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Review

Solid waste management in European countries: A review of systems analysis techniques

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A B S T R A C T

In the past few decades, solid waste management systems in Europe have involved complex and multi-faceted trade-offs among a plethora of technological alternatives, economic instruments, and regulatory frameworks. These changes resulted in various environmental, economic, social, and regulatory impacts in waste management practices which not only complicate regional policy analysis, but also reshape the paradigm of global sustainable development. Systems analysis, a discipline that harmonizes these integrated solid waste management strategies, has been uniquely providing interdisciplinary support for decision making in this area. Systems engineering models and system assessment tools, both of which enrich the analytical framework of waste management, were designed specifically to handle particular types of problems. Though how to smooth out the barriers toward achieving appropriate systems synthesis and integration of these models and tools to aid in the solid waste management schemes prevalent in European countries still remains somewhat uncertain. This paper conducts a thorough literature review of models and tools illuminating possible overlapped boundaries in waste management practices in European countries and encompassing the pros and cons of waste management practices in each member state of the European Union. Whereas the Southern European Union (EU) countries need to develop further measures to implement more integrated solid waste management and reach EU directives, the Central EU countries need models and tools with which to rationalize their technological choices and management strategies. Nevertheless, considering systems analysis models and tools in a synergistic way would certainly provide opportunities to develop better solid waste management strategies leading to conformity with current standards and foster future perspectives for both the waste management industry and government agencies in European Union.

Abbreviations: ADEME, Agence de l'Environnement et de la Maîtrise de l'Energie; AWAST, aid in the management and European comparison of a municipal solid waste treatment for a global and sustainable approach; BMW, biodegradable municipal waste; CBA, cost–benefit analysis; CERA, comparative environmental risk assessment; DP, dynamic programming; DSD, Duales System Deutschland; DSSs, decision support systems; EASEWASTE, environmental assessment of solid waste systems and technologies; EC, European Community; EDX/EDI, electronic data exchange; EEA, European Environment Agency; EEC, European Economic Community; EIA, environmental impact assessment; EIONET, European environment information and observation network; EPR, extended producer responsibility; ERA, environmental risk assessment; ES, expert system; EU, European Union; EUDIN, European Data Interchange of Waste Notification System; FM, forecasting models; GHG, greenhouse gas; GIGO, garbage in, garbage out; GIP, grey integer programming; GIS, geographic information system; IMS, integrated modeling system; IOA, input–output analysis; ISWM, integrated solid waste management; IWM, integrated waste management; LATS, landfill allowance trading system; LCA, life cycle assessment; LCI, life cycle inventory; LP, linear programming; MCDM, multicriteria decision making; MFA, material flow analysis; MIP, mixed-integer programming; MIMES/WASTE, model for description and optimization of integrated material flows and energy systems; MIS, management information system; MSW, municipal solid waste; NIMBY, not in my backyard; NLP, non-linear programming model; OM, optimization models; ORWARE, ORganic WAste REsearch; PAYT, pay-as-you-throw; PET, polyethylene terephthalate; QAS, quality assurance system; RA, environmental and ecological risk assessment; SA, sustainability assessment; SD, scenario development; SDS, sustainable development strategy; SEA, strategic environmental assessment; SFA, substance flow analysis; SFINX, substance flow inter-nodal exchange; SM, simulation models; SoEA, socioeconomic assessment; STAN, subSTance flow ANalysis; SWIM, solid waste-integrated model; SWM, solid waste management; TASAR, tool for analyzing separation actions and recovery; WASTED, waste analysis software tool for environmental decisions; WHP, waste hierarchy principle; WISARD, waste-integrated systems for assessment of recovery and disposal; WRAP, Waste Resources Allocation Program; WRATE, waste and resources assessment tool for the environment; XML, extensible markup language.

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1. Introduction

In the 21st century, the sustainable management of municipal solid waste (MSW) will become necessary at all phases of impact from planning to design, to operation, and to decommissioning. As a consequence, the spectrum of new and existing waste treatment technologies and managerial strategies has also spanned from maintaining environmental quality at present to meet sustainability goals in the future. Such an orderly evolution allows both waste management industries and government agencies to meet common needs of waste management with greatest green potential, to recycle materials out of waste streams, to enlarge the renewable energy supply, to seek for more socially acceptable options, and to preserve biodiversity and natural ecosystems simultaneously. To achieve such goals, all technical and non-technical aspects of a solid waste management (SWM) system should be analyzed as a whole, since they are inter-related with one another and developments in one area frequently affect practices or activities in another area (UNEP, 2005).

Systems analysis techniques have been applied to handle MSW streams through a range of integrative methodologies in the last few decades. A total of five system engineering models and nine system assessment tools were formally classified in this field to illuminate the challenges, trends and perspectives (Chang et al., in press). It is worth knowing that the spectrum of these models and assessment tools was classified based on the following two domains although some of them may be intertwined with each other (Chang et al., in press). They are: 1) systems engineering models including cost–benefit analysis (CBA), forecasting models (FM), simulation models (SM), optimization models (OM), and integrated modeling system (IMS), as well as 2) system assessment tools including management information system (MIS)/decision support system (DSS)/expert system (ES), scenario development (SD), material flow analysis (MFA), life cycle assessment or life cycle inventory (LCA or LCI), risk assessment (RA), environmental impact assessment (EIA), strategic environmental assessment (SEA), socioeconomic assessment (SoEA), and sustainable assessment (SA). Fig. 1 holistically illustrates the interrelationships among these two domains from which fourteen technologies can be connected through such a technology hub in association with these two broad-based domains (Chang et al., in press). In the core part, the five systems engineering models can be seen as the core technologies in which the cost–benefit analysis may be used as a common platform in support of decision making. Integrated modeling systems may flexibly concatenate various optimization models including linear programming (LP), mixed-integer programming (MIP), non-linear programming (NLP), and dynamic programming (DP) models to address the system concerns in which the SM and FM can support the essential background in concert with CBA in the context of systems analysis. With such a core structure, the model-based DSSs can be constructed for separate or collective applications. Yet rule-based, knowledge-based or graphics-based DSSs or ESs can still be formed based on heuristic approaches. All of these core efforts may be enhanced by the rest of system assessment tools described by the eight outer triangles. Communication among the eight triangles canalizes the information flows that in turn improve the credibility of the five systems engineering models being formulated through MIS, DSS, and even ES. Overall, Fig. 1 leads to a sound realization of the structure between systems engineering models and systems assessment tools from which a systems analysis should be well balanced for generating environmentally benign, cost effective, ecologically sound, and socially acceptable solutions (Morrissey and Browne, 2004; Chang and Davila, 2007).

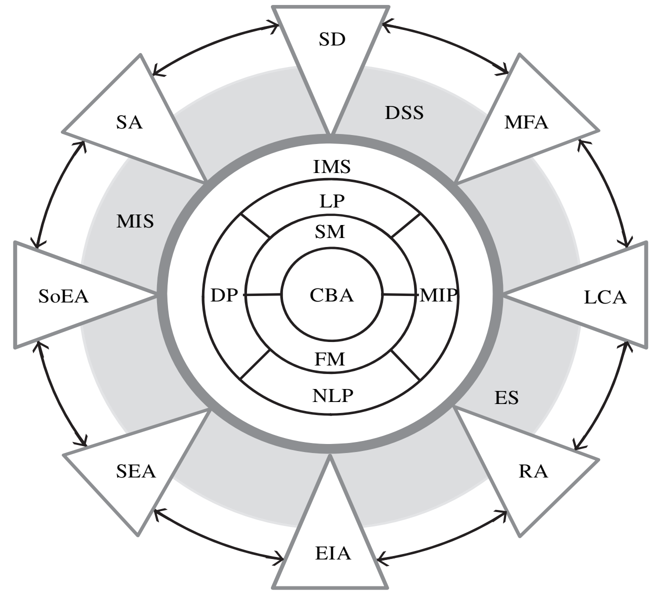


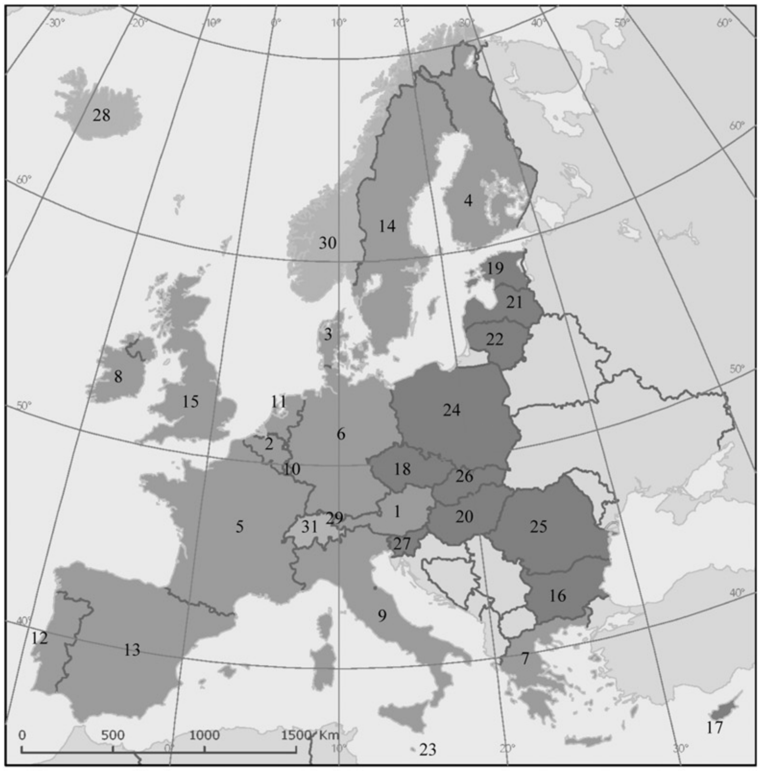
Fig. 1. The technology hub for solid waste management (Chang et al., 2009).

With such a tool, every community can tailor its own unique system to manage various components of the waste streams in a flexible manner (Najm et al., 2002). Yet how to smooth out the barriers toward achieving appropriate systems synthesis and integration of the five systems engineering models and the nine system assessment tools to aid in solid waste management practices in European countries remains somewhat uncertain. It is the aim of this paper to present a thorough literature review and a critical analysis in sequence so as to answer the following key questions: 1) what achievements have been reached so far?, 2) what are the gaps in knowledge of waste management that we need to achieve in the context of sustainable development in the long run? and 3) what are the research needs and future directions in systems analysis for SWM in European countries. At a practical level, discussions of this paper were limited to 15 European Union (EU) member states, facing the same driving forces with similar waste legislation to manage MSW systems. The EU is an economic and political union of 27 member states which are located primarily in Europe, Norway and Switzerland (non-EU members) were also included to understand how other countries within the region with similar waste management legislation applied the techniques of systems analysis to manage their waste management issues. Fig. 2 illustrates the overall study boundaries.

The comparative analysis of this paper provides an all-inclusive view to minimize anomalies of SWM systematically, and should allow possible conflicts associated with different objectives associated with environmental, social, technical, and economic constraints to be confronted more rationally than heretofore. Such a development should enable more solidly based waste management strategies to be pursued, leading to conformity with current standards for both the waste management industry and government agencies in the EU.

2. Current waste management principles in the EU

After the commitments made at the Earth Summit in Rio de Janeiro (1992), the European Council in 2001 adopted the first EU Sustainable Development Strategy (SDS). The overall aim of the renewed EU SDS is to support and promote actions enabling the EU to achieve



EU-15		New Member States		European Free Trade Association	Other European Countries
1. Austria	9. Italy	16. Bulgaria	22. Lithuania	28. Iceland	
2. Belgium	10. Luxembourg	17. Cyprus	23. Malta	29. Liechtenstein	
3. Denmark	11. Netherlands	18. Czech Republic	24. Poland	30. Norway	
4. Finland	12. Portugal	19. Estonia	25. Romania	31. Switzerland	
5. France	13. Spain	20. Hungary	26. Slovakia		
6. Germany	14. Sweden	21. Latvia	27. Slovenia		
7. Greece	15. UK				
8. Ireland					

Fig. 2. Groups of countries within the European Union (adapted from EEA, 2007).

continuous improvement of quality of life for both current and future generations. This is expected to be achieved through the creation of sustainable communities capable of managing resources efficiently, tapping the innovation potential of the economy, ensuring prosperity, environmental protection and social cohesion. These changes will bring about a sense of urgency in SWM. While short-term action is required for tackling operational issues in SWM, maintaining a long-term perspective of SWM also needs to be set out. The most recent legislation published by European Commission (EC) is the New Waste Directive 2008/98/EC (EU, 2008), which reflects EU SDS and brings new challenges to SWM systems. New definitions for waste, by-products and end-of-waste, result in the need for choosing appropriate technologies that aim at improving the protection of human health and environment, promoting reuse and recycling, enhancing waste prevention programs via biowaste separate collection, and implementing extended producer responsibility (EPR) collectively. In addition, key challenges related to long-term waste management are climate change and energy use, linking SWM systems with the reduction of greenhouse gas (GHG) emissions and the enhancement of energy recovery. Sustainable shipping of waste streams is thus an important issue in SWM too. Sustainable consumption and production, related to waste prevention programs have received wide attention in the nexus of resources conservation, recovery, and reuse. Social factors, including population growth and migration, become essential for the accurate forecasting of waste generation and estimation of the proper capacity of the SWM facilities. Public health, which used to be considered by LCA impact categories must be included through the application of a quality assurance system (QAS) for product control. All of them compound the structure of current SWM systems and deepen the need for systems analysis within the EU member states.

Proper consideration of the impacts of climate changes and resources scarcity has been mandatory in environmental management including SWM in Europe. Scarcity of resources has motivated new strategies at European level to promote life cycle thinking in waste management policies, and consequently, the problems of MSW management are tied with how to integrate economically feasible and environmentally sustainable practices holistically. Challenges arise with respect to interfaces between optimal planning and sizing of solid waste management facilities and optimal scheduling of waste flows and throughputs while evaluating new system components and taking into consideration environmental and social costs, such as municipal taxes, user charges, capital opportunity costs and government grants and subsidies. These socioeconomic strategies, which were implemented only by a handful of industrialized countries in the world, might be extended to reduce waste generation and, simultaneously, de-link waste generation from economic growth.

An improved knowledge base influences the advancement of waste collection and shipping, resources use, and disposal alternatives via substitution of more systematic modeling practices. The Thematic Strategy on the Prevention and Recycling of Waste (EU, 2005) is an example of such a policy change. Improving the existing legislation, with simplification and modernization effects on waste definition, end-of-waste criteria, recycling, recovery and disposal activities, is one of the guidelines which is crucial to continue into the next decade. In addition, climate changes have also forced new measures to be implemented at the EU level. They include promoting GHG emissions reduction through biowaste diversion from landfills, improving energy efficiency at waste treatment and disposal facilities, promoting organic fertilizers (compost) in soils as an alternative to mineral fertilizers, enhancing quality in waste management outputs (like recycled materials) to reduce resource consumption, and raising materials' utility. Some social aspects in MSW management have also been made mandatory by EU regulations, like the SEA Directive, related to public participation with respect to the drawing up of certain plans and programs relevant to the environmental directive (EU, 2001).

To ultimately improve urban sustainability and offer the level of service required by the population, the ability to increase the reliability of green infrastructure systems with waste management functionalities, particularly through the proper interfaces between the partnerships of private and public sectors could be even more critical. Ultimately, not only mitigatory solutions related to climate change should comprise a part of the MSW management strategies but also challenges in adaptation are also made necessary for SWM, which are mainly related to waste treatment technologies. On the other hand, waste collection systems should be designed and operated so as to be capable of improving public health protection. For example, higher temperatures after climate change that may result in more biowaste degradation, thereby generating odor control problems which require further attention. More sophisticated societal measures, such as voluntary agreements on encouraging responsibility among producers and consumers, which might become mandatory to reach an integrated solid waste management (ISWM), compound the decision making when arriving at consensus and involvement between stakeholders and decision makers during participation processes in different EU member states. This situation triggers an acute need to thoroughly review all the existing "state-of-the-art" systems engineering approaches and system assessment tools in order to reach such ISWM goals, particularly in EU member states with differing levels of economic development. These goals are necessary to facilitate a unique integration for tackling complexity with respect to multi-objectives, risk, and uncertainty characteristics in decision making as a whole.

3. Systems analysis techniques

In systems engineering regimes, a system can be a set of related components or sub-systems, which interact with each other in some way. The properties of a system are defined by the whole of the sub-systems, their characteristics, and their relationships. The characteristics are related to the boundaries of the system depending on whether they are closed or open systems/sub-systems. With this definition, an MSW management system fits the concept in which the technical aspects like landfill, incineration, anaerobic digestion, composting and collection are sub-systems linked with one another through processed waste streams internally and municipalities through managed truck fleets externally. The sub-systems make up part of the SWM system that has interactions between technical and non-technical aspects, both of which may influence the generation and shipping of waste to some extent.

Considering SWM systems, several systems analysis techniques have been applied to help decision making. These can be divided into two main groups as we mentioned above: systems engineering models and systems assessment tools. Their contribution to SWM systems will be summarized in the following sub-sections in concert with the concept.

3.1. Systems engineering models

Complexity in SWM system arises from siting facilities, selecting technologies, and comparing management options. To tackle the synergistic interfaces, systems engineering models can be helpful for promoting analysis based on cost–benefit analysis (CBA), optimization models (OM), simulation models (SM), forecasting models (SM) and integrated modeling systems (IMS). Table 1 presents the contribution of systems engineering models to SWM system analysis over the past few decades. It offers a systematic overview showing how the landscape of systems engineering models was conceptualized (complexes, structures, functionalities) and the relationship to other components in connection with Fig. 1.

3.2. Systems assessment tools

Most of the time, after systems have been created and implemented, it is necessary to evaluate their performance and consider how improvements could be made, especially in answer to the increasing challenges promoted by regulation. Models that can help decision makers toward such goals are systems assessment tools. Such tools can be MIS, DSS, ES, SD, MFA, LCA, RA, EIA, SEA, SoEA and SA. Table 2 presents the contribution of systems assessment tools to SWM with significant ramifications on how the relationships between system assessment tools and systems engineering models are described when connected with Fig. 1. As a consequence, the appropriate use of system assessment tools has such a large effect on the overall optimization especially in the context of IMS because the outputs from these tools are normally used as the primary inputs in models reflecting socioeconomic, climate change, and managerial considerations.

Table 1
The contribution of systems engineering models to SWM systems (Chang et al., in press).

Types of systems engineering models	Description	Contribution to SWM system
Cost–benefit analysis	To assess positive and negative economic and physical effects independently or support simulation and optimization models for systems analysis	Well-defined cost–benefit models may translate environmental aspects into economic terms. However, the intergeneration externalities are very difficult to address.
Optimization model	To reach the best solution among numerous alternatives, considering one or several objectives.	Models have solved the following issues: • single network planning (Anderson and Nigam, 1967; Anderson, 1968; Fuertes et al., 1974; Helms and Clark, 1974; Kuhner and Harrington, 1975; Jenkins, 1979; Clayton, 1976; Rao, 1975) • dynamic, multi-period investment (Marks et al., 1970; Marks and Liebman, 1971) • size and site facilities (Chapman and Yakowitz, 1984; Li and Huang, 2006a,b, 2009a,b; Nie et al., 2007; Li et al., 2007, 2006, 2008a,b; Huang et al., 2001, 2002; Xu et al., 2009) • manage infrastructures like landfill (Davila et al., 2005) Models developed: WRAP (USEPA, 1977)
Simulation model	To trace the lengthy chains of continuous or discrete events based on cause-and-effect relations describing the operations in complex systems and helping investigate the dynamic behavior of the system (Wang et al., 1996).	Models developed for SWM systems: SWIM (Wang et al., 1996), GIGO (Lawver et al., 1990; Anex et al., 1996), AWAST (Villeneuve et al., 2009), EcoSolver IP-SSK (Krivtsov et al., 2004), TASAR (Tanskanen and Melanen, 1999)
Forecasting model	To characterize waste streams quantitatively and qualitatively and construct a management information system to accumulate information over time. To predict waste generation, time-series regression analysis (Katsamaki et al., 1998; Navarro-Ésbri et al., 2002), system dynamics models (Dyson and Chang, 2005), and other regression models have been applied (Grossman et al., 1974).	Models have related variables like population (Grossman et al., 1974), income level (Grossman et al., 1974; Beigl et al., 2005), dwelling unit size (Grossman et al., 1974), total consumer expenditure and gross domestic product (Daskalopoulos et al., 1998), production measures, household size, age structure, health indicators (Beigl et al., 2005), per capita retail and tipping fees for waste disposal (Hockett et al., 1995) to waste generation, total income per service centre, people per household, historical amount generated, income per house and population (Dyson and Chang, 2005).
Integrated modeling systems	To improve synergistic connections among different models, concatenating their total functionalities.	IMS have provided: • dynamic information of waste generation and waste shipping (Chang et al., 1993) • optimal capacity expansion patterns for waste-to-energy and landfill facilities over time (Baetz, 1990) • Models developed: ORWARE (Dalemo et al., 1997; Björklund et al., 1999)

4. Systems analysis used for solid waste management in European countries

4.1. Methodology

Several types of SWM systems in European countries can be identified and classified. The characterization of these systems in the EU and its member states was mainly performed by the authors in 2008 and 2009 based on the databases developed by European Topic Centre on Sustainable Consumption and Production. In the case of Belgium and Spain, for example, the inquiry was made through the regional entities of Flanders and Catalonia, respectively. To understand which are the research needs and future directions in regard to the systems analysis techniques for SWM in European countries, a comparative analysis was also conducted in this paper for the distinction of relevant applications.

4.2. Waste management systems in European countries

From a life-cycle point of view, an all-inclusive MSW management system includes all essential operational units from collection, to shipping, to treatment, to recycling, and to disposal. Yet the current European regulations promoting the hierarchy of waste management inevitably involve a wealth of waste management practices tied to policies, institutional settings, financial mechanisms, technology selection, and stakeholder participation. For instance, the landfill directive promoted biodegradable municipal waste (BMW) management systems, which focus on building separate collection systems provided by local authorities through specific bins leading to separate, mandatory BMW treatment systems (Austria, Netherlands). Some of the EU member states applied economic instruments including Pay-As-You-Throw (PAYT) and an organic waste tax to create economic incentives for residents to divert BMW from regular waste streams normally being collected by municipalities to specific collection avenues. They recognized that the diversion costs that each waste disposal authority would face would differ according to the particular circumstances (EIONET, 2007a). For example, both BMW system and Landfill Allowance Trading System (LATS) in the United Kingdom (UK) were launched to provide local authorities with the flexibility to manage waste streams more effectively. The LATS system revolves around transferable allowances which enable the greatest amount of waste diversion to occur in areas where it is cheapest, and most practicable to do so.

The Packaging waste directive has also promoted similar incentives by using the "EPR system" and the "deposit-refund system" to ensure the maximum reuse and recycling. The most well known EPR system is the packaging waste Duales System

Table 2
The contribution of systems assessment tools to SWM systems (Chang et al., in press).

Systems assessment tools	Description	Contribution to SWM systems
Management information system, decision support system and expert systems	Consists of different methods applied to exchange and manage information; used to help in decision making	MIS/DSS/ES have been applied: • to provide information storage and transmission through countries (EIONET, 2009) • to yield specific decision support (Chang and Wang, 1996; Barlishen and Baetz, 1996; Haastrup et al., 1998; Bhargava and Tettelbach, 1997; AEA Technology, 1998) • to relate waste stream characterization with implications on shipping, processing and disposal of waste streams (MacDonald, 1996)
Scenario development	To create hypothetical sequences of events constructed for the purpose of focusing attention on causal processes and decision points (Kahn and Wiener, 1967)	Has the ability to explore events (events in this case are policies and decisions taken) that might occur associated with SWM on a temporal scale. Such events can be inside or outside the SWM system. Fell and Fletcher (2007) have contributed with scenario developments for future lifestyle trends and forecasting based on lifestyle scenarios for waste composition
Material flow analysis	Consists of a systematic assessment of the flows and stocks of materials within a system defined in space and time (Brunner and Rechberger, 2003)	Software developed in MFA: SFINX (van der Voet, 1995a,b), FLUX (Huijbregts, 2000), STAN (TU Vienna, 2009), DYNFLOW (Elshkaki, 2000), GaBi (PE International, 2006) and Umberto (IFU, 2006)
Life cycle assessment	Consists of a process to evaluate environmental burdens associated with a product, process or activity by identifying and quantifying energy and materials used, wastes and emissions released to the environment, to assess impact of those energy and material uses and releases and to identify and evaluate opportunities that lead to environmental improvements (EEA, 2003)	Models developed for SWM systems: IWM (White et al., 1995; McDougall et al., 2001), WASTED (Diaz and Warith, 2006), WISARD/WRATE (Ecobilan, 2004; Buttol et al., 2007), EASEWASTE (Christensen et al., 2007)
Risk assessment	To relate environmental and human health risk to accidents quantitatively, through a statistical evaluation	Help in the evaluation of transversal SWM systems
Environmental impact assessment	A procedure that aims to ensure that the decision-making process concerning activities that may have a significant influence on the environment takes into account the environmental aspects related to the decision (Tukker, 2000)	EIA associated to a specific project attempts to solve controversial issues from the target project such as siting issues originated from the NIMBY effect, technical issues to justifying the choice of technology for emission reduction, and even the rejection of the project (Chang et al., 2009). In Europe, EIA is mandatory for landfills and incineration plants with regard to capacity limits through EU Directive 85/337/EEC (EU, 1985), as amended by EU Directive 97/11/EC (EU, 1997). A good example can be found in Barker and Wood (1999)
Strategic environmental assessment	Consists of the environmental assessment of a strategic action as a policy, a plan or a program (Thérivel and Partidário, 1999)	Its applicability is emphasized by EU Directive 2001/42/EC (EU, 2001), to which it is obligated for the promotion and elaboration of an SEA for SWM plans. More details can be found out in Dutch Ten Year Program on Waste management 1992 and 2002 (Verheem, 1999)
Socioeconomic assessment	Consists of computer-based practices that apply integrated market-based and/or policy/regulation requirements for SWM	Has allowed the inclusion of user-charges, landfill disposal fees, recycling credits, product charges, deposit-refund schemes, and producer-responsibility schemes into the decision making in SWM systems, promoting a more sustainable management of waste. For such purposes, several methodologies have been applied: CBA-based LP (Chang et al., 1997, 1996), CBA-based MIP (Chang et al., 2005), CBA-based fuzzy goal programming (Chang and Wang, 1997), fuzzy contingent valuation (Chang et al., 2009), minimax regret optimization (Chang and Davila, 2007), GIP-based game theory (Davila et al., 2005), CBA-based MCDM (Karagiannidis and Moussiopoulos, 1997; Rousis et al., 2008), optimal control of landfill space (Chang and Schuler, 1991) inexact fuzzy-stochastic constraint (Li et al., 2009), IOA (Brahms and Schwitters, 1985; Franklin Associates, 1999; Gay et al., 1993; Hekkert et al., 2000; Joosten et al., 2000; Patel et al., 1998; Nakamura, 1999; Pimenteira et al., 2005)
Sustainable assessment	Refers to the integration of different methodologies in such a way that obtaining an analysis, an evaluation or a planning that approaches several management aspects in which sustainability implications may be emphasized and illuminated	SWM systems assessed to reach sustainable management, focusing on different aspects. Models developed: LCA-IWM (den Boer et al., 2007) and MSW-DST (Thorneloe et al., 2007; Weitz et al., 1999). Several methods have been combined to reach sustainability: Cherubini et al. (2008) have combined LCA with MFA and energy analysis methods, Nakamura and Kondo (2002) used IOA and LCA to construct a waste input–output model, Huppes et al. (2006) and Tukker et al. (2009) have combined both methods to obtain IOA with environmental extensions for different sections (including waste management sectors). A Geographical Information System (GIS) combined with LCI, EIA and optimization model has been promoted by Chang et al. (2008, 2009) for landfill siting

Deutschland (DSD) (or Green Dot system) that was firstly applied in Germany in the 1990s and later on all over Europe (Buclet, 2002). The basic idea of the DSD is to establish a privately organized channel assuring that all primary packaging can be collected from the consumers will then undergo a material-specific recycling process through the consumers and service providers. This is done through the so called "Green Dot" which is a label on packaging material used to identify the product belonging to the dual system during the consumption phase (Klepper and Michaelis, 1994). As for these deposit-refund systems, Dansk Retursystem is one of the oldest ones, and has been in use since 1984; it is applicable for refillable, non-refillable, reusable and disposal, and ready-to-drink beverages and mineral water bottles (Pro-Europe, 2009). However, in Denmark there is no producer-responsibility scheme, namely no separate management system for packaging waste (Danish EPA, 1999; Pro-Europe, 2009), making the costs for handling packaging waste uncertain, and resulting in a higher budget for waste management in local authorities (EEA, 2005).

The remaining part of waste streams usually called residual household waste or mixed municipal waste still need to be cleaned up by municipalities and local authorities. The Danish Waste Model is a representative residual/mixed waste system as it is based on a join venture to form a coherent whole (Danish EPA, 2001). According to the Danish EPA (2001), the structure of the SWM systems is characterized by the following principles: 1) the system includes all types of waste (e.g. household, industrial and hazardous waste); 2) the responsibility for the SWM lies solely with the local authorities (council), which are responsible for establishing capacity for waste management and for providing information on how to dispose of the waste produced within the local council, irrespective of whether this waste originates at households or trade and industry (EIONET, 2007b); 3) the duty to assign waste treatment and disposal facilities lies with the local authorities, and waste generators are bound to those who use them; 4) financing of the system rests on the polluter-pays principle (PPP); and 5) waste collection and waste treatment rest on the principle of source separation (EIONET, 2007b). With these principles, the systems boundaries are quite well defined, such as packaging waste collection created by local authorities was managed by an external system. Considering the main waste streams in MSW – residual waste, BMW and packaging waste – a review on SWM systems in European countries may be summarized in Table 3.

In addition to existing SWM systems handling related material and cash flows at scales, there is also a need for building up proper information exchange platforms capable of offering decision makers the basis for the assessment of relevant projects, programs, and plans. Member states must provide information to supply European waste information systems like Eurostat, EIONET, and ReportNet. Eurostat's main role is to process and publish comparable statistical information at European level (Eurostat, 2009). The Eurostat data centre on waste is responsible for providing robust data, indicators and other relevant information for assessing the effectiveness of the community waste policy (Eurostat, 2009). The functions of the Eurostat information system are divided into four sectors which correspond to the various stages in the processing of data from their collection to their dissemination including production (collection, validation and storage of the data and metadata), storage of the reference data (acceptance of the information), use of the reference data (visibility/security and find/deliver), and dissemination of information (Dubois, 1997).

EIONET is a collaborative network of the European Environment Agency (EEA) and its member states, connecting National Focal Points in EU and accession countries, European Topic Centres, National Reference Centres, and Main Component Elements. EIONET provides a mechanism whereby National Focal Points in European countries can make documents available to the EEA and also retrieve documents of interest from the EEA. The integrated electronic workplace environment allows online collaboration between environmental personnel across Europe. EIONET supports the collaborative process and reduces the reporting burden for environmental protection agencies across Europe (EEA, 2002).

ReportNet aims to develop common tools and a shared information infrastructure as the European Environmental Information System; and it is based on a set of inter-related tools and processes which all build on the active use of the World Wide Web (EIONET, 2009). ReportNet is EIONET's infrastructure for supporting and improving data and information flows (EIONET, 2009). With this platform, ReportNet also aims at providing an effective network infrastructure whereby collaboration can be achieved so that the environmental reporting burden of the EU member states can also be reduced (EEA, 2002).

4.3. Comparative analysis

To understand how to deal with multiple alternatives and a plethora of outcomes regarding systems analysis for SWM in European countries, a comparative analysis was conducted based on 218 applications in this paper. Such a comparative analysis is presented in Fig. 3. Sometimes the assessments conducted for waste management overlap with several SWM systems simultaneously; such cases happened when a specific decision maker responsible for waste management at a geographical area of interest is the same as the decision maker inside such boundaries handling several sub-systems.

Fig. 3 clearly indicates that 1) more cases were associated with MSW, 2) the studies on residual/mixed waste and packaging waste streams were received equal emphasis, and 3) BMW received the least attention. Such phenomena can be explained by the fact that the BMW system is less established in European countries, as opposed to other parts of the world. Comparing the relative distribution between groups of models and tools for systems analysis, the most common practices for waste management in European countries are those using various systems assessment tools rather than system engineering models. Table 4 further confirms the same observations after the realization of application metrics of systems assessment tools.

The comparison across the boundaries implies that systems assessment tools have been applied to evaluate and help in decision making based on environmental issues have great potential to integrate other aspects, like economics or social impacts. Given that EU regulations have given emphasis to EIA in SWM, the inclusion of EIA has become favored by decision makers at national, regional, and local levels. Thus, the primary stage of decision analysis normally leads to assess a suite of management options, evaluate managerial and strategic plans, and collect and share information. Likewise, climate change and resources depletion are emerging issues of most concern, which are even more influential when managing SWM, and decisions and policies were oftentimes made with the aid of LCA or LCI in public institutions.

With fewer applications, systems engineering models were capable of studying waste production processes and assessing the interactions in numerous types of SWM systems addressing impacts from technical to social, and to economic perspectives. However, such applications are not easy to implement since the necessary assumptions being made may or may not be realistic. As a consequence, systems engineering models have not been applied to the same extent as systems assessment tools in EU member states. Oftentimes, these models are not geared toward helping decision makers' needs. Their contribution is often limited to use a mathematical functional form structured to derive strategic

Table 3
Waste management systems in European countries.

Country	Residual/mixed waste system	BMW system	Packaging system
Austria	Yes, with ban of landfill regulation for BMW	Yes, being mandatory with penalties	• Alstoff Recycling Austria system (Green Dot Dystem) – EPR • Bonus Holsystem (commercial packaging waste) – EPR • Öko-Box for beverage carton containers • Pet2Pet for polyethylene terephthalate (PET) bottle • Deposit-refund system for beverage containers but only mandatory for refillable plastic beverage containers • ARO system for wastepaper • AGR system for glass • ArgeV for lightweight fraction
Belgium	Yes, with cash tax, residual waste and/or environmental tax and organizations like Fost Plus	Yes, with PAYT	• Fost Plus (Green Dot System) – EPR
Denmark	Yes, with collection fee based on polluter-pays principle	Yes, but is voluntary and only for garden waste	• Dansk Retursystem – deposit-refund system • Packaging glass system: recycling schemes • Wastepaper and waste cardboard system: recycling schemes are mandatory • Packaging tax
Finland	Yes, with waste charge: sorted materials pays less	Yes, promoted by information instruments	• Suomen Palautuspakkaus Oy (Palpa) – deposit-refund system for packaging waste, including beverages • Newspaper, copy paper and other paper products and packaging waste – EPR • Beverage containers – packaging tax (exemption or lower tax rates only if package is part of a returnable deposit scheme)
France	Yes, with fees	Exists but not consolidated	• Eco-Emballages (Green Dot System) – EPR
Germany	Yes	Bio-Bin system and other mandatory systems	• Duales System Deutschland – EPR • Deposit-refund system
Greece	Yes, with fees to cover the service	No	• Green Dot System called HERRCo – EPR • KEPED – packaging waste system for waste oils • Supermarkets as individual systems
Ireland	Yes, with PAYT	Exists but not consolidated	• Repak – Green Dot system – EPR
Italy	Yes, with municipal waste tariff	Yes	• Consorzio Nazionale Imballaggi (CONAI) (Green Dot System) – EPR
Luxembourg	Yes. With PAYT system	Yes (green bins)	• Valorlux (Green Dot System) – EPR
Netherlands	Yes, with levy	Yes, mandatory	• Compulsory deposit return systems for refillable glass bottles and one-way packaging • Nedvang – EPR • Stichting Retourverpakking Nederland – one-way deposit-bearing PET containers for soft drinks and water larger than 0.5 L • Wastepaper and waste cardboard – EPR
Norway	Yes, with waste tariffs	Yes, with organic waste tax	• Norsk Resy AS – packaging waste and corrugated and solid board packaging – EPR • Norsk GlassGjenvinning AS for glass • Norsk MetallGjenvinning AS for metal • Gront Punkt Norge for plastic packaging, beverage cartons and carton packaging • Norsk Resirk AS – deposit-refund system for beverage packaging, steel and aluminium cans, plastic bottles non-refillable
Portugal	Yes, by water consumption fee	No	• Sociedade Ponto Verde (Green Dot System) – EPR • Valormed (Medicine packaging waste) – EPR • Marão mineral water system (private) – deposit-refund system for one-way PET bottles of Marão trend mark
Spain	Yes for Catalonia, with a landfill tax, incineration tax	Only in Catalonia for municipalities with >5000 inhabitants	• Ecoembes SL (Green Dot System) – EPR • Ecovidrio, for glass packaging – EPR
Sweden	Yes	Yes	• EPR for several waste streams like packaging and wastepaper • Deposit-refund systems for cans, plastics and glass bottles • Returpack – deposit-refund system for all plastic and metal beverage containers for ready-to-drink beverages, including refillable glass bottles
Switzerland	Yes, with Canton tax	Yes, whenever possible	• Beverage bottles – EPR • Reusable packaging – deposit-refund system • PET-Recycling Schweiz – packaging PET one-way – EPR • IGORA for aluminium cans – EPR • Ferro-Recycling for tinplate – EPR • VetroSwiss for glass – EPR, mandatory system • Disposable packaging in PVC – obligatory deposit • Wastepaper and cardboard system related to municipalities/local authorities
United Kingdom	Yes, landfill tax only for companies, local authorities or other organization	Yes, LATS and for garden waste (from civic amenity)	• PRN system – EPR • PERN system – EPR

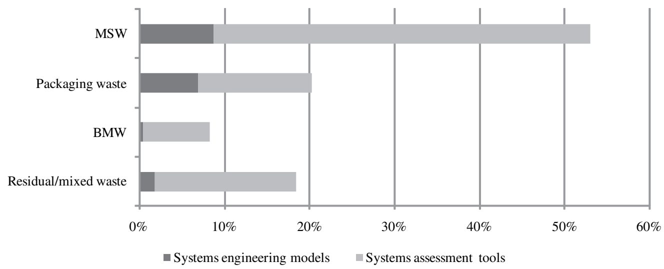


Fig. 3. Systems analysis applied in solid waste management systems in Europe.

guidelines and/or orientations in an SWM system. Sometimes, the mathematical outputs are contradictory with existing ideas that have already embedded in decision makers' minds. In such cases, CBA may be defined or refined well to fit in the LCA framework in the decision making arena, the application potential may be improved. Table 5 further confirms the observations across MSW, residual/mixed waste, packaging waste, and BMW after the realization of application metrics of systems assessment tools.

Table 6 presents individual efforts in each country level; apparently all European countries involved can be classified into three groups according to their application of systems analysis methodology. Countries that have mostly applied systems analysis techniques include Italy, Sweden, the United Kingdom, and Denmark; countries with a moderate number of applications include France, Germany, Austria and Finland; and countries with low interest in such applications include Spain, Greece, Ireland, Luxembourg, Portugal, Belgium, the Netherlands, Norway and Switzerland. Why do such discrepancies occur, given that all EU member states are under the same European guidelines? It is mainly due to national differences in waste management policies within each country. In countries where more systems analysis practices have been applied, the driving forces for the applications are related to the need for solving multi-faceted environmental issues linked with various facilities while complying with international, EU, regional, and local regulations.

Sweden, a country where sustainability principles were heavily promoted by national/international entities and its waste management policies were born based on EPR, can be selected as a particular case. Such sustainability principles have infiltrated into the municipality level, such as Stockholm, which is the city where the development of models to aid in decision making of SWM was favored. In Denmark, the packaging refundable system was assessed due to the presence of the Packaging Waste Directive. In Italy, due to a legal action against it within EC in a waste crisis that had plagued Naples and the Campania region for more than ten years, Mastellone et al. (2009) conducted an MFA to provide scientific support for decision makers who were managing the waste crisis. These three cases, including Sweden, Italy, and Denmark, concur with our observations.

Concerning countries which have applied systems analysis techniques only moderately, motivations for doing so are based on the political concern with regard to environmental impacts due to SWM. For example, in France, Ecobilan-Pricewaterhouse Coopers developed several assessments for Agence de l'Environnement et de la Maîtrise de l'Energie (ADEME) concerning SWM. Additional motivations were tied to the need to comply with European regulations and to manage the waste streams in a sustainable way. As for those European countries with no prevalent applications of systems analysis techniques, the true reason is that they were lacking sustainable development concepts and communication channels among stakeholders in the waste management regime.

Even though some European countries did not promote systems analysis practices for SWM solely, it did not imply that the issues of SWM were ignored. LCI/LCA was deemed the most popular system assessment tool in the EU so far. In the nexus of environmental management and industrial ecology, LCA is actually a normalized method in connection with the norm family ISO 14040 (2006). In reality, LCA may be integrated with other system assessment tools while standing up to close scrutiny and achieving a higher level of evaluation for SWM system wide. In addition, further advantages via applying LCA/LCI can be assured by the elaboration of environmental indicators in the scope of ISO 14025 (2006) (Gallo et al., 2009). Both ISO 14040 and ISO 14025 allow the gap to be bridged between waste management and industrial ecology. For example, at this juncture, the Netherlands applied LCA, MFA, CBA and EIA collectively to materials management, which includes product use phase and waste production phase.

SA models, mainly developed in Sweden, were the second mostly applied system assessment tool in the EU for SWM because of the possible linkage between SWM and energy recovery (e.g., waste-to-energy) given the presence of a large number of incineration plants. Besides, the ORganic WAste REsearch (ORWARE) model, mainly developed in Sweden, combines the concept of LCA and MFA to simulate and assess MSW and BMW systems. This type of system analysis that is considered highly novel in Sweden has been widely applied. On the other hand, the application of MIS/DSS/ES, the third mostly applied systems assessment tool in the EU, is related to the need to provide information flows among the EU member states and to evaluate how member states carry out legislative measures. Such a mandatory process was defined simultaneously by several European Directives and Regulations, like EU 91/692/EEC (EU, 1991), EU 2003/35/EC (EU, 2003), and Waste Statistics Regulation no 2150/2002 (EU, 2002). Almost all European countries had already developed MISs at regional and national levels, like in the North Rhine-Westphalia region in Germany, Italy, Denmark (ISAG information system), United Kingdom, and Austria. Such MISs may also improve connections of waste producers and consumers, which have been channeled for possible waste exchange activities almost all over Europe. Many European projects in this direction have been developed. A salient case co-developed by Austria, Belgium, Germany, and the Netherlands is the EUDIN (European Data Interchange of Waste Notification System) which is an electronic data interchange platform for waste transportation control within, into and out of Europe boundaries. It consists of an electronic data base that enables an electronic exchange of the data of the notification form and the movement/tracking form (EUDIN, 2002). Such an information sharing platform can be further integrated and improved to develop more powerful ESs and DSSs for waste management. Further justification for the use of MIS/DSS/ES has been for the siting of infrastructures like landfills and incineration plants since some systems engineering models for siting infrastructures can be handled by GIS to make spatial interactions comprehensive and understandable for decision makers instead of domain experts in SWM systems (Chang and Wang, 1996; Barlishen and Baetz, 1996; MacDonald, 1996; Haastrup et al., 1998).

5. Future perspectives of systems analysis for solid waste management in Europe

5.1. Current status and limitations

The assessment of SWM by using systems analysis techniques allows decision makers to learn about total system complexity. A quantifying *complexity factor* requires evaluating interfaces. Whereas system assessment tools provide a wealth of composite

Table 4
The purposes of systems assessment tools.

SWM systems	Systems assessment tools	References
MSW	To collect and share information flows in SWM	Nationale Reststoffenbeurs, 1986; Waste Exchange UK, 2000; CIWM, 2003; Dall et al., 2003; Becker et al., 2007; Denmark Waste Exchange, 2008; LUA NRW, 2006; International Synergies Limited, 2007; Fahy, 2007; Economie, 2008; Jean-Gerard, 2008; APA, 2008; IHK Recyclingborse, 2008; IWEN, 2008; EIONET, 2009; Mochty, 2009
	To understand environmental impacts in SWM system with respect to pollutant fate and transport, or the waste itself	Dahlbo and Assmuth, 1997; Obernosterer and Brunner, 1997; Powell et al., 1996, 1999; Döberl et al., 2002; Melloni et al., 2003; Bolze, 2004; Beigl and Salhofer, 2004; Sokka et al., 2004; Ecobilan, 2004; Xará et al., 2005; Kirkeby et al., 2005; Badino et al., 2007; Mastellone et al., 2009; Rigamonti et al., 2009a,b; Frakgou et al., 2009
	To assess SWM plans, regulations, policies, and strategies	EU, 1997; Björklund et al., 1999; Saarikoski, 2000; Arbter, 2001; Moberg et al., 2002; Aumônier, 2002; Ministry of the Environment Government of Japan, 2003; Salhofer et al., 2005, 2007; Pladerer et al., 2007; SEA Wiki, 2007; Escalante et al., 2007; Buttol et al., 2007; Cheshire County Council, 2007; SEPA, 2007b; Pisoni et al., 2009; NLWA, 2009; Desmond, 2009
	To assess options for decision making in SWM systems	Sundberg, 1993; Karagiannidis and Moussiopoulos, 1997; Sivertun and Le Duc, 1998; Ljunggren, 1998, 2000; Wilson, 2002; Reich, 2002; Fiorucci et al., 2003; Karagiannidis et al., 2003; Skordilis, 2004; Muñoz et al., 2004; Costi et al., 2004; Viotti et al., 2005; Eriksson et al., 2005; Reich, 2005; Gentil et al., 2005; Dornburg and Faaij, 2006; Jansen and Gerlo, 2006; Minciardi et al., 2007; SEPA, 2007a; Ulli-Beer et al., 2007; Bovea and Powell, 2006; Rodríguez-Iglesias et al., 2007; Cherubini et al., 2008; Gallo et al., 2009; de Feo and Malvano, 2009; Federico et al., 2009; Ekvall et al., 2009; Tunesi and Rydin, 2009; Abeliotis et al., 2009
	To site infrastructures	Lahdelma et al., 2002; EEA, 2003
	To assess part of the system including waste production steps with respect to perspectives	Finnveden et al., 2002; Fell and Fletcher, 2007; Bovea et al., 2007; Grosso et al., 2008; Karadimas and Loumos, 2008
Residual/ mixed waste	To collect and share information flows in SWM	LUA NRW, 2006
	To assess environmental impacts related to SWM infrastructures	Harrop and Pollard, 1998; Coutinho et al., 1998; Snary, 2002; Allgaier and Stegmann, 2003; Verro et al., 2003; Capuzzo and Farina, 2003; Cossu et al., 2003; Boerboom et al., 2003; Marques and Hogland, 2003; Belgiorno et al., 2003; Belfiore et al., 2005; Zorzi et al., 2005; Morra et al., 2005, 2006; Masi et al., 2007; Bour and Zdanevitch, 2007; Cangialosi et al., 2008; Moutavtchi et al., 2008; Perkoulidis et al., 2010
	To assess SWM options and the system itself	Loeschau and Rotter, 2005; van der Linden and Torfs, 2005; Chanchampee and Rotter, 2007
	To evaluate operations occurring in the SWM system (collection, treatment, and disposal)	Ecobilan, 2004; Bergsdal et al., 2005; Emery et al., 2007; Wittmaier et al., 2009
	To site infrastructures	Vaccari et al., 2005
	To assess policies and economic instruments	Nilsson et al., 2005; Björklund and Finnveden, 2007
Packaging waste	To collect and share information	GS1, 2008
	To assess management options for a specific packaging material, considering environmental perspectives	Finnveden et al., 1994; Kaila, 1998; Ryberg et al., 1998; Person et al., 1998a,b; Widheden et al., 1998a,b; Frees et al., 1998, 2004; Detzel et al., 2003; Pancaldi et al., 2005; Schmidt et al., 2007; Dahlbo et al., 2007
	To assess management options for a specific packaging material considering targets to be established	Dalager et al., 1995; Fehringer and Brunner, 1997
	To analyze the specific parts of the system, including collection, treatment, and disposal	Baumann et al., 1993; Finnveden and Ekvall, 1998; Holmquist, 1999; Rutegård, 1999; Ibenholt and Lindhjem, 2003; Ecobilan, 2004
	To assess and compare different SWM systems applied to a specific packaging waste	Frees and Weidema, 1998; Ekvall et al., 1998; Jahre, 1998; Ekvall and Bäckman, 2002; Hischier et al., 2005; Heilmann and Winkler, 2005; Dahlbo et al., 2005; Vercalsteren et al., 2007
	To assess policies	Bruvoll, 1998; Wäger et al., 2001
BMW	To assess and improve the system, including environmental perspectives	Björklund et al., 2000; Wassermann et al., 2003; Shmelev and Powell, 2006; Güereca et al., 2006; Schmidt and Pahl-Wostl, 2007; EUNOMIA, 2007
	To understand environmental impacts in SWM system with respect to pollutant fate and transport, or the waste itself	Boldrin and Christensen, 2007
	To understand the source of the waste streams	Purcell and Magette, 2007, 2009
	To compare system outputs with substitute products	Eriksson et al., 2002
	To compare technologies applied to the collection, treatment and disposal in SWM systems	Edelmann and Schleiss, 1999; Danish EPA, 2003; Lang et al., 2006a,b

measures of complexity inside procedures/components and between them, joint formulation of human factors and physical/biochemical features in system engineering models in concert with those well-defined procedures/components brings about a considerable contribution to the improvement of SWM. Such a successful joint endeavor across the boundaries between models and tools can be evidenced by the development of EUDIN, LATS, Green Dot system, and ORWARE.

Without good practices or guidelines, however, such joint endeavors inevitably tend toward the cost-effectiveness principle. For example, a potential social factor that can drive the implementation of systems analysis toward a cost-ineffective condition is

Table 5
The purposes of systems engineering models.

SWM systems	Systems engineering models	References
MSW	To predict solid waste production	Brahms and Schwitters, 1985; Dennison et al., 1996a,b; Andersen et al., 1998, Patel et al., 1998; EEA, 1999; Navarro-Esbrí et al., 2002; Lebersorger et al., 2003; Beigl and Lebersorger, 2009
	To optimize the system for choosing the best option	Kaila, 1987; Hokkanen and Salminen, 1997; Gottinger, 1988; Cosmi et al., 1998; Komilis, 2007
	To assess recycling rate	Huhtala, 1997
	To site infrastructures	Mitroupoulos et al., 2009
	To analyze specific parts of the system	Tanskanen and Melanen 1999; Villeneuve et al., 2005, 2009
	To assess the system	MCCK and Consultancy, 1998
Residual/mixed waste	To site infrastructures	Arnold and Terra, 2006
Packaging waste	To analyze how to reach recycling targets	Radetzki, 1999; Angst et al., 2001
	To study/predict waste production	Bach et al., 2004; Maunder et al., 2006
	To analyze the specific parts of the system, like collection, treatment disposal	Hanley and Slark, 1994; Powell et al., 1995; Tucker et al., 1998; Wäger et al., 1998; Ekvall and Bäckman, 2001; Petersen and Andersen, 2002
	To understand and know social cost and benefits of different packaging waste systems	Vigsø, 2004
	To assess policies	McHenry et al., 2003
BMW	To assess the system	Le Bozec et al., 2009

the NIMBY (Not in my backyard) syndrome. More human factors that may tilt the balance/scales of the SWM system should be certainly included to address the impacts from socioeconomic conditions, policy instruments, and regulatory requirements such as EU Directives, national regulations, and regional or local plans and strategies. With the aid of the technology hub proposed in Fig. 1, which pinpoints the synergistic effect between system engineering models and system assessment tools, the SWM communities become able to get over the hurdle of system complexity to some extent. A salient case of regulatory requirement is the mandatory EIA and SEA for some specific cases due to the emergency of European Directives 85/337/EEC (EU, 1985) and 2001/42/EC (EU, 2001), respectively. While European Directives with mandatory targets and features are significant, national policy instruments may drive more incentives to achieve the prescribed goals by a more cost-effective, efficient, and forward-looking way. In this pathway, CBA, LCA, MFA, and others may be glued together to support high-end analysis.

5.2. Gaps on knowledge of waste management

All of these system complexities may encourage the creation of a system of systems (SoSs), which may include large-scale concurrent and distributed sub-systems in relation to the WHP. In other words, each SoS might be a collection of task-oriented or dedicated sub-systems that pool their resources and capabilities together to obtain a more specific goal from an integrated solid waste management perspective. The selected system assessment tools in support of developed scenarios are the workhorses that may enrich the SoS and empower the systems analysis when dealing with contemporary, emerging challenges. These challenges include but are not limited to climate change, resource depletion, and energy crisis as they are the long-term challenges facing SWM communities. Systems engineering models in concert with system assessment tools may be capable of contributing to a fundamental understanding of environmental, technical, economic and social aspects of SWM systems in response to these challenges. To quantify the pros and cons of each alternative at the EU or national level, however, green accounting might be an additional tool for tackling these challenges at different scales.

With the increase of stakeholders' involvement, information flows in and out of the SWM systems increase the complexity. Additionally missing data and information in terms of both quantity and quality can make such high-end systems analysis difficult to advance. Thus, the need to effectively and efficiently collect data through identifiable data sources, recognized pathways, and involved agencies, may be justified with respect to the related complexity via the development of MISs, ESs and DSSs. The need for

Table 6
Number of published articles studying SWM systems in European countries.

Countries		AT	BE	DE	DK	ES	FI	FR	GR	IE	IT	LU	NL	PT	SE	UK	NO	CH	Total
Systems engineering models	CBA	1	0	0	2	0	0	1	0	1	0	0	0	0	2	3	2	0	12
	FM	4	0	0	1	1	0	0	1	2	0	0	0	0	0	1	0	0	10
	SM	0	0	0	0	0	1	3	0	0	0	0	0	0	0	1	1	1	7
	OM	0	0	1	0	0	2	0	3	0	1	0	0	0	0	0	0	0	7
	IMS	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	2
Systems assessment tools	MIS/DSS/ES	2	1	**7**	2	0	0	1	1	1	**4**	1	1	1	1	**3**	0	0	**26**
	SD	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	2
	MFA	2	1	2	0	1	2	0	0	0	1	0	0	0	0	0	0	1	10
	LCA/LCI	1	2	7	**13**	6	2	**13**	0	0	**10**	0	2	1	7	5	1	2	**72**
	RA	1	0	0	0	0	0	1	0	0	7	0	1	0	1	2	0	0	13
	EIA	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	2
	SEA	4	0	0	0	0	1	0	0	1	1	0	2	0	0	3	0	0	12
	SoEA	0	0	2	0	0	0	0	0	0	3	0	0	0	4	1	0	2	12
	SA	1	0	0	1	0	5	0	3	2	5	0	1	0	**10**	2	0	1	**31**
Total		**16**	4	**19**	**19**	8	**15**	**19**	8	7	**32**	1	8	3	**25**	**23**	4	7	**218**

Note: Country abbreviations – AT (Austria), BE (Belgium), DE (Germany), DK (Denmark), FI (Finland), FR (France), GR (Greece), IE (Ireland), IT (Italy), LU (Luxembourg), NL (Netherlands), NO (Norway), PT (Portugal), CH (Switzerland), SE (Sweden), ES (Spain), UK (United Kingdom). Bold numbers represent meaningful countries concerning the number of published articles in systems analysis (more significant in systems assessment tools).

a Quality Assurance System (QAS) to enhance confidence in data and information products can be assured. Such electronic platforms (e.g., MIS, ES, and DSS) would be helpful to support decisions and facilitate research to gain deeper knowledge in SWM. Only this way will it become possible to reach the end-of-waste criteria, supporting waste recycling, treatment and disposal and create a more sustainable management.

5.3. Research needs for the future

SDS is a precautionary principle and European directives have reflected it to some extent. However, waste prevention programs at the EU level should have an important role in system analysis because failures can occur in association with environmental, economic and social aspects. These waste prevention plans in SWM systems generally have multi-objective, interactive, dynamic, and uncertain features that complicate the applications of modeling and assessment techniques. The application of EPR, such as the Green Dot system, should be expanded as an integral part of modern SWM systems, since it may provide a possible route to maximize resources utilization and confirm the sustainability. To achieve this goal, carrying out site-specific and process specific CBA, MFA, LCA, EIA, etc would be required. With these site-specific and process specific inputs, next-generation systems engineering models would be able to reflect environmental impacts through an integrated approach. It should lead to consider more options across waste treatment technologies at all planning, construction, and operational stages, and evaluate more policy instruments to promote waste prevention, reuse and recycling.

To achieve these high-end decision analyses, systems engineering models may be simultaneously and flexibly integrated with system assessment tools in the context of IMS or may be sequentially applied in multiple stages so that the results from one model or tool are the inputs needed for the next one. Given that the New Directive of Waste defines public participation in the assessment of waste management plans and waste prevention programs through SEA, conducting such quantitative decision analyses should include more stakeholders in the decision making process. With this trend, future CBA, LCA, MFA, EIA and SEA might become a multitude of essential models and/or tools that may be mandatory in specific situations. On many occasions, we envision that LCA should be designed based on the framework of MFA since the object to be assessed is a process, not a product. Besides, an MIS would be essential to manage information flows from different sources, support large-scale systems analyses in search of some adaptive solid management strategies, and assess not only technology-based options but also market-based instruments.

6. Conclusions

MSW management is normally seen as a major decision making issue with respect to sustainable development in all local communities of the EU. Due to the lack of appropriate system analysis methodologies to define, evaluate, optimize or adapt their waste treatment strategies and to meet the progressive targets set up at the EU level, this paper reviews all the possible trends, and evaluates the present situation of SWM systems in the EU countries in terms of waste processing systems, policy and decision making issues. Facing all regulatory agencies, industrial, and municipalities in the EU, whereas the Southern EU countries (e.g. Portugal, Greece, Spain) require developing measures to implement more integrative SWM systems and reach the objectives of the EU directives, the Central EU Countries (e.g. Germany, Austria, The Netherlands, United Kingdom, France) and certain Northern countries (e.g. Norway) need models and tools in order to rationalize their technological choices and management strategies.

With a thorough literature review and elaborate investigation on how the system analysis techniques were developed and applied in these EU countries, a few future foci in research presented were also organized in this paper for public and private sectors to determine their future strength, thereby achieving the sustainability goals easily. These few milestones required for future development can be carved up front for EU members as follows:

- Deepen the structure of systems engineering models in the context of IMS which may incorporate more multi-faceted features covering economic, environmental, social, ecological, political; cultural, and managerial aspects for the sustainability assessment of current and future SWM systems.
- Provide synergistic tools to account for uncertainty associated with economic, environmental, social, ecological, political; cultural, and managerial aspects for SWM systems.
- Develop large-scale system analysis techniques in order to combine system assessment tools such as EIA, LCA, MFA, and even green accounting with systems engineering models such as optimization models to assess global warming potential, energy saving, and resources conservation practices so as to achieve sustainable waste management goals.
- Investigate both carbon and water footprints for all waste management alternatives as an integral part of system analysis leading to support complicated decision making and policy analyses under the global change impacts.
- Improve current waste management informatics such as MIS, DSS, and ES for the fulfillment of targets of environmental management and data reporting requirements to the EU in the context of cyber infrastructure applications.
- Conduct more cohesive CBA to support resources conservation plans such as Green Dot or the deposit-refund systems – packaging waste in SWM systems proposed by European Directives and incorporate more advanced assessments in terms of economic, environmental or social behavior of such systems with the aid of some system assessment tools such as LCA and MFA.
- Expand all ideas described above at different spatial and temporal scales.

With these efforts above, it is believed that the trends of current SWM systems and the perspectives of future SWM in association with the potential applications via integrating a plethora of different systems engineering models with a variety of system assessment tools should lead to improved insights and generate a suite of better management policies and strategies needed for the future.

References

AEA Technology, 1998. Computer-based Models in Integrated Environmental Assessment. Technical report 14. European Environmental Agency.
Abeliotis, K., Karaiskou, K., Togia, A., Lasardi, K., 2009. Decision support systems in solid waste management: a case study at the national and local level in Greece. Global NEST 11 (2), 117–126.
Allgaier, G., Stegmann, R., 2003. Development of a new risk assessment model for small old landfills. In: Proceedings of the Ninth International Waste Management and Landfill Symposium Sardinia (on CD Rom).
Andersen, F.M., Fenhann, J., Larsen, H., Schleisner, L., 1998. A Scenario Model for Generation of Waste. Risø National Laboratory, Roskilde, Denmark.
Anderson, L., 1968. A Mathematical Model for the Optimization of a Waste Management System. SERL Report. Sanitary Engineering Research Laboratory, University of California at Berkeley.
Anderson, L.E., Nigam, A.K., 1967. A Mathematical Model for the Optimization of a Waste Management System. ORC 67-25. Operations Research Center, University of California at Berkeley.

Anex, R., Lawver, R., Lund, J., Tchobanoglous, G., 1996. GIGO: spreadsheet-based simulation for MSW systems. Journal of Environmental Engineering 122 (4), 259–262.
Angst, G., Slark, W., Hutterer, H., Pilz, H., Hutterer, H., 2001. Kosten - Nutzen - Analyse Verpackungsverwertung. (Costs–benefit Analysis of Packaging). Umweltbundesamt GmbH, Wien, Austria.
Arbter, K., 2001. Wissenschaftliche Begleitstudie zur Strategischen Umweltprufung zum Wiener Abfallwirtschaftsplan (Report on SEA Vienna Waste Management Plan). Final report. BMLFUW, Vienna.
APA (Agência Portuguesa do Ambiente), 2008. SIRAPA - Sistema Integrado de Registo da Agência Portuguesa do Ambiente. http://sirapa.apambiente.pt/GuiaUtilizacaoSirapa.pdf.
Arnold, O., Terra, S., 2006. Consentement local a payer et localisation d'un incinerateur. Ministère de l'Ecologie et du Developpement Durable.
Aumônier, S., 2002. Identifying the best practicable environmental option assessment: application of LCA and other decision-aiding tools. In: Proceedings of a Workshop on Systems Studies of Integrated Solid Waste Management Stockholm.
Bach, H., Mild, A., Natter, M., Weber, A., 2004. Combining socio-demographic and logistic factors to explain the generation and collection of waste paper. Resources, Conservation and Recycling 41 (1), 65–73.
Badino, V., Blengini, G.A., Fantoni, M., Fischetti, M., 2007. Integrated MSW management in the Asti district (Piedmont): application of LCA to energetic and environmental issues. In: Proceedings of the Eleventh International Waste Management and Landfill Symposium Sardinia (on CD Rom).
Baetz, B., 1990. Optimization/simulation modeling for waste management capacity planning. Journal of Urban Planning and Development 116 (2), 59–79.
Barker, A., Wood, C., 1999. An evaluation of EIA system performance in eight EU countries. Environmental Impact Assessment Review 19 (4), 387–404.
Barlishen, K., Baetz, B., 1996. Development of a decision support system for municipal solid waste management systems planning. Waste Management and Research 14 (1), 71–86.
Baumann, H., Ekvall, T., Eriksson, E., Kullman, M., Rydberg, T., Ryding, S.-O., Steen, B., Svensson, G., 1993. Miljömässiga skillnader mellan återvinning/återanvändning och förbränning/deponering. (Environmental Differences between Recycling/reuse and Incineration/landfill) FoU No 79, Stiftelsen Reforsk, Malmö, Sweden.
Becker, C., Hegemann, M., Morstadt, S., Striegel, K.-H., 2007. Automatic reporting based on a central data base in north Rhine-Westphalia/Germany - first step: the digital waste disposal atlas. In: Proceedings of the Eleventh International Waste Management and Landfill Symposium Sardinia (on CD Rom).
Beigl, P., Lebersorger, S., 2009. Forecasting municipal solid waste generation for urban and rural regions. In: Proceedings of the Twelfth International Waste Management and Landfill Symposium Sardinia (on CD Rom).
Beigl, P., Salhofer, S., 2004. Comparison of ecological effects and costs of communal waste management systems. Resources, Conservation and Recycling 41 (2), 83–102.
Beigl, P., Gamarra, P., Linzner, R., 2005. Waste forecasts without 'rule of thumb': improving decision support for waste generation estimations. In: Proceedings of the Tenth International Waste Management and Landfill Symposium Sardinia (on CD Rom).
Belfiore, F., Toma, A., D'Aprile, L., Marella, G., Musmeci, L., Beccaloni, E., 2005. A national framework for risk assessment of landfills. In: Proceedings of the Tenth International Waste Management and Landfill Symposium Sardinia (on CD Rom).
Belgiorno, V., de Feo, G., della Rocca, C., Napoli, R., 2003. Risk assessment of solid waste landfill. In: Proceedings of the Ninth International Waste Management and Landfill Symposium Sardinia (on CD Rom).
Bergsdal, H., Stromman, A., Hertwich, E., 2005. Environmental assessment of two waste incineration strategies for Central Norway. The International Journal of Life Cycle Assessment 10 (4), 263–272.
Bhargava, H., Tettelbach, C., 1997. A web-based decision support system for waste disposal and recycling. Computers, Environment and Urban Systems 21 (1), 47–65.
Björklund, A., Finnveden, G., 2007. Life cycle assessment of a national policy proposal – the case of a Swedish waste incineration tax. Waste Management 27 (8), 1046–1058.
Björklund, A., Dalemo, M., Sonesson, U., 1999. Evaluating a municipal waste management plan using ORWARE. Journal of Cleaner Production 7 (4), 271–280.
Björklund, A., Bjuggren, C., Dalemo, M., Sonesson, U., 2000. Planning biodegradable waste management in Stockholm. Journal of Industrial Ecology 3 (4), 43–58.
Boerboom, A., Foppen, E., van Leeuwen, O., 2003. Risk assessment methodology for after-care of landfills based on the probabilistic approach. In: Proceedings of the Ninth International Waste Management and Landfill Symposium Sardinia (on CD Rom).
Boldrin, A., Christensen, T., 2007. Environmental assessment of garden waste management in the city of Herning (Denmark) by means of LCA-modelling (EASEWASTE). In: Proceedings of the Eleventh International Waste Management and Landfill Symposium Sardinia (on CD Rom).
Bolze, B., 2004. Waste management LCA in France. What has been done and what is left to do. In: Proceedings of the Integrated Waste Management & Life Cycle Assessment Workshop and Conference. European Commission - DG Joint Research Centre, Prague, Czech Republic.
Bour, O., Zdanevitch, I., 2007. Risk assessment and comparison of short-term and long-term emissions for different treatment and disposal phases of MSW. In: Proceedings of the, Eleventh International Waste Management and Landfill Symposium Sardinia (on CD Rom).
Bovea, M.D., Powell, J.C., 2006. Alternative scenarios to meet the demands of sustainable waste management. Journal of Environmental Management 79 (2), 115–132.
Bovea, M.D., Powell, J.C., Gallardo, A., Capuz-Rizo, S.F., 2007. The role played by environmental factors in the integration of a transfer station in a municipal solid waste management system. Waste Management 27 (4), 545–553.
Brahms, E., Schwitters, H., 1985. Hausmüllaufkommen und Sekundärstatistik. (Household Waste Generation and Secondary Statistics). UBA-FB 84-097, Report No. 103 03 507. Erich Schmidt Verlag, Berlin, Germany.
Brunner, P.H., Rechberger, H., 2003. Practical Handbook of Material Flow Analysis. CRC Press, Florida, USA.
Bruvoll, A., 1998. The Costs of Alternative Policies for Paper and Plastic Waste. Statistical Central Office (Statistisk sentralbyrå), Oslo.
Buclet, N., 2002. Municipal Waste Management in Europe – European Policy between Harmonisation and Subsidiarity. Kluwer Academic Publishers, Dordrecht.
Buttol, P., Masoni, P., Bonoli, A., Goldoni, S., Belladonna, V., Cavazzuti, C., 2007. LCA of integrated MSW management systems: case study of the Bologna District. Waste Management 27 (8), 1059–1070.
CIWM (Chartered Institution of Wastes Management), 2003. Welcome to the WasteDataFlow Website. http://www.wastedataflow.org/home.aspx.
Cangialosi, F., Intini, G.L., Notarnicola, M., Stellacci, P., 2008. Health risk assessment of air emissions from a municipal solid waste incineration plant - a case study. Waste Management 28 (5), 885–895.
Capuzzo, L., Farina, D., 2003. Application of risk analysis to old landfills sited in low permeability areas in the Marche region, Italy. In: Proceedings of the Ninth International Waste Management and Landfill Symposium Sardinia (on CD Rom).
Chang, N.B., Pires, A., Martinho, G. Empowering systems analysis for solid waste management: trends and perspectives. Critical Reviews in Environmental Science and Technology, in press.
Chanchampee, P., Rotter, S., 2007. Material flow analysis as a decision support tool for waste management in growing economies. In: Proceedings of the Eleventh International Waste Management and Landfill Symposium Sardinia (on CD Rom).
Chang, N.-B., Davila, E., 2007. Minimax regret optimization analysis for a regional solid waste management system. Waste Management 27 (8), 820–832.
Chang, N.-B., Schuler, R.E., 1991. Optimal pricing of the sanitary landfill use over time. Journal of Resource Management and Technology 19 (1), 14–24.
Chang, N.-B., Wang, S.-F., 1996. The development of an environmental decision support system for municipal solid waste management. Computers, Environment and Urban Systems 20 (3), 201–212.
Chang, N.-B., Wang, S.-F., 1997. A fuzzy goal programming approach for the optimal planning of metropolitan solid waste management systems. European Journal of Operational Research 99 (2), 303–321.
Chang, N.-B., Pan, Y., Huang, S., 1993. Time series forecasting of solid waste generation. Journal of Resource Management and Technology 21 (1), 1–10.
Chang, N.-B., Yang, Y., Wang, S.-F., 1996. Solid-waste management system analysis with noise control and traffic congestion limitations. Journal of Environmental Engineering 122 (2), 122–131.
Chang, N.-B., Chen, Y., Wang, S., 1997. A fuzzy interval multiobjective mixed integer programming approach for the optimal planning of solid waste management systems. Fuzzy Sets and Systems 89 (1), 35–60.
Chang, N.-B., Davila, E., Dyson, B., Brown, R., 2005. Optimal design for sustainable development of a material recovery facility in a fast-growing urban setting. Waste Management 25 (8), 833–846.
Chang, N.-B., Parvathinathan, G., Breeden, J., 2008. Combining GIS with fuzzy multicriteria decision-making for landfill siting in a fast-growing urban region. Journal of Environmental Management 87 (1), 139–153.
Chang, N.-B., Chang, Y.-H., Chen, H.-W., 2009. Fair fund distribution for a municipal incinerator using GIS-based fuzzy analytic hierarchy process. Journal of Environmental Management 90 (1), 441–454.
Chapman, R., Yakowitz, H., 1984. Evaluating the risks of solid waste management programs: a suggested approach. Resources and Conservation 11 (2), 189–199.
Cherubini, F., Bargigli, S., Ulgiati, S., 2008. Life cycle assessment of urban waste management: energy performances and environmental impacts. The case of Rome, Italy. Waste Management 28 (12), 2552–2564.
Cheshire County Council, 2007. Strategic Environmental Assessment. Environmental report. http://www.cheshire.gov.uk/NR/rdonlyres/3D7C04D3-A017-4F21-B507-7A67790686D7/0/FinalReportPDF.pdf.
Christensen, T.H., Bhander, G., Lindvall, H., Larsen, A.W., Fruergaard, T., Damgaard, A., Manfredi, S., Boldrin, A., Riber, C., Hauschild, M., 2007. Experience with the use of LCA-modelling (EASEWASTE) in waste management. Waste Management and Research 25 (3), 257–262.
Clayton, K., 1976. A planning model for regional solid waste management systems. Unpublished Ph.D. Dissertation, Purdue University.
Cosmi, C., Cuomo, V., Macchiato, M., Masi, S., Salvia, M., 1998. An innovative application of Markal model to the analysis of the waste management system on a regional case. In: Proceedings from Systems Engineering Models for Waste Management - International Workshop. Waste Research Council (AFN), Göteborg, Sweden.
Cossu, R., Pivato, A., Raga, R., 2003. Preliminary risk assessment of old landfills in Italy. In: Proceedings of the Ninth International Waste Management and Landfill Symposium Sardinia (on CD Rom).

Costi, P., Minciardi, R., Robba, M., Rovatti, M., Sacile, R., 2004. An environmentally sustainable decision model for urban solid waste management. Waste Management 24 (3), 277–295.

Coutinho, M., Conceição, M., Borrego, C., Nunes, M., 1998. Atmospheric impact assessment and monitoring of dioxin emissions of municipal solid waste incinerators in Portugal. Chemosphere 37 (9–12), 2119–2126.

Dahlbo, H., Assmuth, T., 21–23 January 1997. Analysis of lead fluxes in municipal solid waste systems for identification of waste prevention and recycling potential. Part II-C. In: Proceedings of the Conference from Paradigm to Practice of Sustainability. ConAccount, Leiden, Netherlands.

Dahlbo, H., Koskela, S., Laukka, J., Myllymaa, T., Jouttijärvi, T., Melanen, M., Tenhunen, J., 2005. Life cycle inventory analyses for five waste management options for discarded newspaper. Waste Management and Research 23 (4), 291–303.

Dahlbo, H., Ollikainen, M., Peltola, S., Myllymaa, T., Melanen, M., 2007. Combining ecological and economic assessment of options for newspaper waste management. Resources, Conservation and Recycling 51 (1), 42–63.

Dalager, S., Drabaek, I., Ottosen, L.M., Busch, N.J., 1995. Miljøøkonomi for papir- oq papkredsløb. Sammenfatning. (Environmental Economics of Paper and Cardboard Circulation. Part 1: Method Description, Material Flow, and References). no. 28-31. Miljøstyrelsen (Danish EPA). http://www2.mst.dk/udgiv/Publikationer/1995/87-7810-353-3/pdf/87-7810-353-3.PDF.

Dalemo, M., Sonesson, U., Björklund, A., Mingarini, K., Frostell, B., Nybrant, T., Jonsson, H., Sundqvist, J.-O., Thyselius, L., 1997. ORWARE - a simulation model for organic waste handling systems. Part 1: model description. Resources, Conservation and Recycling 21 (1), 17–37.

Dall, O., Lassen, C., Hansen, E., 2003. Waste Indicators. Environmental Project no. 809. Danish EPA.

Danish EPA (Danish Environmental Protection Agency), 1999. Waste in Denmark. Danish Environmental Protection Agency. http://www.mem.dk/ukindex.htm.

Danish EPA (Danish Environmental Protection Agency), 2001. The Danish Model for Sustainable Waste Solutions. Danish Environmental Protection Agency. http://www2.mst.dk/common/Udgivramme/Frame.asp%3F. http://www2.mst.dk/udgiv/Publications/2001/87-7944-863-1/html/default_eng.htm.

Danish EPA (Danish Environmental Protection Agency), 2003. Systems Analysis of Organic Waste Management in Denmark. Environmental Project No. 822. Danish EPA.

Daskalopoulos, E., Badr, O., Probert, S., 1998. Municipal solid waste: a prediction methodology for the generation rate and composition in the European Union countries and the United States of America. Resources, Conservation and Recycling 24 (2), 155–166.

Davila, E., Chang, N.-B., Diwakaluni, S., 2005. Dynamic landfill space consumption assessment in the Lower Rio Grande Valley, South Texas by GIP-based game theory. Journal of Environmental Management 75 (4), 353–366.

de Feo, G., Malvano, C., 2009. The use of LCA in selecting the best MSW management system. Waste Management 29 (6), 1901–1915.

den Boer, J., den Boer, E., Jager, J., 2007. LCA-IWM: a decision support tool for sustainability assessment of waste management systems. Waste Management 27 (8), 1032–1045.

Denmark Waste Exchange, 2008. Denmark Waste Exchange. Denmark Waste Exchange. http://www.auctionwaste.net/.

Dennison, G.J., Dodd, V.A., Whelan, B., 1996a. A socio-economic based survey of household waste characteristics in the city of Dublin, Ireland, I. Waste composition. Resources, Conservation and Recycling 3 (17), 227–244.

Dennison, G.J., Dodd, V.A., Whelan, B., 1996b. A socio-economic based survey of household waste characteristics in the city of Dublin, Ireland, II. Waste quantities. Resources, Conservation and Recycling 3 (17), 245–257.

Desmond, M., 2009. Identification and development of waste management alternatives for Strategic Environmental Assessment (SEA). Environmental Impact Assessment Review 29 (1), 51–59.

Detzel, A., Giegrich, J., Weber, H., Christiani, J., 2003. Eco-efficiency in integrated waste management systems environmental and economical assessment of packaging recycling. In: Proceedings of the Ninth International Waste Management and Landfill Symposium Sardinia (on CD Rom).

Diaz, R., Warith, M., 2006. Life-cycle assessment of municipal solid wastes: development of the WASTED model. Waste Management 26 (8), 886–901.

Döberl, G., Huber, R., Brunner, P.H., Eder, M., Pierrard, R., Schönbäck, W., Frühwirth, W., Hutterer, H., 2002. Long-term assessment of waste management options – a new, integrated and goal-oriented approach. Waste Management and Research 20 (4), 311–327.

Dornburg, V., Faaij, A.P.C., 2006. Optimizing waste treatment systems. Part B: analyses and scenarios for The Netherlands. Resources, Conservation and Recycling 48 (3), 227–248.

Dubois, R., 1997. Statistical databases: the reference environment and three layers proposed by Eurostat. Qüestiió 21 (1), 233–240.

Dyson, B., Chang, N.-B., 2005. Forecasting municipal solid waste generation in a fast-growing urban region with system dynamics modeling. Waste Management 25 (7), 669–679.

EEA (European Environment Agency), 1999. Baseline Projections of Selected Waste Streams. European Environment Agency, Copenhagen.

EEA (European Environment Agency), 2002. Reportnet: Development of Common Tools and a Shared Information Infrastructure for the European Environmental Information System. European Environment Agency, Copenhagen.

EEA (European Environment Agency), 2003. Assessment of Information Related to Waste and Material Flows: a Catalogue of Methods and Tools. European Environment Agency, Copenhagen.

EEA (European Environment Agency), 2005. Effectiveness of Packaging Waste Management Systems in Selected Countries: An EEA Pilot Study. European Environmental Agency, Luxembourg.

EEA (European Environmental Agency), 2007. Recent trends in municipal waste incineration with energy recovery, 2000-2005. EEA. http://dataservice.eea.europa.eu/atlas/viewdata/viewpub.asp?id=2871.

EIONET (European Environment Information and Observation Network), 2007a. United Kingdom. http://waste.eionet.europa.eu/facts/factsheets_waste/United%20Kingdom.

EIONET (European Environment Information and Observation Network), 2007b. Denmark. http://waste.eionet.europa.eu/facts/factsheets_waste/Denmark.

EIONET (European Environment Information and Observation Network), 2009. European Environment Information and Observation Network. http://www.eionet.europa.eu/.

EU (European Union), 1985. Council Directive 85/337/EEC of 27 June 1985 on the Assessment of the Effects of Certain Public and Private Projects on the Environment. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do%3Furi=CELEX:31985L0337:EN:HTML.

EU (European Union), 1991. Council Directive 91/692/EEC of 23 December 1991 Standardizing and Rationalizing Reports on the Implementation of Certain Directives Relating to the Environment. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do%3Furi=CELEX:31991L0692:EN:HTML.

EU (European Union), 1997. Environmental Assessment – Case Studies on SEA. http://ec.europa.eu/environment/eia/sea-studies-and-reports/sea-case-studies.htm.

EU (European Union), 2001. Directive 2001/42/EC of the European Parliament and of the Council of 27 June 2001 on the Assessment of the Effects of Certain Plans and Programmes on the Environment. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do%3Furi=OJ:L:2001:197:0030:0037:EN:PDF.

EU (European Union), 2002. Regulation (EC) no 2150/2002 of the European Parliament and of the Council of 25 November 2002 on Waste Statistics. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do%3Furi=OJ:L:2002:332:0001:0036:EN:PDF.

EU (European Union), 2003. Directive 2003/35/EC of the European Parliament and of the Council of 26 May 2003 Providing for Public Participation in Respect of the Drawing Up of Certain Plans and Programmes Relating to the Environment and Amending with Regard to Public Participation. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do%3Furi=OJ:L:2003:156:0017:0024:EN:PDF.

EU (European Union), 2005. Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions: Taking Sustainable Use of Resources Forward: A Thematic Strategy on the Prevention and Recycling of Waste. COM (2005) 666. http://eur-lex.europa.eu/LexUriServ/site/en/com/2005/com2005_0666en01.pdf.

EU (European Union), 2008. Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on Waste and Repealing Certain Directives. <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do%3Furi=OJ:L:2008:312:0003:0030:EN:PDF>.

EUDIN (European Data Interchange for Waste Notification Systems), 2002. EUDIN - The Project EUDIN. http://www.eudin.org/index.html.

EUNOMIA, 2007. Managing Biowastes from Households in the UK: Applying Life-cycle Thinking in the Framework of Cost–benefit Analysis. WRAP. http://www.wrap.org.uk/downloads/Biowaste_CBA_Report_Appendices_May_2007.cab1d970.3823.pdf.

Ecobilan, 2004. WISARD - Waste Integrated System for Analysis of Recovery and Disposal. http://www.ecobilan.com/wisard/index.php.

Economie, 2008. Belgian Waste Exchange. FPS Economy, SMEs, Self-Employed and Energy. http://economie.fgov.be/enterprises/waste/home_fr.htm.

Edelmann, W., Schleiss, K., 1999. Ökologischer, energetischer und ökonomischer Vergleich von Vergärung, Kompostierung und Verbrennung fester biogener Abfallstoffe. (Ecological, Energetic and Economic Comparison of Fermentation, Composting and Incineration of Biowaste). BFE/BUWAL, Geneva.

Ekvall, T., Bäckman, P., 2001. Översiktlig samhällsekonomisk utvärdering av at använda pappersförpackningar. (Outline of Socioeconomic Evaluation of Using Paper Packaging). CiT Ekologik AB.

Ekvall, T., Bäckman, P., 2002. Assessing external and indirect costs and benefits of recycling. In: Proceedings from Workshop on System Studies of Integrated Solid Waste Management. IVL Swedish Environmental Institute, Stockholm, Sweden.

Ekvall, T., Person, L., Ryberg, A., Widheden, J., Frees, N., Nielsen, P.H., Weidema, B.P., Wesnæs, M., 1998. Life Cycle Assessment of Packaging Systems for Beer and Soft Drinks – Main Report. Miljøprojekt no. 399. Danish EPA. http://www2.mst.dk/Udgiv/publications/1998/87-7909-014-1/pdf/87-7909-014-1.pdf.

Ekvall, T., Björklund, A., Eriksson, O., Söderman, M.L., Östblom, G., Sjöstrom, M., Stenmarck, Å, Sundqvist, J.O., 2009. Modelling to assess policy instruments. In: Proceedings of the Twelfth International Waste Management and Landfill Symposium Sardinia (on CD Rom).

Elshkaki, A., 2000. Modelling substance flow analysis in Simulink. Assistance to use Dynflow. MSc Thesis, CML, Leiden University.

Emery, A., Davies, A., Griffiths, A., Williams, K., 2007. Environmental and economic modelling: a case study of municipal solid waste management scenarios in Wales. Resources, Conservation and Recycling 49 (3), 244–263.

Eriksson, O., Frostell, B., Björklund, A., Assefa, G., Sundqvist, J.-O., Granath, J., Carlsoon, M., Baky, A., Thyselius, L., 2002. Energy recovery and material and nutrient recycling from a systems perspective. In: Proceedings from Workshop on System Studies of Integrated Solid Waste Management. IVL - Swedish Environmental Research Institute, Stockholm, Sweden.

Eriksson, O., Reich, M., Frostell, B., Björklund, A., Assefa, G., Sundqvist, J.-O., Granath, J., Baky, A., Thyselius, L., 2005. Municipal solid waste management from a systems perspective. Journal of Cleaner Production 13 (3), 241–252.

Escalante, N., Kranert, M., Hafner, G., 2007. Environmental evaluation of household waste management system in southern Germany. In: Proceedings of the Eleventh International Waste Management and Landfill Symposium Sardinia (on CD Rom).

Eurostat, 2009. Environmental Data Centres. http://epp.eurostat.ec.europa.eu/portal/page/portal/about_eurostat/activities/environmental_data_centres.

Fahy, C., 2007. Improving access to information on the environment. In: Proceedings of the Eleventh International Waste Management and Landfill Symposium Sardinia (on CD Rom).

Federico, G., Rizzo, G., Traverso, M., 2009. In itinere strategic environmental assessment of an integrated provincial waste system. Waste Management and Research 27 (4), 390–398.

Fehringer, R., Brunner, P., 1997. Flows of plastics and their possible reuse in Austria. In: Proceedings of from Paradigm to Practice of Sustainability, Part II C. Con-Account, Leiden, Netherlands.

Fell, D., Fletcher, J., 2007. Household waste and waste composition: the possible impact of future lifestyles. Communications in Waste and Resource Management (CWRM) 8 (2), 52–57.

Finnveden, G., Ekvall, T., 1998. Energi-eller materialåtervinning av pappersförpakningar?. (Energy Recovery or Material Recycling of Paper Packaging?) Svensk Kartongåtervinning AB, Stockholm.

Finnveden, G., Person, L., Steen, B., 1994. Förpackningar i kretsloppet: Återvinning av mjölkkartong — En LCA-studie av skillnader i miljöbelastning. (Packaging in Circulation: Recycling of Cardboard for Milk — An LCA Study of the Differences in Environmental Load) Report 4301, Stockholm.

Finnveden, G., Johansson, J., Lind, P., Moberg, A., 2002. Life cycle assessment of energy from solid waste - total energy use and emissions of greenhouse gases. In: Proceedings from Workshop on System Studies of Integrated Solid Waste Management. IVL Swedish Environmental Research Institute, Stockholm, Sweden.

Fiorucci, P., Minciardi, R., Robba, M., Sacile, R., 2003. Solid waste management in urban areas. Development and application of a decision support system. Resources, Conservation and Recycling 37 (4), 301–328.

Frakgou, M.C., Vicent, T., Gabarrell, X., 2009. A general methodology for calculating the MSW management self-sufficiency indicator: application to the wider Barcelona area. Resources, Conservation and Recycling 54 (6), 390–399.

Franklin Associates, 1999. Characterization of Municipal Waste in the United States: 1998 Update. EPA530-R-99-021. US Environmental Protection Agency, Washington, DC, USA. http://www.epa.gov/epaoswer/non-hw/muncpl/pubs/98charac.pdf.

Frees, N., Weidema, B.P., 1998. Life Cycle Assessment of Packaging Systems for Beer and Soft Drinks. Miljøproject no 406. Danish EPA. http://www2.mst.dk/Udgiv/publications/1998/87-7909-027-3/pdf/87-7909-027-3.pdf.

Frees, N., Ryberg, A., Ekvall, T., 1998. Life Cycle Assessment of Packaging Systems for Beer and Soft Drinks — Steel Cans. Miljøproject no 403. Danish EPA. http://www2.mst.dk/Udgiv/publications/1998/87-7909-024-9/pdf/87-7909-024-9.pdf.

Frees, N., Hansen, M.S., Ottosen, L.M., Tønning, K., Wenzel, H., 2004. Opdatering af vidensgrundlaget for de miljømæssige forhold ved genanvendelse af papir og pap. (Update of the Knowledge Basis on the Environmental Impact of Paper and Cardboard Recycling). Danish Environmental Protection Agency.

Fuertes, L., Hudson, J., Mark, D., 1974. Solid waste management: equity trade-off-models. Journal of Urban Planning and Development 100 (2), 155–171.

GS1, 2008. Efficient Processes in Waste Management — Preparing Europe for Global Markets. http://ec.europa.eu/environment/seis/pdf/3b-GS1-Piller-SEIS_TF-Prague.pdf.

Gallo, M., Cattaneo, del Borghi, A., 2009. Life cycle assessment (LCA) as decision supporting tool for waste management: analysis of Italian case studies. In: Proceedings of the Twelfth International Waste Management and Landfill Symposium Sardinia (on CD Rom).

Gay, A.E., Beam, T.G., Mar, B.W., 1993. Cost-effective solid-waste characterization methodology. Journal of Environmental Engineering 119 (4), 631–644.

Gentil, E., Hall, D., Thomas, B., Shiels, S., Collins, M., 2005. LCA tool in waste management: new features and functionalities. In: Proceedings of the Tenth International Waste Management and Landfill Symposium Sardinia (on CD Rom).

Gottinger, H., 1988. A computational model for solid waste management with application. European Journal of Operational Research 35 (3), 350–364.

Grossman, D., Hudson, J., Marks, D., 1974. Waste generation methods for solid waste collection. Journal of Environmental Engineering 100 (6), 1219–1230.

Grosso, M., Rigamonti, L., Sunseri, M.C., Dainese, C., Figundio, F., Viganò, F., Bianchini, A., Pellegrini, M., 2008. Optimal strategies for the recovery of material and energy from MSW. In: Proceedings of the Second International Symposium on Energy from Biomass and Waste Venice (on CD Rom).

Güereca, L.P., Gassó, S., Baldasano, J.M., Jiménez-Guerrero, P., 2006. Life cycle assessment of two biowaste management systems for Barcelona, Spain. Resources, Conservation and Recycling 49 (1), 32–48.

Haastrup, P., Maniezzo, V., Mattarelli, M., Rinaldi, F., Mendes, I., Paruccini, M., 1998. A decision support system for urban waste management. European Journal of Operational Research 109 (2), 330–341.

Hanley, N., Slark, R., 1994. Cost–benefit analysis of paper recycling: a case study and some general principles. Journal of Environmental Planning and Management 37 (2), 189–197.

Harrop, D., Pollard, S., 1998. Quantitative risk assessment for incineration: is it appropriate for the UK? Water and Environmental Management 12 (1), 48–53.

Heilmann, A., Winkler, J., 2005. Influence of the source separation efficiency of recyclable materials on the environmental performance of municipal waste management systems. In: Proceedings of the Tenth International Waste Management and Landfill Symposium Sardinia (on CD Rom).

Hekkert, M.P., Joosten, L.A.J., Worrell, E., 2000. Analysis of the paper and wood flow in the Netherlands. Resources, Conservation and Recycling 30 (1), 29–48.

Helms, B., Clark, R., 1974. Locational models for solid waste management. Journal of Urban Planning and Development 97 (1), 1–13.

Hischier, R., Wäger, P., 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 (5), 525–539.

Hockett, D., Lober, D., Pilgrim, K., 1995. Determinants of per capita municipal solid waste generation in the Southeastern United States. Journal of Environmental Management 45 (3), 205–217.

Hokkanen, J., Salminen, P., 1997. Choosing a solid waste management system using multicriteria decision analysis. European Journal of Operational Research 98 (1), 19–36.

Holmquist, J., 1999. Materialåtervinning eller energiutvinning av returkartong? — Fallstudie för Gothenburg. (Material Recycling or Energy Gothenburg). Dept. Environmental Sciences, Goteborg.

Huang, G., Sae-Lim, N., Liu, L., Chen, Z., 2001. An interval-parameter fuzzy-stochastic programming approach for municipal solid waste management and planning. Environmental Modeling and Assessment 6 (4), 271–283.

Huang, Y., Baetz, B., Huang, G., Liu, L., 2002. Violation analysis for solid waste management systems: an interval fuzzy programming approach. Journal of Environmental Management 65 (4), 431–446.

Huhtala, A., 1997. A post-consumer waste management model for determining optimal levels of recycling and landfilling. Environmental and Resource Economics 10 (3), 301–314.

Huijbregts, M.A.J., 2000. Priority Assessment of Toxic Substances in the Frame of LCA. Institute of Biodiversity Dynamics, University of Amsterdam, Amsterdam, The Netherlands.

Huppes, G., de Koning, A., Suh, S., Heijungs, R., van Oers, L., Nielsen, P., Guinée, J.B., 2006. Environmental impacts of consumption in the European Union: high-resolution input–output tables with detailed environmental extensions. Journal of Industrial Ecology 10 (3), 129–146.

IFU (Institute for Environmental Informatics Hamburg), 2006. Umberto — Know the Flow. http://www.umberto.de/en/.

IHK Recyclingborse, 2008. IHK Recyclingborse. http://www.ihk-recyclingboerse.de/.

ISO 14025, 2006. Environmental Labels and Declarations. Type III Environmental Declarations — Principles and Procedures. International Organisation for Standardisation.

ISO 14040, 2006. Environmental Management: Life Cycle Assessment. Principles and Framework. International Organisation for Standardisation.

IWEN, 2008. Italian Recycle Exchange Network. http://www.riciclilloscambio.net/.

Ibenholt, K., Lindhjem, H., 2003. Costs and benefits of recycling liquid board containers. Journal of Consumer Policy 26 (3), 301–325.

International Synergies Limited, 2007. NISP - National Industrial Symbiosis Programme. http://www.nisp.org.uk/.

Jahre, M., 1998. The logistics costs of collecting recyclable household waste - modelling systems for cost consequence analysis. In: Proceedings from the Systems Engineering Models for Waste Management - International Workshop. Waste Research Council (AFN), Goteborg, Sweden.

Jansen, B., Gerlo, J., 2006. Worldwide Environmental Impacts of Consumption and Production in Flanders: Feasibility of an Environmental Input–output Model for Flanders. MIRA/2006/11. Flemish Institute for Technological Research and Centre for Sustainable Development — Ghent University, Ghent, Belgium.

Jean-Gerard, W., 2008. Bourse-des-dechets. http://www.bourse-des-dechets.fr/.

Jenkins, A., 1979. Optimal location of facilities for recycling municipal solid waste in Southern Ontario. Unpublished Ph.D. Dissertation, University of Toronto, Toronto, Ontario, Canada.

Joosten, L.A.J., Hekkert, M.P., Worrell, E., 2000. Assessment of the plastic flows in the Netherlands using STREAMS. Resources, Conservation and Recycling 30 (2), 135–161.

Kahn, H., Wiener, A., 1967. The Year 2000. MacMillan, New York.

Kaila, J., 1987. Mathematical Model for Strategic Evaluation of Municipal Solid Waste Management Systems, vol. 40. Technical Research Centre of Finland, Espoo, Finland.

Kaila, J., 1998. Modelling sustainable recycling - a case study on glass recycling. In: Proceedings from Systems Engineering Models for Waste Management - International Workshop. Waste Research Council (AFN), Goteborg, Sweden.

Karadimas, N., Loumos, V., 2008. GIS-based modelling for the estimation of municipal solid waste generation and collection. Waste Management and Research 26 (4), 337–346.

Karagiannidis, A., Moussiopoulos, N., 1997. Application of ELECTRE III for the integrated management of municipal solid wastes in the Greater Athens Area. European Journal of Operational Research 97 (3), 439–449.

Karagiannidis, A.M., Diamandopoulos, G., Kaggelides, K., Perkoulidis, G., 2003. Simulation modelling software for integrated solid waste management at regional level. In: Proceedings of the 8th International Conference in Environmental Science and Technology. Global Network for Environmental Science and Technology, Lemnos Island, Greece.

Katsamaki, A., Willems, S., Diamadopoulos, E., 1998. Time series analysis of municipal solid waste generation rates. Journal of Environmental Engineering 142 (2), 178–183.

Kirkeby, J., Christensen, T., Bhander, G., Hansen, T., Birgisdottir, H., 2005. LCA modelling of MSW management system: approach and case study. In: Proceedings of the Tenth International Waste Management and Landfill Symposium Sardinia (on CD Rom).

Klepper, G., Michaelis, P., 1994. Economic incentives for packaging waste management: the Dual System in Germany. In: Curzio, A.Q., Prosperetti, L., Zoboli, R. (Eds.), The Management of Municipal Solid Waste in Europe – Economic, Technological and Environmental Perspectives, vol. 5. Elsevier, Amsterdam, pp. 170–190.

Komilis, D., 2007. Conceptual models to optimize the haul, transfer and disposal of municipal solid waste. In: Proceedings of the Eleventh International Waste Management and Landfill Symposium Sardinia (on CD Rom).

Krivtsov, V., Wäger, P.A., Dacombe, P., Gilgen, P.W., Heaven, S., Hilty, L.M., Banks, C.J., 2004. Analysis of energy footprints associated with recycling of glass and plastic—case studies for industrial ecology. Ecological Modelling 174 (1–2), 175–189.

Kuhner, J., Harrington, J.J., 1975. Mathematical models for developing regional solid waste management policies. Engineering Optimization 1 (4), 237–256.

Lahdelma, R., Salminen, P., Hokkanen, J., 2002. Locating a waste treatment facility by using stochastic multicriteria acceptability analysis with ordinal criteria. European Journal of Operational Research 142 (2), 345–356.

Lang, D., Binder, C., Stauffacher, M., Ziegler, C., Schleiss, K., Scholz, R., 2006a. Material and money flows as a means for industry analysis of recycling schemes: a case study of regional bio-waste management. Resources, Conservation and Recycling 49 (2), 159–190.

Lang, D.J., Binder, C.R., Scholz, R.W., Schleiss, K., Stäubli, B., 2006b. Impact factors and regulatory mechanisms for material flow management: integrating stakeholder and scientific perspectives. The case of bio-waste delivery. Resources, Conservation and Recycling 47 (2), 101–132.

Lawver, R., Lund, J., Tchobanoglous, G., 1990. GIGO - A solid waste management model for municipalities. In: Proceedings of the Sixth International Conference on Solid Waste Management and Technology, p. 8. Philadelphia, Pennsylvania, USA, Paper no. 15.

Le Bozec, A., Robin, D., Mollaret, M.-E., 2009. Biodegradable waste: economic assessment of collection-biological treatment options. In: Proceedings of the Twelfth International Waste Management and Landfill Symposium Sardinia (on CD Rom).

Lebersorger, S., Schneider, F., Hauer, W., 2003. Waste generation in households - models in theory and practical experience from a case study of multifamily dwellings in Vienna. In: Proceedings of the Ninth International Waste Management and Landfill Symposium Sardinia (on CD Rom).

Li, Y.P., Huang, G.H., 2006a. An inexact two-stage mixed integer linear programming method for solid waste management in the City of Regina. Journal of Environmental Management 81 (3), 188–209.

Li, Y.P., Huang, G.H., 2006b. Minimax regret analysis for municipal solid waste management: an interval-stochastic programming approach. Journal of the Air & Waste Management Association 56 (7), 931–944.

Li, Y.P., Huang, G.H., 2009a. Dynamic analysis for solid waste management systems: an inexact multistage integer programming approach. Journal of the Air & Waste Management Association 59 (3), 279–292.

Li, Y.P., Huang, G.H., 2009b. Interval-parameter robust optimization for environmental management under uncertainty. Canadian Journal of Civil Engineering 36 (4), 592–606.

Li, Y.P., Huang, G.H., Nie, S.L., Huang, Y., 2006. IFTSIP: interval fuzzy two-stage stochastic mixed-integer linear programming: a case study for environmental management and planning. Civil Engineering and Environmental Systems 23 (2), 73–99.

Li, Y.P., Huang, G.H., Nie, S.L., Qin, X.S., 2007. ITCLP: an inexact two-stage chance-constrained program for planning waste management systems. Resources, Conservation and Recycling 49 (3), 284–307.

Li, Y.P., Huang, G.H., Nie, X.H., Nie, S.L., 2008a. A two-stage fuzzy robust integer programming approach for capacity planning of environmental management systems. European Journal of Operational Research 189 (2), 399–420.

Li, Y.P., Huang, G.H., Yang, Z., Nie, S.L., 2008b. An integrated two-stage optimization model for the development of long-term waste-management strategies. Science of the Total Environment 392 (2–3), 175–186.

Li, Y.P., Huang, G.H., Yang, Z.F., Chen, X., 2009. Inexact fuzzy-stochastic constraint-softened programming – a case study for waste management. Waste Management 29 (7), 2165–2177.

Ljunggren, M., 1998. The MWS model - a systems engineering approach to national solid waste management. In: Proceedings of the Systems Engineering Models for Waste Management - International Workshop. Waste Research Council (AFN), Göteborg, Sweden.

Ljunggren, M., 2000. Modelling national solid waste management. Waste Management and Research 18 (6), 525–537.

Loeschau, M., Rotter, S., 2005. Input–output analysis for modelling of complex networks of waste treatment processes. In: Proceedings of the Tenth International Waste Management and Landfill Symposium Sardinia (on CD Rom).

LUA NRW (Landesumweltamt Nordrhein-Westfalen), 2006. Waste Information Systems and Waste Management Web Application. http://www.lanuv.nrw.de/englisch/abfall/bewertung/abandaenglisch.htm.

MCCK and Consultancy, 1998. Waste Management, a Strategy for Dublin. Local Authorities, Dublin.

MacDonald, M., 1996. A multi-attribute spatial decision support system for solid waste planning. Computers, Environment and Urban Systems 20 (1), 1–17.

Marks, D., Liebman, J., 1971. Location models: solid waste collection example. Journal of the Urban Planning and Development Division 97 (1), 15–30.

Marks, D.H., ReVelle, C.S., Liebman, J.C., 1970. Mathematical models of location: a review. Journal of the Urban Planning and Development Division 96 (1), 81–93.

Marques, M., Hogland, W., 2003. Groundwater risk assessment for different waste streams disposal: Spillepeng landfill, Sweden. In: Proceedings of the Ninth International Waste Management and Landfill Symposium Sardinia (on CD Rom).

Masi, S., Caniani, D., Trulli, E., Perilli, G., Sdao, F., Zirpoli, P., 2007. Environmental risk assessment and prioritization of uncontrolled landfills by using GIS technology. In: Proceedings of the Eleventh International Waste Management and Landfill Symposium Sardinia (on CD Rom).

Mastellone, M.L., Brunner, P.H., Arena, U., 2009. Scenarios of waste management for a waste emergency area – a substance flow analysis. Journal of Industrial Ecology 13 (5), 735–757.

Maunder, A., Howard, M., Farmelo, C., Yates, T., 2006. Modelling the impact of lifestyle changes in household waste arisings. In: Proceedings of Waste, pp. 295–305.

McDougall, F., White, P., Franke, M., Hindle, P., 2001. Integrated Solid Waste Management: a Life Cycle Inventory. Blackwell Science Ltd., Oxford.

McHenry, P., Longhurst, P., Lowe, M., Macintosh, B., Seaton, R., 2003. The development of a decision support tool for innovative waste strategy planning. In: Proceedings of the Ninth International Waste Management and Landfill Symposium Sardinia (on CD Rom).

Melloni, R., Carlini, N., Neri, P., Pozzi, V., Bergonzoni, M., 2003. Environmental and economic analysis of mechanical biological pre-treatment of MSW: an LCA approach. In: Proceedings of the Ninth International Waste Management and Landfill Symposium Sardinia (on CD Rom).

Minciardi, R., Paolucci, M., Robba, M., Sacile, R., 2007. Multi-objective optimization of solid waste flows: environmentally sustainable strategies for municipalities. Waste Management 28 (11), 2202–2212.

Ministry of the Environment Government of Japan, 2003. Effective SEA System and Case Studies. Ministry of the Environment Government of Japan, Tokyo.

Mitroupoulos, P., Giannikos, I., Mitropoulos, I., 2009. Exact and heuristic approaches for the locational planning of an integrated solid waste management system. Operational Research 9 (3), 329–347.

Moberg, A., Finnveden, G., Johansson, J., Lind, P., 2002. Life cycle assessment of energy from solid waste - landfilling as a treatment method. In: Proceedings from Workshop on System Studies of Integrated Solid Waste Management. IVL Swedish Environmental Research Institute, Stockholm, Sweden.

Mochty, F., 2009. Electronic Data Management – An Integrated EGovernment – Application in the Environmental Field in Austria. http://www.e-envi2009.org/presentations/S2/Mochty.pdf.

Morra, P., Spadoni, G., Lisi, R., Maschio, G., 2005. Assessment of the human health risk using a GIS approach: the case of the Pace Valley. In: Proceedings of the Tenth International Waste Management and Landfill Symposium Sardinia (on CD Rom).

Morra, P., Lisi, R., Spadoni, G., Maschio, G., 2006. An integrated quantitative approach for the assessment of human health risk in the Pace Valley of Messina with EHHRA-GIS tool. In: Proceedings of the Biomass and Waste to Energy Symposium Venice (on CD Rom).

Morrissey, A., Browne, J., 2004. Waste management models and their application to sustainable waste management. Waste Management 24 (3), 297–308.

Moutavtchi, V., Stenis, J., Hogland, W., Shepeleva, A., Andersson, H., 2008. Application of the WAMED model to landfilling. Journal of Material Cycles and Waste Management 10 (1), 62–70.

Muñoz, I., Rieradevall, J., Doménech, X., Milà, L., 2004. LCA application to integrated waste management planning in Gipuzkoa. The International Journal of Life Cycle Assessment 9 (4), 272–280.

NLWA (North London Waste Authority), 2009. North London Joint Waste Strategy. http://www.nlwa.gov.uk/cms_images/documents/FinalStrategy.pdf.

Najm, M., El.Fadel, M., Ayoub, G., El-Taha, M., Al-Awar, F., 2002. An optimisation model for regional integrated solid waste management I. Model formulation. Waste Management and Research 20 (1), 37–45.

Nakamura, S., 1999. An interindustry approach to analyzing economic and environmental effects of the recycling of waste. Ecological Economics 28 (1), 133–145.

Nakamura, S., Kondo, Y., 2002. Input–output analysis of waste management. Journal of Industrial Ecology 6 (1), 39–63.

Nationale Reststoffenbeurs, 1986. Nationale Reststoffenbeurs. http://www.reststoffenbeurs.nl/.

Navarro-Esbrí, J., Diamadopoulos, E., Ginestar, D., 2002. Time series analysis and forecasting techniques for municipal solid waste management. Resources, Conservation and Recycling 35 (3), 201–214.

Nie, X., Huang, G., Li, Y., Liu, L., 2007. IFRP: a hybrid interval-parameter fuzzy robust programming approach for waste management planning under uncertainty. Journal of Environmental Management 84 (1), 1–11.

Nilsson, M., Björklund, A., Finnveden, G., Johansson, J., 2005. Testing a SEA methodology for the energy sector: a waste incineration tax proposal. Environmental Impact Assessment Review 25 (1), 1–32.

Obernosterer, R., Brunner, P., 1997. Construction wastes as the main source of CFC-emissions. In: Proceedings of from Paradigm to Practice of Sustainability, Part II C. ConAccount, Leiden, Netherlands.

PE International GmbH, 2006. GaBi Software Family. http://www.gabi-software.com/.

Pancaldi, E., Ferrari, L., Melloni, R., Neri, P., 2005. LCA analysis of possible scenarios of plastics disposal. In: Proceedings Sardinia 2005, Tenth International Waste Management and Landfill Symposium Sardinia (on CD Rom).

Patel, M., Jochem, E., Radgen, P., Worrell, E., 1998. Plastics streams in Germany - an analysis of production, consumption and waste generation. Resources, Conservation and Recycling 24 (3–4), 191–215.

Perkoulidis, G., Papageorgiou, A., Karagiannidis, A., Kalogirou, S., 2010. Integrated assessment of a new waste-to-energy facility in central Greece in the context of regional perspectives. Waste Management. doi:10.1016/j.wasman.2009.11.021.

Person, L., Ekvall, T., Weidema, B.P., 1998a. Life Cycle Assessment of Packaging Systems for Beer and Soft Drinks – Disposal PET Bottles. Miljøprojekt no. 405. Danish EPA. http://www2.mst.dk/Udgiv/publications/1998/87-7909-026-5/pdf/87-7909-026-5.pdf.

Person, L., Ekvall, T., Weidema, B.P., 1998b. Life Cycle Assessment of Packaging Systems for Beer and Soft Drinks – Refillable PET Bottles. Miljøprojekt no. 404. Danish EPA. http://www2.mst.dk/Udgiv/publications/1998/87-7909-025-7/pdf/87-7909-025-7.pdf.

Petersen, M.L., Andersen, H.T., 2002. Nyttiggørelse af returpapir — en samfundsøkonomisk analyse. (Utilisation of Recycled Paper—A Socioeconomic Analysis). Institut for Miljøvurdering (Environmental Assessment Institute), Copenhagen.

Pimenteira, C.A.P., Carpio, L.G.T., Rosa, L.P., Tolmansquim, M.T., 2005. Solid wastes integrated management in Rio de Janeiro: input–output analysis. Waste Management 25 (5), 539–553.

Pisoni, E.B., Raccaelli, R., Dotelli, G., Botta, D., Melià, P., 2009. Accounting for transportation impacts in the environmental assessment of waste management plans. The International Journal of Life Cycle Assessment 14 (3), 248–259.

Pladerer, C., Meissner, M., Koblmuller, M., Tappeiner, G., 2007. Strategic environmental assessment (SEA) for waste management plans - case studies in Austria. In: Proceedings Sardinia 2007, Eleventh International Waste Management and Landfill Symposium Sardinia (on CD Rom).

Powell, J., Craighill, A., Partfitt, J., Turner, R., 1995. The costs and benefits of recycling. In: Proceedings of the R'95 International Congress Geneva, Switzerland.

Powell, J., Craighill, A., Parfitt, J., Turner, R., 1996. A lifecycle assessment and economic valuation of recycling. Journal of Environmental Planning and Management 39 (1), 97–112.

Powell, J., Sherwood, N., Dempsey, M., Steele, A., 1999. Life Cycle Inventory Analysis of Alternative Waste Management Options for Bristol City Council. Summary Report. Environmental Management Research Group, University of Gloucestershire, UK.

Pro-Europe, 2009. Packaging Waste Legislation in Denmark. http://www.pro-e.org/Denmark.

Purcell, M., Magette, W.L., 2007. Prediction of residential BMW generation according to socio-economic and household characteristics for the Dublin region. In: Proceedings Sardinia of the Eleventh International Waste Management and Landfill Symposium Sardinia (on CD Rom).

Purcell, M., Magette, W.L., 2009. Prediction of household and commercial BMW generation according to socio-economic and other factors for the Dublin region. Waste Management 29 (4), 1237–1250.

Radetzki, M., 1999. Etervinning utan vinning. (Recycling without Gaining). ESO-Report Ds 1999:66. Regeringskansliet (Government Offices of Sweden), Stockholm, Sweden.

Rao, D., 1975. A dynamic model for optimal planning of regional solid waste management. PhD Thesis, Clarkson College of Technology, Potsdam, NY.

Reich, M., 2002. Economic assessment of waste management systems - case studies using the ORWARE model. In: Proceedings from Workshop on System Studies of Integrated Solid Waste Management. IVL Swedish Environmental Research Institute, Stockholm, Sweden.

Reich, M., 2005. Economic assessment of municipal waste management systems – case studies using a combination of life cycle assessment (LCA) and life cycle costing (LCC). Journal of Cleaner Production 13 (3), 253–263.

Rigamonti, L., Grosso, M., Giugliano, M., 2009a. Life cycle assessment for optimising the level of separated collection in integrated MSW management systems. Waste Management 29 (2), 934–944.

Rigamonti, L., Grosso, M., Sunseri, M.C., 2009b. Influence of assumptions about selection and recycling efficiencies on the LCA of integrated waste management systems. The International Journal of Life Cycle Assessment 14 (5), 411–419.

Rodríguez-Iglesias, J., Castrillón, L., Marañón, E., Fernández, Y., Vázquez, I., 2007. Life cycle assessment of municipal solid waste management possibilities in Asturias (Spain). In: Proceedings of the Eleventh International Waste Management and Landfill Symposium Sardinia (on the CD Rom).

Rousis, K., Moustakas, K., Malamis, S., Papadopoulos, A., Loizidou, M., 2008. Multicriteria analysis for the determination of the best WEEE management scenario in Cyprus. Waste Management 28 (10), 1941–1954.

Rutegård, G., 1999. Konsekvensanalys i livscykelperspektiv av att använda insamlade tidningar och tidskrifter till materialåtervinning alternativt energiutvinning. (Consequential Analysis of Using Collected Newspaper and Journals for Material Recycling or Energy Recovery in a Life Cycle Perspective). Pressretur AB, Sweden.

Ryberg, A., Ekvall, T., Person, L., 1998. Life Cycle Assessment of Packaging Systems for Beer and Soft Drinks – Aluminium Cans. Miljøproject no. 402. Danish EPA. http://www2.mst.dk/Udgiv/publications/1998/87-7909-023-0/pdf/87-7909-023-0.pdf.

SEA Wiki (Strategic Environmental Assessment Wiki), 2007. Waste Management Plan for Pikanmaa. http://sea.unu.edu/wiki/index.php/Waste_management_plan_for_Pirkanmaa_(in_German).

SEPA (Scottish Environment Protection Agency), 2007b. Waste Management Options for North and South Lanarkshire Councils. http://www.sepa.org.uk/waste/waste_publications/research_and_development.aspx.

SEPA (Scottish Environment Protection Agency), 2007a. Life Cycle Assessment of Municipal Waste Management Options in Scotland Waste Summit October 2007. http://www.sepa.org.uk/waste/waste_publications/research_and_development.aspx.

Saarikoski, H., 2000. Environmental impact assessment (EIA) as collaborative learning process. Environmental Impact Assessment Review 20 (6), 681–700.

Salhofer, S., Binner, E., Wassermann, G., 2005. Strategic environmental assessment in waste management planning, an Austrian case study. In: Proceedings of Sardinia 2005, Tenth International Waste Management and Landfill Symposium, CISA. Cagliari, Sardinia, Italy.

Salhofer, S., Wassermann, G., Binner, E., 2007. Strategic environmental assessment as an approach to assess waste management systems. Experiences from an Austrian case study. Environmental Modelling & Software 22 (5), 610–618.

Schmidt, S., Pahl-Wolst, C., 2007. Modeling biowaste flows for life-cycle assessment – calculation of the potential and collected weight of kitchen and garden waste. Journal of Industrial Ecology 11 (1), 181–199.

Schmidt, J., Holm, P., Merrild, A., Christensen, P., 2007. Life cycle assessment of the waste hierarchy – a Danish case study on waste paper. Waste Management 27 (11), 1519–1530.

Shmelev, S., Powell, J., 2006. Ecological–economic modelling for strategic regional waste. Ecological Economics 59 (1), 115–130.

Sivertun, A., Le Duc, M., 1998. A systems analysis of pollutants flow in an area and their environmental impact modelled by a Geographic Information System (GIS). In: Proceedings of the Systems Engineering Models for Waste Management - International Workshop. Waste Research Council (AFN), Göteborg, Sweden.

Skordilis, A., 2004. Modelling of integrated solid waste management systems in an island. Resources, Conservation and Recycling 41 (3), 243–254.

Snary, C., 2002. Health risk assessment for planned waste incinerators: getting the right science and the science right. Risk Analysis 22 (6), 1095–1105.

Sokka, L., Antikainen, R., Kauppi, P., 2004. Flows of nitrogen and phosphorus in municipal waste: a substance flow analysis in Finland. Progress in Industrial Ecology 1 (1/2/3), 165–186.

Sundberg, J., 1993. A system approach to municipal solid waste management: results from a case study of Goteborg - Part l. In: Proceedings of Int. Conf. on Integrated Energy and Environmental Management. Air & Waste Management Association, New Orleans, USA.

TU Vienna (Vienna University of Technology), 2009. STAN – Software for Substance Flow Analysis. http://www.iwa.tuwien.ac.at/iwa226/stan.html.

Tanskanen, J.-H., Melanen, M., 1999. Modelling separation strategies of municipal solid waste in Finland. Waste Management and Research 17 (2), 80–92.

Thérivel, R., Partidário, M., 1999. The Practice of Strategic Environmental Assessment. Earthscan Publication Ltd., London.

Thorneloe, S., Weitz, K., Jambeck, J., 2007. Application of the US decision support tool for materials and waste management. Waste Management 27 (8), 1006–1020.

Tucker, P., Murney, G., Lamont, J., 1998. Predicting recycling scheme performance: a process simulation approach. Journal of Environmental Management 53 (1), 31–48.

Tukker, A., 2000. Life cycle assessment as a tool in environmental impact assessment. Environmental Impact Assessment Review 20 (4), 435–456.

Tukker, A., Poliakov, E., Heijungs, R., Hawkins, T., Neuwahl, F., Rueda-Cantuche, J.M., Giljum, S., Moll, S., Oosterhaven, J., Bouwmeester, M., 2009. Towards a global multi-regional environmentally extended input–output database. Ecological Economics 68 (7), 1928–1937.

Tunesi, S., Rydin, Y., Oct 5–9, 2009. Comprehensive assessment of WM strategies in England: the North London waste authority case. In: Proceedings of the Twelfth International Waste Management and Landfill Symposium Sardinia, Italy (on CD Rom).

UNEP (United Nations Environment Programme), 2005. Solid Waste Management, vol. 1. UNEP.

USEPA (United States Environmental Protection Agency), 1977. WRAP: a Model for Solid Waste Management Planning User's Guide. EPA/530/SW-574. U.S. Environmental Protection Agency, Ohio, USA.

Ulli-Beer, S., Andersen, D., Richardson, G., 2007. Financing a competitive recycling initiative in Switzerland. Ecological Economics 62 (3–4), 727–739.

Vaccari, M., Collivignarelli, C., Vercesi, P., 2005. Risk analysis as a decisional tool for the location of landfills. In: Proceedings of the Tenth International Waste Management and Landfill Symposium Sardinia (on CD Rom).

van der Linden, A., Torfs, R., 2005. Evaluation of MSW treatment systems in Flanders to improve policy decisions. In: Proceedings of BOKU Waste Conference. Institute of Waste Management BOKU—University of Natural Resources and Applied Life Sciences, Vienna, Austria.

van der Voet, E., Heijungs, R., Mulder, P., Huele, R., Mulder, P., 1995a. Substance flows through the economy and environment of a region – Part I: system definition. Environmental Science and Pollution Research 2 (2), 90–96.

van der Voet, E., Heijungs, R., Mulder, P., Huele, R., Mulder, P., 1995b. Substance flows through the economy and environment of a region – Part II: modeling. Environmental Science and Pollution Research 2 (3), 137–144.

Vercalsteren, A., Spirinckx, C., Sarlée, W., 2007. 4 types of drinking cups used on events: life cycle assessment and eco-efficiency analysis. In: Proceedings of LCM 2007 Conference. Swiss Federal Institute of Technology Zurich, Zurich, Switzerland.

Verheem, R., 1999. SEA of the Dutch Ten-Year Programme on Waste Management 1992–2002. In: Thérivel, R., Partidário, M. (Eds.), The Practice of Strategic Environmental Assessment. Earthscan Publication Ltd., London, pp. 86–94.

Verro, R., Genah, D., Benfenati, E., 2003. Chemical analysis, distributed modelling and risk indices in a GIS based methodology for landfill risk assessment. In: Proceedings of the Ninth International Waste Management and Landfill Symposium Sardinia (on CD Rom).

Vigsø, D., 2004. Deposits on single use containers – a social cost–benefit analysis of the Danish deposit system for single use drink containers. Waste Management and Research 22 (6), 477–487.

Villeneuve, J., Michel, P., Fournet, D., Lafon, C., Ménard, Y., Wavrer, P., Guyonnet, D., 2009. Process-based analysis of waste management systems: a case study. Waste Management 29 (1), 2–11.

Villeneuve, J., Wavrer, P., Michel, P., Menard, Y., 2005. Comparative analysis of integrated waste management solutions: a case study. In: Proceedings of the Tenth International Waste Management and Landfill Symposium Sardinia (on CD Rom).

Viotti, P., Marella, G., Leccese, M., Verde, K., 2005. Analysis of the environmental performance of the integrated MSW management in district of Frosinone (Lazio) by means of an LCA-based software. In: Proceedings of the Tenth International Waste Management and Landfill Symposium Sardinia (on CD Rom).

Wäger, P., Gilgen, P., Widmer, H., 1998. Effects of Thermal and Material Recycling of Plastics Waste on Swiss Waste Management System. In: Proceedings of the Systems engineering models for waste management - International workshop. Waste Research Council (AFN), Göteborg, Sweden.

Wäger, P., Gilgen, P., Widmer, H., 2001. A dynamic model for the assessment of plastics waste disposal options in Swiss waste management system. In: Proceedings from Workshop on System Studies of Integrated Solid Waste Management. IVL Swedish Environmental Research Institute, Stockholm, Sweden.

Wang, F., Richardson, A., Roddick, F., 1996. SWIM - a computer model for solid waste integrated management. Computers, Environment and Urban Systems 20 (4–5), 233–246.

Wassermann, G., Odic, M., Chedlberger, E., 2003. The applicability of geographic information systems as decision support tools in waste management. In: Proceedings of the Ninth International Waste Management and Landfill Symposium Sardinia (on CD Rom).

Waste Exchange UK, 2000. Waste Exchange UK. http://www.wasteexchangeuk.com/.

Weitz, K., Barlaz, M., Ranji, R., Brill, D., Thorneloe, S., Ham, R., 1999. Life cycle management of municipal solid waste. International Journal of Life Cycle Assessment 4 (4), 195–201.

White, P., Franke, M., Hindle, P., 1995. Integrated Solid Waste Management: a Lifecycle Inventory. Blackie Academic & Professional, Glasgow.

Widheden, J., Ekvall, T., Nielsen, P.H., 1998a. Life Cycle Assessment of Packaging Systems for Beer and Soft Drinks – Disposal Glass Bottles. Miljøprojekt no. 401. Danish EPA. http://www2.mst.dk/Udgiv/publications/1998/87-7909-022-2/pdf/87-7909-022-2.pdf.

Widheden, J., Ekvall, T., Nielsen, P.H., 1998b. Life Cycle Assessment of Packaging Systems for Beer and Soft Drinks – Refillable Glass Bottles. Miljøprojekt no. 400. Danish EPA. http://www2.mst.dk/Udgiv/publications/1998/87-7909-021-4/pdf/87-7909-021-4.pdf.

Wilson, E.J., 2002. Life cycle inventory for municipal solid waste management – Part 2: MSW management scenarios and modeling. Waste Management and Research 20 (1), 23–36.

Wittmaier, M., Langer, S., Sawilla, B., 2009. Possibilities and limitations of life cycle assessment (LCA) in the development of waste utilization systems – applied examples for a region in Northern Germany. Waste Management 29 (5), 1732–1738.

Xará, S., Almeida, M., Silva, M., Costa, C., 3–7 October 2005. Porto 1990/2000: evaluation of environmental burdens from MSW management using life cycle assessment. In: Proceedings of the Tenth International Waste Management and Landfill Symposium Sardinia, Italy (on CD Rom).

Xu, Y., Huang, G.H., Qin, X.S., Huang, Y., 2009. SRFILP: a stochastic robust fuzzy interval linear programming model for municipal solid waste management under uncertainty. Journal of Environmental Informatics 14 (2), 72–82.

Zorzi, M., Dagnino, A., Delucchi, F., Dondero, F., Borasi, M., Cossa, G., Ariati, L., Trivero, P., Viarengo, A., 2005. Monitoring and risk assessment activities of exhausted rubbish dump characterized by a release of leachate in the superficial groundwater aquifer. In: Proceedings of the Tenth International Waste Management and Landfill Symposium Sardinia (on CD Rom).