Circular Economy Transition in EU and Italy in Key Priority Sectors: Policies, Initiatives and Perspectives

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Abstract

In this work, we address the transition to the circular economy in the European Union (EU) and in Italy by focusing on the case of some value chains of products identified by the EU Circular Economy Action Plan for their significant environmental impacts. After a brief theoretical and political background on circular economy, the present study summarizes, with reference to the realities of the EU and Italy, the generation flows and recycling rates of municipal solid waste, total waste, packaging waste, plastic packaging waste, e-waste and food waste. The analysis is complemented by the evaluation of the circular practices of 32 organizations in Italy operating in the selected product value chains. The conclusions highlight the key results of the study and the main features of circular economy patterns at the macro and micro scales. The analysis highlights the emergence of two models: the recycling model (mainly applied at macro scale) and the circular economy practices model (repair, reuse, regeneration) applied at a micro and local scale with connections with the meso scale and the chain of supply.

Keywords

EU Circular Economy Action Plan · Municipal waste · Waste packaging plastic · WEEE · Food waste · Reduction · Reuse · Remanufacturing · Recycling

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S. K. Ghosh, S. K. Ghosh (eds.), *Circular Economy Adoption*,
https://doi.org/10.1007/978-981-99-4803-1_7

7.1 Introduction

The circular economy (CE) as a model of economy aims to maintain the environmental value of products, materials and components in their life cycle at the highest levels and for as long as possible (Ellen Mac Arthur Foundation 2023; Webster 2021) making smarter and prudent the production and consumption activities and the overall society, aligning the latter with the imperatives of sustainable development (Holden et al. 2018). In that, the contribution of CE to sustainable development is increasingly recognized in many studies and at political level (Bauwens et al. 2020; Silvestri et al. 2020; Geissdoerfer et al. 2017; Ghisellini et al. 2016) where the CE is expected to contribute to face the global environmental challenges such as climate change and resource scarcity (The European and Social Committee 2019). In this regard, increasing resource efficiency (Tecchio et al. 2017) and extending the life cycle of products, components and materials help in reducing their environmental impacts (including CO_2 emissions) while maintaining to a higher extent their environmental value (Haupt and Hellweg 2019).

Circular design makes products that are more durable, or that could be easily repairable, upgraded or remanufactured helping saving natural resources (European Commission 2021). The overall environmental value of such resource-saving strategies can be very high as in the case of waste electrical and electronic equipment (WEEE) (Bressanelli et al. 2020; Baldè et al. 2017). Sustainable products also mean less impactful production and consumption activities and supply chains leading to further environmental, economic and social benefits to the economy and society (Walker et al. 2021). In that, the improvement of the stock of existing capitals (natural, social, cultural) beyond the economic and financial (Nogueira et al. 2019) helps in increasing the resilience of the society (Sucheck et al. 2021). Case studies of companies show how the adoption of eco-innovation oriented to CE leads to the creation of collaborations and resource exchange networks with other private or public companies or research centres as well as to the improvement of the social relations of businesses with citizens and employees favouring in some cases their reintegration into the labour market and into the production cycle (Ghisellini and Ulgiati 2020).

The New CE Action Plan adopted by the European Union (EU) identified key product value chains and related materials (electronics and ICT, batteries and vehicles, packaging, plastics, textiles, construction and buildings, food, water and nutrients) as relevant for their environmental impacts and circularity potential. For these sectors, the urgency of taking actions is strongly encouraged by the EU, due to their potential contribution in achieving carbon neutrality by 2050 and the decoupling of economic growth from the use of natural resources (European Commission 2020). At the global level, the importance of adopting specific measures in some of these product value chains (e.g. metals, electronics and ICT, plastics, municipal waste, bioeconomy, construction) is also recently pointed out by other relevant think tank organizations as it would have the potential to reduce the GHG emissions by 39% to the year 2050 and contribute to maintain the average global temperature increase below 2 °C. This would imply the achievement of a global

circularity rate by 17% compared to the current 8.6% (Circular Economy Network 2021).

In this chapter, we focus our attention on the waste flows of some these sectors (electronics and ICT, municipal solid waste including waste packaging and plastic waste packaging, food) that we have deeply investigated within the bilateral China-Italy High-Relevance Research Project funded by the Italian Ministry of Foreign Affairs and International Cooperation (years 2018–2020) and the Sino-Italian Cooperation Commission of the China Natural Science Foundation. We evaluate the adoption of CE principles (repair, reuse, remanufacturing, recycling) in these sectors in EU and in particular in Italy with the purpose of providing a state-of-the-art knowledge for the generation and management of these waste streams, their reverse cycles and supply chains, the preventive actions and strategies, main political tools and involved technologies and businesses for potential interest in Europe and worldwide.

7.2 Circular Economy Transition in the European Union

In this section, some of the relevant elements of the New EU CE Action Plan are summarized along with the presentation of the indicators that are proposed by the EU monitoring framework[1] to evaluate the progresses towards a circular economy. Finally, an overview of the main initiatives towards the transition to CE in Italy is presented.

7.2.1 The Circular Economy Action Plan

In 2015, the European Union adopted the First Circular Economy Action Plan with the aim of supporting the transition to the CE in EU and strengthening its global competitiveness in the CE. The latter was considered as an opportunity to transform the EU economy into a more sustainable one with new job opportunities for its citizens and green businesses for the companies. The Plan proposed a set of measures covering production, consumption, waste management, the take-up of secondary raw materials and water reuse as well as the legislation of waste.[2]

The New Circular Economy Action Plan[3] adopted in 2020 continues the political agenda of the First Action Plan for accelerating the circular economy

[1] Circular economy indicators, available at https://ec.europa.eu/eurostat/web/circular-economy/indicators. Last accessed: 10/06/2021.

[2] Closing the loop—An EU action plan for the Circular Economy, COM (2015) Final, 2.12.2015, available at https://eur-lex.europa.eu/resource.html?uri=cellar:8a8ef5e8-99a0-11e5-b3b7-01aa75ed71a1.0012.02/DOC_1&format=PDF. Last accessed: 26/05/2021.

[3] A new Circular Economy Action Plan for a cleaner and more competitive Europe, COM/2020/98 final, available at https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1583933814386&uri=COM:2020:98:FIN. Last accessed: 25/05/2021.

(CE) transition[4]. Currently, the CE is also one of the core elements of the European Green Deal the recent and further political programme promoted by the EU aimed at tackling the climate and environmental challenges[5]. The New CE Action Plan considers the contribution of CE as crucial for achieving the climate neutrality by 2050 and decoupling economic growth from resource use. At the same time, the Plan also evidences the CE contribution in maintaining the competitiveness of the EU and its goals of perceiving an inclusive economic development. In fact: "The EU needs to accelerate the transition towards a regenerative growth model that gives back to the planet more than it takes, advance towards keeping its resource consumption within planetary boundaries, and therefore strive to reduce its consumption footprint and double its circular material use rate in the coming decade" (p. 2).

The Action Plan highlights that the CE has the potential to provide benefits for all the actors of the society: companies, consumers, citizens and civil organizations. For companies, the adoption of more sustainable production models will increase profit opportunities and make them more resilient towards resource scarcity as well as on the price of material fluctuations. The role of digital technologies is emphasized in facilitating the strengthening of the industrial sector, the creation of new business models and the dematerialization of the economy contributing to reduce the EU dependence from primary raw materials. For consumers and citizens, the CE will provide "high-quality, functional and safe products, which are efficient and affordable, last longer and are designed for reuse, repair, and high-quality recycling. A whole new range of sustainable services, product-as-service models and digital solutions will bring about a better quality of life, innovative jobs and upgraded knowledge and skills will open up new job opportunities also at the local level and social integration".

The Plan contains the different instruments to achieve its main goals centred in the creation of a market where sustainable products, services and business models have a highest share compared to the conventional linear products and consumption patterns and are oriented towards waste avoidance and minimization, as indicated in the upper options of the waste hierarchy scheme proposed by EU (Fig. 7.1). Besides identifying key product value chain, the Plan also anticipates the adoption of further measures to support the reduction of waste as well as the presence of a well-functioning internal market for high-quality secondary materials in the EU.

The role of Eurostat is emphasized as it should provide an easy access to the relevant data for citizens and policy makers in order to support (in particular for the latter) the monitoring process and the evaluation of the effectiveness of the adopted political actions, the main trends over time and their revision.

Within the EU, some member states (such as Italy, Germany, Poland, France, Spain, Greece, the Netherlands, Belgium, Portugal and Slovenia) have already

[4] https://ec.europa.eu/eurostat/web/circular-economy/overview.

[5] The European Green Deal, COM (2019) 640 final, available at https://eur-lex.europa.eu/resource.html?uri=cellar:b828d165-1c22-11ea-8c1f-01aa75ed71a1.0002.02/DOC_1&format=PDF. Last accessed: 26/05/2021.

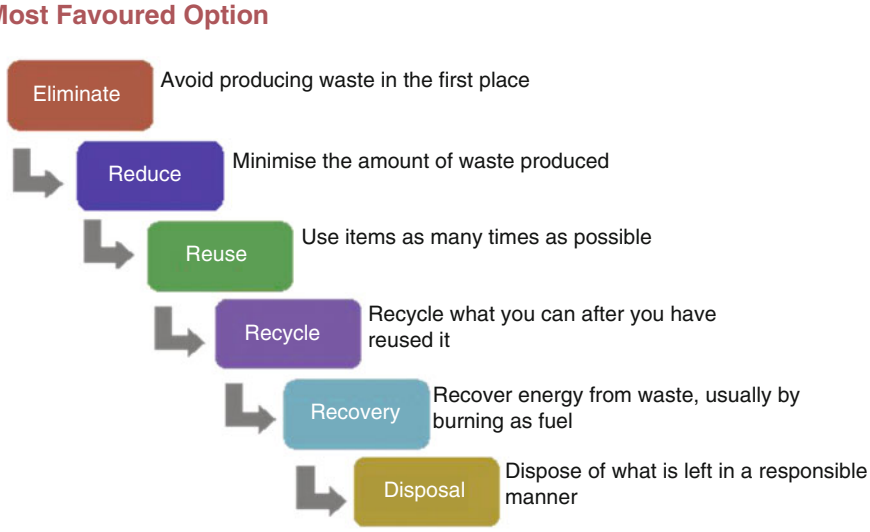

Fig. 7.1 Summary of the main options for waste treatment ranked according to their environmental sustainability in the so-called waste hierarchy

defined their CE strategy, while others are updating it (Finland) or are planning their CE strategy (Estonia). In overall, the CE strategies aim to support the transition to CE as well as coordinate the CE achievement with the global challenges including climate change, resource scarcity and the United Nations Millennium Development Goals (The European and Social Committee 2019)[6].

7.2.2 Circular Economy Indicator Framework

The monitoring framework of the EU for the CE transition considers a set of 15 indicators classified into 4 main areas (Table 7.1): production and consumption, waste management, secondary raw materials and competitiveness and innovation.

In this chapter, we will mainly focus on the "waste management" area by discussing the related indicators at European and Italian levels.

[6]See, for further reading on the CE strategies by the EU member states, the final report of the European and Social Committee, Circular economy strategies and roadmaps in Europe: Identifying synergies and the potential for cooperation and alliance building, available at https://www.eesc.europa.eu/sites/default/files/files/qe-01-19-425-en-n.pdf. Last accessed: 27/05/2021.

Table 7.1 Monitoring framework of the EU for the CE (Eurostat, Circular economy indicators, available at https://ec.europa.eu/eurostat/web/circular-economy/indicators. Last accessed: 27/05/2021)

Areas of the indicators	Indicators for the CE
Production and consumption	• EU self-sufficiency for raw materials
	• Generation of municipal waste per capita
	• Generation of waste excluding major mineral waste per GDP unit
	• Generation of waste excluding major mineral waste per domestic material consumption
Waste management	• Recycling rate of municipal waste
	• Recycling rate of all waste excluding major mineral waste
	• Recycling rate of packaging waste by type of packaging
	• Recycling rate of e-waste
	• Recycling rate of biowaste
	• Recovery rate of construction and demolition waste
Secondary raw materials	• Contribution of recycled material to raw material demand—end-of-life recycling input rates (EOL-RIR)
	• Circular material use rate[a]
	• Trade in recyclable raw materials
Competitiveness and innovation	• Private investments, jobs and gross value added related to circular economy sectors
	• Patents related to recycling and secondary raw materials

[a]The indicator measures the share of material recovered and fed back into the economy—thus saving extraction of primary raw materials—in overall material use. The circular material use, also known as circularity rate, is defined as the ratio of the circular use of materials to the overall material use. The overall material use is measured by summing up the aggregate domestic material consumption (DMC) and the circular use of materials. DMC is defined in economy-wide material flow accounts. The circular use of materials is approximated by the amount of waste recycled in domestic recovery plants minus imported waste destined for recovery plus exported waste destined for recovery abroad. Waste recycled in domestic recovery plants comprises the recovery operations R2 to R11—as defined in the Waste Framework Directive 75/442/EEC. The imports and exports of waste destined for recycling—i.e. the amount of imported and exported waste bound for recovery—are approximated from the European statistics on international trade in goods. A higher circularity rate value means that more secondary materials substitute for primary raw materials, thus reducing the environmental impacts of extracting primary material

7.2.3 Circular Economy Transition in Italy

Italy as an EU member state has started to support the transition to the EC since 2014 by first contributing to the preparatory stages of the First EU Action Plan on the EC and then by adopting the legislative instruments for its adoption at national level. As a matter of fact, the Commission for the Environment of the Italian Parliament approved several resolutions, and then the Italian government adopted the Law 221 of 28 December 2015, the so-called Collegato Ambientale, and further ministerial decrees and laws to promote the implementation of the CE in the country. The government has also funded research projects in particular areas such as the circular design of product, processes and services as well as the research and technologies for

the recovery and recycling of waste electrical and electronic equipment (WEEE).[7] Moreover, the Ministry of the Environment has appointed a specific working group on both the CE and the efficient use of resources. In 2017, such group has also elaborated a strategic position document "Towards a circular economy model for Italy" that has been subject to public consultation.

The document provides a general overview of the CE and the strategic positioning of Italy with regard to the transition to CE in line with the commitments (adopted at EU level and G7 countries) established by the Paris Agreement on climate change and the United Nations 2030 Agenda on sustainable development. Moreover, the document underlines its centrality at national level being a key pillar of the National Sustainable Development Strategy contributing to the definition of the goals for an efficient use of natural resources and the adoption of more sustainable production and consumption models.

The general principles of the CE as well as the new concept of "circular economic system" are provided to appreciate the difference with the linear economic system. The purpose is to show how the circular economic system is embedded in the natural environment and the implications of such integration. In particular, the awareness of the environmental functions and services for the economy and society and their limits cannot be disregarded.

The document also emphasizes the role to businesses and industry but also of consumers that are required to actively and critically rethink their linear consumption models in favour of more sustainable and circular models. In this context, it is crucial to promote efficiency in the resource use and therefore their traceability.

Finally, the document deals with the economic tools needed on both the production side and the demand side, as well as how to transfer the tax burden in the new context of the CE. For the public sector, it stresses the opportunities derived from the adoption of the "Minimum Environmental Criteria" to render the important tool of Green Public Procurement more EC-oriented.[8]

Besides the institutional measures, there are many initiatives in the country oriented to adopt the CE at the micro, meso and macro scales in practice. Cities are including the principles of the CE in their urban regeneration policies[9]. Indicator's frameworks have been developed to monitor the transition to CE at urban level (Beccarello and Di Foggia 2020; Santagata et al. 2020). Three cities (Milan, Prato and Bari) have also been designated "pilot city" in a national project headed by the Ministry of the Environment for the experimentation on innovative

[7] Ministry for the Ecological Transition, Circular Economy in Italy, available at https://www.minambiente.it/pagina/leconomia-circolare-italia. Last accessed: 27/05/2021.

[8] https://www.minambiente.it/pagina/verso-un-modello-di-economia-circolare-litalia.

[9] New Prato, green city, available at https://www.cittadiprato.it/IT/Sezioni/480/Economia-circolare/. Last accessed: 07/06/2021.

Fig. 7.2 Graphical interface of the Atlas of the CE. (Source: Modified from https://economiacircolare.com/atlante)

actions on the CE and on all high environmental impact issues related to waste generation and treatment.[10]

At the micro scale, Italian companies increasingly see CE as a business opportunity to increase their competitiveness (Antonioli 2021; Bianchini et al. 2021; Chioatto 2021) rather than only a cost (Mura et al. 2020). This more positive attitude to CE is also showed by the increasing number of companies included in the Atlas of the CE since its creation in 2017. The latter is a web platform that gathers together the CE stories of organizations (private, non-profit, cooperatives, benefit corporation and so on) in order to share their information with citizens and promote collaboration between actors and the construction of "circular" supply chains based on the principles of sustainability and circularity. The web platform uses a map and specific cards (according to industry-based criteria) (Fig. 7.2) to help users identify individual organizations. The number of organizations is constantly updated with new Italian CE stories application in companies at the micro scale[11]. Moreover, also consumers/citizens show a positive attitude in engaging in circular behaviours that is also associated with an increase of their environmental awareness (Bianchini et al. 2021; Waste Watcher International Observatory 2020).

[10]Prato innovativa: green city, economia circolare, available at https://www.cittadiprato.it/IT/Sezioni/480/Economia-circolare/. Last accessed: 13/06/2021.

[11]CDCA, available at http://cdca.it/atlante-italiano-delleconomia-circolare/. Last accessed: 02/06/2021.

7.3 Municipal Solid Waste

In this section, we analyse the transition to CE in some of the key product's value chains evidenced in the EU Action Plan (electronics and ICT, packaging plastic and food). The analysis starts with municipal solid waste (MSW) and then widens on "plastic" as one of the relevant fractions of waste packaging composing MSW. After the analysis of MSW, the study evaluates the CE transition in waste electrical and electronic equipment (WEEE) value chain and finally in food supply chain.

7.3.1 Generation and Recycling of Municipal Solid Waste in EU

The most recent data from EUROSTAT evidence that the average amount of MSW generated annually per capita (pc) was 502 kg in EU, in the year 2019 (Fig. 7.3). The amount per capita (pc) changes across member states ranging from 280 kg/pc generated in Romania to 884 kg in Denmark. The latter with other countries shows an increasing trend in the period 2005–2019. On the contrary, Romania, Estonia, Hungary, Bulgaria, Sweden, Spain, Italy and the Netherlands evidence a decreasing trend of generated MSW per capita. These countries generated an amount of MSW pc similar or lower than the EU average. Italy generated 503 kg/pc in the year 2019 and occupies an average position in the EU. Besides economic development and consumption patterns, the amount generated is also affected by the collection and management of MSW.[12]

When it comes to the amount of waste and the different types of treatments (Fig. 7.4), the total amount of municipal waste landfilled has strongly declined over the years. In the period 1995–2019, such amount fell by 67 million tonnes, from 121 million tonnes (286 kg per capita) in 1995 to 54 million tonnes (120 kg per capita) in 2019. In that, the landfilling rate (landfilled waste as a share of generated waste) in the EU reduced from 61% in 1995 to 23% in 2019. The reduction is due to different factors including the adoption of two EU directives (Directive 62/1994 on packaging and packaging waste and Directive 31/1999 on the reduction of the amount of biodegradable waste going to landfill) and of the First Circular Economy Action Plan. The latter revised the legislative proposals on waste with a higher common target for the recycling of MSW and packaging waste and the reduction of landfilling for MSW[13].

The amount of MSW recycled (material recycling and composting) increased from 37 million tonnes (87 kg per capita) in 1995 to 107 million tonnes (239 kg per

[12] There are differences between countries regarding the degree to which waste from commerce, trade and administration is collected and managed together with waste from households. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Municipal_waste_statistics#Municipal_waste_generation.

[13] European Parliament, The circular economy package: New EU targets for recycling, available at https://www.europarl.europa.eu/news/en/headlines/society/20170120STO59356/the-circular-economy-package-new-eu-targets-for-recycling. Last accessed: 10/06/2021.

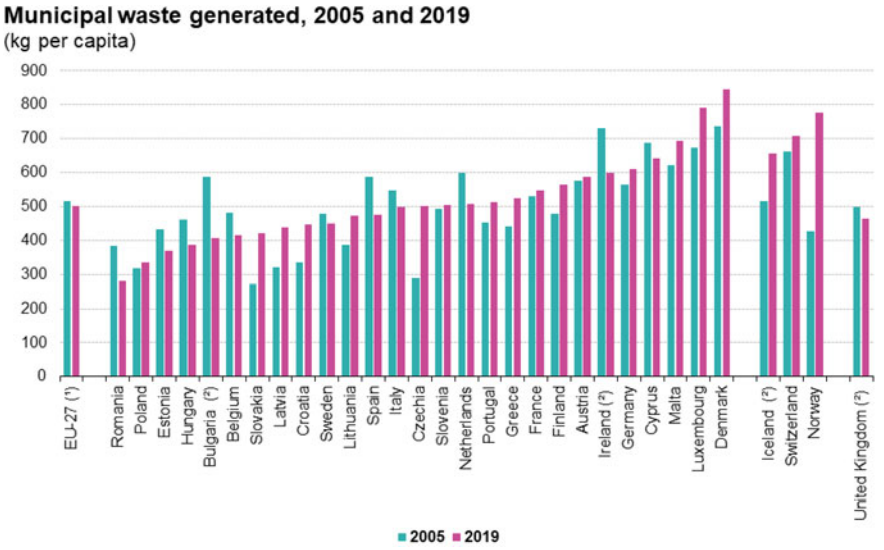

Fig. 7.3 Municipal waste generated per capita in the EU (years 2005 and 2019). Note: Countries are ranked in increasing order by municipal waste generation in 2019. (1) Estimated. (2) Bulgaria, Ireland and UK 2018 data and Iceland 2017 data. (Source: EUROSTAT (online data code: env_wasmun))

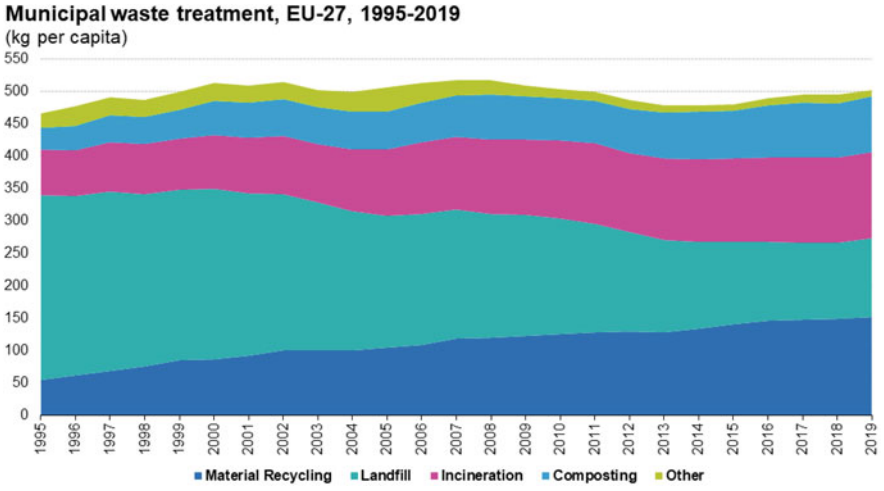

Fig. 7.4 Municipal waste by type of treatment in the period 1995–2019. Note: Estimated by Eurostat. (Source: EUROSTAT (online data code: env_wasmun))

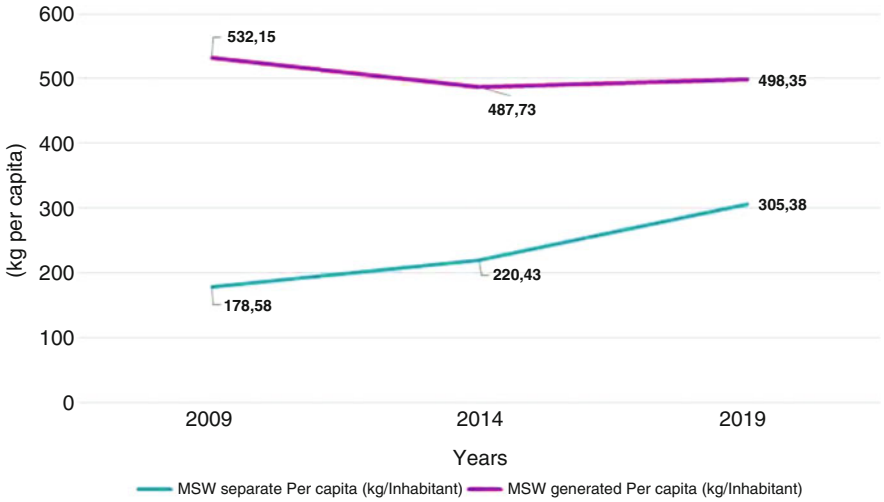

Fig. 7.5 Evolution of the amount of separate MSW and total MSW generated per capita in Italy. (Source of the data: ISPRA 2009, 2014, 2019)

capita) in 2019 at an average annual rate of 4.3%. In overall, the share of MSW recycled increased from 19% (year 1995), to 32.5% (year 2005), to 48% (year 2019).[14] With regard to the available data for Italy, the recycling rate increased from 18.5% to 51.4% from 2005 to 2019[15].

7.3.2 Generation and Management of MSW in Italy

The average national production of MSW per capita in Italy was 498.35 kg in the year 2019. Figure 7.5 shows that in the last decade, the trend of MSW generated per capita in Italy is decreasing, while the amount of separate MSW is increased over time shifting from 178.58 kg/per capita (year 2009) to 305.38 kg/per capita in the year 2019.

Across Italy, there are some differences between the geographical areas, with the Central Italy generating 543.12 kg per capita being well above the national average (Table 7.2). On the contrary, the average MSW generated in the southern area of the country is below the national average being 444.96 kg per capita. The average fraction of separate MSW that is collected and sent to recovery/recycling at national level is more than half of the total MSW generated (61.28% of the total MSW). Also,

[14]Municipal waste Statistics in the EU, available at https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Municipal_waste_statistics#Municipal_waste_treatment. Last accessed: 27/05/2021.

[15]EUROSTAT, available at https://ec.europa.eu/eurostat/databrowser/view/sdg_11_60/default/table?lang=en.

Table 7.2 MSW generated and separated in Italy at national level and in the three macro areas (north, centre and south). (Source of data: ISPRA, 2019)

Areas	Population (*n.*)	MSW separated (tonne)	MSW generated (tonne)	Percentage of MSW separated (%)	MSW separated (kg/pop.*year)	Per capita MSW gen. (kg/pop.*year)
North	27,774,970	10,021,294.61 tonne	14,398,682.47 tonne	69.6	360.8	518.4
Centre	11,986,958	3,761,965.27 tonne	6,510,345.53 tonne	57.78	313.84	543.12
South	20,482,711	4,614,058.82 tonne	9,114,005.34 tonne	50.63	225.27	444.96
National	60,244,639	18,397,318.69 tonne	**30,023,033.33 tonne**	**61.28**	**305.38**	**498.35**

The numbers in bold represent national data, while the other data pertain to specific areas of the country

in this case, there are differences between the northern area of the country where on average 69.6% of the total waste are separated, whereas in the southern area, only 50.63% of the total MW are separated and sent to recovery/recycling (ISPRA 2019).

With regard to the different materials composing the total MSW generated in the year 2019, a share of 38% of MSW is still unseparated. The most relevant fractions that compose the separate share of MSW are organic (24%), paper and cardboard (12%), glass (7%) and plastic (5%).

7.3.3 Generation and Recycling of Total Waste in the EU and Italy

Total waste produced in the EU (27 countries) was 2,248,790,000 tonnes in the year 2004. The evolution shows that after a decrease in the year 2008 (2,144,700,000 tonnes), total waste slightly increased reaching an amount of 2,336,760,000 tonnes in the year 2018 (+3.9%) (EUROSTAT 2021)[16]. Italy also increased the amount of total waste from 139,806,106 tonnes (year 2004) to 172,502,773 tonnes (+23.4%) (year 2018) (EUROSTAT 2021)[17].

The analysis of these data by economic activities in the year 2018 evidences that the most relevant sectors were construction and demolition with a share of 35.9%, followed by mining and quarrying (26.6%), manufacturing (10.6%), waste and water services (9.8%) and households (8.2%), and the rest (9.1%) mainly involves services (4.2%) and energy (3.4%) sectors (Fig. 7.6).

On average, in the year 2018, in the EU, 55% of all waste excluding major mineral waste was recycled compared to the total (EUROSTAT 2018).[18] The EU recycling rate slightly increased from the year 2010 when it was 53% of total waste produced. Italy shows higher recycling rates compared to the EU average shifting from a recycling rate by 60% in the year 2010 to a recycling rate by 67% in the year 2018 (Fig. 7.7).

With regard to Italy, the available data in national statistics for the year 2018 of the amount of waste produced by the economic activities are summarized in Fig. 7.8. The wastes produced are classified on the basis of the specific chapter of the European List of Waste (Commission Decision, 2000/532/EC)[19]. Figure 7.8 shows that most of the waste generated comes from C&DW in chapter

[16]EUROSTAT, available at https://ec.europa.eu/eurostat/databrowser/view/ENV_WASGEN/default/table?lang=en. Last accessed: 04/06/2021.

[17]EUROSTAT, available at https://ec.europa.eu/eurostat/databrowser/view/ENV_WASGEN/default/table?lang=en. Last accessed:07/06/2021.

[18]EUROSTAT, Recycling rates of all waste excluding major mineral waste, available at https://ec.europa.eu/eurostat/databrowser/view/cei_wm010/default/table?lang=en. Last accessed: 04/06/2021.

[19]Commission Decision of 18 December 2014 amending Decision 2000/532/EC on the list of waste pursuant to Directive 2008/98/EC of the European Parliament and of the Council (2014/955/EU), available at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014D0955&from=EN. Last accessed: 27/05/2021.

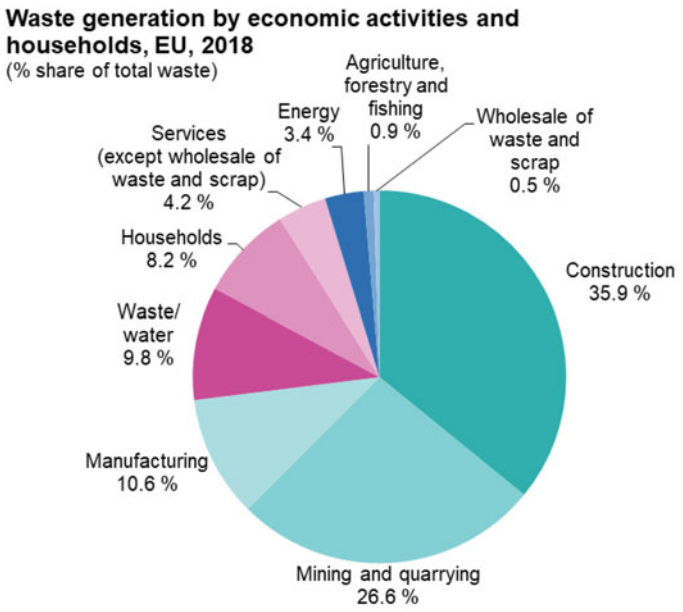

Fig. 7.6 Waste generation by economic activity in the EU (year 2018). (Source: EUROSTAT (online data code: env_wasgen))

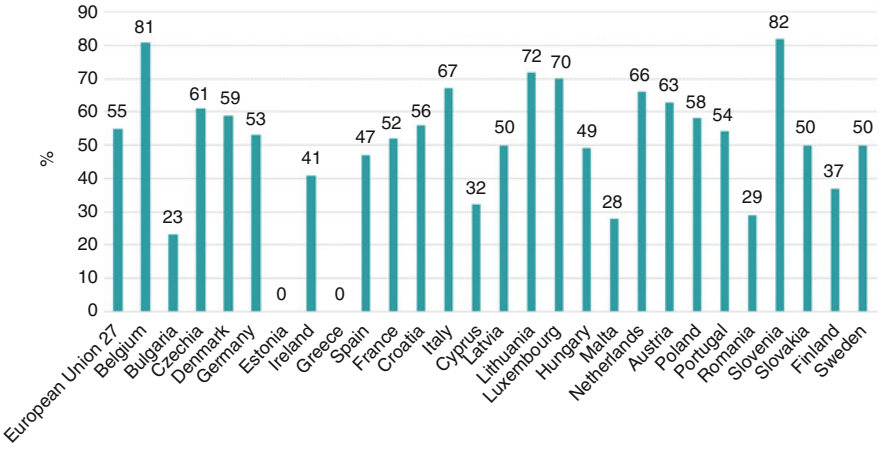

Fig. 7.7 Recycling rates of total waste excluding major mineral waste in the year 2018 in EU countries. (Source of the data: EUROSTAT 2018 (EUROSTAT, available at https://ec.europa.eu/eurostat/databrowser/view/cei_wm010/default/table?lang=en. Last accessed: 04/06/2021))

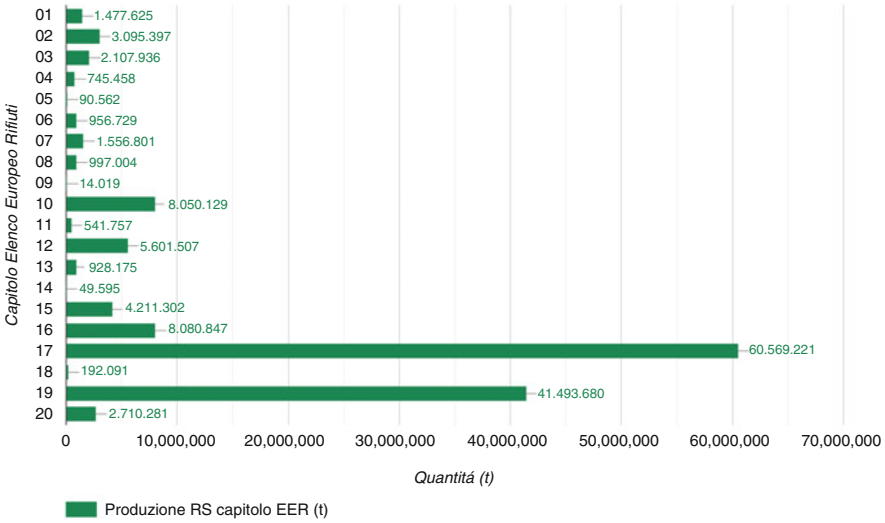

Fig. 7.8 Waste from all economic activities generated in Italy classified according to the chapter of the European List of Waste (vertical axes). (Source: ISPRA 2018 (National Cadastre of special waste, available at https://www.catasto-rifiuti.isprambiente.it/index.php?pg=prodrsnazione&aa=2018&atecocer=atecocer. Last accessed 04/06/2021))

17 (60,569,221 tonnes). Waste of the chapter 19 identifies waste from waste management facilities, off-site wastewater treatment plants and the preparation of water intended for human consumption and water for industrial use (41.493.680 tonnes), waste from thermal processes (chapter 10 with an amount of 8.050.129) and waste from chapter 12 including waste from shaping and physical and mechanical surface treatment of metals and plastic (5.601.507 tonnes).

In Italy, in accordance with the current legislation (Legislative Decree No. 152/2006), waste is classified on the basis of their origin as municipal waste and special waste. The latter category gathers waste coming from construction and demolition; agricultural, industrial and manufacturing activities; commercial services; and the recovery and disposal of waste from sanitary activities (ISPRA 2019). Moreover, depending on their dangerousness, waste is defined as hazardous and non-hazardous waste (ISPRA 2019).

The total special waste produced in Italy increased by 11% from 129.314.201 tonnes in the year 2014 to 143.479.702 tonnes in the year 2018 (ISPRA 2018)[20].

[20] National Cadastre of Special Waste, available at https://www.catasto-rifiuti.isprambiente.it/index.php?pg=prodrsnazione&aa=2018&atecocer=atecocer. Last accessed: 04/06/2021.

7.3.4 Generation and Recycling Rate of Packaging Waste in EU and Italy

Over the last decade, both the total and individual quantity of generated waste packaging in EU increased compared to the year 2008. After achieving a minimum in 2009 during the economic crisis with 149.9 kg per capita, the generated waste packaging increased almost every year achieving 174 kg per capita in 2018. The total quantity of generated packaging waste in EU was 77.7 million tonnes in the year 2018.[21] Figure 7.9 shows the amount of generated and recycled waste packaging per capita. The first indicator ranges from 67.8 kg/pc in Croatia to 227.5 kg/pc in Germany. Italy generated in 2018 an individual quantity (211.2 kg/pc) higher than the EU average (174 kg/pc). With regard to recycled waste packaging pc, Italy recorded in the year 2018 one of the highest recycled amounts with 140.1 kg pc, much higher than the EU average. In the period 2008–2018, the generated waste packaging pc in EU increased by 7.7%, while the recycled waste packaging pc increased by 18.2%.

In terms of packaging waste composition, Fig. 7.10 shows that "paper and cardboard" has by far the highest share (40.9%) in waste packaging materials

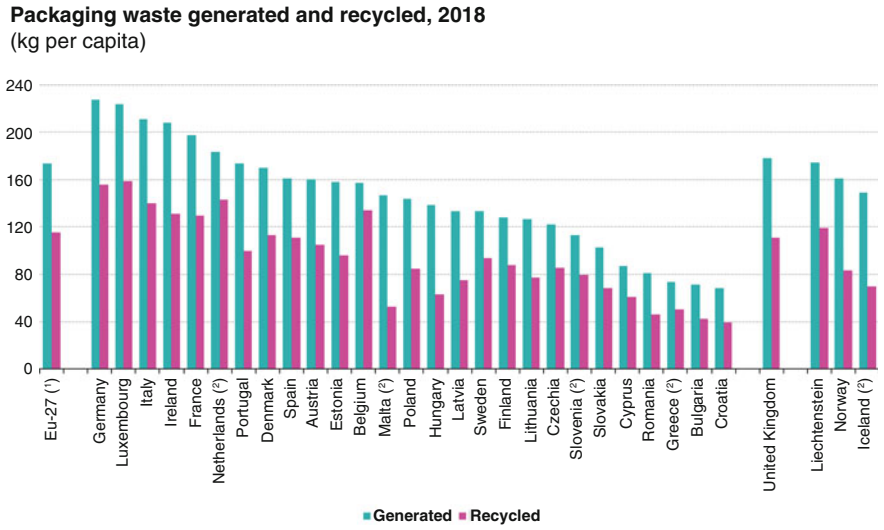

Fig. 7.9 Packaging waste generated and recycled in 2018. Note: Countries are ranked based on "Waste Generated". (1) Eurostat estimates. (2) 2017 data instead of 2018. (Source: EUROSTAT (online data code: env_waspac))

[21] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Packaging_waste_statistics.

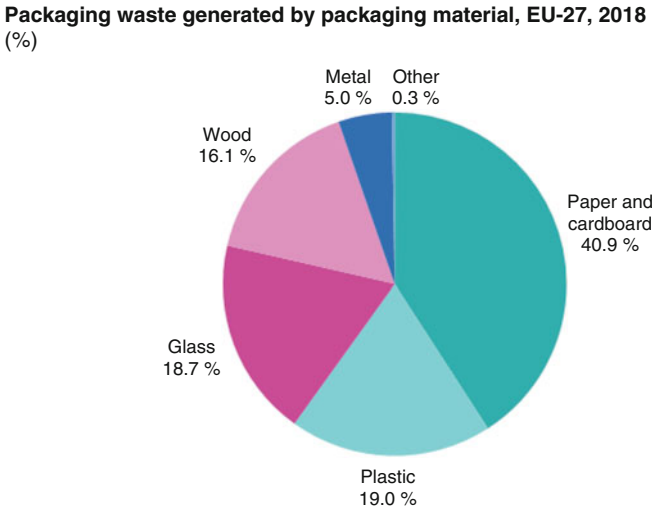

Fig. 7.10 Packaging waste generated by packaging material in the year 2018. Note: Eurostat estimates. (Source: EUROSTAT (online data code: env_waspac))

followed by "plastic" (19.0%), "glass" (18.7%), "wood" (16.1%) and "metal" (5.0%).

When it comes to the treatment for packaging waste after their use, the most common form in the EU is recycling including material recycling and other forms of recycling (e.g. organic recycling) (Fig. 7.11), while energy recovery represents a limited treatment.

The Article 6 of the Packaging Waste Directive (94/62/EC) defined the recovery and recycling targets for packaging waste by the year 2008 as well as the recycling targets by the years 2025 and 2030.

Figure 7.12 shows that in the year 2018, the target of 55% for the year 2008[22] set by the Packaging Waste Directive (94/62/EC)[23] was achieved by almost all of the member states except Hungary (46.1%) and Malta (35.6%, 2017 data). The Packaging Waste Directive (94/62/CE) sets a target of 65% to be met by 2025[24].

According to the latter, by 2025, the different packaging waste materials must be recycled as follows: 50% of plastic, 25% of wood, 70% of ferrous metals, 50% of aluminium, 70% of glass and 75% for paper and cardboard. The recycling rate for

[22] The Article 6 of the Directive 94/62/CE set that no later than 31 December 2008 between 55% as a minimum and 80% as a maximum by weight of packaging waste will be recycled.

[23] European Parliament and Council Directive 94/62/EC of 20 December 1994 on packaging and packaging waste, available at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:01994L0062-20180704&from=EN.

[24] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Packaging_waste_statistics#Waste_generation_by_packaging_material.

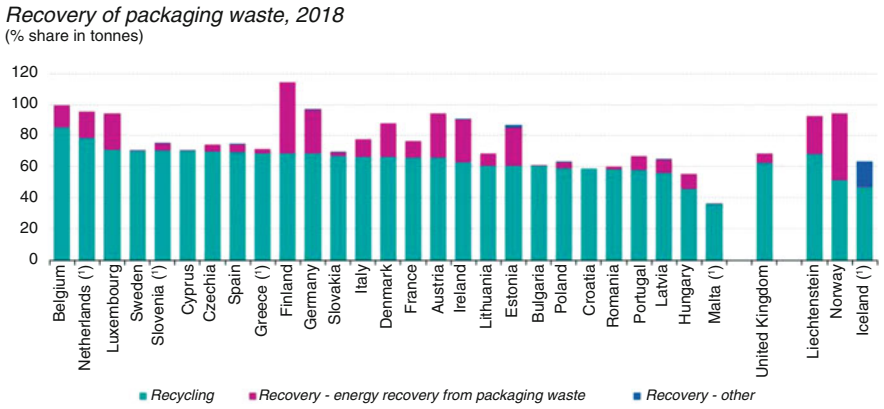

Fig. 7.11 Recycling and recovery of packaging waste in the year 2018 in EU. Note: Countries are ranked based on the share "Recycling". (1) 2017 data instead of 2018. (Source: EUROSTAT (online data code: env_waspac))

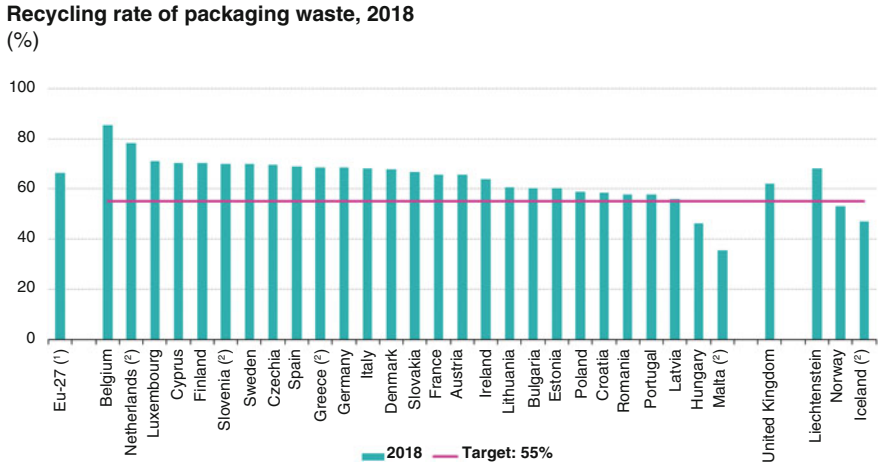

Fig. 7.12 Recycling rates of packaging waste for the EU countries and target of 55% set by the Packaging Waste Directive (94/62/EC). (1) Eurostat estimates. (2) 2017 data instead of 2018. (Source: EUROSTAT (online data code: env_waspacr) (EUROSTAT, available at https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Packaging_waste_statistics#:~:text=In%20the%20EU%2C%20the%20recycling%20rate%20of%20packaging,%25%20in%202008%20to%2080.9%20%25%20in%202018. Last accessed: 04/06/2021))

packaging waste for the EU 27 was 66%, while the one for Italy was a little higher being 68.3%.

The EU Action Plan evidences that the EC will review the Directive 94/62/EC by strengthening the mandatory essential requirements of packaging with the purpose

of assuring the reusability/recyclability of all packaging in the EU market at viable costs. Moreover, other measures in the review of the directive that will be considered by the EC are those related to the following aspects:

- Reduction of overpackaging and packaging waste by setting targets and other waste prevention measures
- Strengthen of design for reuse and recyclability of packaging. Limits to the use of packaging for specific applications in particular in case of reusable products or consumer goods that can be provided safely without packaging
- Reduction of the complexity of packaging materials in terms of number of used materials and polymers
- Assessment of the feasibility of EU-wide labelling to enhance the correct separation of packaging waste at the source
- Definition of rules for the safe recycling for food contact materials made of plastic
- Monitoring and support of the implementation of the Drinking Water Directive and its requirements for making drinkable tap water accessible in public places and reduce the use of bottled water and prevent packaging waste

7.3.5 Recycling Rates of Plastic Packaging Waste in EU

Worldwide plastic waste is raising much concern due to the negative effects that its poor management and subsequent release have on the environment and human health. Deposits of plastics and microplastics are increasingly found in land, rivers and oceans[25]. Thus, an improvement of waste management including the associated infrastructure is essential to avoid that uncontrolled plastic waste will enter in the oceans from the land[26].

In EU, about 40% of whole plastic produced is mainly used as a raw material for packaging. The main types of plastic for packaging are polypropylene (PP), high-density polyethylene (PE-HD), low-density polyethylene (PE-LD), linear low-density polyethylene (PE-LLD) and polyethylene terephthalate (PET). At the end of life, plastic packaging waste is recycled as a material (42%) or undergoes energy recovery (39.5%), while the rest is landfilled (Plastic Europe 2020). With regard to the recycling rates of plastic packaging waste, the average in EU was 41.5% in the year 2018, while Italy recycled 44.6% of all plastic packaging waste (Fig. 7.13) (EUROSTAT 2018), and the rest was treated as energy recovery (43%) and landfilling (12.5%) (Plastic Europe 2020). It is important to mention that over the period 2006–2018, the plastic packaging waste sent to landfill strongly reduced from 883 kilotons (year 2006) to 287 kilotons (year 2018).

The EU lacks the capacity of managing the increasing amount of plastic waste generated in a circular and sustainable manner calling for the need to reduce its

[25] https://www.eea.europa.eu/publications/the-plastic-waste-trade-in.

[26] https://www.earthday.org/plastic-pollution-and-management-of-waste/.

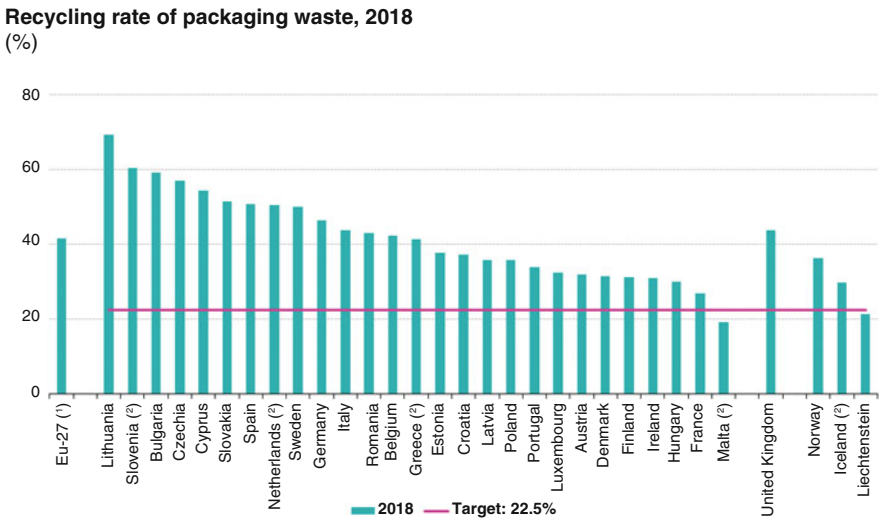

Fig. 7.13 Recycling rate for plastic packaging waste in EU. (1) Eurostat estimates. (2) 2017 data instead of 2018. (Source: EUROSTAT 2018 (online data code: env_waspacr))

generation[27]. The EU has also adopted in 2018 the "Plastic Strategy" that is an important part of the current CE Action Plan as well as of the whole EU Green Deal. Therefore, the CE contribution is also expected to be central in the achievement of the goals by 2030 of the Paris Climate Agreement, the Sustainable Development Goals and the EU's industrial policy objectives[28].

7.3.6 Collection and Recycling of Plastic Packaging Waste in Italy

In Italy, the collected plastic packaging waste comes from two different main flows: municipal waste and waste from economic activities (agriculture, industry and services). Municipal waste considers the collection of plastic packaging waste from the households. However, depending on the municipality, also part of the plastic packaging waste from services and industrial sectors are managed along with municipal waste from households. After the collection, the plastic packaging waste is sent to the selection plants and finally to the recycling plants. These two stages are also be managed by the Consortia such as "COREPLA[29]" if the

[27] https://www.eea.europa.eu/publications/the-plastic-waste-trade-in.

[28] https://ec.europa.eu/environment/strategy/plastics-strategy_en#:~:text=The%20EU%20adopted%20a%20European%20strategy%20for%20plastics,transition%20towards%20a%20carbon%20neutral%20and%20circular%20economy.

[29] COREPLA, National Consortia for the collection, recycling and recovery of plastic packaging waste, available at https://www.corepla.it/. Last accessed: 04/06/2021.

municipality has previously been involved in the Agreement with the Consortia. In the year 2019, about 35 selection plants and 77 recycling plants have treated the selected amount of plastic packaging waste generated in Italy. The plants for selection and recovery could also include the recycling. This "all-in-one" solution on the same industrial site is often the most suitable solution to maximize the resource recovery, as well as reduce the logistical, economic and environmental costs. However, the aspects related to specialization and the achievement of economies of scale are also taken into account to make very efficient the integrated systems (Italia del Riciclo 2020).

With regard to the market opportunities of recycled materials from packaging waste, the materials of the CPL family (Plastic Containers for Liquids) based on PET and HDPE are products with a consolidated quality with many and reliable applications. New technologies and experience in recycling make the market for materials derived from plastic waste packaging (flakes and granules ready for the "putting in the car") now essential for some applications. In particular, the recycled materials from CPL PET-based are now also used for the production of packaging for food use (trays and bottles). The recycling industry has developed decontamination and recovery processes that make recycled materials safe in contact with food (Italia del Riciclo 2020).

7.3.7 Scaling Up the Waste Hierarchy: Case Studies of Plastic Waste Packaging Reduction in Italy

The search of organizations by category "packaging" in the Atlas of the CE platform brings out 12 organizations. The evaluation of the circular practices and stories of such organizations evidences how the latter achieve in different ways the common goal of reducing plastic waste packaging. The different practices can be identified and grouped in the following:

1. Product substitution and expansion of the range of products to include packaging made of other materials than plastic:
   (a) **Cartonspecialist**: **biodegradable, compostable and recyclable products for the food sector**. The company produces food packaging products (dishes, glasses and other types of food packaging for take-away food) with lower environmental impact. The products are made of cardboard mono-material that is biodegradable, recyclable and compostable and are substitute of food packaging made of plastics[30].
   (b) **Napoletana Plastica: regenerated polyethylene bags for separate solid urban waste collection**. This company produces and distributes conventional and more sustainable bags and other products for urban separate

[30]Cartonspecialist, available at https://economiacircolare.com/atlante/cartonspecialist/. Last accessed: 03/06/2021.

collection made of plastic or biomaterials. The company also produces bags with a barcode that allows the traceability of waste contained in the bags from the urban collection stage (households) until the recycling stage. The production processes in the company is designed for the internal recycling of the scraps that become input for its products. Finally, the company organizes educational programmes for children aimed to promote best practices of recycling by means of laboratories of "eco-mosaic"[31].

(c) **Ecoplasteam: recycling of polylaminates in polyethylene and aluminium to produce EcoAllene, a secondary raw material**. This is a start-up that produces and distributes an innovative material named "EcoAllene" coming from the recycling of waste packaging materials used for producing food and drink packaging made up of polylaminates, PO-AL (plastic-aluminium) (well-known as "Tetra Pak"). Such containers were previously disposed of in landfills (as they are made of layers of cellulose, plastic and aluminium), incinerated or partially recycled by separating the three components. However, such process faces high cost and energy consumption and generates a low quality of the materials[32]. The innovative EcoAllene is a secondary raw material totally recyclable and is also certified "Remade in Italy", Class A[33]. The company also optimizes the use of energy and water. The water used in the process of cleaning of the raw material composing "EcoAllene" is reused, thanks to a purification and recycling system that allows the reuse of 50% of the water resource of the process of cleaning[34].

(d) **100% Campania: sustainable packaging in recycled cardboard**. It is a network of companies supporting the local recycling of paper waste for packaging and other products as well as the adoption of closed-loop cycles by the clients. This involves helping the latter to reuse or recycle their paper waste in closed-loop cycles. Since 2013, it has brought together six companies in a green district in the form of an integrated paper supply chain that offers packaging with a lower environmental impact in the whole life cycle. The latter starts from the recovery of waste paper to the finished product. The waste paper is sent to the paper mill of the network to be recycled and become, after a particular process, a new type of secondary raw material suitable for industrial use named "Greenpaper". The latter is then used for producing a new paper packaging "GreenboxX" made by the box factories of the network and distributed to their clients. GreenboxX is also FSC and EPD certified and communicates reliable and comparable data

[31] Napoletana Plastica, available at https://economiacircolare.com/atlante/napoletana-plastica/. Last accessed: 03/06/2021.

[32] Ecoplasteam, available at https://www.ecoplasteam.com/en/. Last accessed: 03/06/2021.

[33] Product Certification "Remade in Italy", product "EcoAllene", available at https://www.remadeinitaly.it/portfolio/ecoallene-ba20c05ap/. Last accessed: 03/06/2021

[34] Ecoplasteam, available at https://economiacircolare.com/atlante/ecoplasteam/#field-group-tab-4. Last accessed: 03/06/2021.

on resource and CO_2 savings, improving the transparency and the information available to the stakeholders about the environmental impacts and its origin in a local closed-loop recycling. The network also promotes the research and development of new types of materials and processes needed for the production of sustainable packaging, new market opportunities for the recycling of local pulp and develop sustainability projects whose goal is the progressive reduction of the GHG emissions and the environmental impacts of the participating companies and their products. Dissemination campaigns are used to inform citizens and institutions of the environmental and economic benefits for the territory of a local paper reuse/recycling cycle and encourage the quantity and quality of separate waste collection. All the companies of the network have one or more of the following certification schemes: ISO 9001 and 14001, SA 8000 (Social Accountability), FSC (Forest Stewardship Council), Environmental Product Declaration, Carbon Trust Standard and British Retail Consortium[35].

2. Product substitution and reduction of packaging per product:
   (a) **Bio al Sacco: a shop that minimizes waste generation, products without packaging and organic, short-chain products**. The food shop has been created with the aim of reducing packaging (and in particular plastic) and then waste. The shop also promotes organic agriculture, products coming from short food chains or zero kilometres as well as a daily menu (e.g. for breakfast) with quality products that are heathier and environmentally sustainable at affordable prices. The shop also participates to the European Week for Waste Reduction (EWWR) that is the biggest initiative in Europe favouring waste prevention by bringing together all the most social actors—citizens, schools, businesses, NGOs and associations—who organize activities to raise awareness about the importance of adopting waste reduction[36].
   (b) **Solo Peso Netto: shop of bulk products**. The shop has been founded in December 2017 with the aim of reducing in particular the use of packaging and plastic. Almost all the products in the shop are bulk and range from food products (such as pasta, rice, from legumes to cereals, honey) to liquid and solid household and personal hygiene products, as well as tea and herbal teas, spices, candies and pet food. Customers are encouraged to come to the store with their containers and reuse them in order to reduce the amount of waste packaging. Those who come to the shop without containers are provided with paper bags and containers for liquid products. Another key principle of the activity is quality, thanks to a careful selection of suppliers, which favours organic producers. The core business of "Solo Peso Netto" is the sale of bulk

[35] 100% Campania, available at https://economiacircolare.com/atlante/100-campania/. Last accessed: 03/06/2021.

[36] Bio al Sacco, available at https://economiacircolare.com/atlante/bio-al-sacco/. Last accessed: 03/06/2021.

products and partly local products from Tuscany. Customers can also purchase creams and toothpastes made in the laboratory of the shop and packaged in salvaged glass jars[37].

3. Product substitution and creative reuse:
   (a) **Palm Design: design products and containers from certified surplus wood**. The company focuses on the production of packaging products designed for upcycling or creative reuse after the end of life. For example, the wood and wine packaging line comprises containers, packaging and wooden objects handmade on the basis of the clients' requirements. The packaging products of such line are made of surplus wood (coming from a certified and legal supply chain), and after the first use, they can be reused for many other purposes adhering in this way to the principles of waste reduction and prevention[38].
4. Plastic packaging reuse:
   (a) **Scutaro Vincenzo & Figlio: industrial packaging and reuse**. The company sells industrial packaging (small tanks, plastic drums, plastic cans and iron drums) as well as restores them. The industrial packaging in plastic and iron are collected dirty from the clients, and after a washing process, they are reintroduced into the industrial market for a new reuse. All unsuitable packaging is recycled as a secondary raw material. The production process has also obtained its own patent. All the packaging of the company conform to the existing mandatory regulation (D.Lgs. 2005 n.152) including the technical standards for environmental labelling of packaging (UNI 10667) and the decisions of the European Commission[39]. The company has also adopted certification schemes such as ISO 9001/14001 and OHSAS 18001. Moreover, it also employs local workers and those falling into protected categories and promotes training and the continuous updating of safety standards in the workplace[40].
5. Academic research on waste packaging reuse:
   (a) **AWARE (Assessment on Waste and Research) academic research group: mapping of packaging reuse practices and research on waste management systems and technologies.** Besides the mapping of packaging systems, the research group also studies the environmental performance of waste management systems by means of the life cycle thinking approach and assessment methods (e.g. LCA). The current research performed by the AWARE team on behalf of the National Packaging Consortium consists in

[37] Solo Peso Netto, available at https://economiacircolare.com/atlante/solo-peso-netto/#field-group-tab-3. Last accessed: 03/06/2021.

[38] Palm Design, available at https://economiacircolare.com/atlante/palm-design/. Last accessed: 03/06/2021.

[39] Vincenzo Scutaro e Figlio, available at http://www.scutarosrl.com/etichettatura-ambientale-imballaggi/. Last accessed: 11/06/2021.

[40] Vincenzo Scutaro e Figlio, available at https://economiacircolare.com/atlante/scutaro-vincenzo-figlio/#field-group-tab-3. Last accessed: 03/06/2021.

the mapping and the environmental assessment of reusing packaging. This option is considered in the waste hierarchy as a preferable solution to recycling in terms of reduction of the amount of waste generated and increase of the efficiency in the use of natural resources. The project aims above all to collect uniform and reliable data on the reuse of packaging in the Italian context and propose guidelines for the continuous monitoring of the system. The analysis considers packaging of any materials that can be reused in the business-to-business or business-to-customer contexts after a possible recovery process[41].

7.4 Waste Electrical and Electronic Equipment (WEEE)

WEEE comprises a wide range of materials of different economic and environmental values. Estimates evidence that about 60% of their weight is made of rare earth metals (lanthanum, cerium, praseodymium, neodymium, gadolinium and dysprosium); precious metals including gold, silver and palladium and other metals with high intrinsic value (such as copper, aluminium or iron); plastics (about 15% by weight); and glass (Ibanescu et al. 2018; GWMO 2015). The valorization of these materials in a sustainable manner (compared to the disposal in landfills or waste to energy) (Remedia 2019) provides relevant benefits for the environment and the economy (Bressanelli et al. 2020; Ibanescu et al. 2018). WEEE also contains toxic materials and metals[42] (European Commission 2019a, b) and for this reason should be properly managed as it could be a source of risks for human health and the environment (Perkins et al. 2014).

The EU has adopted two relevant directives (the WEEE Directive and RoHS Directive) in order to regulate and improve the management of WEEE. Both directives have undergone a process of revision over time on the basis of the proposal of the European Commission (European Commission 2019a). The first WEEE Directive (Directive 2002/96/EC), which entered into force in February 2003, contributed to the creation of WEEE collection schemes (free of charge for the consumers) with the purpose of increasing their reuse or recycling[43] (European Commission 2019a, b). In 2008, the European Commission proposed to revise the first WEEE Directive to address the fast-increasing WEEE stream. The new WEEE

[41] AWARE, available at https://economiacircolare.com/atlante/aware/#field-group-tab-2. Last accessed: 03/06/2021.

[42] Toxic materials contained in WEEE include, e.g. brominated flame retardants from plastics; lead-containing glass; ozone-depleting substance as chlorofluorocarbons contained by cooling agents from refrigerators/air conditioners as well as toxic metals, cadmium, copper, lead and chromium; and persistent organic pollutants (dioxins, dibenzofurans, polyvinyl chloride, polycyclic aromatic hydrocarbon) (Ibanescu et al. 2018).

[43] Directive 2002/96/EC, available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32002L0096.

Directive 2012/19/EU entered into force on 13 August 2012 and became effective on 14 February 2014[44]. Its overall aim, underlined at the Preambular paragraph 6 of the directive, is "to contribute to sustainable production and consumption by, as a first priority, the prevention of WEEE and, in addition, by the re-use, recycling and other forms of recovery of such wastes so as to reduce the disposal of waste and to contribute to the efficient use of resources and the retrieval of valuable secondary raw materials. It also seeks to improve the environmental performance of all operators involved in the life cycle of Electrical and Electronic Equipment, e.g. producers, distributors and consumers and, in particular, those operators directly involved in the collection and treatment of WEEE" (Directive 2012/19/EU).

The first RoHS Directive (2002/95/EC) was aimed to limit the use of hazardous substances in electrical and electronic equipment, and in particular cases, heavy metals (lead, mercury, cadmium and hexavalent chromium) and flame retardants (polybrominated biphenyls (PBB) or polybrominated diphenyl ethers (PBDE)) required their substitution with safer alternatives[45]. The RoHS 2 Directive 2011/65/EU[46] has been introduced on the basis of the proposal of the European Commission on December 2008 becoming effective on 3 January 2013. Further, in January 2017, the Commission adopted a legislative proposal to introduce adjustments in the scope of the RoHS 2 Directive, supported by the impact assessment. The respective legislative act amending the RoHS 2 Directive, adopted by the European Parliament and the Council, has been published in the Official Journal on 21 November 2017 (European Commission 2019b)[47].

The WEEE Directive 2012/19/EU covers all electrical and electronic equipment (EEE) (extended to photovoltaic panels) used by consumers and EEE intended for professional use.[48] Until 2015, the minimum collection target (4 kg/per capita/year) only regarded WEEE from private households, whereas from 2016 onwards, the collection target covered both types of WEEE: from households and other subjects[49] (European Commission 2014).

The Directive 2012/19/EU, among others, established minimum collection rates for WEEE in EU. These have been transposed in Italy with the Decree

[44] Directive 2012/19/EU, available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32012L0019.

[45] RoHS Directive 2002/95/EC, available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32002L0095.

[46] RoHS 2 Directive 2011/65/EU, available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32011L0065.

[47] http://ec.europa.eu/environment/waste/rohs_eee/index_en.htm.

[48] From 15 August 2018, subject to paragraphs 3 and 4, to all EEE. All EEE shall be classified within the categories set out in Annex III. Annex IV contains a non-exhaustive list of EEE which falls within the categories set out in Annex III (open scope).

[49] "commercial, industrial, institutional and other sources which, because of its nature and quantity, is similar to that from private households", https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:02012L0019-20180704, last accessed: 11/06/2021.

49/2014 (Decree Law 49 2014)[50], and the Art. 14 underlined the following target set by the directive:

- By 31 December 2015, an average rate of WEEE collected from households equal to 4 kg/per capita/year should have been achieved.
- From 1 January 2016 a minimum rate of 45% of WEEE collected calculated on the basis of the total weight of the WEEE collected in a given year and expressed as percentage of the average weight of EEE products put on the market in the three preceding years. From 1 January 2016 to 31 December 2018, the amount of WEEE collected should increase gradually to achieve the final rate of collection indicated for the year 2019.
- From 2019 the minimum rate of 65% of the average weight of EEE products put on the market in the three preceding years or in alternative should be achieved a minimum rate by 85% of the weight of WEEE produced at national level.

Figure 7.16 shows total collection rates in the year 2017 as a share of the EEE put on the market in the EU. From the reference year 2016 onwards, the annual collection target is defined "as the ratio between the collected amount and the average weight of EEE put on the market in the three preceding years"[51]. "The collection target is set at 45% for reference year 2016 (as reported in 2018) and will rise to 65% for reference year 2019 (to be reported in 2021)"[52]. The collection rates in Fig. 7.14 are calculated as the ratio of the amount of collected WEEE in 2017 in relation to the average amount of EEE put on the market in the three preceding years as, for example, 2014–2016. The collection rates calculated for each one of the EU member states allow the comparison with the two targets of 45% and 65% set by the WEEE Directive (2012/19/EU). The data show that more than half of the EU member states (Bulgaria, Croatia, Estonia, Sweden, Hungary, the UK, Ireland, Portugal, Slovakia, Luxembourg, Czechia, Austria, Denmark, the Netherlands, Finland, Poland, France and Germany) had collection rates beyond the 45% target in 2017, while Italy and other countries, such as Lithuania, Belgium, Greece, Slovenia, Romania and Malta, were below the 45% target. Moreover, Bulgaria and Croatia by reaching an amount of collected WEEE of 79.4% and 81.6%,

[50] The Decree 49/2014 by transposing the Directive 2012/19/EU further promotes the principle of producers' responsibility for the management of WEEE (that was also carried out in the previous Decree 151/2005) that applies to the first (producer, importer or distributor) who put on the Italian territory the EEE. Responsibility entails the financing and management of the recovery and recycling system of the WEEE. As such, the responsibility ends up only when WEEE are treated adequately and transformed into secondary materials. However, the responsibility of the producer is collective as it is proportional to the market share of the producer. Consequently, producers have created the collective systems that are associations of producers (Remedia 2019).

[51] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Waste_statistics_-_electrical_and_electronic_equipment#EEE_put_on_the_market_and_WEEE_collected_in_the_EU.

[52] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Waste_statistics_-_electrical_and_electronic_equipment#EEE_put_on_the_market_and_WEEE_collected_in_the_EU.

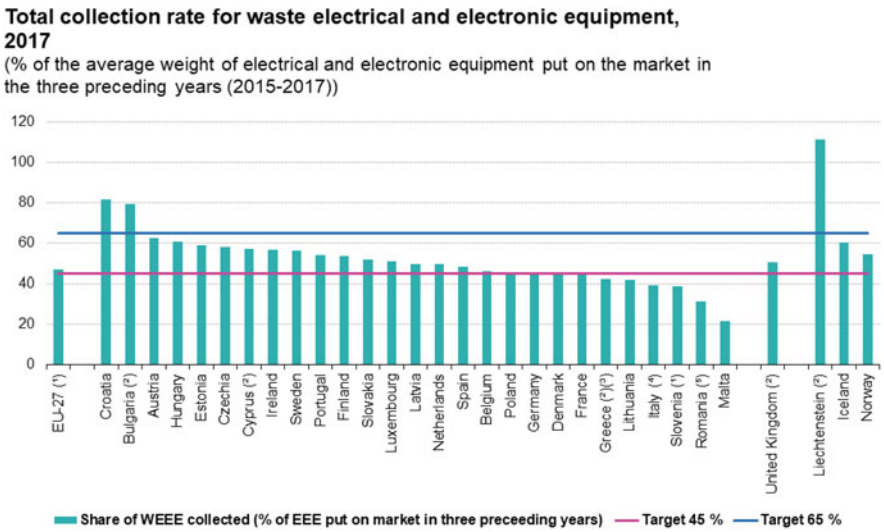

Fig. 7.14 Total collection rate for waste electrical and electronic equipment in 2017 as a percentage of the average weight of EEE put on the market in the three preceding years (2013–2015) (%). (1) Eurostat estimates. (2) Definition differs. (3) Estimate. (4) Data on collection 2015 instead of 2017; % of average weight of EEE put on the market 2013–2015. (5) Data on collection 2016 instead of 2017; % of average weight of EEE put on the market 2014–2016. (Source: EUROSTAT (online data code: env_waselee) (available at https://ec.europa.eu/eurostat/statistics-explained/index.php/Waste_statistics_-_electrical_and_electronic_equipment#EEE_put_on_the_market_and_WEEE_collected_in_the_EU))

respectively, had already reached in 2017 the new 65% target that became effective from the reference year 2019 onwards.

7.4.1 E-Products Put on the Market and Generation and Recycling of WEEE in the EU

Figure 7.15 shows the amount of EEE (such as computers, TV sets, fridges and cell phones), sold in the last decade in EU (EUROSTAT 2017). The sold EEE has grown rapidly due to the continuous and fast development of new technologies and the attitude of consumers to devote larger shares of their income to buy hi-tech products of the last generation (Ecolight 2019; Isernia et al. 2019). The lifetimes of EEE products have also reduced dramatically over the years (Bhutta et al. 2011). The amount of EEE put on the market in the EU was 7.3 million tonnes in 2013. From such year onwards, the amount of EEE put on the market strongly increased, reaching 9.0 million tonnes in 2017 (+24.1%). More or less the same trend can be observable for WEEE being collected, treated or recycled or undergoing to energy recovery.

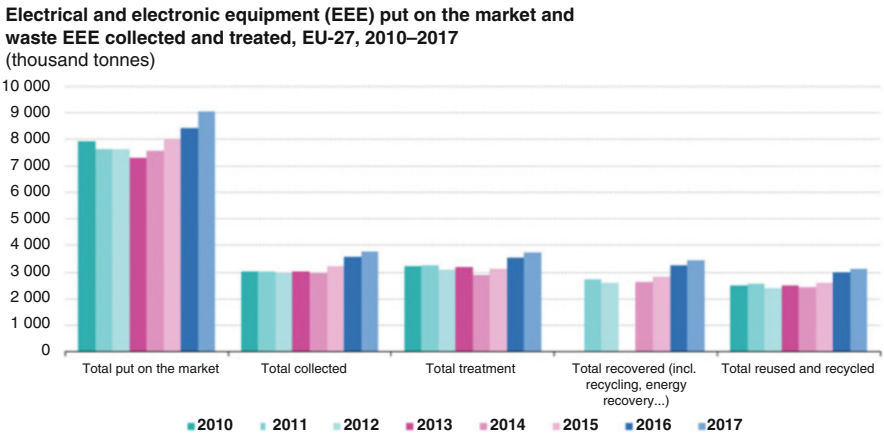

Fig. 7.15 Evolution of the amount of EEE put on the market and waste EEE collected and managed in the EU. Note: 2010, 2016 and 2017 data, as well as 2011 data for reused and recycled EEE waste: Eurostat estimates. (Source: EUROSTAT (online data code: env_waselee))

As for the recycling rates for WEEE, in the EU 27, it was 27.9% (year 2010) and 38.9% (year 2018), while for Italy, it was 27.8% (year 2010) and 32.1% (year 2015 as the latest available data) (EUROSTAT 2018)[53]. The recycling rates for both the EU and Italy increased over time.

An important aspect of WEEE management in EU is the relevant heterogeneity among member countries. Figure 7.16 shows how the WEEE collection rates per capita change across EU ranging from 2.4 kg per capita in Romania (year 2016) to 14.1 kg per capita in Sweden and 18.7 kg per capita in Norway. In 2016, compared to 2008, the total amount of collected WEEE per capita changed substantially for some countries such as the UK that almost doubled the collection rate as well as Liechtenstein. On the other side, some countries such as Italy reduced the amount of WEEE collected shifting from 7.6 kg to 6.3 kg per capita in 2017, resulting in below the EU 27 average in 2017 (8.4 kg per capita).

Finally, Fig. 7.17 shows the composition of WEEE collected into the main EEE categories. In the year 2017, the category "Large household appliances" has a share of 51.8% compared to the total WEEE collected (accounting 1.9 million tonnes). Then followed "Consumer equipment and photovoltaic panels" (14.8%) and "IT and telecommunications equipment" (14.6%) accounting about 555,000 tonnes and 547,000 tonnes, respectively, and "Small household appliances" contributed almost 383,000 tonnes and a share of 10.2% of total collected WEEE in the EU in 2017. The last category, "Other waste EEE", totalled almost 327,000 tonnes, corresponding to a share of 8.7% of WEEE collected.

[53] EUROSTAT, available at https://ec.europa.eu/eurostat/databrowser/view/cei_wm050/default/table?lang=en. Last accessed: 04/06/2021.

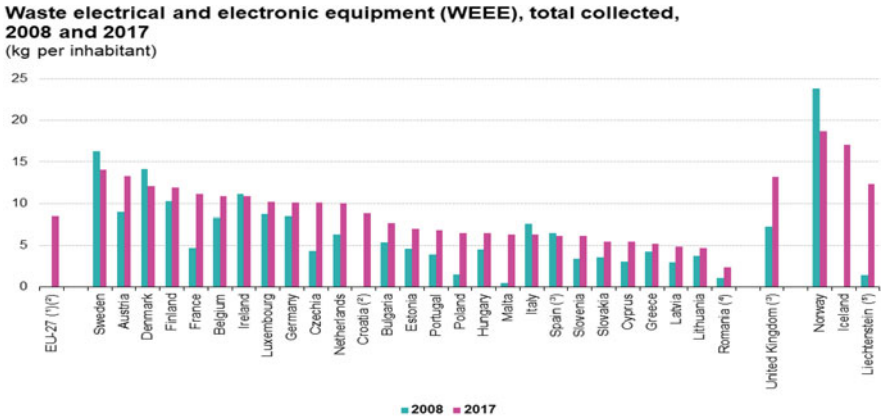

Fig. 7.16 WEEE collection rates per capita (kg/per capita) in EU 28 in 2008 and 2017. Note: Countries are ranked based on 2017 data. (1) Eurostat estimates. (2) 2008 data not available. (3) 2008 data: Eurostat estimate. (4) 2016 data instead of 2017. (5) Definition differs. (Source: EUROSTAT (online data code: env_waselee) (available at https://ec.europa.eu/eurostat/statistics-explained/index.php/Waste_statistics_-_electrical_and_electronic_equipment#EEE_put_on_the_market_and_WEEE_collected_in_the_EU and https://ec.europa.eu/eurostat/statistics-explained/index.php/Waste_statistics_-_electrical_and_electronic_equipment))

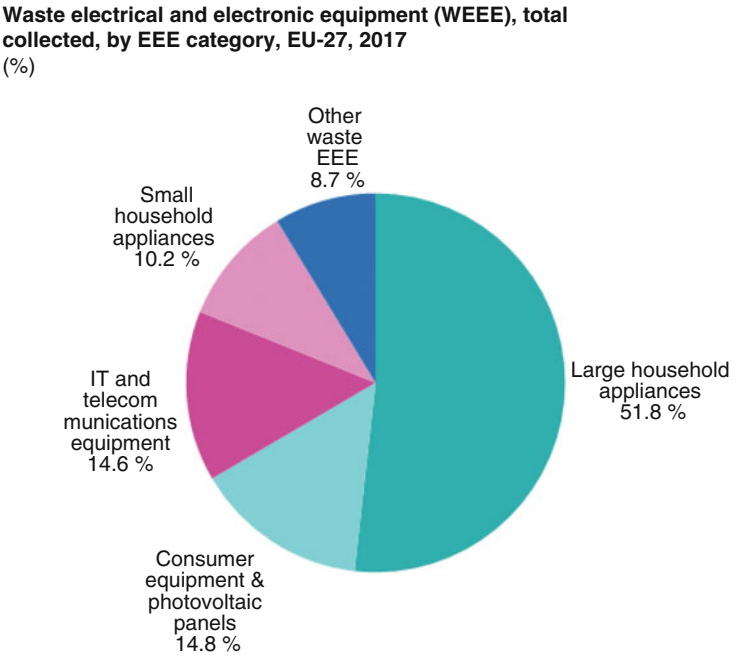

Fig. 7.17 Collected WEEE per product category in the EU (year 2017). Note: Eurostat estimates. (Source: EUROSTAT (online data code: env_waselee))

7.4.2 Collection Amount for WEEE in Italy[54]

More recent data are available for Italy compared to the EU. In the year 2020, the total collected WEEE resulted in 365.897 tonnes, whereas the amount per capita was 6.14 kg with an increase of 6.35% compared to the year 2019. The highest increase of collected WEEE resulted in the category R2 "Large household appliances" with an increase of 9.13% followed by the category R4 "Small household appliances, consumer electronics, office automation, computer appliances, lighting devices", whereas the category R5 "Light sources" recorded a decrease compared to the year 2019 (Fig. 7.18).

shows the results by WEEE category of collection rates achieved in Italy compared to the minimum EU target of 65% set by the Directive 2012/19/EU. The minimum rate of 65% of the average weight of EEE products put on the market in the previous 3 years (reference year 2019) has been achieved only by the category "R3" TV sets and displays.

7.4.3 Organization of the WEEE Management System in Italy

On the basis of the WEEE Directives and Italian Ministry Decree No. 185 of the year 2007 (Decree Law 185, 2007), the organization of the WEEE system in Italy involves the following bodies:

- The WEEE Coordination Centre (so-called CdC) that has been established by the collective systems. It optimizes and coordinates the activity of the collective

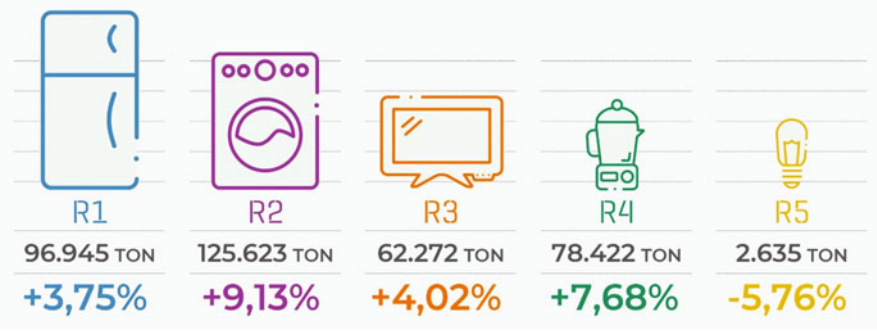

Fig. 7.18 Amount of collected WEEE by product category and percentage change compared to the year 2019 of the amount of WEEE collected. (Source: WEEE Report 2021, https://www.raeeitalia.it/it/rapporto/2021)

[54] https://www.cdcraee.it/GetPage.pub_do?id=2ca980954c369c25014ce55c67350385.

system with the purpose of guaranteeing that collective systems operate according to homogeneous practices.
- The National Register of EEE Producers that should finance the management of WEEE system. The register collects the data of the amount of EEE products put on the market. The registration is compulsory for all the producers of households EEE.
- The Supervision and Control Committee that manages the National Register of EEE Producers by calculating the market shares of the producers/collective systems. It monitors the amount of WEEE flows in relation to the target rates of WEEE separated collection and supervises on the correct application of WEEE legislation.
- The Steering Committee on the management of WEEE at the Ministry for Environment, Land and Sea Protection of Territory and Sea that has the task of supporting the Supervision and Control Committee as well as of monitoring the operativity, logistic functionality and economic efficiency of WEEE system (ANIE 2019; Remedia 2019).

At national level, 12 collective systems operate in Italy for the transport, treatment and recovery of WEEE. Every collective system manages an amount of WEEE proportional to the amount of EEE put every year on the market by the producers of the same collective system[55]. In a similar manner, some collective systems are specialized in the management of all categories of WEEE (so-called multi-supply chain collective systems) whereas others in the management of only some categories of WEEE (Remedia 2019; WEEE Coordination Centre 2018). Table 7.3 lists the 12 current Italian collective systems along with the location of their headquarters in Italy[56].

The collection of WEEE is managed and coordinated at national level by the WEEE Coordination Centre. The WEEE are collected from the different channels evidenced in Table 7.4[57]. The WEEE Coordination Centre ensures that the collected WEEE are picked up by the collective systems from the different channels. The

[55] The Decree 185/2007 evidences at the Art. 6 that the collective systems should enrol themselves in the National Register of EEE Producers before they start their operativity and communicate the data related to their establishment, the producers that join their collective system and for each producer the category of EEE according to the Decree 151/2005 (attachment 1A) as well as the types of WEEE according to the following classification: historical household WEEE, historical professional WEEE, new household WEEE and new professional WEEE. Moreover, they should communicate every year to the Supervision and Control Committee (on behalf of the EEE producers) the data related to the weight of the collected WEEE, recovered, reused and/or recycled.

[56] RAEE Italy 2019, available at https://www.raeeitalia.it/assets/uploads/rapporto-annuale-2019.pdf#:~:text=Nel%202019%20in%20Italia%20i%20Sistemi%20Collettivi%20hanno,a%20una%20raccolta%20pro%20capite%20di%205%2C68%20kg Last accessed: 11/06/2021.

[57] Recovery of waste from electrical and electronic appliances (WEEE). Available in English at https://eng.gruppohera.it/group/business_activities/business_environment/separated_collection/vegetable_oils_and_weee/page6.html. Last accessed: 12/06/2021.

Table 7.3 Collective system (consortia) operating in Italy

Collective system	Location
Apiraee	Turin
Cobat RAEE	Rome
Consorzio RLG	Turin
Ecolight	Milan
Ecoem	Pontecagnano Faiano, Salerno
Ecolamp	Milan
Ecoped	Milan
Erion	Milan
ESA Gestione RAEE	Bagno a Ripoli, Firenze
European Recycling Platform	Cassina de'Pecchi, Milan
PV CYCLE Italia	Milan
Ridomus	Milan

Table 7.4 Main channels for the collection of WEEE in Italy. (Re-adapted from data by Hera Group 2019))

Types of WEEE collection centres	Description
Waste collection centres (drop-off points)	These are set up and managed by municipalities and companies authorized to handle WEEE. Collection centres are open to citizens that can dispose of household WEEE free of charge. Collection centres can also collect WEEE from one or more municipalities and accept WEEE from distributors, installers and repair centres
Consolidation centres	These sites apply for WEEE the schemes "One against One" and "One against Zero". They are served directly by the consortia and can be set up at the point of sale of a distributor or at another place
Large users	These are sites registered by public or private organizations (airports, companies, hospitals, barracks, etc.) that produce significant amounts of WEEE in the lighting category (R4 and R5) and can therefore be served by a pick-up service provided by the consortia
Private collection centres	These centres are mainly set up by the consortia to store WEEE from voluntary collection activities and mainly for lamps
Installers	These centres are directly served by the consortia and managed by light source installers (R5), where WEEE from private households is stored after installing a new equipment
Repair centres and points of sale	In retail points of sale and repair centres, WEEE from private households are collected free of charge against the sale of equivalent household appliances ("One against One")
Treatment plants	These regard the companies that provide storage (to a large extent) and/or processing for recovery, recycling or waste to energy

collective systems are in charge of their subsequent transferring to the treatment and recovery plants authorized by the Coordination Centre[58].

After the collection, the WEEE are transported to the first treatment plants where they are dismantled in order to safely remove the hazardous components and to separate the valuable materials that can be recovered (Biganzoli et al. 2015). Then, separated components are transported from the first treatment plants to recovery plants (material or energy recovery) or disposal plants (Ecorit 2017). On 2016, 940 treatment plants were operative in Italy. Most of the plants were located in Northern Italy (665 plants) whereas in a lower extent in the centre (148 plants) and in the south and the islands (127 plants). Only a few of these plants perform the treatment for the recovery and recycling of the WEEE as most of them store temporarily the WEEE (WEEE Coordination Centre 2016).

7.4.4 Beyond Recycling: Case Studies from Italy

The Atlas of the CE shows the following case studies of individual organizations whose activities involve the repair, reuse or remanufacturing of WEEE. The organizations and their CE policies can be classified in the following:

1. Web platform connecting sellers and consumers of unsold EEE products:
   (a) **BEPRO: website for the purchase and sale of surplus original cartridges and spare parts for printers.** The web platform has been created in the year 2015 by a company active in the remarketing of consumables and spare parts for original printers, copiers and faxes. It allows consumers and companies to sell toner, cartridges and other original equipment for printers that have been purchased previously by them and never been used before. Such products are then put on the sales site where users of such products can purchase toner and cartridges for their printing devices at an advantageous price. This provides both economic benefits for them and environmental benefits for the society coming from the landfilling avoidance[59].
2. Repair of WEEE products (hardware, software):
   (a) **E-Repair: repair and regeneration of industrial electronic boards**. The company (active since more than a decade) has implemented a collection and repair system for obsolete electronic boards, which are disposed of by manufacturing companies. The extension of the life of industrial electronic boards (in some cases are more than 30 years old) regenerates still functional products reducing the number of electronic boards to be disposed of. The

[58] Recovery of waste from electrical and electronic appliances (WEEE). Available in English at https://eng.gruppohera.it/group_eng/sustainability/thematic-reports/tracking-waste/vegetable-oils-and-weee/recovery-of-waste. Last accessed: 12/06/2021.

[59] BEPRO, available at https://economiacircolare.com/atlante/bepro-italia/. Last accessed: 03/06/2021.

company adopts a specific process of regeneration that entails the reduction of the amount of water, the use of detergents with a lower environmental impact and the use of renewable energy self-produced by means of PV panels placed on the roof of the factory. Finally, in order to avoid the consumption of space and energy use, the company uses a system of automatic vertical warehouses allowing the optimization of the available space[60].

(b) **Binario Etico: repair of personal computer and use of recovered and regenerated hardware**. This is a benefit corporation founded in 2006 that is involved in the provision of hardware products and services and recovery of hardware products. The latter are collected and then recovered in the plants of the company whenever is possible or are correctly disposed of if they cannot be recovered. The company works with local suppliers who share the same mission with regard to the use of software (that should be non-proprietary software) as well as other social criteria. Finally, the employees are also involved in the mission of the company and adopt more sustainable and circular behaviours such as the use of public transport or bicycles to go to the work[61].

(c) **Reware**: **recovery and regeneration of IT equipment discarded by companies**. The cooperative company (social company) has a decade of experience in the repair and regeneration of personal computers disposed of by the companies. The computers undergo disassembling in the plants of the company, the components are tested, and the data are deleted in a safe and certified way. The remanufactured computers are then sold again as they can be used for many years, thanks to the regeneration of various devices, both hardware (increase of ram, change processors, use of SSD disks) and software (use of GNU/Linux distributions in particular). With regard to the results of the company's activities, since 2015, it has regenerated about 1500 computers or about 6 tonnes of IT equipment. Moreover, it estimates of having doubled the useful life from an average of 4 years to an average of 8 years. This contributed to avoid relevant environmental impacts since remanufactured computers avoid the purchase of an equivalent new computer. The company is also involved in several projects such as those in collaboration with non-profit organizations (such as Legambiente) aimed at increasing the awareness of environmental sustainability of the sector or related to the training of professionals in the electronics sector as well as to cooperation projects in Africa[62].

(d) **Hacking Labs: regeneration of WEEE and recovery of broken or dismantled PC, tablet, TV and smartphones**. This is an association of social

[60] E-Repair, available at https://economiacircolare.com/atlante/e-repair/. Last accessed: 03/06/2021.

[61] Binario Etico, available at https://economiacircolare.com/atlante/binario-etico/. Last accessed: 03/06/2021.

[62] Reware, available at https://economiacircolare.com/atlante/reware/#field-group-tab-4. Last accessed: 03/06/2021.

promotion with a laboratory that repairs electronic products (personal computers, desktops and notebooks, servers, smartphones and tablets) in both the software and hardware. The electronic products and components that cannot be reused are dismantled to recover raw materials such as iron, copper and aluminium or are sent out for creative reuse such as the production of key rings made with chips or alarm clocks and electronic cards. The association also aims to disseminate knowledge about the electronics and IT sector in particular cases where the economic conditions prevent the purchase of a personal computer or the attendance of courses. It promotes the culture of reuse, repair and regeneration of personal computers and their subsequent donation to schools, parishes and other associations[63].

(e) **Astelav: regeneration and redistribution of household appliances**. The company has a long history in the repair of households' appliances and distribution of accessories and spare parts for household appliances. Astelav started dealing with the circular economy since 2016 with the launch of Ri-Generation project aimed to the regeneration of WEEE and in particular washing machines, dishwashers, kitchens and refrigerators. Through Ri-Generation, the WEEE products, instead of being sent to costly disposal, are put back into a new production cycle and resold at advantageous prices (−50% of the original price). The remanufactured appliances can be purchased at three points of sale in Turin, by associated retailers throughout Italy or through the e-commerce service. It is also important to mention the social responsibility of the company that promotes the correct treatment of WEEE by collecting them by the citizens of the city of Turin who can donate their WEEE. Moreover, in the Ri-Generation project, people in particular conditions such as the immigrants are employed and trained[64].

(f) **RIMAFLOW: repair and recycling laboratories and production and distribution of agricultural products**. The laboratory has been created by the former employees of a factory that closed their activities after a crisis. RIMAFLOW has many laboratories including one dealing with the recovery of WEEE. These come from companies or private individuals and after the repair are donated or sold at low prices to schools, institutions and less well-off individuals[65].

3. Remanufacturing of electronic products and components:

(a) **SAPI: production of remanufactured cartridges and refurbished printers**[66]. The company is active since the year 1993 and specialized in

[63] Hacking Labs, available at https://economiacircolare.com/atlante/hacking-labs/. Last accessed: 03/06/2021.

[64] Astelav, available at https://economiacircolare.com/atlante/astelav/. Last accessed: 03/06/2021.

[65] RIMAFLOW, available at http://economiacircolare.com/staging/atlante/rimaflow/#field-group-tab-2. Last accessed: 06/06/2021.

[66] SAPI, available at https://economiacircolare.com/atlante/sapi/#field-group-tab-2. Last accessed: 03/06/2021.

the remanufacturing of printers, multifunction and copier (toner, used original cartridges, drums and spare parts) and related hardware (printers and photocopiers). In the 2 factories of the company, up to 50,000 cartridges per month are remanufactured in a high-quality manner (the quality of the remanufactured cartridges is the same as the original cartridges) and sold again at more affordable prices. The environmental and economic benefits of the regeneration of such products are very relevant as, e.g. in Italy, every year about 30 million inkjet cartridges and 10 million toner cartridges end up in landfills or are burned. Such benefits have been certified by an LCA study whose results evidenced that remanufactured cartridges avoid environmental impacts compared to original cartridges (−83.99%).[67]

4. Promotion of the reuse of regenerated electronic products:
   (a) **Green Idea Technologies: start-up company for certified environmental consulting services in the personal computer sector.** The start-up is active since 2014 in the cities of Sanremo and Bologna located, respectively, in Liguria and Emilia-Romagna regions (Northern Italy). It is the first European company dealing with "Certified environmental consultancy in the IT sector". Its activity consists in helping its customers to reduce CO_2 emissions by providing innovative solutions for the purchasing and recycling of electronic products. In that, the start-up supports the customers in the purchase stage as well as at the end of life by allowing for the reuse processes (reconditioning) of electronic products avoiding the production of new waste and increasing its service life. The company also certifies the saving in terms of CO_2 derived from the reconditioning of the personal computers. In 2017, the company has received by the European Institute of Innovation and Technology the "Climate-KIC Accelerator" award as the best Italian company involved in the improvement of climatic conditions[68]. Finally, the company is certified as a benefit corporation since 2017.
5. Academic research in the electric and electronic product value chain:
   (a) **RISE (Research & Innovation for Smart Enterprises): modelling the impacts of the implementation of circular economy in companies.** The research laboratory of the Department of Mechanical and Industrial Engineering (University of Brescia) contributes to the development of innovation (including the orientation to circular economy innovation) of processes and products and of business models supporting companies to become more competitive and circular. In this early stage of the transition, the development of methods and frameworks that show the multiple benefits of CE scenarios is

[67] More details about the results are available at the following website of the company: https://www.sapionline.it/en/regenerate-a-benefit-for-all. Last accessed: 01/06/2021

[68] Green Idea Technologies, available at https://economiacircolare.com/atlante/green-idea-technologies/. Last accessed: 03/06/2021.

very useful in favouring companies' decision of implementing circular practices[69].

7.5 Food Value Chain

The production of food is noteworthy known to generate relevant impacts to the environment. About one-third of global GHG emissions come from the food sector and in particular from the intensification of farming activities including intensive livestock farming. These are also the cause of negative effects on the biodiversity of natural ecosystems and on human health[70]. Additionally, a relevant issue in food value chain regards the loss or waste of food. In overall, for example, the latter is estimated about 17% of the total food available to consumers in 2019 according to a recent research by the United Nations[71]. In order to further address the issue, the EC evidenced in the EU CE Action Plan that it would have proposed a target on food waste reduction in the EU Farm-to-Fork Strategy. The latter has been adopted last year with the aim of promoting and supporting a more fair, healthy and environmentally friendly food system[72]. In that, it proposes by 2030 to reduce in agriculture the use of pesticides (including more hazardous pesticides) by 50%, the excess of nutrients, as well as supports the development of organic agriculture. Moreover, the strategy aims to sustain healthy diets, develop a sustainable food labelling framework to empower consumers in their choices of sustainable and healthy diets and fight food waste by proposing legally binding targets that can reduce food waste generation in the EU[73].

The transition to CE will contribute to further strengthen the EU Farm-to-Fork Strategy (Fig. 7.19) given its focus on cleaner and sustainable production processes and natural resources' efficiency, waste avoidance and minimization by design, renewable energy transition and better conservation of finite resources. In that, it will favour the achievement of EU Farm-to-Fork Strategy goals in the whole food

[69] RISE, available at https://economiacircolare.com/atlante/laboratorio-rise/#field-group-tab-4. Last accessed: 03/06/2021.

[70] European Commission, Farm to Fork Strategy, available at https://ec.europa.eu/food/horizontal-topics/farm-fork-strategy_en#:~:text=The%20Farm%20to%20Fork%20Strategy%20is%20at%20the,the%20COVID-19%20pandemic%20if%20they%20are%20not%20sustainable. Last accessed: 03/06/2021.

[71] https://www.unep.org/news-and-stories/press-release/un-17-all-food-available-consumer-levels-wasted.

[72] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0381.

[73] European Commission, From Farm to Fork: our food, our health, our planet, our future. The European Green Deal, available at https://ec.europa.eu/commission/presscorner/detail/en/fs_20_908. Last accessed: 03/06/2021.

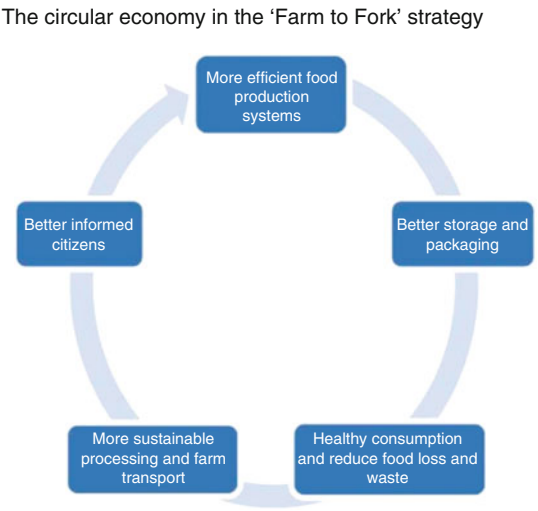

Fig. 7.19 Circular economy contribution to Farm-to-Fork Strategy in the whole food value chain. (Source: European Commission 2020)

value chain by improving some hotspots such as packaging, storage, transport, food waste and imported food[74].

7.5.1 Generation and Recovery Opportunities for Food Waste in the EU

Food waste is defined in the framework of the EU FUSION project (2014) as "food and inedible parts of food removed from the food supply chain" that is to be disposed of (e.g. crops ploughed back into the soil, left unharvested or incinerated, food disposed of in sewers or landfill sites or fish discarded at sea) or used for nutrient recovery or energy generation (e.g. through composting or anaerobic digestion and other bioenergy pathways). The definition of food waste widens the concept of biowaste since it includes the food and inedible parts removed from the food supply chain and points out the need for its disposal or the opportunities for its resource or energy recovery. At this regard, as we evidenced in Sect. 7.2.2, the EU monitoring indicators framework for the CE includes a specific indicator named "recycling rate of biowaste". A further distinction appears between the concept of food losses and food waste. The first term refers to the stages before consumption and arises from inefficiencies in food production and processing, whereas food waste is due to factors in the consumption stage (e.g. food not eaten because of purchase of an excessive amount than what is needed, it reached the expiry date, of inappropriate

[74] European Parliament, From Farm to Fork strategy on sustainable food, available at https://www.europarl.europa.eu/RegData/etudes/ATAG/2020/646132/EPRS_ATA(2020)646132_EN.pdf. Last accessed: 03/06/2021.

packaging, of low consumer appeal and so on) (European Commission's Knowledge Centre for Bioeconomy 2020). Finally, food wastage comprises both food loss and waste since it includes any food lost by deterioration or waste. In the EU, the amount of food waste has been calculated to be about 20% of the total food produced in the year 2011 (European Commission's Knowledge Centre for Bioeconomy 2020). There are uncertainties in the estimates of the annual amount of food waste due to the different approaches used in the studies. For example, Caldeira et al. (2019) calculated an annual amount of 129 Mt. of food waste, while the FUSION project calculated about 88 Mt. of food waste.[75] In the EU food supply chain, most of the share of total food waste is generated in the consumption stage (46%). Then follow the other stages, production with a share of 25% and processing and manufacturing (24%), while the distribution and retail stage has the lowest share (5%). shows that in the agricultural stage or primary production, the categories "fruit" and "vegetables" account for the most significant food losses (76% of the total), while in the consumption stages, they are wasted less compared to other food categories (42%).

Food losses and waste in the supply chain can be valorized in different options (Santagata et al. 2021; European Commission's Knowledge Centre for Bioeconomy 2020). At present, for example, waste that cannot be consumed by humans can undergo different types of valorization routes whose economic value ranges from low to high value. The latter regard, for example, the extraction and recovery of value-added components for industrial applications (e.g. cosmetics and nutraceuticals, food preservation and packaging products, pharmaceuticals, etc.), as well as to the conversion of food waste into bio-based building blocks that can be used in a wide range of applications as biomaterials (e.g. bioceramics, biopolymers, etc.) (Santagata et al. 2021; European Commission's Knowledge Centre for Bioeconomy 2020). There are environmental, social and economic benefits associated with the recovery of food waste and in particular those related to the avoidance of disposal in landfills and avoided extraction of natural resources (Ghisellini et al. 2023; Santagata et al. 2021). Many challenges (economic, technological, environmental) still exist in the recovery, while the opportunities of food waste recovery should be properly evaluated taking into account the whole life cycle of by-products by means of standardized methods e.g. life cycle assessment (Camana et al. 2021; Mirabella et al. 2014). The latter is widely used in evaluating the application of circularity in the agri-food sector (Ncube et al. 2021; Stillitano et al. 2021; Pollaro et al. 2020) both as a single method or in combination with other methods (Camana et al. 2021) such as Emergy Accounting (Santagata et al. 2021). In this latter case, with LCA and Emergy Accounting, it is possible to widen the range of the environmental categories and scale of analysis (both temporal and spatial)

[75] For example, Caldeira et al. (2019) adopt a mass balance approach that combines different sources of information with the breakdown into the major EU food groups. FUSIONS uses normalization factors (based on, e.g. food produced, population and turnover) from a limited number of countries and upscales the data to the EU level (From European Commission's Knowledge Centre for Bioeconomy 2020).

increasing further the understanding of the proposed valorization routes for food waste (Santagata et al. 2021).

7.5.2 Generation of Food Waste in Italy

The Last-Minute Market/Waste Watcher Observatory evidences that in the year 2020, food waste generation in the Italian households for the first time recorded a decline of about 25%. The results of the survey also revealed that 66% of Italians believe that there is a strict connection between food waste and environmental and human health. For one Italian out of three, aspects related to the impact on human health are relevant in the purchasing decisions of buying food. Moreover, 40% of the respondents declared to be aware of the needs of protecting the environment even without the influence of movements like the "Fridays for future". Instead, 33% of respondents evidenced to be influenced by the awareness of this movement that has contributed to increase their attention to sustainability in everyday life (16%) or at least to start reflecting on such issues (17%)[76].

With regard to the data about food waste, in the year 2020, the amount per capita was about 27 kg (529 g in a week). Compared to the year 2019, the reduction of food waste has been equal to 11.78% (or 3.6 kg). This means that in the year 2020, over 222,000 tonnes of food have been saved from being wasted in Italy totalling a saving of €6 per capita or €376 million at national level. The value of national domestic food waste reaches €6 billion and 403 million that ends up to €10 billion if considering the losses in the food value chain from agricultural stage to distribution which amount is €3,284,280,114. By weight, this means that in 2020, 1,661,107 tonnes of food at home were wasted in Italy and 3,624,973 tonnes if losses and wastes of the supply chain are included (data Waste Watcher International/DISTAL University of Bologna for Waste campaign Zero and Ipsos surveys)[77].

7.5.3 Food Sustainability in the Whole Life Cycle: Case Studies from Italy

The Atlas of the CE includes the circular practices of organizations that aim to make more sustainable the production of food at the farming stage as well as in other stages of the life cycle including the reduction of food losses and waste after the consumption stage. We have grouped the organization as follows:

[76] Waste Watcher International Observatory, available at https://www.sprecozero.it/waste-watcher/. Last accessed: 03/06/2021.

[77] https://www.foodaffairs.it/2021/02/03/sostenibilita-spreco-di-cibo-cause-e-strategie-di-prevenzione-lo-studio-spreco-il-caso-italia-di-waste-watcher-international-observatory/.

1. Non-profit organizations operating in food recovery and redistribution:
   (a) **Avanzi Popolo 2.0**: **contrast to food waste, food sharing, recovery of food surplus and awareness**. The association recovers food surpluses for social and ecological purposes. Its activity of recovery and redistribution of food surpluses' activity is based on the creation of a network of stable relationships with a high number of third sector subjects located as close as possible to the place where the surplus occurs, in order to minimize the distance and the impacts for both food and the environment as well as valorize the contribution of partners who are involved in the food redistribution of their specific area.
   (b) **Equoevento: recovery and redistribution of food surplus from parties and other events.** Their activity deals with the recovery of food surplus from weddings, conferences and sports events and its redistribution to charitable canteens. In this way, by avoiding food to become waste, all the resources and ingredients used for the preparation of the food are optimized. Furthermore, the surplus bread is delivered to a craft brewery where people (in external criminal execution), coming from the Roman prison of Rebibbia, are trained and inserted in the craft beer supply chain. In the year 2020, the organization launched a project against food waste in supermarkets and food shops named YouFeed where shops can register on the platform and offer boxes, with surplus fresh products or those close to expiry, and donate to families who need them and can collect from the shops closest to their home[78].
   (c) **Banco Alimentare: recovery of food surpluses from large events and redistribution to charities and canteen for poor people.** The activity of the organization consists in recovering food that is still edible but no longer marketed and redistributing it to associations that help poor people in Italy. The organization has been founded in 1989 and currently has a network of 21 associated organizations in Italy. In 2016, it recovered about 70,000 tonnes of food and redistributed it to about 8000 associations that help a half million of poor people. It operates through 1700 volunteers and 120 employees[79].
   (d) **RECUP: against food waste and social exclusion, a project of active citizenship.** The project born in 2014 from the idea of a group of academic students (girls) aimed to disseminate the importance of citizens' actions against food waste and its valorization as well as contrast social exclusion. From 2016, the group operates in an association of social promotion that currently is active in local markets of the city of Milan. The food is recovered and delivered at the closure of the markets on the same packaging of the

[78] Equoevento, available at https://economiacircolare.com/atlante/equoevento/#field-group-tab-2. Last accessed: 02/06/2021.

[79] Banco Alimentare, available at https://economiacircolare.com/atlante/banco-alimentare/. Last accessed: 02/06/2021.

shops and delivered with trolley and cargo bikes. The food is not delivered in plastic bags as people are invited to take the recovered food with reusable bags[80].

(e) **Io Potentino**: **recovery of food and redistribution of food surpluses**. The association is operative in the city of Potenza (Southern Italy). Since 2014, it has created a system for managing food surpluses from commercial activities and/or public and private events and its redistribution to people in need throughout the city at the end of the harvest. The entire donation, collection and distribution process is carried out with maximum transparency, thanks to a software that guarantees the traceability of donations. So far, the association has collected and redistributed 11,302.77 kg of food.[81]

(f) **Disco Soupe: public events of circular cooking for recovering unsold food**. The main goal of the organization is increasing the awareness of people on the problem of food waste and the need for alternative solutions to the problems of waste and climate change by proposing participative solutions. Disco Soupe recovers perfectly edible foods that would be discarded and gives them a second life by cooking it through public awareness events. The collected food mainly consists of fruit, vegetables and bread products (thrown away for various reasons such as aesthetic factors as in the case of products from local farms or unsold at the end of the day or week from local markets). Everything is recovered at "zero km" in order to minimize the transport of goods and, at the same time, increase the awareness of local traders and the importance of new practices in the area. The project involves the local community, which is encouraged to minimize excessive waste and reach the event in the most sustainable way[82].

(g) **Eco dalle Città**: **promotion of good practices for the management of food and recovery of surplus food from local markets.** The association is involved in many projects that are aimed to revalorize food and other goods such as books and save them from being incinerated. With regard to food, the members and volunteers of the Eco dalle Città association every day, from Monday to Saturday, recover unsold food from the street vendors of the Porta Palazzo market (Turin) and then redistribute it for free to a group of people in need. It is interesting to point out that before the recovery, volunteers and members distribute bio-compostable bags to street vendors to promote separate collection within the market. After the recovery and distribution of the bags, the members of the association help in collecting the empty boxes and organic waste[83].

[80] RECUP, available at https://economiacircolare.com/atlante/recup/. Last accessed: 02/06/2021.

[81] Io Potentino, available at https://economiacircolare.com/atlante/io-potentino/#field-group-tab-4. Last accessed: 02/06/2021.

[82] Disco Soupe, available at https://economiacircolare.com/atlante/disco-soupe-firenze/#field-group-tab-2. Last accessed: 02/06/2021.

[83] Eco dalle Città, available at https://economiacircolare.com/atlante/eco-dalle-citta/#field-group-tab-2. Last accessed: 02/06/2021.

(h) **Foodbusters: recovery of surplus food and increasing awareness against food waste.** The association is located in the Marche region (Central Italy). Surplus food that is recovered during parties, meetings and weddings is delivered to social canteen closest to the place of the event, preventing the production of waste and supporting those who offer a social assistance service. The donation of the surplus food coming from public events makes the latter fairer and more sustainable and conveys particular ethical values for the participants[84].

2. Sustainable and circular agro-food production chain:
   (a) **De Matteis Agroalimentare: pasta made with durum wheat 100% Italian from short supply chain**. The company produces the pasta "Armando" that is made with 100% Italian durum wheat from the supply chain that the company created in 2010 with over 1400 companies located in Central and Southern Italy. The wheat coming from such companies is worked directly in the mill included in the pasta factory and transformed into semolina that is used for the production of the pasta. The latter is distributed in FSC-certified packaging that can be recycled as paper in separate collection. This eliminates plastic in packaging, thanks to more innovative materials[85].
   (b) **Noi Genitori Factory: social cookie, energy efficiency and waste reduction**. It is a social company that produces dry bakery products with a high social, economic and environmental value. The biscuit factory uses renewable energy and raw materials from the local supply chain (e.g. the butter from the Latteria Sociale Valtellina and the organic honey from a local producer) and employs people with disabilities who enhance with this work their skills and improve their well-being[86].
   (c) **Life DOP Virgilio Model: circular model for the Parmigiano Reggiano and Grana Padano chain**. This is a project funded by the European Union as part of the 2015 Life Program and involves the Parmigiano Reggiano and Grana Padano supply chain in the creation of a circular economy model with lower environmental impact. The Life DOP project involves partners throughout the Grana Padano and Parmigiano Reggiano production chain: Consorzio Latterie Virgilio, Associazione Mantovana Allevatori, Consorzio Gourm.it, San Lorenzo Agricultural Cooperative, Northeast Agricultural Consortium and University of Milan. The goals of the project imply among others the definition of an environmentally sustainable production model for Parmigiano Reggiano and Grana Padano in the Province of Mantua, the promotion in the entire production chain of an efficient and circular use of

[84] Foodbusters, available at https://economiacircolare.com/atlante/foodbusters/#field-group-tab-2. Last accessed: 02/06/2021.

[85] De Matteis Agroalimentare, available at https://economiacircolare.com/atlante/de-matteis-agroalimentare-pasta-grano-italiano-filiera-corta/#field-group-tab-2. Last accessed: 03/06/2021.

[86] Noi Genitori Factory, available at https://economiacircolare.com/atlante/noi-genitori-factory/#field-group-tab-2. Last accessed: 03/06/2021.

resources, the evaluation of innovative good practices suitable for the territory and the dairy cattle chain. Moreover, the project adopts LCA method based on primary data collected at all stages of the supply chain aimed to develop a sustainable model and its replicability[87].

(d) **Filab dairy circular company producing Mozzarella di Bufala Campana DOP**. The Mozzarella is made only with fresh milk and Ricotta di Bufala Campana DOP (buffalo ricotta cheese) with the whey coming from the production of mozzarella cheese. The additional by-products of buffalo milk are destined for pastry shops/butter factories and to other the local farms. The primary packaging is recyclable, while the secondary packaging is currently at a research stage to make it recyclable. The company is launching policies to reduce the purchase of energy from fossil sources. Moreover, it promotes employee awareness towards the reduction of wastewater in the processing phases as well as reduction of emissions related to the transport of its products by choosing transport with contractors who carry out groupage. The choice of the company's suppliers (for both typical and ordinary purchases) is made on the basis of their involvement in environmental and social certifications and/or qualifications[88].

(e) **Fermenti Sociali: production of beer with self-produced crops and machines**. The company is an authorized microbrewery where 100% of the cereals to make the beers are self-produced, cultivated and transformed in the company. Most of the equipment used for malting and making the beer is recovered and adapted for these purposes. The production process generates as by-products heat that is partially recovered, while the wastewater ends up in the phytodepuration plant of the company. The beer is distributed in local markets and local restaurants in reusable packaging[89].

(f) **Serrocroce: brewery and farm, recovery of by-products of barley cultivation.** The barley, hops and spices used as raw materials to produce the beer are self-produced. The latter is the first beer from an agricultural and zero-km supply chain in the Campania region. The CE policies of the company entail the recovery of materials and the valorization of raw materials and of by-products. The beer threshers, which are the by-product coming from the hot extraction of germinated barley, are reused for the production of taralli (a type of salted biscuit) and bread that are the typical products offered during tastings in the brewery. The remaining by-product, rich in fibre and sugars, is used by local livestock farms as food for the animals. The company also

[87] Life DOP Virgilio Model, available at https://economiacircolare.com/atlante/life-dop-modello-virgilio/. Last accessed: 03/06/2021.

[88] Filab, available at https://economiacircolare.com/atlante/filab/#field-group-tab-2. Last accessed: 03/06/2021.

[89] Fermenti Sociali, available at https://economiacircolare.com/atlante/fermenti-sociali/#field-group-tab-2. Last accessed: https://economiacircolare.com/atlante/fermenti-sociali/#field-group-tab-2 .

recovers the cleanest fraction of the water used for washing the plants as well as the rainwater. These are then reused for field irrigation.[90]

7.6 Concluding Remarks

The aim of the present study was to provide an overview of the current transition to CE in both the EU and Italy in some key product value chains (electronics and ICT, packaging, plastics and food) considered as relevant for their environmental impacts and circularity potential in the EU Action Plan of the CE. In order to achieve our goals, the present study summarized some of the key elements of the EU Action Plan of the CE and its role in the EU environmental political agenda as well as the CE indicator framework. A brief background on the transition to CE in Italy at different scales (micro, meso and macro) is also provided highlighting some of the main institutional initiatives and documents such as the strategic position document that defines the Italian strategy for the CE.

Then, we evaluated for the EU and Italy the annual flows of municipal solid waste (MSW) generated and recycled, the total waste and their composition, the amount of packaging waste generated and recycled per capita as well as the recycling rates for plastic packaging waste and e-waste. Moreover, some data about food waste losses and waste in EU and Italy have been discussed.

In the EU 27 countries, the EUROSTAT data related to MSW evidence a reduction in the year 2019 compared to 2005 of the amount of the generated MSW, while the recycling rates increased from 32% (year 2005) to 48% (year 2019). Instead, the amount of total waste generated evidences an increase in 2019 compared to the year 2004 for both the EU 27 countries (+3.9%) and Italy (+23.4%). The recycling rates of the different waste streams (packaging waste, plastic packaging waste and e-waste) for the EU 27 countries and Italy show an increase in the investigated periods.

For each of the selected waste stream (plastic packaging, electronics and ICT and food), we also evaluated the CE practices of 32 companies that are available on the Italian Atlas of the CE. The 32 case studies show alternative CE practices (reduction, material substitution, repair, reuse, remanufacturing) to the recycling for the prevention/management of the different waste streams and in overall a different system for the management of the waste streams compared to the recycling option.

The cases of packaging show the availability of alternative materials to plastic packaging that have a lower environmental impact (paper and biomaterials) as well as that the impacts of alternative packaging materials (e.g. “Greenpaper”) and packaging products (e.g. “GreenboxX”) are evaluated and certified by product certifications such as “EPD”. The valorization of packaging waste materials

[90] Serrocroce, available at: https://economiacircolare.com/atlante/serrocroce/#field-group-tab-2. Last accessed: 03/06/2021.

previously disposed of in landfills contributes to generate new secondary materials ("EcoAllene") totally recyclable whose quality and origin are certified by "Remade in Italy" in class A^+, a label that is given in the case of materials with a recycled content higher than 90% compared to the total. Moreover, at both industrial and consumer level, the product design aimed to the reuse at the end of life of a packaging contributes to reduce the environmental impacts of materials such as plastics by increasing its lifetime. For other materials, the creative reuse (e.g. wood) of packaging can be designed. Moreover, the shops that sell bulk products reduce the amount of packaging waste and increase the awareness of the importance of waste reduction and packaging minimization and reuse.

The cases of treatment of WEEE (personal computer and other related hardware, household appliances), beyond recycling, show the several companies involved in applying the different options (repair, reuse or remanufacturing) for the valorization of WEEE products and their reintroduction in the production and/or consumption cycles. By means of such options, the lifetime of electrical and electronic equipment (EEE) and their components can be expanded. The e-repair companies also contribute to overcome the negative perception of consumers towards such products by sharing and disseminating the knowledge on them including the importance of their correct management. Given the lower price of remanufactured EEE compared to new products, they can also be purchased by people who cannot afford a new EEE. Finally, with regard to the food supply chain, the analysed associations by recovering and redistributing surplus food (coming from events or local markets or other context) or still edible food (not marketable) make concrete actions towards food waste avoidance and its further valorization as well as contrast social exclusion and poverty. Moreover, they also favour the diffusion of less impactful mobility lifestyles by promoting the recovery of food by bikes or minimizing the transport distance through an adequate planning and by means of the use of digital technologies and web platforms. In the agro-food supply chain, the creation of collaborations between companies and their suppliers as well as with other stakeholders contributes to develop many sustainability-oriented practices and activities, namely, to improve the traceability of products, the promotion across the supply chain of an efficient and circular use of resources, the evaluation of innovative good practices suitable for the specific territory and the different food product chain (crops, dairy, beverage) and the adoption of renewable energies and more sustainable recyclable packaging made of recycled inputs.

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