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Comparison of energy and material recovery of household waste management from the environmental point of view – Case Kaunas, Lithuania

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ABSTRACT

The results of life cycle assessment of five different energy recovery – based waste management system options are presented. The system options were designed for the city of Kaunas, Lithuania. The Kaunas model was formed according to the Simple Integrated System Management concept developed at Lappeenranta University of Technology. CML2001 was selected as the method according to which the life cycle impact assessment profiles were compiled and analyzed.

The results suggest that energy recovery from biowaste, paper and cardboard derived from households could be a more recommendable waste management option than material recovery of the fractions (composting of biowaste and recycling of paper and cardboard). The calculations were carried out with limited process information, and cannot thus be generalized in all parts.

1. Introduction

Lithuania is going through a major transition phase. The growing economy causes changes in people's consumer habits. The growth of the economy requires more support from the infrastructure, including waste management and energy supply. Since its entry into the European Union in 2004 Lithuania has started to change its waste management policy to meet the EU standards. Updating the whole waste management system, including source separation, collection and transportation of waste, different material recovery, energy recovery, and final disposal options is an ongoing and endless task. The decisions concerning strategies involving large regions are made usually for tens of years ahead. Thus, the strategies should be considered from different angles before any binding decisions are made.

The next steps in the development of the Lithuanian Municipal Waste Management System may be the arrangement of some environmentally friendly mixed municipal waste incineration plants. Such scenarios fully satisfy the requirements of the Council Directive on Landfill of Waste and the Lithuanian State Strategic Waste Management Plan concerning reduction of landfilled biodegradable waste. According to these scenarios the incineration of mixed municipal waste for the two largest Lithuanian cities, Vilnius and Kaunas, would be started in 2013.

Waste recovery (as material or energy) is commonly accepted as a more sustainable alternative for waste management than final disposal to landfills. Earlier interpretations of the EU Waste Hierarchy placed material recovery before energy recovery in the Hierarchy List. With the help of the development of waste management assessment methods (such as life cycle assessment) it is now easier to compare material recovery (composting and recycling) with energy recovery case-by-case also from the environmental point of view.

Waste management system – related papers have been published widely throughout the beginning of this millennium, covering the field from waste generation to the environmental impacts of different waste management system options. Recently, Sokka et al. [1] and Salhofer et al. [2] have published papers about waste generation and prevention. Furthermore, Beigl et al. [3] reviewed 45 different published approaches of estimating present or future waste generation, and discovered a high heterogeneity of applied models in spite of similar issues dealt with in the models.

Life Cycle Assessment (LCA) has been utilized extensively in waste management system studies, especially in Sweden [4–6]. Different LCA applications of waste management system studies have been compared by Winkler and Bilitewski [7].

Studies of energy recovery from municipal waste from different points of view have been published. Several research groups [8–11] have studied the economy of the use of waste-derived fuels in energy production. LCA studies involving energy recovery have also been recently published by several research groups [12–16].

Although some future waste management options for the city of Kaunas have been assessed by Wade et al. [17] and Rimaitytė et al. [18], there is still need for further studies concerning different system options.

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The nature of waste management system assessments (the results are usually valid locally) supports the development of different assessment approaches. Knowledge about the environmental impacts of processes increases continuously, and the results of today's assessments may not be valid in the light of tomorrow. Thus, there is a continuous demand for new system models and better databases for impact assessments.

This paper presents the results of the study concerning the environmental feasibility of energy recovery from household waste in Kaunas. Kaunas is the second largest city in Lithuania with 369 000 inhabitants in 2004. The size of the population is decreasing due to various reasons, however the household waste generation is increasing due to the increase of GDP. Household waste constitutes about 60% of the overall MSW in Kaunas. Five different alternatives were chosen as possible waste management strategies for Kaunas. Kaunas' household waste was divided into eight fractions which can be separated in the households, if necessary. The fractions were directed to different purposes (material recovery, energy recovery, final disposal) in the alternatives in order to study the feasibility of material and energy recovery of certain household waste fractions.

The Kaunas model was formed according to the Simple Integrated System Management (SISMan) concept [19,20] developed at Lappeenranta University of Technology. The SISMan concept can be considered as a frame of reference which defines the major features that should be considered when system assessments are made. The features include consideration of mass, energy and financial flows of the system together with environmental impacts, restrictions and targets.

2. Methods

The procedure and results of a comparison of five different energy recovery based waste management alternatives are presented from the environmental point of view in this paper. The integrated waste management and energy supply system under discussion is located in Kaunas, Lithuania. As authentic local data as possible was used in the calculations, including the composition and amount of municipal waste. The assessment process was carried out for household waste due to insufficient information concerning the packaging wastes of business and industry in the studied area. The aim of the model formation and the calculations was to study the feasibility of energy recovery from different fractions of household wastes in Kaunas city from the environmental point of view. As the outcome, the most feasible option of the presented energy recovery alternatives was chosen.

The SISMan concept [19,20] was utilized in forming the Kaunas model. The SISMan concept focuses on technical and economical consideration of the integrated waste management and energy supply system, and could be adapted and used in calculating the mass, energy and financial flows of the Kaunas system. However, the focus in this context is on the environmental aspects of different energy recovery -based waste management system alternatives.

The CML2001 [21] Life Cycle Impact Assessment (LCIA) method was selected as the tool to evaluate different energy recovery – based waste management options in Kaunas from the environmental point of view. In general the results of the LCIA process, together with the results of the techno-economical results form the information base that decision makers can utilize in decision making processes involving e.g. waste management systems which require large investments.

2.1. Description of the cases

The composition of household waste in Kaunas was derived from the results presented by Rimaitytė et al. [18]. The total amount of household waste in Kaunas (151 096 t/a) was divided into eight fractions: glass, metals, biowaste, paper, cardboard, plastics and composites, other combustibles (wood, textiles and vulcanized rubber), and minerals (inerts, non-combustibles). Hazardous waste was not considered in this context, because it has to be collected and treated separately from the other fractions. The amounts and percentages of the fractions of Kaunas household waste are presented in Table 1.

Table 1
Contents of Kaunas household waste [17,18]

Classification	Percentage of total mass [%]	Fraction [t (a)$^{-1}$]
Biowaste	44	66 482
Plastics & composites	9	13 599
Paper	10	15 110
Cardboard	4	6044
Wood, textiles & vulcanized rubber	17	25 686
Minerals	2	3022
Metals	3	4533
Glass	11	16 621
	100	151 096

The efficiency of source separation (how much of the fraction is actually placed in the right container) has to be taken into consideration in order to get more realistic interpretations and estimates of the different system options. The efficiencies for the current situation of Kaunas (Case 0) were calculated according to the data presented by Rimaitytė et al. [18]. The principle of the determination of the separation efficiency is presented in Table 2. The annual amounts of the six fractions were given for the cases K1–K4. The amounts in the cases K2–K4 were used to determine the waste generation rate for the fractions. Separation efficiencies for the fractions were then calculated "backwards" by dividing the actually separated amount of each fraction (Current situation – K1) by the generation of the fraction.

Five scenarios (Cases 1–5) of waste management system options were selected for the basis of the assessment process. The current situation (Case 0) was used as the reference case. The cases are presented in Table 3. It should be noted that although the present situation seems to be well organized (a material recovery system is available for most of the fractions), the efficiency of the source separation of the fractions needs to be improved in order to increase the recovery rates (material recovery: 15%, energy recovery: 0%).

The principle behind the case selection is based on the idea that the eight fractions can be separated from each other relatively easily in the source (households). Dealing with eight different fractions does not necessarily lead to the use of eight bins in households, as the fractions that are directed to the energy recovery process can be collected in the same bin. Also landfill waste will be collected in one container. Furthermore, if metals and glass are collected in separate collection stations, the source separation would involve 2–6 containers (Case 1: 4 bins; Case 2: 3 bins; Case 3: 6 bins; Case 4: 5 bins; Case 5: 2 bins).

It is also possible to separate different fractions from each other in a mechanical–biological treatment (MBT) plant. In that case practically no source separation would be necessary. However, Finnish calculations [22] show that the MBT process is an expensive addition to the waste management process, as it produces little benefit to the system compared to the large investments it requires. Thus, we have left the MBT process out of this consideration.

The efficiency of source separation (how much of the waste fraction ends up in the right container) has been taken into consideration in the model presented here. The percentage that equals the efficiency of the waste fraction is directed to the selected recovery (material or energy) process. The rest of the fraction ends