Circular Economy and Plastics
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Introduction

Most people have heard of the three Rs of the environment – Reduce, Reuse, and Recycle. As the global waste problem continues to grow, many have started adding additional Rs, such as Renew and Recover. Although significant attention has been paid to conventional recycling of plastics, only a small portion of plastics produced are currently recycled. While increasing conventional recycling rates is a priority, with more attention being focused on a creating a circular economy, new focus is being put on conversion technologies, which can complement recycling.

The overarching vision of the circular economy is the reduction of plastics into natural systems and decoupling from fossil feedstock in the plastic production process. The circular economy will be realized by a combination of technology innovation, and with the collaboration between governments and businesses.

There are several approaches to dealing with the problem of waste disposal, in particular waste generated by plastics. These approaches include reduction and sorting at source, recycling, incineration and landfilling.

Figure 1. The Rs of environment for sustainability
Trends in plastic waste sustainability

Sustainability is driven from two angles, by the consumer and through government policy. Consumer-facing industries, such as retail, consumer packaged products and automotive have been naturally the first to be affected by the consumer push for sustainability. As these consumer-facing industries have increasingly addressed their sustainability practices, initiatives are being pushed back up the value chain. While the economic benefit of investments such as energy efficiency improvements have the potential to be tangible and immediate, the impact of major reformulations and other expensive process changes may be less certain.

Leading consumer packaged goods companies (CPG) have embraced corporate sustainability, from setting mid to long term goals to driving alignment with business objectives. CPG companies focus on reducing the consumption of packaging materials, increasing the amount of recycled materials in the package itself, and increasing the amount of packaging which can be recycled. In addition to aiming for improved sustainability in product use, the CPG industry is also targeting improved end-of-life implications for their products. The impact of these initiatives on the CPG supply chain and the internal disruption to operations is illustrated in Figure 1.2.

Plastic sustainability in downstream industries

To ensure continued business growth in a consumer environment highly focused on sustainability, industries located downstream of the chemical industry are altering their approach to directly address the demands from their clientele. Consumer packaged goods (CPG) are receiving a lot of pressure to offer “green” products. Nexant profiled the sustainability report of the top global consumer packaged goods companies. Proctor & Gamble (P&G), Unilever, and Johnson and Johnson (J&J), all generate annual revenues of above USD 60 billion.

- Proctor & Gamble is the world’s largest consumer packaged goods company. P&G has led the industry wide “Holy Grail” project aimed at developing an additional dimension for sorting plastics at material recovery facilities and/or recycling plants. This will allow the reduction of plastics for packaging and improve quality of recycled material.

- Unilever is an Anglo-Dutch consumer goods company co-headquartered in Rotterdam, Netherlands and London, United Kingdom. In 2010, Unilever launched the Unilever Sustainable Living Plan (USLP). The ULSP Waste &

![Figure 1.2 CPG sustainability impact](source:Nexant)

- Promoting recycling and the circular economy
- Developing better waste management technologies
- Promoting recycling and the circular economy
- Renewable ingredients and packaging materials
- Recyclable packaging materials
- Formulations and materials of construction
- Disposal
- Size = Prevalence

Source: Nexant
Packaging commitment is to halve the waste associated with the disposal of its products by 2020. This reduction will be achieved through a combination of discontinuing brands/products whose packaging is not widely recycled, improving the recycling and recovery of packaged materials. If successful, Unilever will be a strong driver of sustainability, engaging all players across the value chain and leading other companies to follow.

- Johnson & Johnson is an American multinational medical devices, pharmaceutical, and consumer goods manufacturing company. J&J are to increase the recyclability of consumer product packaging to 90+ percent (on a weight basis) via design and partnerships in 5 key markets where mature recycling infrastructure exists (U.S., UK, France, Germany and Canada). In other markets, where recycling infrastructure is less mature, J&J will engage in partnerships to advance material recovery and recycling efforts.

The consumer packaged goods industry is pushing sustainability programs both up and downstream of its operations and is showing clear commitment to sustainability in their own activities. Retailers have little direct impact on their business’s sustainability aside from in their own operations. They are highly focused on driving more sustainability up the value chain, holding CPG suppliers to high sustainability standards and increasing the proportion of highly sustainable goods on their shelves.

In the automotive sector, the largest sustainability challenge is associated with the use of vehicles. End of life solutions are of moderate focus for the industry. Vehicle recycling primarily impacts players downstream of the automotive supply chain as it requires recycling infrastructure to be in place.

To achieve a systematic shift towards a new plastic circular economy, existing players in the CPG, retail and automotive industry will need to be guided by a collaborative and concerted initiative that identifies the challenges and opportunities in the road ahead. One such initiative is the Ellen MacArthur Foundation, a charity that has emerged on the forefront on the circular economy initiative putting it on the agenda for businesses, governments and in academia. Danone, Google, H&M, Intesa Sanpaolo, NIKE, Inc, Philips, Renault and Unilever have all partnered with the foundation. Solvay joins as the only global partner from the chemical sector. However, the global plastics industry supports the foundation through the World Plastics Council, an association of 20 leading, global, polymer producers who represent 80% of the global polymer production. As downstream industries sectors increasingly improve their own sustainability profiles, shifting pressure upstream from their own operations, it will eventually influence the operations of chemical companies.

**Figure 1.3 Sustainability in downstream industries**

<table>
<thead>
<tr>
<th>Adoption of sustainability practices</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Effective after-use plastic economy</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Industry focus</strong></td>
<td></td>
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<tr>
<td>Consumer Packaged Goods</td>
<td></td>
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<tr>
<td>Retail</td>
<td></td>
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<tr>
<td>Automotive</td>
<td></td>
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<tr>
<td><strong>Infrastructure needs</strong></td>
<td></td>
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<tr>
<td>General Availability</td>
<td></td>
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<tr>
<td>Refinement away from unsustainable inputs</td>
<td></td>
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<tr>
<td>Improving product use and end of life implications; Pushing up and down the supply chain</td>
<td></td>
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<tr>
<td>Reduced environmental impact of operations</td>
<td></td>
</tr>
<tr>
<td>Available infrastructure for improved product lifecycle (i.e., recycling infrastructure)</td>
<td></td>
</tr>
<tr>
<td>Available alternative materials</td>
<td></td>
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</tbody>
</table>

Source: Nexant
Plastic sustainability in government policy

Government policy will be a driving factor in efforts for plastic sustainability. The impact of regulation is more tangible than consumer sentiment. It is a key, unavoidable element of business operations and regulation reform on plastics will impact the chemical industry. Certain governing bodies recognise the need for specific measures on plastic and promoting its reuse, recycling and recovery by enabling the creation of an adequate market environment.

In January 2018, the European Commission (EC) published a vision, continuing from its Circular Economy Package on the future of plastics in the European Union. The EC wants all plastic packaging in to be recyclable or reusable by 2030, in a cost-effective manner. The EC will place emphasis on chemicals in plastics within the automotive, furniture and electronic sectors. Additives need to have the ability to be easily removed for further processing during recycling. Quality standards for sorted and recycled plastics are to be worked out in 2018. Uniform guidelines for the collection and sorting of waste through Europe are planned to be published in 2019, improving waste separation.

The European Union has established a roadmap and set timelines for achieving zero waste to landfill by 2025, across all member states. Germany was one of the first countries to introduce landfill limiting policies in the 1990’s. A ban on landfilling untreated municipal waste, producer responsibility and a focus on separate collection have proven to be an important policy initiatives for increasing recycling rates in Germany. As a result, landfilling in Germany was almost zero in 2010 and has remained at similar level since. Countries in Benelux and Scandinavia regions have also implemented landfill restrictions all achieving higher recycling rates of plastic post-consumer waste compared to their counterparts in the European Union.

The United Arab Emirates (UAE) government policy is geared towards sustainable use of plastics. The UAE set a target in its 2021 vision agenda, which states that 75% of solid waste will be diverted from landfill sites. Indications of the efforts to improve the waste recovery rate is the collaboration between Masdar Abu Dhabi’s renewable energy company with Bee’ah, Sharjah’s integrated environmental and waste management company. The signing of a memorandum of understanding between the two companies set in motion for a new 300 000 ton per year waste to energy plant in Abu Dhabi. Overall, the UAE national agenda highlights the importance of treating waste and reducing the total waste generated.

The UAE has the most advanced momentum regarding waste management, with other countries in the GCC starting to place further emphasis on the plastic waste management issue. Bahrain operates a single landfill for the entire country, and has the added pressure that the site is reaching full capacity. It is reported that the Bahrain ministry will ban landfill in 2018, leaving the waste to be recovered or exported. The government grants the necessary licenses for the export of waste outside the Kingdom of Bahrain for the purposes of treatment, recycling or use. Going forward concepts of sustainability will be an important part of the government strategy in the GCC and its interactions with the private sector.

China notified the World Trade Organization (WTO) in 2017 of a proposed untreated solid waste import ban, citing environmental and human health and safety concerns as the primary reasons for the material embargo. The prohibition covers household plastic wastes. Specific materials included in the import ban include, waste polymers of ethylene, styrene, vinyl chloride and PET. Imports of plastic waste into China totalled 7.3 million tons in 2016, with Western Europe, North America accounting for over 30 percent of the waste material. The import ban was effective at the start of 2018 and will disrupt recycling operations worldwide.

To control the use of recycled plastics and encourage recycling over landfill, national governments have tended to react by enforcing taxes and bans. A tax on plastic bags has been adopted by several countries including China, Brazil, South Africa, Germany and in states or cities in the United States. Although taxation and outright bans will serve to encourage recycling, other economic instruments such as subsidies to coordinate recycling projects will need to be part of the solution to move towards a new plastic circular economy.
Since plastics entered industrial production, they have pervaded consumer goods and modern life. The major polymers by type are: polyolefins, polyvinyl chloride (PVC), polystyrene and polyethylene terephthalate (PET).

Polyolefins are commodity plastics that are used globally in a wide range of market segments including consumer, automotive, construction, general industry and agriculture. Demand growth for polyolefins is a function of economic growth. Other factors that impact demand growth are environmental actions, for example recycling and limiting plastic bag use, energy and feedstock costs, inter-polymer and inter-material competition, and new product development.

The major uses of PVC are in the construction industry, with growth trending to track regional GDP growth. PVC has proved successful as a sliding (i.e. cladding) material in preference to wood because of its low maintenance requirement. PVC is also popular for window and door profiles because it provides better sound and heat insulation, as well as being air and water tight. PVC is strong, flexible, easy to sterilize. These properties are valued in applications varying from garden hose or food handling to medical tubing.

Polystyrene is the main end-use for styrene and has shown minimal growth since 2000, as a result of inter-polymer competition, consumer behaviour changes and technology development. Polystyrene was challenged by competition from other polymers and feedstock costs.

PET bottle grade is a semi-crystalline opaque material, which is injected into preforms, and then stretch blow moulded to form transparent bottles. PET bottle grade market remains comparatively evenly spread around the world, with most plants selling to their local or neighbouring countries with the exception of some export based players in Asia and Middle East. PET’s versatility and recyclability has cemented its position as the material of choice for beverage packaging.

Demand for bio-chemicals that include bio-polymers, natural rubber, industrial enzymes, natural oleochemicals accounted for around 20 million tons in 2016. Bio-polymers are a small segment when compared to the total consumption of plastics that are derived from fossil fuels. This does leave ample room for significant expansion in the biopolymer industry before it would have any appreciable impact on the conventional commodity polymer markets.

Concerns have been mounting about the economic costs and environmental sustainability of relying on non-renewable sources. Consequently, some of the major players in the petrochemical industry have started to seek and develop new renewable feedstocks and products derived from bio-based materials.

Polylactic acid (PLA) has become a forerunner in the bio-polymers market, with companies such as BASF, involved in the development of PLA. However, the current price of PLA is significantly higher compared to that of conventional commodity polymers and to compete for significant market share the price will need to be more competitive. Additionally, the properties are not on par with conventional commodity polymers and thus will need to be improved to compete for a greater market share.
Recycling has environmental and energy advantages. In the case of plastics, energy savings are particularly significant since the structural material of the package is itself an energy resource. Recycling of plastic bottles, lends credence to the argument that the “feedstock” energy is not actually consumed but merely “borrowed”, (i.e., available for use again). There are four basic levels of recycling, commonly referred to as: primary, secondary, tertiary and quaternary.

- **Primary Recycling**: Industrial and manufacturing scrap is processed (i.e., remelted and reused) into products with similar or identical to those in the original application.
- **Secondary Recycling**: processing of plastic waste from post-industrial and post-consumer waste streams into products with similar or decreased properties compared to the original application.
- **Tertiary Recycling**: production of basic chemicals, monomers, and/or fuels by chemical or thermal conversion of post-industrial and post-consumer plastic waste
- **Quaternary Recycling**: recover the energy content of post-industrial and post-consumer waste by incineration

Film recycling market

Polyethylene (LDPE, LLDPE, HDPE), polypropylene and PET are the most used resins in film. The rest of the film market consists of PVC and other resins. The global film market is estimated to be close to 70 million tons in 2017. The recycling rates for films are lower compared to that of bottles as it more difficult to collect and sort films. Recycled films are mostly used in the production of composite lumber and rigid products such as outdoor decks and fencing.

In the Middle East, polyolefin demand is dominated by the film and sheet industry and demand from this end-use is expected to continue to grow. Continuous innovation in packaging applications is helping the replacement of traditional packaging materials with polyolefins; food packaging, which includes thin walled containers and films, is driving the demand for packaging. As a result of such innovation, the demand for film in packaging applications is a growth potential among the various end-use applications.

A major application for HDPE films worldwide is in supermarket shopping bags, which are usually made from thin gauge HDPE and are designed for single use. The nature of a single use carrier bag is that, once the bag has been used it enters the waste stream and often ends up in landfill sites. Consumption of HDPE into carrier bags has declined as the market has been affected by changing consumer trends, regulations and downgauging. Regulations that restrict usage have had a significant effect on the carrier bag market. In 2014, the European Commission passed a bill as part of the Packaging and Packaging Waste Directive to restrict the use of lightweight, thin gauge carrier bags (thickness below 50 microns). A carrier bag charge was introduced in the United Kingdom towards the end of 2015, reducing bag usage by almost 80 percent.

![Figure 1.5 Global film resin demand by polymer (2017-estimate, percent)](image1)

![Figure 1.6 Middle East film resin demand by polymer (2017-estimate, percent)](image2)
**Film recycling technology**

After PET bottle recycling, plastics film recycling is one of the most important sources of income for the recycling industry, due to the large amount available for recycling. Plastic films are probably the main largest detectable material in a collection waste stream, of which HDPE represents the biggest proportion.

In plastic bag recycling, the plastic waste is placed on a conveyor belt where large contaminants are removed by hand. Next, the bags are washed to remove non-metallic contaminants, and then placed on a conveyor where metallic objects are removed by magnets located on the conveyor belts. Afterwards, the waste is introduced into a shredder. Since contamination is a major factor influencing the recyclability of films, washing is an important step during recycling of film waste. The plastic film leaves the washer and is propelled forward into a separation water filled tank by using rotating paddle drums. In order to avoid formation of bubbles in the final granules, the wet plastic film pieces are dried. Extrusion of films is the last step of the process; the process consists of a melting and densification stage, where the plastic is compacted to increase throughput.

**Bottle recycling market**

PET and HDPE are the most commonly used resins in producing consumer bottles, accounting for more than 95% of the bottles that get recycled. The remainder consists of polypropylene bottles, and some PVC and LDPE bottles. Post-consumer bottles consist mainly of beverage and water bottles.

PET bottle resin demand is estimated to be about 24 million tons globally in 2017. PET’s versatility, recyclability, and low energy requirement has strengthened its position as the material of choice for beverage packaging, and even allowed continued displacement of other packaging materials (particularly PVC and polystyrene) for other retail packaging items. PET accounts for over half of all plastics recycling in some regions, due to its lower cost and energy consumption than alternative materials.

In countries such as the United Arab Emirates (UAE) the per capita consumption of bottled water are among the highest in the world. Desalination is the major source of portable water in the United Arab Emirates. Desalinated water comes with a high price tag as it is produced by using associated gas. The per capita consumption of bottled water will remain high given the economic prosperity in the region and the presence of local brands. In terms of recycling, the high consumption rates of PET bottles in UAE will also be complemented by the government agenda to reduce solid waste and for it to be diverted away from landfill sites.

Globally, recycled HDPE consumption in blow moulding has a small market compared to PET bottle resin. In the recycling process for HDPE, there are difficulties in removing volatile contaminates, when compared to removing these in PET. In most cases, recycled HDPE cannot be used in food- or pharmaceutical-related products, which are the major end use applications for HDPE bottles.

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**Figure 1.7 Plastic film recycling system**

1. Raw materials feeding conveyor
2. Raw material crusher
3. Raw materials rinser
4. Crushed and rinsed raw material feeding conveyor
5. Agglomerator
6. Cooling bath
7. Granulator

Bottle recycling technology

The recycling of PET, primarily from beverage bottles, has progressed faster than for the other plastics with most of the recycled PET being used to manufacture fibre applications (such as carpets and textiles).

The recycling of post-consumer PET bottles, for the production of fibre grade PET, involves sorting the collected bottles (to separate from non-PET bottles), grinding the PET bottles into flakes, washing the flakes, removal of labels and caps, followed by the drying of the flakes. The flakes are then fed into an extruder (in charge of the melting process), filtered, and spun to get recycled PET fibre.

Commercial PET recycling operations are based on physical separation of PET from other components in post-consumer bottles (i.e., paper labels and aluminium caps), or from manufacturer’s scrap. The production of food grade PET, from post-consumer PET bottles, involves a superclean (mechanical/physical) recycling route and a feedstock (or chemical) recycling route. These routes are a means to further clean the PET flakes by removing volatile contaminants, while increasing the intrinsic viscosity (IV).

Fibre recycling market

The main types of recycled synthetic fibres include polyester and polypropylene. The global market for virgin synthetic fibres is estimated to be around 80 million tons in 2017, with PET accounting for about 70% of the market. PET fibre is used mainly in clothing and carpets. Polypropylene accounts for around a quarter of fibre demand. The rest of the fibre market consists of mainly of nylon.

The global recycling rate for fibres is lower compared to that for bottles or films. Mechanical recycling is not suitable for fibres woven into fabrics, as the fabrics almost always have a chemical backing, lamination or other finish, or they have blends of other polymers, such as a mixture of polyester and nylon, which makes mechanical recycling non feasible. Hence, only chemical recycling can be used in this case, which is more capital intensive than mechanical recycling. Additionally, collection and sorting remains a barrier to the widespread recycling of fibres.

Fibre for the production of carpets is the main use of polypropylene in the Middle East. Turkey is the largest market for polypropylene in the Middle East. In Turkey, fibre production accounts for 70 percent of polypropylene demand. After Turkey, Iran is the second largest market for polypropylene. In Iran, fibre production accounts for 60 percent of polypropylene demand. Increasing end-use applications, product and process innovations in the flooring and carpet designs, will be market opportunities in the region.

Even though the market for polypropylene fibres is larger than that of nylon fibres, nylon carpets are the most commonly recycled among all fibres. Nylon collection and recycling is cost efficient when there are large volumes of relatively homogenous waste material, such as in the case of carpet. Also, the high price of nylon resin makes it more profitable for recycling compared to polypropylene and polyester, which are lower priced resins.

Fibre recycling technology

The process for recycling textiles (clothing) is assumed to follow similar steps as those for the physical recycling of carpets.

Most carpets are made by joining a surface material (face fibre) to a backing layer. Face fibres can be made of synthetic polymers, such as nylon, polypropylene, polyester, or natural fibres, such as wool, and sisal. Some carpets also have a secondary backing (jute or polypropylene), and a synthetic foam cushion.

Face fibers can be shaved from the carpet backing, or the entire carpet can be shredded, pulverized, and separated from the face fiber using a density technique. Pulverized carpet materials are separated in two stages using centrifuges. The first stage separates the backing from the face fiber. The
second separates polypropylene from the nylon face fiber. In addition to melt processing, depolymerization and dissolution techniques can also be used to recover nylon from carpets.

**PVC recycling market**

Global virgin PVC demand is estimated to be about 45 million tons in 2017. The major growth driver for PVC is the construction sector. In recent years, environmental and safety issues as well as substitution by polyethylene have negatively affected PVC consumption. Several countries have legislated against the use of plasticized PVC in children’s toys. PVC consumption in food packaging has also declined, although more as a result of the better cost-performance of other polymers rather than a poor environmental and health perception.

Most of the PVC waste ends up in landfills. In addition to landfills, incineration is another option for disposal of PVC waste. However, disposal of PVC waste by incineration is an area of environmental concern as it is difficult to efficiently combust the components without producing dioxins. Overall, dioxins are believed by some to be among the most genetically disruptive compounds known, but the scientific understanding of the issues surrounding dioxins and related compounds (so-called “estrogen mimics”) is not at all complete.

To deal with environmental issues of PVC waste during incineration or leaking at landfills, a number of technologies have been investigated and include mechanical recycling (where plastic is ground down into a powder base for new products) and chemical recycling (where chemical separation occurs allowing removal and reclamation of chlorine and toxins).

**PVC recycling technology**

Mechanical recycling is a route to recycle PVC. Products recycled in this manner include coated fabrics, flooring, pipes, roofing membranes, and window profiles. This route has the advantage of producing PVC recyclate that has the same quality as virgin PVC. Mechanical recycling involves sorting, grinding, washing (to eliminate dirt and other materials), removal
of steel, iron, and other non-ferrous metals. The recovered granulated recycled PVC is then transported to a reprocessor so it can be converted into ready-to-use feedstock by melting the PVC recylcate.

An example of non-conventional mechanical recycling is Solvay’s VinyLoop® technology. The recycling process of PVC containing heavy metals involves pre-treatment of PVC waste using physical operations such as cleaning and reducing the size for fast dissolution, followed by dissolving the PVC in a solvent. The mixture is then stirred and allowed to settle so that the complexed heavy metal compounds can precipitate before centrifuging. A simplified diagram of the VinylLoop process is illustrated in Figure 1.13.
Technology is available to break down a polymer into either its base component or an intermediate product. As such, these processes are designed for specific resins. The resulting product is generally suitable to be used as feedstock for the production of virgin resin. The polymer briefly covered in this prospectus is PET.

Chemical recycling of polyester, particularly PET resin used in bottle and other container applications, is continuing to grow in importance as a viable means of recycling. This process also offers the opportunity to add value-added products to post-consumer PET.

Developments in the chemical recycling of PET have been driven by its use in application that comes in contact with food. Until recently, “no objection letters” (NOL) were issued by the United States Food and Drug Administration (FDA), once the agency had established that the recycling process (including tertiary recycling), as submitted by the manufacturer, produced plastic suitable for food contact applications. However, the FDA has now determined that tertiary recycling produces post-consumer recycled (PCR) PET with the right purity required for packaging that comes in contact with food. Thus, the FDA no longer evaluates PET tertiary recycling processes to issue NOL.

During the 1995-2005 timeframe, companies that have received NOL for a methanolysis process include Eastman (the process is a combination of glycolysis and methanolysis), Teijin Limited, and Mitsubishi Chemical Corporation. Companies that have received NOL for a glycolysis process included Hoechst Celanese (now Celanese), Roychem, Wellman, Innovations in PET Pty, Eastman, DAK Americas, Nan Ya Plastics, and OHL Apparatebau & Verfahrenstechnik (now OHL Technologies).

A selected company process to break PET bottles into their precursor chemical is SABIC’s VALOX iQ technology. The technology breaks the PET bottles and then purifies it to produce polybutene terephthalate (PBT). It is claimed that the resulting VALOX iQ resin contains up to 65 percent recycled content and that its processing performance is “nearly equivalent” to virgin PBT since neither the mechanical nor aesthetic performance of the PBT produced is impacted by the use of recycled material. The company also claims that its resin can save up to 0.87 kg of post-consumer PET from ending up in local landfills and it is an energy efficient process.
Incineration with energy recovery is a type of modern Waste-To-Energy (WTE) technology that is a significant advance over incinerators of the past. Using municipal solid waste (MSW) as the primary fuel source, these WTE facilities recover electricity and steam for the site or communities, in which they operate. In addition to the WTE technologies currently being employed to convert MSW into energy, the waste industry is exploring alternative waste conversion technologies that convert waste to other useful fuel products. These technologies present the opportunity for fuel and chemical production besides providing an alternative to landfilling.

Pyrolysis of petroleum-based plastics can help recover light oil that can be used in the production of new plastics. A medium fuel oil that is equivalent to diesel can be generated as well as any heavy oil that can be used to produce electricity for export to the grid.

While the pyrolysis of polyethylene and polypropylene can yield a fuel that burns almost clean, the pyrolysis of PVC can be problematic. Chlorine in PVC is mainly in organic chlorine form, and in the atmosphere of pyrolysis, chlorine compounds, such as HCl, are released during PVC thermal conversion processes, with risks to process equipment, the environment, and/or human health. Pyrolysis of PET is also problematic, since it releases oxygen, affecting the rate of the process. Recycling of PET is best done through traditional secondary recycling methods. Plastic feedstock types and the corresponding pyrolysis product type are shown in the Table 1.1.

While the plastics to fuel processes vary, they include the same steps of collecting and sorting the plastic waste, shredding it, heating (in an oxygen-free environment) at around 400 °C, melting and vaporizing the waste, and cooling and condensing the gases into products, such as synthetic crude, ingredients for diesel, gasoline, or kerosene, and fuel. While plastic to fuel plants are operating at pilot and demonstration scale globally. The technology is available for licensing from a handful of players. The majority of suppliers offer smaller design capacities relative to other MSW conversion systems like mass burn waste-to-energy and gasification that commonly process more than 200 tons per day (TPD). The capacity of plastic to fuel systems typically range from 10 to 60 TPD.

Table 1.1 Plastic feedstock type and pyrolysis product type

<table>
<thead>
<tr>
<th>Plastic Feedstock Type</th>
<th>Pyrolysis Product Type</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>PE, PP, PS, PMMA</td>
<td>Liquid hydrocarbons</td>
<td>Most commonly used feedstock in PTF plants</td>
</tr>
<tr>
<td>ABS</td>
<td>Liquid hydrocarbons</td>
<td>Not preferred as feedstock as nitrogen containing fuel produced</td>
</tr>
<tr>
<td>PET</td>
<td>Solid products</td>
<td>Formation of benzoic acid and terephthalic acid</td>
</tr>
<tr>
<td>PU, Phenol resin</td>
<td>Carbonaceous products</td>
<td>Not preferred as feedstock</td>
</tr>
<tr>
<td>PVC</td>
<td>Hydrogen chloride and carbonaceous products</td>
<td>Not preferred as feedstock</td>
</tr>
</tbody>
</table>

Source: American Chemistry Council
Like all other modern urban centres, cities in the Middle East also face challenges in environmental protection due to tremendous tonnage of waste produced in different forms. The gross urban waste generation from Middle East countries exceeds 150 million tons per annum, out of which 10-15 percent is contributed by plastic wastes. The burgeoning population, growing consumption, and an increasing trend towards a “disposable” culture, is causing nightmares to municipal authorities across the region and beyond.

The Gulf Cooperation Council (GCC), the political and economic alliance of six Middle Eastern countries—Saudi Arabia, Kuwait, the United Arab Emirates, Qatar, Bahrain and Oman—has a long way to go with plastic recycling. The GCC countries recycle only around 10% of plastic waste. This is in comparison to the US, which has a plastic recycling rate of 34% and the European Union member states which had a recycling rate of 36.5% in 2016.

The governments, particularly in the developed countries and manufacturers are supporting plastics recycling, and the regulations are framed to support sustainable solutions. On the other hand, developing regions such as the GCC still consider plastics scrap as “waste”, but if the GCC authorities begin to understand that it is a resource, there is tremendous potential for business, in-country value creation and job growth in this part of the world.

There is the need for a change in approach with regard to plastic waste imports, particularly in the GCC as the region is losing out on the opportunity of receiving the raw material that is essential for sustaining the recycling industry initiatives. The local recycling units need to have modern machinery and know-how, a sound system and an optimum level of production, which is not possible at present as the region does not have the necessary quantity of raw materials and the free flow is restricted. What is required, is to convince the government authorities to study the situation, before responding to these questionnaires from plastic waste exporting countries or regions (e.g. the EU), looking at the availability of plastic waste.

The GCC authorities have given permission to set up recycling plants, but these facilities don’t have a sufficient and constant flow of materials. And there are many of the GCC countries do not respond to these export questionnaires mainly due to lack of awareness. There is an urgent need to convince the GCC authorities to respond; otherwise you are losing resources, employment, revenue and prosperity. There is a major opportunity for the GCC to import some of the plastic waste that China has recently banned, thus increasing the stream of available plastic waste to fully develop the GCC plastics recycling industries.
Conclusions

The vision of the circular economy is that plastics do not enter natural systems (in particular the marine environment), decoupling plastics from fossil fuels and creating an effective after use economy. It is consumer facing industries that are increasingly addressing plastic sustainability, with initiatives being pushed back upstream. Government policy will also be a driving force in efforts for to increase plastic sustainability.

PET bottle and plastic film recycling are the most important sources of feedstock for the recycling market, due to the large amount of material available for recycling. The global film market is estimated to be close to 70 million tons in 2017. Primary recycling routes is the most common routes for PET bottle and film plastics. Although the chemical recycling of PET bottles, is continuing to grow in importance as a viable means of recycling.

Uncommon plastic packaging materials of which only relatively low volumes are put on the packaging market include PVC. It’s lack of viable after-use pathways make it particularly prone to escaping collections systems and ending up in the natural environment. Chemical recycling and other technologies will continue to be explored to process uncommon packaging materials into new plastic feedstock.

Plastic to fuel plants, do not decouple the recycling system from fossil fuel feedstock. Plastic to fuel technology has the added advantage of being applied to plastics that cannot be economically recycled, such as food contaminated plastics, agricultural plastics, etc. Therefore, plastic to fuel conversion is not expected to disrupt the recycling industry, but rather complement it.

There has been a significant recent development regarding the Paris Agreement on climate change related to the reduction of carbon emissions, the UAE and Saudi Arabia have signed and enforced this agreement. This will have serious implications on the recycling industry with 197 countries having signed the accord and at the moment, the GCC countries are not fully aware that they need to turn to recycling on a much larger scale, to achieve the agreed target of carbon emissions; they have to put plastic recycling on their radar.

Further information can be found in Nexant’s Petrochemicals Market Dynamic Reports. Contact Anna Ibbotson, aibbotson@nexant.com, a Principal in Nexant’s Energy and Chemicals Advisory (ECA) practice.

Nexant is an independent international energy consulting company and can provide expertise in areas such as strategy and business planning, master planning/feasibility studies, techno-economic and commercial analyses, transaction related support and financial evaluation. For more details on Nexant’s capabilities, please refer to David Lines, dlines@nexant.com, a Bahrain-based Nexant Principal in the ECA practice.

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The Gulf Petrochemicals and Chemicals Association (GPCA) represents the downstream hydrocarbon industry in the Arabian Gulf. Established in 2006, the association voices the common interests of more than 250 member companies from the chemical and allied industries, accounting for over 95% of chemical output in the Gulf region. The industry makes up the second largest manufacturing sector in the region, producing over USD 108 billion worth of products a year.

The association supports the region’s petrochemical and chemical industry through advocacy, networking and thought leadership initiatives that help member companies to connect, to share and advance knowledge, to contribute to international dialogue, and to become prime influencers in shaping the future of the global petrochemicals industry.

Committed to providing a regional platform for stakeholders from across the industry, the GPCA manages six working committees - Plastics, Supply Chain, Fertilizers, International Trade, Research and Innovation, and Responsible Care - and organizes five world-class events each year. The association also publishes an annual report, regular newsletters and reports.

For more information, please visit www.gpca.org.ae

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