Transition from Waste Management to Circular Economy: the EU Roadmap

Ms. E. Chioatto[1,3] (elisachioatto@gmail.com) – Dr. P. Sospiro[2,3] (sospiro@unifi.it)

[1] *Università di Venezia Ca' Foscari* (Venezia, Italy), V. Palmirano 100/B Ferrara, Italy.
[2] *Facoltà di Ingegneria Università di Firenze* (Firenze, Italy), V. S. Marta 3 Ancona, Italy.
[3] *EUAbout* Rue Martel 54 Brussels, Belgium.
Contact person E. Chioatto (email address) elisachioatto@gmail.com, (telephone) +39347/4124115

Keywords: Waste Disposal, Waste Management, Resource Efficiency, Circular Economy, EU Comparative Analysis

Abstract

In the last twenty years, European Union (EU) has enhanced Waste Management (WM) strategies toward Circular Economy (CE). Starting from the previous analysis carried out by (Fabrizi, Sospiro, 2017), this paper analyses firstly EU Member States (MSs) Roadmap toward Sustainable Waste Management (SWM) and secondly to CE. Four case studies (FR, DE, IT, NL) were selected in order to investigate their policies, criteria, methodologies and outcomes for CE implementation at national level. The study considered the most notable recent findings on CE, Eurostat data, and Eurostat Circular Material Use (CMU) indicator. Beside SWM positive practices and results, it emerged that EU countries needs a further step in order to close materials' loops. Indeed, a larger quantity of Secondary Raw Materials (SRMs) should return to manufacture, and this requires stronger intervention that goes beyond the waste sector. The research presents four barriers to CE, which suggest that major changes are needed to boost virgin material savings and Resource Efficiency (RE). In light of this, the EU Commission recently entrusted the Joint Research Centre (JRC) to assess and compare the environmental impacts of alternative feedstock for plastic products. This reveals EU attempt to re-balance the intervention on CE, by striving new products' design approaches. New design strategies and production process could indeed support waste minimization and help end-of-life products' resources to return into industrial systems.

Introduction

Since the Industrial Revolution, the increase of human action is reducing environmental self-organizing properties. Mankind's activities became so extensive to influence natural processes and to produce long-lasting biophysical effects. This leads a different relationship between man and nature. The planet is becoming «less biologically diverse, less forested, much warmer, and probably wetter and stormier state» [1].

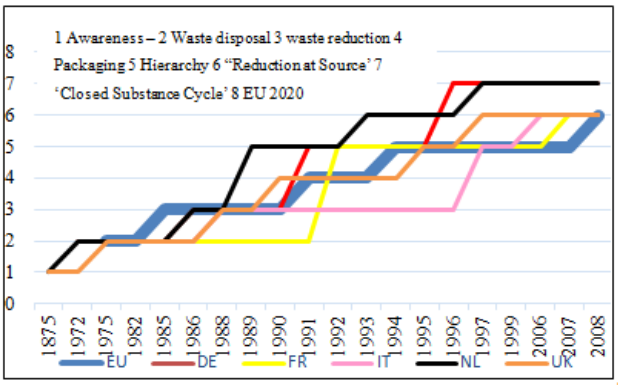

Fig. 1: Convergence on MWM in EU MSs.
Source: Fabrizi, Sospiro, 2017.

Current human-driven natural phenomena are contributing to create new economic and social challenges. Since the first IR, resources' extraction has increased due to a rise in world's population, an enhancement of the living standards, manufacture automation which led to mass production and consumption. Consequently, while our societies are experiencing an economic growth without precedent, the quantity, the quality and the accessibility of finite resources are progressively falling, more solid waste is generated and emissions to the environment became severe [2]. Therefore, the traditional linear-based production process should turn toward more sustainable circular approach. Specifically, while within the current business models raw materials are extracted, processed, consumed and returned into the environment as waste. On the contrary, CE allows to *turn waste into a valuable resource* [3]. Accordingly, by reducing raw materials and energy inputs for production and encouraging the use of Renewable Energy Source (RESs), less resources will be depleted and less emissions and waste generated. CE will contrast the increasing prices of the progressively scarce raw materials and it will decrease countries' dependency on price oscillation at global level.

This paper starts from a previous analysis led by one of the authors on Municipal Waste Management (MWM) [4]. The main question was whether the EU framework does facilitate the convergence of EU-MSs (FR, DE, IT, NL, and UK) in terms of policies and outcomes (see Fig. 1). Beyond this, in this research the authors analysed the policies, criteria, methodologies and outcomes state-of-art of EU-MSs (comparing the same countries, except UK) in the transition from WM to CE.

Recently the EU has showed a great interest in enhancing RE, and promoting a full CE. Hence, an economy that preserves growth and competitiveness but operates within environmental boundaries by halving resources consumption [5]. This shift needs a complex change, which involves various systems.

This paper will focus on WM sector, which «will have to become a key partner in building new business models that focus both on waste prevention and turning waste into a resource» [6]. The CE requires, indeed, «high-quality SRMs that can be fed back into production processes» [6]. This originates the necessity to find effective measures that, on the one side, discourage the generation of waste (waste prevention), and, on the other, help to manage the end-life-products that become waste (re-use, recycling, refurbishment). The EU issued several documents to define the main guidelines on RE such as: "Roadmap to a resource-efficient Europe;" the "EU2020 Strategy", the "Seventh Environment Action Programme, 'Living well, within the limits of our planet.'", and the 2015 CE plan "Closing the Loop: an EU Action Plan for the CE". The Package has indeed proposed the revision of the main EU Dirs on waste, namely Dir 2008/98/EC (waste), Dir 1999/31/EC (landfill), Dir 94/62/EC (packaging). These last were definitively amended on the 30/5/2018 with the new *Dir 2018/851*, *Dir 2018/850*, and *Dir 2018/852*. It emerges that in the last twenty years, EU has framed a comprehensive regulatory action aimed at shifting WM practices, based on end-of-stream solutions, to SWM systems focused on strengthening «the link between waste treatment and resource recovery» [7]. Specifically, to enable the reintegration of waste as a resource within the economic cycle.

However, given the heterogeneous sources of waste (i.e. households, Small-Medium Enterprise (SME), healthcare origin, agriculture, and industry) [8], to notice that the authors will focus on Municipal Solid Waste (MSW)[1]. Notwithstanding the residual component on overall waste production (10% according to [9]), MSW represents one of the most difficult waste sources to manage[2] [4].

The authors carried out a literature review firstly to define the concept of CE and the role of WM in the transition. (Korhonen, Antero, & Jyri, 2018), (Kalmykova, Sadagopan, & Rosado, 2018) and (Van Buren & all., 2016) present the definition and strategies to implement CE. On the other side, (Cobo & Antonio Dominguez-Ramos, 2018) show the importance of SWM to valorise end-of-life products by prolonging their lifetime, so that they can be reintegrated into manufacture. These studies have been analysed from an EU perspective in order to identify the current state-of-play at the EU and MSs levels. Hence, a review of the main EU legislation in matter of CE and WM has been examined supported by (Lieder & Rashid, 2016) (Domenecha & Bahn-Walkowiakb, 2018), (Halkos & Kleoniki, 2018). The comparative analysis has been performed to confront MSs WM practices and their performances in shifting WM to SWM and CE. The study was based on, *France*: (Buclet & Godard, 2000), (Ministere de la transition ecologique et solidaire, 2018), (EEA, 2016). *Germany*: (Wilts, 2017), (Wilts, 2016), (EEA, 2016), (Nelles, Grunes, & Morscheck, 2016), (Ministry of the Infrastructure and Environment, 2013), (BMU, 2018), (Dornack, 2017), (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Published January 2019), (Bilitewsky, 2017). *Italy:* (EEA, 2016), (Ministero dell'Ambiente e della Tutela del territorio e del mare ; Economico, Ministero dello Sviluppo, 2017), (Testa & all., 2011), (Agovino & Garofalo, 2016), (Ambiente Italia Work Group). *The Netherlands*: (EEA, 2016), (EIONET, January 2012), (The Ministry of Infrastructure and the Environment, Ministry of Economic Affairs, 2016), (Ministry of the Infrastructure and Environment, 2013), (OECD, 2016). (Eurostat, February 2019) data were used to assess MSs outcomes in waste prevention, recycling, incineration, and landfilling. Specifically, the method to calculate the recycling rates in this paper corresponds to method 4 according to Eurostat. Indeed, Commission Decision 2011/753/EU allowed MSs to choose between four different calculation methods to report targets' compliance[3]. In this regards, France, Italy and the Netherlands have chosen method 2 while Germany method 4. It follows that results can slightly vary. Currently, after the amendment set by Dir 2018/851, MSs must use only one calculation method. Finally, SWM results have been confronted with CMU rate data provided by (Eurostat, 2018). There were identified several barriers that prevent RE and CE in EU in (Kirchherr & all., 2018) study. In addition from (Domenecha & Bahn-Walkowiakb, 2018) research emerges that EU policy results mostly output oriended, as the (JRC Report, 2018) confirms.

The following sections will firstly examine the EU legislative framework on MSW management. Then, the authors intend to assess the current state of Germany, Netherlands, France, and Italy on the way towards CE. The overarching legislation on WM and outlined countries' implementation strategies will be reviewed. Particular attention will be devoted to underline the synergy that waste legislation has produced to close the material loop. Hence, its relevance to transform waste in SRMs that need to be returned into production processes. Finally, it will be assessed if SWM practices also favour circularity of resources by relying on the CMU rate instrument.

[1] According to *Dir 2018/851* corresponds to *"mixed waste and separately collected waste from households, and other sources that are similar to it, for nature and composition, such as "retail, administration, education, health services, accommodation and food services."*

[2] This derives from its heterogeneous nature, the potential impact on the environment and human health, the influential political profile of the topic, and its connection to consumption patterns.

[3] 1) paper, metal, plastic and glass household waste; 2) paper, metal, plastic, glass household waste and other single types of household waste or of similar waste from other origins; 3) household waste; 4) municipal waste.

EU Legislative Framework

Fig. 2: Waste hierarchy
Source: Institute for Sustainable Futures

Currently, the EU legislation on MSW is mainly disciplined by Dir 2018/851 of the EUP and of the EUC of 30/5/2018 amending Dir 2008/98/EC. The Dir renewed the importance of waste prevention and treatment, in compliance with the 'waste hierarchy' [8], which organizes WM in five steps: prevention, reuse, recycling, incineration, and disposal.

Firstly, to stimulate prevention and re-using approaches, MSs have the obligation to develop and adopt WM plans (Article 28 Dir 2008/98/EC) and waste prevention programmes (Article 29 Dir 2008/98/EC). In line with this, EU has reinforced the targets set by the Dir 2008/98/EC (Article 11), which encouraged 50% preparing for reuse and recycling of MSW by 2020. Dir 2018/851 indeed approved more ambitious goals listed in *Table 1*. Improving recycling rates requires the enhancement of waste separated collection. Efficient collection schemes will encourage recycling practices, and boost the quality of SRMs. On top of them, Dir 2008/98/EC recommends that "by 2015 separate collection shall be set up for at least: paper, metal, plastic and glass."

Table 1: MSW targets for re-use and recycling

THE PREPARING FOR RE-USE AND THE RECYCLING OF MUNICIPAL WASTE SHALL BE INCREASED TO A MINIMUM OF		
By **2025**	By **2030**	By **2035**
55% by weight	60% by weight	65% by weight

Secondly, EU wants to contrast packaging waste production. On the one hand, by addressing the reduction of packaging products placed on the market, on the other by guaranteeing better handling of end-of-life packaging products through recycling and recovery practices. This is set by Dir (EU) 2018/852, which amends Dir 94/62/EC. Among the others, EU support the adoption of Extended Producer Responsibility (EPR) schemes. Indeed, if industries are financially responsible of the disposal/handling of their products, they are encouraged to prevent waste generation. This will create a virtuous-cycle that can positively foster e.g. the design of reusable packaging and new methods to reuse packaging (Dir 2018/ 852 Article 5 (1)), the introduction of packaging made with recycled materials, and the manufacturing of recyclable packaging (by using materials conform to multiple recycling processes or bio-based materials (Dir 2018/ 852 (6)). EU proposes several methods that MSs can adopt inter alia: a) use of deposit-return schemes; b) qualitative or quantitative targets; c) economic incentives; d) minimum percentages of reusable packaging (for each stream) placed on the market per year. This trend is further supported by an increase of packaging waste targets, *Table 2*. Clearly, in order to achieve those goals, WM based on separated collection is needed.

Table 2: MSW targets for packaging waste recycling

RECYCLING TARGETS OF PACKAGING WASTE SHALL BE INCREASED TO A MINIMUM OF			
By **2025**		By **2030**	
65% by weight		70% by weight	
Plastic	50%	Plastic	55%
Wood	25%	Wood	30%
Ferrous metals	70%	Ferrous metals	80%
Aluminium	50%	Aluminium	60%
Glass	70%	Glass	75%
Paper and cardboard	75%	Paper and cardboard	85%

Finally, EU action addresses the reduction of landfilled waste, and the safe disposal of such waste into sites. For this purpose, Dir 2018/850 strengthened the landfill restrictions laid down by Council Dir 1999/31/EC. To guarantee a shift toward prevention, reuse, and recycling it is indeed necessary to reduce at minimum the amount of landfill waste. Particularly, the type of waste that would be better handled through other recovery practices, such as plastic, glass, paper, metals, and Biodegradable Municipal Waste (BMW). For this reason, Article 5(3)f requires that MSs intervene to restrict the landfill for all wastes that have already been collected for re-use or recycling. This objective is particularly important in the case of untreated BMW. This last, if not supervised has demonstrated to produce large negative environmental impact (see Dir 1999/31/CE). Concerning waste reduction, Article 5(3a) lays down that MSs shall diminish the amount of MSW landfilled to less than 10% of the total amount of MSW generated by 2035.

In conclusion, over the last twenty years, MSs have progressively enhanced WM strategies in the direction of CE. Dir 2008/98/EC regulated the main procedures and requirements to reduce waste generation (waste hierarchy), see fig. 2. Moreover, Dir 1999/31/ aimed at diverting waste from landfills, jointly with Dir 94/62/EC promotes separated collection for waste recycling. Furthermore, the new EU Dirs of 2018 strengthen the objectives of waste reduction and increasing waste recycling. As a result, in EU between 2006-2016 the total amount of MSW landfilled decreased from 220 kg/person to 118 kg/person, waste incineration grew from 103 to 133 kg/person, and the quantity of waste recycled rose from 119 to 141 kg/person. Despite those results, however, WM needs a further improvement in order to close materials' loops. The next section will present four case studies, which were selected to investigate the different plans across EU related to the transition from WM to CE and their outcomes.

Comparative Analysis

France

In the 1960s, while the French population was doubling with the so called "baby-boom", also new technologies started to spread, leading to an acceleration of MSW production. In the period between 1960-1990, MSW increased by 60% mainly affected by a rapid growth of packaging and paper waste [10]. This situation has combined with an emerging saturation of landfill sites. Many disposal services were indeed closing, because not in compliance with the environmental rules. Therefore, WM schemes were reconsidered in favour of prevention and recovery practices. Accordingly, in 1992 the French WM was revised through the *Waste Law No 92-646* (July 1992), which regulated WM in the period between 1992-2007. The law foresees a program for waste reduction, waste recovery promotion, landfill ban, and disposal requirements. However, this legislation did not provide any quantitative target, hence throughout 2007-2008 a broader WM policy has been discussed within the so called *Grenelle Environment Process*. This consultation covered different environmental issues and involved many stakeholders (Unions, NGOs, etc). At the end of the consultation, it was created a new legal framework for WM, based on quantitative targets, as EU requires. It follows, *Grenelle I Law* of 2009 and *Grenelle II Law* of 2010 [10]. In 2015 a decisive step toward CE was made through the *Law on Energy and Transition* (Law 2015-992), whose objectives have been recently strengthened by the 2018 *Roadmap toward 100% CE "Feuille de route"*. The ministerial action plan, among the others, aims at increasing the amount of material collected and recycled, enhancing its quality, and incorporating more recycled materials into new goods [11].

In matter of MSWM[4], coherently with the amended Dir 2008/98/EC on waste, Grenelle first step concerned the *reduction of MSW generation*, through the introduction of a municipal waste prevention programme (Article 29 of the amended Dir 2008/98/EC). The *National Waste Prevention Programme* (Plan de reduction et de valorisation des déchets) covers the period 2014-2020. It enabled France to identify WM criticalities, establish preventive and corrective measures, and record operations results. The plan acts through quantitative targets: MSW per capita must reduce by 7% by 2020, and food waste production decoupled by 2025 [12]. Waste prevention targets were subsequently renewed, in 2015, by the *Law on Energy and Transition*, which sets per capita waste reduction of 10% by 2020 (baseline 2010) [12].

Concerning *MSW treatment*, the *Decree 2012/22* fixed higher recycling targets to enhance MSW material and organic resources' savings. In this regard, more efficient collection systems have been organized[5], as follow:

- Household waste (residual waste, comingled plastic and metal): Door-to-Door (DTD) collection;
- Packaging waste: DTD collection system;
- Paper and glass: bring sites collection;
- Green waste, bulky waste, construction and demolition waste, and recyclables, mainly from households: civic amenities;
- Biodegradable waste: separated collection (especially food waste), after the implementation of Grenelle II Law in 2011. However, still only 3% of the national territories have applied it [12].

Recently, the French MSWM has been reconsidered in direction of the CE The 2018 Ministerial *Feuille de Route*, indeed, recommends for new collection methods, with a specific concern for plastic packaging. Recyclable plastics are indeed expected to be 100% collected by 2025, also with the support of EPR for cans and bottles in hospitality industry [11]. The waste types covered by EPR schemes were broadened to cover medicines, paper, and textiles products. The Ministry additionally demands instruments for citizens that favour waste sorting. This includes, for example, the use of the 'Triman logo'[6] on goods, which provides information on the place to throw the various components of the products [11]. The plan further intends to increase the collection of BMW, which represents the largest part of French MSW. All these objectives will be supported by pricing incentives for WM (e.g. Pay as you Throw (PAYT), increase of the TGAP), and an efficient regulatory framework.

Finally, new objectives have been set to reduce the amount of *MSW incinerated and landfilled*, in order to limit the environmental and health impacts of waste [11]. Firstly, an incineration tax was introduced, in 2009, by the reform on the *Taxe Générale sur les Activités Polluantes* (TGAP) in accordance with the objectives set by the Grenelle II Law. The tax in 2009 was € 7/t, and increased in 2015 to € 14/t. The tax foresees a reduction in case of thermal recycling, indeed in 2015 it corresponded to € 3/t [12]. Secondly, the Government decided to recur also to disposal taxation. The TGAP reform in 2009 increased the landfill tax in accordance with the requirements set by the Grenelle I Law. Recently, the latter has been supplemented by the introduction of a landfill ban on untreated waste going to landfill, which nonetheless, is not fully respected [12]. Currently, waste reduction targets are based on the *Law on Energy and Transition* (2015), which requires the 50% reduction of non-hazardous waste landfilling, by 2025 (baseline 2010) [12].

[4] According to [12], French MSW is defined as: street sweeping; sewage sludge (not included in Eurostat data); garden and park waste from municipal sources; household waste (included waste delivered to recycling centres, bulky items, household hazardous waste and mixed and separately collected household waste); trade waste similar in nature to household waste.

[5] French collection services rely on three financing systems, depending on municipalities' decisions. The TEOM, Taxe d'enlèvement des ordures ménagères, is paid by households but not strictly related to the use of WM services. It depends on councils' discretion the decision to fund the service by using this tax. The REOM, Redevance d'enlèvement des ordures ménagères, is related to the use of WM services, and it is calculated on families composition, residential space or waste volumes. Finally, the municipal budget covers certain WM costs.

[6] The Triman Logo is a pictogram represented on products' packaging or directly on products that indicates how to sort them correctly.

Those measures brought some results on waste prevention (2004-2016). The *total waste generated* has first, increased from 2004, 296.58 Mt, to 2010, 355.08 Mt and, then, it progressively decreased until it reached 323.47 Mt in 2016. By contrast, *MSW generation* has remained almost stable during the whole period, with a growth rate of 6% from 2004 to 2016. In 2016, it was calculated that *MSW generation per capita* was 514 kg/p (Fig. 3).

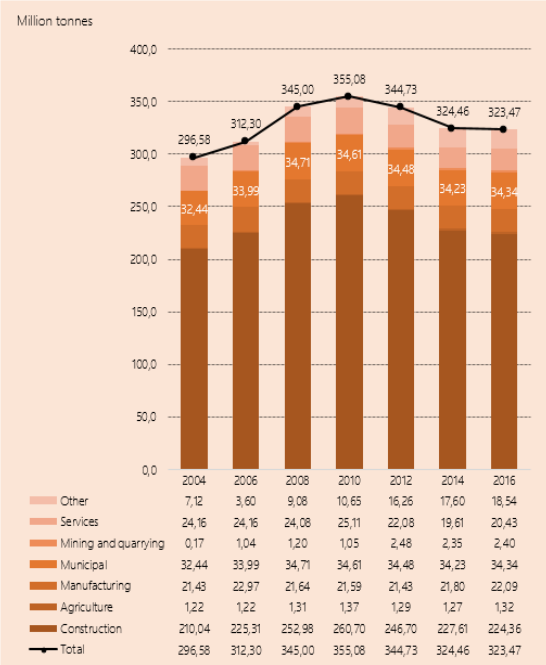

Fig. 3: Waste generation in France (hazardous-non-hazardous) 2004-2016.
Source: own elaboration from Eurostat, 2019

MSW recycling rates (*total recycling*) increased about one percentage point per year, from 29% (2004) to 34% (2014) to 42% (2016) [12]. Specifically, in 2016, on overall 34.34 MT of MSW generated, *material recycling* accounted for the 23%, and *organic recycling* for 18% of total MSW produced [13]. Concerning BMW, France achieved the targets set by Dir 1999/31/EC for 2006 (75%) and 2009 (50%), nonetheless, it is still approaching the 2016 objective (35%) [12].

The positive trends on waste recycling derive, first, by the improvements in the separate collection infrastructures, second, by investments made on recycling operations, and, third, by the revenues of landfill and incineration taxes. Nevertheless, according to EEA (2016), the landfill and incineration tax had weaker effects than expected on increasing recycling performance and reducing respectively landfilling and incineration [12]. Indeed, even if in the period 2009-2014 less waste was discarded compared to 2001 (41% against 21%), the tax increase led to a reduction of landfill rate of just 6 percentage points [12]. Then, in 2016, MSW *landfill rate* raised again to 23% [13]. Still too high in relation to EU objectives of less than 10% by 2035. Similarly, the incineration rate is decreased 2001-2014 (32%-36%) but still high. In 2016, *incineration* accounted for 36% of MSW [13].

According to EEA, the absence of strong correlation, between tax imposition and landfill reduction, could originate by the fact that France set low landfill and incineration taxes, compared to EU western MSs,(e.g. Germany and the Netherlands) and provided many types of tax exemption. Accordingly, «in 2010, the average landfill tax was € 14.6/t, compared to regular one 20 €, while the average incineration tax was € 2.9/t while the regular one is € 7» [12].

In conclusion, after ten years from the implementation of the new legal framework on WM (Grenelle Laws, 2009-2010), several improvements towards more sustainable operations can be highlighted:

- After a peak in 2010, both total waste and MSW generation decreased;
- MSW recycling rates are progressively increasing even if at a slow pace;
- Despite Incineration still a large share of MSWM, nevertheless it mainly regards for energy recovery;
- Binding separate collection for BMW has diminished bio-waste amounts into landfills compared to the 1990s, despite the 2016 EU goal is not on track;
- Landfill rates have been halved compared to 2001, but further efforts are required to achieve EU objectives.

Germany

Germany benefits from a high-developed industrial system, which nonetheless imports large quantities of energy and raw materials. Therefore, RE became fundamental for German business to continue guaranteeing the competitiveness of its economy. RE indeed does not only represent an ecological urgency, but given the rising prices also an economic concern [14]. For this reason, since the 1990s, CE is considered a priority within the German policy makers.

Currently, the core EU requirements on WM have been transposed by the *German CE Act* (Kreislaufwirtschaftsgesetz - KrWG), which entered into force June the 1st 2012. Among the others, the KrWG incorporates the EU legal definitions and principles on waste (concept of waste, recovery, recycling, and the polluter – pays principle). In addition, the KrWG included the application of the waste hierarchy, as disciplined by Art. 4 of the revised Dir 2008/98/EC. Beside the KrWG, other regulations have been formulated for specific waste streams [15]. Notice that the competence for WM is shared between the Federal Government and Local Authorities (Las). The central government defines the priorities and requirements for WM, in accordance with EU dispositions. Thereafter, Landers and LAs are entitled to issue further measures to comply with national and EU laws. Therefore «there is no national WM planning, rather each lander develops its own WM plan» [15].

The primary purpose for CE fulfilment is the reduction of waste volume and its pollutant substances. In line with the amended Dir 2008/98/EC, Art. 33 KrWG sets the obligation to draw up a program for *MSW prevention*[7]. In 2013, it has been adopted the first *National Waste Prevention Programme*, to revise in 2019, which includes targets (also for the prevention of specific waste streams, e.g. packaging, electronic waste, end-of-life vehicles) and related strategies for their attainment [16]. Several rules for waste avoidance also derives from the 1994 *Recycling Management and Waste Act*, which authorizes Federal Government to adopt a series of binding ordinances (e.g. ban of products containing hazardous substances, put on the market reusable products, set requirements for the labelling of products and for products' design, establish take back requirements for distributors/manufacturers, determine give-back requirements for consumers, and reporting obligation) [17]. Furthermore, waste avoidance does not only require a change in production technologies, but also consumers' contribution. Indeed, each year, Germany organises a series of raising awareness events within of the EU Week for Waste Reduction. Individuals' behaviours are indeed crucial to minimize waste and increase recycling rates. For example, by choosing more durable, repairable and recyclable products, or by using in place of owning [18].

To increase the share of *recovered materials* from waste, in 1991, the *Packaging Ordinance* (VerpackV) transposes EU Directive on packaging and packaging waste, by establishing targets for collection, recycling, and recovering [19]. From 1st January 2019, the VerpackV has been substituted by the *Packaging Act* (VerpackG), reinforcing the goals on packaging waste avoidance and recycling, and EPR schemes. Concerning products' responsibility, Germany was the first EU MS to commit manufacturers for the handling of end-of-life products. «It means that anyone putting goods into packaging or importing packaged goods to Germany also has to pay for disposal of the packaging» [20]. This system operates «either as placing takeback option in the markets, reusing or recycling the packaging or paying for a third party» [19]. In the case of household packaging waste, producers pay a licence fee to third agencies in-charged of organizing the recycling. This is defined as 'dual system', since private companies operate at the side of public services for the collection of packaging waste. In line with this, the Federal Environment Minister, Svenja Schulze, resumed the purposes of the VerpackG, by stating "*We want industry to really contemplate what packaging is necessary and what environmentally friendly materials could be used. This works especially well when environmentally harmful behaviour is expensive and environmentally friendly behaviour is being rewarded*". To this end, VerpackG establishes a "Central Packaging Registry". Every business using packaging or packaging waste must be listed in the registry, and provide information about the quantity and the destination (household or commercial) of packaging that it will put on the market. «The Central Registry will compare these data with the data provided by the dual system providers on the quantity of recycled packaging. It will then become public knowledge which businesses are fulfilling their financial product responsibility and thus ensuring that targeted recycling quotas can be met» [20]. Besides packaging waste, Germany wants to maximize the recovery of all recyclable products. In compliance with EU Dir 2008/98/EC, from January 1, 2015 the KrWG introduced the mandatory separated collection for paper, metal, plastics, glass wastes [19] and BMW (Art 5 Dir 1999/31/EC). Currently, Germany can benefit from a well-established MSW separate collection system, which nonetheless is not uniform throughout the country[8]:

- Residual waste: DTD services;
- Recyclable waste: DTD system (urban areas, e.g. by using bins) and disposal collection points (rural areas);
- Packaging waste: DTD collection or collection points of co-mingled packaging materials, as plastics and metals (e.g. by using bins or sacks);
- Deposit re-fund systems both for single-use and refillable recipients.

Waste collection and efficient waste segregation strategies should ensure high-quality recycled materials. The most innovative solution has been implemented in the field of material recycling. The new system enables the automatic identification of waste characteristics, through X-rays, near-infrared sensors, cameras, etc. Specifically: «Near-infrared sensors analyze materials or do an analysis of their molecular structure. Rapid camera systems identify the shape, surface, and/or color. Different camera types identify waste components by opacity or transmission. "CMYK" sensors were developed to distinguish printing inks with Cyan, Magenta, Yellow, and Black to sort paper» [21].

In the late 1980s, landfilling was highly widespread in Germany. A shortage of landfill capacity and pollution-related problems required an immediate response. Government firstly intervened on enhancing the safety of disposal sited and incineration plants, by placing limits on incinerators' emissions, restrictions on the landfilling of certain materials, and requirements for the construction and functioning of landfills [22]. At the beginning of the new century, waste regulation has been strengthened (2005) banning untreated MSW landfilling. This allowed the reduction of BMW going to landfill, as required also by the current EU Dir 2018/850. Accordingly, in Germany «before being landfilled, organic waste undergoes mechanical-biological or thermal treatment to render it inert and minimise the release of leachate and landfill gas» [22]. Between 2006-2012, it was reported that zero tonnes of BMW were disposed into landfills [15].

[7] MSW is defined as «waste from private households and similar institutions, as well as domestic-type waste produced by trade and industry». It includes «household waste, separately collected recoverable materials (glass and paper, packaging waste, organic waste and bulky waste)» [19] .

[8] The collection system is financed by citizens' fees (household residual and bio-waste) while EPR schemes provide funds for the DTD and collection point of packaging waste [15].

Fig. 4 shows a decrease on the *total amount of waste generated*, from 364 Mt (2004) to 363 Mt in 2010, which in 2016 has raised again to 400 Mt [23]. In this concern, it was observed that waste reduction rates are no longer linked to Gross Domestic Product (GDP) fluctuations. The waste intensity indicator[9] reveals that, although after the financial crisis there was an acceleration of total waste production, it was less sharp compared to economic growth [18].

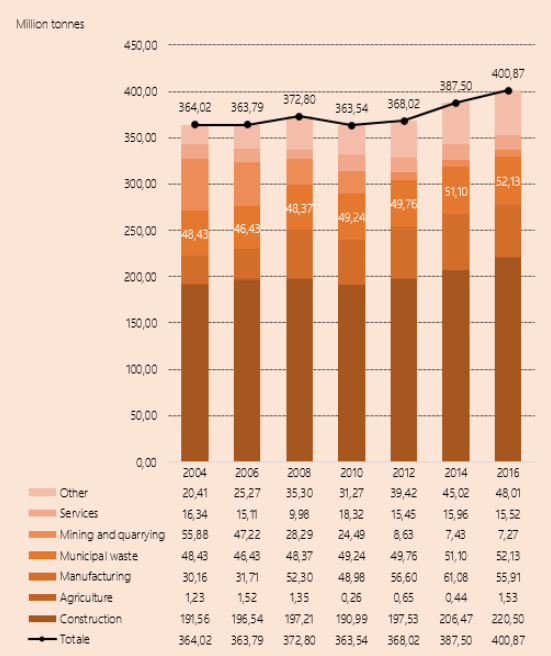

Fig. 4: Waste generation in Germany (hazardous-non-hazardous) 2004-2016.
Source: own elaboration from Eurostat, 2019

In spite of this, and despite «all generated waste reported is sent into treatment operations» [15] (after the 2005 ban), *MSW waste generation* remained almost stable. Moreover, on overall 400 Mt (2016), 52.133 Mt derives from MSW [13]. *MSW generation per capita* increased from 602 kg/p in 2010 to 633 kg/p in 2016 [13].

Therefore, the requirement of MSW pre-treatment, combined with separated collection measures of the VerpackV and KrWG, the EPR schemes, as well as efficient collection and sorting technologies, and rising in citizens awareness, strongly incentivized waste diversion from landfills, and addressed it to recycling operations [15]. *Total recycling* raised from 56% of the total MSW generated (2004) to 63% (2010), and 67% in 2016. As a result, Germany has already achieved the EU target of 65% recycling by 2035 (Art. 11 Dir 2018/851). In 2016, total MSW recycled was: *material recycling* 49% and *organic recycling* 18% (of the total MSW generated). Concerning organic waste, in 2016, 4.83 Mt of bio-waste were collected by household bio-bins, which were used for compost and digestate production. This is coherent with the report that registered zero tonnes of BMW waste going to landfill between 2006-2012 [15]. In light of this, *landfill rates* are progressively decreasing. In 2016, Germany indeed landfilled 1% of the total MSW generated.

On the other hand, should be noticed that even if 2005 ban on untreated MSW has had a strong impact on MSW recycling rates, still a significant share of MSW, 32%, is incinerated (of which 27% *thermal recycling*) «although material recycling would be ecologically beneficial» [16]. This derives, first, from the high costs that characterized the construction of many incinerators (Cologne, Stuttgart, and Frankfurt). High investments costs corresponds to long-term repayment perspectives. It follows that, private and public investors are more interested in using these infrastructures in order to maximize the return. Secondly, the low prices of waste incineration made material recovery uncompetitive. Thirdly, accordingly to KrWG «for waste streams with a calorific value exceeding 11,000 kJ/kg incineration has been declared equivalent to recycling» [14]. In doing so, Germany is incinerating material that could be recovered and used by industries.

In conclusion, despite a large amount of waste is still generated, Germany achieved important objectives in terms of municipal SWM, characterized by:

- High recycling performances (by: collection strategies, technologies for separation, citizens awareness);
- High safety standards for incinerators since the 1990s, but still incineration rate is too high;
- Zero BMW landfilled;
- Almost zero residual MSW landfilled.

Italy

The Ronchi Decree (*Legislative Decree 22/97*), issued in 1997, represents the first relevant piece of the Italian WM legislation. It transposes into national law three EU Dirs, namely the repealed EU Dir on Waste (1991), Dir on Hazardous Waste (1991), and Dir on Packaging and Packaging Waste (1994). It traces a change in the Italian approach to WM: from the handling of waste into landfills or incinerators, to the reduction of waste production and its hazardousness, and the increase of reusing and recycling. Accordingly, the Decree reshaped the Italian WM system, by reorganizing the actors involved, introducing new targets for MSW separate collection, and replacing the old waste tax with a new tariff [24].

After 1997, *Regions* are responsible for drawing WM plans. This includes the regulation of MSW separate collection, the authorization of waste disposal practices, such as the definition of criteria through which identifying the most favourable option for waste allocation. On the other side, *Provinces* have to monitor and supervise the compliance of local collection processes, while *Municipalities* are entitled to organize MSW collection and management, with the support of ATOs, optimal management areas [24].

[9] It measures the relation between GDP growth and net waste volume increase.

In 2006, the Decree 22/97 was repealed by the Environmental Code (*Legislative Decree 152/2006*), which has been subsequently revised to transpose the EU requirements of Dir 2008/98/EC by the *Decree 205/2010*. The latter, on the one side, confirms the main provisions set by the previous Decree 22/97, on the other it introduces innovations for ATOs organization[10] and increases the objectives for municipal separate collection. In the last years, Italy has been actively committed for the reorganization of WM in compliance with the CE Package. In this regard, in November 2017 the Ministero dell'Ambiente e della Tutela del Territorio e del Mare (MATTM) jointly with the Ministero dello Sviluppo Economico (MISE) have published the document *Toward a model of CE for Italy* with the aim to better define the national strategy on the issue [25].

For the fulfilment of CE, Italy put into the foreground the objectives of *reducing MSW*[11] amounts, lowering waste negative impacts on health and environment, and the presence of harmful substances into products. In 2013, indeed, the MATTM adopted the *National Waste Prevention Programme* (2013-2020), which endorses preventive measures before any material become waste. The plan primarily introduced targets to decouple waste GDP correlation (measures on quantitative prevention are established for MSW, which is expected to diminish of 5% per unit of GDP, by 2020 (2010 baseline)). Further measures target specific waste types, such as BMW, paper, and packaging waste [24]. In addition, the Government has elaborated multiple instruments to support prevention policies. Among the others, the Green Public Procurement (GPP) become a cornerstone in favouring sustainable consumption and production among the policy makers. Accordingly, to include environmental criteria into the purchasing decisions of public administrations, have often produced positive results [26]. On the other side, Testa F. et al. outlined several obstacles to GPP implementation, which also distinguish Italian realities. The limits encountered by the public administrations are: economic (higher cost of environmental friendly products); political (lack of promotion and resources to promote GPP practices); cognitive (lack of competent figures and training courses to overcome the problem). As a consequence, Italy needs higher level of awareness in order to entirely implement mature GPP instruments.

In order to further disincentive waste production, the Italian government has also introduced the waste tax, TARI, in 2014. The amount of the tax and its application is a municipal competence. In accordance to Law 147/2013, each municipality is entitled to decide the variable part of the TARI, to add to the fixed amount of the unified municipal tax Imposta Comunale Unica (IUC). TARI can be calculated or through a standardized method (in compliance with Presidential Decree 158/1999), or based on PAYT [24].

The Italian law has determined three objectives to be achieved on waste separate collection: 35% by 2006; 45% 2008, and 65% by 2012 [27]. Italian collection systems are highly diverse. Therefore, it is difficult to recognize a unified framework which brings together all municipal initiatives. Some regions, for instance, recur to kerbside collection schemes for BMW. Several regions have adopted special measures to enhance recycling operations. For example, Emilia Romagna promotes the use of compost by providing subsidies to farmers. On the other side, the Marche region allows a landfill tax reduction depending to the rate by which national separation targets are overcame [24]. Furthermore, few municipalities decided to apply the PAYT system. A survey carried out in 2014 involving 1.892 municipalities, about 23% of them, just 5% of them introduced the PAYT [24].

With regard packaging waste, Legislative Decree 22/97 instituted the National Packaging Consortium (CONAI) to guarantee the coordination of six material consortia, for the recovery of aluminium, plastic, glass, paper wood, and steel. These last have to be collected according to specific targets set by the Environmental Code for packaging waste. The activity of CONAI is self-financed by an environmental fee, whose revenues are mainly used to compensate municipality expenses for the take-back of packaging waste from waste separate collection [24].

In the last twenty years, the *landfill policies* have been shaped mainly around the requirements set by EU. Particularly, Italy has transposed the targets on BMW disposal introduced by the Landfill Dir[12], whose final aim is the progressive reduction of BMW landfilled by 1995. In this period, however, Italy landfilled the 82% of BMW, hence further objectives were adopted based on the quantity/weight of BMW landfilled per person [24][13]. The *Legislative Decree 36/2003* requests the integration of these goals within the regional WM plans to apply by ATOs [24]. Along with this, in order to reduce the amount of MSW diverted to waste sites, Italy introduced a landfill tax (*Law 549/1995*) in 1996. This last defines the maximum and the minimum level of the levy, whom amount is fixed at the discretion of the regions and paid by municipalities. It resulted a high heterogeneity «ranging, as an average, between 1999 and 2013, from € 6.9/tonne in Valle d'Aosta to € 25.8/t in Umbria and Veneto» [24]. Currently, the tax levels correspond to € 1–10/t for inert waste and € 5.17–25.82/t for hazardous and non-hazardous waste

[10] The Environmental Code has established that MWM shall be organized in regional plans and implemented by ATOs. They are, indeed, the managerial units which implement the plan designed by regions, and which ensure the attainment of separate collection targets. As a consequence, in cases in which the minimum percentages of waste collection are not achieved, ATOs will be fined. Specifically, «the payment has to be divided among the municipalities whose bad performances did not allow the ATO to meet the goal» [24].

[11] The DL152/2006 Article 184 (c 2) also contains the definition of MSW as household waste included bulky waste, non-hazardous waste from similar institutions, waste from gardens, public parks and streets.

[12] The Landfill Dir was incorporated into Italian law in 2003 with 18 months of delay.

[13] 173 kg/person for 2008; 115 kg/person for 2011; 81 kg/person for 2018.

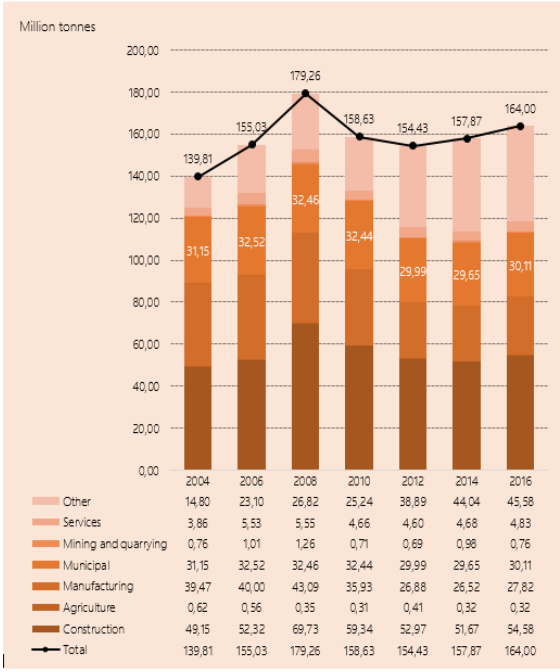

Fig. 5: Waste generation in Italy (hazardous-non-hazardous) 2004-2016.
Source: own elaboration from Eurostat, 2019

Fig. 5 displays the fluctuations of the Italian *total waste generation* in the period 2004-2016. Accordingly, waste production peaked in 2008 at 179.26 million tonnes, and has since diminished to 157.87 due to the economic slowdown. Shortly after it has slightly increased to 164 million tonnes in 2016. *MSW generation* followed the same trends. Indeed, after a significant increase in 2008 to 32.46 million tonnes, then it has progressively decreased to 29.65 million tonnes in 2014, and grew to 30.11 in 2016 [23]. On the other side, the Italian *MSW generation/person* positively shifted from 516 kilograms/person in 2001 to 488 kg/person in 2014 [23].

In Italy the amount of MSW generated in 2016 (30.11) varies from the quantity of waste treated, which in 2016 was equal to 27.11 million tonnes.

The majority of the Italian MSW generated has normally been landfilled. In 2001, the *landfill rate* was 68% of total MSW generated. This has progressively decreased in the last years, and in 2016 it counted for 25% of total MSW generated. The reduction was supported by the increase of the average tax level. Which from € 14.23/ t (2001) rose to € 19.35/t in 2013 [24]. However, there still exist significant differences between regions. For instance, while in 2014 Friuli Venezia Giulia landfilled 6% of its MSW, Sicily diverted 84% of MSW generated into waste sites [24]. Generally, regions that reported lower landfill rates, have developed more efficient separate collection strategies and/or higher landfill taxes. However, this last is not always the case, for example «in 2013, FVG, with 59% separate collection and 7% landfilling applied a landfill tax of € 25.8/t, while Lombardy with 53% separate collection and 6% landfilling, applied a landfill tax of € 10.5/t» [24]. Despite the overall reduction, in Italy landfilling continue to be widespread, mostly due to the low level of the tax compared to the others EU countries [24].

On average, the Italian *recycling rates* are receiving the positive impulse of the new policies aimed at waste recovery [28]. «The recycling industry, together with all its various components, has become a fully-fledged economic sector, characterized by high innovation content, particularly if waste reprocessing and product innovation are considered» [28]. Accordingly, from 31% in 2010, Italy joined 46% recycling rate on total MSW generated in 2016. Of which, 27% was *material recycling* and 19% *organic recycling* [13]. Nonetheless, the disparities on population density and on economic development among Italian regions resulted in remarkable heterogeneity of performance in recycling rates of MSW. Besides the lack of management infrastructures, several authors (such as D'Amato et al. (2015)) attributed the poor performance of Southern regions to the existence of illegal activities that involve the WM sector, often controlled by criminal organization [27].

Lastly with regards to incineration, Italy reached a percentage of 20% of MSW incinerated in 2016. According to the MATTM and the MISE in the document *Toward a model of CE for Italy*, Italy should foster the role of incineration in order to replace the still high quantities of MSW landfilled [25].

In conclusion, MSW generation in Italy has slightly decreased from 2004. Despite that, it is possible to underline positive progresses toward more sustainable management of municipal waste, particularly in the Northern regions. On average Italy fulfilled:

- MSW separate collection coverage in every regions;
- Economic relevance of recycling industry, which has brought to higher recycling rates compared to 2010;
- The reduction of biodegradable waste landfilled has exceeded EU targets. Accordingly, 33% of bio-waste was landfilled in 2014, against the EU target of 35% for 2016;
- Reduction of MSW landfilled from 2001.

The Netherlands

Dutch policies on WM has long been at the forefront of the EU regulation and often preceded it in the use of core principles. To contrast the high level of landfilling, indeed, the government, in 1994, incorporated into legislation the concept of the *Lansnik's ladder*, which corresponds to the 'waste hierarchy', included in the EU Dir 2008/98/EC [29].

In 1997, Dutch WM competences began a process of centralization from the provincial to the governmental authority. The change definitely came into effect in 2002, through the amendment to the *Environmental Management Act*. This last represents the implementation of EU Dir 2008/98/EC on waste and establishes that every six years the Ministry for Housing, Spatial Planning and the Environment (in-charged of all environmental policies) must elaborate a *WM Plan*

[29]. The executive branch of the Ministry, is the Rijkswaterstaat. He has to support the implementation of the environmental policies, which are handled by municipalities.

Generally, the National WM Plans (NWMPs) stipulate WM rules «of all waste covered by the Environmental Management Act» [30], with the objective of reducing waste disposal and enhancing recovery practices. It addresses to national authorities, provinces, and municipalities [30]. The 1st NWMP 2002-2012, entered into force in 2003. In 2009 it was revised by the 2nd NWMP, which covered the period 2009-2015 and provides targets for 2021. Currently, the 3rd NWMP is in force and covers the period 2017-2023 looking ahead to the period up 2029. [30].

In order to promote RE and CE transition, the Dutch government has broadened its objectives. Accordingly, in 2014 it has published the programme *Waste to Resource* (VANG). In 2016, this last was incorporated in a wider policy programme *A CE in the Netherlands 2050*, which sets more specific measures for achieving the CE transition. Among all, the plan directs 50% reduction of primary virgin material use (minerals, fossil and metals) by 2030, and by 2050 the Netherlands will be able to realise a fully-CE. To this end, indeed, raw materials will be used as many times as possible, and deployed according to the most favourable options. In the cases in which the avoidance of resources consumption is not possible, these will be extracted through sustainable methods, e.g. use of renewable resources [31]. This entails the need to continue focusing on «the sustainable acquisition of raw materials and on the preservation of our natural capital in order to provide future generations with raw materials as well» [31].The attainment of these objectives requires the combination of different measures: an efficient legal framework, market incentives, financing, business innovation, and the support of international cooperation [31].

In line with EU Dir 2008/98/EC on waste the Netherlands adopted the *National Waste Prevention Programme* in 2014, which includes MWM plans. The latter identifies a series of quantitative targets and measures directed towards the *prevention of municipal waste*[14], which has been incorporated in the 2nd NWMP (2009-2021). Furthermore, based on EU legislation, the government implemented (among the others) the *Decree on Eco-design*, sustainable procurement, producers' responsibility, strategies to influence consumers' habits, and performance calculation methods [17].

In the last twenty years, a large amount of material consumption, the lack of space and land deterioration in the Netherlands determined Government intervention towards landfill reduction. Accordingly, for the attainment of waste prevention targets and waste disposal limits, the Dutch government developed a strategy based on: waste separated collection requirements, *treatment and recovery* (i.e. reuse, and material, organic and thermal recycling), agreement with industries, and EPR schemes [32].

Municipalities are in charged for the collection of waste[15] related to their territories. Generally, MSW is collected:

- Mixed waste: DTD services;
- Recyclable waste: DTD collection or comingled[16](e.g. paper, plastic, bottles, etc.);
- Bring sites is an alternative for DTD that can involve all the above-mentioned recyclables and also glass and metal packaging waste;
- Organic household waste: separated collection, compulsory since the Environmental Management Act (2008) [30];
- Deposit re-fund systems both for single-use and refillable of glass and PET recipients [29] .

Since 2001, the government has been interested in stimulating thermal recycling. The 2nd NWMP (2009) indeed establishes several targets to enhance energy recovery, to combine with the inflation of landfill prices. These manoeuvres, jointly with the effect of external factors[17], determined the expansion of incineration. However, the objective of higher recycling rates is concurrent with the goal of enhancing incineration capacities [32]. This has led to an increase of residual waste import and the introduction of an incineration tax, in 2014, to apply only to the Dutch waste [32], according to the objectives set by the *Waste to Resource* programme.

Another important instrument, in matter of waste recovery, is the cooperation between the government and industry. In 2011, it has been launched the *Green Deal Programmes* «The deal consists of agreements between the government and various private parties that focus mainly on removing non-financial barriers related to regulations, legislation or licensing» [32]. Currently, given the high recovery rates, the Deals mainly focus on the quality improvement of recycled

[14] The definition of MSW in the Netherlands mainly corresponds to household waste, which is separated in different categories, such as: vegetable, fruits, food, garden waste, small chemical residues (batteries), paper, bottles and glass, textile, furniture, wood, and metal [31].

[15] On the one side, the collection of MSW is funded by local taxation. Municipal charging schemes has been a key measure to favour separate collection among citizens. For example, since 2015 the 40% of municipalities have introduced the PAYT system [30]. Other cities have instituted reverse-collection schemes, according to which the DTD collection of recyclable is intensified and, by contrast, the collection of residual waste is reduced or handled only through amenity services [30]. On the other side, the collection of municipal packaging waste is financed by fees deriving from EPR schemes. In 2005, indeed, the Dutch Packaging Decree conferred to producers the responsibility of the separate collection and recycling of end-of-life products' packages. In this concern, in 2013 was introduced an EPR scheme for the management of separate collection of packaging waste [30].

[16] Recyclable waste, which is collected through comingled systems, is subsequently sorted by recycling facilities.

[17] For example, in 2005 the German introduction of a landfill ban for untreated waste, mostly prevented the exportation of Dutch waste, which ended into incinerators. Then, in 2010, the EU defined a distinction between incineration for disposal and energy recovery. This allowed Dutch incineration plants, which produced heat and electricity, to be recognized as *recovery installations*. Finally, EU introduction of renewable energy targets enhanced the value of thermal recycling with energy recovery for the achievement of the national objectives [32].

waste. In accordance, the government has recently developed an *e-tool*, which enables companies to assess independently the quality and status of materials. Another example, is the *Sustainable Trade Initiative*, signed by the government and private organizations, which aims to guarantee the sustainability of raw material extraction and gathering.

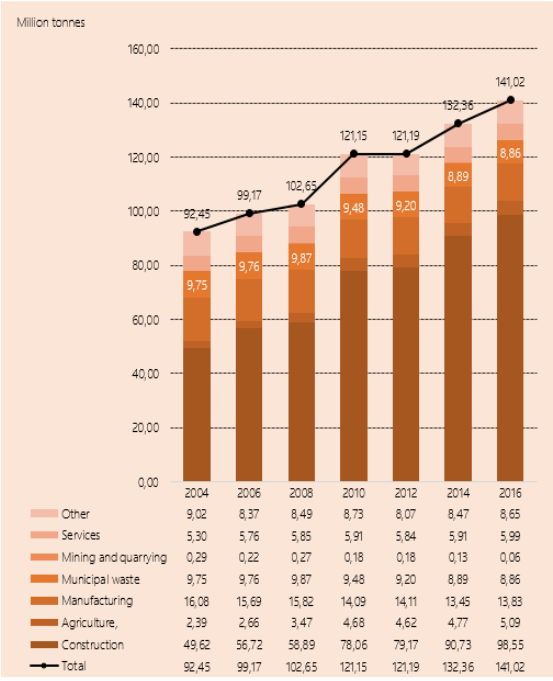

Fig. 6: Waste generation in The Netherlands (hazardous-non-hazardous) 2004-2016.
Source: own elaboration from Eurostat, 2019

In accordance with the restrictions on BMW set by the amended EU Dir 1999/31/EC, the *Waste Decree*, in 1995, enacted a landfill ban for 35 waste categories, which includes bio-waste and also introduced a landfill tax, which had a significant impact on the waste generation and recycling and incineration rates. From 2002 to 2012 the landfill tax was subjected to several fluctuations. The tax corresponded to € 79/t in 2002, and reached € 107.5/t in 2010, the highest level in EU [29]. In line with the decline of dumped waste and support of energy recovery, also the revenues from landfill tax started to diminish. The tax mostly became an administrative burden; consequently, it was eliminated in 2012, but subsequently reintroduced in 2014 [29].

The *total amount of waste generated* increased from 92.45 million tonnes (2004) to 121.15 Mt in 2010 and has raised again to 141 Mt in 2016, Fig. 6. Contrarily, MSW presents a reduction from 9.75 million tonnes in 2004 to 8.86 in 2016. Specifically, *MSW generated per capita* remained stable until 2008 around 600 kg/person [23], although in 2003 it significantly declined due to a hot and dry summer, which has affected the production of organic waste [29]. Since 2009, MSW amounts started to reduce progressively, MSW generation per person indeed decreased from 571 kg/person in 2010 to 520 kg/p in 2016 [13].

In the Netherlands MSW generated is equal to MSW treated. All results have been assessed by relating waste generated and waste treated amounts.

In 2004, MSW *total recycling* was 46% of total municipal waste generated. The subsequent years have been characterized by a slight increase in recycling levels due to both the already high percentages and relative cheap incineration. Indeed, the Netherlands reached the 51% recycling of MSW in 2010 [29], and 53% in 2016 [13]. Despite the slow progress during the last period, the Netherlands has almost achieved the EU target for 2025 (Dir 2018/851 art. 11). More into details, in 2016, on overall 8.86 million tonnes of MSW generated: 25% were subjected to *material recycling*, and 28% to *organic recycling.*

The landfill tax together with the landfill ban and the 2nd NWMP initiatives had strong impacts on diverting waste from landfills. Accordingly, in 2000 around 9% of total MSW was landfilled, but in 2007 it has already dropped to 2%. In this regard, the EEA affirms that «there is no simple correlation between the landfill tax increase and the total recycling of MSW» [29]. However, it is possible to notice a steady increment in recycling in correspondence to the landfill tax growth, which can be interpreted as more MSW diverted to recycling. Currently, the Netherlands *landfills* 2% of the total MSW produced. On the other side, high landfill taxation and measures to favour incineration have translated into lower incineration prices [29], which has boosted incineration. Indeed in 2012 the 49% of MSW (9.2 million tonnes generated) was incinerated, of which 46% for energy recovery [13]. Still in 2016 incineration rate was relatively high at 44% of MSW generated. This indicates that more efforts are needed to reinforce material and organic recycling [32].

The OECD (2015) has defined the Netherlands as a pioneer in SWM planning [32]. It indeed combined a wide range of instruments: political, economic, financial, and information based. Dutch SWM translates into:

- Decrease of MSW generation from 9.45/tonnes in 2004 to 8.85/tonnes in 2016;
- High level of recovery practices, even if further efforts are needed to divert part of waste incinerated to recycling;
- High performances by maintaining MSW charges low;
- Low BMW landfilled;
- Almost zero residual MSW landfilled;
- High-quality waste data.

Conclusions

Case studies' analysis confirms an overall positive trend on SWM transition. The best results have been achieved by Germany, which reduced at minimum its landfilling burden, and overcame the 2035 EU recycling target in 2016. The Netherlands is placed slightly behind. The results show that the Dutch legislation has had positive effects on driving the country towards higher recycling rates, which exceeded EU 2020 targets, and very low dumping. On the other side, despite both France and Italy are not still on track with EU targets, particularly in relation to landfilling, the analysis displayed positive progresses since 2004, which shows an enhancement in MSW management practices.

Nevertheless, besides SWM achievements, this paper aims to analyse, from the qualitative point of view at this stage, whether an improvement on MWM might be an intermediate step towards CE. In this regard, the authors resorted to the CMU rate elaborated by Eurostat in 2018[18]. EU indeed did not provide a unique indicator for circularity, therefore Eurostat has identified the ratio which measures, at macro economical level, «the share of material recovered and fed back into the economy — thus saving extraction of primary raw materials — in overall material use» [33], which corresponds to $\frac{U}{M}$. The indicator is composed by M, which is the overall material use, calculated by the sum of the domestic material consumption plus the amount of circular use of materials, hence $M = DMC + U$. By contrast, U indicates the secondary raw materials returned into the economy, which is the amount of waste recycled[19] into recovery operations minus the imported waste delivered to recovery and plus the exported waste delivered to recovery abroad $U = RCV\_R - IMP + ESP$.

The EU presents a progressive increase in CMU in the period 2004-2016. From 8,3% in 2004 joined 11,7% in 2016 (even if with a small negative peak in 2011). Nonetheless, the increase of CMU indicator, according to Eurostat must be interpreted according to a decrease of DMC experienced by EU in this period, rather than an enhancement of recycling practices. Indeed, «In the year 2008 more than 880 Mt of waste were recycled. From that year on, the amount steadily decreased down to 864 Mt in 2013, to raise again in 2016 to 906 Mt. On the other hand, DMC has dropped from 8,270 Mt in 2008 to 6,827 million tonnes in 2016» [33]. Furthermore, EU countries strongly differentiate in CMU results. Considering the four case-study countries, indeed, in 2016 in France CMU rate was equal to 19.5%, in Germany 11.4%, in Italy 17%, and in the Netherlands 29%.

CMU rate confirms that WM is in the right direction while the SRM is just started its way. The reasons have been classified by the research of J. Kirchherr et all. (2018) in four barriers to CE: *cultural, regulatory, market failure, and technological***.** The authors identified that *culture* is the most significant constraint to CE. Business and policy expert revealed that consumers are attracted by new products. This discourage investments on enhancing goods' durability. On the other side, notwithstanding the general idea that CE is currently widely welcomed by industries, rather this research suggests that sustainability is still restricted to a business niche. This may depend on lack of consumers' demand, to whom companies is mostly conditioned, or on lack of manufacturers' trust. Furthermore, many industries declared that the current supply chain is largely conservative. «If you talk about CE, these players only glance at you with a question mark in their eyes» [34]. This confirm the finding that CE is not a mainstream concept. The second barrier regard *market failures*, which include 'Low virgin material prices' and 'high investments costs'. CE products and initiatives, indeed, do not result economically convenient compared to the traditional ones. For example, oil-based plastics are more expensive than bio-based plastics. In light of this, it is possible to consider *market barriers* at the roots of the above-mentioned cultural barriers. Higher raw material prices may render circular products' more affordable, whereby enhance consumers' interest, and consequently firms' convenience to abandon linear systems. On the other side, high investments' costs can be at the basis of 'Hesitant company culture'. Sceptical leaders against CE may indeed refuse to take initiative because is too expensive. Thirdly, *regulatory barriers*, although are not perceived among the core barriers, they represent a further limitation for CE. Despite EU interest in bringing a circular transition, the aforementioned market barriers may partially depend on legislative intervention. In certain cases indeed, low raw material prices are artificial by means of subsidies application, e.g. on fossil fuels. In other cases, products' prices do not consider the externalities generated during the entire life-cycle. In addition, to provide further financial support can help industries to face the high investments costs, which are perceived by business as a pressing obstacle in their decisions. Finally, *technological barriers* have been identified as the less influential, even if they represent a prerequisite for CE transition. They include: 'Limited circular design' 'Ability to deliver high quality remanufactured products', 'Lack of data, e.g. on impacts' 'Limited circular design'.

From Kirchherr et al., research emerges that the government is a crucial actor in favouring the CE change. Indeed, by intervening on the outlined market barriers, it may be possible to tackle the cultural constraints, which play the main role in slowing down the transition. A critical view to the EU policy on RE is provided by the work of Domenech and Bahn-Walkowiak. The authors indeed affirm that although the decoupling of resource exploitation from economic growth is part of EU priorities, few instruments and strategies have been specifically dedicated to the issue, both at EU and national level [5]. Generally, both still appear mostly *output oriented*. Regarding waste, the waste hierarchy is not efficiently regulated. Accordingly, no target for prevention and reuse have been introduced nor at EU neither at national level. This entails that, «most countries refer to resource policies as an efficiency issue, not an issue of reducing the absolute input».

The progresses on recycling, outlined by this work, are undoubtedly the right direction to pursue in order to close the loops and encourage the circularity of resources. However, they are not sufficient without the support of material use decoupling. From here, EU Commission revealed the necessity to implement a process that foresees products' recyclability since manufacturing. Industrial systems must develop new design approaches, in line with the use of regenerative sources of energy, the extension of products' lives and their recovery, and the elimination of toxic materials. Product design indeed has a fundamental role to enhance material efficiency [35].

[18] Eurostat calculated CMU referring to official statistics reported by MSs under legal commitment. There are comprised, waste statistics (data extracted from: env_wastrt), economy-wide material flow accounts (EW-MFA, data extracted from: environmental-economic accounts), and trade statistics (data extracted from: COMEXT website [33].

[19] Exclusion of energy recovery and backfilling.

Design strategies develop in accordance to critical material research. In this regard, The EU Commission has recently entrusted the JRC with the project "*Environmental sustainability assessment comparing through the means of LCA the potential environmental impacts of the use of alternative feedstocks (biomass, recycled plastics, $C0_2$) for plastic articles in comparison to using current feedstocks* (oil and gas)" [20]. The research developed under the framework of the EU Plastic Strategy in a CE (COM(2018 20 final). The strategy promotes the use of innovative materials and alternative feedstocks (e.g. biodegradable or compostable plastics) for the production of plastic products, when evidence demonstrated that they are more sustainable compared to traditional non-renewable options. Therefore, scientific researches are needed in order to identify in which conditions biodegradable or compostable plastics provide clear environmental benefits. LCA studies were applied to a selection of plastic articles to test the methodology, which will be applied to all sectors. The most impacting plastic-related sectors were selected. The five case studies included: beverage bottles, food flexible packaging film, mulch film, insulation material, and car interior panels.

In conclusion, this paper aimed to analyse, from the qualitative point of view, how the EU developed a SWM in terms of philosophy, methodology, indicators, targets and finally policies based in terms laws and enforcement. On the other hand, how the EU is trying to develop an efficient and efficacy system to go on the direction of CE. In nutshell, some steps have been already set up but much more should be done. In terms of research, the next step should be to analyse how the CMU indicator might be used in order to analyse the CE from the quantitative point of view. Potential in terms of sector growth, R&D and labour market. In this last instance indeed, there is a lack of employments statistics in the waste sector. The EPSU Report recognized that employment in the WM sector is increasing. For instance, in 2014 1.1 million full-time jobs were employed and this corresponds to a 36% increase since 2000. The big proportion of workers is employed in waste collection (56% of waste sector employees), by contrast few jobs have been found in the recycling sector[21], although the recycled amount of waste has increased between 2010-2014 by 27 million tonnes[22]. Furthermore, still not much has been written on CE potential employment creation. According to (EPSU Report, 2017) CE activities are supposed to generate 1 million new jobs across EU-28 by 2030[23]. However, in this regard CE employment conditions are still an under-researched topic [36].

References List

[1] W. Steffen, P. J. Crutzen and J. McNeill, "The Anthropocene:Are Humans Now Overwhelming the Great Forces of Nature?," *Ambio 36, 8,* pp. 614-621, December 2007.

[2] M. Lieder and A. Rashid, "Towards circular economy implementation: a comprehensive review in the context of manufacturing industry," *Journal of Cleaner Production,* pp. 36-51, 2016.

[3] EPRS, "Briefing:Turning waste into a resource: moving towards a 'CE," (Prepared by Didier Bourguignon), 2014.

[4] S. Fabrizi and P. Sospiro, "Waste Management in Europe: A Comparative Study of the main EU countries: Methodology and Evaluation of Local Waste Management System," Lambert Publisher, Saarbücken, Germany, 2017.

[5] T. Domenecha and B. Bahn-Walkowiakb, "Transition Towards a Resource Efficient Circular Economy in Europe: Policy lessons from the EU and the Member States," *Ecological Economics,* pp. 7-19, 2018.

[6] European Commission, "Implementation of the CE Action Plan," Report from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions COM(2017) 33 final), Brussels, European Commission, 2017.

[7] S. Cobo and A. I. Antonio Dominguez-Ramos, "From linear to circular integrated waste management systems: A review of methodological approaches," *Resources, Conservation & Recycling,* p. 279–295, 2018.

[8] J. Castillo-Giméneza, A. Montañés and A. J. Picazo-tadeo, "Performance and convergence in municipal waste treatment in the European Union," *Waste Management,* pp. 222-231, 2019.

[9] Eurostat, "Municipal waste statistics," data extracted July 2018.

[10] N. Buclet and O. Godard, "Municipal Waste Management in France," in *Municipal Waste Management in Europe: a Comparative study in building regimes,* Environment & Management, 2000.

[11] Ministere de la transition ecologique et solidaire, "Roadmap for the Circular Economy: 50 measures for a 100% circular economy," 2018.

[20] Further details on the project are available on http://eplca.jrc.ec.europa.eu/?page_id=1862.

[21] In January 2013, 190.222 people were employed in the material recovery sector in EU-28. By the end of 2014 only 2500 people more were employed in the same sector which corresponds to a 1,3% increase in nearly 2 years.

[22]

[23] In 2015 there were estimated 3.38 million people were employed in CE.

[12] EEA, “Municipal Waste Management: France,” 2016.

[13] Eurostat, “Municipal waste by waste management operations,” Last update February 2019.

[14] H. Wilts, “Germany on the road to a Circular Economy,” WISO Diskurs, 2016.

[15] EEA, “Municipal Waste Management: Germany,” 2016.

[16] M. Nelles, J. Grunes and G. and Morscheck, “Waste Management in Germany: development to a sustainable Circular Economy?,” *Procedia Environmental Sciences,* pp. 6-14, 2016.

[17] Ministry of the Infrastructure and Environment, “Factsheet for waste and resource management,” 2013. [Online]. Available: https://rwsenvironment.eu/subjects/from-waste-resources/downloads-waste-and/factsheet-waste/..

[18] BMU, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, “Waste Management in Germany,” 2018.

[19] C. Dornack, “Waste Policy for Source Separation in Germany,” in *Source Separation and Recycling*, The Handbook of Environmental Chemistry, 2017.

[20] Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, “The packaging Act has entered into force: less packaging, more transparency and recycling,” Published January 2019. [Online]. Available: https://www.bmu.de/en/press/press-releases/..

[21] B. Bilitewsky, “40 years of source separation in Germany and its Future,” in *Source Separation and Recycling*, Springer, 2017, pp. 5-319.

[22] Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, “Background: the development of waste policy in Germany,” Last Modified January 2019. [Online]. Available: https://www.bmu.de/en/topics/water-waste-soil/waste-management/waste-policy/..

[23] Eurostat, “Generation of waste by waste category,” February 2019. [Online].

[24] EEA, “Municipal Waste Management:Italy,” 2016.

[25] Ministero dell'Ambiente e della Tutela del territorio e del mare ; Economico, Ministero dello Sviluppo, “Towards a model of Circular Economy for Italy: Overview and Strategy Framework,” 2017.

[26] F. Testa and e. all., *What factors influence the uptake of GPP (Green Public Procurement) practices? New evidence from an Italian survey,* 2011.

[27] M. Agovino and A. Garofalo, “Effects of the environmental regulation on separate waste collection dynamics:empirical evidence from Italy,” *Journal of Cleaner Production,* pp. 30-40, 2016.

[28] Ambiente Italia Work Group, “Executive Summary taken from "Eco-Efficient Recycling: Economic, Environmental and Energetic performance perspective”,” Edizioni Ambiente, 2008.

[29] EEA, “Municipal Waste Management: The Netherlands,” 2016.

[30] EIONET, “Faactsheet for Netherlands,” Last update January, 2012. [Online]. Available: https://scp.eionet.europa.eu/facts/factsheets_waste/2009_edition/factsheet?country=NL. .

[31] The Ministry of Infrastructure and the Environment, Ministry of Economic Affairs, “Government-wide programme for a Circular Economy " A Circular Economy in the Netherlands by 2050",” 2016.

[32] OECD, “Environmental performance review: The Netherlands,” 2016.

[33] Eurostat, “Circular Material Use rate: calculation methods,” 2018.

[34] J. Kirchherr and e. all., “Barriers to the Circular Economy:Evidence from the European Union (EU),” *Ecological Economics,* pp. 264-272, 2018.

[35] H. Wilts, “Key Challenges for Transformations Towards a Circular Economy: The Status Quo in Germany,” *International Journal of Waste Resources,* pp. 1-5, 2017.

[36] V. Weghmann, “Waste Management in Europe. Goods jobs in the Circular Economy,” Commissioned by European Public Service Union (EPSO), December 2017.

[37] Ministero dell'ambiente e della tutela del territorio e del mare, "Economia circolare: l'economia circolare in Italia," Last update October, 2017. [Online]. Available: https://www.minambiente.it/pagina/leconomia-circolare-italia..

[38] N. Van Buren and e. all., "Towards a Circular Economy: the role of Dutch logistic industries and governments," *Sustainability,* pp. 1-17, 2016.

[39] M. Cox, H. Nugteren and M. and Janssen-Jurkovičová, Combustion Residues: current novel and renewable applications, Wiley, 2008.

[40] J. Korhonen, H. Antero and S. Jyri, "Circular Economy: The concept and its limitations," *Ecological Economics,* pp. 37-46, 2018.

[41] Y. Kalmykova, M. Sadagopan and L. Rosado, "Circular Economy: from review of theories and practices to development of implementation tools," *Resources, Conservation, and Recycling,* pp. 190-201, 2018.

[42] G. Halkos and N. P. Kleoniki, "Assessing 28 EU member states' environmental efficiency in national waste generation with DEA," *Journal of Cleaner Production,* pp. 209-521, 2018.

[43] J. Fellner, J. Lederer, C. Scharff and D. Laner, "Present potential limitations of a Circular Economy with respect to primary raw material demand," *Circular Economy,* pp. 494-497, 2017.