Demonstrating resource efficiency through innovative, integrated waste recycling schemes for remote areas

PAVEtheWAySTE

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1. Introduction

Waste is strongly related to the production of greenhouse gases and therefore to climate change. This is because waste is related to production and consumption: more waste means more consumption and production and therefore more Greenhouse Gases (GHG) emissions into the atmosphere. On the other hand, if waste is not properly managed and is dumped in landfills, methane emissions are produced, with the consequent problems this causes for the environment.

Therefore, a comprehensive waste management, which considers the impact on the environment and seeks to counteract it, is essential to promote sustainable development. This adequate waste management should revolve around five axes.

- **Reduce methane emissions from landfills**. To do this, there is nothing better than sorting waste and avoiding it going to landfill either through recycling or through the energy recovery of waste.
- **Promote recycling**. If waste is properly managed, it can be recycled and given a new life. Therefore, greenhouse gas emissions will be reduced in cities, industry and other productive sectors.
- **Energy valorisation**. Some waste cannot be recycled, but can be used as fuel for industry. Taking advantage of this possibility will help to make development more sustainable.
- **Monitor paper consumption**. We are running out of forests, in many cases because of the demand for paper. If we reuse paper, do not print unnecessary documents or use recycled paper, we will stop deforestation and trees will be able to produce the oxygen needed to counteract GHG emissions.
- **Less transport of waste over long distances**. By leveraging the infrastructure of nearby waste treatment plants, long distances are avoided with the resulting energy consumption and gas emissions.

2. EU & National Policies, Laws & Goals on Solid Waste Management

At European level several regulations are actually in force regarding waste and its management. **Waste Framework Directive** (Directive 2018/851 of the European Parliament and the Council on amending Directive 2008/98/EC on waste). It sets the basic concepts and definitions related to waste management, such as definitions of waste or recycling. It introduces the waste hierarchy, the Polluter Pays principle and the Extended Producer Responsibility and sets out separate collection targets.

Landfill Directive (Directive 2018/850 of the European Parliament and of the Council amending Directive 1999/31/EC on the landfill of waste). It aims to prevent or reduce the adverse effects of the landfill of waste on the environment. It defines the different categories of waste and applies to all landfills. It also classifies the types of landfills and obliges Member States to minimize biodegradable waste to landfills.

Packaging and Packaging Waste Directive (Directive 2018/852/EC of the European Parliament and of the Council amending Directive 94/62/EC on packaging and packaging waste). It sets out measures and requirements for the prevention, re-use and recovery of packaging wastes in Member States. Member States must ensure that packaging placed on the market complies with the essential requirements. The Directive implies the Producer Responsibility principle.

Waste Shipment Regulation (Regulation (EC) No 1013/2006 of the European Parliament and of the Council on shipments of waste). It specifies the procedures for controlling waste shipments to improve environmental protection and sets out a system

of control for the movement of waste. It concerns almost all types of waste shipped. The European Commission is currently working on a proposal for revision.

Moreover, there are a number of relevant European Commission's communications which are worthy of particular attention due to the strong link to the EU waste policy and circular economy. The **European Green Deal** provides the overall EU strategy to achieve the efficient use of resources by moving from a linear to a circular economy model and aims to restore biodiversity and cut pollution. In particular, it identifies a need to reduce waste generation and foresee changes in the EU waste collection and the **Circular Economy Action Plan 2.0** that announces specific strategies to move from a linear to a circular model on a wide range of materials (plastics, textiles, food, batteries, construction, etc.) and foresees waste reduction targets as well as actions to promote reuse, repair and recycling.

In Spain, regulations really take into account the relationship between climate change and waste management, thus the new waste framework Directive is coming to by transposed under the **draft Law on waste and contaminated soil**. However, **Law 22/2011 of 28 July** is currently in force and recognises that there is a significant potential for reducing GHG emissions associated with the waste sector. To this end, it requires the adoption of the necessary measures to ensure that waste management is carried out without endangering human health and the environment and that it is consistent with strategies to combat climate change. Furthermore, the authorities' waste management planning must be in line with the commitments made on climate change.

Regarding to the draft Law, which is about to be adopted, the initiative is committed to increasing separate collections of different waste fractions, including door-to-door collection and other solutions. Another of the general lines contained in the latest draft of the Law is the establishment of an "integrated state network of waste disposal facilities and facilities for the recovery of mixed household waste" and that waste management will be encouraged in infrastructures "as close as possible to the point of generation". In addition, certain measures included in this draft are foreseen to start from 31 December 2021.

On the other hand, the **State Framework Plan for Waste Management 2016-2022 of the Directorate General for Environmental Quality and Assessment and the Natural Environment** includes a commitment to reuse, recycling, recovery and disposal. Furthermore, this plan takes into account the fact that different waste materials behave differently in terms of GHG emissions, as well as the importance of efficiency in the use of resources and raw materials.

European Directives targets are focus on:

- Increase re-use and recycling of waste materials from households, e.g. at least paper, metal, plastic and glass, to 50% by 2035;
- Increase re-use, recycle and other material recovery of non-hazardous construction and demolition waste to 70% by 2020.
- Reduce the amount of biodegradable municipal waste going to landfills to 35%.
- The preparing for re-use and recycling of municipal waste shall be increased to a minimum of 55 %, 60% and 65% by weight by 2025, 2030 and 2035 respectively.
- 60% as a minimum by weight of packaging waste should be recovered or incinerated at waste incineration plants with energy recovery;

- 55% as a minimum and 80% as a maximum by weight of packaging waste should be recycled;

Accomplish with European targets, at national level, regulations have also in mind several goals regarding to protect the environment and human health and make the transition to a circular economy to ensure the efficient functioning of the internal market and Spain's long-term competitiveness, preventing and reducing the impact of certain plastic products, and the decontamination of soils.

3. Municipal solid waste management in Spain

The Spanish population distribution further complicates municipal waste management. Only 0.8 percent of Spanish municipalities have more than 100,000 inhabitants, whereas 60 percent have less than 1,000 inhabitants. However, cities with more than 100,000 inhabitants represent 50% of the population and produce 70% of the waste, while municipalities with less than 1,000 inhabitants represent 5% of the population and produce 3% of the waste. Furthermore, 90% of the Spanish territory counts on a population density less than 20 inhabitants per km^2. This dispersion of the population and its concentration in small administrative units give waste collection a more rural character. Furthermore, there are rural and island areas whose characteristics cause them to be isolated zones. In order to perform the upscale at European level a threshold of “45 minutes travel time to reach an urban centre with at least 50,000 inhabitants” has been selected to classify a commune as “remote” or “close to an urban centre”. According to this definition, 55% of the Spanish territory can be considered as remote.

The collection, treatment, transport and removal of solid urban waste are considered as public services of general interest, provision of which is obligatory in all the Spanish municipalities and, in the case of councils of more than 5,000 inhabitants, selective waste collection is also required by law. Although Spain does not have the recycling facilities such as those found in Northern Europe, facilities have improved remarkably in recent years and most municipalities, including some located in remote zones, now recycle glass, paper, cardboard, aluminum, cans, plastic, batteries and other materials, although there are sometimes few collection points. Many municipalities also recycle garden waste, which is then sold as compost.

In Spain, regional and municipal governments are responsible for the development and management of municipal solid waste (MSW) services in their territories under European and national legal directives. Although heterogeneity among Spanish regions is very high, and the economic resources invested into developing functional markets for recycled MSW have increased in recent decades, efforts to increase recycling rates through the selective collection of MSW recyclable materials remain largely insufficient[1]. Thus, the debate on the need for the revision of the Spanish current model of MSW recycling and management has been opened since the goals set by the EU 2020 strategy remain far from being achieved[2].

3.1 MSW collection

The three main MSW selective-collection models implemented in Spain at a regional level are shown in Table 1, based on street side containers. Although the selective collection of recyclable waste materials is widespread throughout the country, collected by the municipalities through appropriate containers and a national code of unified colours (yellow for plastic, blue for paper and cardboard, green for glass, and grey or

[1] https://www.miteco.gob.es/
[2] The efficient functioning of waste markets in the European Union (2016).

brown for the remaining types of waste including bio-waste), a significant proportion of the Spanish population is still not sufficiently familiarised and/or have inadequate access to appropriately classified containers, as confirmed by the low rate of selective collection of recyclable MSW in regions such as Andalusia. These collection figures are shown in Table 2. As a result, there is still a great amount of municipal waste that is mixed-collected in street-side containers. After being compacted at a transfer station, this mixed waste is normally taken to a material recovery facility (in the cases that municipalities have access to this type of facility), where the waste is separated out into organic material and recyclable fractions, the latter being sent to recycling plants. Lastly, the various rejected materials obtained in this process are compacted into bales and either sent to be deposited in a landfill facility or incinerated (with or without energy recovery).

Table 1. Selective collection of MSW in Spain.

Model 1	Model 2	Model 3
Glass	Glass	Glass
Paper/Cardboard	Paper/Cardboard	Paper/Cardboard
Plastic and metal	Plastic and metal	Plastic and metal
Rest	Rest (incl. Bio-waste)	Rest (incl. Bio-waste)
Bio-waste	Garden waste	

The heterogeneity across Spanish regions regarding mixed-collected MSW and selective collection of the main recyclable wastes is shown in more detail in Table 2. While Basque Country shows the best performance in terms of the minimum rate of mixed-collected MSW (58.3%) and maximum selective collection rate (30.8%), the region of Murcia registers the poorest performance due to its high rate of mixed-collected MSW (88%) and its very low rate of MSW selective collection (9.3%), which is far from meeting the target set by the EU by 2020.

Table 2. MSW collection figures by region from Spanish National Institute of Statistic (INE)[3].

	Selectively collected recyclable waste (% of total recyclable MSW)	Mixed-collected (% of total MSW)
Andalusia	7.7%	87.2%
Aragon	10.9%	75.4%
Asturias	14.6%	76.2%
Balearic Islands	14.8%	75.8%
Canary Islands	9.4%	83.6%
Cantabria	7.4%	82.1%
Castile-Leon	11.8%	85.0%
Castile-La Mancha	8.5%	87.6%
Catalunya	20.9%	61.5%
Valencia	9.2%	84.4%
Extremadura	11.2%	88.2%
Galicia	10.0%	84.1%
La Rioja	17.5%	81.7%
Madrid	16.1%	73.3%
Murcia	9.3%	88.0%
Navarre	22.1%	60.2%

[3] Municipal waste collection statistics from Spanish National Institute of Statistic from 2019.

Basque Country	30.8%	58.3%
Average	13.7%	78.4%

3.2 MSW treatment and disposal

In 2019, there were 22.7 million tons of MSW generated in Spain, of which only about 8 million tons were sent to recycling plants. The latest official data available for Spain - which appears as an estimate in Eurostat[4], the EU's statistical office - puts the country's municipal waste recycling and reuse rate at 34.7% in 2019 (more than 15 points below the target set for 2020), far from the European average rate of 47.6%.

MSW treatment and disposal differ between waste streams. Separately collected paper/cardboard and glass are taken to dedicated recovery plants with recycling rates close to 100%; Light packaging is treated at light packaging sorting plants where the average recycling efficiency was 71.9% in 2018[5]. Mixed-collected MSW can be either pre-treated at mechanical-biological treatment plants in order to recover valuable materials or directly disposed of in incinerators or landfills. In Spain, there are three types of mechanical-biological treatment plants. Firstly, there are plants where only mechanical sorting is carried out. Secondly, there are plants where mechanical sorting plus biostabilisation of organic matter and composting is undertaken. Thirdly, there are plants where, besides mechanical sorting, organic matter is treated through anaerobic digestion prior to composting and biostabilisation. Each type of facility has different recycling efficiencies ranging from 10% to 61%. Lastly, food and garden waste are usually treated at dedicated composting or anaerobic digestion facilities. In a few cases, food and garden waste are treated in separate treatment lines or together with mixed-collected MSW at mechanical-biological treatment plants. In 2018, dedicated composting or anaerobic digestion facilities recycled from 43% to 90% of the inputs.

In 2018, 4.0 Mt of MSW were separately collected, compared to 18.2 Mt of mixed-collected MSW. With respect to mixed-collected MSW, 6% was treated at mechanical sorting plants, 45% was treated at mechanical sorting plus biostabilization of organic matter and composting plants and 18% was treated at mechanical sorting plus anaerobic digestion and composting of organic matter plants. The non-treated amounts of mixed-collected MSW were either incinerated (5%) or landfilled (26%).

Regarding waste management and recycling methods, there are many solid waste treatment systems, as described above, although at Spain the main and most widely used are incineration, controlled landfill, pyrolysis, composting and biomethanization.

- **Incineration** consists, as the name suggests, of incinerating waste, i.e. thermally destroying it to the point where it is transformed into combustion gases or products such as ash. With specialised plants it is possible to obtain large amounts of energy from the incinerated waste, which makes this system of solid waste treatment.
- **Controlled landfilling** is one of the most widely used solid waste treatment system. Good landfill management and landfill design are necessary to prevent waste from contaminating the surrounding land or water. Landfills can be underground or on the surface. Quarries or abandoned mines are commonly

[4] https://ec.europa.eu/eurostat
[5] Annual report on waste generation and management. Municipal Waste 2018.

used for this purpose, but either way, they must be studied and controlled so that the impact of the waste on the environment is minimised.

- **Pyrolysis** is another of the most commonly used solid waste treatment systems. This is a system in which waste is subjected to thermal treatment in a sealed container under high pressure. What makes this system of MSW treatment stand out is that its effectiveness is greater than that of incineration, since with pyrolysis much greater amounts of energy are obtained. The thermal degradation of the waste is done with a very limited amount of oxygen and results in gases, liquids and inert materials.
- **Composting and biomethanization** are other commonly used solid waste treatment systems. Composting a biological process in which the organic portion of refuse is allowed to decompose under carefully controlled conditions. It offers a method of processing and recycling both garbage and sewage sludge in one operation. Biomethanization consists of obtaining biogas from the anaerobic digestion of the organic fraction of waste, which can be recovered as a renewable gas for residential, industrial or mobility uses.

4. The Green Kiosk & its benefits

The project PAVEtheWAySTE includes the design, construction and implementation in selected remote areas (islands and rural areas) of a "Green Kiosk" (Figure 1), a space for the collection, sorting and compaction of certain types of waste that is linked to a system of points for the user, exchangeable for services or gifts, in order to encourage recycling.

Figure 1. Green Kiosk.

The Green Kiosk is a transportable module (as can be seen in Figure 1), which should be located at a point accessible to the public and which may require some land for external storage of the material after sorting and, if necessary, compacting and packaging. In the absence of specific regulations for this type of system, given its novelty, both the Greek and Spanish administrations (countries in which its implementation has been tested) assimilate these installations to clean points, and therefore apply the corresponding regulations, without taking into account the differences between a traditional clean point and this type of installation, which is much simpler and has a smaller scope in terms of the quantity of waste managed.

Residents will carry the separated at source MSW and will dispose them in the prototype innovative recycling systems.

5. Steps & Scenarios for implementing the Green Kiosk

The work performed was based on the requirement that the developed prototype Green Kiosk should manage specific MSW streams:

- recyclable materials such as paper/cardboard, glass, plastic and metal
- specific waste streams such as used cooking oils, small batteries, lamps,
- materials for re-use such as common hygienic products, clothing & footwear, books, toys etc.

Recyclable materials will end up in Green Kiosks either by direct delivery by the participants or by collecting and transporting the pre-selected materials from the municipal cleaning service. Thus, recyclable materials will be delivered to the Green Kiosks in 4 distinct predetermined basic waste streams, i.e. (i) paper / cardboard, (ii) glass, (iii) plastic, and (iv) metal and will be subjected to treatment.

Specific waste streams and **materials for re-use** will be delivered directly to the operator of the Green Kiosk and then will be stored without any intermediate processing.

A replication case study regarding a region of Tierras de Medina (Castilla y León, Spain), where the prototype system (Green Kiosk) could be installed, integrated and operated as part of the existing waste management system, has been done, ultimately aiming to achieve an integrated solid waste management scheme in this remote area. As Project scenario, a fixed “Recycling Percentage Value” of 25% has been set.

In order to decide where and how many Green Kiosk should be established to be operational, critical factors are the generation and composition of the recyclable waste, under the general premise that any established Green Kiosk should be self-sufficient in economic terms.

Within this context, through a series of hypotheses and calculations, it was estimated that each prototype system should gather and manage at least 350 kg of recyclable waste per day in order to be self-sustainable. This value of 350 kg/day serves as a threshold, so as to decide whether a certain municipality or city generates sufficient recyclable waste for the system to be self-sustainable.

From the regulative point of view, when there is an innovation, normally there are no specific regulations associated with that innovation, so regulations that affect similar systems are usually applied to it.

In this case, the Green Kiosk is a transportable module which should be at a point accessible to the public and which may require some land for external storage of the material after its classification and, given the case, compaction and packing. As there is no specific regulation for this type of system, given their novelty, both the Spanish administration assimilates these facilities to clean points, so they apply the corresponding regulations, without taking into account the differences between a traditional clean point and this type of facility, which is much simpler and with less scope in terms of the amount of waste managed.

In the case of Castilla y León (where the replication analysis has been carried out), the regulations applied are as follows:

> *The Clean Points facilities are subject to the authorization regime, in accordance with the provisions of article 27 of Law 22/2011, of July 28, on waste and contaminated soils. If the entity that owns the facility also carries out the waste treatment operations, a single authorization will be granted, as established in*

article 27.3 of Law 22/2011, of July 28. In the event that the owner of the facility is not the one who carries out the management operations, the authorization will be granted by virtue of article 27.1 of said Law 22/2011 and, therefore, the natural or legal person that carries out the operations on waste treatment must have the corresponding authorization, as established in article 27.2 of Law 22/2011. To find more information in this regard, it is convenient to visit the website of the Junta de Castilla y León (Environment - Environmental quality - Waste - Procedures - Authorization requests and prior communications): https://medioambiente.jcyl.es/web/jcyl / Environment / en / Template 100/126950 9257104 / _ / _ / _

6. Conclusions

An environmental comparison between current and potential municipal waste management scenarios considering the possibility of implementing the “Green Kiosk” model in the area under study leads to one main conclusion: due to the Green Kiosk operation, the environmental impact of the waste management in “Tierras de Medina” municipality association is decreased 82 kg CO_2 eq per ton of waste management. In other words, 1,295 ton CO_2 eq. could be avoided per year in this region due to the waste separation at source carried out Green Kiosk operation.

The new waste treatment model encourages separation at source, which is key to achieving environmental objectives.