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).

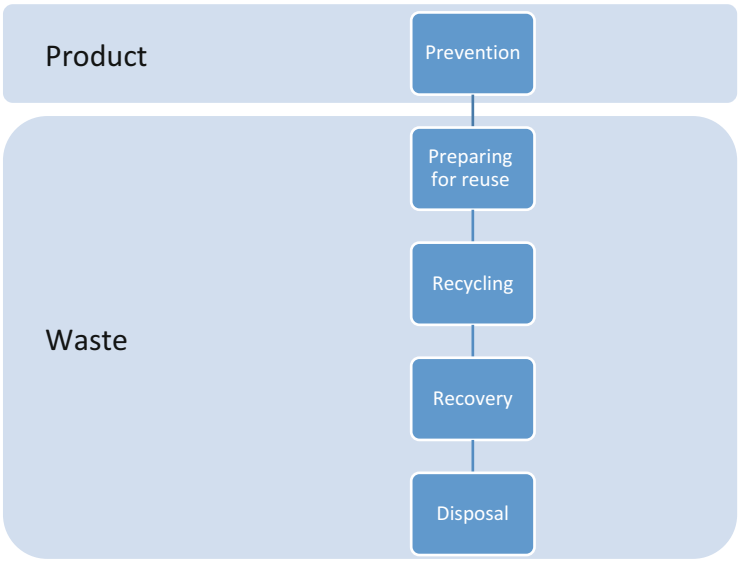

Fig. 2.1 Waste hierarchy principle according to Waste Framework Directive of European Union

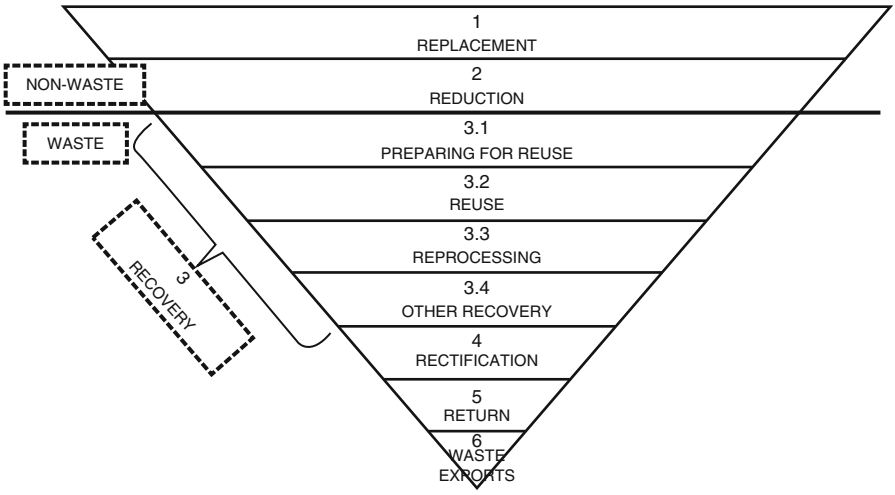

Fig. 2.2 Six stages of the hierarchy of resources use. (Source: Gharfalkar et al. (2015))

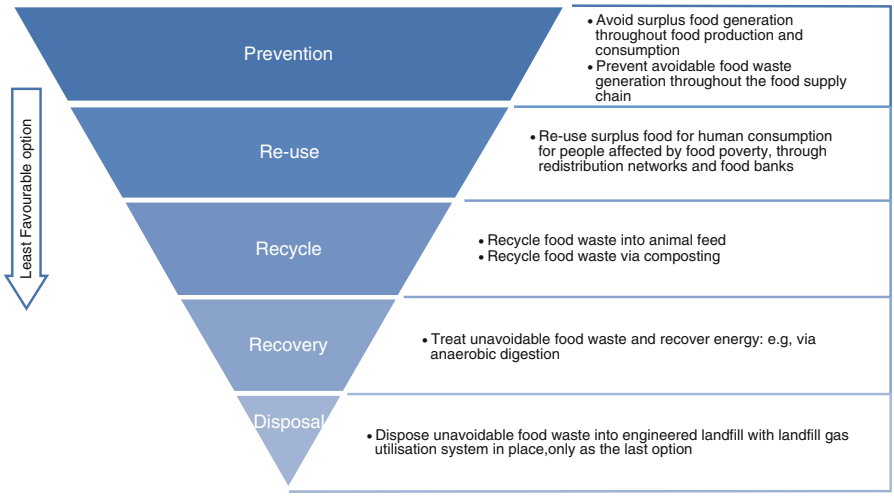

Fig. 2.3 Food WHP. (Source: Papargyropoulou et al. (2014))

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)

2.3 Products and Goods Reuse

Besides the definition of prevention, Waste Framework Directive 2008/98/EC also defines specific operation on products and goods before they become waste. The one defined is reuse, as being "any operation by which products or components that are not waste are used again for the same purpose for which they were conceived." It differs from "preparation for reuse" because, in this case, it consists of "checking, cleaning or repairing recovery operations, by which products or components of products that have become waste are prepared so that they can be re-used without any other pre-processing." In practical terms, reuse occurs inside the factory, or a company, or inside homes, when products are repaired or subjected to any operation that makes them usable again. The prevention mentioned here is before the good is put on waste collection system, because if such happens, it means that the users intended to get rid of it. All the reuse at a prevention perspective intends the notion that the users intend to keep using the product or good.

In this reuse concept, the operations that could implement reuse as preventing waste are remanufacturing, refurbishing, where the owner of the product does not change, and the owner itself can make the changes needed to the product keep performing in the same. Intensification considered by Hutner et al. (2017) fits better in reuse definition. The product used by the owner can be increased by sharing the product with other users or by prolonging the use phase of the product through repair. Reuse can be promoted by ecodesign, through improvement of reparability and by design for reuse of parts of the product (Wimmer and Züst 2003).

Several policy instruments can be implemented to promote products or goods reuse. Green public procurement applied can require products or goods with high levels of durability and easiness of repair, making them adequate to be used until exhaustion. Awareness campaigns about sustainable consumption in the way that could promote the acquisition of goods that can be used for such a long time are another type of instrument. The awareness concerning sustainable consumption is relevant. In the study conducted by Martinho et al. (2017b), men are keen to change their smartphone and tablets because they are obsolete and new models appear on the market. The notion of obsolesce is dependent of the appearing of new devices, with questionable new features, being a marketing strategy from devices producers. A better information of citizens concerning the environmental consequences of their consumption pattern is needed to break such pattern.

Voluntary actions such as product service systems can be useful to promote product reuse. Product service systems are "a marketable set of products and services capable of jointly fulfilling a user's need. The product/service ratio in this set can vary, either in terms of function fulfilment or economic value" (Goedkoop et al. 1999). The way how PSS promotes reuse is through the sale of the use (the service) of the product and not the product keeping its ownership (like laundry services), by implementing the leasing, which induces changes in consumer from product acquisition into service acquisition (Mont 2002; Roy 2000). According to Roy (2000), product service system can be divided into four types: service products (or demand services or result services), shared utilization services, product-life extension services, and demand-side

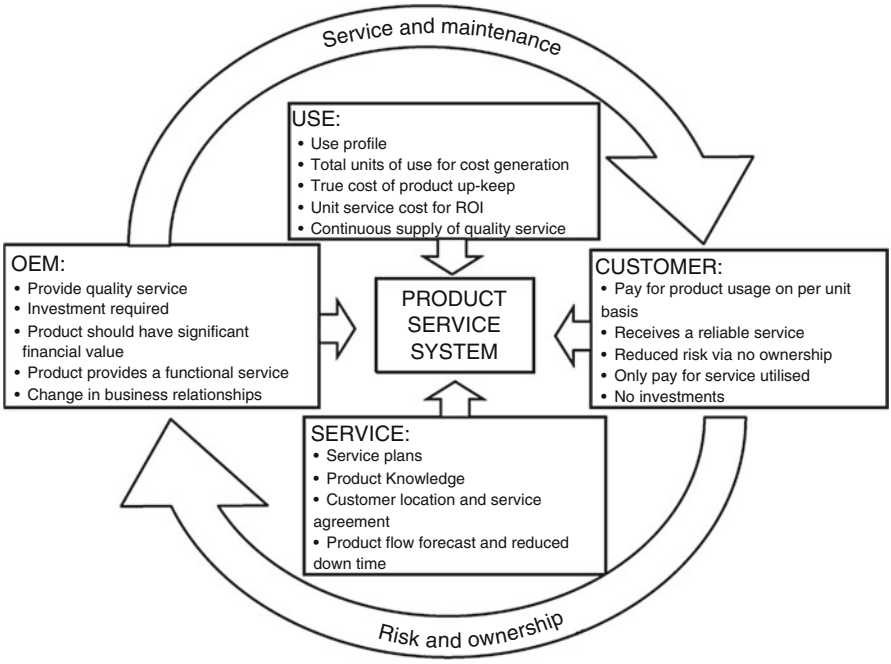

Fig. 2.4 Main features of a product service system. (Source: Bindel et al. (2012))

management (although this last one is applied to energy systems only). Service products intend to sell the result or service that the device/machinery can provide, like in the case of laundry service, which sells clean clothes rather than washing machine (Roy 2000). One of the main examples of service products is Xerox. The modular design strategy of their products allows the remanufacturing of their products, converting 160,000 machines from European customers (in 1997) by reprocessing them, making US$ 80 million of net savings (Maslennikova and Foley 2000). Shared utilization services (also called product-use services or community products) intend to increase the use of products by sharing, like in the case of community wash center instead of individual households washing machines (Roy 2000). Car sharing and bicycle pooling can also be cases of shared utilization service of transportation and can reduce the car use and the need to manufacture and park fewer vehicles (Roy 2000). Product-life extension services aim to increase the useful lifetime of products or goods through a spiral-loop system that minimizes matter, energy, and environmental deterioration, without compromising economic growth and progress (Giarini and Stahel 1993). This is a service being provided to electric and electronic equipment in countries like Portugal, after the 2-year guarantee provided by European regulation. Also, car stations are promoting product-life extension services, once cars are durable and expensive goods that compensate their owner to repair and provide maintenance to avoid the acquisition of a new one.

In a graphic representation of how a product service system works (Fig. 2.4), is notorious that the changing of the ownership from customer to the manufacturer will

make the goal is not sale the product, but instead, to increase its operation time, leading more durable products, design for disassembly products, extending as far as technically and economically possible the use phase of the product. Issues such as customer location, product return planning, and service/maintenance plans are additional tasks of the manufacturer that in a product-oriented approach they do not occur (Bindel et al. 2012).

2.4 Final Remarks

The waste hierarchy was useful to include in the policy of the drivers of a better management of resources. Although it is a questionable performance in terms of the overall environmental benefits, its relevance cannot be forgotten in terms of the impact on the way waste should be managed. With the diffusion of circular economy concept all over the world, the waste hierarchy changed for "preservation stages of resource value" by Reike et al. (2018), where the hierarchy "R-ladders" or imperatives constitute a principle to operationalize waste as resources in the economy (Reike et al. 2018).

The definitions and boundaries of the concepts of prevention and reuse and the activities which can contribute to them are difficult to establish. Although the European legislation intended to separate products or goods reuse from waste getting prepared for reuse, in practical terms, the most relevant concern should be to know how can waste prevention be measured, which are the factors that are making prevention and reuse difficult, and what if there is no shifting of waste and environmental impacts. Waste prevention and reuse measures in specific phase of a product may create more waste in subsequent life stages, or the avoidance of toxic materials that are used to increase durability that, in its absence, may force a more frequent replacement (Roy 2000). Life cycle assessment focused on waste is a possible method to assess if waste prevention has occurred effectively.

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