

Chapter 14

Industrial Ecology and Portugal's National Waste Plans

Paulo Ferrão, António Lorena, and Paulo Ribeiro

Abstract This chapter explores how industrial ecology concepts and tools were used to support the design of waste management systems and policies in Portugal. The focus is on a set of case studies that illustrate the results of a successful cooperation between government, private institutions, and academia to transform waste into a useful resource for socio-economic development.

The “Relvão Eco Industrial Park”, an industrial symbiosis case study, is analyzed, showing that it was possible to build from scratch a large number of synergies between companies, creating over 300 local jobs and attracting an investment of over €19 million to a region which was industrially undeveloped.

The partnership between the Portuguese Environment Agency and IST to develop the National Waste Management Plan enabled design of a policy instrument that explicitly identified the need for a life-cycle approach to underpin waste management policies and that supported a circular economy to contribute to increasing resource efficiency.

The recent national strategy for urban waste management (PERSU 2020), developed in 2014, is the latest case study of cooperation between academia and the government to develop a public policy whose results show that the proposed changes will lead to a major qualitative leap in the environmental and economic performance of the sector by 2020. It is estimated that the net GHG emissions will be reduced by 47 %, as demonstrated by an LCA study promoted to support policy development. These benefits are due not only to reduction of the quantity sent to landfill, especially the biodegradable fractions, but also to the expected increase in MSW recycling resulting from the increase of selective collection and more efficient treatment and recovery of mixed wastes. An hybrid input-output model, i.e. with both monetary and mass flows, that explicitly considers seven types of waste, showed that the new policy will allow for increasing the economic added value of the urban waste management system by 26 % to €451million and that the number of direct and indirect jobs will increase to 13,000 and 5,500, respectively.

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The evidence reported in this chapter shows that the cooperation between government, academia and private sector in Portugal, based on industrial ecology principles and tools, has been able to significantly improve waste management performance in Portugal since the late 1990s, making the sector an important actor of the green economy, by combining better environmental performance with economic growth and job creation, critical dimensions for enabling sustainable development.

Keywords Waste • Industrial symbiosis • LCA • Hybrid input-output analysis • Waste management policy

1 Introduction

Earlier works of industrial ecology placed strong emphasis in resource efficiency and waste minimization. The seminal paper by Frosch and Gallopoulos (1989) summarized the industrial ecosystem as one in which “the consumption of energy and materials is optimized, waste generation is minimized and the effluents of one process serve as the raw material for another process. Manufacturing processes in an industrial ecosystem simply transform circulating stocks of materials from one shape to another; the circulating stock decreases when some material or energy is unavoidably lost, and it increases to meet the needs of a growing population.” The authors argue that the traditional model of industrial activity, in which individual manufacturing processes take in raw materials and generate products to be sold plus waste to be disposed of, should be transformed into an industrial ecosystem model, analogous to a biological ecosystem.

Industrial ecology is rooted in this ecological metaphor that provides a conceptual model for industrial development, based on improving the material interactions in and between firms, within a certain geographical distribution or industrial cluster, emulating ecosystems. Industrial systems would adopt principles such as cooperation, symbiosis (Ehrenfeld 2007), loop-closing (Graedel and Allenby 1995), diversity and systemic approaches (Lifset and Graedel 2002). Industrial ecology has long evolved from a metaphorical approach to a broad transdisciplinary field (Ehrenfeld and Gertler 1997, Ehrenfeld 2004) that encompasses both conceptual approaches (e.g. industrial symbiosis, loop closing, design for recycling) and tools (e.g. life-cycle assessment, materials and substance flow accounting, economic and physical input-output based techniques), making it a rich discipline and ripe for interdisciplinary knowledge transfer.

This chapter explores how industrial ecology related concepts and tools were used to support the design of waste management systems and policies in Portugal, through a set of challenges in which the authors have been involved at Instituto Superior Técnico (IST) of the University of Lisbon during their academic careers and PhD studies and subsequently, for Lorena and Ribeiro, as consultants.

Industrial ecology's systemic approach to waste management extends the analysis beyond the waste and its collection and treatment processes and includes the production and use phase of the products that are transformed into waste at the end of their life. Outcomes of this approach include the Industrial Symbiosis concept, in which waste flows from one industry are used as resource inputs for another, and loop-closing, which emphasizes the reintroduction of used material and energy resources at the production phase in order to reduce extraction and extend the lifetime of stocks.

This chapter is organized in four sections, including this introduction. The next section provides a historic perspective of the Portuguese waste management policies and highlights key developments in terms of Industrial Ecology principles. Section 3 is focused on the most recent municipal solid waste management plan recently developed in Portugal, and Sect. 4 quantifies its impact assessment making use of different industrial ecology tools.

2 Portuguese Waste Management Policy 1990–2014: The Contribution of Industrial Ecology

Modern Portuguese waste management policies date from the 1990s, when urban waste was first considered to be a priority for the national environmental policies. In this context, in 1996, the first national municipal solid waste (MSW) management plan (PERSU) was approved for the period 1997–2007. Its main goals were focused on banning waste dumping in inadequate sites, which represented 73 % of the destination of the MSW generated in Portugal, and structuring a set of regional entities that would be responsible for local waste management and would have access to funding for new infrastructures.

In 2006, the revision of the PERSU was launched; it resulted in a new strategy, PERSU II (2007–2016), and provided additional funding for installing a set of new infrastructures that the regional management systems considered necessary to fulfill the national waste management targets, as derived from EU directives, in terms of separating the different waste streams during waste collection, avoiding deposition in landfill and promoting the valorization of the waste collected, particularly wastes from packaging and those which are biodegradable.

In parallel, industrial ecology principles emanating from academia, with major involvement of the authors at Instituto Superior Técnico (IST) – University of Lisbon, were fundamental to establish common development strategies shared by governmental, private and regional institutions, and to create mechanisms to foster the closing of material cycles through integrated management systems for end of life (EOL) products and industrial symbiosis in eco-parks.

The industrial ecology academic contributions to reshape the Portuguese waste management activities were particularly relevant in the design of the systems that managed the Extended Producer Responsibility (EPR) of different products such as

automobiles, tires, electric and electronic products, lubricants and packaging. They were focused on improving the environmental performance of products and services through their life cycles, and, in particular, their end-of-life (EOL) disposal and subsequent processing. This was particularly successful in Portugal due to the excellent articulation between governmental authorities, academia and the private sector. More recently, IST has contributed to assessing the benefits of EPR schemes with the use of IE tools, as will be described in the third section.

Another significant contribution of the IST team consisted in supporting the development of an eco-industrial park to promote industrial symbiosis. In January 2004, the Portuguese government issued the Law Decree 3/2004, with the objective of calling for a new approach to hazardous waste management. To prevent fragmented treatments and minimize movements and transfers, the Government called for the creation of an integrated recovery, treatment and elimination center for hazardous wastes (CIRVER). As a result, two companies were to be established in the municipality of Chamusca. Soon after, several companies approached the municipality with projects and requests to locate their business in the municipality.

IST was invited by the mayor to be a strategic advisor to establish and disseminate information about IE and IS principles to local agents and to analyze how IE and IS could be better integrated into the municipality's strategy. These efforts resulted in the "Relvão Eco Industrial Park" (REIP) project, in 2006, under the leadership of the municipal government. A middle-out approach was adopted (Costa and Ferrão 2010), that supported the successive governmental, university and business interventions in the municipality of Chamusca. National government introduced the objectives and policy instruments, and businesses were free to provide solutions to those challenges. Local government was able to influence the social context, at the local level, by promoting a variety of events in which agents interacted (e.g. community, industry, university). By establishing an eco-industrial park to anchor important waste management infrastructures, industries were attracted to the region and synergies began to emerge. Local government and the university monitored the process evolution and disseminated information to agents at all levels, in order to foster IS development.

As a result, between 2006 and 2009, a large number of synergies were established between companies installed in the eco-park and beyond it, and local jobs increased from 50 to about 350 in 14 companies, attracting an investment of over €19 million, to a region which was industrially undeveloped. The eco-park was viewed as very successful model for combining environmental and economic development, or the green economy in practice.

All this work has resulted in various academic contributions covering different aspects, set out in a number of scientific papers, including:

1. The contribution of industrial ecology principles to environmental policy and business practices: Ferrão and Heitor (2000); Eherenfeld et al. (2002); Thore and Ferrão (2002); Ferrão and Nhambiu (2006); Dijkema et al. (2006); Ferrão (2007); Costa and Ferrão (2010); Niza et al. (2014).

2. The contribution of industrial ecology principles and tools to the design of specific EOL managing schemes for products: Freire et al. (2000, 2001); Giacomucci et al. (2002); Ferrão et al. (2002, 2006, 2008); Ferrão and Amaral (2006a, b); Amaral et al. (2006a, b); Ferrão and Lorena (2014).

In Portugal, the successful cooperation between academia, the Portuguese government and the private sector was also reflected in different partnerships, notably between IST and the authorities responsible for waste management, to perform a variety of tasks such as improving the information management system in Portugal, technical support on waste management systems and support for policy development.

An example was the partnership between the Portuguese Environment Agency and IST to develop a proposal for the Portuguese National Waste Management Plan (PNGR), made available for public discussion in 2011, which represented the first policy instrument in Portugal that explicitly identified the need for a life-cycle approach to underpin waste management policies and that supported a circular economy to contribute to increasing resource efficiency. The goal of the PNGR was to “promote waste prevention and management as a part of the life-cycle of products, support the circular economy and enable a greater resource efficiency.” This vision or goal is clearly aligned with central concepts of industrial ecology – life-cycle approach and its systemic approach.

The 2011 version of the PNGR was revised in 2014 in order to reflect the most recent European strategic and legislative framework and waste generation and management data. However, as a testament to its conceptual relevance and currency, the vision, goals and objectives of the 2011 version were not significantly altered.

In 2014, the municipal solid waste management strategy, a component of PNGR, was also reviewed to enable more ambitious targets. Paulo Ferrão was invited to coordinate the working group responsible for the task and the authors of this chapter were involved in developing the models that facilitated it. As the most recent example of the use of IE principles in establishing advanced waste management policies, the next section will detail the use of IE principles and tools in the design and impact assessment of the new Portuguese National Plan for MSW – PERSU 2020.

3 PERSU 2020

The Portuguese National Plan for Municipal Solid Waste 2014–2020 – PERSU 2020, was commissioned by the Secretary of State for the Environment to be developed by a Working Group that included the participation of the national and local public entities, government and academia. This section summarizes the methodology adopted and main results of the work developed.

In 2010 and 2011, the European strategic framework emphasized resource efficiency as a pillar of environmental policy. While this was not new – for instance, the 6th Environmental Action Program had already pointed in this direction – there was

a set of strategic and legislative proposals that marked a clear shift toward the intersection of waste and resource efficiency policies (e.g. Commission Communication “Roadmap for a Resource Efficient Europe”). Waste was to be seen as a resource that should be reintroduced into productive processes, avoiding the extraction and imports of resources.

PERSU 2020 would need to provide a response to the MSW management targets for 2020, particularly the target of reaching 50 % of preparation for reuse and recycling of MSW (as defined by EU Directive 2008/98/EC). The ambition was also for the MSW sector to open up tangible opportunities for economic growth and job creation. Constraints on the growth of the sector were to be identified and avoided so that key players could take advantage of these opportunities and contribute simultaneously to the reduction of environmental impacts of waste management and increase of wealth. The impact of the new plan in these dimensions was to be quantified making use of IE tools.

In this context, the PERSU 2020 approved by the law: “Portaria n.º 187-A/2014, publicada em DR (I Série) n.º 179, de 17 de setembro de 2014”, proposes objectives for the MSW sector that stem from the PNGR and are aligned with the European strategic framework: “The PERSU 2020 maintains the objective of protecting the environment and human health through the correct use of processes, technologies and infrastructures, but goes further by promoting waste prevention and the reintroduction of waste in the productive processes, thus reducing the need for resource extraction and ensuring a secure supply to the Portuguese economy, while creating new jobs and value added”.

In designing the PERSU 2020 vision, several principles were established, including:

- Protection of the environment and of human health by preventing or reducing the adverse impacts of waste generation and management.
- Full compliance with the national and European legislation.
- PERSU 2020 should not impose technological solutions and allow regional waste management institutions to determine their own approaches to reach the defined targets.
- Performance targets should be established at the regional level.
- Efficient use of infrastructures – regional infrastructures are encouraged to increase process efficiency and to share available treatment capacity.
- MSW treatment should support principles of regional self-sufficiency and proximity.
- Emphasize actions targeting the upstream stages, namely waste prevention and the collection of sorted MSW.

The IE principle of loop closing stands at the base of PERSU 2020, as clearly stated in the vision: “PERSU 2020 (...) goes further by promoting (...) the reintroduction of waste in the productive processes, thus reducing the need for resource extraction.” It is a central objective that is materialized in the national targets of preparation for reuse and recycling and recycling of packaging waste. Regarding policy options, circularity is promoted through two major vectors: the first is by limiting new investments in end-of-the-line technologies – new landfills and incin-

eration plants – to cases where these are necessary as operational buffers (e.g. when an adjacent treatment plant is shut down for maintenance) or for waste streams where recovery is not economically or technically viable (e.g. waste from road sweeping). This policy is further supported by a suggested increase in landfill and incineration taxes, historically lower than other Member-states (Watkins et al. 2012). The second vector aims to upgrade the materials recovered from MSW in order to increase the uptake, in quantity and value, by upstream industries. From the several actions proposed to achieve this, the priority was to strengthen collection schemes to increase separation at source, thus reducing contamination and overall unsorted MSW, to promote ecodesign through voluntary agreements with the packaging industry, and to review the regulatory framework concerning secondary streams from the waste sector (Residue derived fuels – RDF, compost, biogas).

The concepts of cooperation and symbiosis in industrial systems are based on the premise that a firm can divert unwanted materials from the waste system (or ecosystem) by having them used as resource in a different firm. The same reasoning can be extended to the secondary wastes of waste treatment. For instance, the bottom ash from MSW incineration can be used as secondary material for cement production and the stabilized organic material from mechanical and biological treatment facilities (MBT) can be used to increase organic content in forest soil. Waste management systems can also be considered as necessary intermediary processes between industries, i.e. enablers of industrial symbiosis at a larger scale, if some constraint prevents the transformation process from occurring at the point of generation of the waste (e.g. limitations by environmental protection legislation).

Other forms of collaboration occur when firms of the same sector share infrastructures. For instance, a MSW management firm can use a neighboring RDF preparation facility to avoid the deposition of residual streams from material recovery facilities in landfill. A positive corollary of this approach is that it allows greater economies of scale.

The principle of efficient use of infrastructures is supported by the concepts of symbiosis and cooperation in the Portuguese MSW sector. By restricting new infrastructures to situations where these are absolutely necessary, PERSU 2020 induces cooperation between regional companies and the establishment of agreements with firms from other sectors. Practical examples include the use of RDF in energy intensive industries or deposition of compost in vineyards, forest and other soils with low organic content. The plan suggests that financial support from available funding to the MSW sector should be focused on processes that add value to MSW streams (e.g. MSW separation at source, RFD preparation facilities).

To realize the vision, principles and objectives, it was necessary to develop a full material flows model of the MSW management system from 2012 to 2020 in order to evaluate the distance-to-target and identify challenges and opportunities in the sector.

All 23 regional institutions responsible for local MSW management – MSW RMS (MSW regional management systems) – were consulted in order to establish a Business-as-Usual (BaU) scenario for MSW generation and management. The material flows expected to occur in 2020 are represented in Fig. 14.1. It is clear that there is a strong reliance on treatment operations for MSW from unsorted collection. This

Business as Usual (2020)

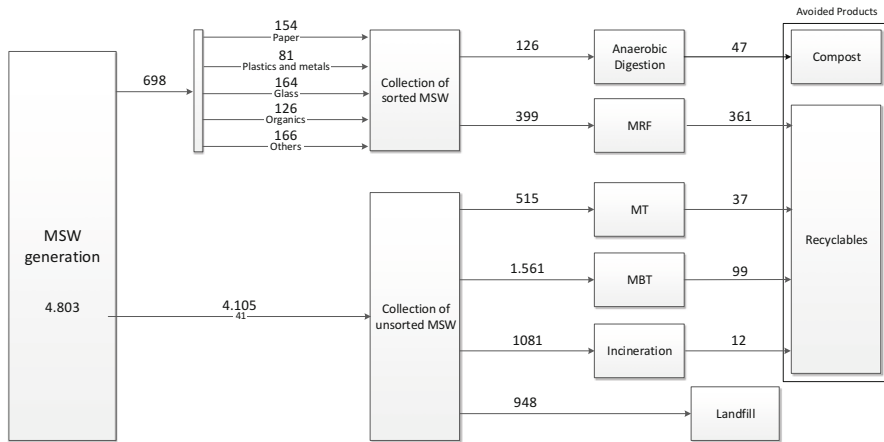


Fig. 14.1 Most important material flows in the Portuguese MSW sector in the BaU 2020 scenario. Values in thousand tons (*MRF* material recycling facility, *MT* mechanical treatment facility)

results in significantly lower recycling rates when compared to other EU Member-States, even if significant progress is made in the diversion of MSW from landfill. These data provided a strong argument for the policy option of emphasizing collection of sorted waste. Despite the increase in MBT and MT capacity compared to 2012, the BaU pathway was not sufficient to reach the 2020 proposed targets, specifically in:

- Preparation for reuse and recycling: to reach a minimum of 50 % preparation for reuse and recycling of MSW
- Recycling of packaging waste: to reach a minimum of 70 % recycling of packaging waste
- Diversion of biodegradable MSW from landfill: to reach a maximum of 35 % of deposition of biodegradable MSW in landfill (measured relative to the amount of biodegradable MSW in 1995)

PERSU 2020 assumed the innovative challenge of defining specific targets for each of the MSW RMS, in accordance with the overall goals established and taking into account the existing differences between regions and infrastructures. Each of the 23 MSW RMS is responsible for the treatment and deposition of waste and, in most cases, they are also responsible for the collection of sorted MSW (waste that is sorted by households and deposited in specific containers). Exceptions occur in the most densely populated areas of Lisboa and Porto, where municipalities are responsible for the collection of sorted waste. Finally, unsorted waste always falls under municipality responsibility. The involvement of private companies has been mostly restricted to service contracting by municipalities or minor participation in the capital of regional companies. There are also major differences in terms of territory, population and socio-economic profile, which translate to different waste generation patterns and management options (collection schemes, infrastructures,

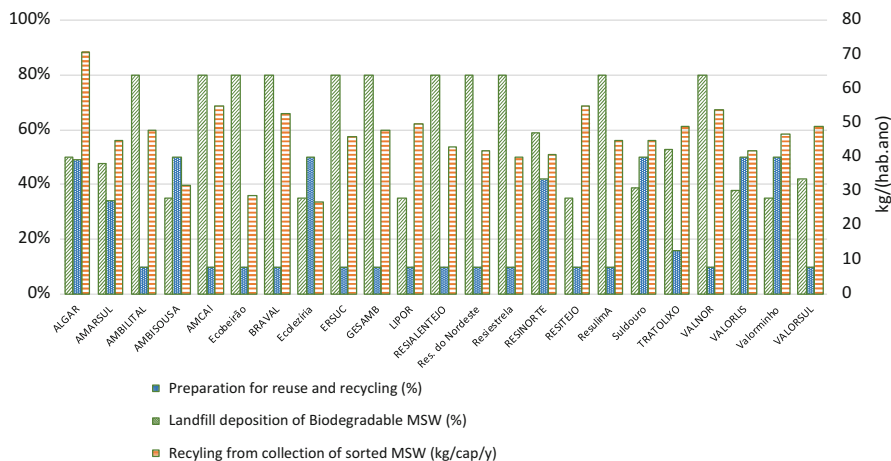


Fig. 14.2 PERSU 2020 targets for each MSW regional management system

technology). Target setting for each regional company was a major innovation in the planning process in Portugal, as in the past the national target did not result in specific targets for each of the MSW RMS. The targets for each system were based not only in their development stage and technology profiles but also on exogenous factors such as population density, in order to ensure proportionality of the effort by each MSW RMS.

The resulting targets for each of the MSW RMS are represented in Fig. 14.2. It shows that there is room to attend to the specificities of each system while promoting a fair incentive for each of them to improve their operation in order for the national targets to be fulfilled with optimal economic and environmental performance.

4 Impact Assessment of the Portuguese National Plan for Municipal Solid Waste 2014–2020

The assessment of the environmental, economic and employment impacts of packaging waste and MSW was commissioned by Sociedade Ponto Verde (SPV), the Portuguese Producer Responsibility Organization (PRO) for packaging waste, and resulted in two studies whose results are summarized here.

4.1 Environmental Impacts

The environmental assessment of the MSW management system in 2012 and 2020 was performed using attributional life cycle assessment (LCA). The functional unit selected as the basis for comparison was 1 ton of average MSW managed in Portugal

in 2012. Coproducts were taken into account by the “substitution by system expansion” or “avoided burden method” considering the average primary route market consumption mix. The “zero burden assumption” was also used, which means that it was considered that the waste carries none of the upstream burdens into the waste management system (Clift et al. 2000).

For modeling purposes, the various activities were organized as groups of associated processes, as follows: (1) waste generation, (2) collection of sorted MSW (material and biodegradable waste); (3) collection of unsorted MSW; (4) organic recovery; (5) sorting at MRF; (6) mechanical treatment; (7) mechanical-biological treatment; (8) energy recovery; (9) recycling; (10) landfill. The secondary wastes from waste treatment, as also the materials and energy recovery processes, were also taken into account.

The detailed analysis of the most important foreground processes constitutes the backbone of the life cycle inventory and was based on primary data obtained from the companies that handle the waste (e.g. SPV) and on secondary data from LCA databases and scientific bibliography which were adapted to better reflect the Portuguese reality.

The results obtained show that for 7 of the 11 environmental impact categories considered in the study, the reference MSW system configuration leads to a positive or neutral environmental balance. In these cases, the benefits due to the recovery of materials and energy obtained by waste recovery processes (avoided impacts), with special focus on recycling, are bigger or at least equal to the negative impacts generated by the various waste management activities, like collection, sorting, transport, treatment and recovery. In the remaining four impact categories, the benefits obtained from waste recovery are not sufficient to mitigate the impacts generated by its management activities. This is due mainly to a still significant MSW fraction that is not recovered and is mostly eliminated in landfills (in 2012, 5.4 % of the Portuguese MSW was directly put in landfill). This is the case, for example, in the climate change category, where it was estimated that the net GHG emissions reached 1.1 Mt CO₂eq in 2012, equivalent to 1.6 % of the annual GHG emissions in Portugal.

Comparing the MSW management as a whole with the specific management of packaging materials, it was found that, on a unit basis, the environmental balance of the packaging materials is more favorable than the remaining fractions. This is due in part to the intrinsic characteristics of packaging materials, but also to higher recycling rates achieved and the consequently lower amount sent to landfill, particularly for glass, paper/cardboard and ferrous metals.

Comparing the 2012 performance with the target for the year 2020 with the strategy defined in PERSU 2020, the results show that the proposed changes will lead to a major qualitative leap in the environmental performance of the sector. For example, it is estimated that the net GHG emissions will be reduced by 47 %, which translates into a emission savings of 522 kt CO₂ eq and that the benefits obtained from the recovery of mineral resources, both fossil and renewable, will increase by 61 % compared to 2012. These benefits are due not only to reduction of the quantity sent to landfill, especially the biodegradable fractions, but also to the expected increase

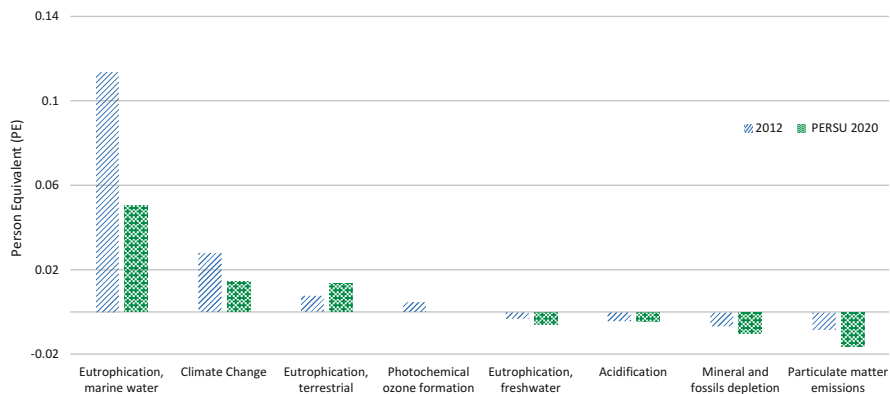


Fig. 14.3 Environmental impacts of MSW management per ton of MSW in 2012 and 2020, according to the objectives of PERSU 2020. Three categories were omitted since in both cases the values were approximately null

in MSW recycling resulting from the increase of selective collection and more efficient treatment and recovery of mixed wastes (Fig. 14.3).

4.2 Economic Impacts

To assess the economic impacts of the PERSU 2020, it was assumed that in 2020 all MSW RMS would meet each of their specific targets. The 2020 scenario (based on these assumptions) was then compared to the reference scenario (based on data from 2012) to determine the net contribution of the PERSU 2020.

Two variables were covered by the assessment of the economic impacts: the gross value added and the number of jobs. The methodology used is based on the input-output (IO) model presented in Ferrão et al. (2014). The economic assessment considers that in the course of its economic activity, a firm uses resources, such as labor or imports, and that these are direct impacts of the firm. A firm also purchases goods and services from other companies, which themselves are going to use resources (these are the first order indirect impacts of the first firm). These firms in turn make purchases to other firms, leading to second order indirect effects of the first firm, and so on (Ferrão et al. 2014). Finally, substitution impacts arise from, as the name implies, the materials and energy recovered in the sector studied which replace output from other sectors (e.g. electricity production from the MSW management sector reduces the output of thermal power plants).

The IO model developed to study the economic impact of the MSW management system was a hybrid, i.e. with both monetary and mass flows, that explicitly considers seven types of waste: unsorted MSW, paper, plastic and metal, glass, refuse (secondary wastes from MT, MBT and MRF) and ashes. It also considered eight

MSW sectors: collection of unsorted waste, collection of sorted waste, material recovery facilities, incineration, mechanical biological treatment, incineration, landfill, packaging PRO, besides the rest of the economy (ROE). The sector ROE was modeled using the 2008 basic prices symmetric product-by-product Input–Output tables of the Portuguese Department of Prospective Planning and International Relations (Dias and Domingos 2011), with an aggregation of 85 sectors using the official Portuguese NACE Rev.3 two digit classification. Data for the MSW management itself was obtained mostly from publicly available accounting reports from regional companies, annual reports from the Portuguese Environment Agency (APA references), and, for the 2020 scenario the PERSU 2020 was used.

PERSU 2020 requires the Portuguese MSW management system to increase the collection rates of sorted waste and to avoid direct deposition in landfill by increasing MT and MBT capacity. Intuitively, the shift from collection of unsorted waste and landfill deposition to these solutions will lead to higher value added; first, because more materials with positive economic value are being returned to the economy (e.g. scrap metal, plastic film); second, because the shift is toward higher labor and capital intensive processes. The obvious increase in the total cost of the MSW management system will be partially supported by the producers' responsibility organizations (PRO) for packaging waste, which are mandated to compensate the higher collection cost of sorted waste. The remaining part should be transferred to the population.

The results obtained for 2012 show that the GVA of the MSW management activities is €357 million, 55 % of which is related to the collection of unsorted waste. The activities related to material recycling, which include collection of sorted MSW and sorting at material recovery facilities, represent 22 % of the total direct contribution in terms of GVA. Indirect impacts, i.e. the economic activity on other sectors due to the operational expenses of MSW management system, were estimated to be €114 million, mostly concentrated in construction activities (contracts for new infrastructure), installation and repair of machinery and specialized services (consultancy, architecture, engineering, etc.). In the reference year, the number of jobs in the MSW management system was 11,700, of which nearly 84 % was attributed to collection activities, especially of unsorted waste. In the rest of the economy, the number of jobs due to the MSW management system amounts to 3,400.

If we look at the GVA and number of jobs per ton, there is a clear indication that the collection of sorted waste and sorting at MRF has higher economic impact than end-of-the-line solutions such as incineration or landfill.

The 2020 results are thus a consequence of the higher unitary impact of these activities. In relation to 2012, the GVA in MSW management system is expected to increase by 26 % to €451 million. The increase in the rest of the economy due to these activities is significantly higher at 55 %, reflecting the higher operational costs, i.e. inter-sectorial transactions, of the growing activities (collection of sorted waste, sorting at MRF, MBT and MT). The number of direct and indirect jobs will also increase to 13,000 and 5,500, respectively (Fig. 14.4).

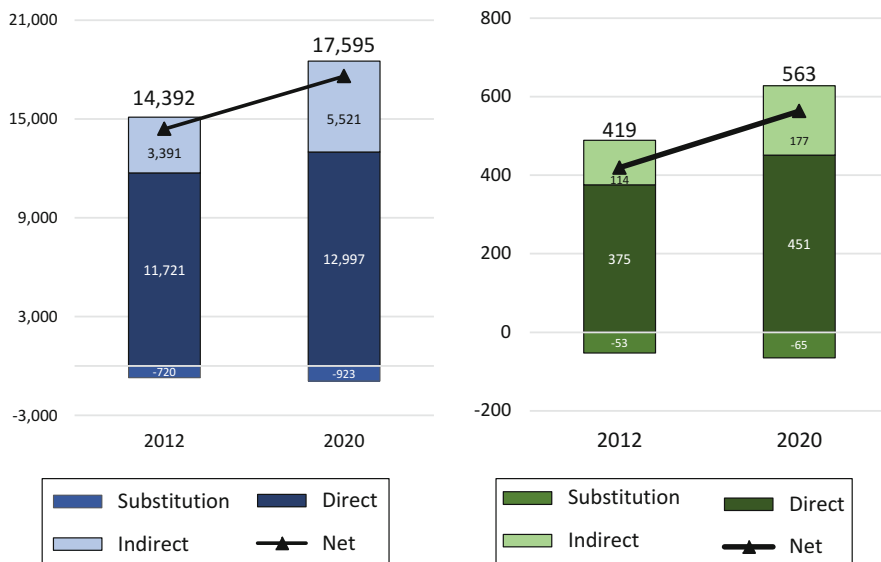


Fig. 14.4 Estimated economic impacts and job creation of the MSW sector in 2012 and 2020 (PERSU 2020 scenario)

The evidence reported in this chapter shows that the cooperation between government, academia and private sector in Portugal, based on industrial ecology principles and tools, has been able to significantly improve waste management performance in Portugal, since the late 1990s, making it an important actor of the green economy, by combining better environmental performance with economic growth and job creation, critical dimensions for enabling sustainable development.

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