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Finding an optimal solution for biowaste management in the Baltic States

Jelena Pubule*, Andra Blumberga, Francesco Romagnoli, Dagnija Blumberga

Institute of Energy Systems and Environment, Riga Technical University, Kronvalda boulv. 1, LV-1010 Riga, Latvia

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ABSTRACT

Using biowaste as a resource is required in order to meet the EU common objectives for waste management. Biowaste management should be considered from the economic, environmental, and social perspectives. The resulting complexity constitutes an important barrier to the implementation of biowaste planning projects. The goal of this study is to propose an effective tool to assess, compare, and select the best biowaste management alternatives for stakeholders. In order to reach research goal a methodological approach based on the combination of Multi-Criteria Analysis and System Dynamics method is proposed. The aim of the proposed method implemented in a modelling tool is mainly addressed to policy and decision makers specifically (1) to evaluate biowaste management options, (2) to assess the sustainability of bioenergy projects, and (3) to find an optimal solution for biowaste treatment given the conditions in a particular region. The proposed method can help to structure and assess complex problems while both responding to the interests of multiple stakeholders and avoiding the weaknesses of other evaluation techniques. The method has been applied to a case study involving the three Baltic States – Latvia, Lithuania and Estonia. The results obtained showed that separate collection and Anaerobic Digestion of biowaste is the best solution in all three Baltic States. Other acceptable options include incineration with energy recovery and Mechanical Biological Treatment with Anaerobic Digestion.

1. Introduction

The European Union has set targets to minimize the amount of biodegradable waste deposited in landfills. European countries are required to comply with Landfill Directive 1999/31/EC (European Council, 1999) and Waste Directive 2006/12/EC (European Council, 2006) to reduce the landfilling of the biodegradable fraction of municipal solid waste (MSW). Member states are also obliged to comply with Renewable Energy Directive 2009/28/EC (European Council, 2009).

During the last decade, clear indications on identifying management solutions different from the landfilling of municipal solid waste (MSW) have been highlighted (European Environment agency, 2013). Nevertheless in the year 2010 for 16 EU countries the share of landfilled MSW was higher than 50% (Van Caneghem et al., 2012). Waste management policies in European countries (and other developed nations) focused on reducing the amount of biowaste landfilled (Burney et al., 2011). In many European countries, large quantities of biowaste are still landfilled with unsorted MSW. This has resulted in the largest portion of greenhouse gas emissions generated being attributed to waste management (Braschel and Posch, 2013). At the same time, the proportion of recycled MSW has increased substantially in recent years. Progress has been made in the rate of recycling due not only to the recycling of waste materials, but also to a lesser degree to the recycling of biowaste. There is, however, still need to improve the management of biowaste in order to promote diversion from landfills in line with the Waste Framework Directive's waste hierarchy (European Environment agency. 2013). Anaerobic digestion (Kastner et al., 2012), incineration with energy recovery, mechanical biological treatment (MBT) with anaerobic digestion (Siddiqui et al., 2013), and gasification are possibilities both to manage biowaste and a waste-to-energy option (Longden et al., 2007). As well composting and use of digestate to stabilise and improve the humus content of soils (Lleó et al., 2013) are proper adaptable solution. The impact of MSW management alternatives depends on the number of the local factors. For example, the selection of acceptable MSW and biowaste management options must be made based on research on the

* Corresponding author.
E-mail addresses: jelena.pubule@rtu.lv, jelena.pubule@gmail.com (J. Pubule).

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impact of different waste management scenarios on the social milieu, the environment, and the economy of each country. Several studies found in the literature compare different MSW management options, including the use of aerobic and anaerobic treatment (Murphy and Power, 2007) incineration, and gasification as substitutes for landfilling (Koroneos and Nanaki, 2012).

Multi-Criteria Analysis (MCA) is used to identify compromises for resolving complex policy planning problems like waste management (Herva and Roca, 2013). The advantage of the MCA method is that it allows the preferred alternative among several to be determined. Maimone (1985) was one of the first to use MCA to evaluate different solid waste treatment systems. MCA studies on landfills (Wang et al., 2013) and waste incinerators (Tavares et al., 2011) have also been completed. A number of tools have been used to do MCA studies. The most commonly applied method is Elimination and Choice Expressing Reality (ELECTRE III) (Karagiannidis and Perkoulidis, 2009), as well as Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) (Vego et al., 2008), The Analytic Hierarchy Process (AHP) (Garfi et al., 2009) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) (Dong et al., 2014) have also been used.

However, there is still lack on research carried out on combining complementary environmental evaluation tools in waste management. Herva and Roca (2013a) ranked MSW treatment alternatives based on footprint methodology and MCA. Dong et al. (2014) used the combination of life cycle assessment (LCA), life cycle costing (LCC), and MCA to evaluate municipal waste management systems. In both studies, the results of additional methodologies were used to implement the MCA in addition to the ecological footprint indicator expressed as a single measure, Herva and Roca (2013a) included the use of five criteria in carrying out the MCA. These were water consumption, air emissions from organic compounds, air emissions from dust, suspended solids in water, and occupied landfill volume. Dong et al. (2014) used LCA and LCC calculations to implement the MCA and evaluate MSW using factors weighted for energy, the environment, and the economy.

The use of System Dynamics (SD) in waste management planning can help predict future trends and analyse system characteristics. SD has been applied in fields related to waste management over the past several years. In the literature, research using SD modelling to analyse solid waste, demolition waste, construction waste and hospital waste has been completed. Since the first studies using the SD approach in the waste sector (Mashayekhi, 1993) a large number of studies have used the SD approach to simulate scenarios in different applications of MSW management and treatment (Wager and Hilty, 2002). Kollikkathara et al. (2010) applied SD modelling to MSW management in a case study of a specific place. Escalante (2013) analysed the behaviour of households adopting biowaste separation and biowaste recovery (Lang et al., 2002).

A limited amount of research has also been carried out on the integration of the SD method with other methods used in the waste sector. Karavezyris et al. (2002) have developed a combined SD and fuzzy logic model to forecast the amount and kinds of MSW. The integration of these methods has allowed for the creation of a supplementary tool to manage and forecast MSW amounts using a combination of SD and fuzzy logic.

Some authors proposed to integrate the MCA and SD methodologies. Brans et al. (1998) proposed to use a combination of MCA and SD as a control measure for socio-economic processes. Santos et al. (2001) proposed to use it for organisational performance measurement and management.

Brans et al. (1998) proposed a new methodology to control socio-economic structures by combining the principles of SD, Control Theory, and Multi-Criteria Decision Analysis (MCDA). The methodology consists of three key steps: development and calibration of the model, definition of long-term strategies, and short-term control. The authors demonstrated the proper control of socio-economic systems through a combination of SD, Control Theory and MCDA. Santos et al. (2001) argued that the integration between SD and MCDA can be predicted if the measurement system is effective in supporting the decision-making process and encourages improvements in organizational performance. SD and MCDA can help with a detailed analysis of the structure and problems and consequently determine the proper action plan for performance improvement. In addition, using SD together with MCDA can reflect the multiple interests involved. As well, the preferred course of action to assist decision-makers in conflicted environments can be identified. The MCDA methodology helps decision makers understand the problem, and can help them make more appropriate decisions. At the same time, the use of SD modelling is able to provide a greater understanding of the system of interest.

The proposed literature review highlights evident lacks on the integration of MCA and SD approaches into waste management. The interests of multiple stakeholders need to be taken into account. MCA and SD individually proved their potential for handling waste management issues. Each method has its advantages and its shortcomings Biowaste management has been stressed as a key component of managing waste. An effective tool to evaluate different biowaste scenarios and assist stakeholders in decision-making is imperative. This would lead to continuous improvement in methods of managing waste.

In light of the previous outcomes mentioned in the literature review, the main goal of this study is to propose an effective tool to assess, compare, and screen biowaste management alternatives based on a combination of both MCA and SD modelling. MCA modelling aims to identify the optimal solution based on a set of specific, identified criteria. While SD modelling is an effective tool to deal with dynamic and complex problems (Sterman, 2000) where the physical processes, information flows, management strategies, and the potential policy measure must be clearly identified to be able to effectively define the interaction between, and among, the aforementioned problems. Thus, a combination of MCA and SD modelling provides a method that gives an holistic approach while taking into account environmental, economic, technical, and social aspects which need to be integrated in a time scale reference.

The remainder of this article is broken up into five parts or sections. Section 2 examines the use of MCA and SD methodologies in the waste sector. Section 3 looks at biowaste management in Latvia, Lithuania, and Estonia – specifically, how these three countries implement their waste management obligations and how they treat biowaste. All three countries have similar obligations under the EU directives, whereas the optimal solution for biowaste treatment is different. The results of the integration of MCA and SD in the case study countries are described in Section 4. The main findings are shown and discussed in Section 5 and 6.

2. Methodology

To achieve the goal of this study, which is to propose an effective framework to assess, compare, and screen biowaste management alternatives that stakeholders can apply to their specific situations, a combination of both MCA and SD modelling has been developed.

The basic concept, reflected within the subsequent proposed model, is defined based on the conceptual scheme provided within the Fig. 1.

Multi-Criteria (sustainability) Analysis allows for the assessment and prioritization of different technologies from technical, ecological, economic, and social perspectives. The MCA method