Plastic Recycling and Carbon Impact

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Executive summary

The aim of this report is help clients understand that whilst we can answer a specific question asked of us about plastics it may not be the right question to answers the client's problem. ***The what you want is not necessarily what you need conundrum!***

This paper does not seek to provide a comprehensive, definitive answer to solve the problem of plastic waste and carbon emissions as we are sure readers can appreciate this complex problem. To answer any question is a detailed process which is hugely location and requirement based.

Instead, we have touched upon some of the important issues that will need addressing and encourage readers to contact us for a more focus answer to their questions around plastic recycling.

Plastics are versatile materials that are part of our life. They are in our homes, in nearly everyday item and used to store and package our food and water. In many cases, plastics are the only solution to a manufacturing problem. Polymer technology is arguable the most influential invention of the last century and potentially has helped to save more lives than any other invention in human history.

The range and volume of single waste plastics continue to grow as the population of the planet increases. Many uses of single use plastic cannot be replaced by other materials, therefore the market will continue to grow. Additionally, in some applications it is either ethically or socially unacceptable to use recycled materials and hence the demand for fresh hydrocarbon feedstocks is essential to maintain the production of these materials. The demand for non-single use plastic continues to increase as the global population grows although with the percentage of this population that has access to consumer goods and a developed way of life.

Tens of millions of tonnes of plastic are manufactured every year with the vast majority of this plastic been produced from fossil resources. Whilst some applications of plastic are longer term, the majority of plastic production is used for single use applications, such a food packaging, and therefore, are thrown away after this use. These waste plastics can be used to make fresh plastics and thus conserving resources. This is the concept of the circular economy insomuch turning waste to products.

Worldwide the problem of waste plastic pollution in the oceans and across landscapes is mounting and increasingly becoming a problem. Most food, drink and goods are packaged in plastic, which is unsuitable for reuse in another purpose. These single-use plastics are then discarded once they have served their purpose. Most countries in the world have polices for collecting this waste and in other locations, the used plastic is simply discarded. If the material can be re-used prior to being discarded this avoids the creation of waste and hence is a possible solution.

Rather than discarding these materials they can be reprocessed as per the concept of the circular economy into new products. However, how does this reprocessing compare to the traditional plastics manufacturing methods from a carbon impact in terms of carbon dioxide emissions to the environment? This is the question we aim to answer.

We aim to look at the traditional production routes and alternative waste plastic manufacturing routes for polymers. When considering chemical recycling we look at process routes in which the materials that can be easily recycled and reused, in a process known as mechanical recycling, are removed and reused before the chemical recycling. Similarly, for fossil-based routes, the impact of disposal is considered after the mechanically recyclable materials are removed.

The options we have considered for treatment of the resulting waste post mechanically recycling is:

- Land filling
- Waste to energy
- Incineration.

The schematic below illustrates the routes for fossil-based process routes for the production of polymers and fuels.

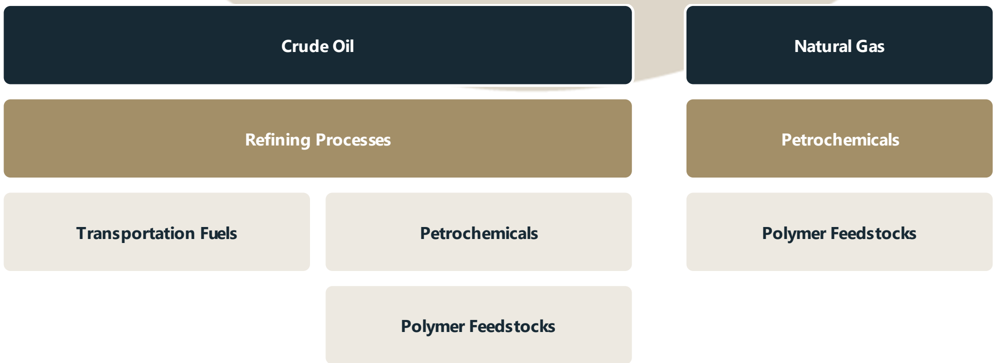

Figure 0-1 Fossil Resources to Products - Processing Steps, Source Advisian

This contrasts with the schematic below which shows the chemical recycling routes for converting waste plastics to polymers and fuels.

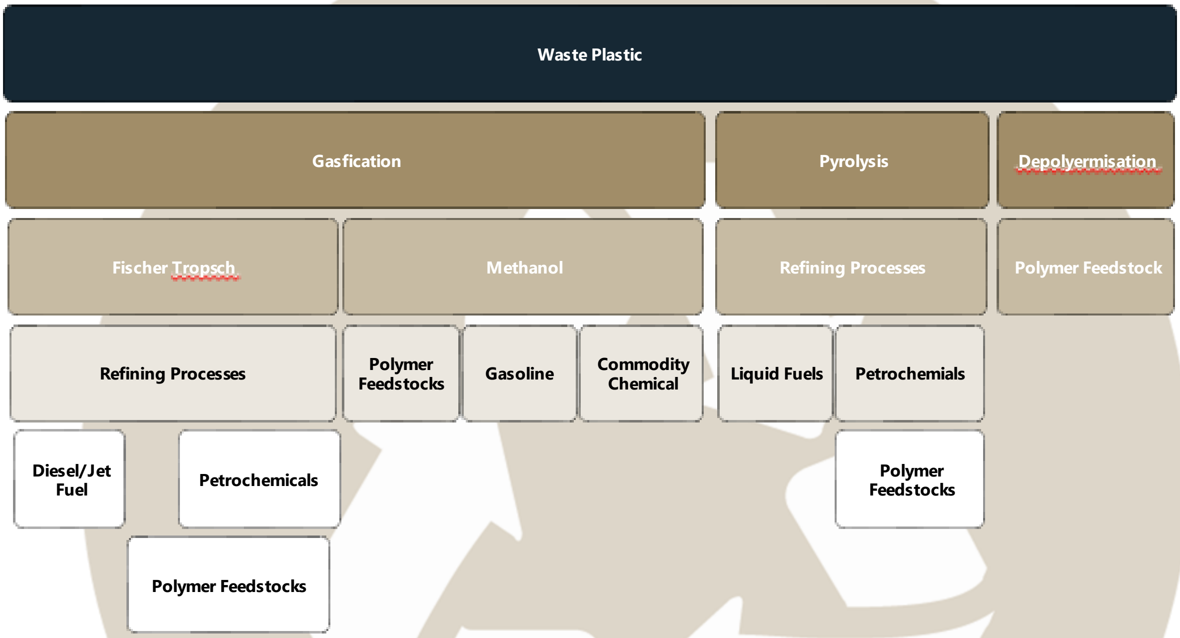

Figure 0-2 Waste to Products - Processing Steps, Source Advisian

In general there are three routes to convert waste plastic to products; namely gasification which is the conversion of the waste stream to a gas which is used to make products; pyrolysis which is conversion of the plastic to an oil like stream which can also be made into products and finally depolymerization which is breaking the plastic into its constituent parts, which then can be used to make more plastic.

We have looked at the carbon intensity of each of the available options and the sustainability of each of the process units and ranked each route on both of these scales. Table 0-1 shows the results of these ranking exercises. In each case, red is the lowest ranking, amber a middling ranking and green a high ranking.

Table 0-1 Carbon Intensity and Sustainability Rankings

Route	Route Short Description	Carbon Intensity Ranking	Sustainability Ranking
1	Landfill		
2	Waste to Energy		
3	Depolymerisation		
4	Pyrolysis – Fuel		
5	Pyrolysis – Polymer		
6	Gasification – FT – Fuels		
7	Gasification – FT – Polymers		
8	Gasification – MeOH – Polymer		
9	Gasification – MeOH – Fuel		
10	Gasification – MeOH		
11	Incineration		
12	Crude Oil – Fuel		
13	Crude Oil – Polymer		
14	Natural Gas -- Polymer		

These results only demonstrate two ranking characteristics of many other possible factors that will affect the ranking as these are based on a commercial, technology availability, market trends, legislation practicality and local basis, which mean every project is different and there is no best solution. The answer is too specific and will vary on a case by case basis. The questions to be asked for the best solution should focus on the following topics:

- Is the solution commercially viable?
- Is the technology suitable from an efficiency, energy consumption and product specification?
- Can the carbon emissions be captured, and better still reused?
- Can the carbon intensity be lowered with the use of biomass and/or renewable power?
- Is the market for the feed and product going to match the plant life?
- Can all environmental aspects be met?

When viewed purely from a carbon emission's perspective, landfill of plastics is not the worst solution. Based on what is currently available today from a technology perspective. We can develop a list of alternative only options that beat landfill as the counterfactual. We can produce summaries these options are either process or transition based. Process based means that different processes have to be put in place to enable the transition. Whilst being transition based in this case means different business practices or different consumption patterns have to be implemented by the consumers and the producers.

Table 0-2 below gives details of the options that can beat landfill, together with the transition or process bases commentary.

Table 0-2 Options

Option	Type
Eliminate polymer use (e.g. reduce packaging)	Transition
Encourage consumer to re-use	Transition
Switch to lower carbon alternative (e.g. paper) if proven	Transition
Mechanical recycling (as carbon emissions arising are lower than those to produce virgin plastic from fossil resources)	Process
Depolymerisation Chemical Recycling if and when suitable technology is available	Process

To bring about these changes, the population, which has become used to seeing products presented in a certain manner and considerable marketing and education, would be required to change their behavior, and hence enable the required transition.

For the options requiring process changes, the polymer industry can support these efforts. The responsibility for introduction and implementation lies with consumers and the producers of the goods. The polymer industry can also continue with its efforts to develop new formulations of polymers which can be mechanically recycled or depolymerize and develop new polymers which cannot be mechanically recycled or depolymerized.

Finally, in summary, fossil resources are required to meet today's and tomorrow's polymer demands. The emergence of new polymer technologies that are more compatible with the circular economy together with advances in plastics recycling technology mean chemical recycling will get more and more carbon efficient. More economic and therefore, reusing waste plastics for plastic will become a larger proportion of the polymer supply chain as technologies continue to mature.

1 Introduction

This paper does not seek to provide a comprehensive, definitive answer to solve the problem of plastic waste and carbon emissions as we are sure readers can appreciate this complex problem. To answer any question is a detailed process which is hugely location and requirement based. We have written this report to answer one of the potential questions which can be asked about plastic recycling. With our aim being to help a reader understand that whilst we can answer a question it may not be the question that answers the readers problem. We have touched upon some of the important issues that will need addressing and encourage readers to contact us for a more focus answer to their questions around plastic recycling.

2 Plastics background

Petrochemicals, the category that includes plastics, accounts for around 14% of oil use, and according to the International Energy Agency (IEA),.is expected to drive half of oil demand growth between now and 2050.

The proportions are higher from a global perspective, with plastics production accounting for about 4% of global oil production. Going by those averages, and based on current global oil production of 90 million b/d, plastics consume about 3.7 million b/d of oil, and 1.24 Gbbl over 12 months.

Plastics are versatile materials that are part of our everyday life. They are in our homes, in nearly everyday item, and used to store and package our food and water. In many cases plastics are the only solution to a manufacturing problem. Polymer technology is arguably the most influential invention of the last century and potentially has helped save more human lives than any other invention in human history.

Plastics have been developed to have desirable properties. They can be lightweight and strong, can insulate from heat and electricity, be formed in virtually any shape, be gas and water permeable or impermeable, provide a protective environment, spun into fibres, used for a thin invisible coating, be coloured or clear, be transparent or opaque, be tough or fragile. In summary plastics have replaced traditional wood, natural fibres and metals in many applications and have found uses in new applications that did not exist before the discovery of plastics.

Plastics can be categorised into to three types, thermoplastics, thermosets and elastomers. Each category contains numerous individual types of plastics that can have widely different properties.

Thermoplastics are defined as material that softens and becomes mouldable at a certain temperature and then solidifies once cooled. Thermoplastics usually have a high molecular weight and can be formed into their desired form by heating and moulding or extruding and allowing to cool. Thermoplastic materials can be reformed into new shapes and forms by reheating, remoulding and allowing to cool.

Thermosetting plastics, more commonly known as thermoset plastics, is permanently hardened, or cured, by heat, or other forms of energy such as ultraviolet light. The heat to harden the material does not always come from external sources but can be generated from a chemical reaction by mixing with a catalyst. Unlike thermoplastics, thermosets, once cured, cannot be reformed into different shapes or forms.

Elastomers are plastics that have viscous and elastic properties and can be either thermoset or thermoplastics. The defining property of an elastomer is a plastic that can deformed and, when the deforming force is removed, it will return to its original shape. Elastomers are used in applications where it is desirable for the material to flex, deform and return to original shape such as car tyres or the lid of a food storage container.

Because of these versatile properties different plastics have many uses in every sector of modern life including:

- Packaging materials
- Building and construction
- Healthcare
- Automotive
- Clothing
- Consumer goods
- Furniture
- Agriculture

Plastics can be further categorised by their type of use. They are either disposal with a single use or are used until they reach end of life. Single use plastics are items that are made to be disposed after their first use such as beverage containers, food packaging and medical syringes. It is these single use plastics that form the majority of plastic waste.

The range and volume of single waste plastics continues to grow as the population of the planet increases. Many uses of single use plastic cannot be replaced by other materials and hence the problem will continue to grow. Additionally, in some applications, it is either ethically or socially unacceptable to use recycled materials and hence the demand for fresh hydrocarbon feedstocks is essential to maintain the production of these materials.

The demand for non-single use plastic also continues to increase as the global population grows along with the percentage of this population that has access to consumer goods and a developed way of life. Even if all plastic materials were to be recycled, this increased demand is likely to require fresh hydrocarbon feed to meet product dema