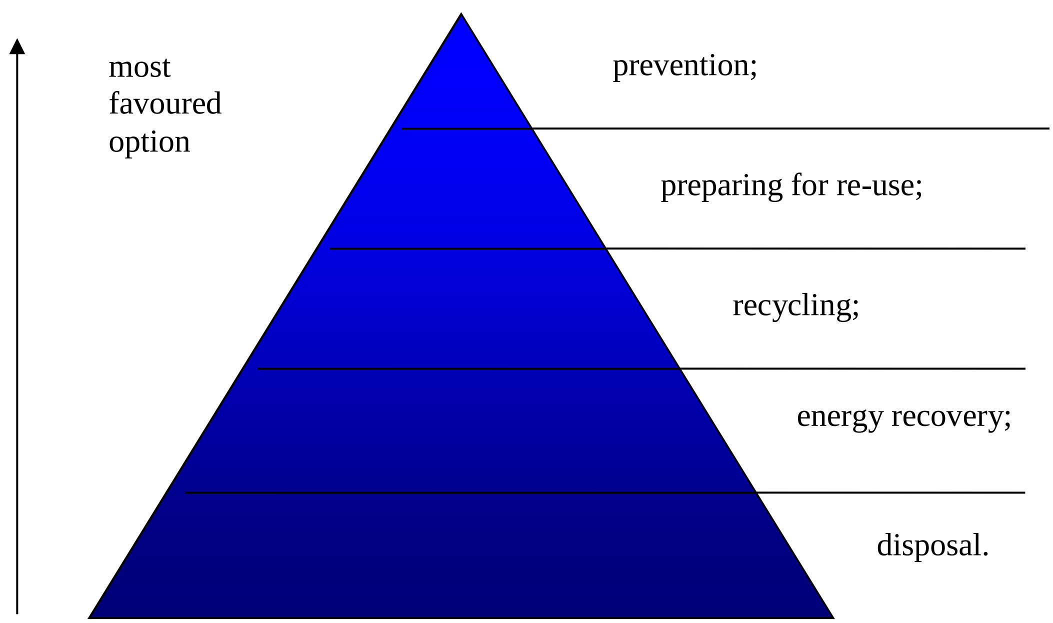
Waste Framework Directive and the waste hierarchy

The waste management system includes some principles, on which the whole environmentally friendly system is built on. These principles must be taken into account and be ensured at planning of different regional systems. Meanwhile the European Union has created new legislation, the Waste Framework Directive in 2008 (Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain directives) and accordingly Hungary has a new Waste Act which comes into force as of 1 January 2013.

In the Waste Framework Directive as well as in the new Hungarian Waste Act the following waste hierarchy shall apply as a priority order in waste prevention and management policy:

a) prevention;
b) preparing for re-use;
c) recycling;
d) other recovery, e.g. energy recovery; and
e) disposal. (Waste Framework Directive 2008)

According to the waste hierarchy the EU strongly recommends the following preferred hierarchy of waste management options:



25. Figure The waste hierarchy

Source: author own contribution based on EC 2008. (Waste Framework Directive, 2008)

However, it must be stated that there are several debates whether incineration or landfilling is more environmentally safe, as incineration itself can also pollute the environment and an incineration needs large amount of waste to be economical, so in terms of waste prevention the incineration does not contribute to the first and most important point in the waste hierarchy.

As Biczó 2012. highlighted, in waste management the following principles must be taken into account: precaution, sustainability, technical feasibility, and protection of resources, economic viability as well as the overall environmental human health, economic and social impacts.

The Waste Framework Directive allows diversion from the waste hierarchy if life cycle thinking can justify this.

> Article 4. "When applying the waste hierarchy … Member States shall take measures to encourage the options that deliver the best overall environmental outcome. This may require specific waste streams departing from the hierarchy where this is justified by life-cycle thinking on the overall impacts of the generation and management of such waste." (EC 2008 Waste Framework Directive).

Directive on Packaging and packaging waste

The other most important regulation is the European Parliament and Council Directive 94/62/EC of 20 December 1994 on packaging and packaging waste which outlines measures aimed at limiting the production of packaging waste and promoting recycling, re-use and other forms of waste recovery.

The Directive says that Member States should take measures to prevent the formation of packaging waste, and to develop packaging reuse systems reducing their impact on the environment in order to attain specifically set targets. According to the Directive 2005/20/EC of the European Parliament and of the Council of 9 March 2005 amending Directive 94/62/EC on packaging and packaging waste Hungary and some other Eastern European countries the date shall not be later than 31 December 2012.

Therefore according to these two directives Hungary should fulfill no later than 31 December 2012 the following targets for materials contained in packaging waste must be attained:

- 60 % for glass, paper and board;
- 50 % for metals;
- 22.5 % for plastics and;
- 15 % for wood.

Hungary has to accomplish these targets by 2012, however most of the European Union Member States were required to reach the goals by 2008.

If the waste hierarchy is taken into account, it is necessary to analyze the different steps of the waste management system and compare their environmental impacts.

As the European Commission (2011) warns, each year in the European Union the Member States dispose of 2.7 billion tonnes of waste to landfill or incineration. On average only 40% of the total solid waste is re-used or recycled, while in some Member States more than 80% of waste is recycled, indicating the possibilities of using waste as one of the EU's key resources. Improving waste management results in a better use of resources and can establish new markets and employment opportunities together with the lower impacts on the environment.

7.2 The Hungarian legislation on waste management

In order to achieve transparency, controllability, accountability, predictability and equal opportunities for the Hungarian market players, the preparation of new waste legislation for the whole waste management sector started in the second half of 2010.

Therefore, in Hungary the solid waste management system had been changed and some new piece of legislation occurred recently.

Due to the fact that Hungary joined the European Union in 2004 the EU legislation was adapted to Hungarian national legislation and waste treatment technologies. Additionally environmental awareness towards waste problems is becoming more sophisticated. Hungary adopted the Law on Waste Management in 2000 and as a requirement to comply the Waste Framework Directive, a new Waste Act has been adopted by the Hungarian Parliament on 8. October 2012 that comes into force from 1. January 2013.

The most important doctrines among them is the Waste Act (Hulladék törvény), and the Environmental Product fee Act (Termékdíj törvény). Both legislative acts are fully harmonious with the Waste Framework Directive, and correct the significant mistakes and deficiencies of the former waste management system. New implementation regulation follows the new laws. The latest waste law will have around 40 implementing regulations, which will aim to form a coherent and controlled system. However, the lack of proper databases has slowed down the revision process. Additionally a lack of reliable data and several contradictions delayed the preparation of the new system, including the Waste Law.

Waste Law

According to the Waste Framework Directive in Hungary a new Waste Act was introduced, which replaces the former Waste Management Law. The Waste Law was accepted by the Hungarian Parliament on 8. October 2012 after a thorough preparation. This law is expected to be accepted by the Parliament at autumn 2012 and will enter into force in 2013. For this research the main points of the new law are the following:

- In terms of life cycle assessment the Law states that it is necessary to take into account whole life cycle of products and materials following the Waste Framework Directive in terms of life cycle. The life cycle determination of the Waste Framework Directive is listed later in the European Union legislation.
- It introduces a landfill fee, which has never been enacted in Hungary so far, which will be discussed later in detail also.
- The selective waste collection will be compulsory from 2015 and it is based on the door-to-door collection system. Waste islands will be implemented at locations where it is not so easy to introduce the door-to-door collection system.
- The public service provider will be the owner of the waste in the waste islands and the punishment for stealing it will be much stricter.
- The increased rate of the state ownership will be a very important element of the new legislation system, and determines the minimal 51 % state/municipal ownership in the public service companies in order to achieve the required targets.

> It is important to mention that the majority of public service companies are already in public ownership – projected to the number of inhabitants – and operating well.

The Waste Law serves the legislative background of the modern waste management system and together its implementing regulations will serve the following targets: the waste management system in Hungary shall be traceable predictable for long term, the waste amount shall be decreased, recycling rates shall be higher, and landfilling shall be only the final possibility. In order to decrease the landfilled waste, a landfill fee will be implemented from 2013 and progressively increased every year. This also complies with the practice in the Member States with high waste management level.

Product fee Act

Before the Waste Law work began with the preparation of a new Act LXXXV of 2011 which introduced an Environmental Product fee and was accepted by the Parliament in 2011, coming into force on 01 January 2012. It is also necessary to mention another very important change. In Hungary there were several coordinating companies who were responsible for the proper collection and utilization of different waste types, which fall under the "product fee system". It means that the big multinational companies entrusted these coordinating companies to report of the amount of the collected and utilized waste. In the case of a given utilization rate, the multinational companies do not have to pay the product fee, which was a tax on the producer as it produces environmentally polluting product.

However, there were several malfunctions in the system, it was not really controlled and the fate of the money and the waste were not exactly known.

Therefore a new law was prepared in 2011 in order to enforce the stricter environmental regulations and to control the waste and material flows. The new legislation provides appropriate frames to resolve the contradictions and to increase the selective waste collection rates even from this year in Hungary. The exemption from the product fee payment was eliminated. Great change was that the twenty three coordinating companies were shut down and instead of them only one coordinating company was established, the state-owned **National Waste Management Agency Nonprofit Ltd. (Országos Hulladékgazdálkodási Ügynökség Nonprofit Kft. - OHÜ).** This agency ensures the transparency for the key players and the Hungarian state and the EU representatives through its coordinating and controlling activities. In addition it provides the same participation conditions for the key players as well as the same accountability. As a result of this process a more efficient market can operate in Hungary in which the real, controlled, and legal companies shall remain, with a requirement to focus on the real waste management tasks as the conditions are accountable and motivating for them. According to the Law on the environmental product fee, the main tasks of the National Waste Management Agency are the following:

- to make contract with the companies who collect and utilize these waste types,
- to control nationally the waste flows and activities of the waste products under the environmental product fee,
- to improve the solid waste management system with innovation and update knowledge on the latest trends, technologies and processes,

- to improve the environmental awareness in the solid waste management.

Therefore the activity of all the coordinating companies were replaced by the OHÜ and it is foreseen that a much stricter control will take place in Hungary in the solid waste management. This trend for the stricter control is also influencing the activities of the FKF Zrt. nowadays in Budapest as well.

Economic incentives to promote the waste hierarchy priorities

In Hungary there is a special incentive for the polluter pay principle, which is basically laid down in the Environmental product fee Act (LXXXV. law in 2011.)

According to Ministry of Rural Development (2011) as a result of the latest changes in the legislation we can conclude that there are three main incentives which are the following:

- product fee,
- deposit refund system and the
- landfill fee.

Product fee

Product fees are applied to products which are polluting the environment because of their respective amount and of the containing materials. According to the Law on the environmental product fee (2011) presently the product fee are relevant to the following products:

- packaging waste,
- car battery,

- waste of electric and electronic equipment (WEEE),
- tires,
- crude oil products,
- advertisement paper.

Deposit refund system

Deposit refund system means that the consumer pay an extra fee on some packaging waste types (presently it is only applied for beer glass, but it may be spread to champagne, wine glass as well as PET bottles, aluminum cans, composite waste, or battery and paint toner) and when the consumer brings this product back to the supermarket he is entitled to receive this extra fee. Therefore the consumer is interested in recycling as he will receive his money back. So this incentive rewards the environmental awareness behavior.

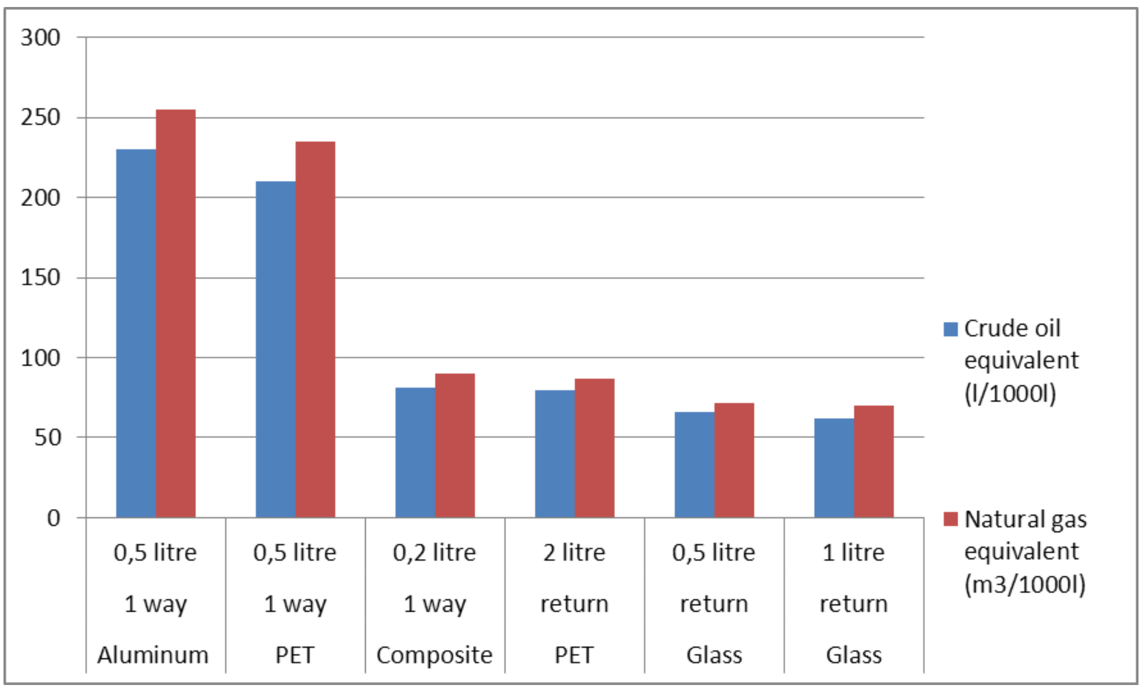
Relevant research was prepared for the deposit refund system which included the evaluation of more than 20 LCA studies for the following waste packaging, which are under consideration for the deposit refund system:

- PET plastic bottle,
- Aluminum cans,
- Glass and
- Composite (for example juice cartons) packaging.

The Vámosi (2011) summary points out that the most important aspect is the primarily production (raw materials) of the product and it this term the following order can be determined:

1. Glass – 9 MJ/kg is the energy demand for the production from the raw materials,
2. Composite - 28 MJ/kg is the energy demand for the production from the raw materials, depending on the HDPE and aluminum content,
3. PET bottles – 80 MJ/kg, but it is produced from oil,
4. Aluminum cans – 140 MJ/kg, as well as red mud is generated during the production.

According to a research lead by Vámosi (2011) we can conclude the crude oil and natural gas equivalent for the different packaging materials are the following:



13. Table Crude oil and natural gas demand of some packaging products

Source: Vámosi O. 2011. Product fee law and waste management objectives. Environmental analysis of the drinking packaging for determining the product fee amount. Summary

From this table it is evident that the crude oil and natural gas demand are the most in case of the one way PET bottles and the smallest at the returnable glass bottle, so the deposit refund system must take this into consideration. The study reveals that the production is beneficial in the case of: returnable glass, PET bottles in big size, and composite. Strongly harmful for the environment the production of aluminum, one way glass and PET in small sizes.

Landfill fee

Landfill fee is an incentive, which is to be paid after landfilling waste, therefore it forces the consumers to consume less and also to use the selective waste collection facilities.

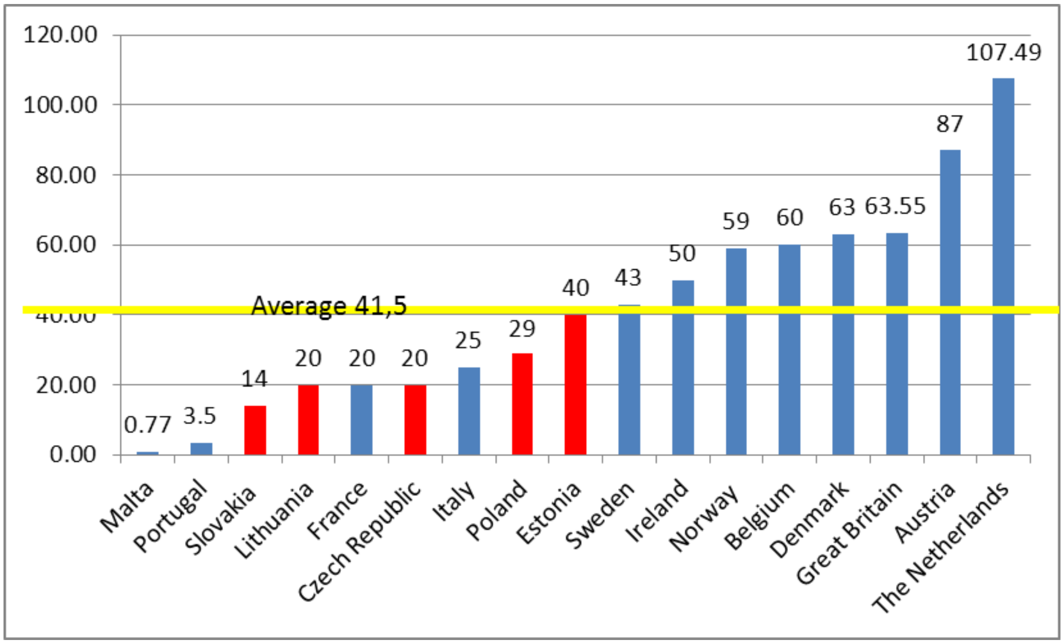
The fee of landfilling of municipal solid waste is HUF 2,000/ton and gradually it will be increased to HUF 12,000 per tons by 2015. However, landfill fee is a common incentive in the European Union Member States in order to decrease the disposed waste and increase the waste prevention and recycling through selective waste collection.

Waste type	Waste landfill fee (net HUF/tons),			
	2013	2014	2015	2016
Municipal solid waste	3 000	6 000	9 000	12 000

14. Table Amount of the landfill fee in Hungary

Source: Waste Act 2011. Draft

Landfill fees have already introduced in other European Union Member States, and this is actually a step which may have to be carried out earlier in Hungary also. In the other countries the amount of the landfill fees are as follows:



26. Figure Landfill fee for MSW in some European countries (EUR/ton, 2011)

Source: Source: own contribution based on CEWEP

The graph shows that the landfill fee is quite high in the countries, where waste management and recycling is high. There are even some countries in which landfilling for some waste streams is forbidden (Austria, German etc.). The red color shows the former socialist countries: Slovakia, Lithuania, Czech Republic, Poland and Estonia.

The landfill fee will be also be implemented in Hungary and this incentive also serves the recovery of the generated waste. The landfill fee is included in the Waste Act and the amount of it will be increased gradually between 2013 and 2016, as follows: HUF 3000 (appr. 10 EUR) from 2013 which will be HUF 6000 in 2014 (appr. 20 EUR, HUF 9000 in 2015 (appr. 30 EUR) and HUF 12 000 in 2016 (appr. 40 EUR). It can be seen that with the 40 EUR value it will take four years of gradual increase to reach the present 43 EUR in Sweden, which is 37% of the 107,49 EUR fee in The Netherlands.

By the gradually increased fee the Hungarian legislation wishes to reach a higher amount of waste recovery every year as well as to decrease the amount of the landfilled waste. By implementing the landfill fee the policy makers wish to avoid any disturbance in the market and within the inhabitants and shall not increase the illegal landfilling.

Summary of the incentives

Comparing the three main incentives – based on the Ministry of Rural Development (2011) we can summarize the connecting impact and measurements.

First, the most important was to regulate the product fee system, as in the long term it is a basic law to establish the efficient waste management. In order to promote waste prevention and recycling in the second step it is necessary to introduce the deposit fee system as well as the landfill fee.

Incentive	**Impact**	**Measurement**	**Comment**
product fee	waste prevention and minimalisation	decreasing waste landfilling rate,	it may lead the consumption to less environmentally polluting products
deposit refund system	promoting waste minimalisation, re-use and recycling,	decreasing waste landfilling rate, national targets for recycling rates,	administrative costs may be high,
landfill fee	decreasing waste landfilling rate to other directions,	obligatory utilization targets, which promotes recycling against disposal, ban on landfilling for special waste streams,	it may be difficult to divert landfilling at some waste types

15. Table Possible impacts of the product fee, deposit system and landfill fee

Source: Ministry of Rural Development 2011. Impact assessment of the modifying recommendations for the environmental product fee Draft

These changes are necessary to understand the present waste management policies in Hungary and in Budapest also. In the new waste management system cautious, more careful preparation will prevail, and this is not expected to be an obstacle to consistent accountability.

7.3 Current trends in the Hungarian waste management sector

Hungarian legislation had been altered, and the new legislation background for the Hungarian waste management sector has been described in detail above.

In Hungary the amount of the waste per capita is increasing, so its selective waste collection and recycling is highly important. In order to improve the environmental and natural status of Hungary the following three conditions must be ensured:

1.) From the produced amount of waste as much as possible must be collected from the production source and after waste collection, recycling the material must be elaborated.

2.) Nationwide environmental awareness is required for the selection, collection and recycling as well as modern infrastructure. The present Product fee Law contributes to this target as it determines the amount of budget which must be spent on environmental awareness. As a part of this there are several events, campaigns and the Ministry of Rural Development is planning to involve children to promote environmental behavior.

3.) A utilization base is required near the selective collection locations, so the distance for the further processing plant shall be short.

As it was described some pages before that OHÜ Nonprofit Kft. is solely responsible for the waste of the products which fall under the product fee obligation system. This was described in detail 10 pages before in case of the Product fee Act, so not repeated here.

The Product fee Law provides opportunity for the individual performance, so the producer or the business player which first introduces the product on the market can contribute to the targets of the OGyHT. OHÜ, as the only coordinator, can organize and manage the collective collection and utilization of the waste of the products which fall under the product fee obligations can be originated from two sources. One of them is the selectively collected waste by inhabitants and the other comes from the industrial sector. In case of the inhabitants the waste collection and transport is made by the public service companies and OHÜ contracts with them with the same conditions for collection and utilization. In the case of the industrial sector, OHÜ can order the service through public procurement process with high attention to the state requirements and meanwhile let competition guide the market. In the new system the producer's administration burden become smaller. It must be mentioned that for some market players it can be difficult to adapt to the new system, because control and the accountability become stronger also. This change in the waste management regulation ensures the predictability and equality of opportunity for the market players.

In Hungary the National Collection and Utilization Plan (Országos Gyűjtési és Hasznosítási Terv, OGyHT) set the recycling targets of different waste types, whereas the Law on the product fee sets the new regulations for the specific waste types.

National Waste Management Plan (Országos Hulladékgazdálkodási Terv) – II.

The National Waste management Plan has not been yet published officially, so it is only possible to determine the targets from the draft version. As a revision of the former OHT we can state the following points must be revised:

- selective waste collection bins must be ensured for at least 80 % of the inhabitants until the end of 2013;
- recovery (either in its material or thermally) of the 50% municipal solid waste must be ensured by the end of 2013.

It is evident that in order to reach these targets it is necessary to enlarge the recycling capacities in Hungary. Therefore these targets must be revised according to the following in the OHT II.:

In order to reach the 50 % recovery target within the organic waste and the recyclable waste by 2020 the use of the selective waste collection facilities must be obligatory from 2014. If Hungary is not able to reach these EU recycling targets than the deposit system must be implemented in order to increase the current recycling targets. This type of incentives was discussed in detail in the chapter on the recent changes in the Hungarian legislation. The recycling facilities must be established in order to increase the rate of the selective waste collection.

In Hungary the waste collection rate reached 93% in 2007, and in Budapest we can say that there is a full collection rate. By 15 July 2009 Hungary had to shut down the existing landfill sites which were not compliant to the EU requirements. The presently operating regional landfill sites are mainly co-financed by the EU financial support. The closed landfills sites are being remediated.

Today in Hungary there are approximately 8,000 waste islands and 100 waste yards and the door-to-door collection reaches more than 900,000 inhabitants. The rate of the selective waste collection was 12% in 2008. However, the waste island collection system is not really efficient, so the door-to-door collection system must be increased in the entire country.

The main targets of the document are the following in relation to this research:

- the recycling rates must be increased above 40% in the recyclable waste types (paper, plastic, metal, glass and organic),
- the 35% recycling rates must be ensured for the paper, glass, metal and plastic waste from the inhabitants by 2014, and 50% by 2020,
- the necessary infrastructure must be established for all of the inhabitants,
- the landfilling rate must be decreased and kept below 60 % by 2014 in the regional landfill sites.

The municipal solid waste generation and treatment can be seen in the following table in the last years:

Name	2007	2008	2009
MSW amount (thousand tons)	4 594	4 553	4 312
Recycling (thousand tons)	554	692	665
Thermal treatment (thousand tons)	383	393	406
Landfilled (thousand tons)	3 428	3 341	3 212
Other (thousand tons)	229	126	29

16. Table Amount of waste treatment in Hungary, 2007, 2008 and 2009

Source: National Waste management Plan, draft

This Hungarian situation is displayed within the treatment methods of the European Union Member States.

Name of the country	MSW generation kg/capita	Waste treatment method (%)			
		Landfilling	Incineration	Recycling	Composting
Germany	587	0	34	48	18
Austria	591	1	29	30	40
Sweden	485	1	49	36	14
The Netherlands	616	1	39	32	28
Denmark	833	4	48	34	14
Belgium	491	5	35	36	24
Luxembourg	707	17	36	27	20
France	536	32	34	18	16
Italy	541	45	12	11	32
Finland	481	46	18	24	12
U.K.	529	48	11	26	14
Spain	547	52	9	15	24
Portugal	488	62	19	8	12
Slovenia	449	62	1	34	2
Ireland	742	62	3	32	4
Estonia	346	75	0	14	11
Hungary	**430**	**75**	**10**	**13**	**2**
Poland	316	78	1	14	7
Greece	478	82	0	17	2
Slovakia	339	82	10	2	6
Czech Republic	316	83	12	2	2
Cyprus	778	86	0	14	0
Latvia	333	92	0	7	0
Lithuania	360	95	0	3	1
Malta	647	96	0	4	0
Romania	396	99	0	1	0
Bulgaria	468	100	0	0	0
EU27 average	**512.22**	**54.85**	**15.19**	**18.59**	**11.30**

Data for the EU 27, Denmark, Germany, Spain, France, Italy, Cyprus, Luxembourg, Netherlands, Romania, Portugal and the United Kingdom are estimated
0 equals less than 0,5 %, "." indicates a real zero.

17. Table Waste treatment method in the EU 27, 2009 (%)

Source: Eurostat News release 37/2011 8 March 2011

From this EUROSTAT comparison data the following consequences can be drawn: if the landfilling rate is high than the country waste management system is underperforming (such as predominantly the Eastern European countries, particularly Bulgaria and Romania etc.), and when the country possesses a high level and sophisticated waste management system where the recycling, composting and incineration rate is high and landfilling rate is low (such as Germany, Austria, The Netherlands, Denmark etc.). From the author's perspective it is suggested that the phrase "incineration" should be changed to "thermal treatment" in this table, because thermal treatment means that during the combustion of the waste electricity and heat are produced whereas incineration means burning without any energy recovery. In Hungary we have only one MSW thermal treatment plant, which is located in Budapest and produces combined heat and power.

National Collection and Utilization Plan

A new element in the system is the National Collection and Utilization Plan (Országos Gyűjtési és Hasznosítási Terv - OGyHT) which determines the waste collection and utilization rates and amounts from the waste of the products which fall under the product fee by waste types. This enables key players to plan the operational and business activities as state requirements are public, and specifically determined so the market players can decide whether to get involved in reaching the waste management targets.

The National Collection and Utilization Plan (Országos Gyűjtési és Hasznosítási Terv, OGyHT) includes the utilization rates for 2013. The OGyHT was written by the OHÜ in order to determine the minimal collection and recycling rates of different waste types.

The OHÜ has the right to modify the OGyHT according to the latest process in the current solid waste management system, so the 01/2013 version was made on 25. August 2012.

It says that the planned amount of the collection and utilization in terms of the packaging waste types are the following:

	Paper	Textile	Metal (without alu)	Alu-minum	Plastic	Glass	Wood	Com-posite	Total
Waste generation (t)	379 810	190	45 000	17 200	240 000	110 000	200 000	23 000	1 015 200
Minimal utilization rate (%)	**60%**	**60%**	**50%**	**50%**	**22,5%**	**60%**	**15%**	**23%**	**60%**
Minimal utilization amount (t)	227 886	114	22 500	8 600	54 000	66 000	30 000	5 290	**609 120**
Collection from industrial partners (t)	285 000	30			43 000	28 000	36 000	4 500	**396 530**
Inhabitant collection (t)	20 592	0	1 200	450	17 000	22 000		650	**61 892**
Consumption collection (t)				500	5 000	16 000		1 000	**22 500**
Independent, individual collection (t)			42 000	1 819		148	250		**44 217**
Planned utilization amount (t)	320 592	30	43 200	2 769	133 767	66 148	36 250	6 150	**608 908**
Utilization rate (%)	**84.4%**	**15.8%**	**96%**	**16.1%**	**55.7%**	**60.1%**	**18.1%**	**26.7%**	**60%**

18. Table Planned collection and utilization rate, packaging 2012.

Source: Országos Gyűjtési és Hasznosítási Terv (OGyHT) 2012 version 01/2013. National Collection and Utilization Plan Budapest, 2012. August 25. Országos Hulladékgazdálkodási Ügynökség

According to the latest Országos Gyűjtési és Hasznosítási Terv (OgyHT), which was prepared in August 2012 we can see a pattern which outlines that by increasing amount of the products on the market the utilization is also increasing. The expected packaging waste on the market for 2012 is 794551 tons and the collected and recovered waste is 465786 tons which means a 58.6 % utilization.

Packaging waste	On the market	Planned recovery
Plastic	195 885,5	96 733,2
Paper and textile	280 920,7	272 142,4
Aluminum	7 612,3	940,1
Metal (without alu)	47 898,8	727,3
Wood	143 341,5	26 000,0
Glass	98 369,2	61 305,3
Composite	20 522,9	6 138,1
Utilization of the selective residual		1 800
Planned output and recovery amount	**794 551,0**	**465 786,4**

19. Table Planned output and recovery amount in the packaging waste (tons, 2012)
Source: Országos Gyűjtési és Hasznosítási Terv (OgyHT'12), Budapest, 2011. September 15.

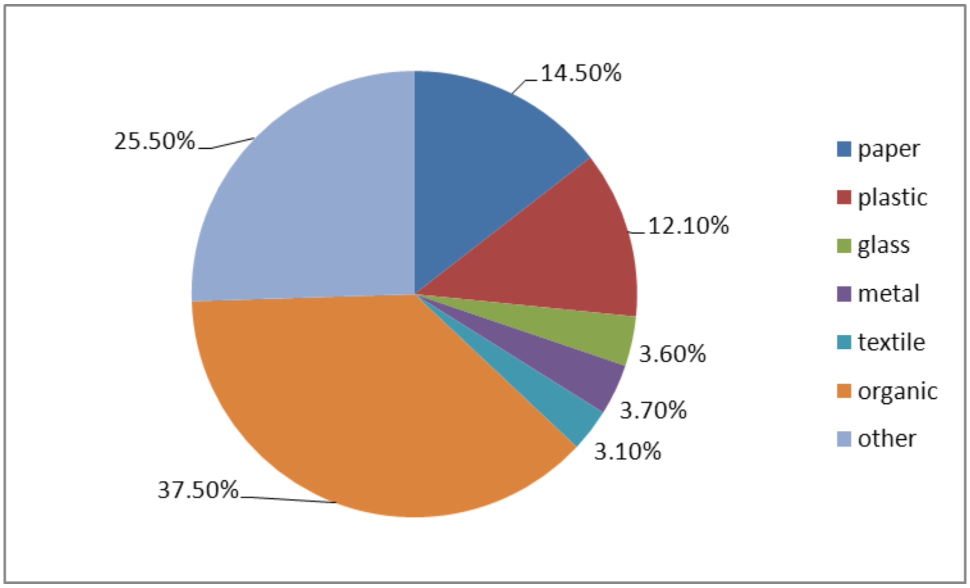
In Hungary the amount of the municipal solid waste is 4.5 million tons per year and from this amount the potentially recovered waste types are: glass, paper, plastic, metal and also the organic waste which can be composted. Therefore, the recyclable waste is 33,9 %, representing 1.5 million tons.

However, the expected recovery amount from the packaging waste is 465 786 tons, which is only 10 % of the municipal solid waste. In order to reach as high rate as possible, the Ministry of Rural Development and the OHÜ will promote the selective waste collection.

The collection and recycling rate of the packaging waste in 2012 according to the OGyHT is 15 % from the inhabitants and 85% from the industrial, commercial and service sector. Within the present system from collected MSW from inhabitants, not even 5% is recycled in national average. This amount was 62 000 tons in 2010 and the plan for this year is 80 000 tons according to the activities of the public service companies who contracted with OHÜ. If this amount has been satisfied and increases further, then in following years as a result of the selective waste collection from the public sector 5-6 % more packaging waste can be included. In summary, the new waste management system in Hungary from 2012, on one hand, will ensure a nationwide planning and implementation on the other hand, takes into account the local needs and possibilities.

7.4 Estimated trends for the waste amount and composition in Hungary

In Hungary annually, 300-450 kg/capita municipal waste is generated which is mainly landfilled. In developed environmental systems in other countries the majority of this amount of waste is recycled or recovered. (Köztisztasági 2003).



27. Figure Composition of the municipal solid waste, 2004

Source: Ministry of Environment and Water. 2006.

The waste composition has not changed significantly in the last years, so it can be regarded as present situation as well.

As Bartus A. (pers.comm. 2009) pointed out that the Budapest waste management plan can be prepared only after finishing the revision of the National Waste Management Plan as well as the regional waste management plans.

Since the changes in EU legislation and the waste principles have influence on Hungarian technologies, it is expected that Hungary will adopt the same technologies. However, it is questionable in what rate the same technologies can be adopted (such as mechanical-biological pre-treatment) and what sort of environmental, financial, legal and social consequences it will result. This thesis will also serve a base to be able to compare these technologies from the aspects, mentioned below and to be able to develop the most appropriate technology for Hungary (e.g. not the most expensive technology, if not necessary). This thesis is going to review and analyze this issue with using the available literature and personal communications and study abroad, if possible as well as calculations and thus comparisons.

The implementation of the new Product fee Law concerns the tasks of the waste collection, treatment and utilization of the waste from the products which fall under the product fee from the inhabitants, industry, and commerce and service sectors. The waste amount of these products is over 1.1 million tons yearly which increases every year apart from observed stagnation in recent years. Nevertheless, Hungary is lagging behind the requirements of the selective waste collection and utilization which is not only environmentally disadvantageous but also results in the failure of the EU requirements. As a result of the improper waste management strategy in the last years several investments took place without determined and goal-system approach and as a consequence, some companies went bankrupt as their status became unpredictable in the observed uneven field of competition. The market became weaker for many of the "adventurers" appearing in this key business sector. For instance, there are too many landfill sites in Hungary compared to its geographical size. Although the present 69 landfill sites comply with the strict EU requirements, Hungary does not properly follow the waste hierarchy. The present government fully agrees with this determination and promotes corresponding waste hierarchy priorities.

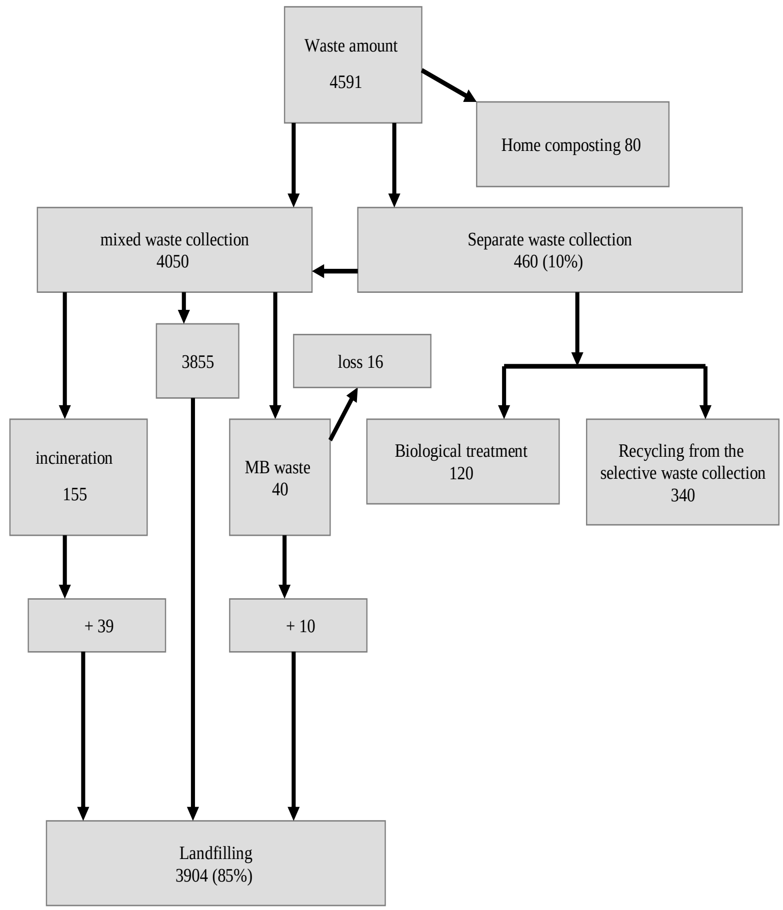
Waste treatment estimations in Hungary

To show the situation in the past the Development strategy of the municipal solid waste 2007-2016 (Ministry of Environment and Water 2006) was used. For the present the

OgyHT 2012 can be used, as this is the official document for the amount of the different types of waste.

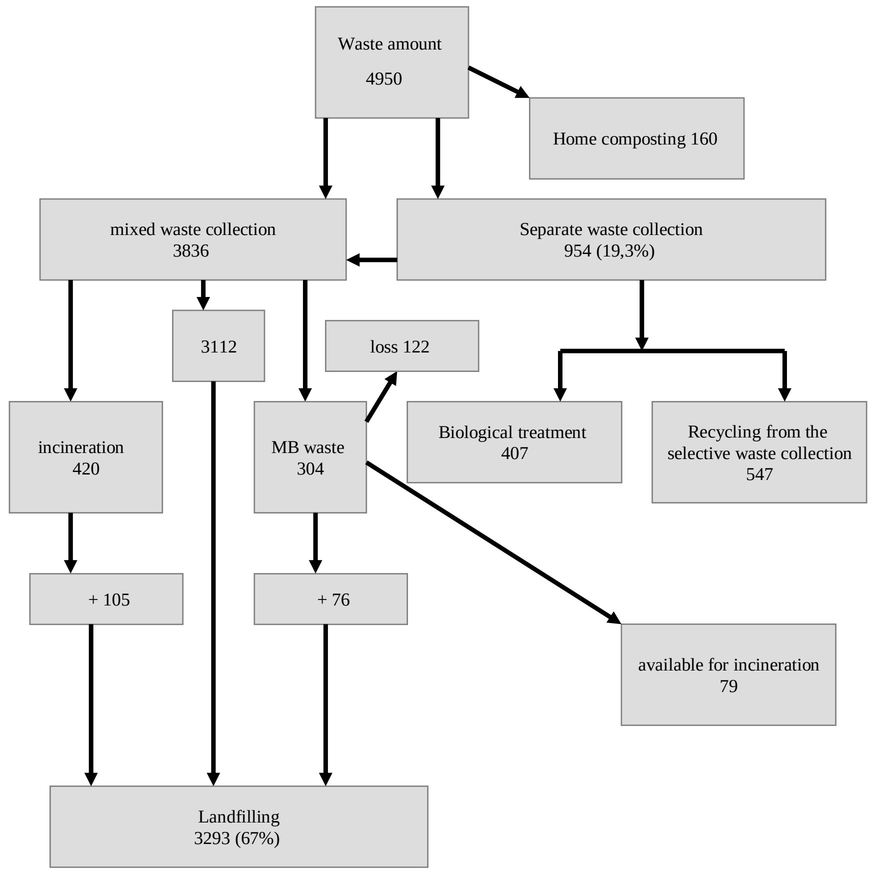
Estimated trends

The following figures show the waste flows for the years of 2004, 2009 and 2016. It can be seen that the trend is the following: the amount of the landfilled waste will be decreased, the amount of the selective waste collection and so the recycled waste will be increased and the mechanical biological treatment will be most common. It is important to note that the latter treatment option requires a new power plant and a new incineration as well.



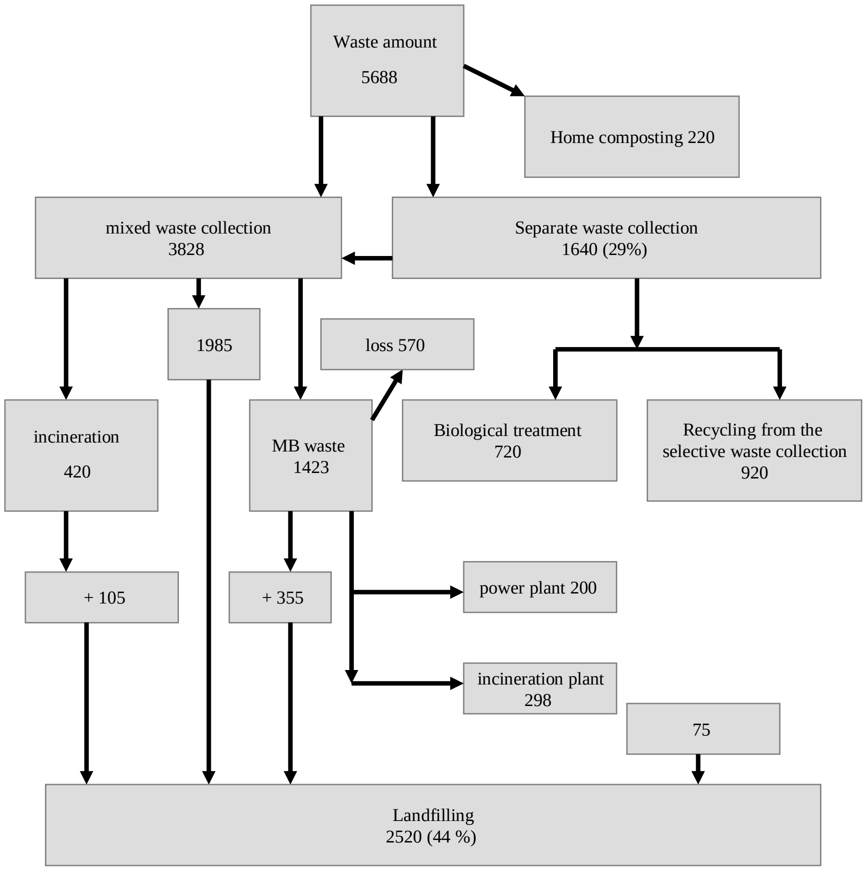
28. Figure The waste flow for 2004 (1000 tons)

Source: Ministry of Environment and Water. 2006.



29. Figure The waste flow for 2009 (1000 tons)

Source: Ministry of Environment and Water. 2006.

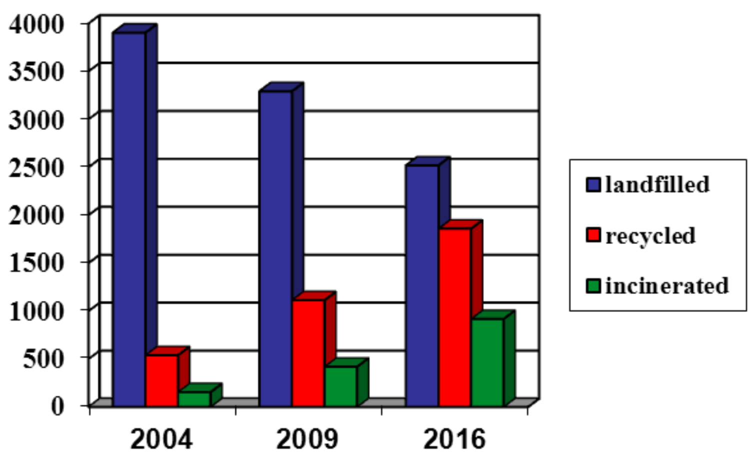


30. Figure Planned waste flow for 2016 (1000 tons)

Source: Source: Ministry of Environment and Water. 2006.

According to the targets, by 2016 only 50% can be disposed of the total generated 5688 000 tons of waste. The recycling will be 1860 000 tons while the incineration of 420 000 t/year is not enough to reach the landfilling targets, so the mechanical biological treatment must be used for 1423 000 tons. In addition the present capacity of the selective waste collection has to be increased an additional 560 000 tons of new capacity (for the collection of 190 000 tons of packaging waste, 220 000 tons of non-packaging waste paper and 150 000 tons of non-packaging other selective waste).

The estimations foresee that the recycling is increasing and the landfilling disposal method is decreasing while the incineration disposal method is increasing.



31. Figure Recycling and disposal rates of the municipal solid waste 2004-2016

Source: Ministry of Environment and Water. 2006.

It is important to note that 40 000 tons of municipal solid waste was treated by mechanical-biological treatment in 2004, but in the chart it was included in the landfilled waste, as it was shown in the Waste management Strategy as well.

The waste landfilling took place in 2005 at 178 landfill sites but only 53 have permission to operate after 2009.

In Hungary the Waste Management Information System, (Hulladékgazdálkodási Információs Rendszer – HIR) database provides the data for the waste amount in the different treatment technologies. The HIR database was launched by the Ministry of Environment and can be accessed at the following site: http://okir.kvvm.hu/hir/

Nationally, waste landfilling can happen with the permit of the Environmental and Natural Directorates (Környezetvédelmi Természetvédelmi és Vízügyi Felügyelőségek). As the National Development Agency provided the table for the current operating landfill sites, it was modified slightly according to the present status. In Hungary at present the following 69 landfill sites are in operation, according to the area of the Environmental Directorates:

Nyugat-dunántúli KTVE		
	Vas county	1. Szombathely
		2. Haraszitfalu
		3. Kőszeg
		4. Csepreg
	Zala county	5. Zalaegerszeg
		6. Nagykanizsa
		7. Zalabér
Észak-dunántúli KTVE		
	Vas county	1. Répcelak
	Komárom-Esztergom county	2. Tatabánya
		3. Oroszlány
	Győr-Moson-Sopron county	4. Győr
		5. Jánossomorja
		6. Fertőszentmiklós
		7. Sopron
Dél-dunántúli KTVE		
	Somogy county	1. Kaposvár
		2. Marcali
		3. Ordacsehi
		4. Som
		5. Kaposmérő (Hetes)
	Baranya county	6. Szigetvár
		7. Görcsöny
Közép-Tisza-vidéki KTVE		
	Pest county	1. Cegléd
	Jász-Nagykun-Szolnok county	2. Karcag
		3. Tiszafüred
		4. Jásztelek
		5. Szelevény
		6. Kétpó
Észak-magyarországi KTVE		
	Borsod-Abaúj-Zemplén county	1. Bodrogkeresztúr
		2. Hejőpapi
		3. Sajókaza
Felső-Tisza-vidéki KTVE		
	Szabolcs-Szatmár-Bereg county	1. Nyíregyháza
		2. Kisvárda
		3. Nagyecsed
Alsó-Tisza-vidéki KTVE		
	Csongrád county	1. Szeged
		2. Csongrád
		3. Hódmezővásárhely
		4. Felgyő
	Bács-Kiskun county	5. Kecskemét
		6. Kiskunhalas
		7. Vaskút
		8. Izsák
Közép-Duna-völgyi KTVE		
	Pest county	1. Százhalombatta
		2. Dabas
		3. Tura
		4. Pusztazámor
		5. Kerepes-Ökörtelek völgy
		6. Gyál
		7. Dunakeszi
		8. Dömsöd
		9. Adony
		10. Csömör
	Nógrád county	11. Bátonyterenye
		12. Salgótarján
		13. Nógrádmarcal
Tiszántúli KTVE		
	Békés county	1. Békéscsaba
		2. Gyomaendrőd
	Hajdú-Bihar county	3. Debrecen
		4. Nádudvar
		5. Hajdúböszörmény
		6. Berettyóújfalu
Közép-dunántúli KTVE		
	Veszprém county	1. Veszprém
		2. Királyszentistván
		3. Zalahaláp
		4. Ajka
	Fejér county	5. Székesfehérvár
		6. Polgárdi
		7. Sárbogárd
	Tolna county	8. Paks
		9. Cikó

20. Table: The current 69 operating landfill sites in Hungary

Source: own contribution to the National Development Agency database

Nevertheless, the irrational numbers of the landfill sites may result in some extra capacity and the improper distribution of them results in the fact that in some regions capacity is low and in other regions there are too many landfill sites. The government and the Ministry of Rural Development have to deal with this problem in addition to the preparation of the comprehensive measures. Similarly the selective waste collection network in Hungary is unevenly distributed, does not take into account the size of the population nearby and therefore it is not efficient. In some municipalities the selective waste collection works well while at other locations there is no selective waste collection at all. The reason of the failure of the selective waste collection has not been analyzed. It is also important fact that in locations which possess selective waste collection bins the inhabitants do not use them. The Ministry of Rural Development highlights the importance of the environmental awareness in order to increase the selective waste collection.

7.5 Contradiction in the data

During the description of landfilling earlier in this document it was shown that the there are several cases when the same data from two data sources are not consistent to each other. In Hungary many waste management data can be seen in the HIR (Hulladék Információs Rendszer – waste information system) database.

The provision of data will become much more transparent and easier to be followed as opposed to past years where available databases were in contradiction with each other in some waste types. In the former legislation system the market players had to report the collection and transmission of the data in different forms and different deadlines to several organizations, which made the work of the organizational companies difficult and expensive with high level of administration. However, this data was not discussed as there was not any „umbrella organization” which would manage them and eliminate the contradictions. The data supply was not unformed with the same requirements so every organization demanded different forms. For instance, the companies operating in the vehicle industry had to report not only on the waste of the products which fall under the product fee but also they had to report to several companies for the same product. Therefore, a vehicle company had to report the five or six data types on the product in different forms to different authorities.

A good example is the following

- the waste management information system (Hulladékgazdálkodási Információs Rendszer – HIR) is a source from the waste producer companies through the ministry responsible for the environment, the 10 regional environmental, nature protection and water management inspectorates,
- the Central Statistical Office (Központi Statisztikai Hivatal, OSAP) is also a source and the following table can illustrate the differences between them.

- data had to be reported to the tax authority also. However, at many cases even the basic principles of the data were not the same, so the data can not be properly valued.

	Amount of the transported mixed waste from the inhabitants (t)		
year	Central Statistical Office	Waste Management Information System	difference
2006	2 724 451	2 333 976	390 475
2007	2 527 534	2 493 659	33 875
2008	2 510 446	2 600 331	89 885
2009	2 383 797	2 886 739	502 942
2010	2 285 357	3 100 215	814 858

21. Table Example for the data inaccuracy, transported waste

With regard to the construction and demolition waste, there is also contradiction with the database from the Ministry of Rural Development – which is responsible for the environmental affairs – and the real amounts. The amount of the soil from the construction and demolition waste (EWC 17 05 04) is for example different in Southern Transdanubia (Dél-Dunántúl) as it can be seen in the following table.

Year	Ministry of Rural Development	HIR
2008	45 000 tons	30 000 m3
2009	36 000 tons	24 000 m3
Difference		54 000 m3

22. Table Example for the data inaccuracy, transported waste

Another example is for the contradiction and the possibility for abuse in the amount of the extra soil recorded during the construction of the M6-M60 highway. This number has been recorded as 900 000 m3 for the M6 area, and 1 300 000 m3 at the M60 area, which is 2,2 million m3 in total. This amount is transported and landfilled to the nearby areas with permit. However, these amounts were not indicated during the highway construction summary so 2,146 million m3 soil is missing from the data supply.

In the new databases these contradictions will disappear and the data for the industrial strategies will be in line with each other. As a consequence the state planning of the waste management will be reasonably predictable which concerns the market participants as well.

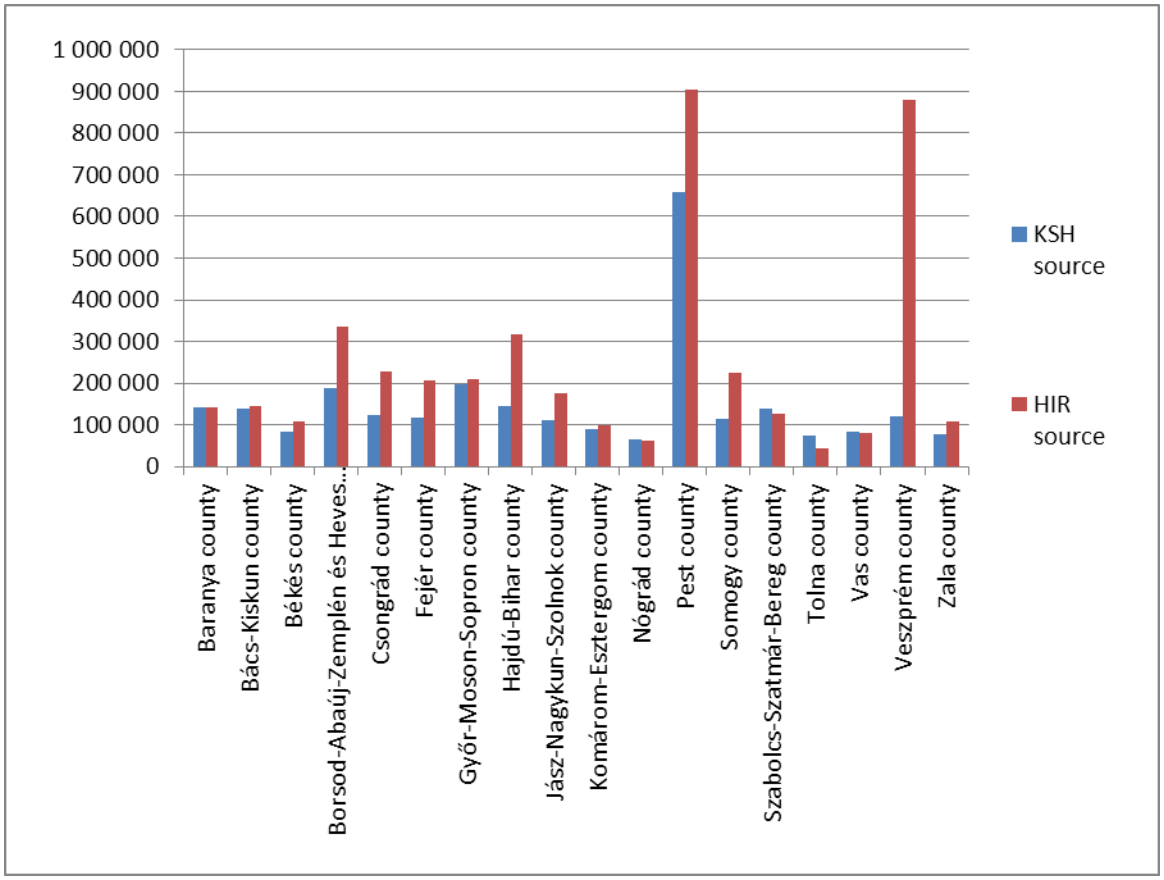
With regard to the waste landfilling it is very important to mention that the data from the different sources are not in line with each other. For instance if we compare the data from the Central Statistical Office (Központi Statisztikai Hivatal - KSH) and the HIR database we can see the following inaccuracy:

County	Amount of landfilled waste in 2010 (t)	
	KSH source	HIR source
Baranya county	141 710	141 405
Bács-Kiskun county	139 437	146 326
Békés county	83 475	106 838
Borsod-Abaúj-Zemplén és Heves county	187 856	336 528
Csongrád county	122 475	227 082
Fejér county	115 930	207 120
Győr-Moson-Sopron county	198 466	209 325
Hajdú-Bihar county	144 622	315 846
Jász-Nagykun-Szolnok county	111 142	176 883
Komárom-Esztergom county	90 583	97 545
Nógrád county	65 882	60 463
Pest county	659 759	903 241
Somogy county	112 963	225 470
Szabolcs-Szatmár-Bereg county	139 555	125 486
Tolna county	74 660	43 657
Vas county	84 476	81 273
Veszprém county	118 837	878 860
Zala county	78 566	109 155

23. Table Amount of the landfill waste in 2010 (t)

Source: own contribution according to KSH and HIR sources

This table can be shown in graphs as well:



32. Figure Amount of the landfill waste in 2010 (t)

Source: own contribution according to KSH and HIR sources

The data inaccuracy takes place at other waste streams as well such as car battery, tires, and construction - demolition waste; however, these waste types are out of the scope of the current research.

7.6 Waste management in other cities – short description

Before discussing Budapest solid waste management it become important to show briefly the waste management of the nearby countries as the Hungarian waste management system has to not only deliver the mandatory recycling rates but also has to save the country or Budapest authorities millions of HUF in avoided waste collection and disposal costs. Taking into account the technologies of the Western European countries provides the opportunity for win–win solutions, as the import of the old fashioned technologies (such as mechanical biological treatment) can be avoided.

This table describes the data for the nearby cities as well as Munich and Vienna from the years 1999 to 2001. (Linzner 2004.)

Name of the city	Municipal solid waste collected (t)			Inhabitants			Municipal solid waste (kg/cap/year)		
	1999	2000	2001	1999	2000	2001	1999	2000	2001
Belgrade	-	303,080	360,679	-	-	1,272,040	-	-	284
Bucharest	581,800	548,628	653,316	1,908,698	1,868,556	2,066,330	305	294	316
Budapest	426,118	-	-	1,838,753	1,811,552	1,759,209	232	-	-
Munich	723,326	718,622	702,086	1,315,254	1,247,934	1,261,597	550	576	557
Prague	240,300	270,439	279,092	1,186,855	1,184,000	1,173,000	202	228	238
Sofia	321,300	-	-	1,133,183	1,142,152	1,096,389	284	-	-
Vienna	817,257	830,908	823,811	1,602,673	1,608,656	1,608,161	510	517	512
Warsaw	650,000	-	710,430	1,615,369	1,610,500	1,609,780	402	-	436

24. Table Municipal solid waste collected (kg/capita/year) of the nearby cities

Source: Linzner R., Municipal solid waste management in the City of Belgrade – Current situation and perspectives 2004, Master Thesis, Vienna

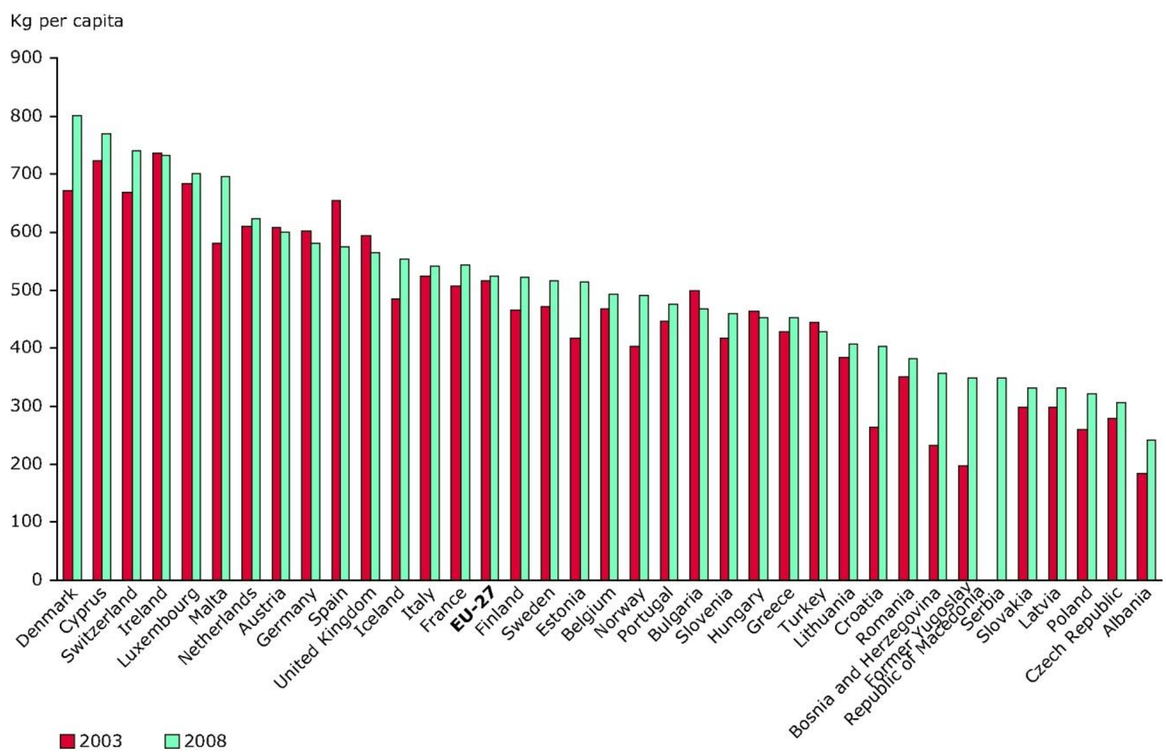
From the above table it can be seen (above from the fact that the population of Budapest is decreasing) that the amount of the collected waste per capita in Budapest (232 kg/capita in 1999) is significantly lower than it is in the cities of the Western European countries (550 and 510 kg/capita in 1999), while nearly the same as it is in the nearby capitals of the Eastern – European countries (202, 284 and 305 kg/capita in 1999).

Generation per capita (kg/capita)	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
EU-15 + EFTA	508	523	539	543	557	571	575	580	569	568	563	569	568	562	553
EU-12	362	359	364	341	354	360	338	347	335	328	362	368	368	369	364
EU-27	474	486	500	496	510	523	521	526	514	513	516	522	523	520	512
Total EU-27 + EFTA	477	489	503	499	513	526	524	530	518	517	520	527	529	523	515
Turkey	441	466	499	506	459	454	454	447	443	418	435	412	433	400	389
West Balkan countries (no data available for all countries and years)									228	251	271	272	290	328	340
Total EU-27 + EFTA + Turkey + West Balkan countries (where available)	472	485	501	500	507	517	516	520	503	499	504	504	508	501	493
EU-15															
Austria	437	516	532	532	563	580	576	608	607	618	618	653	596	599	591
Belgium	451	450	463	456	463	475	470	486	467	486	479	483	495	489	489
Denmark	565	618	587	592	626	664	657	664	671	695	736	740	790	830	831
Finland	413	410	447	466	484	502	465	458	466	469	478	494	506	521	480
France	475	486	496	507	507	514	526	530	506	519	530	536	543	542	535
Germany	623	641	658	647	638	642	632	640	601	587	565	564	582	589	587
Greece	302	337	362	377	392	407	416	422	427	432	437	442	447	452	457
Ireland	512	522	544	554	577	599	699	692	730	737	731	794	780	729	662
Italy	454	457	468	472	498	509	516	522	521	535	540	552	548	543	540
Luxembourg	587	585	604	625	646	654	646	653	678	679	672	683	695	697	701
Netherlands	548	562	588	591	597	613	613	620	609	624	624	622	629	624	611
Portugal	384	398	404	422	441	471	471	443	449	444	450	463	468	515	517
Spain	510	535	560	565	613	658	654	639	649	603	592	594	583	556	547
Sweden	386	385	416	430	428	428	442	467	470	464	481	496	516	513	482
United Kingdom	498	511	532	542	569	577	591	599	592	603	583	586	570	544	526
EU-12															
Bulgaria	694	618	579	497	504	517	499	501	501	492	475	461	433	474	470
Cyprus	595	637	646	660	666	677	699	704	716	730	730	739	748	767	775
Czech Republic	302	310	318	293	327	334	273	279	280	278	289	296	293	305	316
Estonia	371	399	424	402	414	462	373	407	419	449	436	399	449	391	346
Hungary	460	469	487	485	483	446	452	457	464	454	461	468	457	454	430
Latvia	264	265	255	248	256	271	303	339	299	311	311	412	378	332	334
Lithuania	426	401	422	445	351	365	377	402	384	367	377	391	401	408	361
Malta	460	469	487	485	483	446	452	457	464	454	461	468	457	454	430
Poland	285	301	315	306	319	318	290	275	260	256	319	321	322	320	316
Romania	342	326	326	278	314	355	341	384	350	345	378	389	379	392	396
Slovak Republic	295	275	274	259	261	254	239	283	297	274	289	301	309	328	322
Slovenia	596	591	589	585	550	513	478	407	418	417	422	431	439	457	448
Candidate countries															
Turkey	441	466	499	506	459	454	454	447	443	418	435	412	433	400	389
EFTA															
Iceland	427	437	445	452	457	466	469	478	485	506	521	570	566	555	554
Norway	626	632	619	647	596	615	635	677	696	724	759	793	824	490	473
Switzerland	601	603	609	613	637	657	662	678	670	662	663	711	724	741	706
West Balkan countries															
Albania									184	200	199	230	229	240	267
Bosnia and Herzegovina									236	254	262	255	317	356	389
Croatia									268	295	326	373	387	403	394
Former Yugoslav Republic of Macedonia									197	228	281	289	298	349	354
Kosovo under resolution 1244 of the UN Security Council													155	163	186
Montenegro															290
Serbia												233	280	347	359

25. Table Municipal waste generation per capita 1995-2009

Source: European Environmental Agency 2011c.

A significant step in EU policy is to differentiate waste generation from economic growth. This table shows that the generation of the municipal solid waste in the EU-27 remains around 520 kg/capita since 2000, in spite of the economic growth until 2008. Municipal solid waste generation was reduced after the economic crisis. If we take into account the MSW generation per capita than we can say that it has been increased until 2008, nevertheless, it has been slower than that of GDP, thus achieving the decoupling for this waste stream. The growth in waste volumes is influenced by the consumption and the population and not the GDP.



33. Figure Trend in generation of municipal solid waste in 2003 and 2008

Source: European Environmental Agency 2010a.

EU policy promotes less waste to be landfilled and more recycled or incinerated with energy recovery. This development has been driven by EU recycling target and measures, landfill taxes and ban on waste landfilling for some waste types. However, landfilling is still dominant, as in 2006 in the European Union its average rate was 51.5 %, while recovery and recycling rate was 43.6 % and a further 4.9 % went for incineration. The landfilling is the highest in Bulgaria and Romania with 98 % and the smallest in Denmark and Belgium with less than 10 %.

8 Evaluation of Budapest solid waste management system

After introducing the Hungarian waste management system and the present trends in the waste management sector it can be projected that in coming years landfilling will decrease and selective waste collection as well as recycling will increase. The same trend can be seen in Budapest as well, and so the model presented in this research examined the different selective waste collection rates and compared their environmental emissions.

8.1 Waste management in Budapest

Budapest has a quite unique status in the Hungarian waste management system according to the following reasons:

- 20 % of Hungary's solid waste is generated here,
- in Budapest there is a modern collection system,
- the system contains closed collecting containers (isolated, closed system), with standardized bins,
- the only solid waste thermal Waste-to Energy Plant in the country is located in Budapest.

For the evaluation of Budapest's solid waste management system with the EASEWASTE model it was necessary to obtain the required data for the modeling from the capital's municipal cleaning company. This was done through site visits and a number of interviews discussing the potential waste management strategies for Budapest.

Initial contact was started in the autumn of 2008. In October 2009 the FKF Zrt. started to supply data for the waste amount in of the years of 2006, 2007 and 2008.

Local service providers

The local waste treatment service provider is generally not subsidized by municipalities. In Budapest this service is not subsidized, as the property owners of Budapest pay the full price for the disposal of solid waste. The Budapest Cleaning company – Fővárosi Közterület-fenntartó Zrt. (Municipal Public Cleaning Maintenance Ltd.) is 100 % municipality owned.

The municipal solid waste is collected by a consortium, led by the Municipal Cleaning Co. with the participation of together ten companies (Siklóssy pers. comm) presented in detail in Table 26.

	Name	**Address**
1	Fővárosi Közterület-fenntartó Rt.	1081 Budapest Alföldi u. 7.
2	A.S.A. Magyarország Környezetvédelmi és Hulladékgazdálkodási Kft.	2360 Gyál Kőrösi út 53.
3	AVE Tatabánya Hulladékgazdálkodási és Környezetvédelmi Kft.	2800 Tatabánya II. Erdész út "E"
4	LÉ-MA Kereskedelmi és Szolgáltató Kft.	1188 Budapest Szigeti Kálmán u. 75.
5	JÄGER Szolgáltató és Kereskedelmi Kft.	1029 Budapest Ördögárok u. 3.
6	FIDO Szolgáltató és Kereskedelmi Kft.	1106 Budapest Gyakorló u. 4/b
7	Akont Kft.	1194 Budapest Töltény u. 17.
8	Ökont 2008. Környezetvédelmi Kft.	1184 Budapest Lakatos út 61-63.
9	Multiszint Kereskedelmi és Szolgáltató Kft.	1194 Budapest Töltény u. 17.
10	Bencsics József	1062 Budapest Podmaniczky u. 85.

26. Table These companies collect the solid waste in Budapest.

Source: Siklóssy pers.comm.

In addition there is one additional company, which is the subcontractor of Multiszint Kft. This company is called: Müll-Transport Környezetvédelmi és Szolgáltató Kft. 1112 Budapest Repülőtéri út 6. This company, however, is entitled to collect the waste as well, but the company is not a full member of the consortium, as it has no right to issue an invoice.

Waste fee

According to a nationwide comprehensive study from the Köztisztasági Egyesülés (Public Cleaning Association) 2010, it was possible to show the waste fees of the municipalities. The cost is based on a per bin basis. The bins are mostly 120 liters bins but in the block of flats the bigger bins are 1100 liters.

Population	**Waste fee (average) HUF/delivery**
Bigger than 50,000	306
Between 10,000 – 50,000	264
Between 2,000 – 10,000	250
Between 5,00 – 2,000	243
Below 5,00	252

27. Table Average waste fee rates in Hungary depending on the city size

Source: Köztisztasági Egyesülés (Public Cleaning Association) 2010.

Among the bigger cities of above 50,000 inhabitants it is found that the waste fee is the highest in Budapest in Hungary and the differences are quite large as presented in Table 27. It can be justified by the fact that in Budapest there is higher level of service (selective waste islands, waste yards, composting site, landfill and thermal treatment).

Name of the city	Waste fee HUF/pick up	Population [2]
Budapest	575	1 733 685
Szeged	487	170 285
Győr	396	131 267
Debrecen	358	208 016
Kecskemét	343	113 275
Pécs	264	157 721
Nyíregyháza	241	117 852
Székesfehérvár	219	101 943

28. Table Waste fees in some Hungarian cities, 2010

Source: Köztisztasági Egyesülés (Public Cleaning Association) 2010.

The frequency of the pick up of the bins is the following:

- once a week in the suburbs at the border of Budapest (like Rákospalota XV. district),
- twice a week in the residential sector in the suburbs of Budapest (for example XIX. district, Kispest)
- three times a week in the downtown (such as VII. district).

Waste fee is regulated by the Municipal Council, so it is different at every municipality.

Name of the city	Amount of waste fee (HUF)
Budapest	803
Szeged	677
Győr	526
Debrecen	491
Székesfehérvár	483
Pécs	375
Nyíregyháza	356

29. Table Waste fees in some Hungarian cities, 2012

Source: websites of the cities[3] as well as personal communications with Ágnes Szintai-Katona

[2]For the population the data is 01.01.2011. source: http://hu.wikipedia.org/wiki/Magyarorsz%C3%A1g#Legn.C3.A9pesebb_telep.C3.BCl.C3.A9sek

It is clearly indicated that the waste fee is the highest in Budapest among other cities in Hungary. If we compare the same unit with other European Union cities we can see that the waste fee is considerable higher for the cities presented in Table 30.

Name of the city	Amount of waste fee (HUF)
Zürich	1374
Cologne	2826
Berlin	1711
Vienna	1230
Rome	1130

30. Table Waste fees in some Western cities, 2012

Source: websites of the cities[4] as well as personal communications Ágnes Szintai-Katona

Obviously we can not compare the fee in the Western European cities and Hungary due to differences in service and income level, but it can be foreseen that the waste fee will be increased taking into consideration that the landfill fee will be implemented in Hungary.

8.2 Waste amount in Budapest

The following chapter describes the data collection methodology in terms of the EASEWASTE model, the uncertainty factors as well as the possible solutions which were necessary to obtain the required data.

Receiving data for the single, multi and institutional waste generation was not a complete success, so data from the Central Statistical Office was utilized. According to this source the following data can be analyzed:

[3]Budapest - http://www.fkf.hu/portal/page/portal/fkf, Szeged - http://www.szkht.hu/page.fcgi?rx=&item=&nyelv=hu&menuparam3=12&type=3
Győr – http://www.gyorszol.hu/index.asp?inc=hulladekkezeles, Debrecen – http://www.aksd.hu/, Székesfehérvár – http://www.deponia.hu/, Pécs - http://biokom.hu/index.php/hulladzsi-menetrend-2012.html, Nyíregyháza - http://www.thgkft.hu/

[4]Zürich - http://www.stadt-zuerich.ch/content/ted/de/index/entsorgung_recycling/sauberes_zuerich.html#
Cologne – http://www.awbkoeln.de/, Münich - http://www.awm-muenchen.de/, Berlin – http://www.bsr.de/9373.html, Vienna – http://www.wien.gv.at/umwelt/ma48/, Rome – http://www.amaroma.it/

Households

Total population in Budapest in 2011: 1721556 people.

Total number of households: 757250 flats.

Single family housing: 216123 pieces,

Multi family housing: 531474 pieces,

SCBU: 9653 pieces.

Waste amount

The amount of the total and the selectively collected waste can be seen in the following table for every months of year 2008. This year was used as the base year because this was the year where the most data was available (amount of selectively collected waste, consumption of the vehicles etc.)

	tons	2008											
	Detailed	January	February	March	April	May	June	July	August	September	October	November	December
Selective collection - waste islands	Paper and cardboard total	667.45	792.42	893.95	870.53	900.33	973.51	928.36	880.31	874.42	861.79	885.95	1 150.67
Selective collection - waste yards	Mixed paper	29.77	19.54	17.59	18.83	22.40	11.39	32.44	25.84	27.43	20.85	27.19	9.94
	Cardboard paper	8.64	9.62	9.55	10.52	11.25	11.26	11.46	13.07	11.02	11.46	10.38	8.92
	Paper and cardboard total	41.54	40.91	28.78	35.77	31.72	40.64	48.61	38.39	40.19	40.66	37.03	31.01
Selective collection - door-to-door	Paper and cardboard total	3.89	6.89	10.13	14.19	14.65	15.43	17.81	14.32	24.85	31.06	30.02	36.83
	Total paper	712.88	840.22	932.86	920.49	946.70	1 029.58	994.78	933.02	939.46	933.51	953.00	1 218.51
Selective collection - waste islands	Plastic total	257.16	247.98	275.90	292.43	312.27	334.46	349.27	343.07	321.94	298.02	281.94	312.50
Selective collection - door-to-door	Plastic total	1.83	1.60	1.82	2.04	1.68	2.01	2.21	2.23	1.60	1.82	1.87	1.88
Selective collection - waste yards	Plastic total	5.13	4.13	4.02	5.13	4.56	8.21	5.71	6.99	5.99	3.75	9.79	6.37
	Total plastic	264.12	253.71	281.74	299.60	318.51	344.68	357.19	352.29	329.53	303.59	293.60	320.75
Selective collection - waste islands	Colour glass	404.44	230.67	211.87	258.84	241.63	215.50	247.81	184.36	220.66	217.38	198.77	263.91
	White glass	266.82	188.17	250.14	317.06	255.75	235.26	266.95	205.73	294.86	224.13	242.24	240.95
	Glass total	671.26	418.84	337.14	575.90	497.38	450.76	514.76	390.09	515.52	441.51	441.01	504.86
Selective collection - waste yards	Colour glass	5.14	3.40	2.06	5.26	4.46	5.09	6.24	4.01	4.09	4.00	4.86	2.02
	White glass	4.81	6.24	3.75	5.20	5.88	4.41	3.68	3.47	3.16	3.98	4.12	3.38
	Glass total	9.95	9.64	5.81	10.46	10.34	9.50	9.92	7.48	7.25	7.98	8.98	5.40
	Total colour glass	409.58	234.07	213.93	264.10	246.09	220.59	254.05	188.37	224.75	221.38	203.63	265.93
	Total white glass	271.63	194.41	253.89	322.26	261.63	239.67	270.63	209.20	298.02	228.11	246.36	244.33
	Total glass	681.21	428.48	467.82	586.36	507.72	460.26	524.68	397.57	522.77	449.49	449.99	510.26
Selective collection - waste islands	Alu cans total	39.35	31.60	33.71	35.42	40.11	32.02	43.09	36.49	29.88	34.45	30.27	39.62
Selective collection - waste yards	Alu cans total	0.00	0.00	2.33	0.00	0.00	1.20	0.00	0.00	0.84	1.71	0.00	1.66
Selective collection - door-to-door	Alu cans total	0.59	0.56	0.49	0.65	0.37	0.42	0.53	0.31	0.41	0.36	0.44	0.56
	Total alu cans	39.94	32.16	36.53	36.07	40.48	33.64	43.62	36.80	31.13	36.52	30.71	41.84
Residual waste from the selective waste collection		133.38	104.42	111.24	105.46	100.90	92.32	108.30	91.06	98.44	103.52	106.13	95.82
Recyclable selective waste total		1 698.15	1 554.57	1 718.95	1 842.52	1 813.41	1 868.16	1 920.27	1 719.68	1 822.89	1 723.11	1 727.30	2 091.36
Selective total - waste islands		1 640.29	1 497.11	1 544.45	1 783.69	1 755.06	1 795.78	1 844.75	1 659.17	1 748.30	1 643.87	1 650.68	2 017.49
Selective total - waste yards		78.26	77.89	57.47	81.40	65.03	80.18	93.25	79.89	81.36	83.02	85.02	77.39
Selective total - door-to-door		6.31	9.05	12.44	16.88	16.70	17.86	20.55	16.86	26.86	33.24	32.33	39.27
Composting		73.40	60.80	101.86	904.97	1 427.80	1 248.68	1 428.54	1 283.60	1 139.17	1 662.84	1 978.70	244.09
Selective total		**1 771.55**	**1 615.37**	**1 820.81**	**2 747.49**	**3 241.21**	**3 116.84**	**3 348.81**	**3 003.28**	**2 962.06**	**3 385.95**	**3 706.00**	**2 335.45**
Disposal	Landfill site	18 876.85	18 505.40	18 741.20	18 844.50	18 829.58	18 830.87	18 868.93	18 664.57	18 827.31	18 728.30	18 708.25	19 105.37
	Waste-to-energy	29 480.14	29 451.18	29 458.00	29 452.22	29 447.66	29 439.08	29 455.06	29 437.82	29 445.20	29 450.28	29 452.89	29 442.58
	Non selective total	48 356.99	47 956.58	48 199.20	48 296.72	48 277.24	48 269.95	48 323.99	48 102.39	48 272.51	48 178.58	48 161.14	48 547.95
FKF Zrt.	**Waste total**	**50 128.54**	**49 571.95**	**50 020.01**	**51 044.21**	**51 518.45**	**51 386.79**	**51 672.80**	**51 105.67**	**51 234.57**	**51 564.53**	**51 867.14**	**50 883.40**

31. Table: Waste amount in the detailed structure in Budapest per months in 2008

Source: own contribution from the obtained FKF Zrt. data

Table 31. first includes the amount of the selectively collected waste fractions from waste islands, waste yards and door-to-door collection for the different waste fractions such as paper, plastic, glass and aluminum plus organic waste.

	tons	2008				
	Detailed	January	February	March	April	May
Selective collection - waste islands	Paper and cardboard total	667.45	792.42	893.95	870.53	900.33
Selective collection - waste yards	Mixed paper	29.77	19.54	17.59	18.83	22.40
	Cardboard paper	8.64	9.62	9.55	10.52	11.25
	Paper and cardboard total	41.54	40.91	28.78	35.77	31.72
Selective collection - door-to-door	Paper and cardboard total	3.89	6.89	10.13	14.19	14.65
	Total paper	712.88	840.22	932.86	920.49	946.70

32. Table: Waste amount – paper in Budapest for some months in 2008

Table 32. clearly shows that the waste analysis for paper is limited to mixed paper and cardboard paper, which is separated only in case of the waste yard collection type. In the EASEWASTE model there are several other paper types analyzed in detail (office paper, newspaper etc.) and the composition of them were identified in Budapest also, for the first time, as requested by the author.

	tons	2008				
	Detailed	January	February	March	April	May
Selective collection - waste islands	Plastic total	257.16	247.98	275.90	292.43	312.27
Selective collection - door-to-door	Plastic total	1.83	1.60	1.82	2.04	1.68
Selective collection - waste yards	Plastic total	5.13	4.13	4.02	5.13	4.56
	Total plastic	264.12	253.71	281.74	299.60	318.51

33. Table: Waste amount – plastic in Budapest for some months in 2008

From table 33 it can be seen that the amount of plastic is by far the largest from waste island collection than by the other two collection types. In plastic there are neither measurements nor calculations for the different plastic types such as polyethylene terephthalate (PET), polypropylene (PP) or polystyrene (PS) etc.

	tons	2008				
	Detailed	January	February	March	April	May
Selective collection - waste islands	Colour glass	404.44	230.67	211.87	258.84	241.63
	White glass	266.82	188.17	250.14	317.06	255.75
	Glass total	671.26	418.84	337.14	575.90	497.38
Selective collection - waste yards	Colour glass	5.14	3.40	2.06	5.26	4.46
	White glass	4.81	6.24	3.75	5.20	5.88
	Glass total	9.95	9.64	5.81	10.46	10.34
	Total colour glass	409.58	234.07	213.93	264.10	246.09
	Total white glass	271.63	194.41	253.89	322.26	261.63
	Total glass	681.21	428.48	467.82	586.36	507.72
Selective collection - waste islands	Alu cans total	39.35	31.60	33.71	35.42	40.11
Selective collection - waste yards	Alu cans total	0.00	0.00	2.33	0.00	0.00
Selective collection - door-to-door	Alu cans total	0.59	0.56	0.49	0.65	0.37
	Total alu cans	39.94	32.16	36.53	36.07	40.48

34. Table: Waste amount –glass and aluminum in Budapest for some months in 2008

It must be mentioned that in case of glass, there is no door-to-door collection as it is considered to be a hazard for children. However a large amount of glass can be found in inhabitants' homes, but there is no reward for its collection at the moment. Nearly all of the glass amounts are therefore collected by waste islands. The same condition is relevant for aluminum cans, however, their collection may be decreased due to the fact that HUF 2 can be rewarded at some supermarkets for its collection per can.

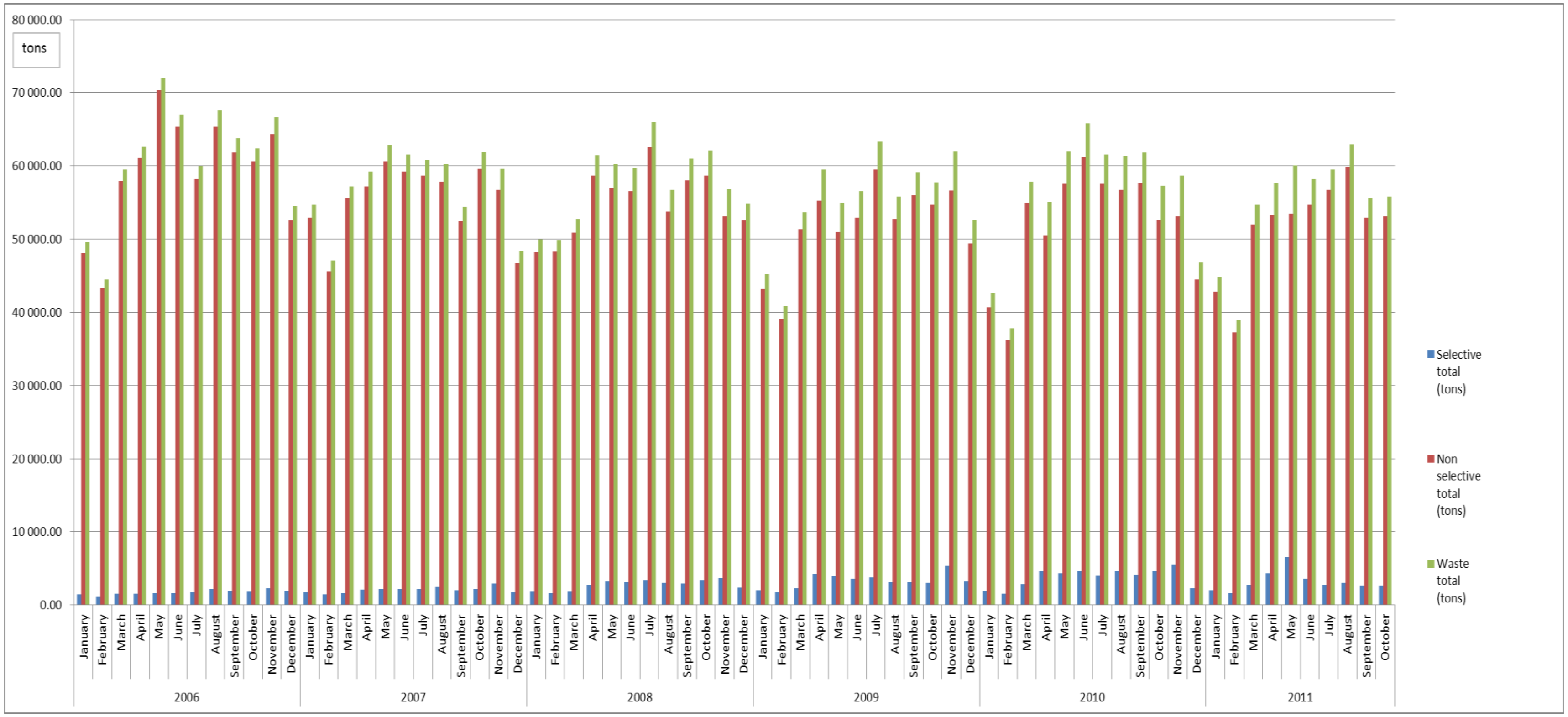
		tons	2008				
		Detailed	January	February	March	April	May
Residual waste from the selective waste collection			133.38	104.42	111.24	105.46	100.90
Recyclable selective waste total			1 698.15	1 554.57	1 718.95	1 842.52	1 813.41
Selective total - waste islands			1 640.29	1 497.11	1 544.45	1 783.69	1 755.06
Selective total - waste yards			78.26	77.89	57.47	81.40	65.03
Selective total - door-to-door			6.31	9.05	12.44	16.88	16.70
Composting			73.40	60.80	101.86	904.97	1 427.80
Selective total			**1 771.55**	**1 615.37**	**1 820.81**	**2 747.49**	**3 241.21**
Disposal		Landfill site	18 876.85	18 505.40	18 741.20	18 844.50	18 829.58
		Waste-to-energy	29 480.14	29 451.18	29 458.00	29 452.22	29 447.66
		Non selective total	48 356.99	47 956.58	48 199.20	48 296.72	48 277.24
FKF Zrt.		**Waste total**	**50 128.54**	**49 571.95**	**50 020.01**	**51 044.21**	**51 518.45**

35. Table: Waste amount – selective total and disposal in Budapest for some months in 2008

It is important to note that there is a small amount of waste which is a residual waste from the selective collection and therefore can not be further processed.

In the year of 2006 this amount was between 2.92% and 4.6%, which shows the proportion of the residual waste compared to the recyclable selective waste (2.92% in January, and the higher amounts were in February, August, November, December). In 2007 the rate was between 3.81% and 7.05% (lower amount in March, April, May and higher rates in October, November). In 2008 this amount was between 4.58% and 7.85% (lower amount in June and December and higher amount in January, February and March). There is no point in analyzing this amount and it can be assumed that the trend is independent from any waste generation. There is no data for the amount of this proportion of waste from 2008. In other years this amount was added to the incinerator as residual waste from the selective waste collection is incinerated.

A table similar to Table 31. was completed for every year between 2006-2011. From this aggregate data the amount of the total, non-selectively collected and selectively collected waste can be concluded for the years of 2006-2011:



34 Figure Total, selective and non-selective waste amount in Budapest 2006-2011

Source: own contribution from the obtained FKF Zrt. data

From this comprehensive graph the following can be concluded:

- the amount of waste is slightly decreasing in general from 2006 (probably due to the economic crisis)
- the amount of the waste is the least in November, December, January, February and the highest in the summer months, due to the changing consumption habits in the winter (Siklóssy pers.comm 2012). Siklóssy also added that there is less money left for the inhabitants in the winter for food consumption and the decreasing waste amount in the winter can be seen in other countries as well (for example in Austria). The high amount of waste in summer months can likely be attributed to the high number of tourists which visit the city.
- the selective waste collection is very low compared to the non-selective waste amount
- the rate of the selective waste is slightly increasing.

In Budapest – as well as in any other city – it is possible to calculate the municipal solid waste generation from three sources:

i. waste from the single family houses
ii. waste from the multi family houses
iii. waste from the small and commercial business units (SCBU)

This is also how the EASEWASTE software requires the input data.

It is important to separate the waste generation per capita into three groups. One of the assumptions of the thesis is that these rates are different. It can be determined by the following mathematical principles:

Equation 1 – Number of total population

$X_1 + X_2 + X_3 = a$

where:

X_i (capita) – population either in single family housing, multi family housing or (number of workers) in the SCBU sector

a – (capita) total number of people relevant in the waste analysis

$_i$is a number, which can be 1,2,3,…

Equation 2 – Amount of waste generated per year

$Y_1 + Y_2 + Y_3 = w$

where:

Y_i (kg) – amount of waste generated per year either in single family housing, multi family housing or in the SCBU sector

w (kg) – amount of total waste generated in the relevant area

$_i$is a number, which can be 1,2,3,…

Equation 3 – Amount of waste per capita

$\lambda_i * Xi = Y_i$

where:

λ_i(kg/capita/year) - amount of waste per person per year

Xi (capita) – population either in single family housing, multi family housing or (number of workers) in the SCBU sector

Y_i (kg) – amount of waste generated per year either in single family housing, multi family housing or in the SCBU sector

Equation 4 – Amount of minimum and maximum values

$l_i \leq \lambda_i \leq u_i$

where:

l_i (kg/capita/year) – minimum value of the amount of waste generated per person

λ_i(kg/capita/year) - amount of waste per person per year

u_i (kg/capita/year) – minimum value of the amount of waste generated per person

$_i$is a number, which can be 1,2,3,…

we are aware that the value of λ_i is between a lower limit as well as an upper limit

Equation 5 – The relative values are not the same

$$\lambda_1 \neq \lambda_2 \neq \lambda_3$$

$$X_1 \neq X_2 \neq X_3$$

$$Y_1 \neq Y_2 \neq Y_3$$

It is known that these values can not be the same as it is evident, that a person in the multi level housing, single level housing or in the commercial sector generates different amount of waste.

From these values the easiest is to estimate λ_i as this value can be estimated with data from our personal house structure.

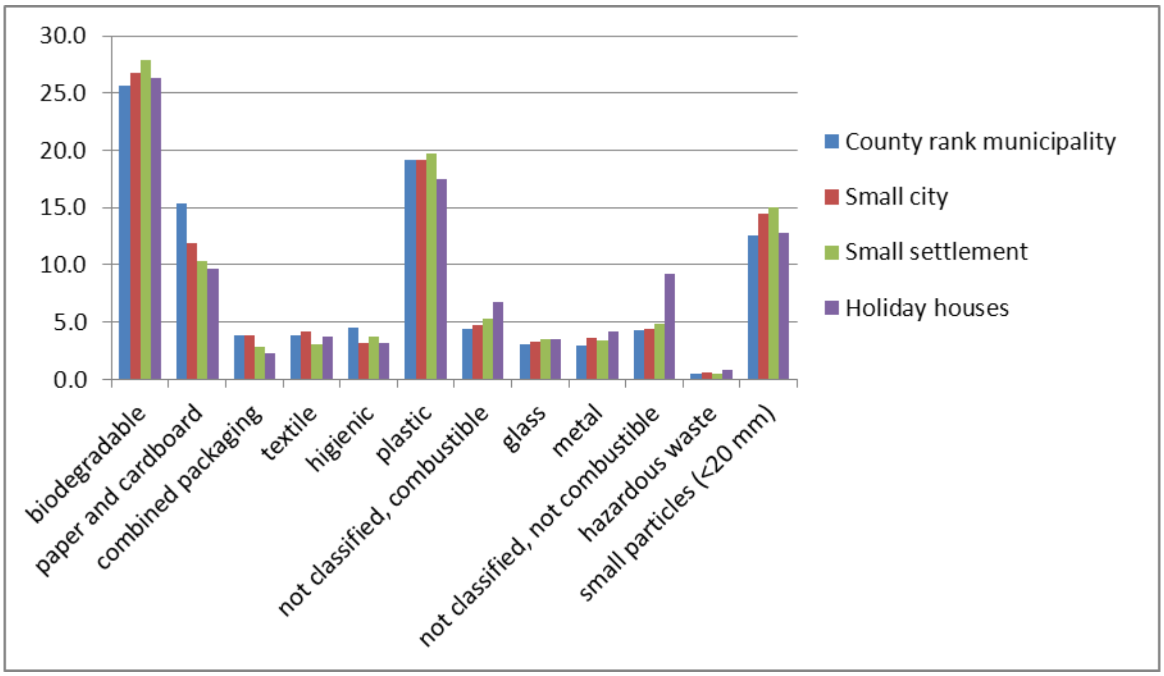
Even in the model the value of λ_i is the same for single family housing, multi family housing and SCBU, but it is found that this value is different in these three cases.

Uncertainty factor: we do not have exact data on the waste generation in these three sectors, only empirical data can be used. Therefore it was necessary to use the data which was given for calculation, as these three groups have the same waste generation rate, a process which can be utilized in this format in the EASEWASTE model default datasets.

8.3 Waste composition in Budapest

Waste composition is one of the most important parameters which influence the environmental performance of the waste management sector and therefore particular attention is needed to ensure the accuracy of proper data.

The average waste composition in Budapest is discussed in this chapter based on data received from FKF Zrt. These numbers were compared with the composition of the different city types in Hungary and are presented in Figure 35.



35. Figure Average composition of the different city types in Hungary, 2008, (%)

Source: constructed based on FKF Zrt. laboratory data

From the above figure it can observed that average waste composition does not significantly differ between the county rank municipality, small cities and small settlements. This rate was different in the last decades as the waste composition in the villages and the bigger cities was significantly different, however, by today – mostly due to the increased amount of packaging waste – the waste composition is roughly the same (Koltaine 2009. pers.comm.).

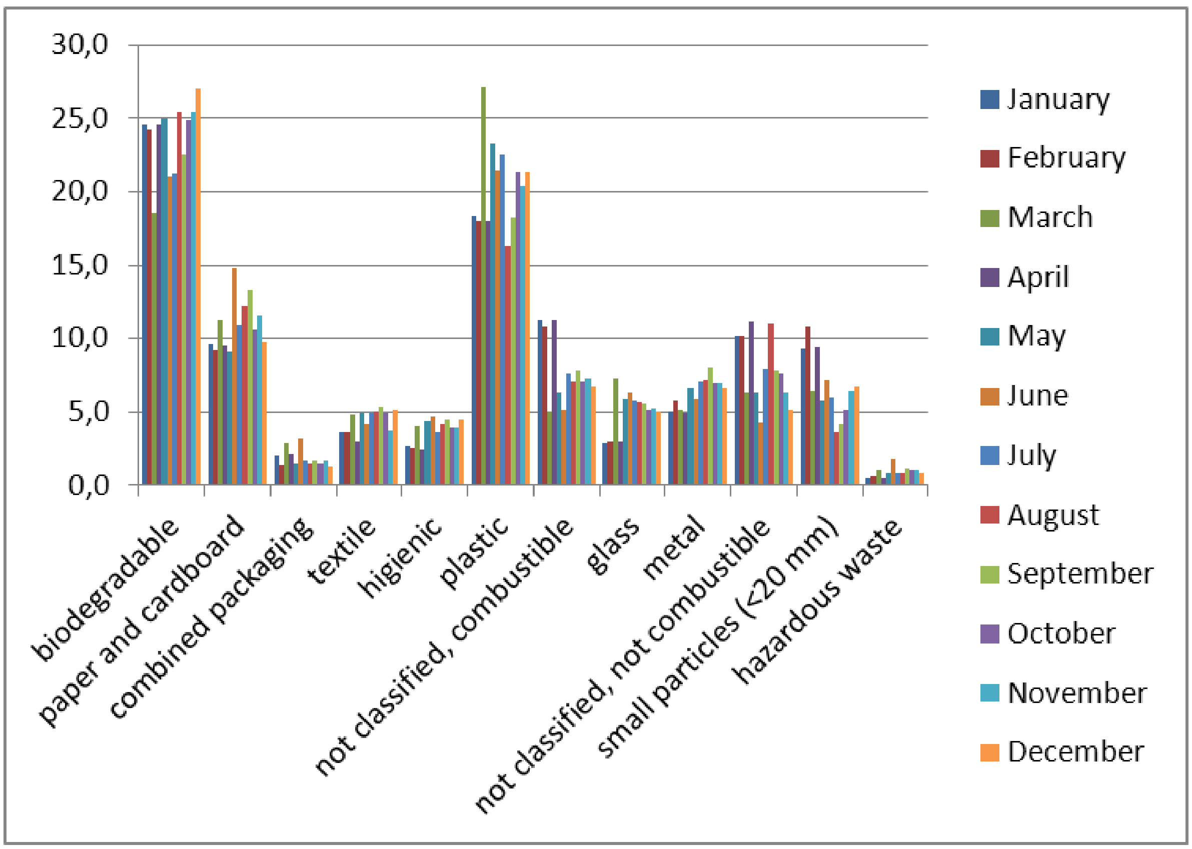
In Budapest the waste composition is checked regularly by the city's own environmental analytical laboratory of FKF Zrt. which has analyzed the waste composition according to the regulations for more than 20 years. According to the MSZ 21420-28 and the MSZ 21420-29 standards the waste must be analyzed daily, quarterly and once a year (generally around October) a detailed analysis must be made. The main categories are the following (Magyar Szabványügyi Testület 2005a and 2005b):

- Biodegradable waste,
- Paper,
- Cardboard,
- Composites,
- Textiles,
- Hygienic waste,
- Plastic,
- Other combustible waste,
- Glass,
- Metal,

- Other non-combustible waste,
- Hazardous waste,
- Small particles waste < 20 mm.

All of these main categories have sub-categories as well, and by request the packaging waste as well as the halogen content of the plastic going to incinerator are analyzed.

For the Budapest waste composition some remarkable data for the different months of the years for 2006-2010 was received. Therefore it was possible to show the waste composition by waste types as well as by months in the different years. We considered 2008 as a base year, and the figures for this year are presented in Figure 36.



36. Figure Waste composition of Budapest by waste types, 2008 (%)

Source: constructed based on FKF Zrt. laboratory data

It can be stated that the amount of waste is less in the winter and bigger amount in the summer. According to the data from 2008 and 2011, it can be declared that in recent years the amount of waste has become smaller than before the economic crisis.

However the waste types and waste categories are different what was required within the EASEWASTE model. As a consequence, the leader of the environmental laboratory, Gábor Király was asked to make estimation for the waste compositions of the 48 waste types what are represented in the model and therefore for block of flats, inner city and family houses was formulated. The inner city can be regarded as SCBU, as it represents the V, VI, VII, XIII districts where the institutions and the small businesses are, while the block of flats can be regarded as multi family houses and the family houses can be regarded as single family houses.

	Mixed waste (%)	2011. SCBU	2011. multi family houses	2011. single family houses	2010. multi family houses	2010. single family houses	2009. multi family houses	2009. single family houses	2008. multi family houses	2008. single family houses
1	Vegetable food waste	13,71	16,35	4,89	14,36	6,13	15,12	8,97	15,46	10,68
2	Animal food waste	0,52	1,81	0,93	2,04	0,80	0,96	1,05	0,45	0,86
3	Newsprints	2,62	1,39	2	4,63	2,70	1,48	3,86	4,26	3,24
4	Magazines	1,98	1,67	1,41	3,51	0,51	1,97	1,19	0,86	1,79
5	Advertisements	3,13	4,26	6,39	2,13	3,15	3,86	1,71	1,78	1,28
6	Books and phonebooks	3,23	2,29	0,45	0,87	0,74	2,39	0,54	0,86	0,78
7	Office paper	5,69	2,86	1,27	2,22	1,62	1,65	0,86	1,23	1,90
8	Other clean paper	0,06	1,47	0,19	2,48	0,78	0,96	0,73	0,59	1,52
9	Paper and cardboard containers	3,65	4,84	0,26	4,28	1,67	5,68	4,76	6,58	2,70
10	Other clean cardboard	2,52	0,41	2,02	0,86	1,15	1,14	0,37	0,25	0,35
11	Milk cartons (carton/plastic)	1,01	0,61	1,80	0,75	2,67	1,12	2,57	2,35	1,88
12	Juice cartons (carton/plastic/aluminium)	0,26	2,22	3,69	2,66	2,86	3,11	0,17	2,30	2,46
13	Kitchen towels	5,69	1,15	2,38	0,14	0,12	0,68	0,14	0,36	0,12
14	Dirty paper	0,06	0,41	1,11	0,24	0,69	0,78	0,47	0,48	0,54
15	Dirty cardboard	0,10	0,11	1,00	0,70	0,39	0,47	0,48	0,55	0,87
16	Soft plastic	6,04	4,81	6,44	3,64	5,57	4,44	2,69	3,61	4,06
17	Plastic bottles	2,64	5,33	3,20	5,92	4,12	4,96	7,59	2,85	6,56
18	Hard plastic	1,45	2,61	0,70	1,11	1,11	3,12	1,91	2,97	2,64
19	Non recyclable plastic	0,38	0,82	0,67	0,54	0,47	1,12	0,28	0,53	0,57
20	Yard waste, flowers	13,81	4,17	17,68	4,92	19,86	5,04	10,20	5,68	11,68
21	Animal excrements and bedding (straw)	0,44	0,00	1,82	0,15	0,15	0,00	0,97	0,86	0,99
22	Diapers, sanitary towels, tampons	0,63	3,12	3,89	3,13	4,38	2,96	4,13	3,82	3,08
23	Cotton, bandages	0,00	0,41	0,13	0,66	0,18	0,36	0,05	0,16	0,27
24	Disposable sanitary products (cloths, gloves)	0,00	0,32	0,10	0,28	0,03	0,18	0,14	0,04	0,28
25	Wood	0,59	3,36	0,15	3,51	1,57	2,68	1,88	1,70	1,67
26	Textiles	1,94	6,84	2,65	3,18	2,61	4,56	4,06	3,52	2,74
27	Shoes, leather	0,53	2,89	1,19	2,86	2,81	2,05	0,73	1,05	0,98
28	Rubber	0,00	0,73	0,2	1,03	1,15	1,11	0,91	0,96	0,86
29	Plastic products (toys, hangers, pen)	0,06	1,12	3,26	4,36	2,76	2,65	1,85	3,11	2,75
30	Cigarette butts	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
31	Other combustibles	0,69	3,22	2,00	0,87	2,11	1,57	0,75	0,91	0,26
32	Vacuum cleaner bags	0,16	0,1	0	0,00	0,00	0	0,11	0	0,00
33	Clear glass	1,13	1,71	1,88	2,32	2,55	2,15	2,98	2,02	0,45
34	Green glass	0,63	2,48	0,14	0,54	1,00	2,37	1,02	0,87	2,01
35	Brown glass	0,00	0,22	0,57	0,68	0,54	1,12	1,35	1,11	0,37
36	Non-recyclable glass	0,06	0,00	0,64	0,66	0,04	1,05	0,82	0,12	0,43
37	Beverage cans (aluminium)	0,34	1,09	1,48	1,74	1,86	1,35	1,30	0,84	0,97
38	Aluminium foil and containers	0,06	0,16	0,00	0,20	0,14	0,21	1,16	0,09	0,20
39	Food cans (tinplate/steel)	0,59	0,66	0,70	1,11	3,65	0,89	0,18	0,77	1,07
40	Plastic coated aluminium foil	0,00	0,22	0,32	0,47	0,21	0,12	0,58	0,12	0,24
41	Other metals	0,00	2,11	0,95	1,41	0,94	2,38	0,78	1,63	2,15
42	Soil	1,27	0,68	2,12	0,00	0,54	0,89	2,37	0,65	1,68
43	Stones, concrete	0,61	0,00	4,95	4,22	1,86	0,56	4,32	2,28	1,24
44	Ash	0,00	0,00	0	0,00	0,00	0,00	0,00	0,00	0,19
45	Ceramics	0,57	3,62	1,01	1,14	2,56	2,15	2,47	0,68	1,98
46	Cat litter	0,24	0,32	2,62	0,41	0,03	0,11	0,07	0,41	0,06
47	Batteries	0,24	0,16	0,10	0,20	0,13	0,24	0,79	0,14	0,84
48	Other non combustibles	20,69	4,89	8,65	6,87	9,08	6,24	13,69	18,12	15,77

36. Table Waste composition in Budapest for multi family, single family and SCBU

Source: FKF Zrt. environmental laboratory by request of author

These calculations have never been made in Budapest and neither in Hungary. This unique waste composition was made as a request of the author for this dissertation by the FKF Zrt. environmental laboratory. Not only the waste composition for 48 categories was made for the first time but also separated collection routes were established for the waste collection from the block of flats, garden area and downtown area. Last year's waste compositions were estimated by the author according to the former measures and interpolations.

8.4 Selective waste collection

In Budapest the rate of the selective waste collection is rather low, but from mid 2013 it will be highly increased, as FKF Zrt. received HUF 4 billion EU co-financing for the gradually increase of the door-to-door selective waste collection.

In Budapest the selective waste types are collected in three ways:

- waste collection islands
- waste yards and
- door-to-door collection.

Waste collection islands

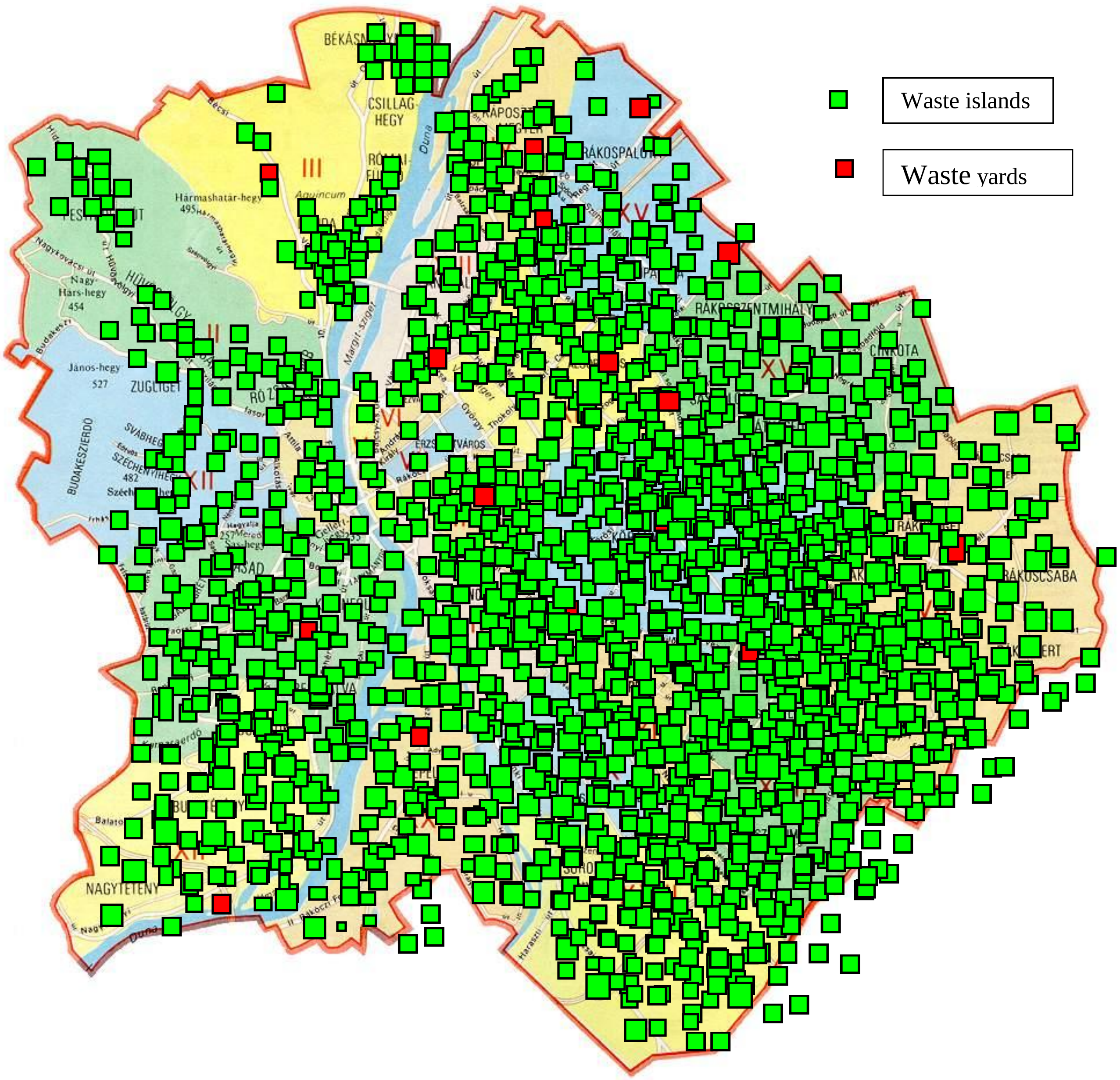
The waste collection islands can be found in the street, these are containers in which you can drop your (paper, plastic, aluminum cans and glass) waste. You can find the exact location of the selective waste collection islands on the FKF Zrt. website and based on this list a map was prepared, which is presented in Appendix 8. According to this list, there are 940 waste islands in Budapest. From these 933 are inside Budapest and 7 near Auchan or TESCO supermarkets nearby. This list divides the waste islands per districts and it is obvious that the most waste islands can be found in district XIV. (69 waste islands), XXI.(67 waste islands), XXII. (66), X. (62), III. (59), XV. (56), XX. (54) which are in the outskirts of Budapest. A smaller amount of waste islands are located in the downtown, such as district VII. (2), V. (4), VI. (5) and I. (12 respectively). The numbers of waste islands in districts VI. and VII. are remarkably low.

Waste yards

Waste yards are guarded areas which are covered with fence. In these facilities you can get rid of your waste, including selective waste types as well as hazardous waste, construction and demolition waste, tires, garden waste and electronic waste. There are 16 waste yards in Budapest, the latest one was opened on 5 July 2012. in Nagytétény, South Buda. This latest waste yard is the most sophisticated of all existing sites.

1. Picture Nagytétény waste yard

In Budapest the first waste yard opened in 2001, the collection with the waste islands started in 2004, whereas the door-to-door collection began in 2006. (Klug 2012 pers.comm.)



37. Figure Location of waste islands and waste yards in Budapest

Source: own contribution based on FKF Zrt. databases

From this map it can be clearly seen that there are locations which are fully covered by waste islands (main streets, traffic junctions, around institutions etc.), however there are locations where the number of the waste collections islands are quite sparse (for instance in III. district, North Buda). It is important to comment that during the display of the locations of the waste islands and waste yards, there were some streets which was indicated in the list, but was not indicated in Budapest map (http://www.budapest-geo.hu/budapest_t%C3%A9rk%C3%A9p) such as Tulipánkert utca in district IV were not found at all. The identification of the locations sometimes are not clear for instance it says: district V. Mayor's Office without the exact street. It can be observed in district VIII. as well where it says: Ciprus utca, új társasházzal szemben which means: opposite the new block of flats. Author realized that in the FKF Zrt. list the districts X., XI., and XII. are in the same block without any break after X. district. After these large blocks the XI. district and the XII. district lists are repeated again, which is confusing.

The map shows that waste islands are generally spreaded throughout Budapest, and the location of them is rare in the mountains in the Buda hills, as the collection would be difficult in these locations, but in the Pest side it is spreaded evenly.

Taking into consideration the waste yards, it can be seen that from the 16 waste yards only 3 are located in Buda, while the others are in Pest side. In the IV and in the XV districts there are two waste yards, so there are some districts which do not possess these waste facilities.

This map is only a draft version of a more detailed, digital waste map of Budapest that will be prepared by FKF Zrt. in the future.

Door-to-door collection

This type of waste collection started in 2006. in some districts and is operating at the moment in 4 districts, with the following number if addresses: district V. 391 addresses, district VII. 883 addresses, district XI. 900 addresses and for district XIII. 386 houses are participating. (Klug pers.comm. 2012) From 1 January 2013. after gradual increase, it will cover the whole capital. This is the most efficient selective waste collection type. The collected amounts were the following: 2006: 103,5 t, 2007: 94,2 t, 2008: 315,3 t, 2009: 700 t, 2010: 934 t and 2011: 1011 tons.

From Table 33., which includes all the necessary data for the model structure for 2008 it can be seen that from these three types of selective waste collection the highest amount of waste comes from the waste islands, waste yards and then from the door-to-door collection. The differences in these amounts for 2008 and 2010 displayed below:

	2008 (tons)	**2010 (tons)**
Waste islands		
Paper	10679,69	11660,89
Plastic	3626,94	4017,29
Glass	5759,03	5756,72
Aluminum cans	426,01	362,37
Waste yards		
Paper	455,25	337,75
Plastic	69,78	74,8
Glass	102,71	109,84
Aluminum cans	7,74	9,42
Door-to-door		
Paper	220,07	688,08

Plastic	22,59	223,34
Aluminum cans	5,69	22,41

37. Table Amount of the selectively collected waste by collection methods 2008 and 2010

Source: own contribution based FKF Zrt. data

In the door-to-door collection system there is no glass collection, it may be dangerous for small children. It must be mentioned that in 2010 a new category – "collection from other inhabitant system" - was introduced, which was not measured and calculated in 2008.

The waste amounts from this type of collection are the following for three waste types:

Paper: 498,61

Plastic: 83,319

Glass: 388,11

This waste collection system represents collection from business offices, institutional or junk waste, and can be counted within the waste island collection system statistics. .

It is of note to mention that after selective waste collection there is always a residual waste which remains from the selective waste collection, which was 1251 tons in 2008, which is 6.06%.

From the comparison table we can state the following:

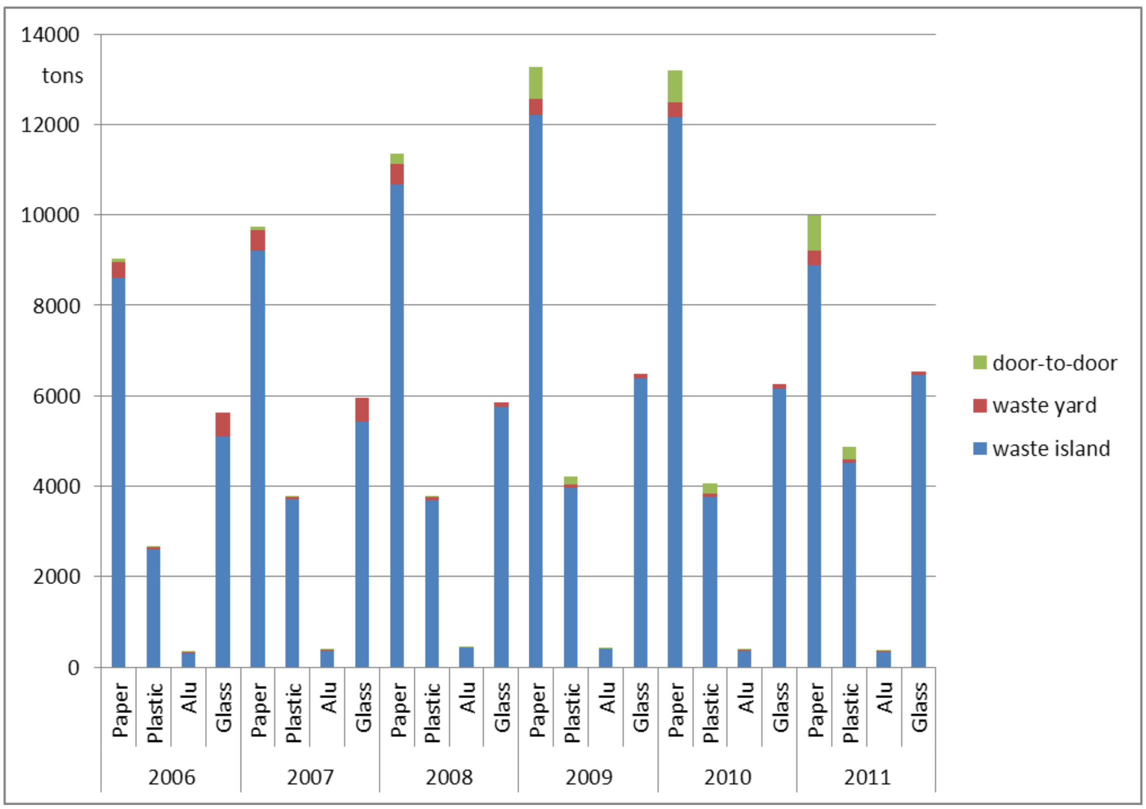
- the selective waste collection in the waste islands and in the waste yards generally has not increased significantly
- the amount of the aluminum cans from the waste islands is decreasing. The reason is accepted to be related to the fact that people can rewarded by HUF 2 per aluminum cans at some supermarkets.
- door-to-door collection is increasing considerably.

Comparison of the collected amount by these three methods

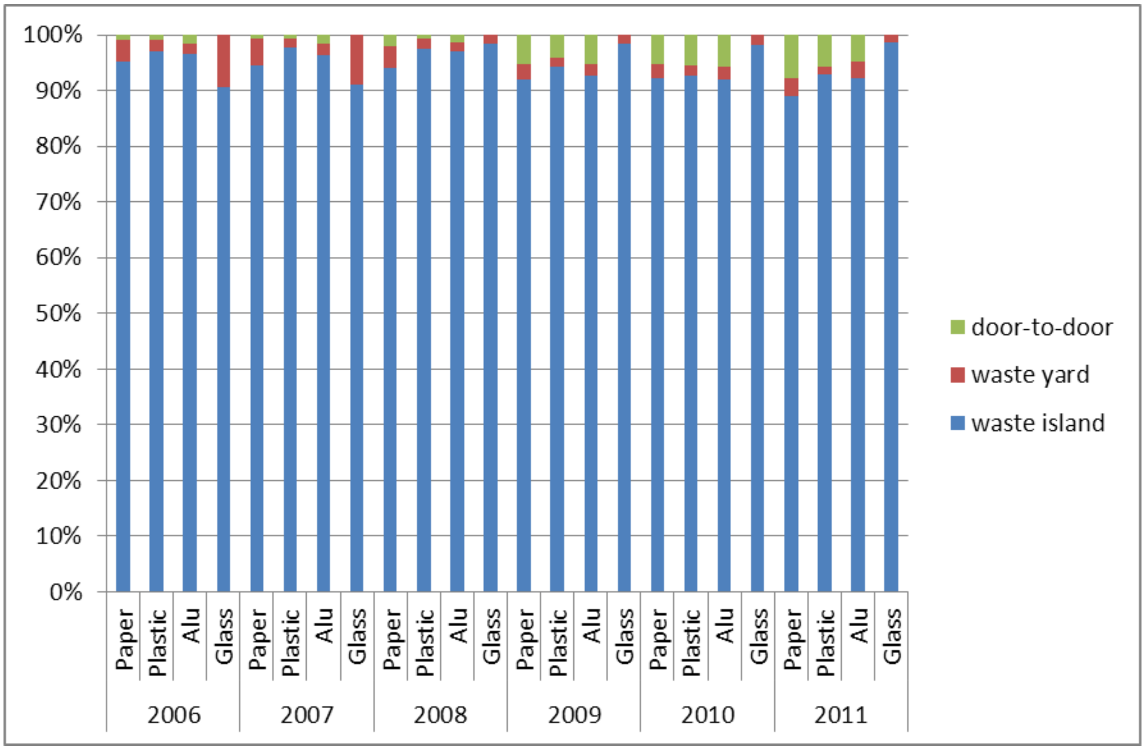
If the waste islands, waste yards and door-to-door collection system are compared to the collected recyclable waste the following table can be created:

	2006				2007				2008			
	Paper	Plastic	Alu	Glass	Paper	Plastic	Alu	Glass	Paper	Plastic	Alu	Glass
waste island	8591,49	2589,07	315,04	5102,78	9212,43	3696,6	362,88	5435,28	10679,7	3684,86	426,01	5759,03
waste yard	364,6	55,97	5,74	523,228	458,15	64,008	7,93	527,12	455,25	69,78	7,74	92,76
door-to-door	71,24	21,33	5,52		65,96	22,59	5,69		220,07	22,59	5,69	
	2009				2010				2011			
	Paper	Plastic	Alu	Glass	Paper	Plastic	Alu	Glass	Paper	Plastic	Alu	Glass
waste island	12213,9	3962,99	404,66	6380,9	12159,5	3768,18	362,37	6144,83	8883,62	4516,23	340,62	6454,13
waste yard	349,2	73,77	9,41	108,07	337,75	74,8	9,42	109,84	327,888	78,132	10,236	93,384
door-to-door	705,72	168,66	22,65		688,08	223,34	22,41		769,404	272,484	18,048	

38. Table Amount of the collected recyclable waste (tons)



38. Figure Amount of the recyclable waste by the different methods (tons)



39. Figure Rate of the three types of selective waste collection by years per waste types

Figure 38. and 39. displays that the most of the waste is collected in waste islands, while the amount of the collected recyclable waste by waste yards and door-to-door collection is relatively low. Door-to-door collection is increasing in case of paper and plastic and aluminum cans, while glass is not collected in the door-to-door system. This is also a strong reason why the door-to-door collection must be increased in the future, as presently this collection method is very low.

It must be stated than in Budapest (and presumably in the whole country) some supermarkets take back aluminum cans and PET bottles in exchange for HUF. At the moment in Hungary TESCO and LIDL use this type of collection and recycling scheme, and they give HUF 2 for each aluminum can and HUF 1 for each PET bottle. The amounts are printed on a receipt when the waste is deposited and the inhabitant can use this receipt to make shopping purchases.

2. Picture Collection scheme of aluminum can and PET bottles at supermarkets

This collection method is very efficient for the supermarket as they receive clean recyclable waste while lowering the burden of the public service provider. This is a very good incentive for the inhabitants, and although they do not receive high amount but this amount is also a value which can be used while shopping. However it is a common result in many cases the aluminum cans and PET bottles returned have been stolen from the waste islands and transported here for low amount of money. This “alternative recycling” method exists in high rate in other countries and also in the US.

Comparison of the selectively collected and non-selectively collected recyclable waste

From calculations it can be seen that a significant amount of recyclable waste (paper, plastic, glass and aluminum cans) can be found in the mixed waste, which eventually becomes landfilled or incinerated.

From the comparison of the selectively collected and not selectively collected waste we can determine the amount of the waste types which can be further recycled. This is the amount of the selectively collected waste type (e.g. paper) plus the amount of the waste type (e.g. paper) in the mixed waste. However, according to experiences 100 % percent recycling is not possible, but there is still too much potentially useful waste which is disposed of in the landfill or by thermal treatment.

The potentially recyclable waste can be calculated with the following equations (the equation is for paper, obviously the similar for the other waste types):

Equation:

$$P_{wa} = \frac{P\ total}{W\ total} x\ 100$$

Where:

P_{wa} – rate of the paper waste in the total waste

P_{total} – Paper total= Paper selective+ Paper not selective

Paper selective = given number (waste islands + waste yards + selective routes)

Paper not selective = (P (%) total selective x Waste total)/100

W_{total} = Waste total = Waste selective total + Waste non selective total

The head of the environmental laboratory of FKF Zrt., Gábor Király determined the waste composition for the 48 waste categories in the mixed waste. Therefore it would be useful to calculate how much recyclable waste fraction can be still found in the waste which is being disposed of. It was calculated for every year taking into account that the base year is 2008. So for instance from plastic, the plastic toys or non-recyclable plastic could also be used, but these waste types are not collected and separated selectively in Hungary, and accordingly included in calculations and not incorporated in the model until it is collected and recycled in the future. By using the calculation method results for the 48 waste fractions it was desired to calculate the maximum potentially recyclable waste fractions. Because of this for instance, non-recyclable plastic can not be included. It is very important that this amount includes not only the selectively collected waste type (e.g. paper) but also the non-selectively collected waste types as well. This is why the potentially recyclable paper rate is much higher than around 1.64 %, which is only the selectively collected paper in 2008. This thesis includes a comparison of the amount of the potentially recyclable waste types in 2008 and 2011.

2008

Paper

For paper the following 8 waste categories can be calculated in the 48 waste types and applied in the model:

- No. 3. – newsprints,
- No. 4. – magazines
- No.5. - advertisements
- No.6. – books and phone books
- No.7. – office paper,
- No.8. – other clean paper,

- No.9. – paper and cardboard containers,
- No.10. – other clean cardboard

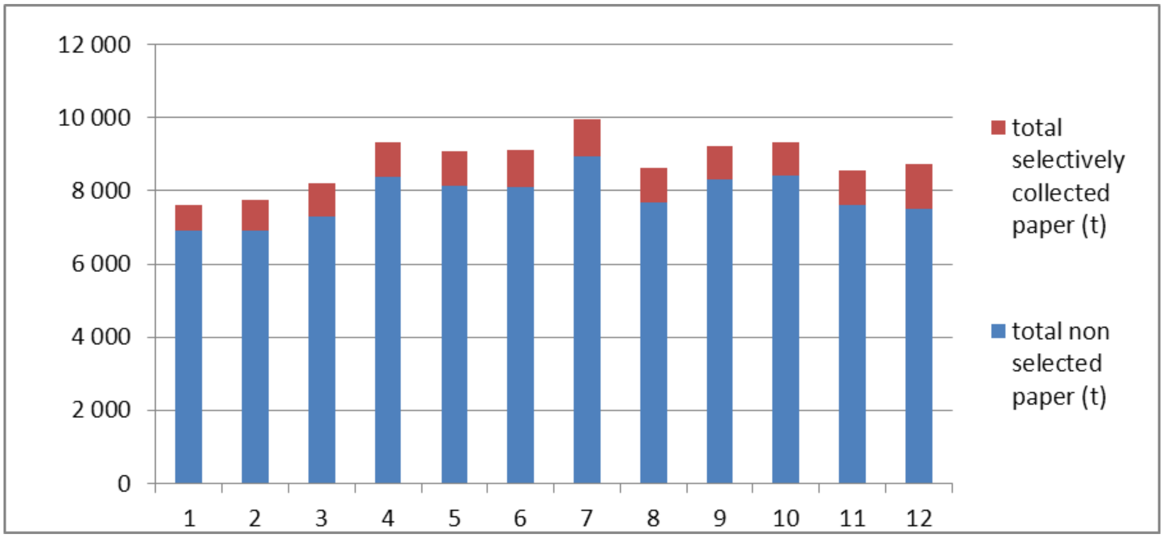
The amounts of the numbers in % related to these waste types in the 48 categories are: 12.98% in SCBU, 16.41% in the multi family houses and 13.55% in the single family houses and the average of them is 14.31%. Therefore 14.31% paper was calculated in the mixed waste.

The numbers for the calculation are as follows:

	2008 Jan	Febr	March	Apr	May	June
Paper						
paper in the mixed waste, %	14.31	14.31	14.31	14.31	14.31	14.31
total non selective waste	48 207.04	48 272.84	50 896.26	58 701.54	56 980.33	56 548.67
total non selected paper	6 898.43	6 907.84	7 283.25	8 400.19	8 153.89	8 092.11
total selectively collected paper	712.88	840.22	932.86	920.49	946.70	1 029.58
total paper	7 611.31	7 748.06	8 216.11	9 320.68	9 100.59	9 121.69
total recyclable selectively collected waste	1 698.15	1 554.57	1 718.95	1 842.52	1 813.41	1 868.16
total waste	49 995.16	49 905.15	52 729.85	61 469.66	60 234.98	59 681.11
	July	Aug	Sept	Oct	Nov	Dec
Paper						
paper in the mixed waste, %	14.31	14.31	14.31	14.31	14.31	14.31
total non selective waste	62 614.84	53 723.89	58 009.17	58 720.00	53 105.44	52 536.17
total non selected paper	8 960.18	7 687.89	8 301.11	8 402.83	7 599.39	7 517.93
total selectively collected paper	994.78	933.02	939.46	933.51	953.00	1 218.51
total paper	9 954.96	8 620.91	9 240.57	9 336.34	8 552.39	8 736.44
total recyclable selectively collected waste	1 920.27	1 719.68	1 822.89	1 723.11	1 727.30	2 091.36
total waste	65 983.39	56 744.99	60 991.78	62 126.77	56 829.15	54 894.73

39. Table Amount of the selectively and non-selectively collected paper, 2008 by months, (tons)

According to these numbers the rate of the selectively collected paper and the amount of paper in the mixed waste can be seen in the following graph:



40. Figure Graph of the selectively and non-selectively collected paper, 2008 by months, (tons)

Plastic

For plastic the following waste category can be calculated in the 48 waste types and applied in the model:

- No. 17. – plastic bottles

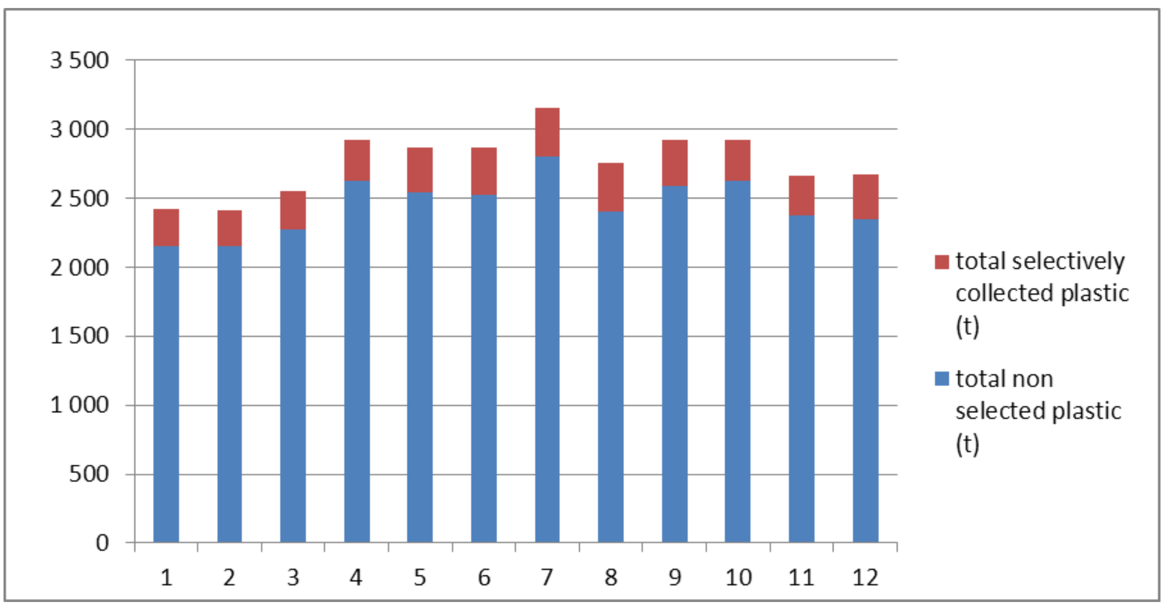
The amount of the numbers in % related to these waste types in the 48 categories is: 4.01% in SCBU, 2.85% in the multi family houses and 6.56% in the single family houses and the average of them is 4.47%. Therefore it was calculated to be 4.47% plastic in mixed waste.

The basic numbers required for the calculation are as follows:

	2008 Jan	Febr	March	Apr	May	June
Plastic						
plastic in the mixed waste, %	4.47	4.47	4.47	4.47	4.47	4.47
total non selective waste	48 207.04	48 272.84	50 896.26	58 701.54	56 980.33	56 548.67
total non selected plastic	2 154.85	2 157.80	2 275.06	2 623.96	2 547.02	2 527.73
total selectively collected plastic	264.12	253.71	281.74	299.60	318.51	344.68
total plastic	2 418.97	2 411.51	2 556.80	2 923.56	2 865.53	2 872.41
total recyclable selectively collected waste	1 698.15	1 554.57	1 718.95	1 842.52	1 813.41	1 868.16
total waste	49 995.16	49 905.15	52 729.85	61 469.66	60 234.98	59 681.11
	July	Aug	Sept	Oct	Nov	Dec
Plastic						
plastic in the mixed waste, %	4.47	4.47	4.47	4.47	4.47	4.47
total non selective waste	62 614.84	53 723.89	58 009.17	58 720.00	53 105.44	52 536.17
total non selected plastic	2 798.88	2 401.46	2 593.01	2 624.78	2 373.81	2 348.37
total selectively collected plastic	357.19	352.29	329.53	303.59	293.60	320.75
total plastic	3 156.07	2 753.75	2 922.54	2 928.37	2 667.41	2 669.12
total recyclable selectively collected waste	1 920.27	1 719.68	1 822.89	1 723.11	1 727.30	2 091.36
total waste	65 983.39	56 744.99	60 991.78	62 126.77	56 829.15	54 894.73

40. Table Amount of the selectively and non-selectively collected plastic, 2008 by months, (tons)

According to these numbers the rate of the selectively collected plastic and the amount of plastic in the mixed waste can be seen in the following graph:



41. Figure Graph of the selectively and non-selectively collected plastic, 2008 by months, (tons)

Source: own contribution based on FKF data

Aluminum

For aluminum the following waste category can be calculated in the 48 waste types and applied in the model:

- No. 37. – beverage cans (aluminum),

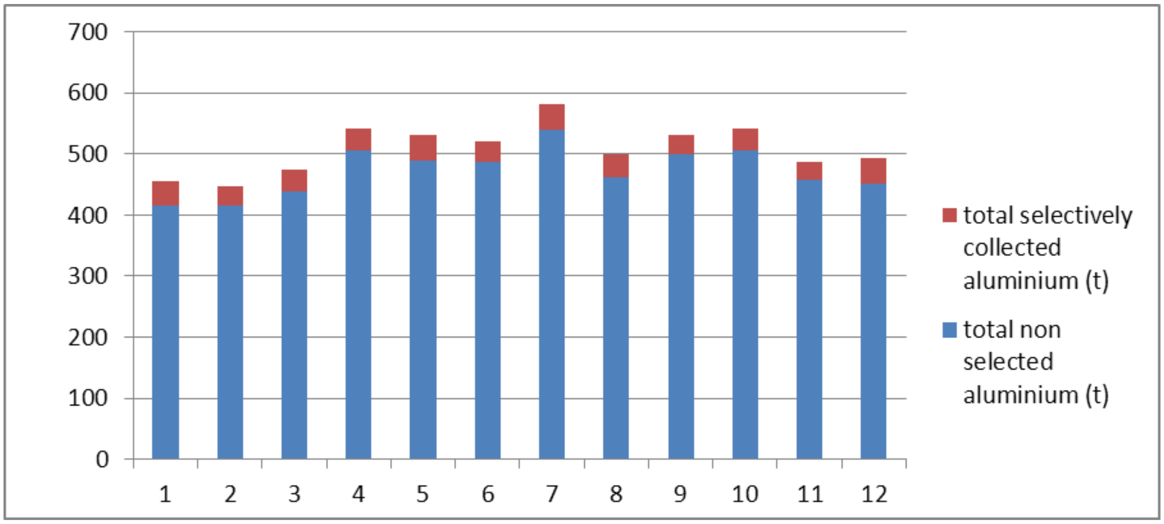
The amount of the numbers in % related to these waste types in the 48 categories is: 0.8% in SCBU, 0.84% in the multi family houses and 0.97% in the single family houses and the average of them is 0.86%. Therefore it was determined that 0.86% aluminum can be found in mixed waste.

The remaining numbers are as follows:

	2008 Jan	Febr	March	Apr	May	June
Aluminium						
aluminium in the mixed waste, %	0.86	0.86	0.86	0.86	0.86	0.86
total non selective waste	48 207.04	48 272.84	50 896.26	58 701.54	56 980.33	56 548.67
total non selected aluminium	414.58	415.15	437.71	504.83	490.03	486.32
total selectively collected aluminium	39.94	32.16	36.53	36.07	40.48	33.64
aluminium total	454.52	447.31	474.24	540.90	530.51	519.96
total recyclable selectively collected waste	1 698.15	1 554.57	1 718.95	1 842.52	1 813.41	1 868.16
total waste	49 995.16	49 905.15	52 729.85	61 469.66	60 234.98	59 681.11
	July	Aug	Sept	Oct	Nov	Dec
Aluminium						
aluminium in the mixed waste, %	0.86	0.86	0.86	0.86	0.86	0.86
total non selective waste	62 614.84	53 723.89	58 009.17	58 720.00	53 105.44	52 536.17
total non selected aluminium	538.49	462.03	498.88	504.99	456.71	451.81
total selectively collected aluminium	43.62	36.80	31.13	36.52	30.71	41.84
aluminium total	582.11	498.83	530.01	541.51	487.42	493.65
total recyclable selectively collected waste	1 920.27	1 719.68	1 822.89	1 723.11	1 727.30	2 091.36
total waste	65 983.39	56 744.99	60 991.78	62 126.77	56 829.15	54 894.73

41. Table Amount of the selectively and non-selectively collected aluminum, 2008 by months, (tons)

According to these numbers the rate of the selectively collected aluminum and the amount of aluminum in mixed waste can be determined and is presented in the following graph:



42. Figure Graph of the selectively and non-selectively collected aluminum, 2008 by months, (tons)
Source: own contribution based on FKF data

Glass

For glass the following waste categories can be calculated in the 48 waste types and applied in the model:

- No. 33. – clear glass,
- No. 34. – green glass
- No. 35. – brown glass

The amount in % related to these waste types in the 48 categories is: 4.97% in SCBU, 4.01% in the multi family houses and 2.84% in the single family houses and the average of them is 3.94%. Therefore it was calculated that 3.94% glass is contained in mixed waste.

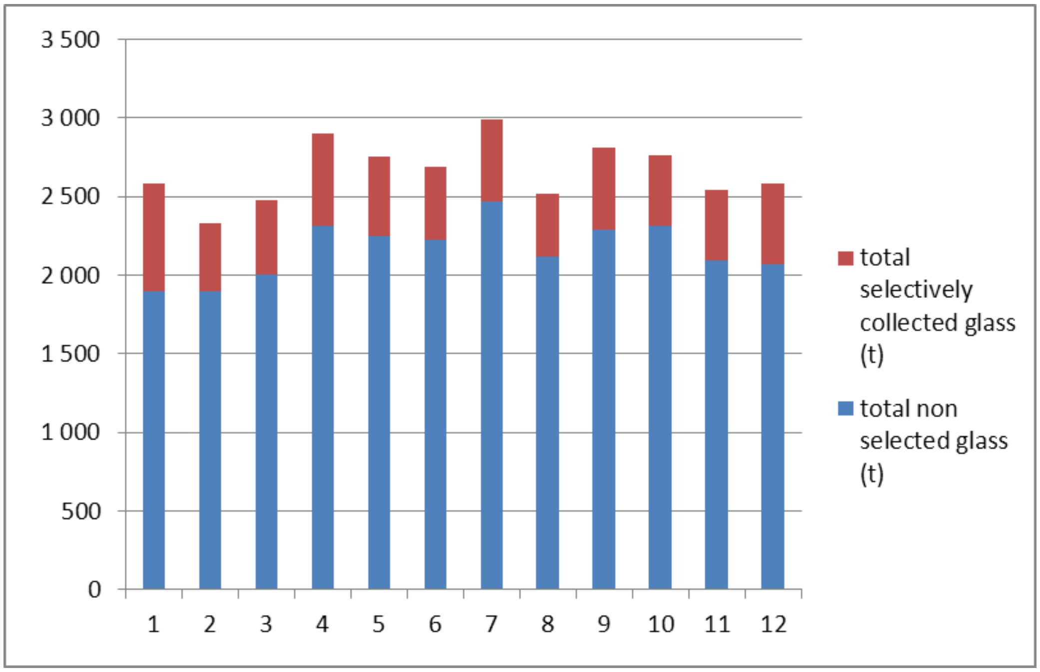
The remaining numbers are as follows:

	2008 Jan	Febr	March	Apr	May	June
Glass						
glass in the mixed waste, %	3.94	3.94	3.94	3.94	3.94	3.94
total non selective waste	48 207.04	48 272.84	50 896.26	58 701.54	56 980.33	56 548.67
total non selected glass	1 899.36	1 901.95	2 005.31	2 312.84	2 245.03	2 228.02
total selectively collected glass	681.21	428.48	467.82	586.36	507.72	460.26
total glass	2 580.57	2 330.43	2 473.13	2 899.20	2 752.75	2 688.28
total recyclable selectively collected waste	1 698.15	1 554.57	1 718.95	1 842.52	1 813.41	1 868.16
total waste	49 995.16	49 905.15	52 729.85	61 469.66	60 234.98	59 681.11
	July	Aug	Sept	Oct	Nov	Dec
Glass						
glass in the mixed waste, %	3.94	3.94	3.94	3.94	3.94	3.94
total non selective waste	62 614.84	53 723.89	58 009.17	58 720.00	53 105.44	52 536.17
total non selected glass	2 467.02	2 116.72	2 285.56	2 313.57	2 092.35	2 069.93
total selectively collected glass	524.68	397.57	522.77	449.49	449.99	510.26
total glass	2 991.70	2 514.29	2 808.33	2 763.06	2 542.34	2 580.19
total recyclable selectively collected waste	1 920.27	1 719.68	1 822.89	1 723.11	1 727.30	2 091.36
total waste	65 983.39	56 744.99	60 991.78	62 126.77	56 829.15	54 894.73

42 Table Amount of the selectively and non-selectively collected glass, 2008 by months, (tons)

Source: own contribution based on FKF data

According to these numbers the rate of the selectively collected glass and the amount of glass in the mixed waste can be calculated and is featured in the following graph:



43. Figure Graph of the selectively and non-selectively collected glass, 2008 by months, (tons)

2011

Regarding the data for the year 2011 it must be mentioned that in spite of several oral and written requests the data for November and December 2011 were not provided throughout the course of this research project.

The same waste types were included here as well, and according to the calculations, mentioned above, the numbers and the graphs are the following:

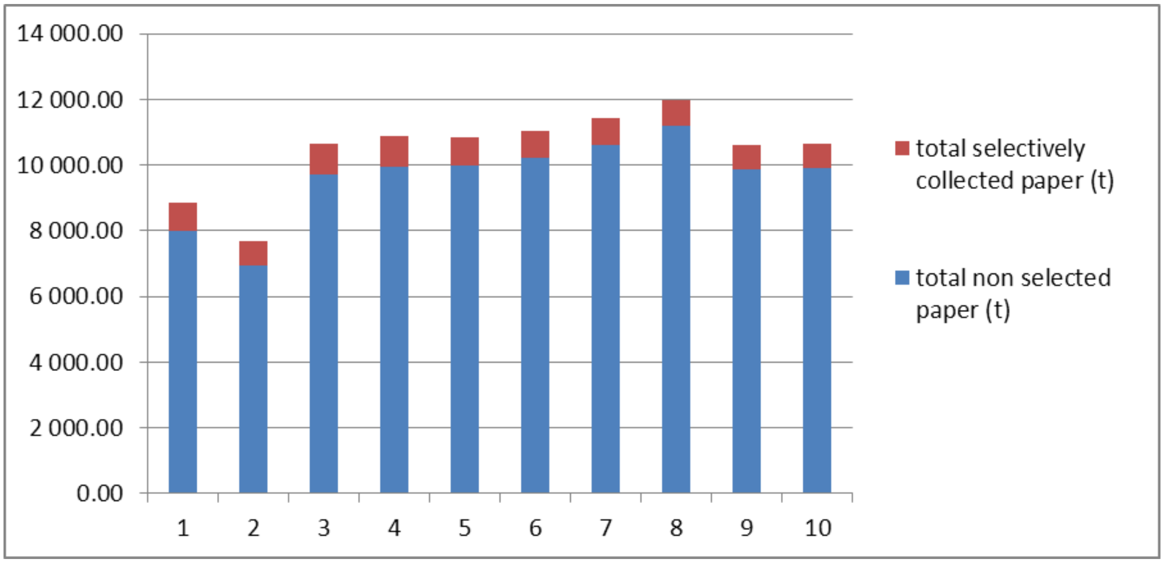
Paper

For SCBU waste it was: 22.87%, for MF the percentage is 19.19% and for single family houses: 13.99%, so the average is: 18.67%. The calculations are as follows:

	2011 Jan	Febr	March	Apr	May	June
Paper						
paper in the mixed waste, %	18.67	18.67	18.67	18.67	18.67	18.67
total non selective waste	42814	37245	51975	53317	53461	54668
total non selected paper	7993.374	6953.642	9703.733	9954.284	9981.169	10206.52
total selectively collected paper	868.09	724.54	957.61	931.18	859.92	821.89
total paper	8861.464	7678.182	10661.34	10885.46	10841.09	11028.41
total recyclable selectively collected waste	1932.54	1557.471	1951.454	1909.058	1868.874	1818.459
total waste	44796.55	38894.84	54707.13	57622.6	60039.29	58870.91
	July	Aug	Sept	Oct		
Paper						
paper in the mixed waste, %	18.67	18.67	18.67	18.67		
total non selective waste	56764	59888	52940	53129		
total non selected paper	10597.84	11181.09	9883.898	9919.184		
total selectively collected paper	820.72	783.05	736.98	742.86		
total paper	11418.56	11964.14	10620.88	10662.04		
total recyclable selectively collected waste	1766.54	1751.11	1685.96	1598.54		
total waste	60193	63930.22	56277.67	56445.68		

43. Table Amount of the selectively and non-selectively collected paper, 2011 by months, (tons)

The graphs show the following rates:



44. Figure Graph of the selectively and non-selectively collected paper, 2011 by months, (tons)

Plastic

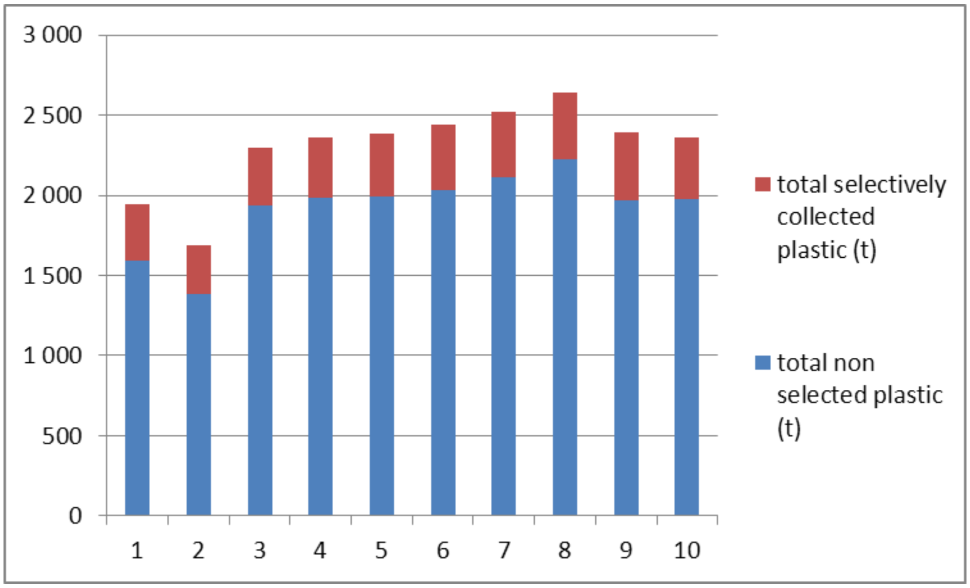
The amount recorded in % related to these waste types in the 48 categories is: 2.64% in SCBU, 5.33% in the multi family houses and 3.20% in the single family houses and the average of them is 3.72%. Therefore 3.72% plastic was found in mixed waste.

The basic numbers for the calculation are as follows:

	2011 Jan	Febr	March	Apr	May	June
Plastic						
plastic in the mixed waste, %	3.72	3.72	3.72	3.72	3.72	3.72
total non selective waste	42814	37245	51975	53317	53461	54668
total non selected plastic	1592.681	1385.514	1933.47	1983.392	1988.749	2033.65
total selectively collected plastic	354.04	304.371	366.804	378.488	395.744	403.259
total plastic	1946.721	1689.885	2300.274	2361.88	2384.493	2436.909
total recyclable selectively collected waste	1932.54	1557.471	1951.454	1909.058	1868.874	1818.459
total waste	44796.55	38894.84	54707.13	57622.6	60039.29	58870.91
	July	Aug	Sept	Oct		
Plastic						
plastic in the mixed waste, %	3.72	3.72	3.72	3.72		
total non selective waste	56764	59888	52940	53129		
total non selected plastic	2111.621	2227.834	1969.368	1976.399		
total selectively collected plastic	406.74	411.63	424.03	384.38		
total plastic	2518.361	2639.464	2393.398	2360.779		
total recyclable selectively collected waste	1766.54	1751.11	1685.96	1598.54		
total waste	60193	63930.22	56277.67	56445.68		

44. Table Amount of the selectively and non-selectively collected plastic, 2011 by months, (tons)

From these calculations the associated graphical representation is:



45. Figure Graph of the selectively and non-selectively collected plastic, 2011 by months, (tons)

Aluminum

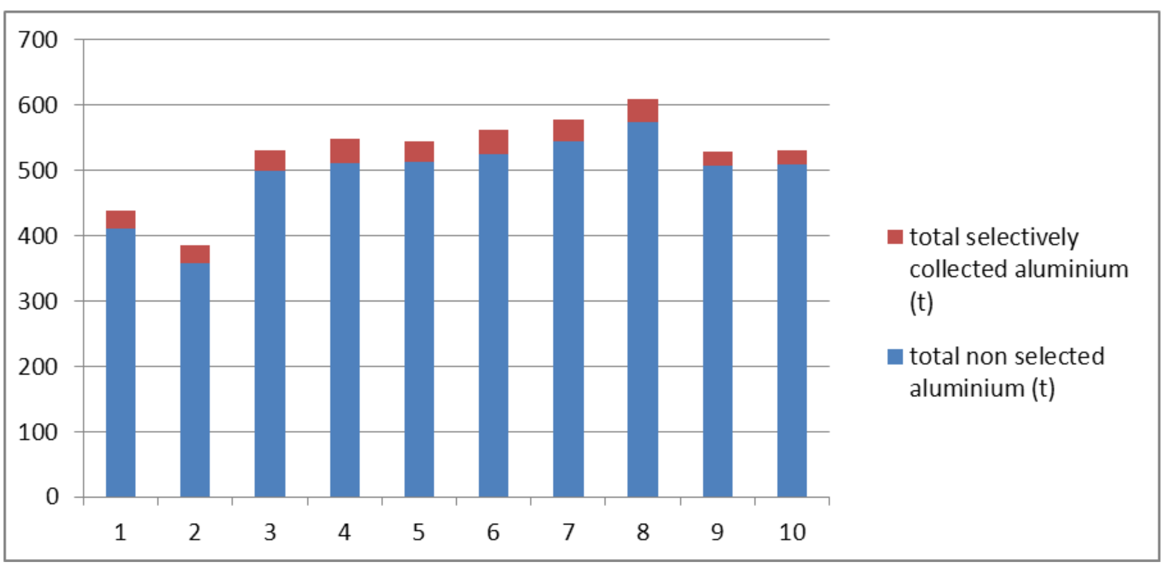
The calculations in % related to these waste types in the 48 categories is: 0.34% in SCBU, 1.09% in the multi family houses and 1.48% in the single family houses and the average of them is 0.96%. Therefore it can be concluded that 0.96% aluminum is found in mixed waste.

The remaining numbers are as follows:

	2011 Jan	Febr	March	Apr	May	June
Aluminium						
aluminium in the mixed waste, %	0.96	0.96	0.96	0.96	0.96	0.96
total non selective waste	42814	37245	51975	53317	53461	54668
total non selected aluminium	411.0144	357.552	498.96	511.8432	513.2256	524.8128
total selectively collected aluminium	27.77	27.94	31.86	36.55	32.49	38.16
aluminium total	438.7844	385.492	530.82	548.3932	545.7156	562.9728
total recyclable selectively collected waste	1932.54	1557.471	1951.454	1909.058	1868.874	1818.459
total waste	44796.55	38894.84	54707.13	57622.6	60039.29	58870.91
	July	Aug	Sept	Oct		
Aluminium						
aluminium in the mixed waste, %	0.96	0.96	0.96	0.96		
total non selective waste	56764	59888	52940	53129		
total non selected aluminium	544.9344	574.9248	508.224	510.0384		
total selectively collected aluminium	34.15	35.66	21.41	21.43		
aluminium total	579.0844	610.5848	529.634	531.4684		
total recyclable selectively collected waste	1766.54	1751.11	1685.96	1598.54		
total waste	60193	63930.22	56277.67	56445.68		

45. Table Amount of the selectively and non-selectively collected aluminum, 2011 by months, (tons)

According to these numbers the comparison of the selective and non-selective waste can be seen in the following graph:



46. Figure Graph of the selectively and non-selectively collected aluminum, 2011 by months, (tons)

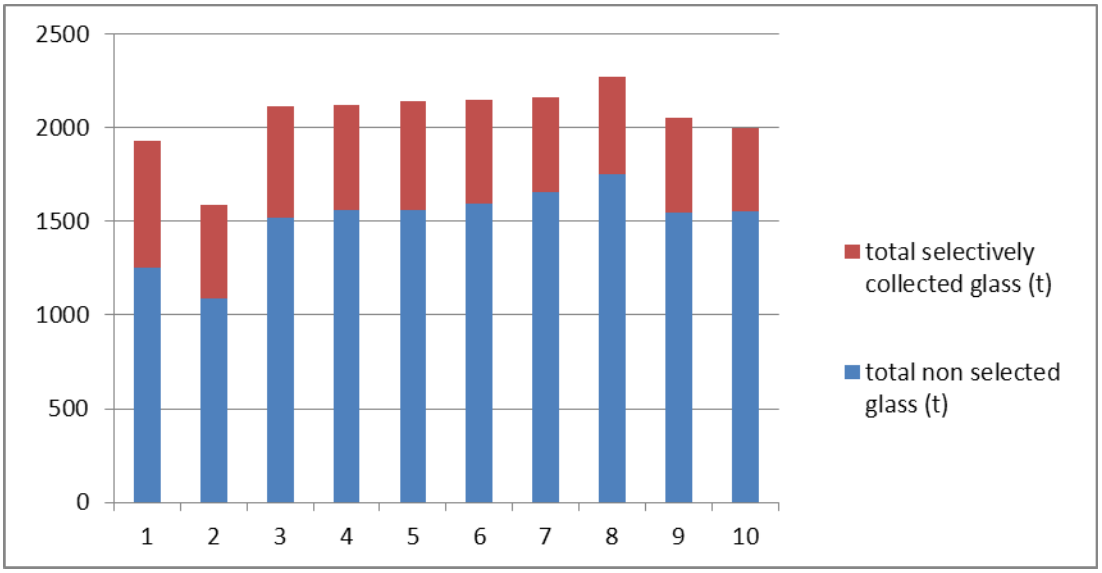
Glass

The figured in % related to these waste types in the 48 categories is: 1.76% in SCBU, 4.41% in the multi family houses and 2.59% in the single family houses and the average of them is 2.92%. Therefore 2.92% glass of glass is found in the mixed waste.

The remaining numbers are as follows:

	2011 Jan	Febr	March	Apr	May	June
Glass						
glass in the mixed waste %	2.92	2.92	2.92	2.92	2.92	2.92
total non selective waste	42814	37245	51975	53317	53461	54668
total non selected glass	1250.169	1087.554	1517.67	1556.856	1561.061	1596.306
total selectively collected glass	682.64	500.62	595.18	562.84	580.72	555.15
total glass	1932.809	1588.174	2112.85	2119.696	2141.781	2151.456
total recyclable selectively collected waste	1932.54	1557.471	1951.454	1909.058	1868.874	1818.459
total waste	44796.55	38894.84	54707.13	57622.6	60039.29	58870.91
	July	Aug	Sept	Oct		
Glass						
glass in the mixed waste %	2.92	2.92	2.92	2.92		
total non selective waste	56764	59888	52940	53129		
total non selected glass	1657.509	1748.73	1545.848	1551.367		
total selectively collected glass	504.93	520.77	503.54	449.87		
total glass	2162.439	2269.5	2049.388	2001.237		
total recyclable selectively collected waste	1766.54	1751.11	1685.96	1598.54		
total waste	60193	63930.22	56277.67	56445.68		

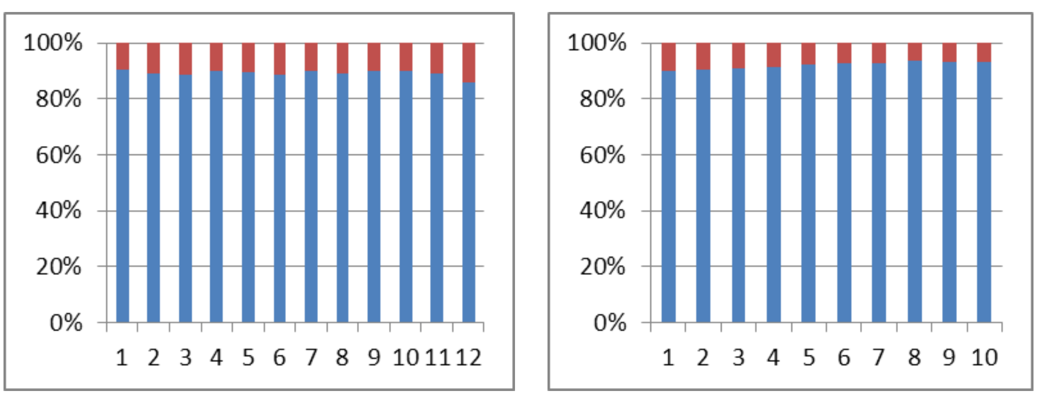
46. Table Amount of the selectively and non-selectively collected glass, 2011 by months, (tons)



47. Figure Graph of the selectively and non-selectively collected glass, 2011 by months, (tons)

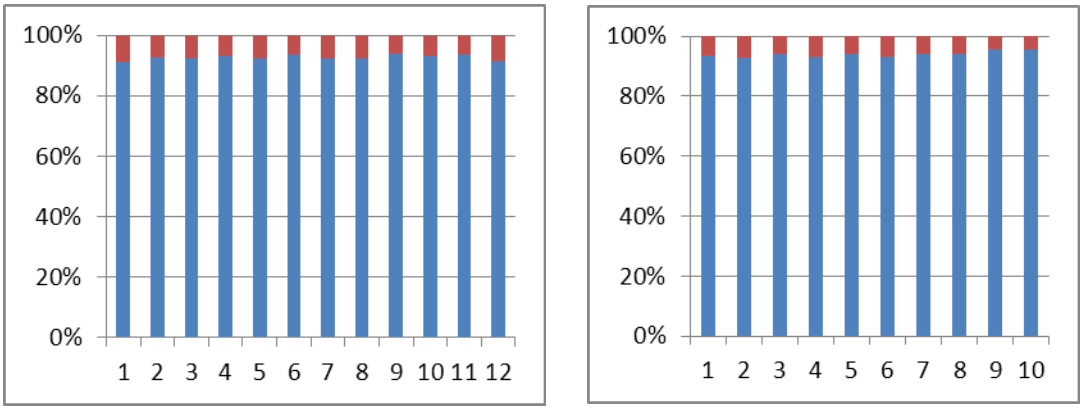
Summary of the comparison graphs

The summarized graphs, were adapted into a 100% graphical representation as well in order to better observe the rates in similar scaling, and can be seen here for the different waste types:

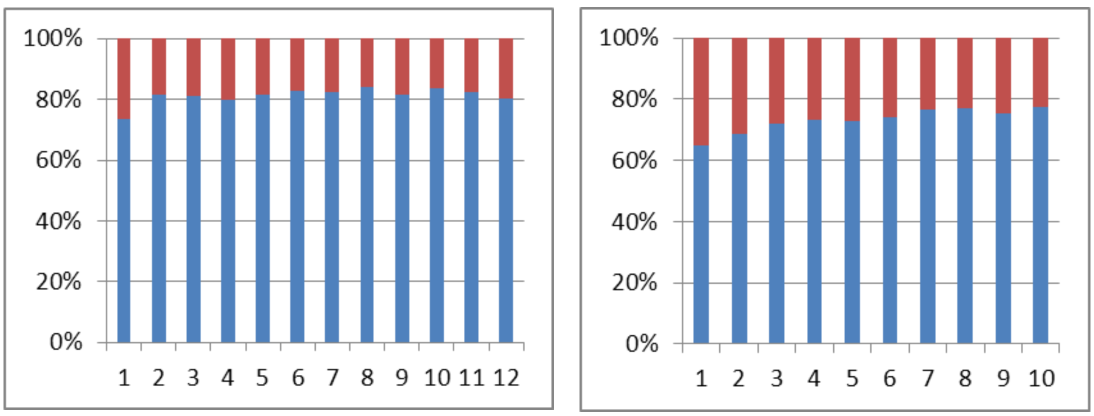


48. Figure Comparison graphs of the selectively and non-selectively collected paper, 2008, 2011 in 100% graphs

49. Figure Comparison graphs of the selectively and non-selectively collected plastic, 2008, 2011 in 100% graphs



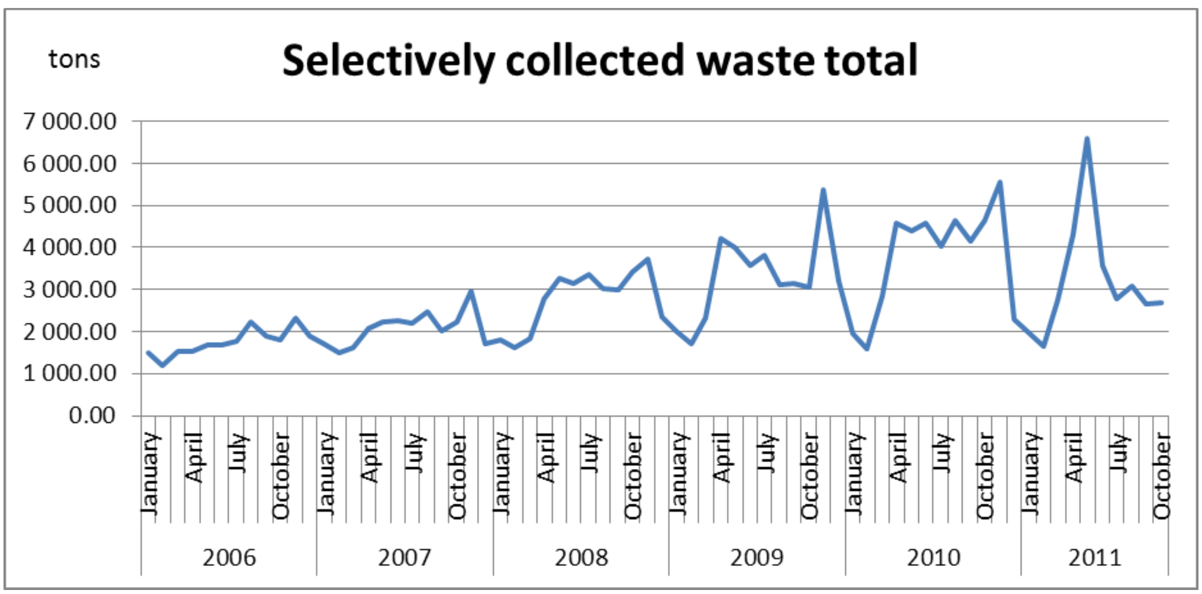
50. Figure Comparison graphs of the selectively and non-selectively collected aluminum cans, 2008, 2011 in 100% graphs



51. Figure Comparison graphs of the selectively and non-selectively collected glass, 2008, 2011 in 100% graphs

Looking at these comparison figures as of 2008 and 2011 it can be concluded that the non-selectively collected waste is much larger than the selectively collected waste. For paper the selectively collected waste is only 9% of the non-selectively waste (which is basically found in the mixed waste), it is 4% at plastic, also 4% at aluminum and 28% at glass. The rate of the recyclable waste is increasing marginally in the case of glass, plastic and for paper it shows no significant increase, while for aluminum cans a minimal decreasing trend can be observed. However, the amount of the waste fraction is the smallest for aluminum – appr. 1,200 tons, with glass accounting for 2,000 – 2,500 tons, 8,000 tons plastic, and 9,000 tons paper. Generally comparing them to each other the selectively collected paper has the highest collection rate. As it was mentioned previously in many cases the selective waste collection islands are burned or even raided as the aluminum cans or the PET bottles have a value of 1 or 2 HUF in several shopping markets. The graphs show that large amounts of recycled waste are disposed of, so a more robust and stricter selective collection method is determined to be necessary.

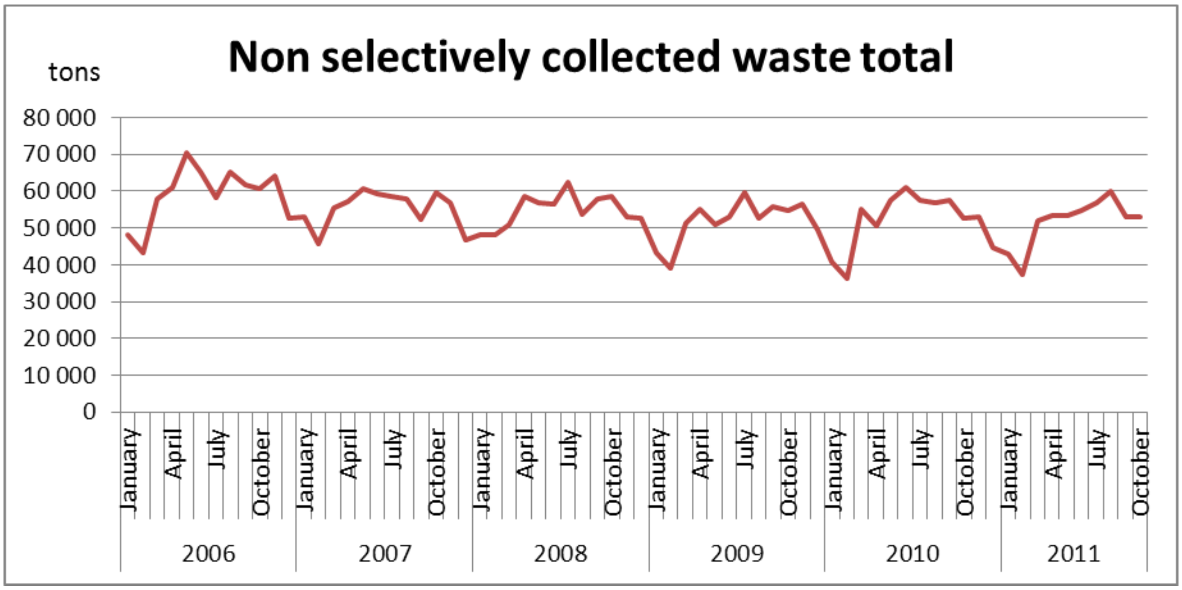
However, it can be stated that the amount of the selectively collected waste is increasing, though still at slow rate.



52. Figure Rate of the selectively collected waste between 2006 and 2011 (tons)
Source: own contribution based on FKF Zrt. data

In this figure the following waste types are included which are selectively collected in Budapest and further reprocessed: paper, plastic, glass, aluminum and organic. The amount of organic waste is low in the winter period which influences the total amount as well.

As a consequence of the increased selectively collected waste, the rate of the non-selectively collected waste is decreasing, though, still a significant amount.



53. Figure Rate of the non-selectively collected waste between 2006 and 2011
Source: own contribution based on FKF Zrt. data

The FKF Zrt. is selectively collecting paper, aluminum cans, glass and plastic waste and transporting them to the site of Fe-Group Invest Zrt.

All of the incoming materials are to be utilized as Fe-Group has the required permits for utilization or pre-treatment and their activity takes place according to them. The director of Fe-Group Invest Zrt. revealed the exact locations of these waste types from their site for further treatment, which are the following (Balatoni pers.comm. 2012):

- paper: Dunaújváros, Hungary - 60 kilometres,
- plastic:
    - PET within Hungary: Szentendre, Fót, Nagyréde
    - PP/HDPE: Tinnye
    - LDPE: Tiszaújváros – average: 90 kilometers,
- aluminum beverage can: mostly Great Britain, Manchester(can to can procedure) – distance: 1640 kilometers,
- glass: Zalaegerszeg, Sződ – average: 110 kilometers.
- the organic waste and the mixed waste are transported to the Pusztazámor landfill site – 28 kilometers, but these waste fractions are managed by FKF Zrt. and not Fe-Group Zrt.

The following waste types are not included in my research, but a listing of the waste processing locations is useful:

- composite drinking cartons: Czech Republic
- materials extracted from WEEE:
    - ferrous metals: Fehérvárcsurgó
    - non-ferrous metals: Budapest
    - plastic: Austria and in small amount China
- refrigerators: Nyírbogát, and from Szeptember: Bodajk stb.

Therefore in the LCA evaluation the related kilometers were used and in the case of the additional cities mentioned the distance of each major city was taken into consideration. From these waste types only the aluminum cans are transported abroad, while all other waste fractions are reprocessed in Hungary.

8.5 Collection vehicles and consumption

For collection FKF Zrt. has 74 types of vehicles, but some of them are for cleaning bridges, tunnel, and other transportation mechanisms. From these vehicles only those types marked with „6085" are the selective waste collection vehicles. In 2008 and 2009 there were 7 types of these vehicles, and in 2010 and 2011 two new vehicles were obtained, bringing the final total to 9. The list of the vehicles was not in order in 2008, making them difficult to locate. The selective waste collection cars and corresponding year are presented as follows:

2008

1. 6085 MAN.TGA 23320
2. 6085 TGS-MUT 01 26320
3. 6085 MAN 18.225 LK
4. 6085 MAN 26.313
5. 6085 MAN 26.313 FNLC
6. 6085 MAN TGA 26.310 6*2-2 BL
7. 6085 MAN.26310

2009

1. 6085 MAN 18.225 LK
2. 6085 MAN 26.313
3. 6085 MAN 26.313 FNLC

4. 6085 MAN TGA 26.310 6*2-2 BL
5. 6085 MAN.26310
6. 6085 MAN.TGA 23320
7. 6085 TGS-MUT 01 26320

2010

1. 6085 MAN 18.225 LK
2. 6085 MAN 26.313
3. 6085 MAN 26.313 FNLC
4. 6085 MAN TGA 26.310 6*2-2 BL
5. 6085 MAN TGS 26.400 6X4 BL - PK8502 B/A
6. 6085 MAN TGS 26.400 6X4 PALFINGER-MEILER
7. 6085 MAN.26310
8. 6085 MAN.TGA 23320
9. 6085 TGS-MUT 01 26320

2011

1. 6085 MAN 18.225 LK
2. 6085 MAN 26.313
3. 6085 MAN 26.313 FNLC
4. 6085 MAN TGA 26.310 6*2-2 BL
5. 6085 MAN TGS 26.400 6X4 BL - PK8502 B/A
6. 6085 MAN TGS 26.400 6X4 PALFINGER-MEILER

7. 6085 MAN.26310

8. 6085 MAN.TGA 23320

9. 6085 TGS-MUT 01 26320

From the consumption the following data can be calculated for the year of 2008:

Amount of waste: 691 586 t

Waste /capita: 406 kg/capita

Consumption of the vehicles: 4 119 419 liter

Necessary consumption for 1 ton: 5,95liter/ton

In order to compare the data we show the following tables:

Months	June	July
Amount of selective waste (tons)	3 132,44	3 368,55
Amount of non-selective waste (tons)	56 548,67	62 614,84
Total waste (tons)	59 681,11	65 983,39
Transport km – selective collection	56 321	59 160
Transport km – non selective collection	550 235	594 420
Transport km – total	606 556	653 580
Fuel consumption (l) – selective collection	38 602	39 717
Fuel consumption (l) - non selective collection	313 132	375 662
Fuel consumption (l) - total	351 734	335 945

47. Table Comparison of June and July 2008 fuel consumption
Source: own contribution based on FKF Zrt. data

Table 47. shows that the amount of the non-selective waste is 18 times more than the selectively collected waste in the summer of 2008. In addition the required transported

distances in kilometers is 10.04 times less for the selective collection waste types than for the mixed waste, however the rate of fuel consumption is 9.45 times higher for the non-selective waste. Therefore it is assumed that in the case of a higher amount of selective waste, fuel consumption can be more efficient.

In this research it was an uncertainty factor that exact information on the vehicles which are collecting the mixed waste was not received, making it problematic to analyze in full detail the selective waste collection.

The data are the following for the tons, kilometers and liters:

	t	km	l
selective	3 132,44	56 321	38 602
non selective	56 548,67	550 235	313 132

48. Table Selectively collection and non-selectively collection vehicles, tons, km and liters, June 2008

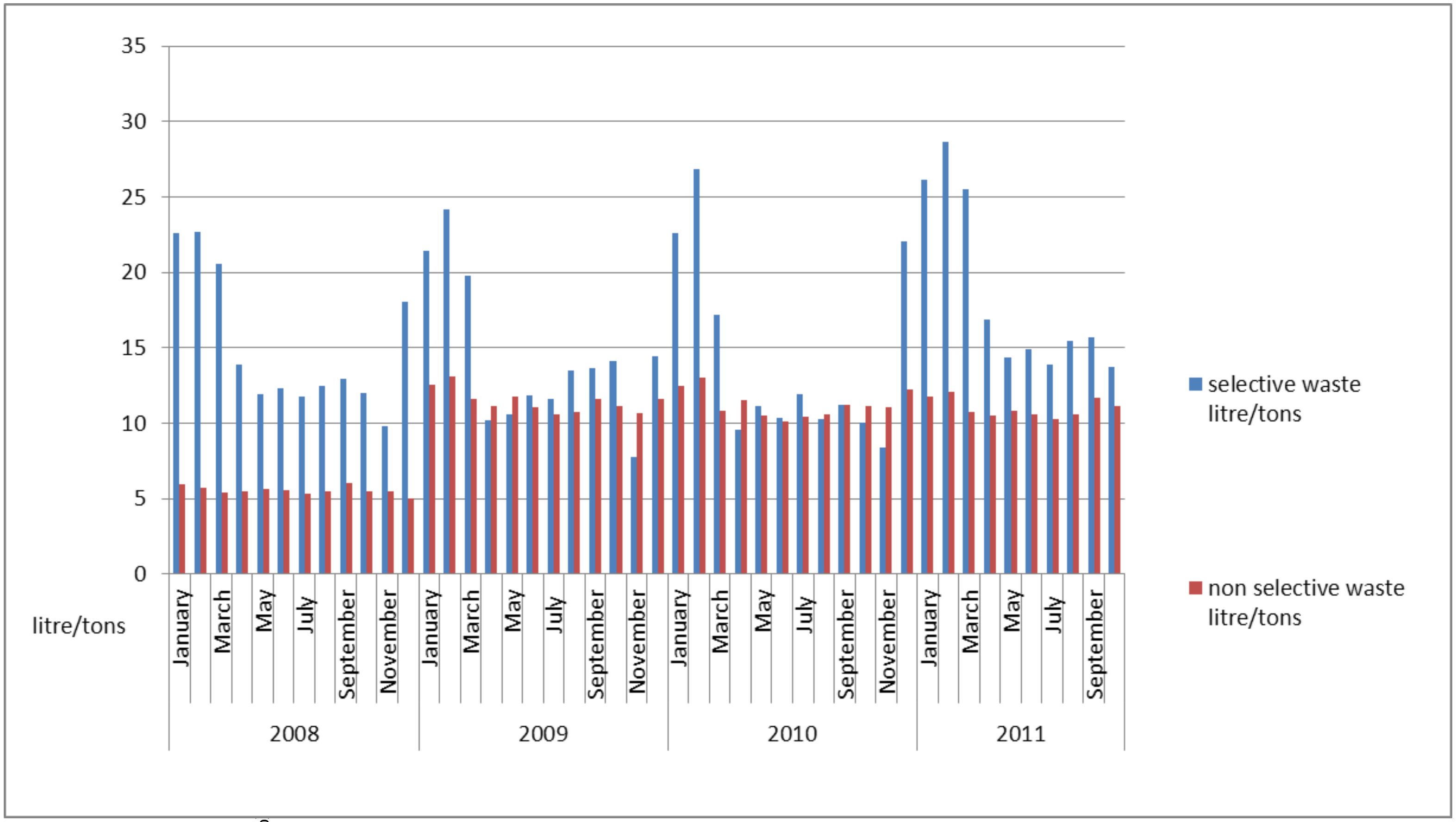
The evaluations from these data are as follows:

	km/t	l/t	consumption
selective	17,98	12,32	68,54
non selective	9,73	5,54	56,91

49. Table Selectively collection and non-selectively collection vehicles, km/tons, liters/tons and fuel consumption/100 km, June 2008

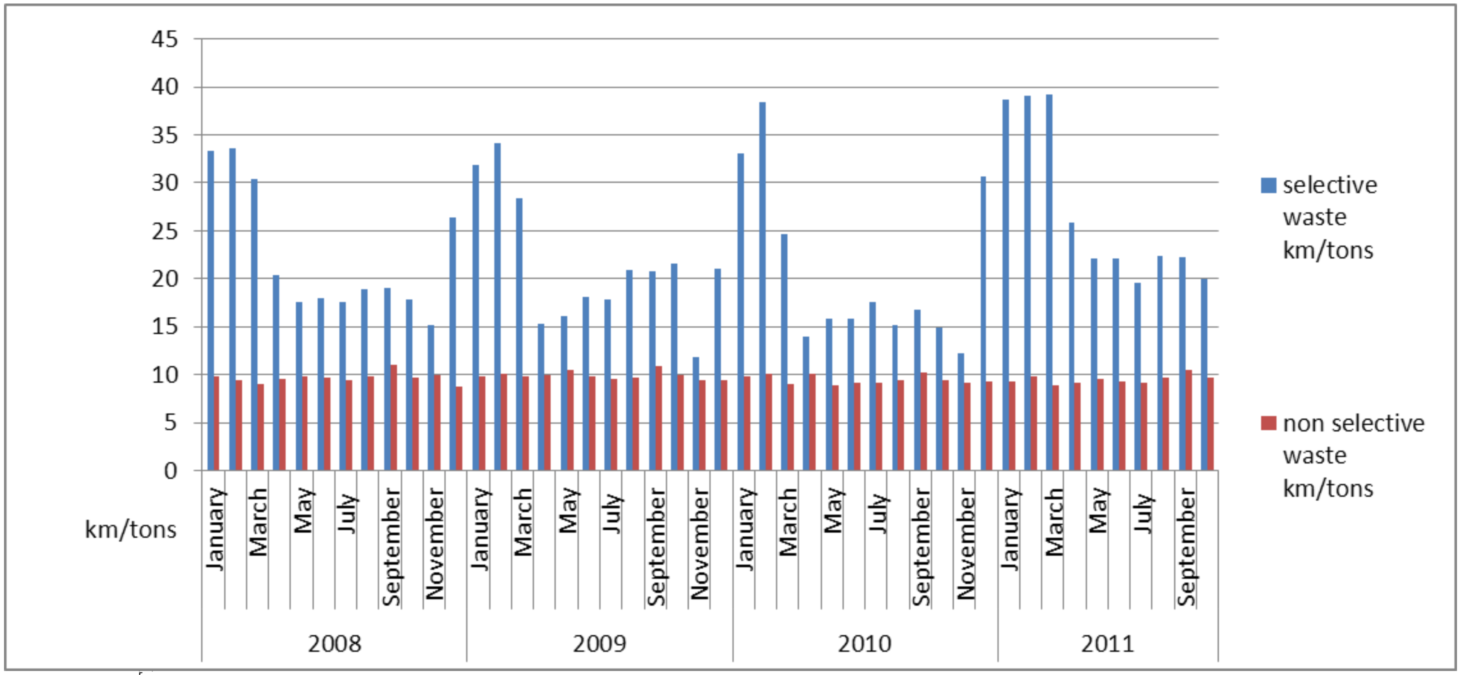
This study collected the liter and km data of the selective waste collection vehicles for every month between 2008 and 2011 and applied the data to the total, selective and non-selective waste amount per month accordingly. It remains unclear how many tons of selective waste can be collected during one route and how many kilometers are necessary such actions. The rate of the selection is very sensitive, and low in the winter period and high in the summer period, however for non-selective waste – due to its huge amount –

such small changes are not fully visible. The results for the collection vehicles can be seen in the following graphs:



54. Figure Evaluation of the selective and non-selective waste collection vehicles liter/tons 2008-2011

The reason for the smaller amounts in 2008 can be that the total liter consumption in 2008 (for example in every consecutive January months) was 328 109 liters, whereas in 2009 it was 585 226, in 2010 550 456 liters, and 553 646 for January 2011. It is assumed that in 2008 not all of the vehicles were used or that some transported less distances than in the following years. The amount (tons) did not show significant differences in these years, only the liters of consumption.



55. Figure Evaluation of the selective and non-selective waste collection vehicles, km/tons 2008-2011

These two graphs display that for selective waste collection more liters are consumed each month than for the non-selective waste collection. The amount of liters of consumption for one tons of waste is 14.9 liter/ton for the selective waste and 10.83 liter/ton for the non-selective waste in June 2011.

For the collection of one ton of waste more distance is required for the selective waste than for the non-selective waste. The values are 22.07 km/tons and 93.5 km/tons for the non-selective waste in June 2011.

The reason that consumption is higher for the selective waste collection is that each vehicle requires more driving distances to collect the same amount of waste, which means that the selectively collected waste locations are quite sparse and the amount of the selectively collected waste is also very low. It is justified by the fact that more kilometers are needed to collect one ton of selective waste than mixed waste.

8.6 Waste disposal in Budapest

In Budapest the waste is mainly thermally treated or landfilled. The waste-to-energy plant (it would not be called incinerator as it generates heat and power and gives them to the inhabitants) in Rákospalota takes appr. 60% of the waste and waste remaining is landfilled, which shows that the current rate of recycling in Budapest is about 4.4%.

Waste-to Energy Plant

The energy efficiency rate is of this plant is 67%, and according to the formula of the 2008/98/EC Waste Framework Directive Appendix No. II it is considered as thermal recovery and not thermal disposal.

In the case of municipal solid waste incineration facilities it can be called recovery only where energy efficiency is equal to or above:

- 0,60 for installations in operation and permitted in accordance with applicable Community legislation before 1 January 2009,
- 0,65 for installations permitted after 31 December 2008,

using the following formula:

Energy efficiency = (Ep - (Ef + Ei))/(0,97 × (Ew + Ef))

Where:

- Ep means annual energy produced as heat or electricity. It is calculated with energy in the form of electricity being multiplied by2,6 and heat produced for commercial use multiplied by 1,1 (GJ/year)
- Ef means annual energy input to the system from fuels contributing to the production of steam (GJ/year)
- Ew means annual energy contained in the treated waste calculated using the net calorific value of the waste (GJ/year)
- Ei means annual energy imported excluding Ew and Ef (GJ/year)

- 0.97 is a factor accounting for energy losses due to bottom ash and radiation.

This formula shall be applied in accordance with the reference document on Best Available Techniques for waste incineration.

The capacity of the Budapest Waste-to Energy Plant is 420,000 tons/year and it works at 408 000 tons/year, acknowledging that in the summer there is always one months of renovation, so the facility is actually in operation for 11 months.

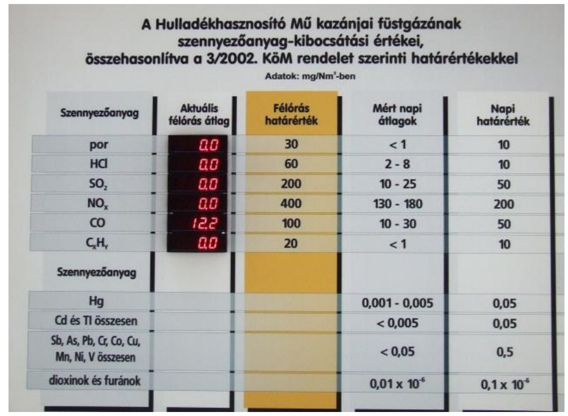
3. Picture Waste-to-Energy Plant 4. Picture Results of the upgrading

It has 6 roller grates, a semi dry cleaning system and the boiler efficiency is 83%. The Budapest Waste-to Energy Plant was built in 1982 and the flue gas filter of the thermal treatment facility was upgraded in 2005, and the separation efficiency of the fly gas in the cyclone is accepted to be 95% (Bánhidy 2008).

5. Picture of the Author in the Waste-to-Energy Plant 6. Picture Lifting up of waste in the incineration facility

The heat created in the Waste-to Energy Plant is used by 25 000 citizens in a district heating system and the electricity is forwarded to 140 000 citizens (Klug 2012 pers.comm.).

7. Picture of the author and László Sámson, director of the Waste-to-Energy Plant



8. Picture Control room **9. Picture Emission values**

Considering the air pollutant measures the Waste-to Energy Plant has to follow the 3/2002 (II.22) Ministry of Environment decree which is similar to the 76/2000/EC regulation. According to Borsi (email communication 2012a) they continuously measure the following air pollutants:

Pollutant	Measured daily average values (mg/Nm^3)	Limit values (mg/Nm^3)
Total dust	< 1	10
HCl	2-8	10
SO_2	10-25	50
NO_x (in NO_2)	130-180	200
CO	10-30	50
C_xH_y	< 1	10

50. Table Continuously measured pollutants

Source: Borsi Zs. 2012. Energetic manager of the Budapest Waste-to Energy Plant.
Email communication 23.02.2012.

The data obtained from the Waste-to-Energy plant was inserted in the model, however in many cases data was missing or not similar to the Danish and Swedish data set, so in such cases it had to be estimated. Please see Appendix 2 for the comparison of the Aarhus and Budapest data. If the data was missing, default data from EASEWASTE was used, but it was always discussed with Danish Professors beforehand.

Pusztazámor Regional Landfill Site

The remaining waste of Budapest is landfilled in Pusztazámor which is 28 km to the south west of Budapest. The present filling rate of Pusztazámor is 73% and the current height of the landfill is 27 meters. The final height is expected to be 55-60 meters, and the total capacity is 4.3 million m^3.

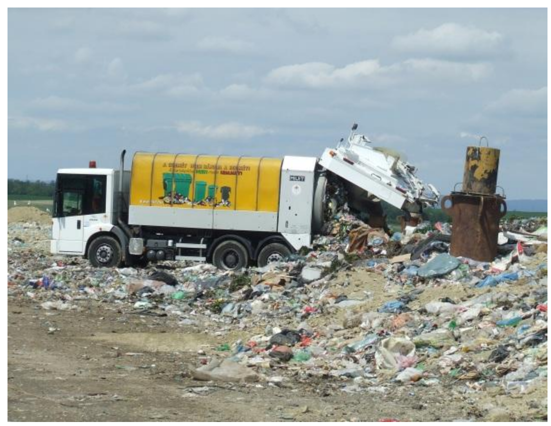
10. Picture Landfill site, entrance buildings

11. Picture New area for landfilling

It also has a biogas collection system and presently they burn 300 m^3/h biogas. Currently five times more gas is generated but not used at the moment. Therefore a biogas power plant is planned to be constructed in coming years.

12. Picture Biogas collection, flaring **13. Picture Composting site**

A composting plant is part of the landfill, and there are on-site composting operations. The collected organic waste from Budapest is composted here. The composting system is also planned to be doubled (Mile 2008).



14. Picture Author at the landfilling area **15. Picture Emptying collection vehicles**

Pictures were taken by Eszter Tanka, National Waste Management Agency Nonprofit Ltd.

For the model, leachate generation and gas production is very important. Unfortunately in Hungary there are no requirements for the analysation of different periods, neither in gas production nor for the leachate periods (Siklóssy pers. comm. 2012) therefore Danish equivalents are described for the periods. Leachate generation depends on yearly precipitation, which is 533 mm/year in average in Budapest. Leachate generation is divided into four periods in the model as follows: 2 years (period 1), 8 years (period 2), 35 years (period 3) and 55 years (period 4) as the same for gas collection. In the first period leachate generation is larger, as a significant amount of leachate infiltrates the waste mass. Afterwards, when the final top soil is constructed it actually lowers the leachate generation in the following periods. The behavior of the bottom line system also significantly influences the overall leachate collection efficiency. During the first 20 years the bottom lining system is regarded as unfractured and therefore leachate collection efficiency is high (95%). However during the following 20 years of operation a partial failure of the lining system is assumed, which lowers the leachate collection efficiency (70%). During the 40 years of operation collected leachate is entirely (100%) diverted to the waste water treatment plant for purification. In Budapest the leachate pool is 30,000 m3 capacity and 100% of it is led to the waste water treatment plant.

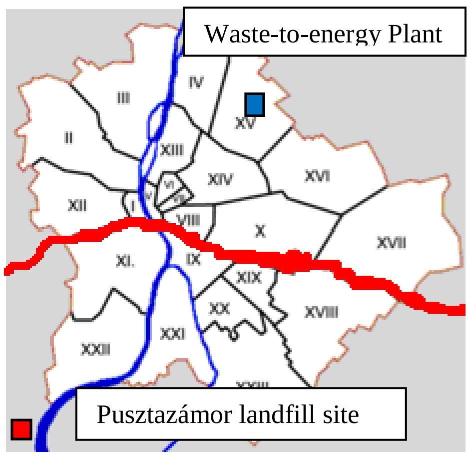
Concerning the landfill gas generation the 100 years of assessment are divided into four periods representing the filling phase, the acetogenic phase, the methanogenic phase and the post methanogenic phase, respectively. The fraction of the overall gas production should be specified in each period. In the first filling phase the gas collection is not practiced. From year 3 to year 40 it can be stated that 90% of the generated gas is collected and if possible the whole amount is diverted to the combined heat and power (CHP) plant. After this period the gas production is stopped. The uncontrolled gas fraction passes through the top soil cover and it receives partial oxidation. In the model the gas production is modeled based on an assumption of maximum methane potential for each waste fraction (as shown in the equation earlier). It is therefore important to control how much is released in the timeframe of the operation and also how much is collected and flared/energy, and how much is oxidized. Finally the final portion is how much is released into the atmosphere.

If a gas motor will be installed at the Pusztazámor landfill site, more gas can be routed to it. The length of time when gas is collected is dependent on the size of the landfill. A large landfill will keep producing gas for 35 years, where a smaller landfill will have too low flows of gas to perform after a number of years.

The data which was obtained from the Pusztazámor landfill site can be seen in the Annexes. According to Mile (pers.comn.2012) there are 109 gas wells at the landfill, all of them can be gradually increased depending on the size of the landfill. That gas wells (57 pieces only) will be extracted when the landfill reaches its final height. In Mile's opinion 30% of the landfill gas still remains in the landfill, and only 70% is utilized and it is not impossible to extract more. It is important to mention that previously gases were extracted from the bottom, while it turned out that extractions were watered down. Because of this they gradually changed the extraction method to upper gas extraction. If all of the gas will be extracted from the top (estimated by next year) then all of the amount can be extracted. They measure the C content of the extracted landfill gas, and it is estimated to be 55-58 % and not changing. They flare 100% of the extracted gas mostly in the 2 flares or partly in the gas furnace which ensures the energy supply of the site. The gas flare will be replaced by gas motor (it has been in the planning phase for several years now) and they hope to install a 2 MW gas motor in 2013, which can be enlarged to 5 MW in the future (the site itself can use 2 MW so the remaining 3 MW can be transported away). Mile (pers.comm. 2012) further added that 55-58 % of the extracted gas is methane, and the energy content of 1 Nm^3 CH_4 is 10kWh. The energy content of the 55-58% biogas is 5,5-5,8 kWh/Nm^3.

Waste routes

The division in the waste transport of Budapest can be seen in the following map. The waste route is determined by distance as the waste from North Budapest is being taken to the Budapest Waste-to Energy Plant and the waste from South Budapest (and other municipalities) are being taken to Pusztazámor.



56. Figure The divided Budapest in terms of the waste transport

Waste from the Northern part is taken to the Budapest Waste-to Energy Plant which is located in Rákospalota, in the XV. district, while the waste from the Southern part is taken to Pusztazámor. The Pusztazámor regional waste management center also accepts waste from the neighboring cities such as Tárnok, Sóskút and Diósd.

9 Policy options

Policy options need to be considered in order to improve the efficiency and reduce the environmental impacts of the operation of the FKF Zrt. Policy options have already been consulted in high management discussions with the main decision-makers within the company (like the managing director of FKF Zrt., the director of the waste-to-energy plant, the main engineer of the landfill site, as well as the head of the environmental department etc.). In addition several policy and technological options were raised by the present researcher according to the life cycle assessment evaluation.

Based on the fact that FKF Zrt. is a municipality owned company we can conclude the following:

- the cleaning waste service company in Budapest is a 100% owned by the Budapest Municipality company, representing full control, but the costs will not be spread out over the years for upfront cost.
- Budapest Municipal Cleaning Co. is in monopoly position, so there is no any driving force to take part in any competition,
- based on the above, efficiency can be increased,
- the whole system is over-secured, and making it more expensive to operate,
- if it was a market-based company they would observe revenues and also decision making would be faster,

- being a state owned company the decisions are very often based on political influence.

Taking into consideration the selective waste collection, it must be stated that the rate of collection is rather low in Budapest. This can be attributing to several factors, which have been discussed previously, but the most important factors are the following:

- the information for the inhabitants about the importance of the selective waste collection is minimal,
- there is no any punishment if the selective waste collection is continuously maintains at a low level,

For improving the technology within the FKF Zrt. waste management system the following recommendations have been made:

1. in order to control the exact route of the waste collection vehicles a GPS system should be installed in the trucks and it should be monitored regularly,
2. globally unique identifier (GUID) system can be installed to follow the route of the waste and ensure it does not get stolen,
3. data provision should be on electronic system and must be controlled,
4. data supply must take place more often, at least monthly or later on a daily basis, if possible,
5. the introduction of two shifts (in several other Hungarian cities the waste collection vehicles works in two shifts and in 12 hours, whereas in Budapest it is only one shift and 6 hours), will improve the utilization rate of the truck, and

therefore it will lower the total amount of the required trucks (even including a higher backup rate),

6. an evaluation of the logistics of the door-to-door selective waste collection system should be conducted, as it will help to efficiently establish the foreseen enlarged door-to-door collection system, (it is assumed that less fuel consumption can be required for the selective waste collection in the case of door-to-door collection than for the waste islands and more waste can be collected)
7. collection of the recyclable waste in the mixed waste, which was determined by Gábor Király,
8. analyzing and optimizing the present collection routes,
9. establishing the radio-frequency identification (RFID) system. With this technology the waste containers are tagged and can be easily traced. This helps operators monitor sorting quality, track the number of collection times and track the weight of the waste inside the bin. It helps the billing process and so supports the implementation of the incentive-based invoicing.
10. a pay as you throw system be initiated, which is a system where selective waste collection combined with different waste fees, meaning that if an inhabitant can collect recyclables and compostable materials separately, than the waste fee is smaller, representing an economic incentive for the inhabitant. This waste fee system is more complex and can not be introduced in a short period.
11. it should be taken into consideration to include a transfer station if this would improve the overall efficiency of the collection truck utilization,

12. the biogas system of the Pusztazámor landfill site should begin as early as possible and gas motor should be used instead of flaring when feasible (from financial reasons also),
13. the waste-to-energy plant consumes more municipal solid waste in the summer than in the winter, however there would be a larger demand in winter for the electricity and heat production. Therefore the feasibility of the waste reserve should be taken into consideration. It should be analyzed whether is it possible to pack and reserve some summer waste for the winter in order to generate more heat in the winter and less in the spring or summer period when heating is not necessary. It is important, nevertheless, that this is only feasible for the non organic fraction, as if organic waste is stored than there is a risk for anaerobic degradation and hence uncontrolled methane production can occur.

Due to the changes in the waste management system in Hungary as well as in Budapest the recent trend is to prevent waste and to recycle in the maximum highest amount.

PR activities at the Waste-to-Energy Plant

One of the most important issues of the policy options is that the FKF Zrt. is to become open to the public and let them obtain the required information. Recently the FKF Zrt. deliberately started to involve inhabitants and let them to observe the operation of their facilities. In the past there was a strong opposition towards waste incineration and waste-to-energy plants but nowadays with the new management the FKF Zrt. is more transparent and seeks cooperation with the public. For instance an open day was held as in the summer of 2012 and they use advertisements in the Budapest underground in order to inform the public about the selective waste collection facilities and the importance of environmental awareness. FKF Zrt. is also preparing future events for the inhabitants such as children's drawing competition or novel writing competition. Every year FKF Zrt. organizes an Open Day in which they invite the public to their facility. The last open day was held at the Budapest Waste-to Energy Plant on 23. June 2012, where they showed the public a short film about the operation of the Waste to Energy Plant and afterwards they invited them to see the technical facilities within the building. The tour was closed by showing the Public Cleaning Museum as well. FKF Zrt. received a second place (after the Manchester Waste Authority and in front of the Vienna MA 48 Agency) in the ISWA Communication Competition from 21 applicants of 13 countries with the following campaign: FKF Zrt. is in service for the Budapest inhabitants – Let us save our environment! (Az FKF Zrt. a budapesti lakosság szolgálatában – Tegyünk együtt a környezetünkért!). The communication award will be obtained on 17 September in Florence, Italy.

10 Results of the environmental assessment

The EASEWASTE software can evaluate different scenarios according to the planned technological changes such as a biogas power plant or a bigger size composting system or a mechanical-biological system. The EU requires Hungary to reach a higher recycling target by 2012 and beyond. Obviously the scenarios will be determined according to the discussion with policy makers of the Budapest waste management system.

10.1 Unique idea for analyzing the trends

The LCA assessments are in most cases relevant only for one year with the comparison of different scenario options. In this research it was decided to run the model not for only one year but, for different months in order to see the trends and the results of the different decisions. Several different options are therefore resultant regarding different selective waste collection and waste recycling rates. This is the only way (apart from doing a daily comparison, which is impossible at the moment due to the lack of proper data) to steadily determine the results of the changes which are primarily due to the increased selective waste collection. In this thesis at the calculations, the collection system, the vehicles and the technological treatment facilities have no change at all, so only the different selective waste collection rates have effect on the model results. The biogas to energy system at the landfill site has not even started, so 100 % flaring is calculated, which is the state even at this moment.

The different waste generation rates are calculated based on the statistical data with the control of other cities data. It must be mentioned that in the model the waste generation rates for MF, SF and SCBU are identical; however in reality these rates would be different.

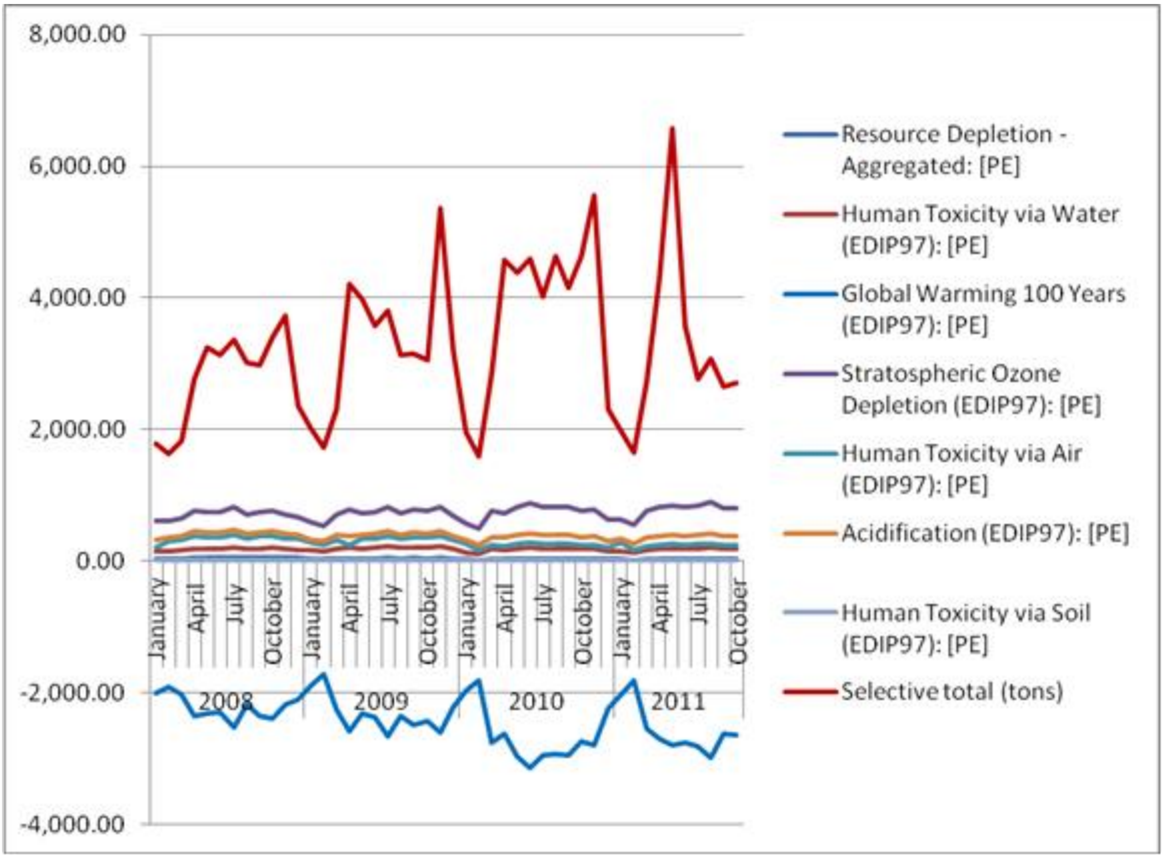
Through a detailed analysis and comparison of the results of the different months and different years some trends and consequences can be drawn.

Model results

The results of the LCA assessment for the years of 2008, 2009, 2010 and 2011 for every different month can be seen in Appendix 4 in detail, and here only the aggregated results are shown.

From these model results the following impacts were eliminated as they need to have different scales in another graph:

- Spoiled Groundwater Resources,
- Stored Ecotoxicity in Water,
- Nutrient Enrichment,
- Ecotoxicity in Water, Chronic.



57. Figure Results of the LCA model for several environmental impact by months for 2008 - 2011

From this figure it can be clearly drawn that the following environmental impacts are decreasing due to the increased selective waste collection:

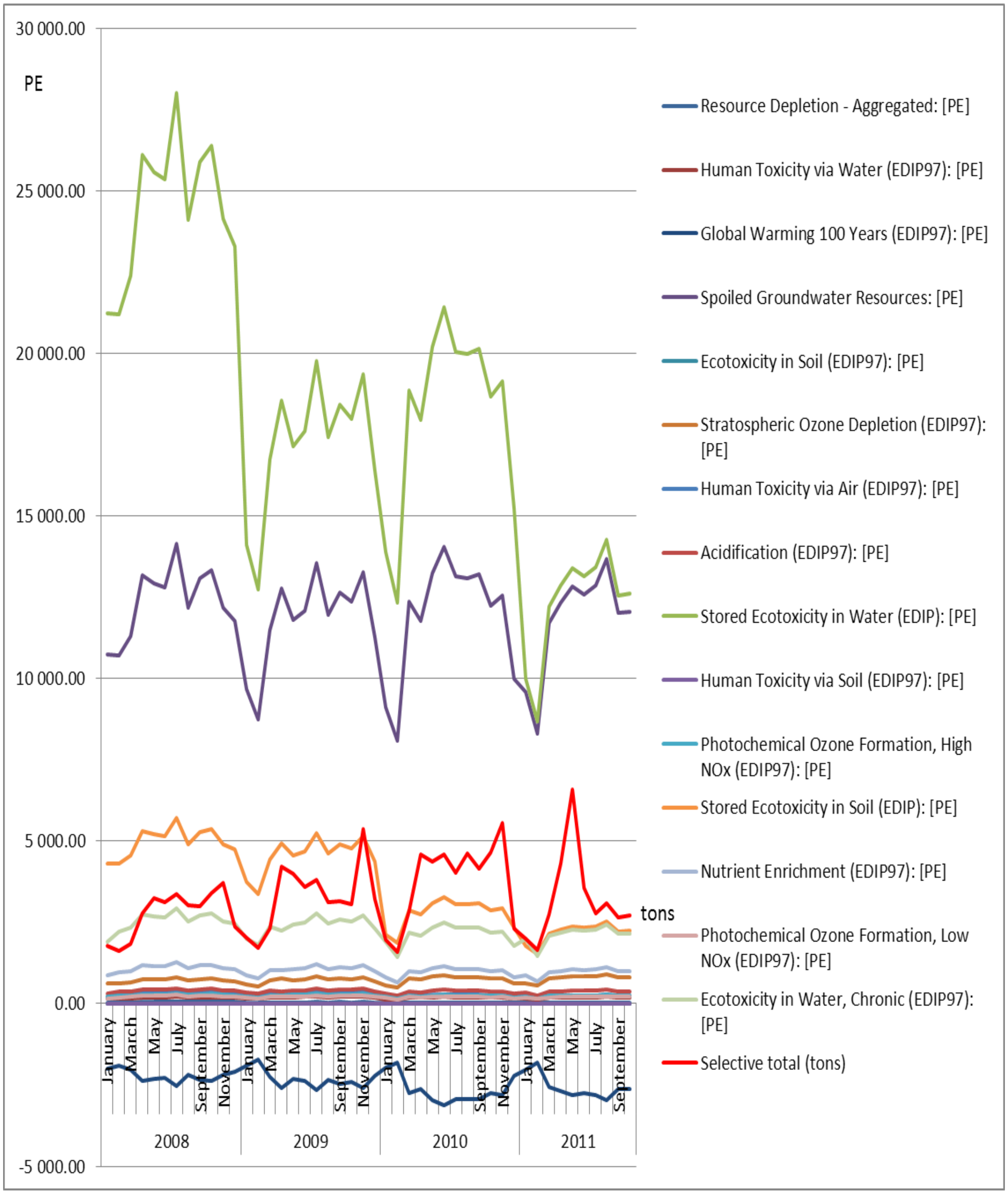
- Resource depletion,
- Human toxicity via water,
- Global warming,
- Stored ecotoxicity in soil,
- Acidification,

In addition the following impacts are decreasing (in detail in the following figure):

- Spoiled Groundwater Resources: [PE]
- Ecotoxicity in Soil (EDIP97): [PE]
- Human Toxicity via Air (EDIP97): [PE]
- Stored Ecotoxicity in Water (EDIP): [PE]
- Human Toxicity via Soil (EDIP97): [PE]
- Photochemical Ozone Formation, High NOx (EDIP97): [PE]
- Nutrient Enrichment (EDIP97): [PE]
- Photochemical Ozone Formation, Low NOx (EDIP97): [PE]
- Ecotoxicity in Water, Chronic (EDIP97): [PE]

The following environmental impact is slightly increasing:

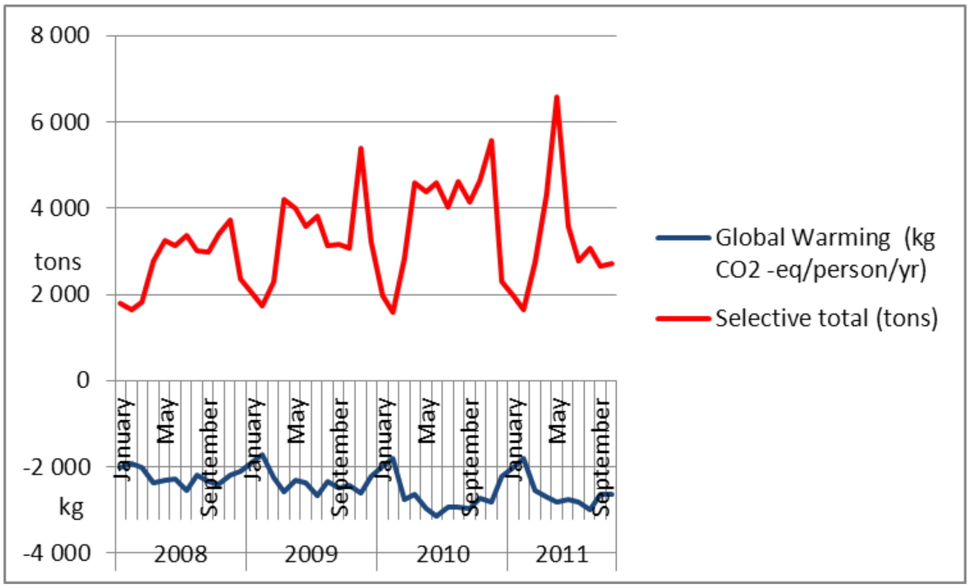
- Stratospheric Ozone Depletion (EDIP97): [PE]



58. Figure all LCA results for every month between 2008 and 2011

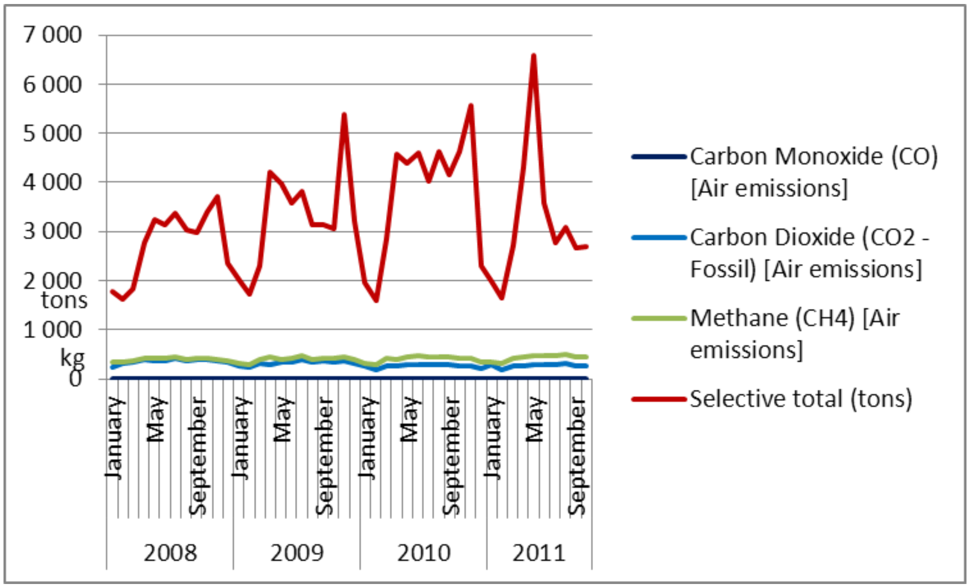
Units are the following: mostly kg, but in case of stored ecotoxicity in water, spoiled groundwater resources and stored ecotoxicity in soil as well as ecoxicity in water is recorded in m3, while the selective waste amount is in tons. All of the figures were displayed in one figure in order to see the trend.

In terms of the global warming, the correlation between the selective waste collection and global warming potential can be visualized as follows:



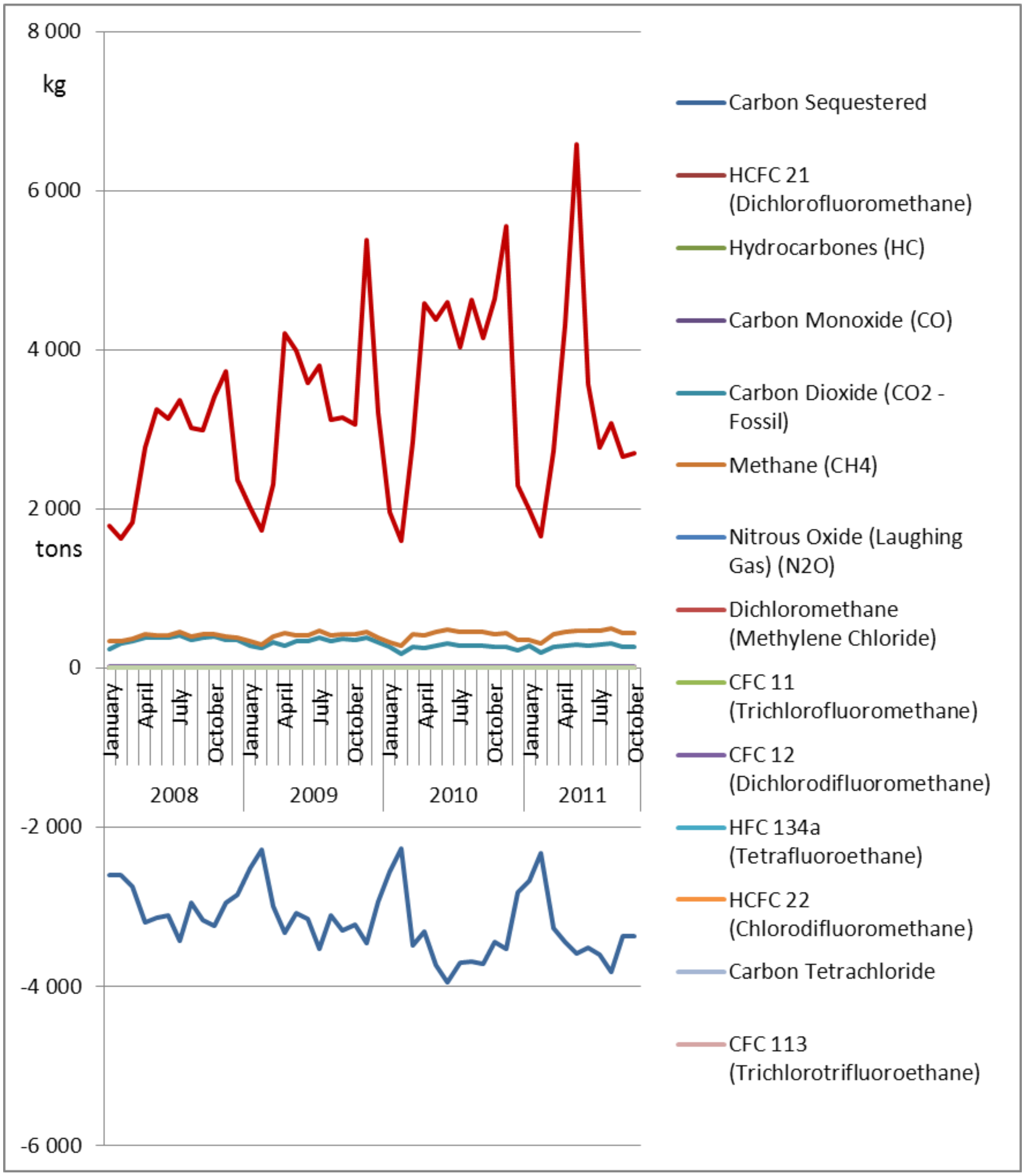
59. Figure Correlation of the selective waste collection and global warming by months 2008-2011

In terms of the global warming familiar and significant emissions were analyzed and shown as follows:



60. Figure: Some global warming factors by months 2008-2011

If we take into consideration all of the emissions included in the global warming potential the following graph can be produced:



61. Figure: All global warming factors by months 2008-2011

10.2 Correlation with increased recycling rates and global warming potential

This research focuses on the relationship between solid waste management systems and global warming potential, assuming that higher selective waste collection rates decreases the amounts of the different GHGs

Therefore it was not enough to run an LCA for the different years, and it was necessary to run the model for increased selective waste collection rates to get an understanding of what increased selective collection would mean to the environmental impact. In this case first the model was run only for one month but with imaginary higher recycling rates and not for the whole year as it shows the trend as well. Therefore the recycling rates were increased, but it is originated from the tons.

In this procedure the recycling rate was increased (according to the tons taking into account that the rate of the total non-selective waste is also decreasing if the rate of the selective waste is increasing), however, the waste collection distances (kilometers) and the fuel consumption had not been changed, provided the assumption that the inhabitants have reached a higher rate of environmental awareness. It is acknowledged that this will add a little uncertainty to the results, but it is expected to be of minor relevance, and it will still show what increased selective collection would mean.

At the moment the selective waste collection in percentages of the different fractions are the following in average:

	2008	2009	2010	2011
Paper	1.64%	1.97%,	1.97%	1.49%
Plastic	0.53%	0.63%,	0.65%	0.69%,
Aluminum	0.06%	0.06%,	0.058%	0.05%
Glass	0.86%	0.98%	0.93%	0.98%
Organic	1.67%	2.38%	3.23%	3.3%.

51. Table Rate of the selective waste collection for waste types, 2008-2011

If the total amount of waste is taking into account which are the following: 2008: 691 586, 2009: 661 405, 2010: 668 711 and 2011: 662 133 tons than these percentages mean the following amounts in tons:

Waste types	2008	2009	2010	2011
Paper	11 355	13 071	13 185	8 246
Plastic	3 719	4 205	4 398	3 829
Aluminum	439	436	394	307
Glass	5 986	6 488	6 254	5 456
Organic	11 554	15 780	21 631	18 221

52. Table Amount of the selective waste collection for waste types, 2008-2011

According to Gábor Király, the Head of the Environmental laboratory the amount of the different waste types are the following in the different years (aggregate values for the SF, MF and SCBU including the selective waste and non-selective waste, showing the potentially recyclable and compostable waste as well, %):

Waste types	2008	2009	2010	2011
Paper	14.31	17.98	18.46	18.67
Plastic	4.47	5.47	4.64	3.72

Aluminum	0.86	0.97	1.34	0.96
Glass	3.94	4.79	3.44	2.92
Composting	12.91	12.97	11.31	12.27

53. Table Potentially recyclable waste collection for waste types, 2008-2011 (%)

If we take into account that the total amount of waste is the following: 2008: 691586, 2009: 661 405, 2010: 668 711 and 2011: 662 133 tons than these percentages mean the following amounts in tons:

Waste types	2008	2009	2010	2011
Paper	99 019	118 936	123 499	123 686
Plastic	30 925	36 190	31 069	24 644
Aluminum	6 015	6 460	8 977	6 415
Glass	27 315	31 694	23 058	19 337
Compost	89 299	85 789	75 001	81 251

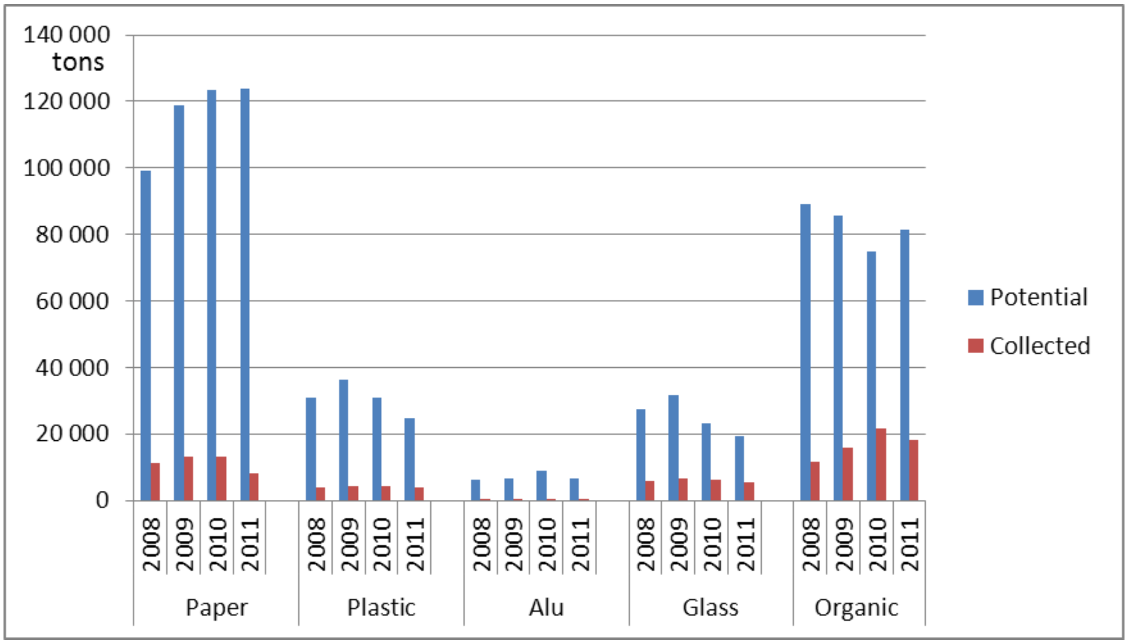
54.Table Potentially recyclable waste collection for waste types, 2008-2011 (tons)

In a summary the following table can be determined for the potentially recyclable and the presently collected waste types in the different years.

Waste types	2008		2009		2010		2011	
tons	Potential	Collected	Potential	Collected	Potential	Collected	Potential	Collected
Paper	99 019	11 355	118 936	13 071	123 499	13 185	123 686	8 246
Plastic	30 925	3 719	36 190	4 205	31 069	4 398	24 644	3 829
Aluminum	6 015	439	6 460	436	8 977	394	6 415	307
Glass	27 315	5 986	31 694	6 488	23 058	6 254	19 337	5 456
Organic	89 299	11 554	85 789	15 780	75 001	21 631	81 251	18 221

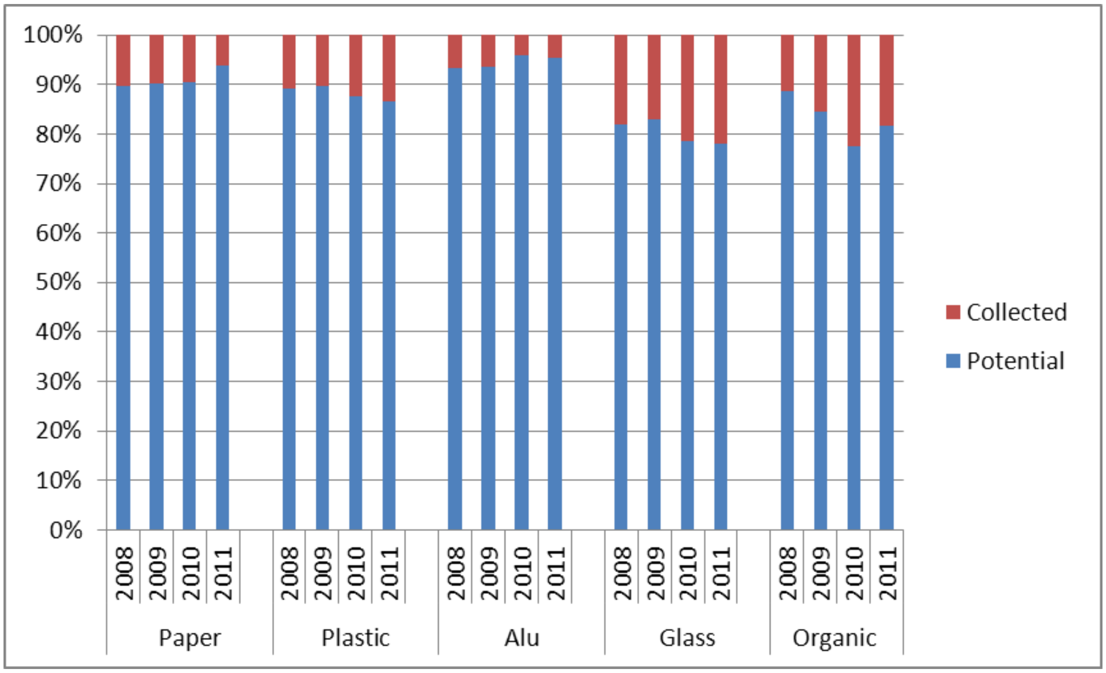
55.Table Comparison amounts of the potentially recyclable waste and the presently selectively collected waste for waste types, 2008-2011 – table

This result can be seen in the following graphs as well:



62 Figure Comparison amounts of the potentially recyclable waste and the presently selectively collected waste for waste types, 2008-2011 – normal graph

This graph shows us that appr. 85% of the potential waste is not recovered in the case of paper. For paper, the percentage is higher as there are plenty of paper types which can be further recycled, and the potential is high at the inhabitants. Plastic and aluminum cans also have a significant reserve for the inhabitants, but as they can be rewarded for HUF, the amount is decreasing over the months. Glass collection is neglected and it must be significantly improved. Organic waste is increasing, and people are not interested in this waste type, so more and more organic waste is collected.



63 Figure Comparison amounts of the potentially recyclable waste and the presently selectively collected waste for waste types, 2008-2011 – 100 % graph

This graph clearly shows that there exists a significant amount of potentially collectable and recyclable waste in the residual waste which is thrown out. The table shows that in case of paper, there is 9 times more paper in the mixed waste, and in case of aluminum there is 22 times more potentially recyclable waste in the mixed waste, while it is 5 times more in case of glass and 3.5 times in composting. However the rates recorded were even higher in 2008 than in 2011. This leads us to the investigation of the environmental impact potential through LCA in case of higher recycling rates.

If we multiply the recyclable and compostable waste amount (tons) to three times and five times the results and the percentages can be seen in the following table (June 2008).

Waste types	original amount		3x more amount		5x more amount	
	tons	%	tons	%	tons	%
Paper	1 029.58	1.73	3 088.74	5.18	5 147.9	8.65

Plastic	344.68	0.58	1 034.04	1.73	1723.4	2.9
Aluminum	33.64	0.06	100.92	0.17	168.2	0.30
Glass	460.26	0.77	1 380.78	2.31	2 301.3	3.85
Organic	1248.68	2.09	3 746.04	6.28	6243.4	10.45
Total selective	3 116.84	n.a.	9 350.52	n.a.	18 701.04	n.a.
Total non-selective	56564.27	n.a.	50 330.59	n.a.	40 980.07	n.a.
Total	59 681.11	n.a.	59 681.11	n.a.	59 681.11	n.a.

56. Table Comparison of 1x, 3x and 5x higher recycling rates, June 2008 (t)

Therefore these recycling rates were installed in the model for the sorting efficiencies respectively.

The mixed waste composition also changes with higher recycling rates

It has to be considered that the waste composition of the 48 fractions is changing with the imaginary higher recycling rates and so the calculation has to be made with the changed waste compositions. The reason for this is that if we take out the 3x or 5x higher amount of selective waste collection then the amount of the remaining non selective waste is smaller and the waste composition within this waste has been changed. In this calculation it is very important that we remove more paper from the mixed waste. If we take into account the mixed (non selective waste) in June 2008, which is 56 564.27 tons, than in case of 3 x bigger selective waste collection we remove 2 x 1029 (2058 tons) more from the mixed waste.

In June 2008 we are considering the following amounts:

- total amount of waste: 59 681.11 tons,
- total amount of mixed (non selective) waste: 56 564.27 tons,
- total amount of selectively collected paper: 1 029.58 tons (1.64%)
- total rate of the potential more paper: 14.31%
- total amount of potential more paper in the mixed waste: 8 094.35 tons (56 564.27 * 14.31%).

If we take out the 3 times more selective waste from the total waste than it means that we take out 2 059.12 more paper from the remaining 8 094.35 tons, so 6 035.23 tons remains in the left mixed (non selective) waste. However, if we take out more paper in this case the waste composition of the remaining waste changes in terms of the selective waste fraction including paper as well. If we calculate the amount of the remaining waste after taking out 3 times more of every single selective waste fraction (total amount of them is 9 350.52 tons) than in the mixed waste 59 681.11 – 9 350.52 = 50 330.59 tons remains.

If we calculate it for the 5 times more selective waste factor, collection is: 59 681.11 – 15 584.2 = 44 096.91 tons remaining, which is the total amount of the remaining mixed (non selective) waste.

It should therefore determine the paper content of the remaining 50 330.59 tons and 44 096.91 tons respectively.

It was calculated that 6 035.23 tons paper are left in the remaining waste (50 330.59) in the 3 times bigger selective waste collection calculation. The rate of paper is therefore: (6035.23/50330.59)*100 which is 11.99%, representing the rate of the potential paper in the remaining residual waste in the case of 3 times more selective waste collection calculation (it was 14. 31 % in case of one time selective waste collection).

In case of 5 times potential higher recycling rate we remove 4 118.32 more, which comes from 4*1029.58 tons, more tons of paper from the mixed paper waste which is 8094.35, so the remaining paper is 3976.03 tons.

The rate of the paper is therefore: (3976.03/44096.91)*100 which is 9.02%, so this is the rate of the potential paper in the remaining mixed waste in case of 5 times more selective waste collection calculation. These percentages therefore have been changed in the model.

The remaining fractions: plastic, glass, aluminum and organic have been calculated according to the example for paper.

Plastic: 689,36 tons from the remaining 2528,42 tons are removed (4,47% of the 56564,27 tons, which is the total non-selective waste). So 1839,06 remains which is 3,65% of the remaining 50330,59 tons). In case of 5 times higher selective waste rate, we take out 1378,72 tons from the 2528,42 tons, so 1149,7 tons is left which is 2,61% of the remaining 44096.91 tons.

Aluminum cans: the remaining amount is 486,45 tons. If we take out 67,28 tons (2 x 33,64) then 419,17 tons is left which is 0,83% of the remaining 50330,59 tons and in case of 5 times more recycling rate we take out 134,56 tons so 351,89 tons is left which is 0,8% of the remaining 44096,91 tons.

Glass: in case of 3 times higher selective waste rate, we take out 920,52 tons from 2228, 63 tons (3,94 % of the 56 564,27 tons), so 1308,11 tons is left which is 2,6% of the remaining 50330,59 tons and in case of 5 times more recycling rate we take out 1841,04 tons so 387,59 tons is left which is 0,88% of the remaining 44096,91 tons.

If we observe organic waste the amount of this type of waste in the mixed waste is 7302,45 tons (12,91%), so if we deduct 2497,36 tons from this than 4805,09 tons remains which is 9,55% of the remaining 50330,59 tons and in case of 5 times more recycling rate we take out 4994,72 tons leaving 2307,73 tons left which is 5,23% of the remaining 44096,91 tons.

The results can be followed in the following table (June 2008):

	1x collection		**3x collection**		**5x collection**	
	tons collected	tons potential	tons collected	tons potential	tons collected	tons potential
Paper	1029	8094	3089	6035	5148	3976
Plastic	344	2528	1034	1839	1723	1149
Aluminum	33	486	101	419	168	352
Glass	460	2228	1380	1308	2301	387
Organic	1248	7302	3746	4805	6243	2307

57. Table Amounts of the collected and potential selective waste fractions in case of 1x, 3x, 5x higher recycling rates, June 2008, rounded.

The composition of the different waste types is the following in the mixed waste for the potential amounts:

	1x collection	**3x collection**	**5x collection**
Paper	14.31 %	11.99 %	9.02 %
Plastic	4.47	3.65	2.61
Aluminum	0.86	0.83	0.8
Glass	3.94	2.6	0.88

Organic	12.91	9.55	5.23

58. Table Percentages of the potential waste by waste fractions in case of 1x, 3x, 5x higher recycling rates, June 2008

As a consequence in the model the following changes have been made:

Paper

In case of three times higher selective waste collection the paper: for No. 3. 4. 5. 6. 7. 8. 9. and 10. the SCBU was changed from 12.98% down to 10.87%, the MF rates was changed from 16.41% down to 13.74 % and the SF rates was modified from 13.55% to 11.35%, and the average become 11.99%.

In the case of the five times higher selective waste collection rate, these numbers have been reduced to 8.18%, 10.34% and 8.54% respectively, so their average is 9.02%.

Plastic

In case of the three times higher selective waste collection rate the plastic: for No. 17. the SF was changed from 6.56% down to 5.35%, the MF rates was changed from 2.85% down to 2.32 % and the SCBU rates was modified from 4.01% to 3.27% so the average become 3.65%.

In the case of five times higher selective waste collection estimation, these numbers have been reduced to 3.83%, 1.66% and 2.34% respectively, so their average is 2.61%.

Aluminum cans

In case of three times higher selective waste collection rate the aluminum: for No. 37. the SF was changed from 0.97% down to 0.93%, the MF rates was changed from 0.84%

down to 0.81% and the SCBU rates was modified from 0.78% to 0.75% so the average become 0.83%.

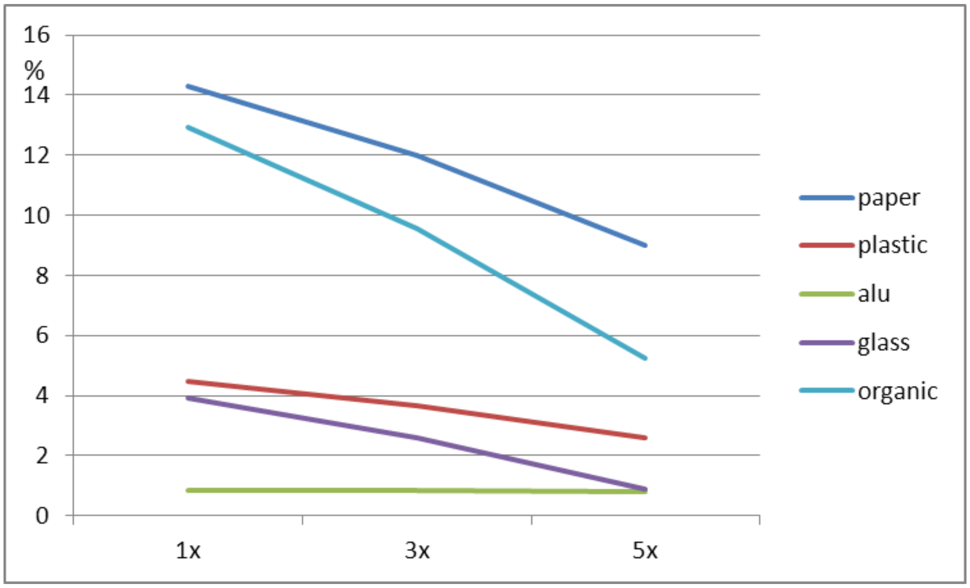
In the case of five times higher selective waste collection rate these numbers have been reduced to 0.90%, 0.78% and 0.72% respectively, so their average is 0.80%.

Glass waste

In case of three times higher selective waste collection for the aluminum: for No. 33. No. 34. and No. 35. the SF was changed from 2.83% down to 1.87%, the MF rates was changed from 4.01% down to 2.65% and the SCBU rates was modified from 4.97% to 3.28% so the average become 2.60%.

In the case of five times higher selective waste collection these numbers have been reduced to 0.63%, 0.90% and 1.11% respectively, so their average is 0.88%.

The composition of the different waste types in the remaining waste is the following if we consider 1x, 3x or 5x higher selective waste collection. The following graph shows that the changes in the waste composition are not linear in spite of the fact that the recycling rate is 3x and 5x higher which is linear. (for example as discussed above the remaining potentially recyclable waste in the mixed waste for example for paper is 14.31%, at 3 times higher selective waste collection the remaining potentially recyclable paper waste is 11.99 %, whereas in case of 5 times higher collection the remaining potential paper is 9.02% in the remaining waste).

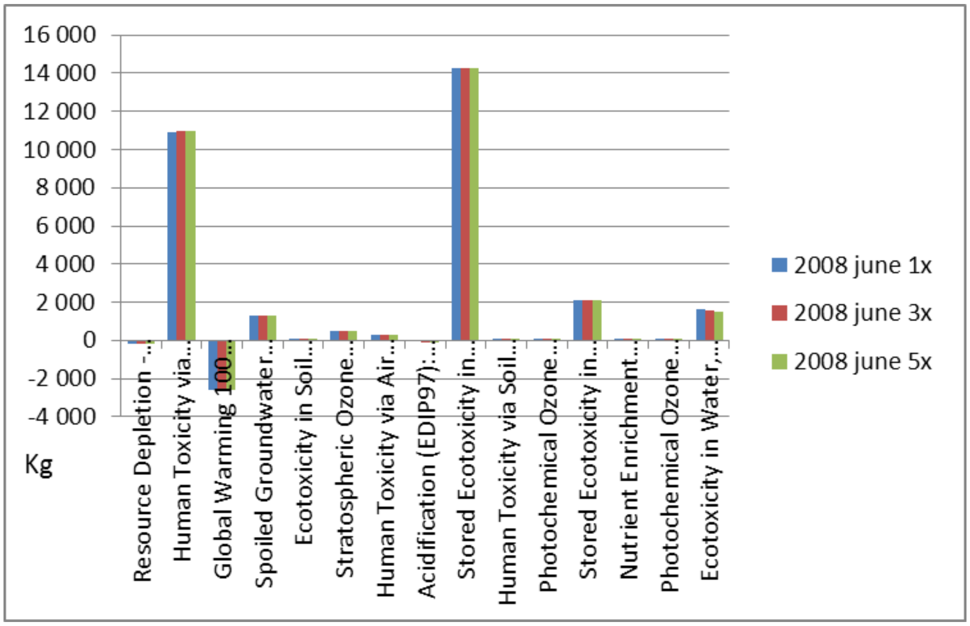


64 Figure Changes in the waste composition of the different waste types in case of 1x,3x and 5x higher recycling rates (%)

LCA results

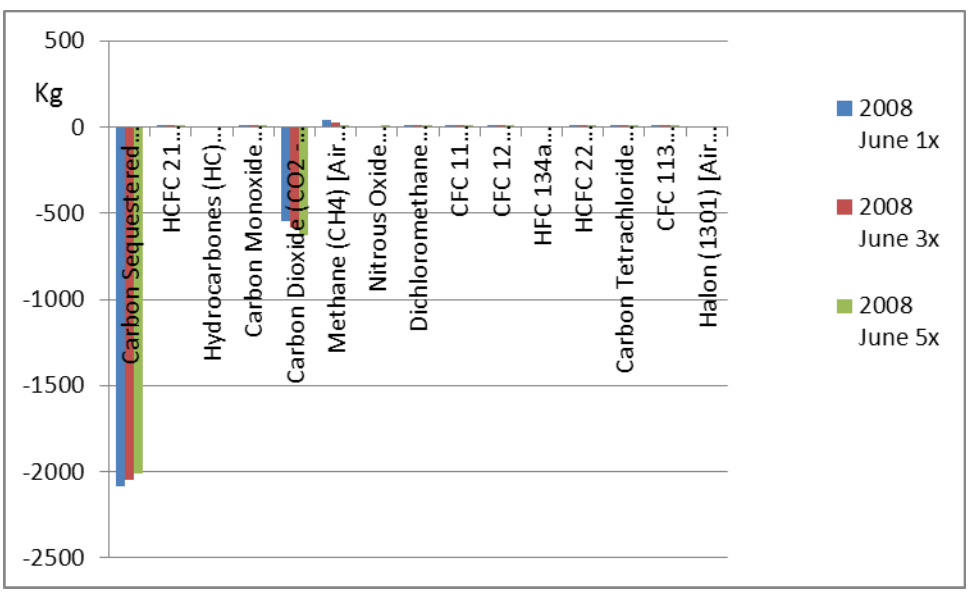
After running the model, larger amounts (which were decreasing) had to be eliminated due to the much higher values, such as: Stored Ecotoxicity in Soil (EDIP): [PE], Stored Ecotoxicity in Water (EDIP): [PE], Spoiled Groundwater Resources: [PE],

The result of the LCA model is the following:



65. Figure LCA model results of the different environmental load in case of 1x, 3x and 5x higher selective waste collection rates, June 2008

Taking into account the global warming potential emissions we can see the following graph:



66. Figure LCA results of the global warming potential emissions in case of 1x, 3x and 5x higher selective waste collection rates, June 2008 (kg)

The following elements contribute to the global warming potential:

1. Carbon Sequestered [Air Emissions]
2. Carbon Dioxide (CO_2 - Fossil) [Air emissions]
3. Nitrous Oxide (Laughing Gas) (N_2O) [Air emissions]
4. Hydrocarbones (HC) [Air emissions]
5. Halon (1301) [Air emissions]
6. HFC 134a (Tetrafluoroethane) [Air emissions]
7. Carbon Tetrachloride [Air emissions]
8. Dichloromethane (Methylene Chloride) [Air emissions]
9. HCFC 21 (Dichlorofluoromethane) [Air emissions]
10. Carbon Monoxide (CO) [Air emissions]
11. CFC 113 (Trichlorotrifluoroethane) [Air emissions]
12. HCFC 22 (Chlorodifluoromethane) [Air emissions]
13. CFC 11 (Trichlorofluoromethane) [Air emissions]
14. CFC 12 (Dichlorodifluoromethane) [Air emissions]
15. Methane (CH_4) [Air emissions]
16. 1,1,1-Trichloroethane [Air emissions]

This list was ranked in order of magnitude of net savings.

HFC 134a still means net savings but from Carbon Tetrachloride the value turns from negative to positive, meaning net emission contributor.

From these elements, through the model the amounts of the following contributors are still nearly zero, and also not significant GHGs, and can be neglected accordingly:

1. 1,1,1-Trichloroethane [Air emissions]
2. HCFC 21 (Dichlorofluoromethane) [Air emissions]
3. Hydrocarbones (HC) [Air emissions]
4. Dichloromethane (Methylene Chloride) [Air emissions]

5. CFC 11 (Trichlorofluoromethane) [Air emissions]
6. HFC 134a (Tetrafluoroethane) [Air emissions]
7. HCFC 22 (Chlorodifluoromethane) [Air emissions]
8. Carbon Tetrachloride [Air emissions]
9. CFC 113 (Trichlorotrifluoroethane) [Air emissions]
10. Halon (1301) [Air emissions]

It is also important to analyze the different treatment processes of the emissions. The different treatment processes were divided to the following:

1. Collection and transport
2. Recycling processes including glass, plastic, paper and aluminum-can recycling
3. Composting
4. Incineration and
5. Landfill

If the one time recycling is considered, than it can be concluded that collection, transport and composting is a net contributor to the emissions, whereas recycling, incineration and landfilling is a net saver, and contributes to avoided impacts.

In order to compare the contributions of each process the following rates can be determined:

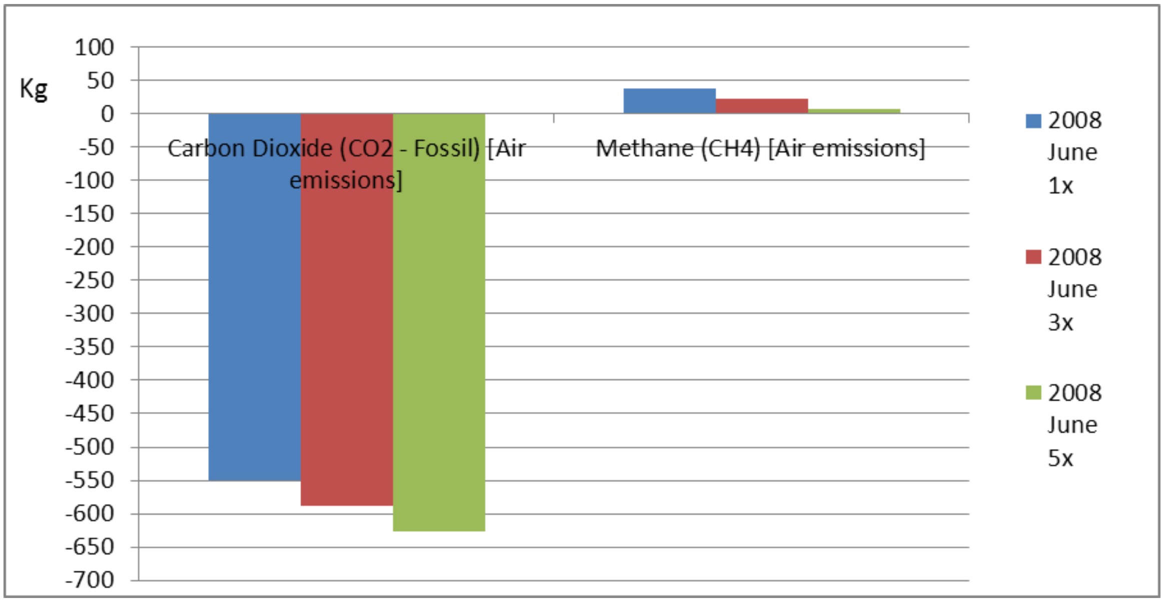
	1x	3x	5x
Collection and transport	-7.16 %	-7.26 %	-7.36 %
Recycling processes	1.53 %	4.56 %	7.57 %
Composting	-0.16 %	-0.50 %	-0.83 %
Incineration	30.78 %	29.94 %	29.10 %

Landfill	75.01 %	73.26 %	71.52 %

59. Table Contribution of the different treatment processes to global warming potential in case of different recycling rates

This table clearly displays that with higher recycling rates the contribution of landfill and incineration processes decreases, however they are the majority of the net savings. The contribution of the recycling process obviously increases with higher recycling rates. The biggest global warming potential savings are caused by carbon sequestration, which is more advantageous if source reduction and recycling of paper products increases, therefore reducing energy consumption and decreasing combustion and landfill emissions. However, it must be stated that there are several uncertainty factors and by eliminating them the calculations may be more precise. These factors are represented for example in the data on recycling facilities, which is not in the scope of FKF Zrt. so they are not able to provide more data on these subjects. Also transport distances may be more punctual and not only estimated, but more time is needed to identify such occurrences.

Taking into consideration the CO_2 and the CH_4 emissions the following graph can be displayed:



67. Figure Carbon dioxide and methane emission in case of 1x, 3x and 5x higher selective waste collection rates, June 2008 (kg)

This graph clearly illustrates that carbon dioxide (fossil) and methane emissions are decreasing if the selective waste collection is higher due to the fact that less waste (less methane) is taken to the landfill between in case of 1x recycling and 5x recycling rate. Methane formation generally takes place at the landfill. For CO_2 distinctions must be made between the fossil CO_2 and the biogenic CO_2. For the fossil CO_2 there is a large advantage if recycling is higher due to the fact the different recycling methods results in smaller amount, because of the fact that the virgin production releases more CO_2 than the similar amount released during secondary production.

It is also useful to relate the proportion of each treatment process to CO_2 and methane emissions. The following table shows the proportion in the case of rates 1x, 3x and 5x times higher than current rates.

CO_2	1x	3x	5x
Collection and transport	-32.71 %	-31.19 %	-29.83 %
Recycling processes	6.20 %	17.34 %	27.17 %
Composting	-0.52 %	-1.45 %	-2.26 %
Incineration	101.30 %	92.18 %	84.12 %
Landfill	25.73 %	23.12 %	20.8 %

60. Table Contribution of each treatment process to CO_2 emission at different recycling rates, 2008 June (%)

The CO_2 emission is negative, showing net savings. Incineration contributes the most to this saving (decreasing by higher recycling rates), and landfilling has the second greatest impact. However, in case of 5 x times higher recycling rate, the recycling process has a larger contribution to savings than landfilling. Collection and transport does not have great influence on CO_2 emissions, mostly because the same distances are used in all of the cases. The amount of CO_2 decreases with higher recycling rates.

Also the landfilling phase displays a significant advantage for CO_2 if recycling is higher. For the biogenic CO_2 it can be stated that there is not any significant difference between 1x and 5x higher recycling rates, mainly due to the fact that there are no changes in organic waste treatment.

CH 4	1x	3x	5x
Collection and transport	12.85 %	21.85 %	69.9 %
Recycling processes	-14.07 %	-70.27 %	-368.25 %

Composting	0.33 %	4.83 %	25.22 %
Incineration	-607.91 %	-1002.66 %	-3109.97 %
Landfill	708.80 %	1146.25 %	3483.1 %

61. Table Contribution of each treatment process to CH_4 emission at different recycling rates, 2008 June (%)

In the case of methane emissions it must be stated that it is positive, representing a net contributor, due to the huge amount of emissions from the landfill. The amount of CH_4 decreases with higher recycling rates. However, the amount of the methane is drastically decreased with higher recycling rate, so the proportion of landfill contribution to the larger amount of methane in the case of 1 x selective collection is high, but the proportion of the landfill in case of 5 x times higher selective collection rate is not a real rate as it is compared to a much smaller amount of methane emissions. Therefore, the proportion of landfilling to the methane amount in the 1x collection was also calculated which is 708.8 % in case of 1x selective waste collection, 682.8 % in case of 3 x times higher selective waste collection rate and 661.4 % in the case of a 5 x higher selective waste collection rate. All of them were compared to the methane amount in the first case. It can be concluded that recycling process decrease methane contributions.

10.3 Interpretation of results

From the model the excel tables can be obtained for substance LCA, normalization results and also for the different processes. Observing these tables and after analyzing the model run for the higher recycling cases the following can be stated **including the analysis of the different treatment methods**:

1. If the selective waste collection rate is higher, then the methane, CO_2 (fossil) and CO emission are visibly smaller, mostly because less waste is transported to the landfill and recycling is higher.
2. From these three greenhouse gases CO_2 (fossil) and methane are dropping considerably (as less waste is transported to the landfill), while CO shows a slight decrease. In terms of CO it is partly increased in the case of incineration, but dropped in a huge amount in the case of paper, aluminum, and glass recycling but decreased in a large amount in the case of landfilling if recycling is higher.
3. The nitrous oxide (laughing gas) is increasing with the increased selective waste collection as more N_2O is transferred to the composting site and this is the main contributor to N_2O.
4. Nutrient enrichment is very high in case of the non-selective waste transport, so it decreases with high rate of selective waste collection. It is caused by NOx, phosphate and ammonia. If there is more transport applied due to increased selective recycling it is assumed that this value would increase.
5. Ecotoxicity in water is caused by the transport of the non-selective waste as well as well as landfilling. It is evident that this value decreases with high selective collection. The main factor for this is PAH (Benzo{a}pyrene TEQ) and mercury as well as Cd, Zn and Sr. Higher transport distances would increase the amount here as well.
6. The amount of the CFC 12 and the CO is not changing significantly with the different selective waste collection rates.

7. Taking into account resource depletion, landfilling is one of the biggest contributors, so in the case of higher recycling rate the value is more beneficial, while at incineration is does not change significantly. It is explained that the selective collection saves resources that would else end up at the landfill and so would be lost for recycling.
8. Landfilling is responsible for stored ecotoxicity in soil, stratospheric ozone depletion, nutrient enrichment, ecotoxicity in water, human toxicity via air, human toxicity via water, spoiled groundwater resources etc. However in case of carbon sequestration landfilling is beneficial as it stores biogenic carbon in the waste (such as lignin in paper) and so it will not be degraded, not combusted so not contributed in the calculation.
9. Incineration is usually beneficial as the coal is replaced, but at human toxicity via water this is far the worst disposal method taking into account either the smallest or the biggest recycling rate. This is caused by mercury first and dioxins secondly can result in lead and cadmium follow. This can be mitigated with better air pollution control. In the US the main contributor to mercury is coal combustion and back yard burning at the moment. (Damgaard pers.comm. 2012.)
10. Spoiled groundwater resources are caused by landfilling. For this toxicity ammonia is the main contributor. Partly phosphates, chloride, xylenes and ethyl benzene can be mentioned. It is obvious therefore that with higher recycling rate this value is smaller, since these emissions are caused by the above mentioned chemicals which instead of landfilling are redirected with increased selective collection.

11. Human toxicity via air is mostly caused by VOC Diesel Engine and lead in case of transport and partly landfilling and therefore the value is increasing with higher transport rate.

    In the global warming potential carbon sequestered is far the biggest amount in the negative side. This is due to the reason that a large amount of recalcitrant biogenic carbon in the waste (such as lignin in paper) is landfilled and will not degrade and contribute to the savings. The overall performance of the landfill is directly connected to whether the methane formation is properly controlled or not. In a waste-to-energy plant this biogenic carbon will be released and assumed zero (due to the biogenic circle assumption). (Damgaard pers.comm. 2012) However, it gains credits from the energy substitution, but on the other hand the WTE releases the fossil part of the waste carbon which impacts global warming potential. This fossil carbon is not considered a storage in a landfill, but as its not combusted it will not contribute to a release. Thus it comes very important what amount electricity the incinerator can avoid. (Damgaard pers.comm. 2012)

12. For acidification the greatest contributor is the fuel consumption for the non-selective waste, as well as landfilling and composting and the largest savings are made by incineration and plastic and paper recycling. Therefore its value decreases with higher selective waste collection.

13. Stored ecotoxicity in water is caused by landfilling, and in detail caused by copper, lead and cadmium, which are left in the landfill at the end of the time period set for calculations, so with increased recycling it can be a little bit diminished.

All in all it can be summarized that this research also justifies what others have already stated (USEPA 2002; Gentil 2011; Bogner *et al.* 2007; European Environmental Agency 2011b.) that selective waste collection and recycling mitigates the environmental load, including global warming potential, while landfilling is a serious contributor to the different environmental impacts. In the Waste Framework Directive landfilling is the least desired option, and in the developed EU Member States landfilling is not a common practice any more.

One of the most important messages learned from using LCA models on waste management systems is that waste management systems actually are fairly sound in terms of recovering resource and restricting environmental emissions.

Global warming potential always seems to be of importance, but also toxic categories may be important where emissions to air are significant. The high CHP energy production from the waste incinerator and the energy savings from paper and glass recycling yielded a significant saving in global warming potential (CO_2 –fossil) assuming that the saved energy originates from the replacement of a traditional coal based power plant. The high human toxicity impact from the incinerator has since been decreased by improved flue gas cleaning. The use of person-equivalence as the unit for potential impacts also provides some possibility to assess the overall magnitude of the impacts from waste management. A well designed and operated waste management system is thus not a major contributor to the environmental load.

If global warming potentials is in the political focus, LCA of waste management systems will reveal that energy utilization and recycling in the waste management system is a key issue. This is as direct energy recovery which partly originates from replacing fossil fuels at combustion and indirectly by recycling of material fractions by replacing the reliance virgin materials for creating new products. If the energy content is efficiently utilized then energy which is necessary for the collection and treatment can be neglected, however if the energy is not properly utilized then energy spent in the collection is an important contribution to global warming. An LCA assessment of a waste management system can be uncertain if not carried out properly with respect to both the system (definition and boundaries) and the data used. It is very important to use the actual waste flows as accurately as possible and ensure that a sensitivity analysis is performed to address the significance of parameters and also to data possessing large scale of uncertainty. In this way, the LCA modeling is accepted by experts in several fields and LCA model results can become a balanced platform for educated decision making.

11 Conclusion

The overarching aim of the present research was to elaborate the environmental assessment of Budapest's solid waste management systems, which included the LCA evaluation as well. LCA is a tool for comparing goods and services (products) and for identifying opportunities for reducing the impacts attributable to associated wastes, emissions and resource consumption. It also recommends fields where the technologies and the mitigation opportunities can be analyzed related to the different environmental load.

Since the research had been finished it is recommended to analyze whether the research objectives have been fulfilled and in addition it is necessary to draw some conclusion.

Research question.

What is the nature and capacity for recycling in Budapest and its impacts on environmental pollution including climate change?

Research assumptions were the following:

Assumption 1.

It is assumed that the environmental pollution can be evaluated in more detail if several months and years are analyzed instead of one year.

Assumption 2.

The research assumes that the data and information that are given to prepare the EASEWASTE model are sufficient, proper, correct and realistic. However, at many cases it is necessary to double check them.

In the present document this issue has been discussed and it can be stated that the data for the Budapest selective waste collection is correct. Some data was missing during the study but in such cases calculated estimations and compatitive data was utilized.

Assumption 3.

It is assumed that the waste generation per capita is different in case of multi family, single family and SCBU cases. During the discussion of the waste amount and waste composition this has been described in detail.

Research aims

Overall aim: To prepare the environmental assessment and policy options for the present and expected municipal solid waste management systems of Budapest. This research used the EASEWASTE model for this assessment. According to the results of the different scenarios in the environmental assessment a discussion with the key stakeholders about their perspective and preferred options was made.

Objective 1.

To acquire the necessary inputs which are required for modeling the Budapest solid waste system.

Objective 2.

Determine the major desirable alternatives taking into account higher recycling rates and run the EASEWASTE model for them.

Objective 3.

Discuss the findings with the key stakeholders, aiming to determine their perspectives and preferred options.

Based on the above research question, objectives and assumptions the research has been completed and the thesis is able to conclude the answers to them. From the results one can make a conclusion, that the model is effective in determining the most important aspects for decision-making in relation to the different potential impact to the environment.

Conclusion of the research for the research question:

The research results have evidently answered the research question. It clearly displays and proves what **the main characteristics of recycling in Budapest** are, and what the **potentials for higher recycling rate** are. The thesis numerically proved **the impacts of the waste management system on environmental pollution including climate change,** showing that with **higher recycling rates environmental pollution is decreasing** and also **higher recycling rates mitigate global warming potential.** This result has also been justified by other research (USEPA 2002; Gentil 2011; Bogner *et al.* 2007; European Environmental Agency 2011b.)

Conclusion of the research for the research assumptions:

Assumption 1.

The research has showed that the environmental pollution can be analyzed in more detail if different months in different years are compared to each other instead of solely annual data.

In the thesis the following trends were analyzed:

a. trends in time (for selective waste collection from 2006-2011, and for the LCA assessment from 2008-2011) and also
b. trends in the amount of the selective, non-selective and total waste in detail.

Assumption 2.

After several consultations it became clear what exactly the obtained data covers. However, in the technology some data was missing, as it was not previously measured in Hungary. This missing data was discussed with the Danish professors, especially Prof. Anders Damgaard, who is the external member of the committee. In such cases mathematical methods were used to determine these values.

Assumption 3.

This issue is discussed in detail in case of the Budapest waste composition and needs further investigation.

Conclusion of the research for the research objectives:

Overall aim: The environmental assessment and policy options have been made for the Budapest solid waste management system with the EASEWASTE model.

It has been proved that EASEWASTE model is an appropriate tool to analyze the Budapest solid waste management system with life cycle assessment. The model verified that higher selective waste collection decreases environmental pollution.

It became clear that the difference between the amount of the collected selective waste and the amount of recyclables left in the mixed waste is significant.

Objective 1.

During the collection of the necessary inputs it was the first time when Budapest waste composition was analyzed is such detail. Never before was any composition analysis for 48 waste fractions carried out. This was prepared by request of the author for the purposes of this thesis. The methodology for the 48 waste fractions composition can be used therefore in any other cities in Hungary in the future.

In addition, based on the obtained data, the author's own contribution is also a draft map on the Budapest waste collection points, which has to be further developed in an electronic system and that be used by residents of Budapest seeking to place their waste in an environmentally proper way.

Furthermore, the following statements can be concluded after analyzing the rate of the selective waste collection system:

1. Taking into consideration the solid waste management in Budapest we can state the following amounts for paper, plastic, aluminum cans, glass and organic waste:

	2006	2007	2008	2009	2010
Amount of selective waste (t)	21 045	24 991	33 270	39 542	45 264
Amount of total waste (t)	730 288	688 171	691 586	661 405	668 711
Percentage % (selective/total)	2.88	3.63	4.81	5.97	6.76

62. Table Rate of the selective waste collection for waste fractions, 2006-2010

It means that the selectively collected waste is around only 4.8% of the total waste. Selective collection of organic waste has increased rapidly from 0.58% (2006) to 3.23% (2010). The rate of the selectively collected paper has not raised significantly from 1.24% (2006) to 1.97% (2010), the same for plastic from 0.37% (2006) to 0.65% (2010), and even the glass from 0.71% (2006) to 0.93% (2010) and it is true for the aluminum can as well, as the rate was slightly increased from 0.04 % (2006) to 0.06% (2010).

2. In spite of the fact that the amount of the selectively collected waste is slightly increasing, it is still a very low amount.

3. There is a significant amount of waste from inhabitants which can be further recycled. In case of paper the selectively collected waste is 9% of the non-selectively waste (which is basically can be found in the mixed waste), as the rate is 4% at plastic, also 4% at aluminum and 28% at glass. It is a huge loss in terms of potential environmental savings as well as business aspects.

4. A very interesting issue is uncovered in analyzing how many extra kilometers and liters are needed to collect the recyclable waste from the inhabitants in the present management system. Evaluation and optimization of the waste collection routes, and associated fuel consumption and distances is a topic of a further research.
5. The majority of selectively collected waste has been done via waste islands and the rate of the door-to-door collection is very low. It has to be increased, and hopefully the new EU co-financed tender will contribute to an increased rate of door-to-door collection.
6. Very often the waste islands are burned down or the waste is stolen, but this will be strictly controlled and strongly punished by the new Waste Law. This is somewhat of a social issue. It may be able to be proven that lower income citizens are often those who tamper with waste bins in attempt to turn their contents into funds which can be utilized to buy basic items. At the moment there are no any social programs which can employ people to retrieve waste, providing a livelihood and supporting waste management.
7. The selective waste collection in the waste islands and in the waste yards has not increased significantly in the last years.
8. The PR activities of FKF Zrt. are increasing, however in many cases the inhabitants are under informed or not even motivated to use the selective waste collection system. Hopefully the new Waste Law will ameliorate this process, taking into account that selective waste collection will be mandatory from 2015.

Objective 2.

The major desirable alternatives, as discussed by the key stakeholders of FKF Zrt., were the LCA evaluation of the environmental impacts of higher selective waste collection, as included in this thesis.

Objective 3.

During the discussion of the findings the higher recycling rates were mentioned.

When calculating the potential higher recycling rates it was very important that the composition of the different waste fractions were changed in the mixed waste to reflect this.

The composition of the different waste types is the following in the mixed waste for the potential amounts: as in case of paper it was 14.31% in case of 1 times selective waste collection which is the current status, and it becomes 11.99% in the case of three times higher selective waste collection and becomes 9.02% paper waste in the mixed waste if we take into account 5 times higher selective waste collection. The same is relevant to plastic (4.47%, 3.65% and 2.61%), or aluminum (0.86%, 0.83% and 0.8%), glass (3.94%, 2.6% and 0.88%) and organic waste (12.91%, 9.55% and 5.23% respectively). The remaining rates are not linear, while the increased rates are linear.

Several key stakeholders also desired to make options for waste transfer stations but later no more information was provided regarding this issue. The Head of the Environmental Department desired to apply the EASEWASTE model in their operation in the future regularly and if possible, apply it for other state owned institutions in Budapest. Taking into account FKF Zrt. the model recommends that a large waste treatment institution, such as FKF Zrt., should collect the data regularly (at least monthly) and the waste composition is recommended to be analyzed for these 48 fractions. Sampling is suggested to be made more often and not only once a year. In the future nationwide representative sampling should be required.

Other important findings:

1. Data inaccuracy is common not only in Hungary but in other countries as well, in many cases the official sources provide different data for the same waste types.
2. It was assumed that a rigorous evaluation of uncertainty and variability would be useful, but it is out the scope of this research. It is encouraged that readers seek more accurate information where it is available.
3. Hungary has to accomplish the EU recycling rates by the end of 2012 for given waste fractions. The National Waste Management Agency Nonprofit Ltd. is solely responsible for these waste types and has the reporting obligation to the EU. The Agency is continuously reviewing the amount of the collected and recycled waste types and set the recycling rates, which are realistic as to be enough for the EU requirements. In September 2012 it seems that in terms of paper, the amount will be enough, plastic and aluminum cans can be found in the Hungarian market, and wood packaging waste can also be fulfilled. Hungary has particular problem with glass recycling. Therefore the glass recycling rate should be increased. It seems

that paper and wood packaging were collected in a higher amount than expected before. The waste management sector produces the following GHG emissions:

a. CO_2 emissions associated with composting,

b. non-biogenic CO_2 and nitrous oxide (N_2O) from combustion, and

c. CH_4 emissions from landfills; (USEPA 2002).

4. Landfilling is a serious contributor to the different environmental impacts, in many cases landfilling had the biggest environmental pollution among the waste management types. Door-to-door collection is the most favorable in terms of the environmental aspects, and even better than the selective collection with waste yards. (USEPA 2002) The reason for that is that if the waste is clean, there is no need to perform post separation and even the fuel consumption of the collecting vehicles is lower for the public cleaning service company compared to the collecting vehicles when the inhabitants take the waste individually.

5. Source reduction usually represents a possibility to reduce GHG emissions to a significant extent. Several LCAs showed that for most materials, recycling has the second lowest GHG emissions, due to the reduction of energy-related CO_2 emissions in the manufacturing process and therefore avoids emissions from waste management. Paper recycling increases the sequestration of forest carbon.

6. The net GHG emissions from composting are lower than landfilling for food discards (composting avoids CH_4 emissions), and higher than landfilling for yard trimmings – depending on gas management. Landfilling is credited with carbon storage that results from incomplete decomposition of yard trimmings. Composting is a management option for discarded food and yard trimmings.

Overall, given the uncertainty in the analysis, the emission factors for composting or combusting these materials are similar (USEPA 2002).

7. It is justified by the European Environmental Agency (2010a.) also, which states that in 2008 in the European Union, recycling of municipal solid waste avoided emission of about 47 million tons of CO_2-equivalent from being created by reducing the demand for primary resource sources.
8. The net GHG emissions from combustion of mixed MSW are lower than landfilling mixed MSW (under national average conditions for landfill gas recovery). The reason is that combustors and landfills manage a mixed waste stream, and the net emissions are determined by technology factors rather than by material characteristics. Material specific emissions, nevertheless, in the case of landfills and incinerators are suitable for comparing the alternatives including source reduction, recycling, and composting. The scope of this report is limited to analyzing emission factors in terms of GHG as a consequence of solid waste decisions. Nevertheless, the differences in emission factors in the different waste management options are large enough to emphasize GHG mitigation policies in the waste sector (USEPA 2002.)
9. Miliūtė (2009) suggests implementing not only the landfill tax but the incineration tax also, which can be a useful tool in Hungary taking into account the priorities of the waste hierarchy.
10. It is assumed (and proven by several equations) that the inhabitants have a different waste generation (kg/capita) rates in case of single family houses, multi

family houses and institutions, but the exact rate can be determined only after further research.

11. This study analyzed the GHG emissions in a higher rate of selective waste collection with the same fuel consumption. It did not make calculations for greater distances (km), however, it was assumed that the inhabitants can reach higher selective waste collection and higher recycling rates. Results clearly showed that higher selective waste collection drastically mitigates the GHG emission in terms of methane respectively.
12. It is still not clear how many tons of selective waste one vehicle can collect and how many kilometers are necessary for one route. This process should be analyzed and optimized in the future.
13. In several cases the Hungarian waste management facilities were not able to provide the necessary data (in case of MRF's, incineration, composting and landfilling), so a weak point of the research is the lack of proper data provision from the FKF Zrt.
14. The present thesis analyzed the trends in Budapest solid waste management, so can most likely bear some technically incorrect data.
15. It is recommended that several Hungarian facilities should measure more values which influence the environmental load. In the Danish model there were several more values which were not detected in Hungary (marginal energy production, TMT 15, polymers, marginal heat production, and several others).
16. It may be useful to analyze the chemical characteristics of the different waste types, as due to the lack of Hungarian measurements it was necessary to count on

Danish laboratory values. (for instance selenium, magnesium, chloride content of the given amount of waste fraction).

17. It can be useful to draw the waste map of Budapest, taking into account the waste generation per capita, the location of the waste islands, waste collection yards and door-to-door collection as well as waste processing facilities. This process would give the key stakeholders a tool to optimize their location, and additionally the inhabitants of the capital would be provided help in locating their waste if required.

18. Interesting analysis can be performed to evaluate the consumption habits by seasons and by regions.

12 Limitations, recommendations for future research

The life cycle assessment of a waste management system is a very complex environmental problem. It is out of the scope of this thesis to evaluate the interrelated connection of the environmental impacts (such as in case of the climate change it is the sea level rising, meteorology, or even carbon credits). This thesis does not include the financial part of waste management systems but it recommends fields where the technologies and the mitigation opportunities can be analyzed related to the different environmental load. Decision making should be based on the interpretation of both the environmental and the economic results. This thesis does not include the evaluation of the financial part of the life cycle assessment and it also can be evaluated in a further stage.

Other limitations of the model according to Kirkeby (2006) are that each treatment or disposal method has a restricted set of emission recipients and residue output flows, so no additional recipient or residue can be added. An additional limitation is that the EASEWASTE model with its current EDIP methodology does not include impacts such as area occupation, working environment, costs, social acceptability, human environment etc. as Kirkeby (2006) emphasized, and these impact areas must be evaluated separately when it is important.

EASEWASTE is demonstrated to be a versatile and detailed (engineering) model with a strong differentiation of individual fractions, but it requires an engineering background to use all the features. The model is especially developed for the modeling of the handling of municipal solid wastes, and therefore, it does not support other wastes such as demolition and large commercial waste.

EASEWASTE has been used in the modeling of a number of real case studies, and much data has been incorporated into it. Several research projects are currently underway under the Danish 3R (Residual Resources Recovery) research school in support of its further development. There are, however, still many issues that have to be improved significantly to facilitate application by other users other than model developers. (Bhander *et al.*2010).The improvements in consideration are to provide data for more treatment and disposal technologies and more flexibility.

The current version of the model supports the environmental assessment (environmental impacts and resource consumption) of household and small commercial business units waste treatment systems in a Danish context, but hopefully the future versions of the model shall support the inclusion of other waste types as well as economic evaluation, and be adjustable so that geographical coverage can be extended to other countries.

In terms of Budapest solid waste management, further research is recommended for the improvement of the selective waste collection and recycling, which is in line with the waste hierarchy. It is necessary in order to optimize the collection routes, analyze its efficiency, fuel consumption and to recommend effective door-to-door collection for the future developments.

LCA evaluation in EASEWASTE is also appropriate to analyze the following issues among others: the water content of the paper material, which fraction has the smallest and the largest diesel consumption, indications of air emission of Hg. and dioxins in the case of thermal treatment, which are the most important substances for toxic impact categories, how much digested material is produced at the biogas facility (if Budapest hopefully will have one), what the yearly infiltration is in a landfill, which leachate substances are the most crucial regarding the groundwater pollution, how the landfill results in case of flaring will be replaced by biogas treatment, and how much Hg is brought to the landfill during one year etc. etc. These issues are presently out of the scope of the present thesis, but it would be useful to analyze them.

EASEWASTE was successfully used in every stages of the waste hierarchy, including the detailed analysis of waste prevention, re-use, recycling, thermal treatment and landfilling. The model is appropriate to analyze these steps individually, a process which can be useful for the Hungarian waste management system in the future.

The thesis examined higher recycling rates in the same amount, but it can be interesting to analyze the LCA results in the case of increased recycling rates, which increase by different factors (for instance two times higher recycling rates at paper and 10 times higher recycling rates at aluminum and three times more in case of glass). In this way it can be visible for every waste type, regarding what rate the increased selective waste collection decreases the different respective environmental pollution individually.

13 References

Abeliotis K., Karaiskou K., Togia A., and Lasaridi K., 2009. *Decision support systems in solid waste management: a casestudy at the national and local level in Greece.* Global Nest Journal, Vol 11, No 2, Pp 117-126

Abeliotis, K. 2010. *Life Cycle Assessment in Municipal Solid Waste Management* Harokopio University Greece

Ágnes Szintai-Katona, National Waste Management Agency Nonprofit Ltd. personal communication 6.05.2012

Anil, K. G. and M, Yunus. 2004. *India and the WSSD (Rio + 10),* Johannesburg: Issues of national concern and international Strategies, Current Science, Vol. 87, No. 1, 10 July 2004

Al-Salem S.M. and Lettieri P. 2009. Life Cycle Assessment (LCA) of Municipal Solid Waste Management in the State of Kuwait. *European Journal of Scientific Research* ISSN 1450-216X Vol.34 No.3 (2009), pp.395-405

Balatoni, H. 2012. Chief, managing director of Fe-Group Invest Zrt. Email communication 19. July 2012.

Bánhidy, J. Director of the Rákospalota waste-to-energy plant. Budapest. Personal communication.05. December. 2008

Barton, J.R., Dalley, D., and Patel, V.S. 1996. 'Life cycle assessment for waste management', *Waste Management*, 16, 1-3, 35-50.

Bartus A. 2009. Expert at the waste management department of the Middle - Danube - Valley Inspectorate for Environmental Protection, Nature Conservation and Water Management. Telephone conversation 20.02.2009.

Bartus G. PhD, 2010. *A megelőzés indikátorai (Waste prevention indicators)*. BME Környezetgazdaságtan Tanszék, CHIRON Tanácsadó Bt.

Basiago, A. D., 1995. *Methods of Defining 'Sustainability'.* (Sustainable Development, pages 109-119), John Wiley, Chichester, UK.

Barlaz M. A., and Weitz K.A. 1995. *Life-Cycle Study of Municipal Solid Waste Management,* System Description, EPA Cooperative Agreement 832052, Barlaz M., Camobreco V., Repa E., Ham R., Felker M., and Rousseau C. 1999. *Life cycle inventory of a modern municipal solid waste landfill.* Proceedings Sardinia 99. Cagliari, Italy CISA;

Beigl P., and S. Salhofer. 2004. Comparison of ecological effects and costs of communal waste management systems. *Resources, Conservation and Recycling*, 41, 83-102.

Bellinger E., Lee N., George C., and Paduret A. 2000. *Environmental Assessment in Countries in Transition* Central European University Press Budapest, Hungary

Benkő T. 2008. *Az életciklus-elemzés integrálása a környezettudatos folyamattervezési gyakorlatba* [Integrating life cycle assessment into the environmental process planning practice]. Budapesti Műszaki és Gazdaságtudományi Egyetem Kémiai és Környezeti Folyamatmérnöki Tanszék. Budapest

Benson, C.H., Barlaz, M.A., Lane, D.T. and Rawe, J.M. 2007. Practice review of five bioreactor/recirculation landfills. *Waste Management*, 27, 13-29.

Bernstad, A., and la Cour Jansen, J. 2011. A life cycle approach to the management of household food waste – A Swedish full-scale case study. *Waste Management.* In Press. doi:10.1016/j.wasman.2011.02.026

Bhander, G., Christensen, T. and Hauschild, M. 2010. EASEWASTE—life cycle modeling capabilities for waste management technologies. *The International Journal of Life Cycle Assessment*, Volume 15, Number 4 403-416, DOI:10.1007/s11367-010-0156-7

Biczó, I. 2012. Életciklus szemlélet alkalmazása a hulladékgazdálkodásban [Using Life Cycle Assessment in the waste management]. Presentation 13.06.2012. Gödöllő

Björklund, A., and Finnveden, G. 2005. Recycling revisited—Life cycle comparisons of waste management strategies. *Resour. Conserv. Recycl.*, 44_4_, 309–317.

Björklund, A. and C. Bjuggren. 1998. Waste modelling using substance flow analysis and life cycle assessment. *Air & waste management association's annual meeting, San Diego,* (1998), p.16

Bogner, J., M. Abdelrafie Ahmed, C. Diaz, A. Faaij, Q. Gao, S. Hashimoto, K. Mareckova, R. Pipatti, and T. Zhang. 2007. *Waste Management, In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Boldrin, A., Andersen, J.K. and Christensen, T.H. 2011. Environmental assessment of garden waste management in the Municipality of Århus (EASEWASTE). *Waste management*, 31 (7), 1560-1569. doi:10.1016/j.wasman. 2011.01.010

Borsi Zs. 2010. Energetic manager of the Budapest Waste-to Energy Plant. Formal interview 20. 10. 2010.

________2012a. Energetic manager of the Budapest Waste-to Energy Plant. Email communication 23. 02. 2012.

________2012b. Energetic manager of the Budapest Waste-to Energy Plant. Personal communication, conversation 4. 06. 2012.

Calabro P.S. 2009. Greenhouse gases emission from municipal waste management: The role of separate collection. *Waste Management.* 29. 2009. p. 2178–2187

CEWEP http://www.cewep.eu/media/www.cewep.eu/org/med_557/852_2011-12-12_cewep_-_landfill_taxes__bans_webiste.pdf

Choate, A., Pederson, L., Sharfenberg, J., and Ferland, H. 2005. *Waste Management and Energy Savings: Benefits by the Numbers*. US EPA, Washington DC, USA.www.epa.gov/climatechange/wycd/waste/downloads/Energy%20Savings.pdf

Christensen. T.H., Bhander G., Lindvall H., Larsen A. W., Fruergaard T., Damgaard., Manfredi S., Boldrin A., Riber C. and Hauschild M. 2007. Experiences On The Use Of LCA-Modeling (EASEWASTE) *In Waste Management and Research June.* 2007. vol. 25 no. 3 257-262

Christensen, T.H., Gentil, E., Boldrin, A., Larsen, A.W., Weidema, B.P., and Hauschild, M .Z. 2009. C balance, carbon dioxide emissions and global warming potentials in LCA-modelling of waste management systems. *Waste Management and Research.* 2009 Nov;27(8):707-15. Epub 2009 May 7.

Clift, R., G. Finnveden and A. Doig. 2000. *The application of LCA to integrated solid waste management.* Trans IChem-E, 78 part B, (2000), p.279:287.

Cox J., Giorgi. S., Sharp V., Strange K., Wilson D.C., and Blakey N. 2010. Household waste prevention – a review of evidence. *Waste Management and Research* 2010: 28: 193–219

Curran, Mary Ann, 1996. *Environmental Life Cycle Assessment.* McGraw-Hill. New York

Dienes T. 2011. Előtanulmány a Magyarországon alkalmazható hulladék-megelőzési indikátorokról [Pre-study on the waste prevention indicators in Hungary] Humusz, Budapest

Directive 2000/76/EC of the European Parliament and of the Council of 4 December 2000 on the incineration of waste **(**http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32000L0076:EN:HTML**)**

Damgaard, A. 2006. *Comparative assessment of LCA-modelling of solid waste systems: DST & EASEWASTE*, Master Thesis, Institute Of Environment & Resources, Technical University Of Denmark;

Damgaard A., Manfredi S., Merrild H., Stensøe and H. Christensen. 2011. LCA and economic evaluation of landfill leachate and gas technologies, *Waste management* Volume 31, Issue 7, July 2011, Pages 1532-1541

Dawkins E., and Allan P. 2010. *Landfill ban investigation*. Department of Sustainability, Environment, Water, Population and Communities Hyder Consulting Pty Ltd Final Report —ABN 76 104 485 289

EASEWASTE webpage, Danish Technical University http://www.easewaste.dk/index.php?option=com_content&task=view&id=19&Itemid=19 (cited at 15. 09. 2009)

EC 1985. Directive 85/337 EEC on Environmental Impact Assessment as amended by 97/11/EC and 2003/35/EC and 2009/31/EC (http://ec.europa.eu/environment/eia/eia-legalcontext.htm) (cited at 11. 09. 2012)

_______1994. European Parliament and Council Directive 94/6/EC of 20 December 1994 on packaging and packaging waste

_______1999. Council Directive 1999/31/EC on the landfill of waste. Official Journal of the European Communities, L 182/1.

_______2005a. Thematic Strategy on the prevention and recycling of waste. Communication from the Commission to the Council, the European Parliament, the European economic and social committee and the committee of the regions.COM(2005) 670. 22 pp.

_______2005b. Taking sustainable use of resources forward: A Thematic Strategy on the prevention and recycling of waste. Communication from the Commission to the Council, the European Parliament, the European economic and social committee and the committee of the regions.COM(2005) 666. 32 pp

_______2005c. Directive 2005/20/EC of the European Parliament and of the Council of 9 March 2005 amending Directive 94/62/EC on packaging and packaging waste

_______2005d. Taking sustainable use of resources forward: A thematic strategy on the prevention and recycling of waste."COM (2005) 666, Brussels, Belgium.

_______2008. Waste Framework Directve. Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain directives.28 pp. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:312:0003:01:EN:HTML [cited 17 July 2012]

_______2011. Roadmap To A Resource Efficient Europe. 2011. Communication From The Commission To The European Parliament, The Council, The European Economic And Social Committee And The Committee Of The Regions. /* Com/2011/0571 Final */Brussles. /* Com/2011/0571 Final */ 20/09/2011

Environment Agency. 2010. *Waste acceptance at landfills*. Guidance on waste acceptance procedures and criteria. Environment Agency Rio House Waterside Drive, Aztec West. November 2010. http://a0768b4a8a31e106d8b0-50dc802554eb38a24458b98ff72d550b.r19.cf3.rackcdn.com/geho1110btew-e-e.pdf (cited 18 September 2012)

Esterberg, K. 2002. *Qualitative Methods in Social Research.* Boston: The MacGraw-Hill Companies.

European Environmental Agency. 2010a. *The European Environment State And Outlook 2010 Material Resources And Waste.* EEA, Copenhagen. Publications Office of the European Union

_______2010b. EEA greenhouse gas data viewer.European Environment Agency. http://www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer (cited 27 February 2012)

_______2011a. *Projections of Municipal Waste Management and Greenhouse Gases.* ETC/SCP working paper 4/2011.European Topic Centre on Sustainable Consumption and Production. Copenhagen

_______2011b. *Waste opportunities Past and future climate benefits from better municipal waste management in Europe.EEA*, Copenhagen. Publications Office of the European Union

_______2011c. http://www.eea.europa.eu/data-and-maps/figures/municipal-waste-generation-per-capita-in-western-europe-eu-15-new-member-states-eu-12-eu-countries-eu-27-and-total-in-europe-eu-27-turkey-croatia-norway-iceland-switzerland-4 (cited 15 April 2012)

Eurostat Newsrelease 37/2011 8 March 2011

Edwards, D. W., and Schelling, J. 1996. *Municipal waste life cycle assessment. Part 1: An aluminium case study*. Trans IChemE, 74, Part B, 205–222.

Ezzy, D. 2002. *Qualitative Analysis: Practice and Innovation.* London, Routledge.

Finnveden, G., and Ekvall, T. 1998. Life cycle assessment as a decision-support tool—The case of recycling vs incineration of paper. *Resour. Conserv. Recycl.* 24, 235–256.

Finnveden, G., Johansson, J., Lind, P., and Moberg, Å. 2005. *Life cycle assessment of energy from solid waste. Part 1: General methodology and results.* J. Ind. Ecol., 13 (3), 213–229.

Francke, M. and F. R. McDougall. 1999. *Integrated waste management: LCA and its practical use.* First international conference on waste minimisation and recycling, May 3-4, 1999, Buenos Aires, European Recovery and Recycling Association

Frankfort-Nachmias, C. and D. Nachmias. 1996. *Research Methods in the Social Sciences.* New York, St. Martins Press.

Gentil, E., Aoustin, E. and Christensen, T. H. 2009. Greenhouse gas accounting and waste management. *Waste Management and Research.*

Gentil et al. 2010. Models for waste life cycle assessment: Review of technical assumptions. *Waste Management* 30 (2010) 2636–2648

Gentil, E. C. 2011. *Life-cycle modelling of waste management in Europe: tools, climate change and waste prevention* PhD Thesis February 2011 Department of Environmental Engineering Technical University of Denmark

Goedkoop, M. and Spriensma, R. 2000. *The Eco-indicator 99 – A damage-oriented method for life-cycle impact assessment*, Methodology report.2nd edition. Pré Consultants, B.V., Amersfoort, NL.

Gray, S. and Toleman, I. 2006. National home composting survey results, 1997–2005. *Sustainable Waste and Resource Management* Conference Proceedings, 19–21 September, Warwick University, UK., pp. 775–786.

Grant, T., K. James, S. Lundie and K. Sonneveld. 2001. *Stage 2 Report for Life Cycle Assessment for Paper and Packaging Waste Management Scenarios* in Victoria. Melbourne, EcoRecycle Victoria. Australia

Green-Con Kft. 2007. A KIOP, ISPA és KA forrásból megvalósuló integrált hulladékgazdálkodási beruházások üvegházhatású gáz kibocsátás csökkentésének lehetőségei [*Possibilities to reduce the GHG emission from the KIOP, ISPA and Cohesion Fund financed integrated waste management investments*]

Guendehou G.H.S., M. Koch, L. Hockstad, R. Pipatti and M. Yamada. 2006. *IPCC Guidelines for National Greenhouse Gas Inventories* Volume 5 Chapter 5 - Incineration And Open Burning Of Waste http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_5_Ch5_IOB.pdf (cited 19 March 2010)

Gugele, B, Deuber, O, Federici, S., Gager, M., Graichen, J., Grassi , G., Muik, B., Hartan, R., Herold, A., Kampel, E., Koether, T., Leip, A., Monni, S., Roubanis, N., Rigler, E., Ritter, M., Schodl, B., Szemsova, J., and Somogyi, Z. 2007: Annual European Community greenhouse gas inventory 1990-2005 and inventory report 2007. Submission to the UNFCCC Secretariat.Technical report n. 7/2007, European Environment Agency.

Guinée J., Heijungs, R., Van Oers, L., Van de Meent, D., Vermeire, T. and Rikken, M. 1996. *LCA impact assessment of toxic releases. Generic modeling of fate, exposure and effect for ecosystems and human beings with data for about 100 chemicals.* Netherland Ministry of Housing, Spatial Planning and the Environment, The Hague, NL. (VROM, no. 1996/21).

Güereca, L. P., Gassó, S., Baldasano, J. M., and Jiménez-Guerrero, P. 2006. Life cycle assessment of two biowaste management systems for Barcelona, Spain. *Resources, Conservation and Recycling*, 49, 32-48

Halász, József. 2012. Head of the economic deparment, FKF Zrt. 31 May 2012

Hanashima, M. 1999. *Pollution control and stabilization process by semiaerobic landfill type: the Fukuoka method.* Proceedings Sardinia 1999, Seventh International Waste Management and Landfill Symposium. S. Margherita di Pula, Cagliari Italy, vol. I, 313-325.

Hansen, T.L., Bhander, G.S., Christensen, T.H., Bruun, S. and Jensen, L.S. 2006. Life cycle modeling of environmental impacts from application of processed organic municipal solid waste on agricultural land (EASEWASTE). *Waste Management and Research*, 24, 153-166.

Hauschild M. and Potting J. 2005. Spatial differentiation in life-cycle impact assessment – the EDIP 2003 methodology. Danish Ministry of the Environment, Environmental Protection Agency, Copenhagen, Denmark *(Environmental News No. 80 – 2005.)*

Hauschild M. Z. 2006. *From Pressures to Impacts - Life Cycle Impact Assessment Department of Manufacturing Engineering and Management*, Technical University of Denmark

Hauschild M. and Barlaz M.A. 2008. *LCA in waste management: Introduction to principle and method* EASEWASTE Training course, Denmark, Copenhagen

Hauschild M., IrvingOlsen S., Hansen E and Schmidt A. 2011. Gone…but not away—addressing the problem of long-term impacts from landfills in LCA *The International Journal of Life Cyle Assesment* Volume 13, Number 7, 547-554

Hargitai M. 2012. Rio +20: nevében csúcs, valójában mélypont [Rio+20: summit in the name but depth in reality] *Népszabadság* 23. June 2012. http://nol.hu/kulfold/rio_20__kornyezeti_csucs_dontesek_nelkul (cited 15 September 2012)

Helias A., Udo de Haes, and O. Jolliet. 1999. How Does ISO/DIS 14042 on Life Cycle Impact Assessment Accommodate Current Best Available Practice? Commentary Articles ISO/DIS 14042 *International Jounal of Life Cycle Assessment* 4 (2)

Hischier, R., Wäger, P., and Gauglhofer, J. 2005. Does WEEE recycling make sense from an environmental perspective? The environmental impacts of the Swiss take-back and recycling systems for waste electrical and electronic equipment (WEEE). *Environmental Impact Assessment Review*, 25, 525-539

Hong, R. J., Wang, G. F., Guo, R. Z., Cheng X., Liu Q., Zhang P. J. and Qian G. R. 2006. Life cycle assessment of BMT-based integrated municipal solid waste management: Case study in Pudong, China. *Resources, Conservation and Recycling*, 49, 129-146

István Zs. 2012 personal communication 25 July 2012.

ISO 14040. 1997. Environmental management – Life-cycle assessment – Principles and framework, International Organisation for Standardization, Geneva, Switzerland

_____14040. 2006. Environmental management-life cycle assessment-requirements andguidelines. International Organisation for Standardisation (ISO), Geneva

_____14041. 1999. Environmental management – Life-cycle assessment – Goal and scope definition and inventory analysis, International Organisation for Standardization, Geneva, Switzerland

_____14042. 2000. Environmental management – Life-cycle assessment – Life-cycle impact assessment, International Organisation for Standardization, Geneva, Switzerland

_____14043. 2000. Environmental management – Life-cycle assessment – Life-cycle interpretation, International Organisation for Standardization, Geneva, Switzerland

Kaplan, P.O., Barlaz, M.A. and Ranjithan, S.R. 2005. Life-cycle based solid waste management under uncertainty. *Journal of Industrial Ecology*, 8, 155-172.

Király, Gábor. 2011. Head of the Environmental Laboratory, FKF Zrt. formal interview 21 October 2011

_______2012. Head of the Environmental Laboratory, FKF Zrt. personal communication 17 April 2012

Kirkeby, J. 2005. Modelling of life cycle assessment of solid waste management systems and technologies, PhD thesis, Institute of Environment and Resources, Technical University of Denmark

Kirkeby, J.T., Birgisdottir, H., Hansen, T.L., Christensen, T.H., Bhander, G.S., Hauschild M. 2006. Environmental assessment of solid waste systems and technologies: EASEWASTE *Waste Management Research* 2006; 24; 3-15

Kirkeby, J.T., Birgisdottir, H., Hansen, T.L., Bhander, G.S., Hauschild M., and Christensen, T.H., 2007. Modelling of environmental impacts of solid waste landfilling withinthe life-cycle analysis program EASEWASTE *Waste Management* 27; 2007; 961–970

Klug., Lajos 2012. Director of Budapest Municipal Public Services Co. Ltd. personal communication

Koci V. and Trecakova T. 2011. *Mixed municipal waste management in the Czech Republic from the point of view of the LCA method*

Koltainé Pfeiffer Zsuzsanna. 2009. Former Head of the Environmental Department, Formal interview. 20 November 2009.

Koneczny et al. 2007. *Environmental Assessment of Municipal Waste Management Scenarios: Part II – Detailed Life Cycle Assessments* European Commission Joint Research Centre Institute for Environment and Sustainability

Köztisztasági Egyesülés [Public Cleaning Association]. 2003. A hulladékgazdálkodás általános kérdései, alapelvei [General questions and principles of the waste management], Ministry of Environment and Water, Waste Management and Technology Department. Budapest

_______2010. A települési hulladék kezelésének jellemző költségviszonyai, a szolgáltatás gazdasági összefüggései a közszolgáltatók szemszögéből [The main characteristics of the municipal solid waste services, economic context of the services from the point of view of the public service companies] Ministry of Environment and Water, Waste Management and Technology Department

Laurent, A., Olsen, S. I., and Hauschild, M. Z. 2011. Normalization in EDIP97 and EDIP2003: updated European inventory for 2004 and guidance towards a consistent use in practice. *The International Journal of Life Cycle Assessment*.

Lavee D., 2007. Is Municipal Solid Waste Recycling Economically Efficient? *Environmental Management* 40:926-943.

Law on Waste 2011, draft

Law on the environmental product fee (LXXXV. law in 2011.) http://www.termekdijinfo.hu/jogforrasok/Documents/2011_LXXXV_tv_2011-06-27.pdf (cited 20 August 2012)

Lemming G. 2010. Environmental assessment of contaminated site remediation in a life cycle perspective. PhD Thesis September 2010 Department of Environmental Engineering Technical University of Denmark

Linzner R., 2004. Municipal solid waste management in the City of Belgrade – Current situation and perspectives 2004, Master Thesis, Vienna

Lundholm, M.P. and Sundström, G. 1985. *Resource and environmental impact of Tetra Brik carton and refillable and non-refillable glass bottles.* Tetra Brik Aseptic environmental profile, AB Tetra Pak, Malmö, Sweden

MacDonald M.L. 1996. Solid waste management models: a state of the art review. *Journal of Solid Waste Technology and Management*, 23 no 2, 73-83.

Magyar Szabványügyi Testület (Hungarian Standards Institution). 2005a. MSZ 21420-28 standard on Characterization of wastes Part 28: Investigation of municipal wastes.Sampling

_______2005b. MSZ 21420-29 standard on Characterization of wastes Part 29: Investigation of municipal wastes. Preparation of sample, determination of material composition by the selection of material categories

Manfredi S. 2009. Environmental Assessment of Solid Waste Landfilling in a Life Cycle Perspective (LCA model EASEWASTE) PhD Thesis June 2009. Technical University of Denmark Department of Environmental Engineering

Manfredi, S., Niskanen, A., and Christensen, T. H. 2009. Erratum to "Environmental assessment of gas management options at the Old Ämmässuo landfill (Finland) by means of LCA-modeling (EASEWASTE)" *Waste Management* 29 (2009) 1588–1594. Waste Management, 29 (9), 2601-2602. doi:10.1016/j.wasman. 2009.06.003.

Manfredi S., Christensen T.H., Scharff H. and Jacobs J. 2010. Environmental assessment of low-organic waste landfills in a life-cycle perspective. *Waste Management and Research*, 28(2), 130-140, DOI: 10.1177/0734242X09104127

McCleese, D.L. and LaPuma, P.T. 2002. Using Monte Carlo simulation in life cycle assessment for electric and internal combustion vehicles. *International Journal of Life Cycle Assessment.* 7, 230-236.

McDougall, F., White, P., Franke, M., and Hindle, P., 2001 *Integrated Solid Waste Management: a Life Cycle Inventory.* Published by Blackwell Science, Oxford, UK.ISBN 0-632-05889-7. http://www.blackwellpublishing.com/book.asp?ref=0632058897 (cited 20 November 2010)

McDougall, F., White, P., Franke, M., and Hindle, P. 2003. *Integrated solid waste management: a life cycle inventory,* 2. edition, 3. print, Cornwall, Blackwell Science

Mecsek Dráva waste management system. 2005. Feasibility Study, 15 June 2005.

Merrild, H., Damgaard, A., and Christensen, T. H. 2008. Life cycle assessment of waste paper management: The importance of technology data and system boundaries in assessing recycling and incineration. *Resources, Conservation and Recycling,* 52 (12), 1391–1398.

Merrild H., Larsen A W., and Christensen T. H. 2012. Assessing recycling versus incineration of key materials in municipal waste: The importance of efficient energy recovery and transport distances. *Waste Management* 2012.

Mile, G., 2008. Chief engineer of the Pusztazámor landfill site, official interview 5 December 2008.

_______2012. Chief engineer of the Pusztazámor landfill site, personal communication 4 June 2012.

Miles, M. B., and Huberman, A. M. 1994. *Qualitative data analysis: an expanded sourcebook.* 2nd. Beverly Hills: Sage Publications.

Ministry of Environment and Water. 2006. A települési szilárd hulladékgazdálkodás fejlesztési stratégiája 2007-2016 [Development strategy of the municipal solid waste 2007-2016] 14 November 2006.

Ministry of Rural Development. 2011. *A környezetvédelmi termékdíjról szóló törvény módosítási javaslatának hatás-vizsgálata Tervezet* [Impact assessment of the modifying recommendations for the environmental product fee 2011. Draft] Budapest. 22 June 2011.

Miliūtė Jurate. 2009. Integrated municipal waste management - System decision support model. Kaunas University Of Technology, Lithuanian Energy Institute. Summary of Doctoral Dissertation. Technological Sciences, *Environmental Engineering* (04T) 2009, Kaunas

Miliute Jurate and Staniskis Jurgis Kazimieras. 2009. Application of life-cycle assessment in optimisation of municipal waste management systems: the case Lithuania. *Waste Management and Research* 2 June 2009

Moberg A. 2006. Environmental systems analysis tools for decision-making, LCA and Swedish waste management as an example. Licentiate thesis. Royal Institute of Technology Department of Urban Planning and Environment Environmental Strategies Research. Stockholm

Mølgaard, C. 1995. Environmental impacts by disposal of plastic from municipal solid waste. *Resource Conservation and Recycling.*, 15, 51–63.

National Communication - 5th National Communication to the UNFCCC Hungary 2009 http://unfccc.int/resource/docs/natc/hun_nc5.pdf

Olgyay-Szabó, A., 2012a. Head of the Environmental Department, FKF Zrt. personal communication 17 April 2012

_______2012b. Head of the Environmental Department, FKF Zrt. personal communication 22 May 2012

_______2012c. Head of the Environmental Department, FKF Zrt. personal communication 31 May 2012

Országos Gyűjtési és Hasznosítási Terv (OGyHT) 2012.version 3. [National Collection and Utilization Plan] Budapest, 4 May 2012 Országos Hulladékgazdálkodási Ügynökség

Özeler D., Yetis Ü., and Demirer G.N. 2005. Life cycle assesment of municipal solid waste management methods: Ankara case study *Environment International* 32 2006. 405 – 411

Patton, M. Q. 1990. *Qualitative evaluation and research methods*. Newbury Park, California: Sage Publications.

Pennington D.W., Potting J., Finnveden G., Lindeijer E., Jolliet O., Rydberg T., and Rebitzer G. 2004. Life cycle assessment Part 2: Current impact assessment practice *Environment International* 30 (2004) 721– 739

Platt B. and Rowe D. 2002. *Reduce, Reuse, Refill!* Institute for Local Self-Reliance 2425 18th Street, NWWashington, DC 20009 April 2002

Profu. 2004. *Evaluating waste incineration as treatment and energy recovery method from an environmental point of view*. Mölndal, Sweden.

Raymer, A. K. P. 2006. A comparison of avoided greenhouse gas emissions when using different kinds of wood energy. *Biomass and Bioenergy*, 30, 605-617.

Riber, C., Bhander, G.S., Hauschild, M. and Christensen, T. H. 2008. Environmental assessment of waste incineration in a life-cycle-perspective (EASEWASTE). *Waste Management and Research*, 26, 96-103.

Sámson L. 2012. Director of the Budapest Waste-to-Energy Plant.Personal communication 04 June 2012.

Sándor R. and Molnár T. Molnár Life-cycle assessment of gasoline and diesel products Bay-Logi – Department of Environmental management and Logistic http://www.lcacenter.hu/fileadmin/user_upload/publikaciok/B._Sandor_Renata__M._Sipos_Timea/Benzin_es_dizel_termekek_eletciklus_elemzese.pdf (cited 23 September 2012)

Seafield Research and Development Services, 9-11 Seafield Terr, Portsoy AB45 2QB, UK http://www.srds.ndirect.co.uk/sustaina.htm (cited 12 May 2009)

Schmidt, J., H., Holm, P., Merrild, A. and Christensen, P. 2007: Life cycle assessment of the waste hierarchy. A Danish case study on waste paper. *Waste Management*, 27, 1519–1530

Siklóssy, M. 2012a. Former chief engineer, today technical advisor, FKF Zrt. personal communication 17 February 2012.

_______2012. Former chief engineer, today technical advisor, FKF Zrt. personal communication 31. May 2012.

Skovgaard, M., Hedal, N., Villanueva, A., Andersen F.M. and Larsen H. 2008. Municipal waste management and greenhouse gases. ETC/RWM working paper 2008/1.

Sonnemann, G.W., Schuhmacher, M. and Castells, F. 2003.Uncertainty assessment by a Monte Carlo simulation in a life cycle inventory of electricity produced by a waste incinerator. *Journal of Cleaner Production*, 11, 279-292.

Steen, B. and Ryding, S. O. 1992. *The EPS environ-accounting method. An application of environment accounting principles for evaluation and valuation of environmental impact in product design.* IVL, Stockholm, Sweden (IVL Reportin B 1080)

Stranddorf, H. K., Hoffmann, L., and Schmidt, A. 2005. Impact Categories, normalization and weighting in LCA – update on selected EDIP97-data. *Environmental News* No. 78. Danish Environmental Protection Agency, Danish Ministry of the Environment, Copenhagen, Denmark

Szita K. T. and Szabó B. P. Life cycle assessment of the polystirol http://www.lcacenter.hu/fileadmin/user_upload/publikaciok/A_polisztirol_eletciklusel emzese.pdf (cited 23 September 212)

Szita K. T. 2010. Fenntarthatósági elemzések [Sustainable evaluations] power point presentation VI. LCA conference Miskolc 07. 12. 2010.

_______2012. e-mail communication 14 September 2012

Technical University of Denmark. 2008. EASEWASTE model, Life Cycle Assesment modelling of solid waste systems, PhD course, 16-22 June 2008

Trochim, W. 2006a. *Introduction to Evaluation.* http://www.socialresearchmethods.net/kb.[cited 8 August 2012]

_______2006b. *Research Methods Knowledge Base*. http://www.socialresearchmethods.net/kb/. [cited 10 August 2012]

Tonglet, M., Phillips, P. S. and Bates, M. P. 2004. Determining the drivers for householder pro environmental behaviour: waste minimization compared to recycling. *Resources, Conservation and Recycling*, 42, 27–48.

Tyskeng S., and Finnveden G., 2010. Comparing Energy Use and Environmental Impacts of Recycling and Waste Incineration *Journal Of Environmental Engineering* © Asce / August 2010

Udo de Haes, H.A. ed. 1996. *Towards a methodology for life cycle impact assessment.* SETAC-Europe, Brussels, Belgium

Udo de Haes, H. A., Jolliet , O., Finnveden, G., Hauschild, M., Krewitt, W and Müller-Wenk, R. 1999. Best available practice regarding impact categories and category indicators in life cycle impact assessment.Background document for the second working group on life-cycle impact assessment of SETAC Europe (WIA-2). *International Journal of Life-cycle assessment*, 4, 66-74 and 4, 167-174.

Udo de Haes, H.A., Finnveden, G., Goedkoop, M., Hauschild, M., Hertwich, E., Hofstetter, P., Jolliet, O., Klöpffer, W., Krewitt, W., Lindeijer, E., Jolliet, O., Mueller-Wenk, R., Olsen, S., Pennington, D., Potting, J. and Steen, B. (eds.). 2002. *Life cycle Impact Assessment: Striving towards best practice.* SETAC Press, Pensacola, Florida

United Nations General Assembly. 2005. World Summit Outcome. Resolution A/60/1, adopted by the General Assembly on 15 September 2005. Retrieved on: 2009-02-17.

US Environmental Protection Agency (USEPA). 2002. *Solid Waste Management and Greenhouse Gases.* A Life-Cycle Assessment of Emissions and Sinks, second edition, EPA Document n. 530-R-02-006. May 2002.

User Manual. 2012. April. Documentation. EASEWASTE, Technical University of Denmark

United Nations Framework Convention on Climate Change. 2012. http://unfccc.int/ghg_data/ghg_data_unfccc/items/4146.php [cited 17 July 2012]

Vámosi O. 2011. Termékdíj törvény és hulladékgazdálkodási célok. Italcsomagolások környezetközpontú elemzése a termékdíj mértékének meghatározása céljából, összefoglaló [Product fee law and waste management objectives. Environmental analysis of the drinking packaging for determining the product fee amount. Summary] power point presentation April 2011.

Villanueva, A., and Wenzel, H. 2007. Paper waste—Recycling, incineration or landfilling? A review of existing life cycle assessments. *Waste Management*, 27(8), S29–S46.

Waste Management Act 2000, Act XLIII of 2000 on waste management

Wenzel, H., M. Hauschild and L. Alting. 1997. *Environmental assessment of products, vol.1: Methodology, tools and case studies in product development*. Kluwer Academic Publishers, Hingham, MA. USA

Wiedemann M. Peter and Susanne Femers. 1993. Public participation in waste management decision-making: Analysis and management of conflicts, *Journal of Hazardous Materials*, 33 (1993) 355-368.

Wilson C. David et al. 2012. Comparative analysis of solid waste management in 20 cities. In *Waste Management and Research* 30(3) 237–254

Water and Resources Action Programme (WRAP). 2006. *Environmental benefits of recycling: An international review of life cycle comparisons for key materials in the UK recycling sector.* Final Rep., Oxon, U.K.

World Commission on Environment and Development. 1987. Our Common Future. United Nations, Oxford University Press, United Kingdom

14 Annexes

Annex 1: Received data from the Budapest waste-to-energy treatment pland and the Pusztazámor landfill site

Budapest incinerator data	**unit**	**2009**									
Incinerated waste amount	t	407904									
Slag	t	96702									
Smoke cleaning residue	t	12563									
Metal waste	t	4817									
Smoke cleaning additional materials:											
Lime powder	t	2584									
Active coal	t	51.06									
Carbamid	t	611									
HCL	kg	605754									
NaOH	kg	199480									
Fuel	t										
Bought water	m3	816845									
Wastewater	m3	277228									
Air pollutants											
dust	kg	929									
Nox	t	328									
SO2	t	87									
CO2	kg	380199									
Total produced heat energy	GJ	2718960									
Electricity (from total)	MWh	169866									
Bought electricity energy	MWh	312695									
Budapest landfill data											
Methane content	(CH4 %)	55-58									
Biogas production	(Nm3/h)	417									
Biogas energy	(kWh/m3)	5.7									
Composting		they measure only the amount, oxygen and temperature									
Landfill height	m	37-41									
Landfill density	t/m3	1.347									
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Gas production								2228000	1449000	3690000	
Leachate production			**9010**	**12210**	**14700**	**30100**	**22700**	**23900**	**26900**	**29600**	

Annex 2: The data for the incinerator in case of Aarhus and Budapest

Incineration	Aarhus	Budapest
$CaCO_3$ terminated, unit/ton, kg	7.85	6,3
Marginal electricity production in fuel production, c	65,7	11,8
FeCL, unit/ton, kg	0.04	0.04
TMT15 unit/ton, kg	0.03	0.03
Polymers, unit/ton, kg	0.003	0.003
Fuel Oil (Heavy), EU (prod+comb)unit/ton, kg	0.421	0.421
Sodyum hydroxide, NaOH, unit/ton, kg	0.66	0,63
Ammonia NH_3, terminated unit/ton, kg	1.48	1.84
Marginal electricity production incl. fuel production	20,7	62
Marginal heat produced at coal CHP, energy quality,	74	74
Output- air emissions		
Hydrogen fluoride, HF, unit/ton, kg	6,2E-5	7,7E-5
Nitrogen Oxides, NOx, unit/ton, kg	1,3	0,803
Carbon Monoxide, CO, unit/ton, kg	0.066	0.082
Sulphur dioxide, SO_2, unit/ton, kg	0.017	0.21
Unspecifides particles, unit/ton, kg	0.0037	0.046
Dioxin (2,3,7,8- TCDD TEQ), unit/ton, kg	3.40E-10	1.27E-11
Hydrogen chloryde, HCL, unit/ton, kg	0.03	0.03

Annex 3: Environmental impact results of the model for 2008, 2009, 2010, 2011 - tables

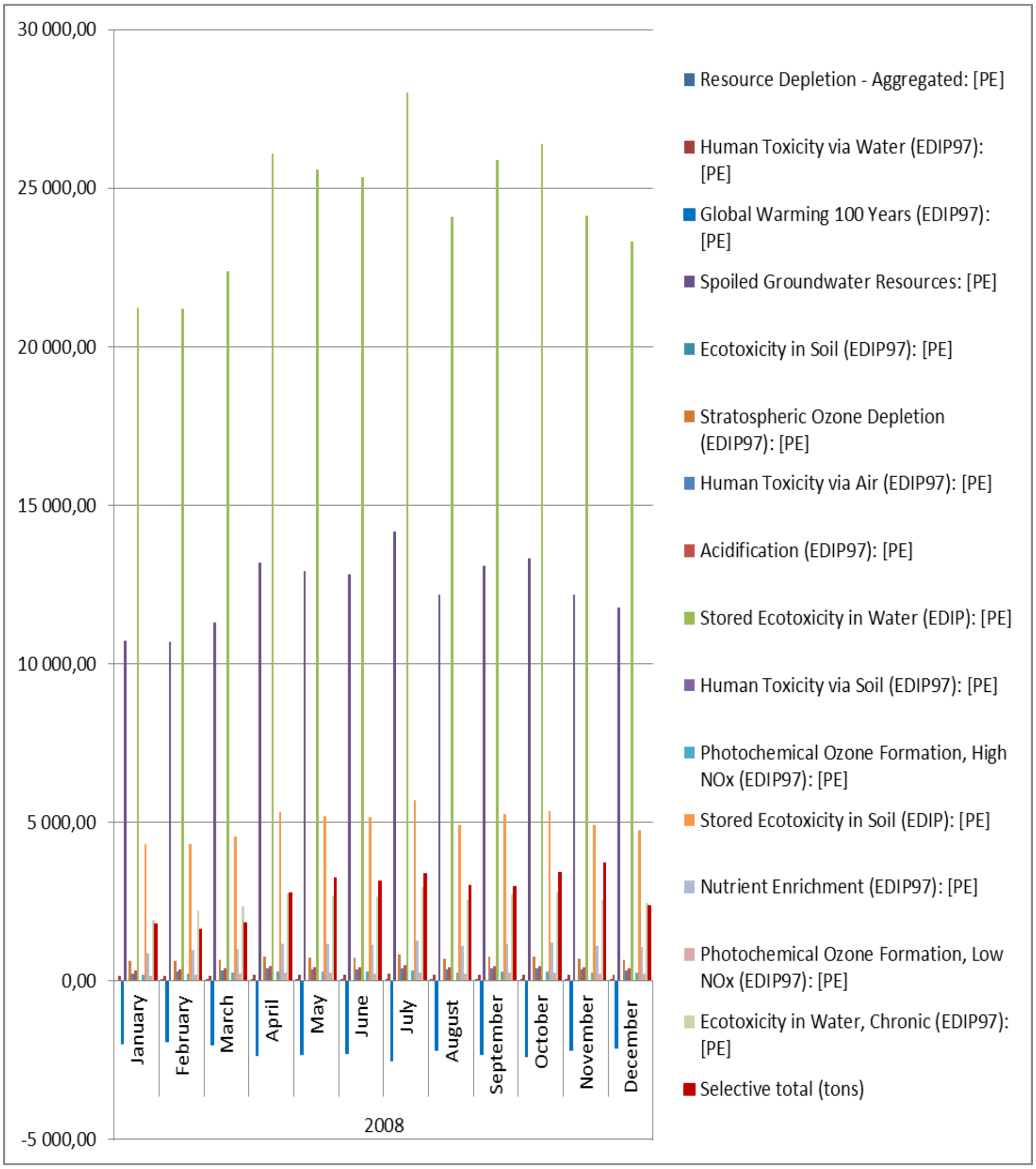
	2008											
	January	February	March	April	May	June	July	August	September	October	November	December
Resource Depletion - Aggregated: [PE]	31,02	40,52	42,81	49,91	48,90	48,46	53,56	46,13	49,52	50,44	46,14	44,56
Human Toxicity via Water (EDIP97): [PE]	155,24	159,66	168,69	196,64	192,67	190,93	211,05	181,55	195,11	198,76	181,79	175,59
Global Warming 100 Years (EDIP97): [PE]	-1 998,05	-1 917,31	-2 025,71	-2 361,37	-2 313,71	-2 292,80	-2 534,43	-2 179,36	-2 343,09	-2 386,84	-2 183,09	-2 108,69
Spoiled Groundwater Resources: [PE]	10 724,35	10 706,12	11 311,44	13 185,74	12 919,54	12 802,86	14 152,06	12 172,01	13 083,64	13 327,95	12 190,24	11 774,54
Ecotoxicity in Soil (EDIP97): [PE]	2,20	2,21	2,33	2,72	2,67	2,64	2,92	2,51	2,70	2,75	2,52	2,43
Stratospheric Ozone Depletion (EDIP97): [PE]	617,05	616,98	651,87	759,88	744,54	737,81	815,57	701,46	754,00	768,08	702,51	678,55
Human Toxicity via Air (EDIP97): [PE]	214,58	306,98	324,33	378,07	370,43	367,10	405,78	349,57	375,15	382,15	349,53	337,56
Acidification (EDIP97): [PE]	316,24	364,33	384,93	448,71	439,65	435,68	481,60	414,60	445,24	453,55	414,84	400,66
Stored Ecotoxicity in Water (EDIP): [PE]	21 226,14	21 190,06	22 388,13	26 097,84	25 570,97	25 340,02	28 010,43	24 091,42	25 895,75	26 379,31	24 127,51	23 304,73
Human Toxicity via Soil (EDIP97): [PE]	8,51	8,57	9,05	10,55	10,34	10,25	11,33	9,74	10,47	10,67	9,76	9,42
Photochemical Ozone Formation, High NOx (EDIP97): [PE]	201,08	238,55	252,04	293,80	287,86	285,27	315,33	271,56	291,53	296,97	271,62	262,33
Stored Ecotoxicity in Soil (EDIP): [PE]	4 317,29	4 309,95	4 553,63	5 308,16	5 201,00	5 154,03	5 697,17	4 900,07	5 267,06	5 365,41	4 907,41	4 740,06
Nutrient Enrichment (EDIP97): [PE]	864,39	956,97	1 011,08	1 178,61	1 154,80	1 144,39	1 264,98	1 088,78	1 169,48	1 191,32	1 089,63	1 052,40
Photochemical Ozone Formation, Low NOx (EDIP97): [PE]	168,81	199,15	210,41	245,27	240,31	238,15	263,25	226,70	243,37	247,92	226,75	219,00
Ecotoxicity in Water, Chronic (EDIP97): [PE]	1 908,17	2 228,85	2 354,87	2 745,07	2 689,56	2 665,36	2 946,24	2 537,76	2 723,81	2 774,67	2 537,82	2 450,95

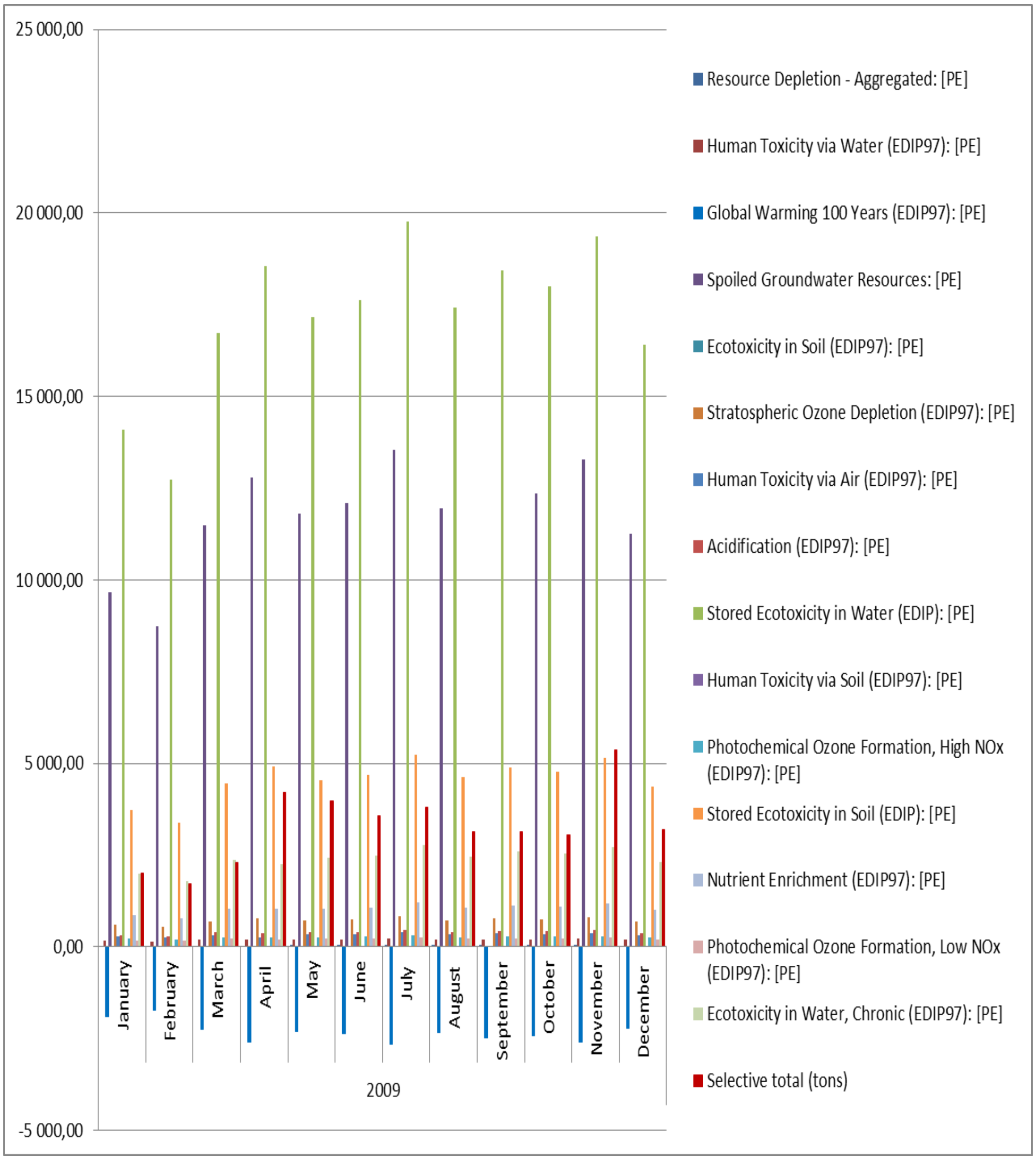
	2009											
	January	February	March	April	May	June	July	August	September	October	November	December
Resource Depletion - Aggregated: [PE]	34.51	31.17	40.94	35.04	42.94	43.12	48.35	42.61	45.10	44.04	47.35	40.15
Human Toxicity via Water (EDIP97): [PE]	160.72	145.19	190.68	198.56	188.74	200.84	225.18	198.48	210.08	205.13	220.53	187.00
Global Warming 100 Years (EDIP97): [PE]	-1 897.26	-1 713.95	-2 251.03	-2 587.07	-2 306.53	-2 370.85	-2 658.30	-2 343.04	-2 479.98	-2 421.50	-2 603.38	-2 207.52
Spoiled Groundwater Resources: [PE]	9 675.63	8 740.80	11 479.80	12 776.79	11 812.78	12 090.90	13 556.79	11 949.03		12 349.15	13 276.71	11 257.92
Ecotoxicity in Soil (EDIP97): [PE]	2.09	1.89	2.48	2.75	2.57	2.62	2.93	2.59	2.74	2.67	2.87	2.44
Stratospheric Ozone Depletion (EDIP97): [PE]	594.27	536.86	705.09	786.38	728.13	742.62	832.65	733.91	776.80	758.48	815.45	691.46
Human Toxicity via Air (EDIP97): [PE]	277.73	250.90	329.52	255.17	338.27	347.06	389.13	342.98	363.03	354.47	381.09	323.15
Acidification (EDIP97): [PE]	329.76	297.90	391.25	378.10	403.23	412.08	462.04	407.24	431.05	420.88	452.49	383.69
Stored Ecotoxicity in Water (EDIP): [PE]	14 099.40	12 737.17	16 728.46	18 548.71	17 149.21	17 618.95	19 755.07	17 412.23	18 429.93	17 995.29	19 346.93	16 405.13
Human Toxicity via Soil (EDIP97): [PE]	7.95	7.18	9.43	10.38	9.68	9.93	11.14	9.81	10.39	10.14	10.91	9.25
Photochemical Ozone Formation, High NOx (EDIP97): [PE]	218.40	197.30	259.13	244.19	267.48	272.92	306.01	269.72	285.49	278.75	299.69	254.12
Stored Ecotoxicity in Soil (EDIP): [PE]	3 744.55	3 382.77	4 442.79	4 925.98	4 554.31	4 679.29	5 246.60	4 624.38	4 894.67	4 779.23	5 138.20	4 356.92
Nutrient Enrichment (EDIP97): [PE]	865.58	781.95	1 026.98	1 027.14	1 053.41	1 081.65	1 212.78	1 068.95	1 131.43	1 104.75	1 187.73	1 007.13
Photochemical Ozone Formation, Low NOx (EDIP97): [PE]	182.45	164.83	216.48	205.17	223.48	228.00	255.64	225.32	238.49	232.87	250.36	212.29
Ecotoxicity in Water, Chronic (EDIP97): [PE]	1 988.69	1 796.55	2 359.52	2 243.64	2 431.76	2 485.14	2 786.41	2 455.96	2 599.51	2 538.20	2 728.85	2 313.91

	2010											
	January	February	March	April	May	June	July	August	September	October	November	December
Resource Depletion - Aggregated: [PE]	32,73	21,84	33,41	31,80	35,79	37,97	35,55	35,41	35,69	33,11	33,90	27,02
Human Toxicity via Water (EDIP97): [PE]	137,41	118,42	181,17	172,44	194,05	205,92	192,77	192,03	193,52	179,52	183,83	146,52
Global Warming 100 Years (EDIP97): [PE]	-1 968,66	-1 805,56	-2 762,30	-2 629,22	-2 958,68	-3 139,64	-2 939,20	-2 927,84	-2 950,56	-2 737,14	-2 802,87	-2 234,02
Spoiled Groundwater Resources: [PE]	9 099,60	8 076,04	12 355,43	11 760,16	13 233,81	14 043,23	13 146,70	13 095,88	13 197,51	12 242,91	12 536,91	9 992,51
Ecotoxicity in Soil (EDIP97): [PE]	2,00	1,76	2,69	2,56	2,88	3,06	2,86	2,85	2,87	2,67	2,73	2,18
Stratospheric Ozone Depletion (EDIP97): [PE]	568,69	503,98	771,04	733,89	825,86	876,37	820,42	817,25	823,59	764,02	782,37	623,58
Human Toxicity via Air (EDIP97): [PE]	261,73	162,31	248,32	236,35	265,97	282,24	264,22	263,20	265,24	246,06	251,96	200,83
Acidification (EDIP97): [PE]	313,99	241,99	370,21	352,38	396,53	420,79	393,92	392,40	395,45	366,84	375,65	299,41
Stored Ecotoxicity in Water (EDIP): [PE]	13 879,63	12 318,38	18 845,74	17 937,78	20 185,53	21 420,14	20 052,66	19 975,15	20 130,17	18 674,11	19 122,55	15 241,57
Human Toxicity via Soil (EDIP97): [PE]	7,45	6,56	10,04	9,55	10,75	11,41	10,68	10,64	10,72	9,95	10,18	8,12
Photochemical Ozone Formation, High NOx (EDIP97): [PE]	208,31	156,35	239,21	227,68	256,21	271,88	254,52	253,54	255,51	237,03	242,72	193,46
Stored Ecotoxicity in Soil (EDIP): [PE]	2 122,44	1 883,70	2 881,85	2 743,01	3 086,73	3 275,52	3 066,41	3 054,56	3 078,26	2 855,61	2 924,18	2 330,71
Nutrient Enrichment (EDIP97): [PE]	820,00	656,82	1 004,86	956,45	1 076,30	1 142,13	1 069,22	1 065,09	1 073,35	995,71	1 019,62	812,69
Photochemical Ozone Formation, Low NOx (EDIP97): [PE]	174,07	131,39	201,01	191,32	215,30	228,47	213,88	213,05	214,71	199,18	203,96	162,57
Ecotoxicity in Water, Chronic (EDIP97): [PE]	1 891,75	1 434,61	2 194,79	2 089,05	2 350,82	2 494,60	2 335,35	2 326,32	2 344,37	2 174,80	2 227,03	1 775,04

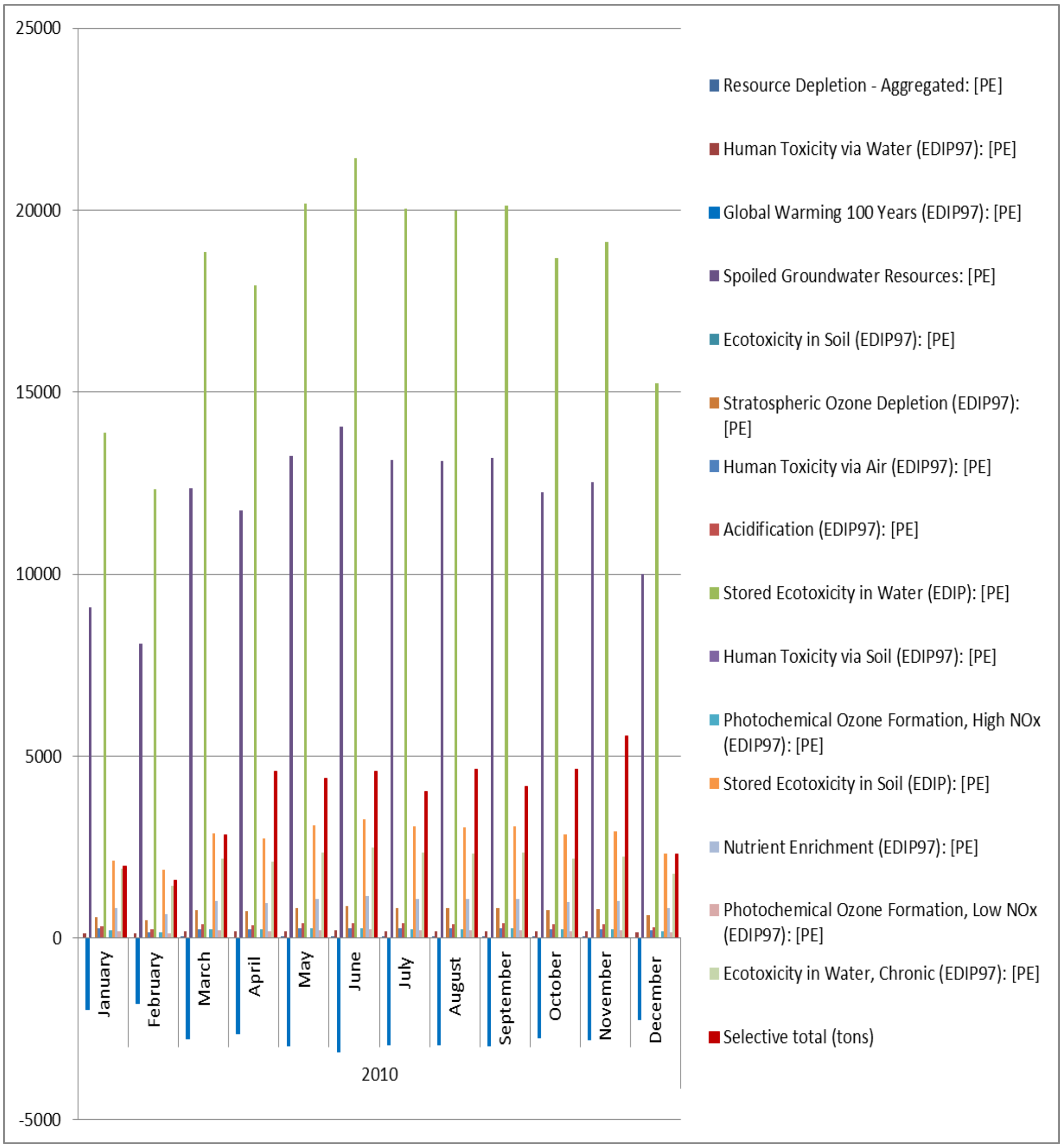
	2011									
	January	February	March	April	May	June	July	August	September	October
Resource Depletion - Aggregated: [PE]	35,81	23,68	33,30	35,08	36,55	35,84	36,64	38,92	34,25	34,36
Human Toxicity via Water (EDIP97): [PE]	149,09	125,82	176,96	186,42	194,23	190,43	194,72	206,82	182,02	182,57
Global Warming 100 Years (EDIP97): [PE]	-2 021,50	-1 815,35	-2 553,23	-2 689,69	-2 802,36	-2 747,61	-2 809,50	-2 984,05	-2 626,22	-2 634,15
Spoiled Groundwater Resources: [PE]	9 573,06	8 312,40	11 691,13	12 316,01	12 831,90	12 581,22	12 864,60	13 663,87	12 025,37	12 061,70
Ecotoxicity in Soil (EDIP97): [PE]	2,20	1,90	2,67	2,81	2,93	2,87	2,93	3,12	2,74	2,75
Stratospheric Ozone Depletion (EDIP97): [PE]	633,94	549,69	773,12	814,45	848,56	831,98	850,72	903,58	795,23	797,63
Human Toxicity via Air (EDIP97): [PE]	275,79	167,44	235,51	248,09	258,48	253,44	259,14	275,24	242,24	242,97
Acidification (EDIP97): [PE]	339,75	257,26	361,82	381,16	397,13	389,37	398,14	422,87	372,17	373,29
Stored Ecotoxicity in Water (EDIP): [PE]	9 997,83	8 681,23	12 209,88	12 862,49	13 401,27	13 139,46	13 435,42	14 270,15	12 558,95	12 596,89
Human Toxicity via Soil (EDIP97): [PE]	8,04	6,92	9,74	10,26	10,69	10,48	10,72	11,38	10,02	10,05
Photochemical Ozone Formation, High NOx (EDIP97): [PE]	223,81	164,98	232,04	244,45	254,69	249,71	255,34	271,20	238,68	239,40
Stored Ecotoxicity in Soil (EDIP): [PE]	1 772,99	1 539,50	2 165,26	2 281,00	2 376,54	2 330,11	2 382,60	2 530,63	2 227,17	2 233,90
Nutrient Enrichment (EDIP97): [PE]	870,04	682,44	959,83	1 011,14	1 053,49	1 032,91	1 056,17	1 121,79	987,27	990,26
Photochemical Ozone Formation, Low NOx (EDIP97): [PE]	187,18	138,76	195,16	205,59	214,20	210,01	214,74	228,09	200,74	201,34
Ecotoxicity in Water, Chronic (EDIP97): [PE]	1 992,14	1 478,29	2 079,17	2 190,30	2 282,05	2 237,47	2 287,86	2 430,01	2 138,61	2 145,07

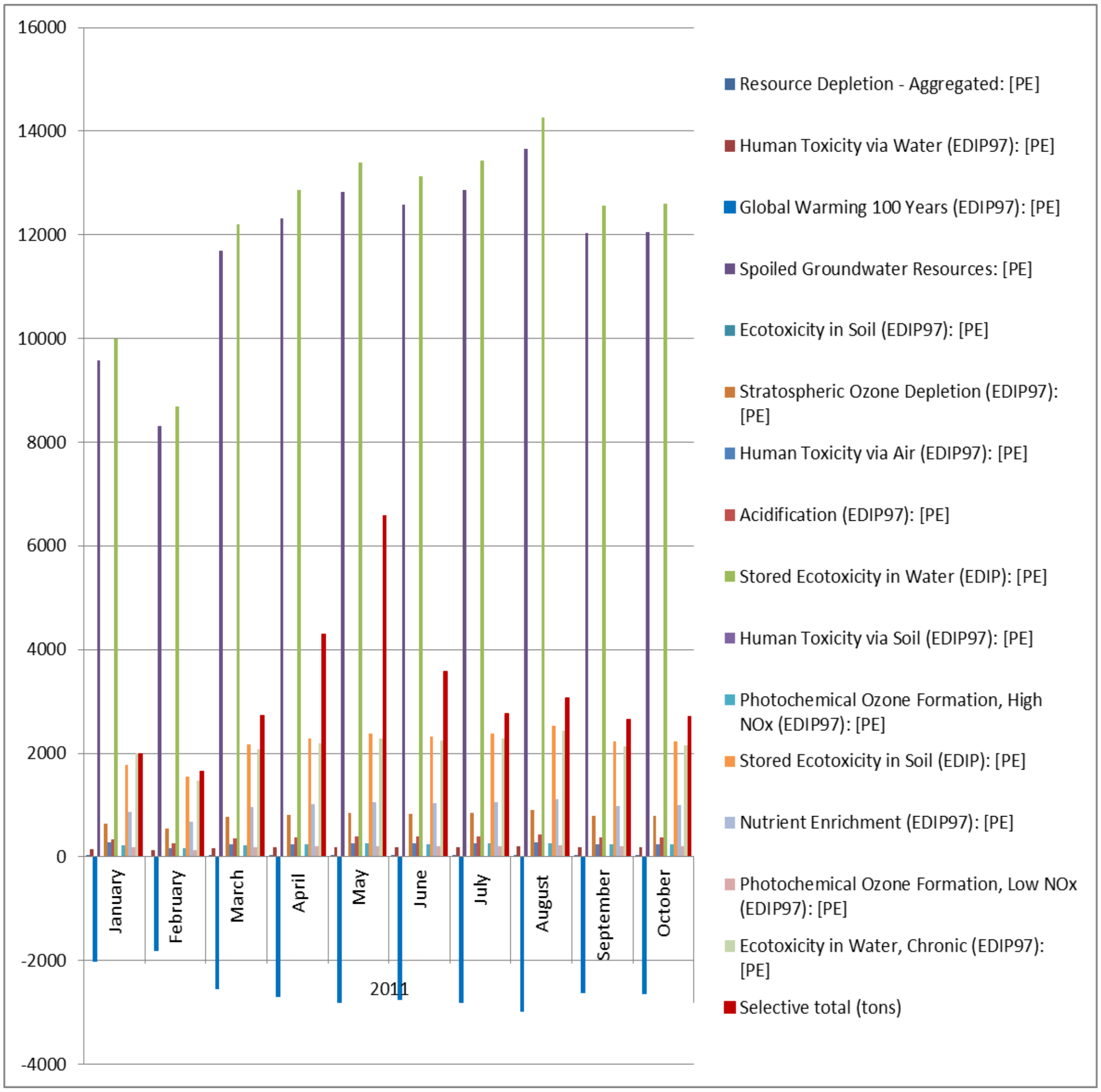
Annex 4: Results of the LCA model run for 2008, 2009, 2010 and 2011– graphs





25 000,00
20 000,00
15 000,00
10 000,00
5 000,00
0,00
-5 000,00
January
February
March
April
May
June
July
August
September
October
November
December
2009
Resource Depletion - Aggregated: [PE]
Human Toxicity via Water (EDIP97): [PE]
Global Warming 100 Years (EDIP97): [PE]
Spoiled Groundwater Resources: [PE]
Ecotoxicity in Soil (EDIP97): [PE]
Stratospheric Ozone Depletion (EDIP97): [PE]
Human Toxicity via Air (EDIP97): [PE]
Acidification (EDIP97): [PE]
Stored Ecotoxicity in Water (EDIP): [PE]
Human Toxicity via Soil (EDIP97): [PE]
Photochemical Ozone Formation, High NOx (EDIP97): [PE]
Stored Ecotoxicity in Soil (EDIP): [PE]
Nutrient Enrichment (EDIP97): [PE]
Photochemical Ozone Formation, Low NOx (EDIP97): [PE]
Ecotoxicity in Water, Chronic (EDIP97): [PE]
Selective total (tons)


25000
20000
15000
10000
5000
0
-5000
January
February
March
April
May
June
July
August
September
October
November
December
2010
Resource Depletion - Aggregated: [PE]
Human Toxicity via Water (EDIP97): [PE]
Global Warming 100 Years (EDIP97): [PE]
Spoiled Groundwater Resources: [PE]
Ecotoxicity in Soil (EDIP97): [PE]
Stratospheric Ozone Depletion (EDIP97): [PE]
Human Toxicity via Air (EDIP97): [PE]
Acidification (EDIP97): [PE]
Stored Ecotoxicity in Water (EDIP): [PE]
Human Toxicity via Soil (EDIP97): [PE]
Photochemical Ozone Formation, High NOx (EDIP97): [PE]
Stored Ecotoxicity in Soil (EDIP): [PE]
Nutrient Enrichment (EDIP97): [PE]
Photochemical Ozone Formation, Low NOx (EDIP97): [PE]
Ecotoxicity in Water, Chronic (EDIP97): [PE]
Selective total (tons)



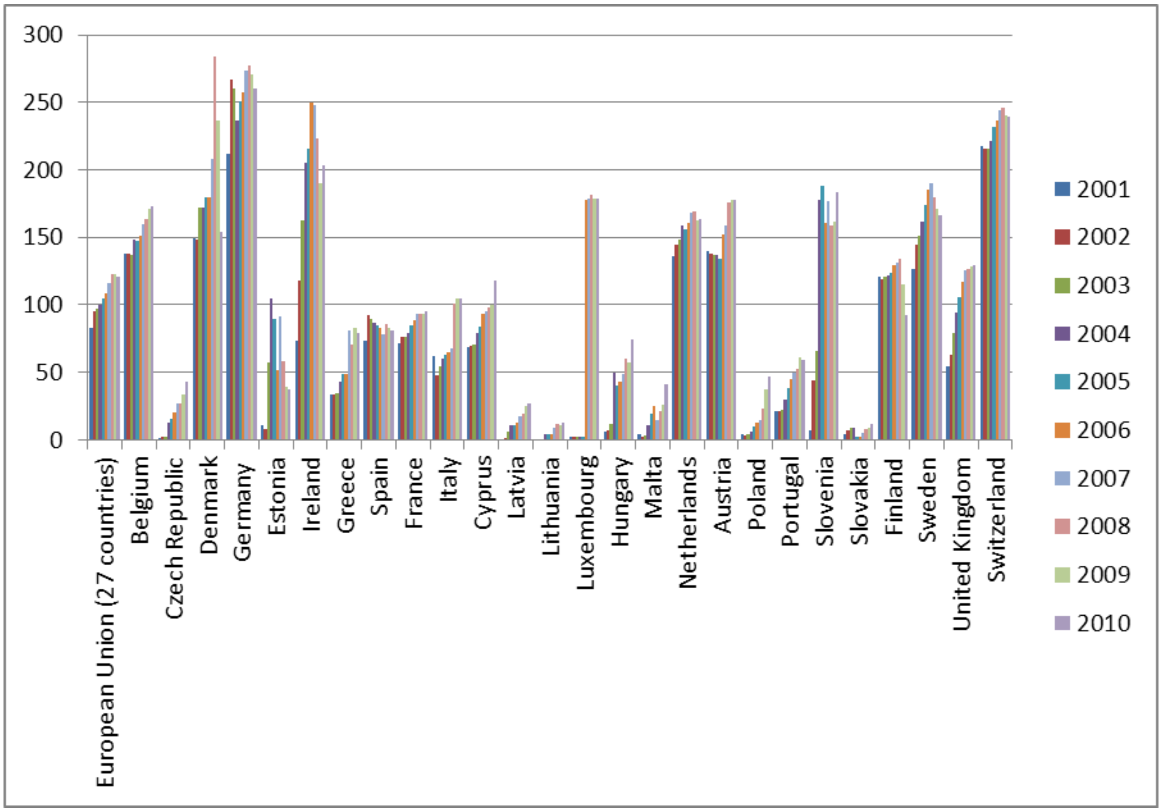
16000
14000
12000
10000
8000
6000
4000
2000
0
-2000
-4000
January
February
March
April
May
June
July
August
September
October
2011
Resource Depletion - Aggregated: [PE]
Human Toxicity via Water (EDIP97): [PE]
Global Warming 100 Years (EDIP97): [PE]
Spoiled Groundwater Resources: [PE]
Ecotoxicity in Soil (EDIP97): [PE]
Stratospheric Ozone Depletion (EDIP97): [PE]
Human Toxicity via Air (EDIP97): [PE]
Acidification (EDIP97): [PE]
Stored Ecotoxicity in Water (EDIP): [PE]
Human Toxicity via Soil (EDIP97): [PE]
Photochemical Ozone Formation, High NOx (EDIP97): [PE]
Stored Ecotoxicity in Soil (EDIP): [PE]
Nutrient Enrichment (EDIP97): [PE]
Photochemical Ozone Formation, Low NOx (EDIP97): [PE]
Ecotoxicity in Water, Chronic (EDIP97): [PE]
Selective total (tons)

Annex 5: Waste amounts and fuel consumption in 2006, 2007, 2008, 2009, 2010 and 2011

2006	2007	2008	2009	2010	2011
730 288 t 429 Kg/cap.	688 171 t 404 Kg/cap.	691 586 t 406 Kg/cap. Fuel consumption: 4 119 419 l 5,95 liter/tons	661 405 t 389 Kg/cap. Fuel consumption: 3 799 719 l 5,74 liter/tons	668 711 t 393 Kg/cap. Fuel consumption: 3 757 248 l 5,61 liter/tons	657 870 t 387 Kg/cap. Fuel consumption: 3 736 282 l 5,68 liter/tons

Annex 6: Recycling rates in some countries between 2001-2010 kg/capita,

Source: Eurostat



Annex 7: Waste amount, distances and fuel consumption in 2008 January - December

Year	2008												Total
Months	January	February	March	April	May	June	Julyx	August	September	October	Nmovember	December	
Selective total (tons)	1 788,12	1 632,31	1 833,59	2 768,12	3 254,65	3 132,44	3 368,55	3 021,10	2 982,61	3 406,77	3 723,71	2 358,56	33 270,53
Non selective total (tons)	48 207,04	48 272,84	50 896,26	58 701,54	56 980,33	56 548,67	62 614,84	53 723,89	58 009,17	58 720,00	53 105,44	52 536,17	658 316,19
Waste total (tons)	49 995,16	49 905,15	52 729,85	61 469,66	60 234,98	59 681,11	65 983,39	56 744,99	60 991,78	62 126,77	56 829,15	54 894,73	691 586,72
Distance, km – selective collection	59 542	54 818	55 729	56 560	57 384	56 321	59 160	57 058	56 750	60 669	56 426	62 340	692 757
Distance, km – non selective collectton	470 859	453 779	458 009	562 683	556 734	550 235	594 420	530 253	637 304	566 405	526 174	462 650	6 369 505
Distance, km – total	530 401	508 597	513 738	619 243	614 118	606 556	653 580	587 311	694 054	627 074	582 600	524 990	7 062 262
Fuel consumption (l) – selective coll.	40 495	37 083	37 719	38 548	38 743	38 602	39 717	37 709	38 660	40 870	36 551	42 582	467 279
Fuel consumption (l) – non sel.coll.	287 614	275 241	274 291	324 015	320 851	313 132	375 662	295 238	347 961	321 267	291 684	264 901	3 652 140
Fuel consumption (l) – total	328 109	312 324	312 010	362 563	359 594	351 734	335 945	332 947	386 621	362 137	328 235	307 483	4 119 419

Annex 8: Location of all of the waste islands and the 12 waste yards in Budapest

This list was made on 14.06.2012, so it can be regarded as updated. Based on: http://www.fkf.hu/portal/pls/portal/!PORTAL.wwpob_page.show?_docname=2538191.PDF

District	No.	Address	District	No.	Address
I.	1	Csalogány utca – Málna utca	III.	1	Arató Emil tér
	2	Fortuna köz másik parkoló		2	Auchan - Aquincum Óbuda
	3	Gellérthegy utca - Orvos lépcső		3	Bárczy Géza utca (iskola kerítése mellett)
	4	Kosciuszkó Tádé utca, CBA áruház mellett		4	Bécsi út - Kocsis Sándor út sarok
	5	Krisztina körút - Mikó utca		5	Bécsi út 136.
	6	Krisztina krt. - Attila út között (járda)		6	Bécsi út 229.
	7	Lánchíd utcai parkoló - Öntőház utca		7	Bogdáni út 4.
	8	Logodi utca		8	Búza utca - Kazal utca sarok
	9	Mészáros utca 56/B - Zsolt utca		9	Búza utca 10.
	10	Naphegy tér		10	Csobánka tér, rendelő előtt
	11	Sánc utca - Mihály utca		11	Doberdó utca 2. és 4. között (Kecske utca)
	12	Somlói út 51. támfal elé		12	Erdőalja út 136. buszforduló
II.	1	Battai lépcső Szabó Lőrinc ált. isk. előtt		13	Erdőalja utca - Remetehegyi utca
	2	Budakeszi út - Labanc út csatlakozásánál		14	Ezüsthegy utca 28.
	3	Csatárka utca 21-gyel szemben, másik oldal		15	Föld utca - Teszársz Károly utca
	4	Cseppkő utcai gyermekotthon előtt		16	Gyógyszergyár utca, a Krúdy iskola előtt
	5	Endrődi Sándor utca - Gábor Áron utca - Gábor Áron köz		17	Hadrianus utca 5-tel szemben
	6	Erőd utca 2.		18	Hatvany Lajos utca (gimnázium behajtója)
	7	Fekete István utca 11. - Szerb Antal utca		19	Hévizi út - Meggyfa utca sarok
	8	Felső Zöldmáli út 3/A		20	Hollós Korvin Lajos utca 6.
	9	Felvinci út - Marczibányi tér		21	Hunor utca - Körte utca sarkán (iskola mögötti járdán)
	10	Frankel Leó út - Ürömi utca		22	Hunor utca 6/a. sz. előtt (Hévizi u. sarok)
	11	Frankel Leó utca 54.		23	Huszti út - Búza utca sarok (körforgalom)
	12	Hárshegyi út 3, iskola előtt		24	Jós utca 2-16.
	13	Heinrich István utca (Hűvösvölgyi útnál)		25	Juhász Gyula utca 8.
	14	Hermann Ottó utca 15-17.		26	Jutas utca 89. - Ürömhegyi út
	15	Hidász utca - Pasaréti út sarok		27	Kelta utca bölcsöde mellett
	16	Hideg utca 2/B-vel szemben, kapu előtt		28	Királyok útja 192.
	17	Hidegkúti út 140. előtt, parkoló szélén		29	Köles u. - Búza u. sarok a Plus áruház mögötti járdán
	18	Hidegkúti út 306-tal szemben		30	Lajos utca - Tél utca
	19	Hűvösvölgyi út - régi buszvégállomással szemben		31	Lajos utca 105. mögött
	20	Hűvösvölgyi út - Sodrás utca		32	Lángliliom utca 4.
	21	Hűvösvölgyi út 57 és 38/A,B,C között		33	Lukács György utca 5.
	22	Kacsa utca - Gyorskocsi utca 33. másik oldal		34	Madzsar József utca 9-11.
	23	Kossuth Lajos utca 17. Waldorf iskola sarok		35	Madzsar József utca HÉV lejáró, buszmegálló bazársor előtt
	24	Kővári utca sarok		36	Matróz utca 8.
	25	Községház utca - Sóvirág utca sarok		37	Nagymihály utca 2.
	26	Máriaremetei út - Hunyadi János utca sarok (szemközti oldal)		38	Orbán Balázs út 35.(garázssor előtt)
	27	Máriaremetei út - Sólyomvölgy utca		39	Pais Dezső utcai iskolánál
	28	Nagy Imre tér 3.		40	Perc utca, a PLUS áruház parkolójában
	29	Nagybányai út - Csalán utca		41	Pethe Ferenc tér (Szérűskert utcai iskola mellett parkolóba
	30	Ördögárok utca - Csatlós utca		42	Pünkösdfürdő - Királyok utca - Napfény utca felőli oldal
	31	Páfrány utca 17-tel szemben		43	Pünkösdfürdő utca – Medgyesi iskola és óvoda közötti út
	32	Pusztaszeri út 18/a,b-vel szemben		44	Remetehegyi út 18-cal szemben, a BÉE előtt
	33	Rodostó utca 4. előtt		45	Római tér parkoló
	34	Rómer Flóris utca 6-tal szemben		46	Szentendrei út 13. és 17. között
	35	Szakadék utca 4-gyel szemben		47	Szentendrei út 2. (gyógyszertár) előtt
	36	Szemlőhegyi út 38-cal szemben		48	Szentendrei út 28-30. (Profi mögött)
	37	Szépvölgyi út 155. előtt		49	Szépvölgyi út 41-43. előtt
	38	Szilágyi Erzsébet fasor 129. - Lotz K. utca		50	Szőlő utca - Kiscelli utca (CBA mögött)
	39	Temető utca - Hidegkúti út torkolata		51	Szőlő utca 2-4. (Viador utca)
	40	Törökvész út 143/a - Nagybányai út sarok		52	Szőlő utca 72-78. számmal szembeni parkoló
	41	Törökvész út 23.		53	Veder utca 10. sz. (Vihar u. sarok a parkoló végébe)
	42	Törökvész út 65.		54	Vihar utca 6. számmal szemben (járda és az úttest között)
	43	Törökvész út 86-tal szemben, parkolóban		55	Vizimolnár utca 2.
				56	Vörösvári út SZTK
				57	Zab utca 3. a parkolóval szemben
				58	Zápor utcai iskola előtt
				59	Zsirai Miklós utca 3.

District	No.	Address	District	No.	Address
IV.	1	Árpád út - felüljáró oldalán	VIII.	1	Asztalos Sándor utca 16-tal szemben
	2	Árpád út - Rózsa utca		2	Asztalos Sándor utca 7.
	3	Árpád út 140-nel szemben		3	Baross utca 111/b mögött
	4	Árpád út 149-cel szemben		4	Bláthy Ottó utca - Vajda Péter utca
	5	Aschner Lipót tér, Tomori utcában		5	Bláthy Ottó utca 18. elé
	6	Bagaria utca (Gázgyár kerítése mellett)		6	Ciprus utca - Százados út
	7	Baross utca - Izzó utca sarok (temető mellett)		7	Ciprus utca, új társasházzal szemben
	8	Bercsényi utca - Deák Ferenc utca		8	Dankó utca 23. előtt
	9	Berda József utca, Autóklubbal szemben		9	Diószeghy Sámuel utca 42.
	10	Bocskai utca - Váci út (vasúti töltésnél)		10	Dobozi utca 49-53-mal szemben
	11	Deák Ferenc utca (Faipari iskola mögött)		11	Dózsa György út 1-gyel szemben
	12	Dugonics utca 21-gyel szemben (parkolóban)		12	Elnök utca 1. számmal szemben
	13	Elem utca parkoló vége Rózsa utca 1-7. tömb mellett		13	Golgota tér - Delej utca
	14	Erdősor út - Sporttelep utca (szervizút mellett)		14	Gutenberg tér 1-gyel szemben
	15	Farkaserdő utca 21.		15	Horváth Mihály tér, Kis Stáció utcával szemben
	16	Fiumei út - Reviczky utca sarok		16	Hős utca 9. (MOL üzemanyagtöltő állomás)
	17	Homoktövis utca – Székpatak utca		17	Hungária krt. 12-14. előtt
	18	Homoktövis utca - Tófalva utca		18	Illés utca 32-vel szemben - Tömő utca sarok
	19	Járműtelep utca - Külső Szilágyi út		19	Illés utca 6-10.
	20	Káposztásmegyer I. Hajló utca (CBA és Profi között)		20	Jázmin utca, trafó előtt
	21	Káposztásmegyeri út - Erdősor út felőli végénél		21	József utca 20-szal szemben
	22	Király utcai patika mögötti parkoló		22	Kálvária tér 8-9.
	23	Külső Szilágyi út 44. (PLUS parkoló)		23	Korányi Sándor utca 14-gyel szemben
	24	Laborfalvy Róza utca - Hídláb utca		24	Korányi Sándor utca 7. - Diószeghy Sámuel utca 19. sarok
	25	Megyeri út 210. előtt parkolóban		25	Kőris utca, szürke betonfal előtt
	26	Óceánárok utca 19.		26	II. János Pál pápa tér - Luther utca 4-gyel szemben
	27	Pozsonyi út 2/B mellett (remízzel szemben)		27	Leonardo da Vinci köz 46-48.
	28	Rózsa utca 9. mellett		28	Lokomotív utca - Vagon tér (a templom mögött)
	29	Szent László tér 2-vel szemben		29	Lujza utca 28.
	30	Szilágyi utca 13-mal szemben		30	Mátyás tér
	31	Szilaspatak sor, ELMÜ kerítés előtt		31	Nagy Templom utca 2.
	32	Tél utca 32.		32	Nagyfuvaros utca, az Auróra rendelő előtt
	33	Tulipánkert utca parkoló		33	Orczy út 35-tel szemben
	34	Virág utca - Tél utca, parkoló sarka		34	Práter utca - Szigony utca
V.	1	Honvéd tér		35	Práter utca 63-mal szemben
	2	Hild tér		36	Rezső tér – Elnök utca sarok
	3	Erzsébet tér		37	Stáhly utca 5-tel szemben
	4	Főpolgármesteri Hivatal		38	Stróbl Alajos utca 11.
VI.	1	Hunyadi tér		39	Stróbl Alajos utca 7. - Strázsa utca sarok
	2	Podmaniczky utca - Ferdinánd híd		40	Százados út – Stróbl Alajos utca
	3	Podmaniczky utca - Eötvös utca sarok		41	Szerdahelyi utca 9.
	4	Podmaniczky utca 113-mal szemben		42	Szigony utca 10.
	5	Podmaniczky utca 99. előtt		43	Teleki László tér, Dobozi utca felőli sarok
VII.	1	Dob utca 35.		44	Teleki tér 17-tel szemben
	2	Városligeti fasor 39-43. szervízút		45	Tisztes utca - Osztály utca sarok
				46	Törökbecse utca-Salgótarjáni út
				47	Vay Ádám utca - Alföldi utca
				48	Verseny utca 12.

District	No.	Address	District	No.	Address
IX.	1	Aszódi utca - Ecseri út 19.	X.	1	Agyagfejtő utca 2.
	2	Aszódi utca 7. mellett		2	Ászok utca 5/D.
	3	Börzsöny utca - Dési Huber utca		3	Bársonyvirág utca 24-gyel szemben
	4	Börzsöny utca 19.		4	Bodza utca 38-cal szemben
	5	Csárdás köz (Ifjúmunkás sarok)		5	Dömsödi utca 29-cel szemben
	6	Csarnok tér		6	Előd utca 10-el szemben
	7	Csengettyű utca közérttel szemben		7	Fagyal utca - Szegély utca sarok - sportpálya mellett
	8	Epreserdő utca 32-vel szemben		8	Gép utca - Luca köz
	9	Epreserdő utca 37. szervízút - Napfény utca		9	Gőzmozdony utca 2-vel szemben
	10	Epreserdő utca 8-cal szemben		10	Gyakorló utca 11/A előtti parkoló sarka
	11	Ferenc tér		11	Gyakorló utca 36-38-cal szemben
	12	Füleki utca, a rendelőintézettel szemben		12	Gyöngyike utca vége, garázssornál (Csilla utca)
	13	Gyáli út 15/a és a Péceli utca között		13	Halom utca 31. mögött, idősek otthona mellett
	14	Haller utca - Soroksári út felőli vége		14	Hangár utca 69-cel szemben
	15	Hentes utca 12. autószervíz előtt		15	Harmat utca - Újhegyi sétány, Szőlővirág utca 8. mellett
	16	Hurok utca 5.		16	Harmat utca 160-nal szemben
	17	Ifjúmunkás utca, Csemege parkoló		17	Hatház utca 2-vel szemben
	18	Illatos út – Gubacsi út sarok, iskola előtt		18	Hortobágyi utca - Rákos patak
	19	Lengyel Gyula Szki Toronyház utcai kerítés mellett		19	Hős utca 17.
	20	Liliom utca 3/a		20	Ihász köz 2. melletti bejáró
	21	Márton utca - Vendel utca sarok		21	Jászberényi út - Köszméte utca
	22	Mester utca - Vágóhíd utca sarok 72. mellett		22	Jászberényi út 109.
	23	Mester utca 26. előtt		23	Jászberényi út 85.
	24	Mihálkovics utca lakótelep, Profi melletti parkoló		24	Kada köz 1 - Harmat utca sarok
	25	Nádasdy utca 2.		25	Kápolna utca - Vaspálya utca óvoda mellett
	26	Napfény utca 21. előtti parkoló sarka		26	Kéknyelű utca 16. előtt, a parkoló sarkában
	27	Napfény utca 26. (MOL üzemanyagtöltő állomás)		27	Kerepesi út 69. mellett
	28	Napfény utca 29-31.		28	Keresztúri út - Váltó utca
	29	Napfény utca ABC előtti tér		29	Kismartoni utca 4.
	30	Pöttyös utca - Üllői út		30	Kocka utca 7.
	31	Réce utca - Osztag utca		31	Korponai utca - Liget utca torkolat
	32	Soroksári út 108. (Kemical gyár) előtt		32	Kovakő utca 21. - Dolomit utca
	33	Soroksári út 44. (Ferencvárosi malom)		33	Kőbányai út 43/a - 43/b között
	34	Táblás utca 15-tel szemben		34	Kőbányai út 54.
	35	Távíró utca - Dési Huber utca - járda		35	Kőér utca 5.
	36	Távíró utca 15.		36	Kőrösi Csoma S. út - Penny áruház előtt
	37	Telepy utca 2. sz. előtt, benzinkút mögött		37	Kővágó utca 18-cal szemben
	38	Timót utca 3. előtt		38	Lavotta utca 1-7. parkoló
	39	Toronyház utca, Csemegével szemben		39	Lenfonó utca 16.
	40	Toronyház utca-Lobogó utca sarok		40	Liget utca 6.
	41	Tűzoltó utca 92. előtt		41	Maglódi út 12. – Algyógyi utca
	42	Üllői út 155.		42	MÁV telep 38. mellett
	43	Üllői út 185. előtt, a parkolóban		43	Medveszőlő utca, CBA parkoló (Szekfűvirág utca)
	44	Üllői út 197 - villamos kocsiszín bejáratával szemben		44	Mélytó utca - Tóvirág utca között
	45	Vágóhíd utca 1-3.		45	Noszlopy utca 62-vel szemben
	46	Vágóhíd utca 31. Lenkey utca sarok		46	Ónodi utca - Kolozsvári utca
				47	Pongrácz út - Szalonka köz
				48	Pongrácz út 9., a CBA mögött
				49	Salgótarjáni szervízút (Hungária krt. közelében)
				50	Sibrik Miklós út - Mádi utca, Mach parkoló
				51	Somfa köz - Balkán utca
				52	Sörgyár utca - Gitár utca
				53	Szőlőhegy utca 9 -11. között, trafónál szegélyhez igazítva
				54	Tavas utca 2-vel szemben
				55	Újhegyi sétány 1-3.
				56	Újhegyi út 2/a
				57	Vásárló utca
				58	Vaspálya utca 18. előtt
				59	Veszprémi utca 2.
				60	Zágrábi utca - Ceglédi utca - Kálavirág utca sarok
				61	Zágrábi utca - Gém utca
				62	Zsombék utca - Korall utca sarok

District	No.	Address	District	No.	Address
XI.	1	7/A buszvégállomás - Sáfrány utca	XIII.	1	Dráva utcai Profi parkolójában
	2	Allende park 14.		2	Árva utca 1.
	3	Andor utca - Albert utca		3	Béke utca 129. - Gyöngyösi utca sarok
	4	Andor utca - Rátz László utca		4	Bodor utca 12.
	5	Auchan - Savoya Park		5	Bulcsú utca 5-tel szemben
	6	Bártfai utca - Fejér Lipót utca		6	Csángó utca 30 - 36.
	7	Bártfai utca - Tétényi út		7	Cserhalom utca - Túróc utca sarok (Marina part)
	8	Bikszádi utca 61.		8	Csizma utca - Frangepán utca
	9	Brassó út - Dayka Gábor utca		9	Dagály utca 8.
	10	Brassó út 12 előtt		10	Esztergomi út 43.
	11	Budafoki út - Irinyi József utca (Schönherz kollégium mögött)		11	Faludi utca 24.
	12	Bukarest utca 19., parkoló végében		12	Gidófalvy utca 1.
	13	Bükköny utca - Fehérvári út (piac - játszótér között)		13	Göncöl utca 40.
	14	Cirmos utca - Boldizsár utca torkolata		14	Göncöl utca 41-43. előtt
	15	Csóka utca		15	Gyermek tér másik oldal
	16	Csukló utca		16	Gyöngyösi utca 11-gyel szemben
	17	Daróci utca 2. - Alsóhegy utca		17	Gyutacs utca - Hajdú utca 48. sarok
	18	Fehérvári út 161. Plus áruház (Andor utca sarok)		18	Hajdú utca 5.
	19	Fraknó utca 32/b. előtt		19	Hegedűs Gyula utca - Dráva utca
	20	Gazdagréti tér		20	Hun utca 2-vel szemben, Lehel utca sarok
	21	Hamzsabégi út 55-57.		21	Jakab József utca 2-vel szemben (idősek otthona)
	22	Harasztos utca, kollégium mögött		22	Jász utca 108. - Keszkenő utca sarok
	23	Kelenföldi út - Thallóczy L. utca (BKV épülete mellett)		23	Jász utca 167. előtt
	24	Kocsis utca, sportpálya előtt		24	Kárász utca 8.
	25	Kondorosi út 7. - Fehérvári út sarok (PLUSZ áruház)		25	Kassák Lajos utca 66.
	26	Kőérberki lakópark		26	Kerekes utca 12.
	27	Kőérberki út 37. garázsok előtt		27	Klapka utca 14-gyel szemben
	28	Kővirág sor - Mustár utca, buszforduló		28	Lehel piac - Kassák Lajos utca torkolat
	29	Leiningen utca		29	Madarász Viktor utca 29. - Faludi utca sarok
	30	Ménesi út, Kelenhegyi lépcső, trafónál		30	Mura utca 1. előtt - Váci út
	31	Menyecske utca 25. mögötti parkoló - Költők Parkja		31	Népfürdő utca szervízút - Dunavirág utca
	32	Mezőkövesd utca - Fehérvári út sarok		32	Országbíró utca
	33	Nagyszeben tér - PLUS áruház mellett		33	Pannónia utca 86.
	34	Nándorfejérvári út 23.		34	Párkány utca 10 - Víza utca sarok
	35	Rátz László utca, iskolával szemben		35	Párkány utca 20-szal szemben
	36	Rodostó utca - Beregszász utca		36	Párkány utca 46-tal szemben (Gyógyszertár mögött)
	37	Sáfrány utca parkoló		37	Petneházy utca 29. sz. mellett, az ORIGO házzal szemben
	38	Saru utca 11.		38	Reitter F. utca 103. - Tahi utca
	39	Sasad Resort, Rupphegyi út		39	Süllő utca 9.
	40	Solt utca 37-tel szemben		40	Szegedi utca - Szent László utca sarok (CBA előtt)
	41	Szent Kristóf utca - Pecz Samu utca		41	Szobor utca 4-8.
	42	Szerémi sor 10. – Hamzsabégi út		42	Tahi utca - Jász utca sarok (Penny Market)
	43	Szerémi út, zajvédő fal mellett		43	Tahi utca 22-vel szemben (a Tomori köznél)
	44	Tétényi köz 1.		44	Tahi utca 48/a (a Tahi köz torkolatában)
	45	Tétényi út - Kondorosi út - Tomaj utca		45	Taksony utca 7.
	46	Vahot utca 6. parkoló		46	Tatai út 120.
	47	Vegyész utca - Fegyvernek utca		47	Tatai út 38.
XII.	1	Béla király út 4/a.		48	Teve utca 52.
	2	Bürök utca - Ágnes utca		49	Tomori utca - Agyag utca sarok, a piac csücske
	3	Csörsz utca 47-tel szemben		50	Tomori utca 29.
	4	Diósárok utca 20/a-val szemközti parkoló		51	Tomori utca 7.
	5	Edvi Illés utca 2/a (Lidérc utca sarok)		52	Turbina utca 1-gyel szemben - Váci út sarok (Metró bejárat)
	6	Eötvös utca 59. (Normafa parkoló)		53	Újpalotai út - Szekszárdi út sarok
	7	Győri út		54	Újpesti felső rakpart - Besssenyei utca sarok
	8	Hadik András utca 23.		55	Váci út 132/b
	9	Hangya utca 37. (Csorna utcával szemben)		56	Vágány utca 21. (MOL üzemanyagtöltő állomás)
	10	Határőr út 17-tel szemben		57	Visegrádi utca 56. előtt
	11	Hegyalja út - Vas Gereben utca - Sashegyi út			
	12	Hegyhát út - Sötétvágás utca			
	13	Ignótus utca 35-tel szemben			
	14	Karthauzi köz (Match áruház mögött)			
	15	Kázmér utca 21-gyel szemben			
	16	Konkoly Thege Miklós út (Szabadidő központ bejárata)			
	17	Konkoly Thege Miklós út 29-33.(KFKI főbejárat)			
	18	Kútvölgyi út 16.			
	19	Kútvölgyi út 48/a-val szemben			
	20	Kútvölgyi út 6 -10.			
	21	Nógrádi utca - Szendrő utca			
	22	Pagony utca (Plus Diszkont mellett)			
	23	Ráth György utca 36.			
	24	Szarvas Gábor út - Zalai út			
	25	Szilassy utca 12/a.			
	26	Thomán István utca 11-gyel szemben parkoló másik oldala			
	27	Zugligeti út 63.			
	28	Zugligeti út 91.			

District	No.	Address	District	No.	Address
XIV.	1	Ajtósi Dürer sor 25/a - Olof Palme stny.	XV.	1	Árendás köz 8. iskola mellett
	2	Álmos vezér útja - Fogarasi út melletti parkoló		2	Bánkút utca, SPAR mögött
	3	Bartl János u 1-gyel szemben		3	Cserba Elemér utca - Kiss Ernő utca sarok
	4	Csertő utca 12-14. Sportpálya mellett, OFFICE Centerrel szemben		4	Drégelyvár utca 13-15.
	5	Csömöri út - Cinkotai út (Hallássérültek Iskolája)		5	Drégelyvár utca 43. mögött
	6	Csömöri út 23. Sporttelep		6	Drégelyvár utca 7-11.
	7	Egressy út - Cinkotai út sarok (Rákosmezei tér)		7	Énekes utca 12-vel szemben - Lóvasút köz
	8	Egressy út - Róna utca		8	Epres sor, Régi Fóti út felől
	9	Egressy út 6. előtt		9	Erdőkerülő utca, SPAR melletti parkoló
	10	Egressy út 73/c (élelmiszer bolt mellett)		10	Fő út 68. a posta hátsó bejáratával szemben
	11	Egressy utca -Vezér utca		11	Gazdálkodó utca - Petrence utca
	12	Egyenes utca 8.		12	Géza fejedelem tér 8-cal szemben
	13	Fogarasi út - Csernyus u.		13	Harsányi Kálmán utca -Töltés utca
	14	Fogarasi utca - Bagolyvár utca óvoda		14	Hősök útja (Gyógyszertár)
	15	Fogarasi utca - Gvadányi utca Smatch mellett		15	Kavicsos köz - Nyírpalota utca parkolóban
	16	Fráter György u. 15 -17.		16	Késmárk utca 3. előtti parkoló
	17	Füredi utca - Vezér utca sarok		17	Kismező utca - Attila utca
	18	Gvadányi út 29/a előtt		18	Kontyfa utca 1. (Vásárcsarnok WC vel szemben)
	19	Gvadányi út 33-39 előtt		19	Kossuth Lajos ltp. Csobogós utca 2. (a templom mögött) új hely
	20	Gvadányi út 62-64. közötti parkoló		20	Kozák tér (M3-Bánkút utca felőli rész)
	21	Horváth Boldizsár utca 8-10. (Közért mögött)		21	Kozák tér keleti oldal
	22	Hungária köz		22	Kőrakás park 12.
	23	Hungária krt. 156-160. Vakok intézete		23	Közvágóhíd tér 30. (olajgyárral szemben)
	24	Irottkő park - Ungvár utca		24	Lőcsevár utca - Molnár Viktor utca óvodával szembeni parkoló
	25	Kacsóh Pongrác út - Rákospatak felüljáró előtt		25	Nádastó park 1-3. az óvoda sarkánál
	26	Kacsóh Pongrác út 120-146. (autóbontó)		26	Népfelkelő utca 96-tal szemben, terelő szigeten
	27	Kassai tér (a közért oldalában)		27	Neptun utca 88.
	28	Kerékgyártó utca - Fűrész utca		28	Nyírpalota út 35.
	29	Kerékgyártó utca - Miskolci út		29	Nyírpalota út 43. mögött
	30	Kerékgyártó utca - Nagy Lajos király útja		30	Nyírpalota út 72-vel szemben
	31	Kerékgyártó utca - Rákospatak utca		31	Nyírpalota út 79/D járda
	32	Korong utca 23-mal szemben (Amerikai út sarok)		32	Obsitos tér, park felőli oldal
	33	Mályva tér 7.		33	Ozmán utca - Szent Korona utca sarok
	34	Mexikói út - Fogarasi út (a töltés mellett)		34	Páskom park 5. előtti kiépített terület
	35	Miskolci utca 132.		35	Páskomliget utca 47. CBA mellett
	36	Mogyoródi út - Öv utca		36	Pattogós utca 6-8. (iskola parkolója)
	37	Mogyoródi út 130. (Gvadányi utca sarok)		37	Pázmány Péter utca 74-gyel szemben
	38	Mogyoródi út 64/b-vel szemben		38	Pázmány Péter utca, a felüljáró alatt
	39	Nagy Lajos király útja 1-9.		39	Rákos út 169-cel szemben, Mozdonyvezető utcában
	40	Ond vezér útja 1-3.		40	Rákospalotai Körvasútsor Drégelyvár utcánál
	41	Ormos utca - Dongó utca sarok, Dongó utca 8-cal szemben		41	Rákospalotai körvasútsor M3 felüljáró alatt
	42	Örs vezér tér 1-3. (Bolgárkertész utcánál)		42	Régi Fóti út 2-4. szervízút
	43	Ötvenes utca - Kerepesi út		43	Sárfű utca - Bánkút utca sarok
	44	Pillangó park 7-9.		44	Sárfű utca - Szentmihályi út parkoló
	45	Pillangó utca LIDL és TESCO áruházak között		45	Szántóföld utca - Kosd utca
	46	Rákospatak u. 13-27-tel szemben (Csömöri út kereszteződésénél)		46	Széchenyi út, felüljáró melletti parkolóban
	47	Rákospatak utca 77.		47	Székely Elek utca 16-tal szemben
	48	Róna utca - Erzsébet királyné útja		48	Szent Korona útja bal oldal
	49	Stefánia út 41-gyel szemben a stadion oldalán		49	Szilas park (játszótér, Pólus Center felőli oldal)
	50	Szentmihályi út - Kerepesi út (az autókereskedés mellett)		50	Taksony sor (Dembinszky utca - Pázmány Péter utca)
	51	Szervián utca 18-20. (Kaffka köz)		51	Tarpai tér 4-gyel szemben (ABC oldalánál)
	52	Szuglói körvasútsor - Egressy út kereszteződésénél		52	TESCO - Pólus
	53	Szuglói körvasútsor 173 -174 között		53	Törökszegfű tér 5. - Csillagfürt utca sarok
	54	Szuglói körvasútsor 202-208. számú ingatlan előtt		54	Vácrátót tér
	55	Teleki Blanka u. 17- tel szemben		55	Wesselényi utca - Őrjárat utca
	56	Tengerszem köz 12.		56	Wesselényi utcai piac
	57	Tengerszem utca -Rákospatak utca 100.			
	58	TESCO - Fogarasi			
	59	Thököly út - Dózsa György út sarok			
	60	Thököly út - Francia út sarkán			
	61	Thököly út - Róna utca			
	62	Újvidék tér			
	63	Ungvár utca - Fűrész utca			
	64	Ungvár utca - Rákospatak utca 97.			
	65	Városligeti körút, parkoló (Hermina út és Petőfi Csarnok között)			
	66	Vezér utca125. - Mogyoródi út			
	67	Zalán utca - Gvadányi utca			
	68	Zalán utca vége, iskola előtti parkoló sarka			
	69	Zsálya utca-nál a Tihany utca 19-cel szemben			

District	No.	Address
XVI.	1	Alsómalom utca - Olló utca 14.
	2	Arany János utcai iskola (benzinkúttal szemben)
	3	Árpádföldi tér
	4	Bökényföldi út 102.
	5	Bugac tér, ABC-vel szemben
	6	Cinkotai strand előtt
	7	Cziráki utca - Szolnoki utca sarok
	8	Dióssy Lajos utca 28. főiskola belső autóparkolója
	9	Gusztáv utca - Szlovák út torkolata
	10	Jókai Mór utca, rendőrséggel szemben
	11	Lándzsa utca ltp. Bejáratánál
	12	Malomkerék tér
	13	Mátyásföld Alsó HÉV megálló mögött
	14	Olga utca 10. Parkoló
	15	Olga utca 3/b szembeni parkoló (eredeti hely)
	16	Pálya utca ltp. - Rigó utca
	17	Pesti Határút 1/A
	18	Sashalmi sétány
	19	Tiszakömlő utca 31-35, iskola Üzbég úti oldalánál
	20	Újszász utca - Perjés utca sarok
	21	Újszász utca (Borotvás utcánál) Computer bolttal szemben
	22	Zalavár utca - Kicsi utca
	23	Zsarnó tér Anilin utca felőli oldal
XVII.	1	545. utca - 526. sor
	2	Anna utca – Pajta utca kereszteződése
	3	Agyagos utca 40. ABC mögött
	4	Bajza utca - Baross utca, Bajza utca 48-cal szemben
	5	Baross utca 118.
	6	Cinkotai út 34. előtt (VOLVO HUNGÁRIA)
	7	Dormánd utca 23.
	8	Egészségház 38. mögött
	9	Egészségház utca 24.
	10	Ferihegyi út 118 - Gyökér utca 6-tal szembeni parkolóban
	11	Ferihegyi út SZTK mögötti hátsó szervízút szigetében
	12	Ferihegyi utca 68-76, a Medical Center bal oldalán
	13	Földműves utca 23.
	14	Gyökér utca 7-9. mögött, a szervízút mellett
	15	Kaszáló utca - sportpálya mellett
	16	Kaszáló utca 119.
	17	Kaszáló utca 121-135-tel szemben, parkolóban
	18	Kucorgó tér - Pesti út
	19	Kvasz András utca 1.
	20	Laffert utca - Péceli út, trafó előtt
	21	Naplás utca 132.
	22	Pesti út (PLUS áruház előtt)
	23	Pesti út 150-152.
	24	Pesti út 20-28. mögött, Malomárok utcában
	25	Pesti út 27. - Újlak utca 49. között, alsó parkoló
	26	Rákoskert sugárút - Erzsébet körút
	27	Rákoskert sugárút - Kisérő utca
	28	Szabadság utca 28-cal szemben
	29	Szántó Géza utca 63 - Temető utca
	30	Szent Imre Herceg út - IV. utca 52-vel szemben
	31	Szigetcsép utca - Pesti út sarok
	32	Tabán utca 12.
	33	Táncsics Mihály út - Damjanich utca saroknál
	34	Tarcsai út - Tóalmás utca buszforduló
	35	TESCO - Pesti út
	36	Újlak utca 11. mögött
	37	Újlak utca 110. (Újlak utcai iskola hátsó bejárat)
	38	Újlak utca 120 - 124.
	39	Újlak utca 16.
	40	Újlak utca, Plus mellett
	41	Újmajori utca 2. – Helikopter utca
	42	Vecsey utca - Gyolcsrét utca 2.

District	No.	Address
XVIII.	1	Ajtony utca 4.
	2	Attila utca 1. - Gyömrői út sarok
	3	Barcika tér
	4	Barcsay utca - Irányi utca
	5	Béke tér 1., Liget szerelvénybolt előtt
	6	Bókay Árpád utca - Fürst Sándor utca sarok
	7	Bükk u 8 - Nyárfás sor
	8	Csontváry utca 15.
	9	Csontváry utca 2.
	10	Csontváry utca 30.
	11	Egressy Gábor utca 30-32.
	12	Építő utca - Dolgozók útja
	13	Fonal utca - Fáy utca
	14	Goroszló utca, a Margó Tivadar utcánál
	15	Gyékény tér
	16	Haladás utca, volt buszvégállomás
	17	Havanna ltp. Match üzlet mögött
	18	Havanna utca 2-vel szemben a PLUS parkolóban
	19	Havanna utca 43.
	20	Iker téri parkoló
	21	Kapocs utca parkoló vége
	22	Kappel Emília utca - Halomi laktanya
	23	Kézműves utca 6.
	24	Kolozsvár utca - Csontváry utca 62.
	25	Kolozsvár utca - Kondor Béla sétány sarok
	26	Kolozsvár utca 27. - Kelet utca
	27	Lakatos úti ltp. Smatch parkoló
	28	Lugos utca - Malév uszoda
	29	Margó Tivadar utca - Sallai utca a Bókai kertnél
	30	Martinovics tér
	31	Mikszáth Kálmán utca - Aranyeső utca
	32	Nagyenyed utca - Halomi út sarka
	33	Nefelejcs utca - József utcával szemben
	34	Nyárfás sorral szemben a játszótér mellett(Alacska l
	35	Szálfa utca - Vasút utca
	36	Szentlőrinc vásárcsarnok mögött
	37	Szövet utca 105-tel szemben
	38	Tátrafüred tér - Szitnya utca
	39	Thököly úti gimnázium mellett, Thököly út 20-szal sz
	40	Tóth Árpád utca - Lőrinci Temető előtt
	41	Üllői út 661 - Lőrinc Center parkoló
	42	Üllői út - Piac tér
	43	Vasút utca 54-gyel szemben - tüzép előtti parkoló
	44	Zemplén utca 2.

District	No.	Address	District	No.	Address
XIX.	1	Ady E út - Toldi utca sarok (garázsok előtt)	XXI.	1	Ady Endre út 13-15. toronyépület
	2	Ady Endre út szervízút - Rendőrséggel szemben		2	Ady Endre út 3-5., a parkolóban
	3	Artur utca 11.előtt		3	Ady Endre utca 17-19. mögött
	4	Bárczy István tér		4	Ady Endre utca 21-23. mögött
	5	Batthyány utca 18-cal szemközti parkoló		5	Ady Endre utca 39-cel szemben
	6	Bem utca - Szigligeti utca sarok		6	Akácfa utca 18-cal szemben
	7	Bem utca 52-vel szemközti parkoló		7	Akácfa utcában kocsi mosóval szemben
	8	Corvin krt. 4. parkoló		8	Árpád utca 6.
	9	Deák Ferenc utca – Üllői út, szervizút parkoló		9	Bajcsy Zsilinszky utca - József Attila utca
	10	Eötvös utca, Üllői út felőli vége		10	Bánya utca - Gombos tér (iskola kerítése mellett)
	11	Europark		11	Bánya utca 25. mellett, ABC-nél
	12	Garázs utca 3-5.		12	Béke tér 1.
	13	Gosztonyi Lajos utca 1-gyel szemben		13	Béke tér 4/a-val szemben
	14	Irányi Dániel utca 31.		14	Cirmos sétány 5. előtt, Erdősor utca 149. mögött
	15	József Attila utca - Hunyadi utca		15	Csepeli piac 8. kapujával szemben
	16	József Attila utca – Jáhn Ferenc utca sarok		16	Cservenka Miklós utca 24-30.
	17	József Attila utca - Kossuth Lajos utca		17	Duna dűlő 5/B
	18	József Attila utca - Nagysándor J. utca		18	Erdősor utca 179. előtti parkoló
	19	Katica utca - Teleki utca		19	Erdősor utca 28-cal szemben
	20	Kispesti uszodánál, parkoló sarkában		20	Erdősor utcai ltp., Csikó sétány
	21	Kiss János altábornagy utca (trafóházzal szemben)		21	Fecske utca orvosi rendelő
	22	Lehel utca 18-22.		22	Festő utca 3-5-tel szemben
	23	Nagysándor József utca - Petőfi utca		23	Hollandi út 237-tel szemben
	24	Pannónia út - Bercsényi utca sarok		24	Hollandi út 3-mal szemben - Kis-Duna öböl lejárata
	25	Puskás Ferenc utca 1-gyel szemben		25	Hollandi utca rév átkelő (buszmegállóval szemben)
	26	Tartsay utcai parkoló - Zrínyi utca		26	II.Rákóczi Ferenc út 345.
	27	Temesvár utca - Ipolyság utcával szemben		27	Iskola tér
	28	Temesvár utca - Karton utca		28	József Attila utca 63-mal szemben
	29	Toldi utca 3.		29	Kapos utca 3-5-tel szemben
	30	Tóth Árpád utca 19. előtt		30	Kikötő utca, Plus parkoló végében
	31	Üllői szervízút - Klapka utca 2. mellett		31	Királyerdei müvelődési ház, Szent István út 230.
	32	Üllői út - Arany János utca sarok		32	Kiss János altábornagy utca 65., ANTSZ mögött
	33	Üllői út - Jáhn Ferenc utca		33	Kokilla tér
	34	Üllői út - Kosárfonó utca		34	Kossuth Lajos utca 101-gyel ferdén szemben
	35	Üllői út - Széchenyi utca sarok		35	Kossuth Lajos utca 112-122. mögött
	36	Vak Bottyán utca – Kosárfonó utca		36	Kossuth Lajos utca 130-cal szemben
	37	Vak Bottyán utca - Eötvös utca sarok		37	Kossuth Lajos utca 142.
	38	Vas Gereben utca 142-146.		38	Kossuth Lajos utca, Penny Markettel szemben
	39	Vásár tér, trafó mellett		39	Krizantém utca 24-gyel szemben
XX.	1	Ady E utca volt Harisnyagyárral szemben		40	Krizantém utca 2-vel szemben
	2	Alsóteleki utca - Helsinki út		41	Láng Kálmán utca parkoló
	3	Attila utca 26-tal szemben		42	Makád utca - Kikötő utca
	4	Bácska tér 29/b		43	Mars utca 17.
	5	Baross utca 25.		44	Nagykalapács utca (épület mellett kiépített terület)
	6	Baross utca 47. - Bíró Mihály utca		45	Nyuszi sétány, pavilonsor
	7	Bíró Mihály utca, McDonalds		46	Petz Ferenc utca - játszótér végénél
	8	Deák Ferenc tér - Kulcsár utca torkolata		47	Puli sétány 1-9, Erdősor utca 165. mögött
	9	Dessewffy utca - Török Flóris utca		48	Rakéta utca - Kozmosz stny.
	10	Eperjes utca 47-tel szemben		49	Rakéta utca 18-cal szemben
	11	Fiume utca – Mártírok utca		50	Szabadság utca 16/a-val szemben
	12	Határ út 1. Parkoló sarkában		51	Szent Imre tér, Kiss János altábornagy utca 34-gyel szemben
	13	Határ út 7-10.		52	Szent István út - Erdőalja út (MOL üzemanyagtöltő állomás)
	14	Helsinki út 2-3. között		53	Szent István út 1-3.
	15	Helsinki út 40. szervizúton		54	Szent István út 159-cel szemben
	16	Helsinki út 9.		55	Szent László úti üzletház, a kék iskola
	17	Hunyadi János tér 2.		56	Szentmiklósi út – Vezeték utca
	18	János utca 6-6b		57	Táncsics Mihály út 83-mal szemben
	19	Kalmár Ilona sétány - Vörösmarty utca - Berkenye sétány		58	Tejút utca 2.
	20	Károly utca - Orsolya utca sarokkal szemben		59	Templom utca 15-17. előtti parkoló
	21	Kossuth Lajos utca 5. számú ház tűzfalával szemközti járda		60	TESCO - Csepel
	22	Köteles utca 65. ABC előtt		61	Toldi Ferenc utca 14-gyel szemben
	23	Lajtha László utca játszótér széle		62	Vízmű ltp. 345. B/2 mögött
	24	Magyarok Nagyasszonya tér 12-vel szemben		63	Völgy utca 39-cel szemben
	25	Mátyás király tér 15.		64	Zrínyi utca - Reggel utca
	26	Nagykőrösi út - Nagysándor József utca 227.		65	Zrínyi utca 23-mal szemben
	27	Nagysándor József utca 18-cal szemben		66	Zrínyi utca 6/a és Óvoda 1-8. ép.
	28	Nagysándor József utca 40/c-vel szemben		67	Zsák Hugó utca 22. parkoló
	29	Nyáry Pál utca 3. - Balassa utca			
	30	Pöltenberg utca 10-12.			
	31	Rákóczi utca 128. - Nagykőrösi út sarok			
	32	Rimaszombat utca 3-mal szemben			
	33	Ritka utca - Ábrahám G. utca			
	34	Serény utca 2. (Iskola bejárata)			
	35	Szabadság utca 67-69. - Klapka utca			
	36	Székelyhíd utca 4-gyel szemben			
	37	Szilágyság utca - Sajó utca			
	38	Tátra tér - Kende K. utca 100-zal szemben			
	39	Tátra tér, piac oldalánál			
	40	Tátra tér, Sas utcával szemben			
	41	Téglaégető utca - Közműtelephely utca			
	42	Téglagyár tér - Vizisport utca 11. támfal előtt			
	43	Téglagyártó út 8-cal szemben			
	44	TESCO - Megapark			
	45	Török Flóris utca - Alsó határút kereszteződés, tüzép előtt			
	46	Török Flóris utca 2/a előtt			
	47	Török Flóris utca 33-mal szemben			
	48	Vágóhíd utca 18-26. társasház előtt			
	49	Vágóhíd utca 59-cel szemben			
	50	Vasútsor és Kulcsár utca között, a Radvány utcával szemben			
	51	Vizisport utca 28-cal szemben			
	52	Vörösmarty tér, a trafó mellett			
	53	Vörösmarty utca 82-vel szemben			
	54	Zilah utca posta előtt			

District	No.	Address	District	No.	Address
XXII.	1	Ady Endre út - Hasadék utca	XXIII.	1	Auchan - Soroksár, üvegvisszaváltó
	2	Angeli út 166-168-cal szemben		2	Bólyai János utca 9-11.
	3	Angeli utca 66.		3	Dinnyehegyi út (a Szentlőrinci út közelében)
	4	Anna utca 13-15. (Budai Nagy Antal gimnázium) előtt		4	Dobó utca, játszótér mellett, trafó előtt
	5	Anna utca 18.		5	Fűzfa köz - Haraszti út
	6	Bányalég utca 104.		6	Grassalkovich út 255.
	7	Barackos út 1-3.		7	Hősök tere, vasudvar mellett
	8	Barackos út 143-mal szemben		8	Hunyadi utca - Haraszti út sarok
	9	Bartók Béla út 165-167.		9	Káposztásföld utca 1., a szennyvízátemelő mellett
	10	Batthyány utca vége		10	Kiskert utca, (Péteri major) a játszótér mellett
	11	Debrő utca - Síp utca		11	Kő utca - Könyves utca
	12	Dévény utca 66-68-cal szemben		12	Kő utca, játszótér mellett
	13	Diótörő utca 115/a		13	Láva utca 1.
	14	Dózsa György út 136. - Bem tábornok utca		14	Meddőhányó utca (az Oázis kertészet után)
	15	Dózsa György út 164. - Török utca		15	Milleneumi telep, Lórév utca, volt közért előtt
	16	Dunatelep-Dunafürdő ABC		16	Molnár sziget, a pavilonok mellett
	17	Füttyös utca 14. mellett, a parkolóban		17	Nyír utca 69. mellett
	18	Gádor utca – Háros utca sarok		18	Szent László utca 165-169.
	19	Gádor utca 97-99. előtt		19	Szent László utca járda - Szentlőrinci út sarok
	20	Gyöngyszem utca 14.		20	Szérűskert dűlő - Vecsés út
	21	Hajó utca OMV kút mögött		21	Szitás utca
	22	Háros utcai buszforduló parkoló-részében		22	Tartsay utca 21. Nyír utca közelében
	23	Hittérítő út 1/a		23	Templom utcai közpark, a Gyáli-patak mellett
	24	Játék utca - Kárpitos utca sarok		24	Török utca, híd előtt
	25	Játék utca, a piac mellett, a parkolóban		25	Vágó köz, a sportpálya mellett
	26	Jókai Mór utca - Művelődés utca		26	Zsellér dűlő, Mikszáth Kálmán általános iskola mellett
	27	József Attila utca 15-tel szemben			
	28	Kápolna utca 2-4. iskola előtt			
	29	Kereszt utca - Alsósas utca			
	30	Kiránduló utca - Avar utca			
	31	Komáromi út 7/b			
	32	Komáromi utca 23. (Kiserdő előtti parkoló)			
	33	Leányka utca 30. mögötti parkoló			
	34	Mária Terézia 25-27.		Waste yards	
	35	Mátra utca 46.			
	36	Mező utca 12. - Gádor utca			
	37	Mező utca 60-nal szemben		III.	Testvérhegyi út 10/a
	38	Nagytétényi út - Bartók Béla út		IV.	Ugró Gyula sor 1-3.
	39	Nagytétényi út - Jókai Mór utca		IV.	IV., Zichy Mihály u. - Istvántelki út sarok
	40	Nagytétényi út 149. szervízút		VIII.	Sárkány u. 5.
	41	Nagytétényi út 162.		IX.	Ecseri út 9.
	42	Nagytétényi út 260. - Pohár utca		X.	Fehér köz 2.
	43	Nagytétényi út 298. - Föld utca		XI.	Bánk bán u. 8-10.
	44	Nagytétényi út 331-gyel szemben		XIII.	Tatai út 96.
	45	Nagytétényi út 374-376. - Dűlő utca		XIV.	Füredi út 74.
	46	Nagytétényi út 51 - Növény utca		XV.	Károlyi S. u. 119.
	47	Nagytétényi út 74-76.		XV.	Zsókavár u. 65.
	48	Növény utca üdülőtelep		XVI.	Csömöri út 2-4.
	49	Óhegy lakópark - Galga utca		XVII.	Gyökér köz 4.
	50	Pécsi utca 1/c-vel szemben		XVIII.	Jegenye fasor 15.
	51	Regényes utca - Arany János utca		XXI.	Mansfeld Péter u. 86.
	52	Rózsakert utca – Terv utca		XXII.	Nagytétényi út 341-343.
	53	Rózsakert utcai lakótelep, SPAR mögötti parkoló széle			
	54	Sörház utca - Diófa utca			
	55	Szél utca 4.			
	56	Tatárka utca 2.			
	57	Tenkes utca (Nagytétényi út)			
	58	TESCO - Campona			
	59	Tompa utcai iskola mellett			
	60	Tűzliliom utca			
	61	Úttörők útja 1. - Szent Flórián tér			
	62	Vidám utca ltp.-Névtelen utcai parkoló			
	63	XIII. utca 82-vel szemben			
	64	XIII.utca - XVI. utca			
	65	Zászlóvivő utca 5.			
	66	Zöldike utca - Liszt F. utca			

Location of the waste islands in Budapest, districts XXII-XXIII and

location of the waste yards in Budapest.

Own contrinution based on the lists of FKF Zrt.