Chapter 3
Solid Waste Management for Circular Economy: Challenges and Opportunities in Romania – The Case Study of Iasi County

Cristina Ghinea and Maria Gavrilescu

Abstract In this work we proposed to answer some questions related with solid waste management and circular economy. The research questions were: What is the connection between circular economy and solid waste sector? How can the circular economy be implemented and which are the necessary policies for waste recycling? Which are the environmental issues related with the waste management in Europe? What are the main problems and opportunities in solid waste management in Romania? Can it be achieved a medium- and long-term prognosis of solid waste generation? In this paper we also suggested strategic solutions for integrated waste management and policies for its improvement. We have discussed the zero waste to landfill target together with the public perception and participation in waste management sector. We have applied the life cycle assessment for environmental evaluation of the proposed waste management scenarios and the trend analysis for waste prognosis.

Keywords Iasi · Romania · Life cycle · Public perception · Zero waste

3.1 Introduction

Waste is a resource – everyone should be aware and acknowledge this, starting from those who manufacture products and continuing with the population who consumes these products. This should be the *leitmotif* of those who are responsible to recover,

C. Ghinea (✉)
Faculty of Food Engineering, Stefan cel Mare University of Suceava, Suceava, Romania
e-mail: cristina.ghinea@fia.usv.ro

M. Gavrilescu (✉)
Faculty of Chemical Engineering and Environmental Protection, Department of Environmental Engineering and Management, "Gheorghe Asachi" Technical University of Iasi, Iasi, Romania

Academy of Romanian Scientists, Bucharest, Romania
e-mail: mgav@tuiasi.ro

M.-L. Franco-García et al. (eds.), *Towards Zero Waste*, Greening of Industry Networks Studies 6, https://doi.org/10.1007/978-3-319-92931-6_3

reuse and recycle the "resources" during the manufacturing and consumption phases. In the last years, *sustainable materials management* was promoted as an approach for the exploitation of materials in a sustainable way in order to reduce environmental impacts and preserve natural capital. It is considered that *sustainable materials management* is a precursor of circular economy, which promotes recycling, reuse and remanufacturing (ISWA 2015).

The classical model of industrial development is based on a linear model, with inputs (raw materials, energy and other resources) and outputs (wastes of products and production which are usually treated by *end-of-pipe* techniques). After ending their period of utilisation, the products are discharged on landfills or incinerated as waste. Usually this model of industrial development ("take-make-dispose") is associated to resource depletion and high environmental impacts (ISWA 2015; WEF 2014).

It was estimated that around 65 billion tons of raw materials were processed by the industrial system at the end of the first decade of the twenty-first century (in 2010), and this quantity is expected to reach about 82 billion tons in 2020 (WEF 2014). The continuous growth of the raw materials price, especially from the natural reserve, the increasing pressures of the society and regulatory constraints are connected with both resources depletion and environmental impacts generated by waste discarded in the environment.

This is why in the last two decades, *circular economy* (CE) is gaining growing global consideration as new development model able to influence the existing production and consumption model. This influence is possible based on increasing resource throughput as a condition for continuous growth (Ghisellini et al. 2015; Zils 2014).

Studies on the application of circular economy principles propose a refined hierarchy of resource use and adoption of the waste value-based recovery concept and related collection practices (Gharfalkar et al. 2015; Ghinea et al. 2012; Singh and Ordonez 2016). Therefore, new actions should be addressed in concerted ways so as to add value to the "closing the loop" concept. Intensified recycling and reuse practices along product life cycles can bring benefits for both environment and economy, with intrinsic positive impacts to the society, as at large.

3.2 Waste Management in the Context of Circular Economy

In the first part of this section, the concept of circular economy is visited in connection to the waste sector; this was with the intention to outline the importance that wastes have in the sustainable strategy like circular economy.

The materials recovery and recycling concepts were also discussed in this section in order to highlight the importance of recovery and recycling of materials and to present the recycling situation in Europe.

3.2.1 Circular Economy and the Waste Sector

There are several reasons for business to start focusing towards industrial production that tends to decouple its development from natural resources exploitation. Numerous studies and research are demonstrating that this new model of industrial development is able to foster sustainable economic growth and create new jobs. This model is based on closed loops or circular setups associated with the concept of circular economy and is materialised by new practices such as (a) reengineering/remanufacturing and (b) exploiting the whole technical and economic value of materials all along the life cycle with favourable consequences on waste minimisation by reusing, refurbishing, maintaining, recycling and recovering operations (Zils 2014).

Circular economy (CE) is a relatively simple but a sustainable strategy, which strives to reduce the inputs of virgin raw materials as well as the generation of waste by closing the economic and environmental loops of resource flows (Haas et al. 2015; MacArthur Foundation 2012). The circular economy, considered as a regenerative and restorative system, determines the shift from the *cradle-to-grave* approach to new ones such as *cradle-to-cradle* and *cradle-to-gate*, which means "closing the loop" of the life cycle of a process, product or service by recycling and reuse (Zils 2014).

According to the Circular Economy Package which includes the European legislation on waste, there are challenging targets of waste minimisation, based on long-term approaches devoted to waste management and recycling.

The key horizons of these approaches include the following targets (COM 2011):

- 2030: recycling of 65% of municipal waste
- 2030: recycling 75% of packaging waste
- 2030: reducing land filling of municipal waste by 10%
- Landfill discouraging and interdiction of landfilling of waste collected separately
- Promotion and stimulation of industrial symbiosis

Circular economy allows for improving the added value of processes and products by avoiding waste. An estimation of the European Commissions (COM 2014) reveals that the improvement of resources efficiency could reduce the entering raw materials in industrial systems by 17%–24% until 2030, which would be equivalent to €630 billion savings per year at the level of European industry, or to an increase of GDP in EU.

Maximising recycling and minimising waste, reducing natural resources consumption and reusing resources and waste are the key actions connected to "zero waste" philosophy. This is based on management principles which compete to achieve the "age of zero waste". There are members states which already apply principles of "zero waste" philosophy. The EU action plan for the circular economy stimulates the preservation of "the value of products, materials and resources in the economy for as long as possible" and waste minimisation or elimination (COM

2015). This policy can be made feasible by going through several steps, starting with tracking waste data and continuing by defining zero waste, prioritising waste-reduction tasks, strengthening supplier partnerships, resolving regulatory challenges, achieving landfill-free waste management and sharing the best practices (changing rules, creating jobs for the environment, promoting producer responsibility, recovering resources, empowering consumers, producing by cleaner technologies, designing for the environment, shifting subsidies, etc.).

The goal of recycling is not purely achieved by high recycling rates, also needs the transformation of the whole production system and adaptation of consumption via technological and social innovation (Jávor 2015).

As an example on the CEP implementation at the European glass industry, representatives of this industry proposed to the European Commission (FEVE 2015) the following actions: (a) stimulation of bottle-to-bottle multiple recycling, (b) evaluation of calculation methods and impacts of recycling targets, (c) a better definition of reuse, (d) encouraging separate collection of glass, (e) the avoidance of double targets and (f) the clarification of multi-material and municipal waste definitions. According to FEVE (2015), the EU circular economy can be made real in seven steps from the glass packaging industry view:

- *Design*: glass is designed for the environment and is 100% recyclable.
- *Production*: has increased by 39.5% in the last 25 years, and the industry maintains 125,000 direct and indirect jobs across Europe.
- *Distribution*: more than 50% of glass bottles are delivered to customers within a 300 km distance.
- *Consumption and reuse*: 87% of Europeans prefer glass.
- *Collection*: over 70% of all glass bottles are collected for recycling annually.
- *Recycling*: glass is available for multiple recycling.
- *Raw materials*: 1 tonne of recycled glass saves 1.2 tons of virgin raw materials and avoids 60% of CO_2 emissions.

Glass is a material that can be recycled indefinitely, and it is also considered that reusing glass is another way to recycle. Another sector which has increased in Europe in the last years is represented by recycling of paper and cardboard waste. The paper recycling rate in 2012 was 71.7% according to CEPI (2012).

Some necessary policies required by ERPC (2011) on paper recycling:

- *Renewable energy policy*: paper recycling must be considered a priority over energy recovery; paper can be used for incineration (energy production) at the end of life when it cannot be recycled anymore.
- *Collection of paper*: development of effective separate collection systems is necessary.
- *Trade of paper for recycling*: there are some issues related to exports of unprocessed waste paper by organisations which are not part of the recycling sector. European countries should focus on increasing the collection of paper for recycling and to maintain the collected volumes at high levels.

- *Recyclability*: policy related with the product should ensure that paper can be recycled at the end of life.

The recycled paper could replace virgin materials to produce a particular product and to reduce emissions (Ghinea et al. 2014).

An important sector of the European economy is represented by plastic industry. Plastics are valuable materials with various applications in everyday life, and they have the potential to be recycled many times (Comanita et al. 2016; PlasticsEurope 2015a). About 50% of collected plastic goes to landfilling, while only 25% is recycled (COM 2015). Plastic innovation can contribute to the circular economy by improving the plastic recyclability, by better food preserving (COM 2015). PlasticsEurope (2015a) provides some recommendations for circular economy, e.g. the recognition of resource efficiency achievements attained in the production of plastics (e.g. only 0.3% material losses in production of polypropylene), and the eco-design requirements should be based on the entire life cycle. Additionally, the legislation governing the legal status of products derived from plastic waste must be effective and consistently applied in which health and safety of workers and consumers must be taken into consideration, among other important aspects. Recycling and energy recovery are necessary to be intensified and applied in a complementary manner in order to achieve the goal of *zero plastics* to landfill by 2020 (Comanita et al. 2015). In order to obtain a recycling society, efforts are being made within and beyond Europe (Ghinea et al. 2014).

3.2.2 Materials Recovery and Recycling

Material recovery is a massive challenge with the aim to minimise the amount of waste sent to landfills by recycling and remanufacturing (Ghinea et al. 2013). The materials which can be recovered from municipal solid waste mainly include paper (basis for new paper production), glass (basis for new glass production or direct reuse of bottles), plastic (basis for new plastic production), electronic scrap and metals (recovering of gold, molybdenum, copper, etc.) and energy (from residual waste: incineration with combined heat and power – CHP) (Ghinea et al. 2013; Hall 2010).

As part of the material recovery, recycling has evident environmental benefits at every stage in the life cycle of a product from the raw material extraction to its final disposal. Recycling reduces air and water pollution associated with making new products from raw materials (such as greenhouse gases emissions, which contribute to global warming) (Ghinea and Gavrilescu 2010b; US EPA 2007). For example, according to Maguin (2015), aluminium recycling saves up to 92% of CO_2 emissions, while steel recycling saves up to 58% of CO_2 emissions.

Recycling is a complex method for protecting the environment by recovering materials or components of used products, resulting in new products (Ghinea 2012). The purpose of recycling is to limit the use of new materials and decrease the amount of waste. Some benefits of recycling are resource conservation (reducing demand for new resources), reducing transport costs and energy production (energy saving by avoiding exploitation of raw materials) and saving resources that otherwise would be lost in storage sites (Ghinea 2012).

Recycling is preferred to incineration and disposal of non-renewable materials such as glass, metals and plastics because the total energy and global warming potential is generally low. For renewable materials (paper and cardboard) in most cases, the global warming potential is lower for recycling than for incineration. Recycling can be sustainable if it is efficient in terms of costs (Ghinea 2012).

European countries have made considerable efforts to convert waste into resources and to promote recycling as a sustainable waste management stage. In 2014 at European level, 7.7 million tonnes of plastic waste were recycled. Plastic demand in Europe in 2014 was 39.5% packaging, 20.1% building and construction, 8.6% automotive, 5.7% electrical and electronic, 3.4% agriculture and 22.7% others (PlasticsEurope 2015b). In 2014, 25.8 million tonnes of post-consumer plastics waste were generated from which 29.7% was recovered through recycling and 39.5% by energy recovery while 30.8% was sent to landfill. According to PlaticsEurope (2015b), the recycling percentage has increased from 2006 to 2014 with +64%. The landfill of plastic is still the first option in many European countries. For plastic waste the recycling option is preferred, and energy recovery is the alternative for plastics which cannot be more environmentally friendly recycled (PlasticsEurope 2015b).

About 58 million tons of paper waste were recycled in Europe in 2014, which is almost 71.7% of all paper consumed (ERPC 2015). According to ERPC (2015), Europe continues to be the world leader in paper recycling, followed by North America.

In Europe according to FERVER (2015), the glass production exceeds 30 million tons per year, and 70% of the material is recycled. The glass can be recycled without loss of material; sorting of waste glass plays an important role in recycling. Glass recycling reduces energy and CO_2 emissions in glass production and creates business and jobs. Two key factors in building a sustainable circular economy are efficient use of raw materials and recycling of packaging in a closed loop, the glass bottle to bottle recycling initiative (FEVE 2015).

However, Eurostat statistics on waste reveals that each European citizen generated 475 kg of waste in 2014. From this amount, only 44% is being recycled or composted, while the remaining 56% ended up landfilled (28%) or incinerated (27%). Zero Waste Europe's Executive Director, Joan Marc Simon said "A residual waste target of 100 kg per capita for 2030 is a good indicator of resource efficiency and resource use, as it works on the top levels of the waste hierarchy, effectively combining prevention, reuse and recycling policies" (ZWE 2016). In this context, the statistics show that there is a large variability across Europe regarding waste generation and waste treatment (ZWE 2016).

Moreover, waste generation in some member states like Romania, Poland or Latvia is under the EU average of 259 kg per inhabitant with less than 300 kg per inhabitant, while some others generate considerably more than the EU average, being over 600 kg per inhabitant (Cyprus and Germany, among others) and even over 750 kg per inhabitant (Denmark). Even further, Slovenia, Romania and Poland are among the recently joined members with the lowest rate of waste generation (under 200 kg per inhabitants). Although with the highest rate of waste generation in Europe, Denmark is the member state with the lowest rate of waste landfilling, together with Germany, Belgium, the Netherlands and Sweden. From Eurostat statistics, Slovenia is the best performing EU country having the lowest amount of waste landfilled (102 kg per inhabitant in 2014) (ZWE 2016).

Therefore, zero waste in Europe in the context of circular economy needs more concerns in terms of waste generation improvements as well as regarding increasing the extent of waste management by recycling.

3.3 Environmental Issues, Resource Conservation and Drivers in Waste Management in Europe

Nowadays, the human ecological footprint overshoots Earth's carrying capacity (Best et al. 2008; Gavrilescu 2011; Holmberg et al. 1999). Resource consumption and production of higher levels of greenhouse gases, toxics and nondegradable waste are higher than this planet has the capacity and the time to regenerate or assimilate. These are the most important issues that must be considered by the entire humanity in relation with sustainability. The resource productivity, dematerialisation and a change from efficiency thinking to effectiveness and sufficiency are required. This latter is in relationship to the fact that materials demand is expected to grow in the following decades (Rossy et al. 2010). In this context the *sustainable materials management* (SMM) concept represents one of the frameworks to sustain strategies for the future and sustainable development visions in the context of circular economy. Hence, the SMM definition as published by the OECD is as follows: *sustainable materials management* is an approach "to promote sustainable materials use, integrating actions targeted at reducing negative environmental impacts and preserving natural capital throughout the life-cycle of materials, taking into account economic efficiency and social equity" (OECD 2007). SMM supports a life cycle view of impacts associated with material use and strongly encourages the creation and execution of policies and practices relating to materials. Future policy directions for SMM are transition from eco-efficiency to eco-effectiveness and further to conservation, to eco-sufficiency (OECD 2011a; Rossy et al. 2010). It can be considered that SMM is a precursor of circular economy.

SMM acts to support sustainable development by a shift from waste management to materials management (OECD 2011a). Moreover, the OECD issued the policy principles of the SMM (OECD 2011a; Rossy et al. 2010; Wante 2010) at different levels, i.e. (i) to preserve natural capital; (ii) to design and manage materials, products and processes for safety and sustainability from a life cycle perspective – maximising positive and minimising negative impacts to the environment and human health/well-being through eco-design; (iii) to use the full diversity of policy instruments to stimulate and reinforce sustainable economic, environmental and social outcomes; and (iv) to engage all parts of society to take active, ethically based responsibility for achieving sustainable outcomes.

The above-mentioned SMM policy principles (SMMPP) have been applied in different countries (AG 2009; OECD 2011a; SEPA 2008; SME 2003) such as Sweden, Finland, Belgium, Czech Republic and the Netherlands. A brief description of those policies is described in the following paragraphs:

- Sweden and Finland, as representatives of some Scandinavian countries, have the *natural capital preservation* in the core of their SMMPP. Sweden established 16 environmental quality objectives so as "to promote human health, safeguard biodiversity and the natural environment, preserve the cultural environment and cultural heritage, maintain long-term ecosystem productivity and ensure wise management of natural resources", while Finland developed long-term goals on how to use natural resources sustainably and to improve eco-efficiency.
- In the case of Belgium, it has developed various strategies such as the transition network established by the Belgian Public Waste Authority in order to promote SMM. Also, Belgium is focused on identifying material cycles with high potential for reduced environmental impact and on collaboration of different actors in order to set up policy measures that work in different phases of the materials life cycle.
- In Czech Republic aside of a large variety of policies and policy instruments including regulations, economic incentives and disincentives, trade and innovation policies, information sharing and partnerships were developed to promote sustainable development. About information sharing the Czech Environmental Information Agency allows public access to different sources of information and statistics on many aspects of sustainability and the environment.
- The Netherlands has one of the best practices in Europe regarding recycling of paper/cardboard among other materials and has a leading position promoting circular economy, globally. In order to achieve SMM, as part of the national Future Waste Policy, the Netherlands has adopted a "Material Chain Approach" (Dutch Chain Approach) which represents a general movement towards SMM. During the implementation of the Dutch SMM approach, the government's role is rather as convener and facilitator (LAP 2 2008; OECD 2011a). The Dutch government ambitions are to minimise environmental pressure over the whole supply chain and to harmonise policy in different areas by means of a chain-oriented waste policy (LAP 2 2008; OECD 2011b; Veeken et al. 2011). The overall goal is to reduce the environmental impact of material chains throughout the life cycle in the most cost-effective manner (LAP 2 2008; OECD 2011b).

Even beyond the European borders, there are other countries framing their waste management under similar policies as the SMMPP: one of them is Australia which has drafted a National Action Plan for Education for Sustainability. The actual name of such plan is "Living Sustainably" that stimulates collaboration between representatives from academia, non-government organisations, youth and local government.

Improving waste management is known as an environmental challenge at international level. The implementation plan agreed at the World Summit on Sustainable Development (WSSD) (Johannesburg, September 2002) was built on the Agenda 21 and calls for further action to "prevent and minimise waste and maximise reuse, recycling and use of environmentally friendly alternative materials, with the participation of government authorities and all stakeholders, in order to minimise adverse effects on the environment and improve resource efficiency" (EC 2005).

In 2005, the European Commission adopted the *Thematic Strategy on the prevention and recycling of waste* which addresses waste prevention as one of the priority issues (EC 2005). This Strategy is one of the seven thematic strategies contained by the 6th Environment Action Plan, which "aims to help Europe become a recycling society that seeks to avoid waste and uses waste as resource" (EC 2016). It entails the use of economic instruments to implement the waste hierarchy so that key actions have to be set out to modernise the existing legal framework and to encourage waste prevention, reuse and recycling, with waste disposal only as a last option (EC 2011a; JRC 2011).

In the context of a continued growth of the world population, combined with stronger emerging economies, the *Thematic Strategy on the prevention and recycling of waste* has "to adapt the EU waste policy approach to this new reality" taking into account the significant increase in the total consumption (DEFRA 2011; EC 2011a; OECD 2010; von Braun 2008). Legislative improvements are the first step towards adapting the regulatory framework, in order to provide a legal structure that is flexible and promotes a recycling society, which avoids losses and uses resources that are found in waste (EC 2005).

Further developing approaches are necessary for determination of the suitable options from technical, economical, social and environmental points of view. Also, setting targets for waste recycling and recovery must be performed taking into account the differences between products and materials and possible alternatives.

The development of innovative policies for sustainability in the medium and long term needs the constant tuning between actions of private operators and the regulatory frame. As a consequence, the spectrum of existing and new waste treatment technologies and managerial strategies has also shifted from maintaining environmental quality at present to meet sustainability goals in the future.

The Waste Directive 2008/98/EC (EC Council Directive 2008) reflects engagement of the EU towards sustainable development, in particular to the SWM systems. Also, it brings new challenges, such as new definitions for waste, by-products and end-of-waste criteria, resulting in the need to (1) choose appropriate technologies that aim at improving the protection of human health and environment, (2) promote reuse and recycling, (3) enhance waste prevention programmes via biowaste separate collection and (4) implement extended producer responsibility (EPR) collectively (Chang et al. 2011, Pires et al. 2011). In addition, key challenges related to long-term waste management are climate change and energy use link SWM systems to the reduction of greenhouse gas (GHG) emissions and the enhancement of energy recovery.

As shown previously, one of the most relevant objectives is to reduce the amount of waste generated. However, these efforts are still very limited, especially in some south-eastern European countries, like Romania, with mixed results and relatively few efforts that have been made to regulate the management of various categories of waste. One of them are the organic materials that usually comprise over 50% of the total waste generation in the cities, construction and demolition waste (Bayer and Méry 2009; Björklund and Finnveden 2005; Papachristou et al. 2009).

3.4 Solid Waste Management in Romania and Iasi County Case Study

In the following sections, we present and discuss some challenging issues and opportunities concerning solid waste management in Romania, taking Iasi County as case study. Separate collection of waste fractions in solid waste is treated as the key factor which we consider as a condition to promote and implement management practices as reuse, recycling of waste in Romania. This approach is adopted since landfilling continues to be the main treatment/elimination method for solid waste – known as the most unfavourable alternative according to the waste hierarchy and totally opposite to what the circular economy promotes. Some policies on waste management in Romania are also presented, along with information on quantities of waste generated in Iasi city and waste amounts forecasting on short, medium and long terms. A trend analysis of solid waste prognosis is also illustrated together with data on mixed collection and waste landfilling. In Sect. 3.5 of the following chapter, we propose some waste management scenarios as sustainable integrated alternatives for solid waste management in Iasi. These were evaluated from an environmental impacts perspective, by applying life cycle assessment. After this evaluation, we established the most suitable scenario from an environmental point of view. This scenario includes unit operation that includes the following steps: *separate collection by waste fraction*, *recycling of materials*, *composting organic waste* and *incineration of the residual waste*. We also make a comparison with the Dutch waste management approach. We found that the Dutch waste management system can be used as a model for waste management in Romania at this moment, even if the Dutch waste management system needs to improve certain aspects. In Sect. 3.6 we present some information about circular economy, policy, proposals for improvement and some aspects regarding material recycling in Romania. We also discuss the possibility to implement of zero waste to landfill in Romania and the public perception and participation in separate collection of waste.

3.4.1 Romanian National Strategy and Policy on Solid Waste Management: Critical Issues and Targets

Romania is a European country situated in the south-eastern side of Central Europe, north of the Balkan Peninsula. The whole inferior course of the River Danube is located on its territory. Romania is a Carpathian country, bordering the Black Sea.

In terms of territorial administration and division, Romania includes 41 counties grouped in 7 regions, while the eighth region is represented by Bucharest and the county of Ilfov (Davidescu and Strat 2014; Ghinea 2012). In 2008, Romania had a population of about 21.5 million inhabitants, while just 20 million of inhabitants were reported according to the INS census in 2011, and various demographical analyses show that a further decrease in population number is expected (Eurostat 2015). Iasi County belongs to the Region 1 North East which also includes the following counties: Botosani, Suceava, Neamt, Bacau and Vaslui.

Before 1990 the waste management in Romania was hardly considered, and the first statistics were only introduced in 1993 (Schiopu et al. 2007). In 1998 the most predominant method of waste disposal was landfilling (99%), and around 250 non-compliant landfills were operational at that time in the country (Oroian et al. 2009; Schiopu et al. 2007). The first National Waste Management Strategy (NWMS) has been elaborated in 2004 for the period 2003–2013, 3 years before Romania's accession to the European Union. NWMS was established for setting waste management objectives aiming at creating the framework for developing and implementing an integrated waste management system (NWMS 2004). The National Waste Management Plan (NWMP) was developed for the implementation of NWMS, while the European acquis on waste has been transposed into Romanian legislation. Also, regional plans for waste management in 2005–2006, county plans waste management during 2007–2009, "master plans" and feasibility studies were developed for assisting and ensuring the implementation of integrated waste management systems (IWMS). This latter was based on the *Sectoral Operational Programme Environment* (2007–2013) provisions and funds. NWMP priorities were established to increase the competitiveness of the productive sector and its attractiveness to foreign investors; improve and develop the transport infrastructure, energy and environmental protection; develop human resources, increase the employment rate and combat any social exclusion; diversify the rural economy and expand agricultural productivity; and to promote balanced participation of all regions in the economic development of the country. National policy on waste management must guarantee European policy objectives in terms of waste prevention and aim to reduce resource consumption and practical application of the new approaches on waste hierarchy. The principle of preventive action is the essential one in Emergency Ordinance 195/2005 (GEO 2005) on environmental protection further amended and supplemented, while the provisions of Directive 2008/98/EC are transposed into the national legislation by Law 211/2011 regarding waste regime.

Romania implemented the *acquis communautaire* at the moment of its joining the European Union (EU) on 1 January 2007, with a few exceptions, among which we mention here those related to waste management (EC 1994, MECC 2016):

- Directive 94/62/EC on packaging and packaging waste, for which was requested and obtained a transitional period until 2013
- Directive 99/31/EC on the landfill of waste, for which was requested and obtained a transitional period until 2017
- Council Directive 2000/76/EC on waste incineration, for which was requested and obtained a transitional period until 2008
- Council Directive 2002/96/EC on waste electrical and electronic equipment (WEEE), for which was requested and obtained a transitional period until 2008
- Regulation no. 259/93 (EEC 1993) on the import, export and transit of waste by the end of 2015

The second National Waste Management Strategy for 2014–2020 was approved in 2013 by Government Decision no. 870 of 06.11/2013 (GD 2013). The need to review the first National Waste Management Strategy derived mainly from the following reasons (NWMS 2013):

- New concepts were established at the level of the European waste management approach (mainly according to the need to address waste as a resource and the extended producer responsibility principle).
- Adoption of Directive 2008/98/EC of the European Parliament and of the Council from the 19 November 2008 on waste and repealing certain directives (new precise drawings Waste Framework), its transposition into national law and the need to integrate the principles and provisions of these documents in national programming. The implementation of Directive 2008/98/EC requires our country to adopt ambitious goals in waste management such as recycling 50% of household waste and 70% of construction and demolition waste by 2020. Also, EU legislation requires the fulfilment of the objectives addressing recycling/packaging materials (glass, metals, plastics), as well as valorisation of biodegradable waste instead of its landfilling.
- Incorporating provisions and legislative requirements arisen during 2004–2012.
- Implementation of integrated waste management development projects in various stages of execution, implementing the proposed new technologies and new waste treatment in Romania.
- Institutional and organisational changes during 2004–2012.

The new NWMS aims also to create a national planning framework needed to develop and implement integrated sustainable waste management. Eight strategic objectives have been formulated to achieve the goals of NWMS (2013), namely, improvement of the environment and protecting human health, supporting research and development in waste management, encouraging green investments, increasing resource efficiency, sustainable waste management, correlation of waste management policies with climate change, development of responsible behaviour on the prevention of waste generation and management and the strengthening of institutional capacity.

In the National Strategy for Sustainable Development of Romania (2013–2020–2030), the development of integrated waste management systems is included as objective (NSDSR 2008) with the following targets:

- The annual quantity of biodegradable waste landfilled should have been decreased to 2.4 million tonnes by 2013, representing 50% of the total amount generated in 1995.
- Practices for materials recovery from packaging waste for recycling or incineration with energy recovery of 60% for paper/cardboard, 22.5% for plastics, 60% for glass, 50% for metals and 15% for wood before 2013.
- Reducing the number of historically contaminated sites in minimum 30 counties before 2015.
- Establishing 30 integrated waste management systems at regional/county level and closure of 1500 small landfills located in rural areas and the 150 oldest waste dumps in urban areas, before 2015.

In 2010, 38% of municipal waste were landfilled, 22% incinerated, 25% recycled and 15% composted in the EU (Eurostat 2010). In Romania, although significant efforts and investments have been made to align the national regulations to the EU waste *acquis*, some old waste management practices remain prevalent: waste disposing and landfilling (NWMS 2013). Although Romania is an EU member state, and the European policy in the area of solid waste management should be implemented as soon as possible, these changes are still difficult to be made.

3.4.2 Strengths and Weaknesses of Solid Waste Management in Romania

Today, in Romania the MSW management is carried out under the European regulation in the field, 100% legally implemented, and based on some documents derived from this (Petrescu et al. 2010). Waste management in Romania is characterised by the continued growth of waste quantities; inadequate waste collection (mixed collection and not selective) and economic benefits of waste are insufficiently developed (Petrescu et al. 2010).

According to NWMS (2013), the strengths of solid waste management are:

- *Legislative*: the existence of a frame harmonised with the European one
- *Planning*: existence of planning documents on all three levels (national, regional and county)
- *Human resources*: experience in development and implementation projects and in running awareness programmes
- *Financial*: 1.167 million euro for development of integrated waste management systems and rehabilitation of historically contaminated sites

Some additional strengths can be highlighted (Luca and Ioan 2014): existence of programmes to collect plastic waste from nature, existence of collection points by purchasing from inhabitants the beverage bottles in the major cities, waste paper is an easily recycled waste, possibility of involvement of local authorities in public waste management, etc.

Some weaknesses in waste management were presented in NWMS (2013) and grouped as:

- *Legislative*: frequent amending and updating legislation.
- *Planning*: insufficient integration with other plans and programmes including other institutions which develop strategies.
- *Data management*: inadequate practice in collecting, integrating and evaluating available data.
- *Implementation*: (a) failure of parties involved in taking ownership of responsibilities, (b) service coverage and low degree of expansion of separate waste collection and (c) *infrastructure* – not enough developed, including infrastructure support (road, water supply, sewerage, gas, etc.).
- *Economic*: stream recycling is still not stabilised due to insufficient implementation of separate collection, low expansion of separate waste collection systems.

Some weaknesses of waste management can be mentioned (Luca and Ioan 2014): paper is recycled to a very small extent, lack of incentive policies for selective collection of plastic waste, metal wastes which are not collected separately are difficult to recycle, selective collection of waste is not done sufficiently, etc.

3.4.3 Data About Iasi, Romania

Iasi County, situated in north-eastern Romania, had 826.552 inhabitants in 2008, with a density of 151 inhabitants per km^2. In the same year, the urban population in Iasi City was 391.654 inhabitants according to INS (2011). In the urban area, the number of inhabitants decreased during 2010–2011 (382,000 inhabitants in 2011) and is increasing from 2012 to 398.000 inhabitants (INS 2015). The relief is characterised by a high unit (with an average altitude of 300–350 metres) and a low plain (100–150 m) (Doba et al. 2008). In the west and south, the average annual temperature of air is between 8 °C and 9 °C, while in the north and north-east, it is between 9 °C and 10 °C.

In 2014 the population from Iasi County was involved in the following main activities: agriculture, forestry and fishing, industry (extractive, manufacturing, production and supply of electricity, gas, steam and air conditioning, water supply, sewerage, waste management and remediation activities, etc.), wholesale and retail trade, repair of motor vehicles and motorcycles (INS 2016). In this county there are concerns about the wrong development of organic farming by using bio-fertiliser and organic fertilisers. Animal husbandry is also an important sector with a rich tradition in this area (Doba et al. 2008; Iasi County Council 2009; INS 2011; RWMP-NE 2006).

3.4.4 *Quantities of Municipal Waste Generated in Iasi and Prognosis on Medium and Long Terms*

Municipal solid waste includes the waste generated and collected (mixed or selective), as well as uncollected waste. The amounts of waste generated in Iasi during 2009–2013 are illustrated in Fig. 3.1. These amounts decreased in 2011, increasing again after this year and reaching approximately 250,000 t/year of waste generated in 2013 (EPAIS 2014a, b). This growth in the volume of generated municipal waste is the consequence of an increased consumption of the population and a higher segment of population assisted by public health services in a centralised system (Doba et al. 2008). The household wastes represent an important component of municipal solid waste (MSW). For example, 67.73% from the total amount of MSW generated in 2012 (almost 233,000 tons) is represented by the household and assimilable waste, followed by demolition and construction waste (30.44%) and waste from municipal services (1.83%) (EPAIS 2014a). The household waste composition illustrated in Fig. 3.2 was estimated using data from the annual statistical survey questionnaires completed by sanitation operators and recyclable waste collectors (EPAIS 2014a, b) and not determined by direct measurements.

Similar to the situation at national level, the biodegradable waste represents an important component of municipal waste in Iasi County (EPAIS 2014b). From Fig. 3.2 it can be observed that biodegradable waste has the highest percentage in the total waste amount. This waste category includes biodegradable gardens and parks waste; food and kitchen waste from households, restaurants, caterers or retail stores; and comparable waste from food processing plants. According to EPAIS (2014a), the biodegradable municipal solid waste percentage dropped from 64% in 1998 to approximately 48% in 2012. Analysing the amount of waste generated in the Iasi County during 2009–2013, it can be perceived that the quantities of waste generated had a slight fluctuation and overall showed a decline. We have considered

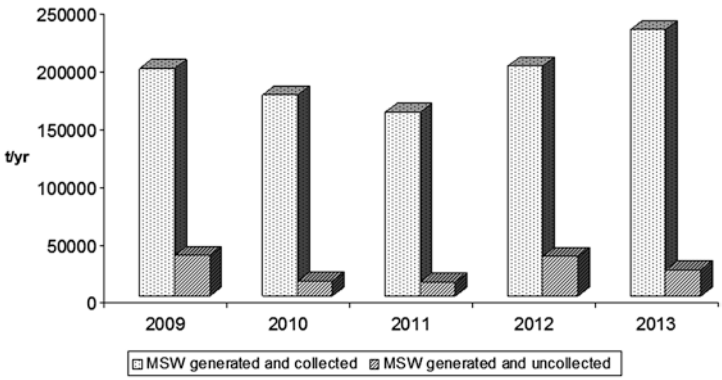


Fig. 3.1 Municipal solid waste (MSW) quantities generated in Iasi (2009–2013). (Data from Iasi County Council 2009, processed by authors)

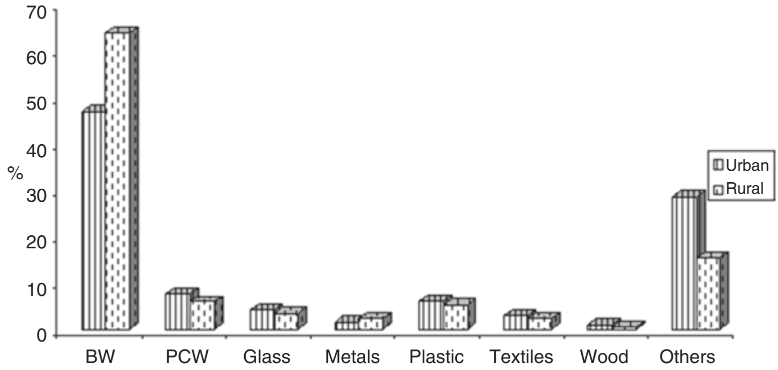


Fig. 3.2 Waste composition in urban and rural areas of Iasi county (*BW* biodegradable waste, *PCW* paper and cardboard waste). (Data from Iasi County Council 2009, processed by authors)

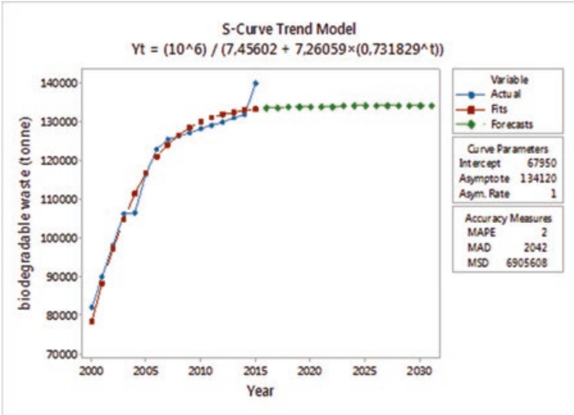
that this trend is mainly due to the economic crisis and decline and less due to preventive measures.

Prognosis of municipal solid waste generation has an important role in planning and implementing of waste management systems (Ghinea and Gavrilescu 2010a). Ghinea (2012) used Waste Prognostic Tool to forecast the amount of waste that will be generated in Iasi city in 2018 based on the quantities of waste generated in 2008 and on socio-economic conditions. Ghinea et al. (2016a) applied regression analysis and time series analysis included in Minitab software to forecast municipal solid waste generation and composition for the same city from Romania. According to EPAIS (2014a), the main factors that influence waste prognosis are changes in population in the county, changes in the county's economy, changes in the demand and nature of consumer goods and changes in production technologies.

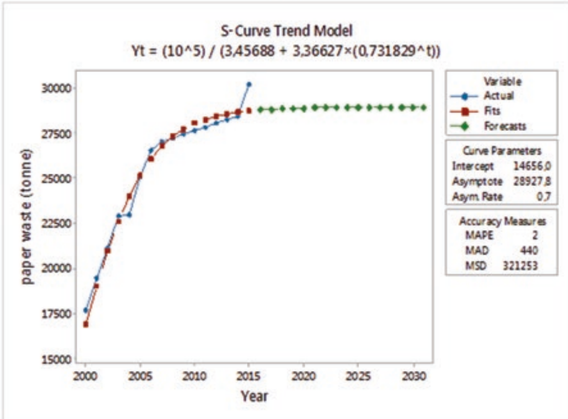
The trend analysis can be also used for solid waste prognosis. In order to achieve waste prediction, we have used Minitab 17 software which includes this analysis. In this paper we will present only some of the obtained results. We have chosen to illustrate the results obtained for biodegradable and paper waste since the fraction with the highest percentage of the total quantity of waste generated is represented by biodegradable waste, while paper wastes are the most separately collected fraction. Figure 3.3a, b illustrates the S-curve trend model applied for biodegradable waste, and paper waste prognosis for Iasi, which included three variables: actual (•), fits (■) and forecast (◆) versus time. The forecasting values were sets until 2030.

The graphs provide the values for mean absolute percentage error (MAPE), mean absolute deviation (MAD) and mean squared deviation (MSD). It is considered that lower values for MAPE, MAD and MSD indicate a better fitting model. In our case we have lower values for MAPE for both waste fractions. The MAD value is lower for paper waste than those for biodegradable waste, while for MSD are registered higher values. It can be concluded that for the paper waste fraction was obtained a better fitting model. The form of graphs is similar for both fractions. The prediction equations are also presented in the graphs. We will use the data obtained

Fig. 3.3 S-curve trend model for: (**a**) biodegradable waste, (**b**) paper waste (authors' Figures)



a)



b)

from the prognosis analysis to propose waste treatment methods which can be included then in different waste management systems and evaluated with various methodologies in order to establish the most suitable MSW system for implementation.

3.4.5 Waste Collection, Transportation and Separation at Source

The municipal solid waste is collected by a public company of local interest, SC Salubris S.A. Iasi. The separate collection of waste is performed with small steps, in pilot projects, usually for materials with high market values. In general, the inhabitants use to bring the solid waste to the collection points distributed over the town at

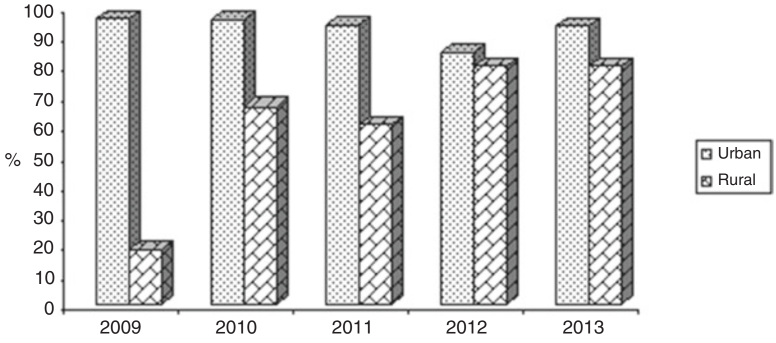


Fig. 3.4 Evolution of coverage degree with sanitation services. (Adapted from EPAIS 2014a)

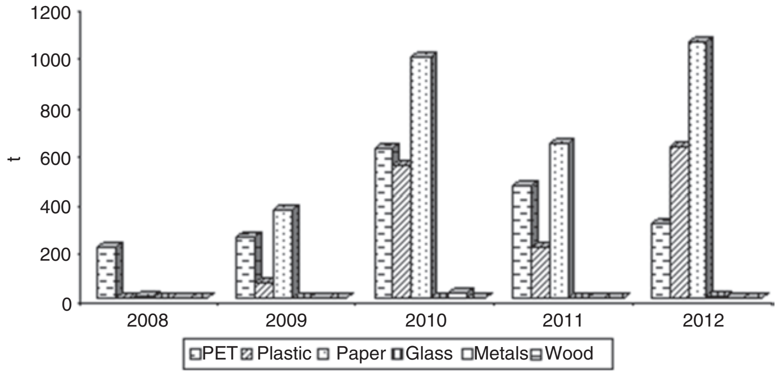


Fig. 3.5 Quantities of waste from households collected selectively in 2008–2012. (Adapted from EPAIS 2014b)

special locations, close to their housing, and place the waste in containers provided by the waste collection company. For separate collection, there are special containers for waste fractions in some collection points located in various parts of the town (Doba et al. 2008; Ghinea 2012). The coverage degree with sanitation services for both urban and rural areas is presented in Fig. 3.4, which shows that rural areas are also covered. The amounts of households waste collected selectively in 2008–2012 are presented in Fig. 3.5 (EPAIS 2014a).

Unfortunately, this practice to collect the mixture of waste without separation at the source is common at national level. Three stages for implementation of selective collection were proposed (BALKWASTE 2010): pilot projects and public awareness (2004–2006), selective expansion of collection at national level (2007–2017) and implementation of selective collection in more difficult areas (2017–2022). Selective waste collection is still in its infancy, while more informative campaigns for citizens to separately collect a larger amount of waste are necessary. The informative campaigns are taken from the example of other EU countries, which purpose is to help to protect the environment and human health.

If until 2009 the collection of waste was performed mostly in urban areas, after 2009, waste collection was expanded also in rural area (Fig. 3.4). It can be observed that collection of waste generated was significantly improved, and this aspect is important because efforts were and are made to collect all amounts of waste generated, so no longer remain wastes dumped in different areas. From Fig. 3.5 it can be observed that was recorded a small increase in the amounts of different waste fraction collected selectively. Paper and plastics are the most selectively collected waste fractions. Considering the data from these figures, we can say that improvements of waste management system should be proposed, focusing mainly on selective collection, recovery and recycling.

3.4.6 Waste Treatment and Landfilling

In 2008 the municipal solid waste management (MSWM) system in Iasi included only waste landfilling at the Tomesti landfill. This was a significant source of soil and groundwater pollution because the leachate collection network was totally improper. The old Tomesti landfill was closed in 2009, when a new compliant landfill was built and put into operation in accordance with the legislation, situated at almost 8 km from the city of Iasi, in Tutora centre for integrated waste management. Tutora landfill surface area is 50 ha, with a storage capacity of 8,613,000 m^3 and with four cells that should serve the entire Iasi County. It includes a leachate collection system, a landfill gas collection system and a rainwater collection system. The leachate treatment plant uses the reverse osmosis (RO) technology with a processing capacity of 84 m^3 leachate/day. The RO plant is complying with the requirements of EU directives (EC Council Directive 1999; EC Council Directive 2008). The centre for integrated waste management Tutora includes, in addition to the landfill, a sorting station with a capacity of 29,000 tons/year and a composting station. This latter was put under construction in 2009. In March 2012 the composting process was supposed to start, based on a turned windrows method, with a pyramidal shape. Since October 2012 windrows with green waste and household waste (25–30%) were supposed to be carried out, but because of various reasons, the composting station did not work in 2012 and 2013 (EPAIS 2014a, b).

3.5 Waste Life Cycle and Strategic Solutions for Integrated Waste Management Systems

In this section we presented eight municipal solid waste management scenarios developed by us, which were evaluated from environmental point of view in order to establish the most suitable scenario for implementation. The evaluation was performed using life cycle assessment (LCA) method. A hierarchy of environmental impacts resulted considering different LCA methodologies are also presented. In this section, a comparison with waste management system from Twente region of the Netherlands is performed to emphasise that systems like the one in the Netherlands could serve as models.

3.5.1 Development of Municipal Solid Waste Management Scenarios for Evaluation and Implementation in Iasi County

Considering specific and relevant methods for treatment of municipal solid waste, we planned and proposed different alternatives for MSW management system for Iasi, Romania (Ghinea 2012; Ghinea et al. 2012). Eight scenarios were developed in order to evaluate them from an environmental point of view (Ghinea 2012). The scenarios labelled from **2 to 8** represent integrated alternatives of waste management unit operations including various methods for treatment of waste. Nevertheless, all scenarios included temporary storage of waste in containers, their collection and transport. The differences between these scenarios consist in the treatment or elimination method chosen (Fig. 3.6) (Ghinea 2012):

- **The first scenario** (**S1**) represents the *system that was in operation until 2009*. Municipal solid waste was landfilled in Tomesti, a non-compliant landfill without systems for collection and treatment of landfill gas and leachate (Doba et al. 2008).
- **The second scenario** (**S2**) *includes mixed waste collection*, *landfilling with collection of biogas and treatment of leachate* on the new landfill that was established in 2009. Facilities compiled with the landfill directive provisions (EC Council Directive 1999).
- **The third scenario 3** (**S3**) includes composting as a method of treating biodegradable waste. The resulted compost can be used in agriculture to replace the synthetic fertilisers. Also, Scenario 3 includes landfilling of municipal solid waste with leachate treatment and biogas collection and valorisation.
- **The fourth scenario** (**S4**) includes both composting and landfilling as solid waste treatment methods but also sorting of recyclable materials.
- **The fifth scenario** (**S5**) includes sorting, composting, landfilling and incineration as a method of treating residual waste in order to generate electricity, with the metal recovery from the treatment of slag and landfilling of ash obtained.
- In the **sixth scenario** (**S6**), there are two ways of dealing with biodegradable waste such as composting (aerobic process) and anaerobic digestion from which compost and biogas result. Biogas can be used as a source of energy.
- **The seventh** (**S7**) and **eighth** (**S8**) **scenarios** include composting of biodegradable waste and waste incineration. The main difference between them is that S7 includes sorting of recyclable materials.

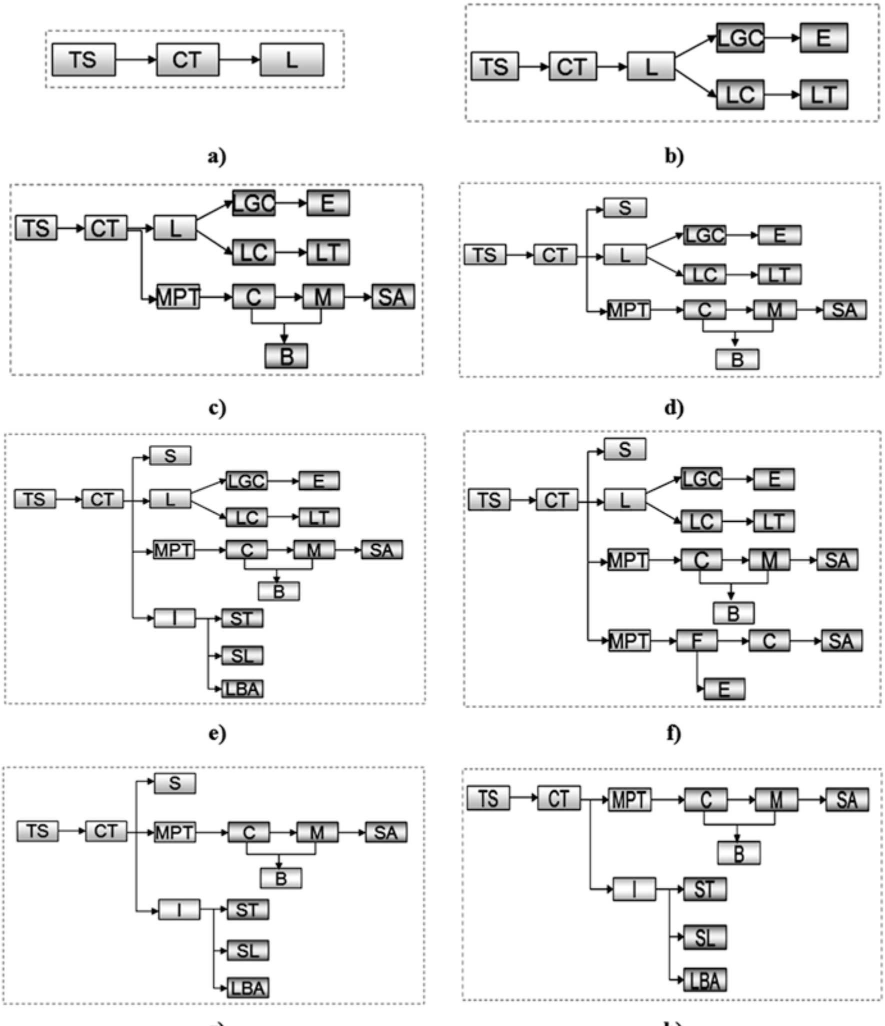


Fig. 3.6 Scenarios proposed for the analysis of MSW management in Iasi, Romania: (**a**) S1, (**b**) S2, (**c**) S3, (**d**) S4, (**e**) S5, (**f**) S6, (**g**) S7, (**h**) S8; *TS* temporary storage, *CT* collection and transport, *L* landfilling, *LGC* landfill gas collection, *LC* leachate collection, *E* engine, *LT* leachate treatment, *MT* mechanical treatment, *C* composting, *M* maturing, *SA* soil application, *B* bio-filter, *S* sorting, *I* incineration, *ST* slag treatment, *SL* slag landfilling, *LBA* landfilling bottom ash, *F* fermentation

The collection of waste is separate for biodegradable waste and mixed for the other waste fractions (in the case of scenarios 3 and 8). For scenarios 4–7 it was assumed that the waste fractions are collected separately.

All scenarios were evaluated from an environmental point of view by applying life cycle assessment (LCA) methodology, according to its four steps: goal and scope analysis, inventory analysis, impact assessment and interpretation. The scope

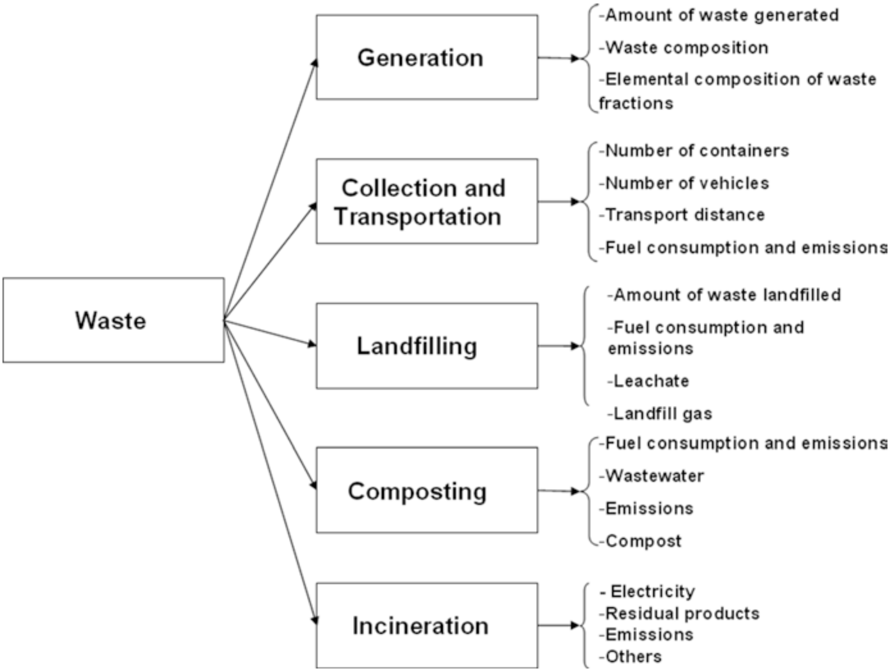


Fig. 3.7 Waste characteristics considered for evaluation

of the study was to determine the environmental impacts of all scenarios proposed and to establish the most suitable scenario for implementation considering the environmental aspects. In the inventory analysis phase, all the inputs and outputs were established for each step included in the scenarios. The characteristics considered for the evaluation are illustrated in Fig. 3.7.

The impact assessment stage was performed using GaBi software, one of the most popular software tools for LCA. After entering all inputs and outputs for each process and connecting the processes, GaBi software allowed us the calculation of the material and energy balances in order to assess the environmental impacts. The evaluation was performed using some of the LCA methodologies included in GaBi software: CML 2001, CML 1996, EDIP1997, EDIP2003, EI95, EI99, etc. CML 2001 is an environmental themes method developed by the Centre of Environmental Science of Leiden University and succeeds the CML 1996 methodology. CML 2001 methodology includes a set of impact categories defined for the problem-oriented approach (Frischknecht et al. 2007; JRC European Commission 2010). Environmental design of industrial products (EDIP 1997) is a Danish LCA methodology, a documented midpoint approach covering most of the emission-related impacts, resource use and working environmental impacts (Wenzel et al. 1997). EDIP 2003 is an update of the EDIP 1997 methodology and a theme-oriented method. The main difference between EDIP 1997 and EDIP2003 lies in the selection of the category indicator (Hauschild and Potting 2005). In the Eco-Indicator 95 (EI 95) methodol-

Table 3.1 The hierarchy of environmental impacts resulting from application of the methodology CML 2001

Impact category	Environmental impacts of scenarios negative impacts → positive impacts
Global warming potential (GWP)	S1 > S2 > S3 > S8 > S5 > S6 > S4 > **S7**
Eutrophication potential (EP)	S1 > S5 > S6 > S7 > S4 > S3 > S2 > S8
Photochemical ozone creation potential (POCP)	S1 > S3 > S2 > S5 > S6 > S4 > S8 > **S7**
Acidification potential (AP)	S1 > S5 > S6 > S3 > S4 > S2 > S8 > **S7**
Human toxicity potential (HTP)	S2 > S1 > S3 > S6 > S4 > S5 > S8 > **S7**

Table 3.2 The hierarchy of environmental impacts resulting from application of CML96, EDIP1997, EDIP2003, EI95, EI99 and HA methodologies

LCA methodology	Environmental impacts of scenarios positive impacts → negative impacts
CML96	**S7** > S6 > S8 > S5 > S4 > S3 > S2/> S1
EDIP1997	S8 > **S7** > S2 > S4 > S6 > S5 > S3/> S1
EDIP2003	S8 > **S7** > S4 > S6 > S5 > S2 > S3/> S1
EI95	S6 > S4 > S3>/ S1 > S5 > S7 > S8 > S2
EI99, HA	**S7** > S4 > S6 > S3 > S5 > S8 > S2/> S1

ogy, "the environmental effects (greenhouse effect, ozone layer depletion, acidification, eutrophication, smog and toxic substances) that damage ecosystems or human health on European scale" are taken into account (Goedkoop et al. 1996). Eco-indicator 99 (EI99) methodology was developed under the authority of the Dutch Ministry of Housing, Spatial Planning and the Environment by a number of Dutch and Swiss LCA experts and is a successor of Eco-Indicator 95. Eco-Indicator 99 is a damage-oriented method, which considers three damage categories: human health, ecosystem quality and resources (Goedkoop and Spriensma 2001).

The hierarchy of scenarios evaluated in terms of environmental impacts with the CML 2001 method is illustrated in Table 3.1. The results indicate that S1 has negative impacts when considering global warming potential (GWP), eutrophication potential (EP), photochemical ozone creation potential (POCP) and acidification potential (AP). In the S7 case, it showed positive impacts for GWP, POCP, AP and human toxicity potential (HTP), with the exception of EP for which S7 has negative impacts.

The environmental impacts of the scenarios evaluated with CML96, EDIP1997, EDIP2003, EI95, EI99 and HA methodologies are presented in Table 3.2. The results show that S1 has negative impacts according to all methodologies, while S7 has positive impacts on the environment (CML96, EI99, HA). S8 has positive impacts according to the results obtained for EDIP1997 and EDIP 2003, while EI99 indicates that scenario S6 has the greatest positive impact on the environment.

Scenario 7 can be considered the most favourable scenario from the environmental point of view, which includes **separate collection by waste fractions, recycling of materials, composting of organic waste and incineration of the residual waste**.

Increasing the separate collection of solid waste will lead to an increase in the amount of waste for recycling that ultimately leads to benefits for the environment and economical retribution. The amount of mixed waste will decrease with the increase of separately collection intensity of municipal solid waste.

3.5.2 Looking at a Comparison with the Waste Management of Twence Company in the Twente Region of the Netherlands

In contrast to Romania, the transition from the traditional waste management towards a circular economy in the Netherlands is underway (OECD 2015). According to OECD (2015), municipal waste generation in OECD countries was 520 kg/inhabitant in 2013. In 2013 there were collected 55 kg/inhabitant of paper for recycling and 75 kg/inhabitant of compostable waste (CBS 2015).

The Dutch waste management is based on Lansink's Ladder incorporated in 1994 in the Dutch legislation, entailing prevention of waste as much as possible, recovering of the valuable raw materials from any waste created, generation of energy by incinerating the residual waste and landfilling the rest of remaining waste (EVD 2008). The main actions of the Dutch policy to discourage landfilling and to improve safety were *landfill decree*, which corresponds to the description of higher technical requirements as much as standards and financial covering of post-closure costs, *landfill ban* that indicates no dumping rules for 32 types of wastes and *landfill tax and reorganisation of the landfill sector* demand that only high standards landfills were financially viable to continue their operation (de Jong 2011; SenterNovem 2006; SenterNovem 2009). To encourage the prevention, reuse and recycling, companies are required to separate waste as much as possible (as condition for their permit). On the other hand, municipalities received task levels for household separation and signed voluntary agreements with the industry on reducing packaging. More importantly, the municipalities introduced the producers' responsibility principle of all those wastes generated of their products (SenterNovem 2009). The policy of the Netherlands played an important role in the development of the professional waste market. Recycling options are cheaper than landfilling, various type of waste can be useful resources, wood can be reused or combusted, metals can be sold to the metal industry, etc. (SenterNovem 2009).

Just 2% of the all Dutch waste was landfilled in 2008, and the number of landfill sites has been reduced from 90 in 1991 to 22 in 2008 (EVD 2008; DWMA 2010a). The landfill tax was introduced in 1995 to divert MSW from landfill. In 2002 the landfill tax in the Netherlands was 79 euro/ton of waste, while in 2010 it was 107.49 euro per ton solid waste (DWMA 2010a; EEA 2013a). From January 2012 the landfill tax has been eliminated (EEA 2013a). Landfilling decreased from 2.1% in 2007 to only 0.3% in 2010 (EEA 2013a). In Enschede where the Twence Company operates, landfilling of household waste was 0% in 2008 (CBS 2011).

Material recycling in the Netherlands has been increasing in the last decades, so that in 2009 all recycling targets were easily met (DWMA 2010a, b). The recycling rates for packaging waste were 80% for plastic, 95% paper and cardboard, 88% metal, 92% glass and 38% wood (DWMA 2010b). Almost 88% of waste generated in the Netherlands in 2010 was recycled (van Eijk 2012).

In the Netherlands more than 95% of construction and demolition waste is recycled (DWMA 2010a). Waste is considered a new raw material, and recycling is a key element in the sustainable use of raw materials. This way of operating reduces the amount of natural resources used due to any increasing of quantity of waste recycled (DWMA 2010c). However, it is not considered *economically feasible to recycle everything*. According to the CBS (2011), a fraction of 20% from the total municipal waste generated in Enschede, Netherlands, was recycled in 2008.

Composting of vegetable, garden and fruit waste in the Netherlands is done for many years, so that almost 600,000 tons of compost are produced yearly by processing of 1.3 million tons of organic waste (biowaste and garden waste) (DWMA 2010d). The Twence Company from the Twente Region (which has a similar number of inhabitants as Iasi County) is able to treat 30,000 tons of green waste each year through composting process (Twence 2009). The CO_2 saving potential for traditional composting is 50 kg of CO_2 eq. (van Haeff 2007).

Another method for the treatment of organic waste used in the Netherlands, as t large, is the anaerobic digestion, as a “combination of energy generation and composting” (DWMA 2010d). The process generates energy in the form of biogas and the residue can be converted into compost. Compost resulted from anaerobic digestion has a better quality than that produced by the conventional process. The combination of energy saving and CO_2 reduction also responds to the sustainability criteria (DWMA 2010a).

Anaerobic digestion of waste began in the Netherlands in 1997 in Orgaworld Plant with a capacity of 35 ktons of waste (DWMA 2010a). An anaerobic digester with the following components, reactor, gas buffer and gas engines, was under construction at the Twence Company in 2011 with a capacity of 50,000 t/y of waste (de Jong 2011). In 2014 a total of 35,000 tonnes of organic waste was processed (Twence 2014).

In the Netherlands, 34% of the municipal solid waste was incinerated to obtain energy in 2008 (EVD 2008). The Dutch emissions from waste incineration are already below EU limit values (DWMA 2010b). In 2011 the optimal use of resources at the Twence Company results in incineration of 520,000 t of waste yearly, as well as 200,000 t of demolition wood producing of 407,000 MWhe electricity (sufficient to supply approximately 123,000 households) and 421,000 MWhe heat. All these mean a reduction of 269,000 ton/year CO_2 (de Jong 2011; EVD 2008). In 2014 a total of 733,000 tons of steam was supplied to AkzoNobel, which produces salt by evaporating brine with the aid of steam (Twence 2014). Heat coming from Twence is used by 7000 households from Enschede; for that 169,000 MWh thermal energy was supplied in 2014 (Twence 2014). The waste management in the Netherlands is practically unique in the world with a good waste processing market including recycling of impressive amounts of waste and incineration of the most of the remaining quantity of waste (EVD 2008). Therefore, the Dutch model can be used in the evaluation of the Romanian waste management system in order to shift from conventional waste technologies to a sustainable waste management system.

3.6 Opportunities for Solid Waste Management in Romania in the Context of Circular Economy

In this section we discussed about some policy potential for improvement of waste management alternatives, zero waste to landfill aspects and possibilities to implement this concept in Romania. Some examples of waste recycling campaigns performed in Romania were also given by us in this section in order to underline that efforts are being made with the purpose to involve population in the selective collection process.

3.6.1 Policy: Potential for Improvement

As discussed above, circular economy is promoting an increase in resource productivity and proposes to change the model "take-make-dispose" to "take-make-recreate" model, focusing on recycling, reuse and remanufacturing (Florin et al. 2015). When applied, these activities will reduce the footprints of materials consumed and natural resources needed to manufacture new products (Florin et al. 2015). So far there are a number of policies and measures at European, national, regional and local levels, and also a series of efforts are made by different stakeholders and interested parties for transition to a circular economy (EC 2014a).

In July 2014 *Circular Economy Package* was published. The policy discussions related with this package includes (EC 2011, 2012, 2014a; EEA 2013b):

- Revised legislative proposals on waste
- Implementation of the *Roadmap to a Resource Efficient Europe* (7th Environmental Action Programme)
- Advancing the green *economy within and beyond the EU*
- Production of renewable biological resources and their conversion into vital products and bioenergy (*Bioeconomy Strategy*)
- Implementation of the *Europe 2020 Strategy*

These policies can serve as a good base, but they are insufficient for progress of circular economy in the EU, which requires an integrated approach (EC 2014a). Better implementation and enforcement of existing regulation (waste framework directive, packaging waste directive, landfill directive, etc.) can facilitate the transition of circular economy and also would reduce the differences in performance.

Revisions of current regulations and new regulation (new targets, restrictions or bans, etc.) are necessary for better support of circular economy (EC 2014a).

EU waste policy aims: "to ensure that by 2020 waste is managed as a resource, to achieve an absolute decline of waste generated per capita, to ensure high quality recycling, to limit energy recovery to non-recyclable materials, virtually eliminate landfilling and eradicate illegal shipments of waste" (EC 2011; EEA 2013b).

However, there are considerable differences between member states in terms of performance (EC 2014b). For example, in the Netherlands, the targets for material recovery address an increase in total waste recovery rate from 77% to more than 83% between in 2000 and 2012, which was achieved in 2005, and increasing the total waste recovery rate from 83% to 85% between 2006 and 2015 also already accomplished by 2010 (OECD 2015). Based on the fact that the recovery rates are so high, the intention is to focus in the next years on increasing the quality of recycled materials.

In comparison with the EU average, the waste sector in Romania is very far behind. In 2011 the recycling rate in Romania was 7% of the total collected waste (Cioca et al. 2015). The National Recycling Materials Commission in 2007 approved 185 recovering companies for waste of paper and cardboard, 266 recovering companies for plastics waste and 55 recovering companies for glass (BALKWASTE 2010). If collected and sorted materials will eventually be used in specific branches of industry, the recovery and recycling will be successful, and the Romanian government is aware of this (NWMP 2004).

3.6.2 Zero Waste to Landfill

Zero waste is considered an alternative solution for waste management problems. This concept can stimulate sustainable production and consumption, recovery and recycling and restricts incineration and landfilling (Zaman 2015). In the negotiations on the circular economy is mentioned that "a way to close the loop is to ban landfilling" (ZWE 2015). It was demonstrated that the European countries (Denmark, Germany, the Netherlands, Norway, Sweden, Austria and Switzerland), which applied this measure, predominantly increased the waste incineration rate, technology that also generates waste (fly and bottom ashes) (ZWE 2015). According to ZWE (2015), the concept of "zero waste to landfill" or landfill ban contributes to a perfect linear economy and considered that "high tax on landfill and waste to energy incineration combined with a lower tax on the landfilling of stabilised waste is more effective in diverting waste towards prevention, preparation for re-use and recycling than a landfill ban".

Under this conceptual framework, the question is *if it would be possible to implement a zero waste to landfill system in Romania*.

As prior mentioned, landfilling is the common method for municipal solid waste disposal in Romania, since in urban areas there is at least one waste landfill (BALKWASTE 2010; Ghinea 2012). More than 95% of the collected wastes were disposed in landfills in 2009, while all rural dumpsites were closed in the same year. On the other hand, a number of 29 compliant landfills were built in 2010 (ENVIROPLAN S.A. 2012). According to EC (2013), there were 80 non-compliant landfills officially operating in 2013, which must be closed before July 2017. The European Commission gave the following recommendations to Romania (EC 2013): introduction of a landfill tax and increasing this tax in order to divert waste from landfills; expanding and improving the cost-effectiveness, monitoring and transparency of existent schemes; implementation of a biowaste strategy in order to divert biodegradable waste from landfills; compliance with legal requirements; development of separate collection infrastructure and schemes; comprehensive awareness raising campaigns on separate collection and proper waste management; and improvement of allocation of available EU funding in order to support waste prevention, reutilisation and recycling.

Romania began with very small steps to apply a landfill tax from the 1st of January 2016: the landfill tax in Romania is 80 RON (€ 18) per ton, and it will increase to 120 RON/ton (€ 27) in 2018 (Econet Romania 2016). The main obstacles in introducing zero waste in Romania are (Tartiu and Petrache 2009) unwarrantable infrastructure for the waste management, low involvement of citizens and economic agents in sustainable waste management, the complexity of zero waste system implementation and lack of experience.

We believe that the involvement of authorities, stakeholders and the population as at large by being one of the key actors in the solid waste management system will lead to changes in the Romanian system. The action should start from the population, which must separate their waste at home in waste fractions. Another measure which can be taken is alternating the municipal collection of organic waste in 1 week and that of other wastes in the next week. Also, the collection of paper waste can be performed by different associations.

Local authorities and sanitation companies should facilitate solid waste collection on waste fractions to recycling companies which can deal with different type of waste and support recycling of materials. The authorities at country level should deal with legal requirements, taxes and funds to support the waste management system. It may take a long time but with the involvement of all these actors may ultimately help in reaching the *zero waste* purpose. The population should become aware about the environmental impact of waste generated and that solid waste can be used as resources.

3.6.3 Public Perception, Awareness and Participation

In recent years various Romanian companies have developed waste recycling campaigns to involve the population in the process of selective collection and to inform them about the importance of selective waste collection. Some examples are given below.

In 2014 Carrefour Romania and Green Group (the largest investor in the green industry in Romania, bringing together five companies specialised in management, recycling and recovery of waste) launched in Buzau, Romania, the pilot project of smart waste collection SIGUREC 1 for collecting plastic bottles, aluminium cans, glass bottles, bottles PE, PP, Tetra Pak, packaging foils, paper, cardboard and waste electrical and electronic equipment. They also tested the solution for collecting PET bottles and aluminium cans in Carrefour Baneasa (Bucharest) and Carrefour Braila using special machines placed inside shopping centres. SIGUREC stations collected over 1000 tons wastes from 1 August to 31 December 2014, which were sent directly to recycling factories in Romania. The quantities of waste taken through the SIGUREC in the last 5 months of 2014 were 772,063 units of PET packaging, cans and glass, 310,121 kg of waste electric and electronic equipment and 259,063 kg of paper/cardboard (Carrefour 2015).

The main advantage of the project consists in that the general public has realised that waste is carrying value, since people received value vouchers that can be used for shopping in Carrefour: 0.05 RON/PET, 0.03 RON/dose aluminium, 0.01 RON/glass bottle and a variable amount per kg for WEEE, depending on the device type taught (e.g. refrigerator 0.8 RON/kg, iron 0.6 RON/kg, laptop 1.5 RON/kg) (Carrefour 2015). In October 2015 the same project was also inaugurated in Iasi.

Another project "Green for recycling!" for information and awareness on the separate collection of packaging waste was launched by Eco-Rom packaging, in partnership with the Intercommunity Development for Sanitation A.D.I.S Iasi during July 25 to August 15, 2015. Under the slogan "Iasi collects separately packaging waste!", people from Iasi were asked to separately collect packaging waste. People who have separately collected packaging waste properly were awarded with frisbee, bracelets, sunglasses and many other prizes. Also, campaigns include radio spots and competitions, in which people from Iasi learned useful information about the separate collection and recycling of packaging waste (Eco-Rom packaging 2016).

"ComPETition for a better future" was also a campaign that the Lidl company carried out all over the country during June–October 2015. Population had to bring PET packaging during the campaign at recycling points located in Lidl shops parking and received awards consisting of in a LIDL shopping voucher and others (Lidl 2015).

On 10th of March 2016 in Iasi, the first centre of municipal waste collection was opened. The inauguration of the centre was accompanied by an extensive information and awareness campaign in the months thereafter. By the 31st of March, citizens who brought recyclable waste to the centre won prizes and were entered in a raffle with ten attractive prizes (Ecotic 2016).

Even if these campaigns are publicised and the population participates to win those awards, there is still much to do to increase awareness. For example, after applying a questionnaire among people in Suceava city in the NE region of the country (100 people surveyed: 57% females and 43% males represented by young people up to 30 years), only 84% of females interviewed consider that there is a problem with waste disposal, while only 69% of males agree on this. Sixty-five percent of females responded that recycling is very important, while 69% of male respondents believe this (Ghinea et al. 2016b). The respondents suggested that installation of recycling bins for different types of waste in every residential area increases the recycling habit of people. Also, the awareness level and education plays a very important role in solid waste recycling participation as reported by Ghinea et al. in 2016b.

3.7 Conclusions

The idea of the circular economy in Europe is achieving further consideration and recognition. The key actions which can support the circular economy are the prevention and decrease of waste generation rate and the intensification in the reuse and recycling of products, but also zero waste. However, there are considerable differences between member states in terms of performance.

Although there are challenging targets in the view of waste minimisation, based on long-term approaches addressing waste management and recycling, Romania is far behind in terms of implementation of the circular economy principles. As demonstrated by the waste management analysis in Iasi, landfilling continues to be the prevalent management practice, although relevant improvements were made after Romania's admission as an EU member state. The most favourable waste management scenario out of eight LCA assessments (environmental point of view) is one which includes separate collection of waste fractions, recycling of materials, composting of organic waste and incineration of the residual waste.

Increasing the separate collection of solid waste will lead to an increase in the amount of waste for recycling that ultimately leads to benefits for the environment. The amount of mixed waste will decrease with the increase of separate collection intensity of municipal solid waste. If collected and sorted, materials will eventually be used in specific branches of industry, the recovery and recycling will be successful and Romania is aware of this. The involvement of authorities, stakeholders and last but not least of the population is a key factor to lead to changes in the Romanian solid waste management system. The practices leading towards zero waste to landfill can be integrated to the existing waste management strategies with the aim to generate additional economic value to Romanian users and operators of SWM system.

Acknowledgement This work was elaborated with the support of EURODOC "Doctoral Scholarships for Research Performance at European Level" project ID_59410, financed by the European Social Found and Romanian Government, GaBi4: Software and database for Life Cycle Engineering, PE INTERNATIONAL GmbH and with the support of two Grants of the Romanian National Authority for Scientific Research, CNCS-UEFISCDI: project PN-III-P4-ID-PCE-2016-0683, contract 65/2017, and project PN-III-P2-2.1-BG-2016-0130, contract 64BG/30.09.2016.

References

AG (2009) Living sustainably: the Australian Government's National Action Plan for Education for Sustainability. Australian Government. Department of the Environment, Water, Heritage and the Arts

BALKWASTE (2010) Action 3: evaluation of waste infrastructure in Region 1 North-East, Romania. Establishment of Waste Network for sustainable solid waste management planning and promotion of integrated decision tools in the Balkan Region (BALKWASTE), Bacau. http://www.balkwaste.eu/?page_id=21. Accessed 14 Nov 2011

Bayer S, Méry J (2009) Sustainability gaps in municipal solid waste management: a case study for landfills. Environ Dev Sustain 11:43–69. https://doi.org/10.1007/s10668-007-9097-0

Best A, Blobel D, Cavalieri S, Giljum S, Hammer M, Lutter S, Simmons C, Lewis R (2008) Potential of the ecological footprint for monitoring environmental impacts from natural resource use. Report to the European Commission, DG Environment. Final Report, May 2008, EC Commission, Brussels

Björklund A, Finnveden G (2005) Recycling revisited-life cycle comparisons of global warming impact and total energy use of waste management strategies. Resour Conserv Recycl 44:309–317. https://doi.org/10.1016/j.resconrec.2004.12.002

Carrefour (2015) Carrefour Romania and Green Group announces results of selective waste collection system SIGUREC, (in Romanian). https://www.carrefour.ro/despre-noi/stiri-presa/noutati/carrefour-romania-si-green-group-anunta-rezultatele-sistemului-de-colectare-selectiva-a-deseurilor-sigurec/. Accessed 10 Mar 2016

CBS (2011) Statistics Netherlands. Centraal Bureau voor de Statistiek. http://www.cbs.nl/en-GB/menu/cijfers/default.htm. Accessed 12 Apr 2011

CBS (2015) Trends in the Netherlands 2015. Statistics Netherlands

CEPI (2012) Paper Recycling, Monitoring Report, 2012. Confederation of European Paper Industries

Chang N-B, Pires A, Martinho G (2011) Empowering systems analysis for solid waste management: challenges, trends, and perspectives. Crit Rev Environ Sci Technol 41:1449–1530

Cioca LL, Ivascu L, Rada EC, Torretta V, Ionescu G (2015) Sustainable development and technological impact on CO2 reducing conditions in Romania. Sustainability 7:1637–1650. https://doi.org/10.3390/su7021637

COM (2011) Roadmap to a resource efficient Europe. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, Brussels. http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011DC0571&from=EN. Accessed 14 Mar 2016

COM (2014) Toward a circular economy: a zero waste Programme for Europe. Communication from the Commission to the European Parliament the Council, the European Economic and Social Committee and the Committee of the Regions. http://eur-lex.europa.eu/resource.html?uri=cellar:aa88c66d-4553-11e4-a0cb-01aa75ed71a1.0022.03/DOC_1&format=PDF. Accessed 14 Mar 2016

COM (2015) Closing the loop – an EU action plan for the Circular Economy. Communication from the Commission to the European Parliament. The Council, The European Economic and Social Committee and the Committee of the Regions, European Commission. Brussels

Comanita ED, Ghinea C, Rosca M, Simion IM, Petraru M, Gavrilescu M (2015) Environmental Impacts of Polyvinyl Chloride (PVC) Production Process. E-Health and Bioengineering Conference (EHB), 2015, 19–21 November 2015, pp 1–4. https://doi.org/10.1109/EHB.2015.7391486

Comanita ED, Hlihor MR, Ghinea C, Gavrilescu M (2016) Occurrence of plastic waste in the environment: ecological and health risks. Environ Eng Manag J 15:675–685

Davidescu A, Strat VA (2014) An empirical analysis of regional poles from the perspective of Romanian sustainable development. Proced Econ Finan 10:114–124. https://doi.org/10.1016/S2212-5671(14)00284-6 de Jong W (2011) Twence from waste to energy. Visit Romanian PhD student from Twente University presentation. Twence Company, Hengelo

DEFRA (2011) Applying the waste hierarchy: evidence summary. Environment Agency – Department for Environment Food and rural Affairs, London

Doba A, Nistorescu M, Pastravanu L, Petruc I, Simionescu I (2008) Strategic plan for integrated waste management in Iasi County, (in Romanian). http://www.scribd.com/doc/13769639/Planul-Judetean-de-Gestionare-al-Deseurilor. Accessed 10 Jan 2010

DWMA (2010a) MEP's about European Agenda. Avalforum. no. 1. Dutch Waste Management Association (DWMA)

DWMA (2010b) Waste companies and producers cooperate on sustainable design. Avalforum. no. 4. Dutch Waste Management Association (DWMA)

DWMA (2010c) Sustainable use of materials on the EU Agenda. Avalforum. no. 3. Dutch Waste Management Association (DWMA)

DWMA (2010d) High time for a European Biowaste Directive. Avalforum. no. 2. Dutch Waste Management Association (DWMA)

EC (1994) European Parliament and Council Directive 94/62/EC of 20 December 1994 on packaging and packaging waste. Off J Eur Commun 365:10–23

EC (2000) Directive 2000/76/EC of the European parliament and of the council of 4 December 2000 on the incineration of waste. Off J Eur Commun L, 332/91

EC (2005) EU waste policy. The story behind the strategy. European Commission. http://ec.europa.eu/environment/waste/strategy.htm. Accessed 17 May 2012

EC (2011a) Report from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on the Thematic Strategy on the prevention and recycling waste, COM (2011), 13 final, Brussels

EC (2011b) Roadmap to a resource efficient Europe. European Commission, Brussels

EC (2012) Innovating for a bioeconomy for Europe sustainable growth. European Commission, Brussels

EC (2013) Support to member states in improving waste management based on assessment of member states' performance. European Commission, Brussels

EC (2014a) Scoping study to identify potential circular economy actions, priority sectors, material flows and value chains. European Commission, Luxembourg

EC (2014b) Towards a circular economy: a zero waste programme for Europe. European Commission, Brussels

EC (2016) Review of the Thematic Strategy on the prevention and recycling of waste. http://ec.europe.eu/environment/waste/strategy.htm. Accessed 14 Mar 2016

EC Council Directive (1999) Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste. Off J Eur Commun L, 182/1, 16.7.1999, Brussels

EC Council Directive (2002) Directive 2002/96/EC of the European Parliament and of the Council of 27 January 2003 on waste electrical and electronic equipment (WEEE). Off J Eur Commun L, 037, 13/02/2003 P. 0024 – 0039

EC Council Directive (2008), Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives. The Official Journal of the European Communities L, 312/3, 22.11.2008, Brussels

Econet Romania (2016) Landfill tax in Romania. http://www.econet-romania.com/en/single-news/731/starting-with-2016-the-landfill-tax-in-romania-will-raise-to-80-lei-18-per-ton.html. Accessed 10 Mar 2016

Eco-Rom packaging (2016) Green for recycling in Iasi! (in Romanian). http://ecoromambalaje.ro/verde-la-reciclare-in-iasi/. Accessed 10 Mar 2016

Ecotic (2016) Premiere for Romania: in Iasi was opened the first center Municipal Waste Collection, (in Romanian). http://www.ecotic.ro/stiri/premiera-pentru-romania-la-iasi-s-a-deschis-primul-centru-municipal-de-colectare-a-deseurilor/. Accessed 10 Mar 2016

EEA (2013a) Municipal waste management in the Netherlands. European Environment Agency (EEA)

EEA (2013b) Towards a green economy in Europe, EU environmental policy targets and objectives 2010–2050. European Environmental Agency
EEC (1993) Council Regulation (EEC) No. 259/93 on the supervision and control of shipments of waste within, into and out of the European Community. Off J Eur Commun L, 30, 6 February 1993, pp. 1–28
ENVIROPLAN S.A. (2012) Romania – Identification of future waste management projects (2014–2020)-Task 1 Baseline report
EPAIS (2014a) Environmental Status Report for 2014 in Iasi County. Environmental Protection Agency Iasi (EPAIasi), (in Romanian). http://apmis.anpm.ro/ro/rapoarte-anuale1. Accessed 10 Oct 2015
EPAIS (2014b) Local action plan for the environment Iasi County 2014–2018. Environmental Protection Agency Iasi (EPAIasi), (in Romanian). http://www.anpm.ro/documents/839616/2172756/PLAM+2014-2018-+judetul+Iasi.pdf/0c22eb6a-819e-4fe8-9b38-7e38a32bf86a. Accessed 10 Oct 2015
ERPC (2011) European declaration on paper recycling 2011–2015. European Recovered Paper Council. http://www.paperforrecycling.eu/uploads/Modules/Publications/DeclarationonPaperRecycling_WebVersion.pdf. Accessed 31 Mar 2016
ERPC (2015). Paper recycling monitoring report. European Recovered Paper Council. http://www.paperrecovery.org/uploads/Modules/Publications/Final_MonitoringReport2014.pdf. Accessed 31 Mar 2016
Eurostat (2010) Waste statistics. http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Waste_statistic. Accessed 10 Oct 2015
Eurostat (2015) Population and population change statistics. Eurostat Statistics Explained. http://ec.europa.eu/eurostat/statistics-explained/index.php/Population_and_population_change_statistics. Accessed 31 Mar 2016
EVD (2008) Made in Holland. Waste a valuable resource. Agency for International Business and Cooperation. http://www.hollandtrade.com/publications/made-in-holland/mih.asp?bron=waste. Accessed 12 Apr 2011
FERVER (2015) Glass recycling: years of improvement. European Federation of Glass Recyclers. http://www.glassmanevents.com/europe/content-images/misc/FERVER.pdf. Accessed 31 Mar 2016
FEVE (2015) European container glass industry welcomes long awaited circular economy package. http://www.feve.org/images/stories/2015/feve-paper-circ-econ-pack-question-2.pdf. Accessed 31 Mar 2016
Florin N, Madden B, Sharpe S, Benn S, Agarwal R, Perey R, Giurco D (2015) Shifting business models for a circular economy: metals management for multi-product-use cycles, UTS, Sydney. http://wealthfromwaste.net/wp-content/uploads/2015/11/P3-FINAL-SHIFTING-BUSINESS-MODELS-FOR-CE-ONLINE.pdf. Accessed 31 Mar 2016
Frischknecht R, Jungbluth N, Althaus H-J, Bauer C, Doka G, Dones R, Hischier R, Hellweg S, Humbert S, Köllner T, Loerincik Y, Margni M, Nemecek T (2007) Implementation of life cycle impact assessment methods. Ecoinvent report no. 3, v2.0. Swiss Centre for Life Cycle Inventories, Dübendorf
Gavrilescu M (2011) Sustainable industrial production. Ecozone Press, Iasi
GD (2013) Government Decision no. 870/2013 approving the National Strategy for Waste Management 2014–2020. Official Gazette of Romania no. 750 of December 4, 2013
GEO (2005) Government Emergency Ordinance 195/2005 on environmental protection. The Government of Romania, Bucharest
Gharfalkar M, Court R, Campbell C, Ali Z, Hillier G (2015) Analysis of waste hierarchy in the European WASTE DIRECTIVE 2008/98/EC. Waste Manag 39:305–313. https://doi.org/10.1016/j.wasman.2015.02.007
Ghinea C (2012) Waste management models and their application to sustainable management of recyclable waste. PhD Thesis, Gheorghe Asachi Technical University of Iasi, Romania

Ghinea C, Gavrilescu M (2010a) Decision support models for solid waste management – an overview. Environ Eng Manag J 9:869–880

Ghinea C, Gavrilescu M (2010b) Models for sustainable waste management. Bulletin of the Polytechnic Institute of Iasi, Chemistry and Chemical Engineering Section, LVI (LX) (2):21–36

Ghinea C, Petraru M, Bressers HTA, Gavrilescu M (2012) Environmental evaluation of waste management scenarios – significance of the boundaries. J Environ Eng Landsc Manag 20:76–85. https://doi.org/10.3846/16486897.2011.644665

Ghinea C, Simion IM, Gavrilescu M (2013) Solid waste recycling for remanufacturing and bioremediation. Bulletin of the Polytechnic Institute of Iasi, Chemistry and Chemical Engineering Section, LIX(2), 35–48

Ghinea C, Petraru M, Simion IM, Sobariu D, Bressers HTA, Gavrilescu M (2014) Life cycle assessment of waste management and recycled systems. Environ Eng Manag J 13:2073–2085

Ghinea C, Dragoi EN, Comanita E-D, Gavrilescu M, Campean T, Curteanu S, Gavrilescu M (2016a) Forecasting municipal solid waste generation using prognostic tools and regression analysis. J Environ Manag 182:80–93. https://doi.org/10.1016/j.jenvman.2016.07.026

Ghinea C, Comanita DE, Gavrilescu M (2016b) Population perception on reduce, reuse and recycling of household solid waste. In: 11th international conference on "Environmental legislation, Safety Engineering and Disaster Management" ELSEDIMA, 26–28 May 2016, Cluj-Napoca, Romania

Ghisellini P, Cialani C, Ulgiati S (2015) A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. J Clean Prod 114:11–32. https://doi.org/10.1016/j.jclepro.2015.09.007

Goedkoop M, Spriensma R (2001) The Eco-indicator 99 a damage oriented method for life cycle impact assessment. Methodology Report. Pre Consultants b.v., Amersfoort

Goedkoop M, Demmers M, Collignon M (1996) Eco-indicator 95. Manual for designers, The Netherlands

Haas W, Krausmann F, Wiedenhofer D, Heinz M (2015) How circular is the global economy? an assessment of material flows, waste production, and recycling in the European Union and the World in 2005. J Ind Ecol 15:765–777. https://doi.org/10.1111/jiec.12244

Hall D (2010) Waste Management in Europe: framework, trends and issues. PSIRU, business school. University of Greenwich, Park Row

Hauschild M, Potting J (2005) Spatial differentiation in life cycle impact assessment – the EDIP2003 methodology. Environmental news no. 80

Holmberg J, Lundqvist U, Robert K-H, Wackernagel M (1999) The ecological footprint from a system perspective of sustainability. Int J Sustain Dev World Ecol 6:17–33. https://doi.org/10.1080/13504509.1999.9728469

Iasi County Council (2009) Long-term investment plan for the period 2008–2038 on integrated waste management. http://www.icc.ro/activitate/mediu/MasterP/MasterPlan.pdf. Accessed 14 Nov 2011

INS (2011) County statistics. Iasi County Statistics. http://www.iasi.insse.ro/main.php?id=373. Accessed 14 Nov 2011

INS (2015) County statistics. Iasi County Statistics. http://www.iasi.insse.ro. Accessed 10 Oct 2015

INS (2016) County statistics. Iasi County Statistics. http://www.iasi.insse.ro. Accessed 31 Mar 2016

ISWA (2015) Circular economy: trends and emerging ideas. International Solid Waste Association, Vienna

Jávor B (2015) Circular economy – what we can achieve with ambitious recycling targets and what is crucially needed beyond. In: Circular economy in Europe towards a new economic model, The European Files, September 2015

JRC (2011) Supporting environmentally sound decisions for bio-waste management. A practical guide to life cycle thinking (LCT) and life cycle assessment (LCA). European Commission, Joint Research Centre, Institute for Environment and Sustainability, Ispra

JRC European Commission (2010) Analysing of existing environmental impact assessment methodologies for use in life cycle assessment. Joint Research Centre Institute for Environment and Sustainability, ILCD handbook

LAP 2 (2008) National Waste Management Plan (LAP) 2009–2021. Ministry for Housing, Spatial Planning and the Environment (VROM), Hague
Law 211 (2011) Law No. 211 of 15 November 2011 on waste regime. The Romanian Parliament, published in Official Gazette no. 837 of 25 November 2011
Lidl (2015) Competition Lidl, (in Romanian). https://www.competitialidl.ro/Regulament_ComPETitia.pdf. Accessed 10 Mar 2016
Luca FA, Ioan CA (2014) Implementation of green marketing in the analysis of municipal waste produced in Romania, correlated with environmental policy management. Environ Eng Manag J 13:3131–3142
Mac Arthur Foundation (2012) Towards a circular economy: business rationale for an accelerated transition. Ellen Mac Arthur Foundation Corves, UK. https://www.ellenmacarthurfoundation.org/assets/downloads/TCE_Ellen-MacArthur-Foundation_9-Dec-2015.pdf. Accessed 10 Mar 2016
Maguin D (2015) Why Europe needs a market-driven circular economy? In: Circular economy in Europe towards a new economic model, The European Files, September 2015
MECC (2016) Waste management, Romanian Ministry of Environment and Climate Change. http://www.mmediu.ro/beta/domenii/gestionarea-deseurilor/. Accessed 10 Mar 2016
NSDSR (2008) National Sustainable Development Strategy Romania 2013–2020–2030. Government of Romania – Ministry of Environment and Sustainable Development. United Nations Development Program – National Centre for Sustainable Development, Bucharest
NWMP (2004) National Waste Management Plan. Ministry of Environment and Water Management, Bucharest
NWMS (2004) National Waste Management Strategy. Ministry of Environment and Water Management, Bucharest
NWMS (2013) National Waste Management Strategy. Ministry of Environment and Climate Change, Bucharest
OECD (2007) Outcome of the first OECD workshop on sustainable materials management. Working Group on Waste Prevention and Recycling, Organisation for Economic Co-operation and Development (OECD)
OECD (2010) OECD-FAO agricultural outlook 2010–2019. Organisation for Economic Co-operation and Development/Food and Agriculture Organization of the United Nations, Paris
OECD (2011a) Policy principles for sustainable materials management. Working Group on Waste Prevention and Recycling, Organisation for Economic Co-operation and Development (OECD)
OECD (2011b) Policy instruments for sustainable materials management. Working Group on Waste Prevention and Recycling, Organisation for Economic Co-operation and Development (OECD)
OECD (2015) OECD environmental performance reviews The Netherlands 2015
Oroian I, Odagiu A, Braşovean I, Burduhos P (2009) Waste management in Romania. Case study: implementing National Strategy on waste management. ProEnvironment 2:235–242
Papachristou E, Hadjianghelou H, Darakas E, Alivanis K, Belou A, Ioannidou D, Paraskevopoulou E, Poulios K, Koukourikou A, Kosmidou N, Sortiko K (2009) Perspectives for integrated municipal solid waste management in Thessaloniki, Greece. Waste Manag 29:1158–1162. https://doi.org/10.1016/j.wasman.2008.04.015
Petrescu V, Ciudin R, Isarie C, Nederita V (2010) Environmental engineering education – waste management in Romania. World Trans Eng Technol Edu 8:107–110
Pires A, Martinho G, Chang NB (2011) Solid waste management in European countries: a review of systems analysis techniques. J Environ Manag 92:1033–1050. https://doi.org/10.1016/j.jenvman.2010.11.024
PlasticsEurope (2015a) Towards a life cycle driven circular economy. http://www.plasticseurope.org/documents/document/20150617095930-plasticseurope_view_paper_circular_economy_june_2015_final.pdf. Accessed 31 Mar 2016
PlasticsEurope (2015b) Plastics – the Facts 2015 An analysis of European plastics production, demand and waste data. http://www.plasticseurope.org/documents/document/20150227150049-final_plastics_the_facts_2014_2015_260215.pdf. Accessed 31 Mar 2016

Rossy A, Jones PT, Geysen D, Bienge K (2010) Sustainable materials management for Europe, from efficiency to effectiveness. Report for the informal Environmental Council on the 12th and 13th of July 2010, Brussels
RWMP – NE (2006) Regional waste management plan, region 1 NE. Ministry of Environment and Water Management, Bucharest
Schiopu AM, Apostol I, Hodoreanu M, Gavrilescu M (2007) Solid waste in Romania: management, treatment and pollution prevention practices. Environ Eng Manag J 5:451–465
SenterNovem (2006) The Dutch waste profile 1990–2005. http://www.senternovem.nl. Accessed 12 Apr 2011
SenterNovem (2009) Progress in Dutch waste management: 1990–2005. Twinning Domestic Waste Management Project. http://www.twinning-waste-bacau.ro. Accessed 12 Apr 2011
SEPA (2008) Swedens environmental objectives in brief. Swedish Environmental Protection Agency, Sweden
Singh J, Ordonez I (2016) Resource recovery from post-consumer waste: important lessons for the upcoming circular economy. J Clean Prod 134:342–353. https://doi.org/10.1016/j.jclepro.2015.12.020
SME (2003) EU priorities to achieve the Swedish environmental quality objectives. Swedish Ministry of the Environment, Government Communication 2003/04:9
Tartiu EV, Petrache AM (2009) The zero waste system – an enduring solution for the waste management in Romania? http://www.iswa.org/uploads/tx_iswaknowledgebase/wm_2009_1-300.pdf. Accessed 31 Mar 2016
Twence (2009) Sustainability report. http://www.twence.nl/en/over%20twence/Download_Annual_Reports.doc/. Accessed 12 Apr 2011
Twence (2014) Forging links. Public annual report
US EPA (2007) Municipal solid waste generation, recycling, and disposal in the United States: facts and figures for 2007. http://www.epa.gov/waste/nonhaz/municipal/pubs/msw07-fs.pdf. Accessed 12 Apr 2011
van Eijk F (2012) Sustainable waste management. Vice-chair DWMA, Rotterdam, 24 October 2012
van Haeff J (2007) Digestion and composting in the Netherlands. Attero. http://www.marm.es/es/calidad-y-evaluacion-ambiental/temas/prevencion-y-gestion-de-residuos/2_6_John_van_Haeff-association_Netherlands_tcm7-1688.pdf. Accessed 12 Apr 2011
Veeken A, Huisman H, van Schaik R, Suurmeijer J, Stoyanov M, Zhivkova S (2011) Handbook for biowaste management in Bulgaria. Draft. Ministry of Housing Spatial Planning and the Environment, Utrecht
von Braun J (2008) Food and financial crises: implications for agriculture and the poor. International Food Policy Resources Institute, Washington, DC
Wante, J. (2010). A European legal framework for enhanced waste management. Paper presented at 1st international symposium on enhanced landfill mining, Houthalen-Helchteren, 4-6/10/2010
WEF (2014) Towards the circular economy: accelerating the scale-up across global supply chains. World Economic Forum, Geneva
Wenzel H, Hauschild M, Alting L (1997) Environmental assessment of products: methodology, tools and case study in product development, vol I. Kluwer Academic Publisher, London
Zaman AU (2015) A comprehensive review of the development of zero waste management: lessons learned and guidelines. J Clean Prod 91:12–25. https://doi.org/10.1016/j.jclepro.2014.12.013
Zils M (2014) Moving toward a circular economy. http://www.mckinsey.com/business-functions/sustainability-and-resource-productivity/our-insights/moving-toward-a-circular-economy. Accessed 31 Mar 2016
ZWE (2015) Zero waste to landfill and/or landfill bans: false paths to a circular economy. ZeroWaste Europe. http://www.zerowasteeurope.eu/2015/11/press-release-landfill-ban-a-false-path-to-a-circular-economy/. Accessed 31 Mar 2016
ZWE (2016) Closing the loop of materials, phasing out toxics & emissions. Zero waste Europe. https://www.zerowasteeurope.eu/2016/03/press-release-eurostat-data-for-2014-confirms-need-for-european-residual-waste-target/. Accessed 2 Apr 2016