1. Introduction

Plastic consumption in the different Spanish industrial sectors was 2,840,000 tonnes in 2010 as observed in the next figure [1].

![Plastics consumption in Spain distributed by industrial sector (Year 2010)](image)

Figure 1: Plastics consumption in Spain distributed by industrial sector (Year 2010)
This consumption generated approximately 2,206,000 tonnes of plastic waste in 2010. About 23% of this waste was recycled and 17% energy recovered, being landfilled about 60% [2].

It can be observed, when analysing the distribution of recycled plastics, that low density polyethylene (LDPE) and high density polyethylene (HDPE) are the most recycled polymers. Both plastics represent together 50.44% of plastic recycling (excluding recycled materials coming from scraps and imports), followed by the Polyethylene Terephthalate (PET), which represents 23.42%, as shown below [3].

Energy recovery, especially through incineration, is the most widely used alternative to take advantage of the energy content of plastic waste. Additionally, other strategies such as the elaboration of alternative and complementary fuels for cement kilns are increasingly important.

Finally, landfilling is still the most common end-of-life option. This situation implies to bury valuable resources.

2. Market according industrial sectors

Existing markets for plastics in Spain are subsequently analysed. Both the consumption and the recovery strategies applied to the waste generated in each of the main industrial sectors are also commented.

2.1. Packaging

Packaging (domestic and industrial) is the most representative application for plastics. The consumption in 2010 was 1,397,689 tonnes, which represents 49.21% of the total plastic consumption as shown before [1].

HDPE was the polymer most used in 2010 for packaging applications, which together with the LDPE, represents 54.18% of the total consumption (figure below). PET is also one of
the most relevant polymers used in this sector with the 24.35 % of the consumption. The rest of the polymers used in this sector are not significant, except Polypropilene (PP), which ranks fourth with 10.95 % of the market share. Thus, it can be considered that Polyolefins (HDPE, LDPE and PP) and PET are the most widely used polymers in this industrial sector, representing a share of almost 90 % of the total consumption [4].

Because of the short life cycle of packaging, usually less than one year, it can be assumed a 1 to 1 relation between the annual consumption and the amount of waste generated. Therefore, it can be considered that 1,397,689 tonnes of plastic waste were generated during 2010 in this sector.

According to Cicloplast and ANARPLA (National Association of Plastic Recyclers), 713,525 tonnes of plastic waste coming from the packaging sector were recovered in 2010. 407,525 tonnes were recycled and 306,000 tonnes were energy recovered. The remaining 684,164 tonnes were landfilled as shown in the figure below [4].

The European Directive of Packaging and Packaging Waste DC 2004/12/CE established a recycling target of 22.5 % for plastic packaging. This target was reached in Spain in 2007. Moreover, this rate is progressively increasing (29.16 % in 2010) as shown below [4].
2.2. Building and Construction

Building & Construction was the second Spanish industrial sector consuming the highest amount of plastic in 2010, which represented 11.3 % of the total consumption, i.e. 321,018 tonnes, as shown before [1].

Unlike packaging sector, the consumption of polyolefins in this industrial sector is not significant, being Polyvinyl chloride (PVC) the mostly polymer consumed in 2010, with 49.98 %. This polymer was used for different applications: pipes, blinds, profiles, fittings, etc. The second mostly used typology of plastics in this sector is the group of engineering polymers, such as polyamides (PA), acrylonitrile butadiene styrene (ABS), styrene acrylonitrile (SAN), etc, with represents 26.78 % of the total consumption. Expanded polystyrene (EPS) and polystyrene (PS) are the third and fourth mostly used polymers, with rates around 6 % [5].

The average relation between consumption and waste generation in this industrial sector is estimated around 14.10 %. That means that the 321,018 tonnes of plastic consumed in construction in 2010 generated 45,279 tonnes of plastic waste. This estimation is made considering as waste generated those fractions coming from the building maintenance and the scraps generated during construction. Moreover, construction waste generated during repairs (pipelines scraps, blinds, profiles or isolation) is also considered.
Only about 27.50% of this construction waste, 12,452 tonnes, was recycled. Nevertheless, this rate also considers those PVC components coming from other industrial post-consumption activities. No specific treatment is applied to the remaining waste generated, being landfilled [5].

Demolition waste is not considered so far, because of the existing difficulty for carry out the collection and separation of plastics from other materials.

2.3. Automotive

Automotive sector accounted for 8.73% of the total consumption of plastics in 2010, which corresponded to 247,818 tonnes [1].

Mostly consumed polymers in this industrial sector in 2010 were engineering plastics such as PA, ABS, SAN. 32,192 tonnes of these plastics were consumed. They were used for interior pieces, coating, moulding pieces, etc. On the other hand 90,542 tonnes of PP, used for the production of bumpers and batteries casings, were consumed. Finally, the consumption of HDPE, used for the production of fuel tanks, and PVC, used for different car pieces, was 13,570 and 11,513 tonnes respectively in 2010 [6].
The consumption of 247,818 tonnes of plastics in 2010 generated 114,608 tonnes of plastic waste by considering an average relation between consumption and waste generation of around 46.24 % for this industrial sector. The basic indicator for the waste generation in this industrial sector is the scrapyard of end-of-life vehicles.

Only 9,509 tonnes of this waste (3.84 %) were recycled, remaining 105,099 tonnes without any recovery treatment [6].

2.4. Agriculture

The consumption of plastics in agriculture was 203,017 tonnes in 2010, which represented 7.15 % of the global consumption [1].

The polymer mostly used in this industrial sector is LDPE, since it is used for the production of films, tubes and irrigation tapes; 89,832 tonnes were consumed in 2010, which represented 44.25 %. PVC and HDPE followed with a consumption of 57,993 (28.57 %) and 31,027 tonnes (15.28 %) respectively. The remaining polymers are not relevant, as shown in the following diagram [7].

Considering a lifespan between 2 and 4 years for the plastics used in this sector, an average relation between consumption and waste generation around 84.6 % is defined. That means that a generation of 171,830 tonnes of plastic waste in 2010 is assumed for this industrial sector. Part of this waste, like films coming from greenhouses and some of the mulching
films, can be recycled. Nevertheless, there is another large amount of mulching films, which are highly contaminated with land (up to 70 %), which cannot be recycled and consequently are deposited in landfill. The use of this plastic waste as alternative fuel in industries is another recovery option to be considered [7].

2.5. Electrical and electronic

Plastics consumed in the electrical and electronic industrial sector in 2010 only represent 6.9 % of the total consumption [1], reaching 196,036 tonnes.

Polymers mostly consumed in 2010 were engineering plastics such as PA, ABS, SAN, etc, which are used for the production of small appliances, cables, electrical equipment, etc. LDPE for cables, PVC for cables and tubes, HDPE for cables, PP for small appliances, and PS for radios, TVs and small appliances, computer, refrigerators, etc are other polymers used in this sector [8].

The average relation between plastic consumption and waste generated is around 50 %. Therefore, 94,581 tonnes of plastic waste were generated in 2010, being recycled only 6,020 tonnes, as shown in the next figure [8].
3. Collection systems of plastic waste in Spain

The recovery process starts with collection. This process presents higher or lower difficulty depending on the waste origin (domestic or industrial). The capability to separate the waste by fractions highly depends on the collection procedure as well as on the treatment processes subsequently implemented. These stages highly impact on the quality and homogeneity of the fractions as well as in the capability to be subsequently recovered.

Waste Framework Directive DC 2008/98/EC states a waste hierarchy which establishes mechanical recycling as the recovery process to be firstly implemented followed by energy recovery and landfilling, once reduction and reuse efforts have been done. Additionally, other Directives establish other management requirements as well as objectives for the recovery of plastic waste generated in different industrial sectors. Integrated management systems have been established in Spain to boost the adequate management of waste in order to guarantee the fulfilment of these targets. Most important Spanish waste management systems are listed below:

- **ECOEMBES**: Packaging waste
- **ECOLEC**: Large and small household appliances (white line)
- **ECOTIC**: Electronic devices (brown line)
- **AMBILAMP**: Lighting equipment
- **SIGRAUTO**: End of life vehicles

Packaging is the most representative plastic waste fraction as commented before. ECOEMBES coordinates in Spain the selective collection of domestic packaging waste. Once collected, the packaging waste fraction is transported to the 95 packaging sorting plants for the separation of the different streams with potential to be recovered. Additionally, 52 municipal solid waste treatment plants are also designed for the separation of the packaging waste fractions with high added value, which are subsequently recovered.

Currently, both the packaging sorting plants and the municipal solid waste separation plants are using different sorting technologies able to optimize the recovery of plastic packaging. Nevertheless, some of these plants are still being operated manually. Typical flowcharts of both typologies of plants are subsequently shown [9].
Figure 14: Flowchart of a packaging sorting plant (above) and a municipal solid waste separation plant in Spain (below)
Industrial packaging waste is collected by authorized waste management companies. Moreover, waste fractions potentially recoverable are directly delivered to recycling companies.

4. Recovery alternatives for plastic waste

Only 40 % of plastic waste recovered is recovered in Spain, being 60 % of these waste fractions landfilled [10].

![Recycling and valorization rates by country](image)

Recovery alternatives are subsequently commented in detail.

4.1. Mechanical recycling

Only 515,674 tonnes of plastic waste, from the 2,206,000 tonnes generated in Spain during 2010, were mechanically recycled. The different origins of these recycled fractions are shown in the Figure 16 [3].

This process was carried out by the 107 plastic recycling companies existing in Spain. These companies are not large. Nevertheless, they have a high technologic level since Research and Development is a key factor for the development of the sector. The production of recycled material in the different Spanish regions is shown in Figure 17 [11].

According to Cicloplast, 27.45 % of the recycled material was commercialized in the same Spanish region of production, 63.29 % in the rest of Spain, 6.20 % in the European Union and 3.06 % in the rest of the countries [1]. Applications in which recycled plastic was used during 2010 are shown in the Figure 18 [1].

Figure 16:
Distribution of recycling material obtained by origin of plastic waste (year 2010)

Figure 17:
Distribution of the production of recycled material in Spain (year 2010)

Figure 18: Distribution of the recycled material production in Spain (year 2010)
Average annual growth rate of plastic recycling in Spain was 13 % until 2007. A reduction of plastic recycling was observed in 2008 and 2009, growing again in 2010 as shown in the next figure [3].

4.2. Energy recovery

There are 10 incinerators with energy recovery focused on the treatment of municipal Solid Waste (MSW). 412,000 tonnes of plastic waste produced in Spain were treated in these plants in 2010 [12]. These plants are located in the different Spanish regions although the presence in Catalonia is higher.

The high energetic content of plastic waste makes it an interesting alternative fuel for industries with high energetic demands such as cement plants, power plants, lime industries etc. Currently, only cement plants are starting to use plastic waste instead of conventional fuels. Moreover, the substitution percentages are still low.
5. Conclusions

2,840,000 tonnes of plastics were consumed in Spain during 2010, generating 2,206,000 tonnes of plastic waste.

Collection and separation of plastic waste are key processes for the obtaining of high quality and recoverable waste streams. These activities are organized through integrated management systems which work for the achievement of the recovery objectives established in the different European Directives. Around 40 % of the plastic waste generated in Spain was recovered in 2010 (23 % mechanically recycled and 17 % energy recovered).

The percentages of plastic recycling achieved in 2010 in the different Spanish industrial sectors were: packaging sector (29,16 %), building & construction (5,7 %), automotive (8,30 %), agriculture (28,13 %), electrical and electronic (6,37 %) and other sectors (10,90 %).

Increasing rates of plastic recycling has been observed in recent years. Nevertheless, 60 % of plastic waste is currently landfilled. Therefore, energy recovery strategies should be implemented in the case of materials presenting limitations to be recycled and high energetic contents. In fact, the use of alternative fuels derived from plastic waste is progressively growing, although they are nowadays only used in cement plants.

Therefore, significant improvements have being made in recent years in the area of waste management. Nevertheless, these working lines should follow in order to achieve the total recovery of the plastic waste generated in Spain.

6. References


