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Preface

Waste collection is one of the most relevant parts of the integrated solid waste management system in technical, economic, environmental, and social terms. However, the vital role of waste collection has not been recognized, and the support given by the quadruple helix – academics, industry, state, and citizens – is reduced when looking for the other operational units of an integrated solid waste management system. To exemplify the missing interest of academia for waste collection, in a Google Scholar search, the results for "waste collection" are about 157,000, for incineration are 375,000, and for landfill are 639,000. This example shows that collection is seen only as the way to make waste to get into high-tech infrastructures, like incineration plants, where real science is applied. The practitioners of the waste collection are the range of workers with lower income backgrounds, making waste collection not attractive enough to be devoted to high-tech solutions for waste collection problems. Many times, waste managers working in waste collection systems are more focused on the trucks and containers and the costs involved in the collection process, which is a considerable amount of local authorities' budget.

In a meeting in 2014 between academia and waste collection sectors at the Nova University of Lisbon, waste collection professionals expressed the need for technical skills and knowledge based on waste collection and management practice, in a bottom-up approach. Technical skill areas include cost-efficiency, recycling behavior, environmental impacts, and technical operation. Waste collection professionals all over the world have the same necessities when implementing and managing a waste collection system to know more about the subject, but in such a way that knowledge could be affordable in technical and economic terms.

The waste collection professionals' call to fulfill the technical background needs required experts in several fields of waste collection and management. This book results from the collaboration from different science areas and experiences in waste collection and management. Dr. Ana Pires, from whom the original idea was formed, has a scientific role in analyzing solid waste management from a system analysis perspective, where the application of life cycle assessment and multi-criteria decision-making are the techniques applied by her to make waste collection and management more sustainable. Prof. Graça Martinho has a long career in solid waste management and recycling behavior studies. Prof. Isabel Gomes has scientific expertise in operational research applied to waste collection and reverse logistics. To keep us focused on the goal of this book, we required someone from the waste collection professional field. Dr. Susana Rodrigues is a waste collection manager, which brought the vision and expertise from the technical operation of waste collection in practice.

This book intends to provide those who work in the scientific field of waste management and who are practitioners the backgrounds of waste collection and its incredible role in the success of an entire waste management system. Bringing the most recent developments on the subject to people who are not keen in searching for scientific articles to obtain knowledge and apply it to its professional life is the challenge of this book. We do not intend to define the best technology to implement waste collection. We want to give readers the tools to improve waste collection by integrating their work within the entire waste management system.

A particular interest for graduate students: this book shows the recent technology tendencies in the field, which will help students finding new directions their study and graduation at waste collection systems. This book will allow students to understand the applicability of system analysis through case studies.

The timeliness of this book is justified by the current context of essential changes in the waste management sector and the critical role that legal aspects and organizations have on the promotion of the sustainable development on a sector essential for well-being and population health. We are facing challenges in developing countries where integrated solid waste management systems are being built, and the scientific background of this book can help them to direct waste collection to become more efficient and sustainable. In developed countries, we are shifting away from a waste collection system, with no value product collection and management, to a resource collection and management system. This shift is a real challenge, where the consumer (the product owner) has the ability to make the collection and management system work as a provider of raw materials to the economy.

Last but not least, we would like to acknowledge the precious help given by Springer in supporting all the questions, issues, and delays that occurred during the writing of this book. Writing a book in English by nonnative speakers required extra effort from us. Springer was very helpful in the entire process of writing and editing this book.

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May 2018

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Part I
Fundamental Background

Chapter 1
Introduction

Abstract The statistics are precise: the population is increasing, and, consequently, the amount of waste generated in the entire world is increasing, ending at open dumpsites, with reduced recycling and recovery. The missing of integrated solid waste management systems that ensure controlled management, where environmental and health risks are reduced and where the waste system drives economic growth and social progress, are major challenges for science and engineering. This chapter intends to emphasize the essence of sustainable development in the collection and management of waste, how to make part of the waste management, and how it can constitute the framework of a usual integrated solid waste management. Case studies that show how to promote the sustainable waste collection and, consequently, solid waste management are introduced in the subsequent chapters.

Keywords Sustainable development · Waste collection · ISWM · Waste flows · SDGs

1.1 The Concept of Sustainable Development

The Sustainable Development Goals are the most recent initiative from the United Nations to leverage sustainable development in the world until 2030. The SDGs are present at the report "Transforming Our World" (United Nations 2015), predicted at "The Future We Want," the document resulting from the Rio+20 Conference, 20–22 June 2012, organized by the United Nations, where all countries were called to renew their commitment to reach a sustainable future.

The United Nations started to call countries to the sustainable development cause on 16 June 1972, when the United Nations Conference on the Human Environment occurred, held in Stockholm, where the "rights" of the human families to a healthy and productive environment were delineated (UN-DESA 2015a). The step was crucial to bring environment into the agenda of industrialized countries, and the theme was again brought into the spotlight with the publication of the "World Conservation Strategy" by the United Nations Environment Programme (UNEP), World Wide Fund for Nature (WWF), and International Union for Conservation of

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Nature and Natural Resources (IUCNNR). This strategy was the precursor to the concept of sustainable development, which aimed (UNEP/WWF/IUCCNR 1980):

- To maintain fundamental ecological processes and life-support systems, vital for human survival and development
- To preserve genetic diversity, on which depend the breeding programs needed for the protection of plants and domesticated animals, as well as much scientific innovation, and the security of the many industries that use living resources
- To ensure the sustainable utilization of species and ecosystems (notably fish and other wildlife, forests, and grazing lands), which supports millions of rural communities as well as significant industries.

The discussion on the accelerated degradation of the environment and its effects on the economic development led the United Nations to discuss "The World Commission on Environment and Development" in 1983. In 1987, the Brundtland Report "Our Common Future" defined "sustainable development" as (WCED 1987):

> The development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

The first UN Conference on Environment and Development in Rio de Janeiro occurred in 1992, where the document of "Agenda 21: A Programme of Action for Sustainable Development," also known as *The Rio Declaration on Environment and Development*, was adopted (UN-DESA 2015b). The Agenda 21 establishes 27 principles around the 3 pillars of sustainability: economy, society, and environment. After Agenda 21, several other documents and programs have been elaborated by the United Nations, which are all being reaffirmed by "The Future We Want" (UN-DESA 2018):

> The Programme for the Further Implementation of Agenda 21, the Plan of Implementation of the World Summit on Sustainable Development (Johannesburg Plan of Implementation) and the Johannesburg Declaration on Sustainable Development of the World Summit on Sustainable Development, the Programme of Action for the Sustainable Development of Small Island Developing States (Barbados Programme of Action) and the Mauritius Strategy for the Further Implementation of the Programme of Action for the Sustainable Development of Small Island Developing States.

The attempt to bring sustainability into practice is a real challenge, and continual removal of the goals is needed to keep the subject on the agenda. However, the definition of the goals has been considered to be vague, weak, or meaningless (Hopwood et al. 2005; Stafford-Smith 2014; Stokstad 2015). Holden et al. (2017) criticize the three pillars: the economic, social, and environmental, sustaining that the critical dimensions of sustainable development should be:

> The moral imperatives of satisfying needs, ensuring equity and respecting environmental limits. The model reflects both moral imperatives laid out in philosophical texts on needs and equity, and recent scientific insights on environmental limits.

The concept of sustainable development by Holden et al. (2017) goes further, by developing a model that quantifies how sustainable the development of the country or groups of countries is. The model includes critical themes, indicators, and thresholds, which would be far way more practicable than the SDGs defined by the United Nations (2015).

The intention of this book goes much further in the establishment of sustainable development definitions. The way how solid waste collection and management should include sustainable development and contribute to the SDGs is, in fact, one of the goals of this book.

1.2 Sustainability in the Context of Solid Waste Collection and Management

Paragraph 218 of "The Future We Want" devotes to the development and enforcement of comprehensive national and local waste management policies, strategies, and regulations, regarding a life cycle approach and promotion of policies of resource efficiency and environmentally sound waste management (UNEP and UNITAR 2013).

Before defining any sustainability waste management policies, the definition of waste should be discussed. The need to define what waste is from what is not influences the need to control or not the output material resulting from a process or from the urban metabolism. According to the European Parliament and Council (2008):

> Waste means any substance or object which the holder discards or intends or is required to discard.

All materials that can be considered as waste according to the definition can also be classified by source, nature, physical and mechanical properties, chemical and elemental properties, biological/biodegradable properties, and combustion properties (Chang and Pires 2015). Concerning the source, waste can be classified as municipal solid waste (which includes commercial and services waste), construction and demolition waste, medical waste, industrial waste, and other wastes that can require a specific identification. Concerning nature, waste can be classified in hazardous waste (presenting one hazard (at least) to humans or environment); inert waste, which has no transformation at physical, chemical, or biological levels; and nonhazardous waste, which has no hazardous features. Physical, mechanical, and chemical properties include physical composition, density, moisture content, particle size and size distribution, pH, chemical composition, C/N ratio, calorific value, and biological features (Chang and Pires 2015).

All the waste can also be divided by waste stream, i.e., by the product that gave origin to the waste. The need to define waste streams started at municipal solid waste, which presents high heterogeneity on materials due to the diversity of products consumed in the urban system. Waste streams present in municipal solid waste can be packaging waste (which is even divided by materials like paper, cardboard, glass, plastic, liquid carton beverages packaging, ferrous metals, nonferrous metals), batteries, food waste, biodegradable waste, green waste, waste of electrical and electronic equipment, construction and demolition waste, and domestic hazardous waste, and many others may appear. The definition of waste by streams is devoted to the need of being separately managed, in the beginning, because the recycling industry wanted the source-separated materials to be recycled in their process, i.e., an internal value market exists for those wastes. If waste streams with potential market value are removed, the residual fraction (or stream) can be managed in such way that only waste can be managed to ensure its processing more efficiently and straightforwardly.

The segregation of waste through its properties, mostly, can impulse its environmental sound management of waste, with financial revenues and positive social impacts. The segregation of waste leads to its management without being contaminated with hazardous (or nonhazardous) materials or allowing its maximum use. Segregation helps to increase the value of recyclables and recyclates, resulting value-added by-products. The use of recyclates contributes to a green gross domestic product (GDP), an index of economic growth that corrects the environmental consequences from GDP (Chang and Pires 2015). The social well-being reached with an integrated solid waste management and with the source separation of waste is notable, although source separation of waste requires citizens' participation which can be demanding and challenging for waste system managers. The public participation in the decision-making process on waste management is also a reality nowadays, where waste players, from products life cycle, can be brought to deliver strategic plans and actions plans to prevent and manage waste.

1.3 The Framework for Sustainability Assessment

Several authors (CSLFG/STSP/PGA/NRC 2013; Sala et al. 2015; Sonnemann et al. 2015) have elaborated their framework for sustainability assessment, with the aim of being used to support decision-making and policy development at any field. Sustainability assessment can have different definitions:

> The goal of sustainability assessment is to pursue that plans and activities make an optimal contribution to sustainable development. (Verheem 2002)

Alternatively,

> Sustainable assessment refers to the interaction of different methodologies in such a way that is geared toward obtaining an analysis, an evaluation, or a plan that approaches several management aspects in which the sustainability implications may be emphasized and illuminated. (Chang et al. 2011)

The proposed sustainability framework by Sala et al. (2015) (Fig. 1.1) presents the comprehensive approach required to impulse the sustainability in the waste

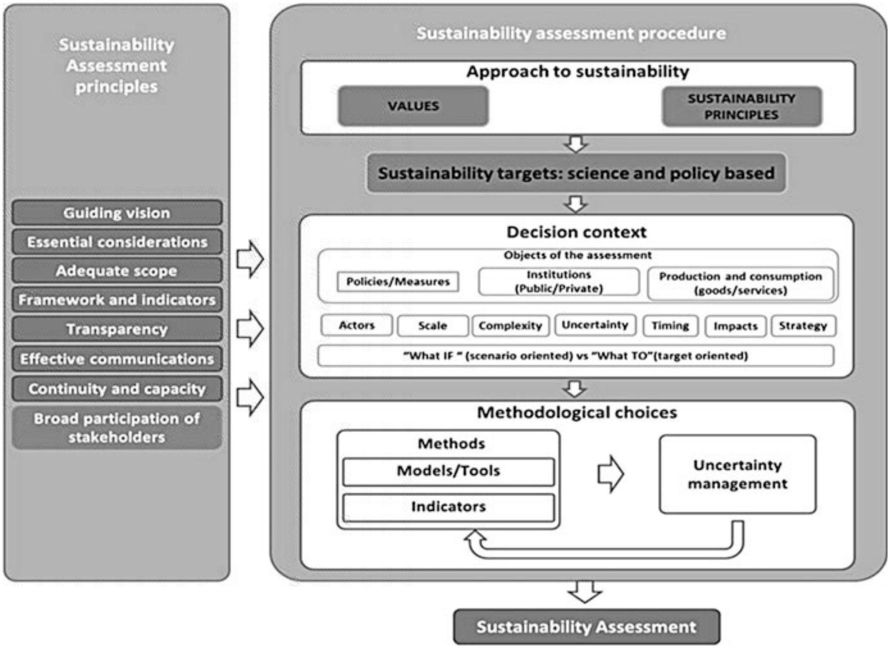

Fig. 1.1 Scheme of the conceptual framework for sustainability assessment. (Source: Sala et al. (2015))

sector. The principles of sustainability defined by Sala et al. (2015), i.e., guiding vision, essential considerations, adequate scope, framework and indicators, transparency, effective communications, continuity and capacity, and broad participation of stakeholders, can constitute the guide for practitioners to perform the assessment. The sustainability assessment procedure comprises several steps (Sala et al. 2015):

- Approach to sustainability: the values and sustainability principles are to be defined by the organization requiring the assessment.
- Sustainability targets: to define the level of sustainability intended to be accomplished.
- Decision context: where information from sustainability assessment will be translated in practical terms.
- Methodological choices for the assessment: the core of the sustainability analysis, which involves the identification of the most suitable assessment methodologies (methods, models, tools, indicators), sensitivity and uncertainty analysis, and definition of the monitoring strategies to track progress toward sustainability targets.

1.4 The Structure of This Book

The interactions between all pillars of sustainability and the urban, agriculture, and industry activities are complicated and often difficult to quantify, manage, and give a rapid response. Technologies, related to machinery or related to computational solutions, are called to contribute significantly to the resolution of sustainability issues in the waste management sector.

Solid waste management complexity occurs like in any other human-based processes. Making decisions in complex systems requires following principles, processes, and practices to proceed from information and desires to choices that inform actions and outcomes (Lockie and Rockloff 2005). The decision process is different in each phase of the waste collection and management. In the begging, the design, planning of the waste collection, and management must consider not only the international, national, and local strategies devoted to waste management (like collection rates, recycling rates) but also the local context where the waste management system is to be implemented, which will define and constraint the type of infrastructure to be employed. During the operation of a waste collection system, decision process requires information on the amounts of waste being collected for several destinations, how the collection routes and vehicles allocated to them are defined, and the waste quality reached, which will influence the following waste management processes. The collection system requires constant redefinition, not only due to the changes in the background where the system is occurring but due to the waste collection system itself, where decisions to improve its performance have to be taken, to not disregard the economic, environmental, and social impacts (positive and negative) of the waste collection system. The book intends to give highlights to waste collection practitioners on the view of their system and is intended to be used in conjunction with existing literature and other relevant guidance, firstly by academic researchers, policymakers, and waste researchers in public and private sectors. It also aimed to challenge the research for an interdisciplinary view where climate change, economic growth, environmental pollution, and social impact are variables which need to be brought to the waste management decision-making.

This book proposes a systemic decision framework where the waste collection has the leading role to leverage solid waste management at a more sustainable level. The processes inherent to waste collection operation are discussed and treated through science-based analysis with various perspectives of sustainable solid waste management. A comprehensive bibliography is provided at the end of each chapter, and some case studies are presented to describe how the system thinking can promote the needed management to reach sustainability in the waste management sector. The integrated approach is reflected in the structure of the four parts as follows.

Part I: Fundamental Background. The context on waste hierarchy upward to waste collection like waste prevention, reduction and reuse, the waste collection itself, and afterward waste hierarchy steps like preparation for recycling, recycling, treatment, and landfilling is provided. The related sustainability science background regarding the environment, social, and economic perspectives of sustainable solid waste management will be addressed. The following chapters lead to the integrated discussion on the role of waste collection in the solid waste management and on the waste hierarchy principle:

- Introduction (Chap. 1)
- Prevention and Reuse: Waste Hierarchy Steps Before Waste Collection (Chap. 2)
- Technology Status of Waste Collection Systems (Chap. 3)
- Preparation for Reusing, Recycling, Recovering, and Landfilling: Waste Hierarchy Steps After Waste Collection (Chap. 4)
- Regulation and Policy Concerns (Chap. 5)
- Psychosocial Perspective (Chap. 6)
- Economic Perspectives (Chap. 7)
- Environmental Context (Chap. 8)

Part II: Models and Tools for Waste Collection. The waste collection in solid waste management is an operation unit that requires, at first, design and planning and then the operation of the collection itself. During operation, it is required to monitor the operation, to understand if it occurs according to the plan. At last, the assessment and improvement of the waste collection system are needed, to find the constraints to be solved to help the collection to be more sustainable and integrated into the solid waste management system.

- Design and Planning of Waste Collection System (Chap. 9)
- Operation and Monitoring (Chap. 10)
- Assessment and Improvement (Chap. 11)

Part III: Sustainable Solid Waste Collection: Integrated Perspective. The role of sustainability in the way how waste is collected and consequences to the solid waste management system is discussed in this part. The following chapters are organized to provide information on the use of systems analysis methods – optimization and multi-criteria decision-making – as well as case studies where those methodologies are used to improve the waste collection systems regarding economic, environmental, and social perspectives.

- Optimization in Waste Collection to Reach Sustainable Waste Management (Chap. 12)
- Multi-Criteria Decision-Making in Waste Collection to Reach Sustainable Waste Management (Chap. 13)
- A Sustainable Reverse Logistics System: A Retrofit Case (Chap. 14)
- Collection of Used or Unrecoverable Products: The Case of Used Cooking Oil (Chap. 15)

Part IV: Challenges and Perspectives for Sustainable Waste Management Through Waste Collection. The waste collection requires new approaches to face the challenges of the future to make economic growth which is capable of satisfying the needs of the citizens, ensuring equity on accessing the waste collection and the solid waste management service, and respecting the environment and public health.

- The Evolution of the Waste Collection (Chap. 16)
- Trend Analysis on Sustainable Waste Collection (Chap. 17)
- Technical Barriers and Socioeconomic Challenges (Chap. 18)
- Future Perspectives (Chap. 19)

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Chapter 2
Prevention and Reuse: Waste Hierarchy Steps Before Waste Collection

Abstract The way how policy instruments and actions can impose measures before products became waste depends on policies based on the waste prevention, reduction, and reuse. A brief review on the concepts in the light of the waste hierarchy principle is discussed, considering the view of European countries and when possible from other countries in the world.

Keywords WHP · Waste Framework Directive · Products reuse · Minimization · Design

2.1 Waste Hierarchy Principle: Saving Materials Before Becoming Waste

Waste is a generic and large concept, which requires definition and, from there, define the strategies to avoid or minimize its generation. Authorities (national and international) defined waste differently:

- Waste Framework Directive (2008/98/EC): Any substance or object which the holder discards or intends to discard or is required to discard.
- US Resource Conservation and Recovery Act (USEPA 2017): any garbage or refuse, sludge from wastewater plant, water supply treatment plant or air pollution control facility, and other discarded materials, resulting from industrial, commercial, mining, and agricultural operations, and from community services.
- Inter-American Development Bank, definition applied at Caribbean and Latin countries (Espinoza et al. 2010): Solid or semisolid waste produced through the general activities of a population center. It includes waste from households, commercial businesses, services, and institutions, as well as common (nonhazardous) hospital waste, waste from industrial offices, waste collected through street sweeping, and the trimmings of plants and trees along streets and in plazas and public green spaces.
- Environment Protection Act (EPASA 2018), for Australia: any discarded, rejected, abandoned, unwanted, or surplus matter, whether or not intended for sale or for recycling, reprocessing, recovery, or purification by a separate

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operation from that which produced the matter, or anything declared by regulation or by an environment protection policy to be a waste, whether of value or not.

- Act on Waste Management at South Korea (Chung 2011): A material that is unnecessary for human life and business activities such as garbage, combustible ashes, sludge, waste oil, waste acid, waste alkali, carcass, etc. and some waste are defined as waste at courts.
- Law n.12.305 (WIEGO 2018) in Brazil: any material, substance, object, or disposed good resulting from human activities in society, whose final destination proposes to proceed or is obliged to proceed in solid or semisolid states, as well as gases and liquids within containers unfeasible to be released into the public sewage system or water bodies, or that require technically or economically unviable solutions in view of the best available technology.

The way how waste should be managed has been, until now, defined by the waste hierarchy principle (WHP). This principle establishes the preferable order in which the solid waste should be managed and treated, being, firstly, preferred the prevention, reuse, recycling, and recovery over landfill (Hultman and Corvellec 2012). The first time that WHP were introduced in European legislation was at 1975 Directive on waste (European Council 1975) and EU's Second Environment Action Program in 1977 (European Commission 1977) and finally defined at the Community Strategy for Waste Management in 1989 (European Commission (1989). Typically the WHP is presented as an inverted pyramid, where the preferred option is on the top and in bigger proportion than the subsequent management options, like in the case of WHP from European Waste Framework Directive (Fig. 2.1).

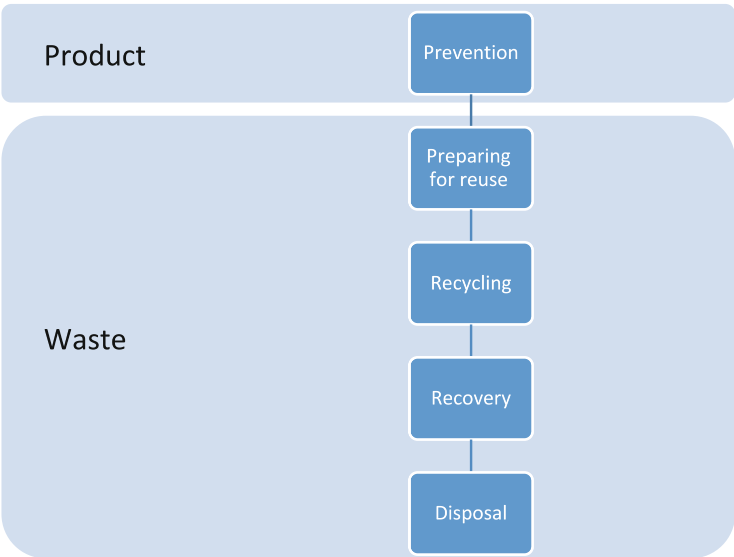

Fig. 2.1 Waste hierarchy principle according to Waste Framework Directive of European Union

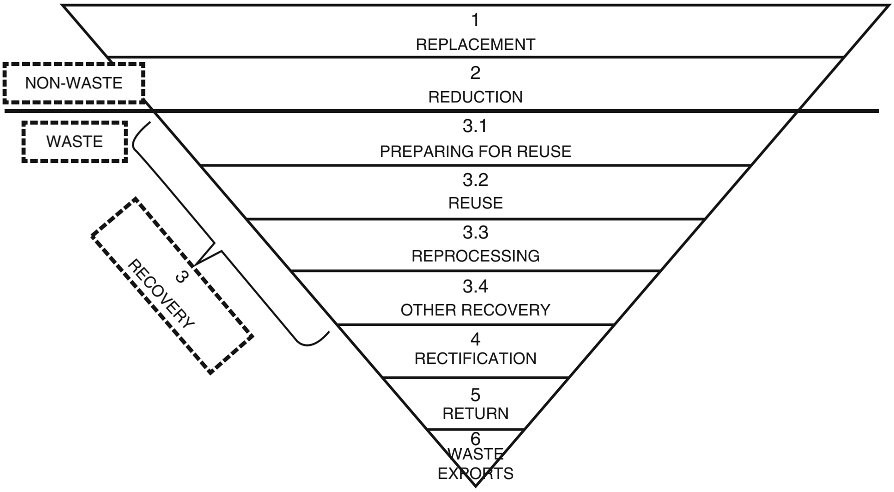

Fig. 2.2 Six stages of the hierarchy of resources use. (Source: Gharfalkar et al. (2015))

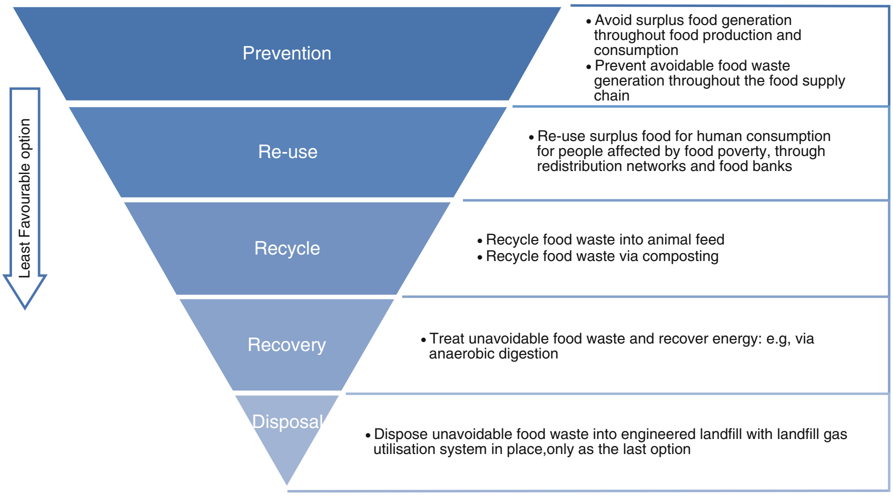

Fig. 2.3 Food WHP. (Source: Papargyropoulou et al. (2014))

An improvement of the Waste Framework Directive has been proposed by Gharfalkar et al. (2015), named "hierarchy of resource use" where a more detailed type of operations can be conducted and prioritized. This new hierarchy intends to help policymakers to provide the adequate incentives on the right waste management operations (Gharfalkar et al. 2015) (Fig. 2.2).

More recently, elaborations of WHP for specific waste streams are occurring. Papargyropoulou et al. (2014) developed a WHP specific for food waste (Fig. 2.3), being to define measures on food waste management but also at the food supply, where waste generation also occur. Knauf (2015) revised the European WHP for waste wood considering the European Union energy policy and European market and life cycle assessment studies on wood waste management, proposing that recycling or other recoveries such as energy recovery have the same level of priority. Richa et al. (2017) proposed and analyzed a WHP combined with circular economy to manage lithium-ion batteries, being highlighted that operations of reuse (direct or cascaded) followed by recycling can be better in terms of ecotoxicity burden that banning such batteries from landfill.

Definitions on WHP all over the world have similarities but also differences that make it difficult to conduct a standard view of all measures to minimize or avoid waste generation. To the better acknowledgment of the concepts, waste prevention and reuse will be characterized by the European view.

2.2 Waste Prevention

In the European view, prevention includes reduction. Reduction includes waste amount reduction, adverse impacts on health and environment, and reduction of harmful content (European Parliament and Council (2008)). A clear message from Waste Framework Directive is that prevention is for products and goods, not for waste. Waste reduction is, sometimes, only seen has the reduction of waste amount landfilled, or send for incineration, not the reduction of waste generated. Even with this narrowed view of waste reduction in terms of its destination, waste prevention concept can be considered, because the adverse impacts from waste management are being prevented (less waste going to landfill or to incineration, lesser environmental adverse impacts).

According to Hutner et al. (2017), types of waste prevention are reduction at source, substitution, and intensification, although intensification is more related to reuse (see Sect. 2.3). Reduction at source occurs during design and production, by applying ecodesign, which is an approach to "design out" waste and other environmental problems but keeping products quality and cost-effectiveness (Bârsan and Bârsan 2014). To prevent waste, ecodesign can focus on the type of materials to be used (environmentally friendly materials, recycled materials), reduction of material input, avoid waste during manufacturing, reduction of packaging, optimization of the product's functionality (which includes multiple functions), prolongation of product lifetime, waste prevention at use stage, and facilitation of maintenance (Wimmer and Züst 2003). Substitution intends to change the materials used in manufacturing to reduce hazardous component (already considered by ecodesign) or to substitute the product or service itself in the sale point by one that generates less waste (durable, reparable) (Hutner et al. 2017).

Waste prevention practices can be implemented by different policy measures. Regulatory, voluntary, and information instruments are possible strategies to implement (Table 2.1). In the study of Kling et al. (2016), the comparison of several economic instruments for waste prevention showed that PAYT is the preferable one

Table 2.1 Policy instruments on waste prevention

Policy instruments	Waste prevention instruments
Regulatory	Landfill ban, incineration bans, plastic bag bans, disposable cutlery bans, to-go or single-use products ban
Market-based	PAYT, landfill tax, incineration taxes and fees, extended producer responsibility principle, precycling insurance, recycling insurance, taxes on products (packaging, plastic bags)
Information	Awareness campaigns, school campaigns, procurement guidelines, information exchange platforms
Voluntary	Home composting, ecodesign of products, designing out waste, bottleless water, nappy laundry services, planning food meals

concerning utility, together with landfill tax. More nonconventional instruments are insurances, for recycling and precycling. Precycling means the "actions taken now to prepare for current resources to become future resources, rather than wastes accumulating in the biosphere" (Greyson 2007). Insurances would serve as a guarantee that future recycling costs or future waste management costs of the product are paid. A recent area where waste prevention is getting further steps is festivals and events. In the study conducted by Martinho et al. (2018), a festival applied mugs to avoid the acquisition of bottled drinks, reusable cutlery at canteen, sugar bowls, proper portion of food, and drinking fountains. The festival is known by the reduced amount of waste generated comparatively to other festivals (Martinho et al. 2018), showing how those measures can be important to promote waste prevention. Another effort to promote waste prevention in Portugal has been the plastic bag tax (Martinho et al. 2017a). The tax was capable to force a change at inquiries, shifting from single-use plastic bags acquisition to reusable bags but also to garbage bags, since single-use plastic bags were used as garbage bags. Plastic bags fee or tax has a considerable positive impact in the reduction on its acquisition in several other European countries (Table 2.2).

The design of instruments requires a profound knowledge of behaviors of the stakeholders which is intended to change the behavior. Without knowing the factors, the instruments to be applied may fail, just because instruments were not transferred considering those factor implications. The study of factors influencing the behavior of waste prevention has been made in the recent years. Cecere et al. (2014) found that prevention behavior is influenced by seldom socially oriented, seldom exposed to peer pressure, and very reliant on purely "altruistic" attitudes. Bortoleto et al. (2012) affirm that clear instructions are needed to citizens prevent waste, where information should emphasize that waste prevention is economically an alternative and has no inconvenient to the citizen. This approach puts in practice the factors of prevention behavior found by Bortoleto et al. (2012): that environmental concern, moral obligation, and inconvenience.

Table 2.2 Policy instruments applied in some European countries for plastic bags

Country	Policy instruments	Outcomes	References
Belgium (2007)	Tax or levy with voluntary agreement	60–80% of reduction	Bio Intelligence Service (2011)
Denmark (1994)	Tax or levy (also for paper bags)	A reduction of 50% on the amount of plastic bags	OECD (2001), The Danish Ecological Council (2015)
Ireland (2002)	Tax or levy	Reduce use by more than 90% and raised revenues around €12–14 million for an environment fund	Convery et al. (2007)
Luxembourg (2004, 2007)	Voluntary agreement to sale "Eco-sac" carrier bag in 2004. Bags started to be charged in 2007, including single-use bags	Saved about 560 million single-use shopping bags until 2013	Valorlux (2014)
Malta (2009)	Tax or levy	Saved around 25 million plastic bags (i.e., more than 50%, corresponding to roughly 150 tons of plastic) in the first 2 years after introducing the tax	Hermann et al. (2011)
Portugal (2017)	Tax	Reduction 20–30% on plastic bags sale in the first 8 months	Silva (2015)
Spain (2009)	Voluntary agreements in Catalonia	A reduction of 40% was achieved in 2010	Bio Intelligence Service (2011)
Romania (2009)	Tax or levy	An increase of plastic bags was verified between 2009 (27 million bags) and 2010 (60 million of bags)	Pre-waste (2011)
UK (Wales in 2011, Northern Ireland in 2013, Scotland in 2014, England in 2015)	Tax or levy with awareness campaigns and voluntary agreement	Wales: 71% reduction in 2015 Northern Ireland: 72% in 2014 Scotland: around 80% in 2015 England: 85% in 2016	BBC (2015), Bio Intelligence Service (2011), DAERA (2016), Howell (2016), Poortinga et al. (2013), The Guardian (2015, 2016)

Source: Adapted from Martinho et al. (2017a)