EXECUTIVE SUMMARY
Consumer trends have been intensely modified during last decades due to economic, cultural and social factors such as the gradual incorporation of women to the labour market, the population aging, the family size reduction or the higher consumption of healthier products. These new consumer trends as well as the increased logistics needs of the products have produced a progressive increase in plastic packaging production and consequently in the plastic waste generation.

Due to that, European Union has developed new legislation in order to minimize the environmental impact derived from the generation of plastic wastes. Directive 94/62/EC (modified by Directive 2004/12/EC) and Directive 2008/98/EC include a waste management hierarchy where prevention followed in order by re-use, recycling and energy recovery are established. In response to this hierarchy, prevention and re-use strategies are being reinforced in the different Member States. Furthermore, recycling technologies have been also improved in order to permit the treatment of the conventional plastic materials.

Nevertheless, new plastics materials and combinations of them (multilayer plastics), not compatible with traditional recycling technologies, are being introduced in the packaging sector in order to improve the product protection as well as the adaptation to the new consumer trends. The introduction of these new materials is hindering the achievement of the future recycling objectives of the European Union. In fact, the Directive 2008/98/EC establishes that 50% in weight of plastic waste coming from the domestic channel has to be recycled by 2020 while only 19,7% of plastic are currently recycled. Aiming to bridge the gap between the current recycling rate and the European Union’s objectives, various scientific experiences are being carried out in order to develop new complementing recycling technologies able to treat plastic multilayer plastics. Some of these investigations have been focussed in the area of chemical recycling considering that these processes have the potential to treat the combination of different polymers at the same time obtaining energetic products as well as initial monomers which can be used in the manufacture of new polymers.

This work aims to analyse state of the art of the current chemical recycling processes from both a theoretical and a practical perspective. In response to that, different activities have been carried out. Firstly, new chemical recycling technologies were identified and analysed from a theoretical perspective. Concretely, this analysis considered three types of thermal depolymerisation (pyrolysis, gasification and hydrogenation) and three types of chemical depolymerisation (hydrolysis, methanolysis and glycolysis). Secondly, chemical recycling experiences carried out in different industrial plants were also analysed in terms
of input material characteristics, process stages and the applicability of the final products obtained. Finally, experiences related with the improvement or adaptation of the different chemical recycling processes to different wastes were analysed from the point of view of the proportion of the products obtained as well as from the process performances. These studies demonstrate that these variables are not only related to the process parameters used but also with the characteristics of the waste materials introduced. Concretely, variables such as the particle size, the density, the moisture and the type of contact between the material and the catalyst present a high influence on these parameters. Therefore, investigation efforts have to be invested not only in the improvement of the process parameters but also in the pretreatment of waste materials to be introduced in the different chemical recycling processes.

INTRODUCTION

Plastics materials have been fundamental in the social development achieved during last decades. In fact, modern lifestyle highly depends on the consumption of products made partially or totally by plastics such as protective packaging, mobile phones, insulation materials, medical devices etc. Due to that, a high increase of plastics consumption has been produced during the last 60 years. Concretely, global plastic consumption was 1.5 million tonnes in 1950, 50 million tonnes in 1976 and 245 million tonnes in 2008 as shown in Figure 1 [14].

![Figure 1. World plastic production 1950-2008. Source: PlasticsEurope 2009.](image)

Moreover, plastic consumption increase during the following decades is also expected both in developed and developing countries. Nowadays the consumption per capita of plastics in North America (NAFTA) and Western Europe is near 100 kg per year. According to PlasticsEurope, the consumption of these regions has the potential to grow to 140 tonnes by 2015, representing an increase of 40%. Furthermore, higher increases are expected in developing Asian countries where the current annual consumption has recently reached 20 kg per capita. Apart from plastic consumption, developed countries also present the higher production rates. Concretely, plastic production is mainly concentrated in Europe, where 60 million tonnes of these materials were produced in 2008 [14]. According to these data, 25% of the total amount of plastic was produced in Europe followed by North America (23%) and China (15%).

As previously mentioned, plastic materials are used in various industrial and commercial applications. As shown in 2, the most important application of plastics materials in Europe is packaging (38%) followed by building and construction (21%), automotive (7%) and Electrical and electronic [14]. Considering these percentages, 93.1 million tonnes of plastic packaging is consumed in Europe every per year.
Packaging sector consumes different types of polymers depending on the demanded properties of the products. Concretely, in the case of the Spanish packaging sector are PE, which represents 54.5% of the total consumption, followed by PET (18.9%) and PP (17.9%). Furthermore, this sector also uses other minority polymers including PS, PVC, EVA and epoxy resins (Figure 3) [18].

In addition, new consumer trends are potentiating the introduction in the market of multilayer packaging materials with the aim to offer a specialized protection to the different products. The combination of these layers generally provides to the final material a mix of the individual performances of the polymers involved, like barrier protection, sealability, moisture or chemical resistance and stiffness, that are usually difficult to be achieved with one single polymer. Some typical combinations of multilayer plastics are presented in Figure 5 [6].

The increase of plastic packaging consumption also represents a rise in plastic waste generation. Concretely, 24.9 million tonnes ended up as postconsumer plastic waste in Europe in 2007, representing an increase of 1.2% over the previous year, when the generation was 24.6 million tonnes [14]. Mechanical recycling processes, which consist of the reprocessing of waste material without changing its chemical structure, can be satisfactorily applied in the case of
thermoplastic polymers (PE, PP, PS, PMMA, PVC, PET, etc) in case that a prior separation has been carried out. Nevertheless, these techniques present limitations to treat thermoset plastics (polyester fibreglass systems, urea-formaldehyde, melamine resin etc) and elastomers (styrenic block copolymers, polylefin blends, elastomeric alloys, thermoplastic polyurethanes, thermoplastic copolyester, thermoplastic polyamides etc) because these types of polymers present a crosslinked structure not fluidizable during the mechanical recycling processes [6]. Therefore, these materials can not be reshaped in new products being the utilization of them as fill materials the only mechanical recycling possibility. These techniques also present limitations in the case of mixed plastics and multilayer plastics mainly due to thermal stability differences and miscibility problems. Firstly, thermal stability differences between the polymers included in the mixture can hinder the joint processing of them without affecting the properties of the final product obtained considering the differences in melting and degradation temperatures. For instance, the presence of only 0,1% of PVC in a PET waste fraction can hinder the recycling process. This is due to the fact that the moulding temperature of PET (250°C) produces the decomposition of the PVC and consequently the production of undesirable colours in the recycled PET [6]. Secondly an even in the case of polymers with similar thermal stabilities, miscibility problems between them can produce heterogeneous mixtures of plastics and consequently low mechanical resistances in the final recycled product. These miscibility problems can affect all the plastic mixtures not able to form specific interactions between the different polymers such as hydrogen bounds or dipole-dipole interactions.

Therefore, a high percentage of plastics waste can not be recycled. Concretely, only 49,9% of plastic waste is valorized by means of mechanical recycling, chemical recycling and energetic recovery in Europe and therefore, 50.1% of plastic waste is disposed in landfill [4]. Considering these rates as well as the total plastic waste generation, 12.3 million tonnes of plastic waste were landfilled in Europe in 2006.

European legislation has been developed in order to facilitate the increase of the waste valorization rates. Directive 94/62/EC on Packaging and Packaging Waste (modified by Directive 2004/12/EC) as well as the Waste Framework Directive 2008/98/EC have established a hierarchy of the possible waste management strategies. This hierarchy establish that waste management sector have to reduce landfilling rates and the increase of the valorization treatment of wastes including recycling and energetic recovery. Furthermore, Directive 2008/98/EC also establish quantitative objectives related to this hierarchy. Concretely, the Directive establish that the preparing for re-use, recycling and other material recovery of waste has to be at least 70% by weigh in 2020 and 50% if only re-use and recycling is considered.

**CHEMICAL RECYCLING**

Innovation and development of new recycling technologies are needed in order to achieve the legal requirements established in Directive 2008/98/CE considering that mechanical recycling technologies are not able to treat certain polymers or combination of polymers.
Investigations efforts in this area are mainly focused in chemical recycling or feedstock recycling considering the potential of these processes in plastic waste treatment. Chemical recycling consists of the cracking or decomposition of polymers by heat, chemicals and catalysts for the production of oil or even the initial monomers, which can be used in the manufacture of new polymers. There are two main types of chemical recycling depending on the needing of chemical reactives during the process: Thermal depolymerization and chemical depolymerization [15]. The convenience of one or another chemical process depends on the characteristics of the polymer. Basically, thermal depolymerization is more adapted for addition polymers (formed by an addition reaction, where many monomers bond together via rearrangement of bonds without the loss of any atom or molecule: vinyl polymers, acrylic polymers, polyolefins etc) whereas chemical depolymerization for condensation polymers (formed through a condensation reaction, releasing small molecules as by-products such as water or methanol: polyamides, polyacetals, polyesters etc) [15].

**Thermal depolymerization**
Thermal depolymerization includes several chemical recycling processes that allow the production of monomers as well as other hydrocarbon fractions from only an input of heat without requiring any addition of chemical reagents into the reactions of rupture of the polymer chains. Moreover, impurities as well as organic matter present in plastic waste have a low influence in thermal depolymerization in comparison with chemical depolymerization. Therefore, these processes (pyrolysis, gasification, hydrogenation etc) are more applicable to multilayer packaging materials [1].

- **Pyrolysis**
Pyrolysis involves the heating of plastic waste at temperatures between 220 and 900 °C, in oxygen-free conditions and various residence times. This process permits the obtaining of different solid, liquid and gaseous products which can be used as combustibles or raw materials for the production of new polymers. The product obtained after the application of pyrolysis to plastic materials include several gases (H2, CH4, CO, CO2 etc), liquids (tars and oils with chemical agents such as acetic acid, acetone and methanol) and solids formed by almost pure carbon mixed with inert material included in the process [5].

- **Gasification**
Gasification involves the heating of plastic waste in low oxygen atmosphere at temperatures slightly higher than the pyrolysis. This process allows the obtaining of syngas that is produced through the partial oxidation of the plastic waste. The process of gasification can be divided into four main stages: 1) preheating and cracking, 2) oxidation and gasification, 3) secondary reaction and 4) carbon residue gasification. During the first
stage, the feedstock undergoes a preheating and is intimately mixed with the oxygen and the water vapour that is present in the reactor. The first stage favours the rupture of the hydrocarbon bonds and consequently the obtaining of carbon atoms, methane molecules and free radicals. Once the ignition temperature is reached, some hydrocarbons react exothermically with oxygen producing CO₂ and H₂O consuming totally the oxygen. Continuously, no oxidised hydrocarbons react endothermically with CO₂ and H₂O producing mainly CO and H₂. Furthermore, depending on the conditions of pressure, temperature and the concentration of water vapour, part of the carbon monoxide can potentially react with hydrogen generating methane, water vapour and carbon dioxide. Finally, the gasification of the carbon residue obtained from the previous stages occurs and new gases and a final carbon residue are produced. To sum up, the product obtained after the application of pyrolysis includes gases (CO, CO₂, H₂, CH₄ etc) low amounts of hydrocarbons (C₂H₆ and C₂H₄), H₂O and several contaminants such as carbonaceous particles, ash, tar and oils [5].

- **Hydrogenation**
  This chemical process is based on the thermal treatment of plastic waste in presence of hydrogen at moderated temperatures (400-500 °C) and high pressures than can vary between 10 and 100 kPa. The hydrogen allows the formation of highly saturated products that can be used as combustibles or as raw material in the refinery industry. The major advantage of hydrogenation is the possibility of obtaining liquid hydrocarbons with yields close to 85%. Nonetheless, dealing with hydrogen at such temperatures has a significant impact on the cost since the security measures needed are special and strict [2].

**Chemical depolymerization: Solvolysis**
The chemical depolymerisation or solvolysis takes place through the introduction of certain solvents that act as chemical reagents in the reaction. This process is applicable to condensation polymers or in other words to the ones that the polymerisation reaction involves the formation of low molecular mass molecules, like in the case of water. There are three different ways of treatment according to the name of the solvent used: Hydrolysis, methanolysis and glycolysis.

- **Hydrolysis**
  Hydrolysis is a depolymerization process based on the use of water as chemical agent in the presence of acids or alkalis. In the case of acid hydrolysis, concentrated sulphuric acid is often used although it can also be performed with phosphoric acid or nitric. In the case of alkaline hydrolysis, sodium hydroxide, potassium and aqueous ammonia are the most commonly substances used. This process can be applied to PET waste and depending on whether the process takes place in the presence of acid or base, the conditions can vary. The aim of the process is the breakage of the polymer chains and the output includes terephthalic acid (TPA) and ethylene glycol (EG). Once the final products are obtained, they have to be filtered and treated so that impurities are the minimum possible for further processing [13].

- **Methanolysis**
  Methanolysis is a depolymerization process that uses methanol as chemical agent. This process occurs in high temperature and pressure conditions (160ºC-300ºC, 7 MPa). The application of methanolysis to PET waste, entails the decomposition of the polymer into basic molecules including dimethyl terephatate (DMT) and ethylene glycol (EG) which can be polymerized again to produce new virgin resin [2]. This process is usually catalysed with transesterification catalysts and the obtained products are regularly
purified through crystallization or distillation. The main advantage of this process is the higher potential to deal with plastic waste with higher presence of pollution than hydrolysis and glycolysis.

- **Glycolysis**
  Glycolysis is the depolymerization process where glycol is used as chemical agent. This process is mainly used for polyesters and polyurethanes. Usually, chemical reaction of glycolysis occurs at medium temperatures (190-200°C) and can be catalysed with amines, alcohoxides or metal salts of acetic acid. When dealing with waste PET, the most commonly used agent is ethylene glycol (EG) and the product obtained is bi(hydroxyethyl) terephthalate (BHET), which, once purified, can be used as substrate for the synthesis of PET [13].

**INDUSTRIAL EXPERIENCES**

The different chemical recycling processes have been developed during the last decades in laboratory and pilot scales. Furthermore, these processes have been introduced in plastic recycling or valorisation plants obtaining different results depending on the technology used. In this article, the functioning technologies and the performances of several plants are analysed: RCP Bremerhaven, Thermoselect, BP chemicals and Veba Oel.

**RCP Bremerhaven**

The technology used in the RCP plant of Bremerhaven (Germany) permits the valorization of the solid fraction of Municipal Solid Waste (MSW) through a pyrolytic process based on two stages of treatment. During the first stage, the waste undergoes a partial treatment through an allothermal pyrolysis (with external heat supply) that takes place in the range of temperatures between 450°C and 600°C, in depression and oxygen poor atmosphere. The second stage is carried out with oxygen injection and temperatures between 1200 and 1500 °C. The capacity of the plant is 5.5 tonnes of MSW per hour obtaining a combustible gas of 15.9 Nm³w/h and a copper and zinc alloy of 0.06 Ton/h [5, 8].

**Thermoselect**

The company Thermoselect has several gasification plants in different Asian and European countries. The gasification process employed in these plants, which comprises four different stages, is compatible with different types of waste, including multilayer plastic materials and Municipal Solid Waste in general. During the first stage, the waste fraction is taken to a compacting press from where is introduced into an excluding air degassing channel. During this stage the material is compacted, degassed and dried. In the second stage, the material is transported through the degassing channel to the high temperature reactor where carbon and carbon compounds are gasified in a water vapour saturated atmosphere with 2000 °C and oxygen injections. During the third stage and in the conditions of the reactor previously defined, chlorinated hydrocarbons, dioxins and furans are destructed, obtaining syngas mainly composed of H₂, CO, CO₂ y H₂O. Then, the ultrarapid cooling process from 1200 °C to 90 °C avoids the new formation of chlorinated hydrocarbons and other contaminants. Finally, the syngas obtained is introduced into a cleaning process, consisting in several stages, where the contaminants are absorbed or condensed. Once cleaned, the syngas obtained can be used as raw material for the fabrication of substances such as methanol.
The rest of substances obtained in the process are also used in different processes. Minerals and metals are melted in the high temperature reactor. Subsequently, melted mass is homogenised in a specific channel where two different phases are formed (minerals and metals). Then this mass is cooled with water obtaining mineral and metallic aggregates which are subsequently classified by material through a magnetic separation process and used in metallurgic industries. The water and the salt recovered are reintroduced in the gasification process. Finally, other contaminants previously separated, such as zinc and sulphur are also used in different industries [16, 5].

**BP chemicals**

According to the journal Gas and oil (1997), the company BP chemicals carries out a thermal cracking process for plastic wastes. This process, which is mainly applied to addition polymers, permits the breakage of the polymers chains in an inert atmosphere at temperatures typically between 500 and 800 ºC. The process carried out in BP chemicals consists of two different stages. During the first stage, the plastic fraction is pretreated in order to reduce the particle size and the elimination of the metallic components. Concretely, the plastic mixture pretreated is composed of polyolefins (80%), PS (15%), PET (3%) and PVC (2%). During the second stage, the pretreated plastic mixture is introduced into fluidized sand bed reactor based on an inert medium at 500ºC. In these conditions plastics are cracked to hydrocarbons which vaporize with the reactor effluent gas. Solid particles are subsequently separated in a cyclone. Then these solid particles passes through a bed of lime which neutralizes HCl formed from PVC. Finally, the gas is cooled and the liquid hydrocarbons are condensed. The final product obtained is composed of liquid hydrocarbons usable in refineries (85%) and gases such as ethylene and propylene (15%) [6,17].

**Veba Oel**

Accoridng to Gomez M.R., the plant of Veba Oel (Germany), currently closed, carried out a hydrogenation process able to process 40000 tonnes per year of plastic waste including up to 10% of PVC. It operates at 150-300 bar and 470 ºC in a hydrogen atmosphere, giving a product composed of paraffin (60%), naphtha (30%), aromatics (9%) and olefins (1%) [6]. The plant includes a depolymerisation section before hydrogenation process. In this section, plastic waste is treated at 350-400 ºC. These temperatures also permit to remove Cl from PVC fractions. The depolymerised product is washed in order to eliminate Cl in the form of HCl. Then, the condensed product and the gases are introduced into the first reactor where hydrogenation occurs at 400-450 ºC and high pressures (100 bar). Subsequently, the materials are feed in the second reactor (fixed bed reactor) where liquid fraction is separated and used in refineries. The residue derived from the hydrogenation process (heavy hydrocarbons contaminated with ashes, metals and inert salts) are normally mixed with coal for the coke production. Finally, the gas obtained is washed in order to eliminate H2S and ammonia [19].

**PARAMETERS INFLUENCING CHEMICAL RECYCLING**

Several studies have demonstrated that the performance of the chemical recycling processes depends on the working parameters used in the reactors. Furthermore, these parameters can also affect the composition of the products obtained as well as the functioning of the process.
According to Hernandez M.R. 2007, reaction temperatures, heating rates, residence times as well as the characteristics of the reactor can affect the process performance, the functioning and the product composition previously commented [7].

Reaction temperature highly affects the composition of the products obtained after pyrolysis. Higher temperatures potentiate the cracking process and consequently the obtaining of high percentages of volatile products in comparison with liquids and solids. In fact, three different pyrolytic temperature ranges can be observed depending on the fractions generated in each of them. The range between 220-330 °C mainly produces solid pyrolytic products. Nevertheless, liquids fractions and gaseous fractions increase relative percentages in the ranges of 330-450°C and >500°C respectively [7].

Two different types of extreme pyrolytic processes can be distinguished depending of the heating rates used: slow pyrolysis and flash pyrolysis. Slow pyrolysis, which presents heating rates of K/min or even K/h, potentiates the formation of solid pyrolytic products while flash pyrolysis potentiates the obtaining of liquids and gases [7].

Residence times in the reactor highly affect the decomposition of the waste materials during the pyrolytic processes. In fact, during the degradation process of the polymer, the components formed have to pass through the reactor before reaching the exit. During this movement the components are subjected to the same temperatures present during the cracking. Therefore, the residence time along the reactor can affect the composition of the products obtained. For instance, in the case of flash degradations, which are produced just in a few seconds, the residence time in the reactor is a key factor which can affect the process performance and the composition of the products obtained [10].

Finally, the parameters previously defined can present higher or lower influences depending on the type of reactor used. Therefore, it can be assumed that the type of reactor highly affects the characteristics of the pyrolytic products obtained [7].

Furthermore, this study has also demonstrated that the process performance, composition of the pyrolytic products obtained as well as the functioning of the process is also related to the initial properties of the waste material introduced in the reactor. Specifically, the parameters analysed in this study were particle size, density, moisture and type of contact between the material and the catalyst [7].

Particle size primarily affects the mass and heat transfer in the reactor, since large particles are not heated as quickly as small ones. The results of the study of Karaduman A. et al show, for the specific case of the pyrolysis of polystyrene, that small particle sizes of this waste generates higher percentages of liquid and gaseous fraction while production of solid pyrolytic products decreases [9]. Furthermore, the particle size of the catalyst can also affect the pyrolysis process due to the effect of its pore size and acidity in the cracking process [11]. In fact and according to several studies in this area the catalysts with small particle size increase the fraction of heavy hydrocarbons obtained while catalysts with larger particle size shows less activity and consequently increases the fraction of liquids formed for light hydrocarbons [10, 11].

Density of the plastic waste also affects pyrolysis. According to Hernandez M.R. 2007, higher densities of the particles introduced in the reactor generate higher tar degradations and consequently the decrease of the production of solid fraction and heavy hydrocarbons [7]. Furthermore, moisture or water content of the sample also affects the pyrolysis process considering that part of the heat or energy of the process will be consumed in the particle drying and consequently less energy will be available for the material degradation. Several studies have evaluated the energy required by certain materials to be dried demonstrating how the moisture can produce and increase in the energy used in the pyrolysis [12].

The type of contact between the waste and the catalyst can also vary the distribution of the products obtained in the process. Chiu et al. [3] studied the degradation of PET using
two different mixtures: one in which the polymer and catalyst were mixed in solid form obtaining a uniform distribution of both (physical mixture) and one in which the polymer was impregnated with catalyst (impregnation). The results showed that the contact of both materials via impregnation allowed a reduction of time required for the development of cracking process.

Other studies have also demonstrated that the characteristics of the initial waste can also affect the gasification process. Specifically, Elias X. (2005) mentioned that the humidity or moisture of the material gasified affects the composition of the products obtained as well as the energy consumption of the process. Water favours the formation of hydrogen during gasification and consequently its presence permits to reduce the quantity of vapour added to the oxidizing agent. Nevertheless, if adequate percentages of humidity are exceed a decrease in the process performance can be observed since the water consumes energy during the vaporization process. The optimal humidity of the materials depends on the type of gasifier considered being the more typical percentages between 10% and 30% [5].

Considering the information previously commented, the optimal characteristics of the waste material to be introduced in the reactor (particle size, humidity, density, type of contact with the catalyst etc) highly depends on the process considered as well as the product demanded. Therefore, efforts have to be focussed not only in the adaptation of the process parameters but also in the pretreatment of the wastes before their introduction in the different chemical recycling processes. These activities will enable to increase the process performances as well as improve the characteristics of the products obtained.

ITENE (Packaging, Transport and Logistics Research Center of Spain) is participating in several projects focussed in the area of waste pretreatment. One of these projects is PROEFIRES [20], which aims to develop of new solutions for the management of municipal waste through more environmental and energetic friendly processes. One of the tasks of this project is directly focussed in the pretreatment activities needed to valorise the different packaging waste, including multilayer plastics, using chemical recycling processes.

These activities are carried out in the modern waste treatment laboratory of ITENE which is provided with the equipment needed to modify the characteristics of the waste materials. One of the tasks carried out in the laboratory is the adaptation of the particle size of the packaging waste through the use of a shredder and a mill in order to analyze the influence of the particle size in different recycling processes (Figure 8).

Apart form the adaptation of the particle size, other pretreatment activities like sorting and washing processes are carried out in the waste treatment laboratory to guarantee the elimination of contaminants. Moreover, drying processes also are used in order to adapt the humidity or moisture of the wastes samples to different ranges according to the specific needs of the recycling processes. Finally, metals can be also sorted, when
required by the recycling processes, by means of magnetic separators able to sort both ferrous and non ferrous particles (Figure 9).

CONCLUSIONS

Mechanical recycling processes, which consist of the reprocessing of waste material without changing its chemical structure, can be satisfactorily applied in the case of thermoplastic polymers not mixed. Nevertheless, these techniques present limitations to treat specific fractions of plastics wastes such as multilayer plastics due to thermal stability differences and miscibility problems between the polymers. For this reason, investigations have been carried out in the area of chemical recycling considering that these processes have the potential to treat the combination of different polymers at the same time obtaining energetic products as well as monomers and other hydrocarbon fractions which can be used in the manufacture of new polymers. Chemical recycling includes a wide variety of different processes which are more or less applicable depending on the characteristics of the waste to be treated as well as the final product demanded. For instance, thermal depolymerization, which includes pyrolysis, gasification and hydrogenation is more adapted to addition polymers while chemical depolymerization, which includes hydrolysis, methanolysis and glycolysis present better results with condensation polymers. Nowadays, these processes have been implemented in several plants obtaining satisfactory results for the recycling of multilayer packaging and other waste materials. Furthermore, research is carried out in order to improve the process parameters of the different chemical recycling technologies. Nevertheless, some studies demonstrate that the performances of the chemical recycling process and the proportions of the products obtained are not only related to the process parameters used but also with the characteristics of the waste materials introduced. Concretely, variables such as the particle size, the density, the moisture and the type of contact between the material and the catalyst present a high influence on these parameters. Therefore, investigation efforts have to be invested not only in the improvement of the process parameters but also in the pretreatment of waste materials to be introduced in the different chemical recycling processes.

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