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The potential for advanced recycling technologies for plastics in South Africa

A circular economy for plastics has projected net economic and job creation benefits in both developed and developing country settings. South Africa has good potential to realise the benefits in a circular economy for plastics, building on expertise in both the plastics production and recycling sectors. This series of 10 briefs provides the context of the plastics industry in South Africa and highlights opportunities in a circular economy: Part 8 of 10

A multitude of advanced recycling technologies are currently being implemented in the global market that are promising an end to plastic waste. These advanced recycling processes, otherwise referred to as chemical or non-mechanical recycling, take materials back to basic plastics, as polymers or monomers. From a chemical composition perspective, the concept is sound in that polymers are highly processed pure fractions of complex hydrocarbons sourced from fossil fuels. It follows that these polymers should be simpler to process than the original source from where they came.

There are hundreds of different plastic variants that have been developed by the packaging industry in the past few decades to cater for a multitude of applications. While the intent may not have been to complicate mechanical recycling of plastics, this is the unintended consequence of the range of additives included in plastics production. "Design for recyclability" is thus important particularly to enable simpler, less energy intensive and less expensive recycling technologies (whether mechanical or advanced recycling technologies).

Simple polymers are relatively easy to break down into their constituent parts for reprocessing or re-polymerising back into the system as new plastics. Such advanced recycling can be done through a variety of technical processes including thermal hydrolysis, pyrolysis, catalytic depolymerisation, gasification, plasma arc depolymerisation, chemical dissolution and a variety of new applications using slight modifications, variations and combinations of these technologies.

Some of these technologies are also able to deal with complex "unrecyclable" plastics, on the understanding that the resultant products are generally lower-value outputs such as boiler fuel or energy, which is then not defined as chemical recycling, but rather a waste-to-energy process. Systems are available for the further refining of these liquid products, but generally at scales and capital costs that are simply not currently economically viable in developing economies.

This brief provides an overview of advanced recycling technologies, their potential role in enabling a circular economy for plastics in South Africa and some of the current barriers to economic viability in the South African context.

Overview of Advanced Recycling Processes

Advanced recycling is a broad term that describes a range of technologies and processes that convert plastic waste into more basic chemicals, which can be used to replace feedstock for virgin polymer manufacture. There are many processes which could be considered advanced recycling. The technologies considered here can be grouped into three broad categories which are represented in **Figure 1** based on the stage in plastic manufacturing to which that the technology returns feedstock:

1. Feedstock recycling (pyrolysis and gasification)
2. Depolymerisation
3. Dissolution (solvent-based purification)

None of these processes are superior to any other: each technology is suited to different polymer types and different challenges.

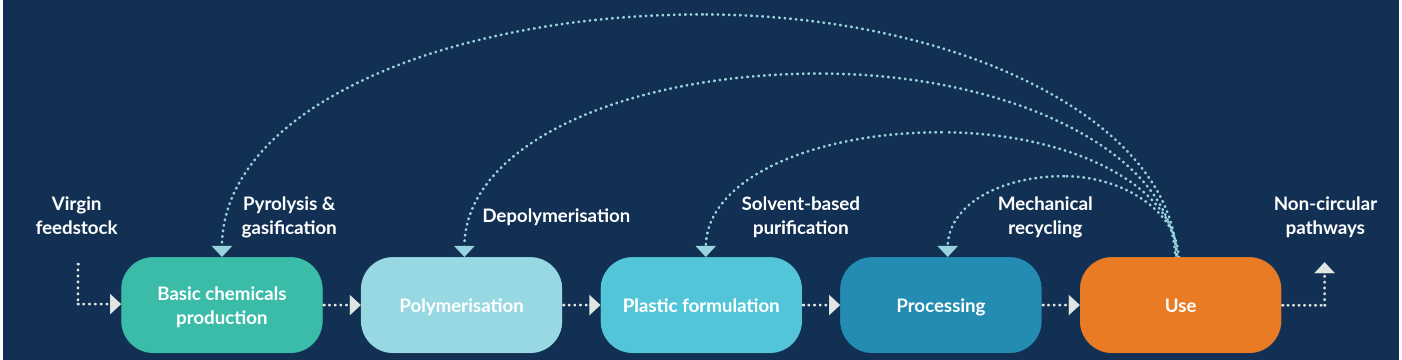

Figure 1: Recycling technologies illustrated by stage of plastic manufacturing to which the technology returns feedstock

Adapted from: Crippa *et al.* (2019)[1]

The Role of Advanced Recycling Technologies

The development of advanced recycling technologies is driven by the need to process materials which are difficult, or not possible, to process through mechanical recycling routes. Mechanical recycling technology is not able to remove additives and contaminants effectively and efficiently from waste plastics. As feedstock for recycling is from mixed sources, when it is processed mechanically the knowledge of composition and inclusion of additives is lost. Advanced recycling offers the ability to remove all potential contaminants thus opening more end markets for this material.

Polymer degradation occurs through repeated mechanical processing, lowering the quality of the output material. Advanced recycling technologies offer a pathway to overcome these constraints as they can take the polymer back to its building blocks, effectively making a 'virgin-like' grade material. There is not one single advanced recycling technology that is best suited to all polymers. The technologies can largely be split into solutions for polyolefins (HDPE, LDPE, and PP) and solutions for PET, and, as such, an initial sort will always be required. In addition to material segregation, this sort will improve the input to the process (in terms of contamination etc.), which, in turn, will improve the output. The output also depends on type of technology.

[1] Crippa, M., De Wilde, B., Koopmans, R., Leyssens, J., Muncke, J., Ritschkoff A-C., Van Doorsselaer, K., Velis, C. & Wagner, M. (2019) A circular economy for plastics – Insights from research and innovation to inform policy and funding decisions, (M. De Smet & M. Linder, Eds.). European Commission, Brussels, Belgium.

Whilst dissolution and PET depolymerisation can achieve high yields, greater than 90% of recovered polymer, pyrolysis and gasification technologies achieve much lower conversion to polymer, reported in the region of 30%-40%.

Overall, the future is thus likely to be a mix of both mechanical and different types of advanced recycling technologies.

Opportunities for Advanced Recycling Technologies

By focussing on polymers and formats not widely mechanically recycled, e.g. pouches and laminates, recycling rates could be significantly increased. Additionally, advanced recycling could be used to produce food grade recycled material where this is not technically possible through mechanical recycling.

New pilot technologies and modular units have the potential to be implemented alongside the current recycling infrastructure. Additionally, the market demand for high quality recycled content for consumer packaging from brands and retailers has the potential to create a favourable economic environment for these technologies. Since advanced recycling can offer recycled content in packaging up to 100% without compromising on quality, this has the potential to vastly increase demand, thus further creating a fertile environment for investment.

Barriers to the Uptake of Advanced Recycling Technologies

There are several challenges that must be overcome to support the advanced recycling sector to reach its potential, whilst working alongside mechanical recycling to help deliver a circular economy for plastic packaging.

Economic Challenges

Where fossil fuel prices are low, it is uncertain whether advanced recycling can be competitive on its own. Advanced recycling processes can be costly due to their high energy and operational costs. The high-quality end products created from advanced recycling can demand a premium compared to mechanically recycled products. But, if virgin materials remain cheap to produce because of low fossil fuel prices, it will be difficult for recycled materials to compete on price alone, and this will be particularly challenging for material produced by advanced recycling.

Investment Challenges

Advanced recycling often requires scale to make a plant financially viable, and therefore often involves substantial investment.

Furthermore, in order to operate at scale, it is necessary to have access to a large amount of feedstock. Collection and sorting infrastructure and capacity for certain plastic streams are well-established, although mainly in the metropolitan municipalities in South Africa, with an input recycling rate (mechanical recycling) of about 40% for plastic packaging in 2019[2]. Of the suitable feedstock for chemical recycling (i.e. contaminated plastics including losses from mechanical recycling processes, mixed plastics, and difficult to recycle plastics), waste plastics from recycling plants are consistently generated and accessible. For streams currently not or poorly recycled, included mixed plastics, a subsidy is needed to compensate for low material value, as well as investment in additional capacity for collection and sorting will be needed.

[2] CE Delft (2020) Exploration chemical recycling – Extended summary: What is the potential contribution of chemical recycling to Dutch climate policy?
Exploratory study on chemical recycling. Update 2019 - CE Delft - EN

Barriers to the Uptake of Advanced Recycling Technologies

As municipal separation-at-source projects grow (there is currently very limited coverage of such schemes in South Africa), the potential to include such mixed plastics will improve, as these systems generally collect mixed bags of dry recyclables from residents.

The new mandatory Extended Producer Responsibility (EPR) system in South Africa, with 2022 as the first year of implementation, has the potential to provide the needed investment in collection and sorting, although the plastics currently not collected would need to be heavily subsidised to incentivise collection by the informal sector and SMMEs, and even larger collectors. The level of subsidy needed may well be in excess of industry resources, especially in the first few years of the mandatory system, as it is highly unlikely that there will be full recovery of mandatory EPR fees in a developing system, where some producers do not yet know the types and tonnages of their packaging for which EPR fees must be paid.

In general, investment needed to establish advanced recycling plants is substantially more than the investment required for the range of mechanical recycling available in South Africa. The quantum of investment required can currently be supported by EPR fees, which are designed to subsidise and support the mechanical recycling value chain.

There are currently no specific government strategies or incentives that would support the development of advanced recycling in South Africa. In addition, current legislative and regulatory requirements dramatically increase costs of technology deployment and as such provide a disincentive for investment. The National Environmental Management: Waste Act (no 59 of 2008) and associated list of waste management activities that have, or are likely to have, a detrimental effect on the environment, includes thresholds on the processing of different waste types and different levels of authorisation. However, thermal treatment of waste (which includes the advanced recycling technologies listed earlier) requires additional licensing under the National Environmental Management Air Quality Act (NEMAQA, no 39 of 2004). The thresholds and requirements of NEMAQA are devised to assess large plants handling tonnes of material, such as coal-fired power stations, or the production of fuels from coal. The tonnages handled, and potential gaseous emissions (provided the plastic waste is well-sorted) are far less for advanced recycling plants (albeit that the capacity of the advanced recycling plants would vary according to type of feedstock being processed). The required licensing costs and monitoring of emissions stipulated are onerous and very costly for a nascent industry.

Technological Challenges

Advanced recycling technologies have significant energy requirements and necessitate further refining of products after the main process has been completed. The output from these processes also includes by-products, such as char, which will either require further treatment for use in other industries, or a suitable disposal route.

In addition, yield can vary and can be particularly low in feedstock recycling processes (pyrolysis and gasification). Further process refinement is thus required to maximise yield and thus improve the economic viability of advanced recycling.

Although certain processes have been around for several years, many other advanced recycling technologies are still at development stage. As such, little is known about the potential environmental and social impacts, both positive and negative. Increased knowledge of the positive impacts and potential unintended consequences might incentivise investment and support. Thus, these technologies need further development with increased time and investment to ensure that they can work on a large commercial scale.

Conclusion

Advanced recycling technologies are attracting increasing interest globally due to their potential to process plastics that are unrecyclable or difficult to recycle. Additional benefits are the purification of polymer achievable by removing additives, and eliminating the problem of degradation of plastic quality with repeated mechanical recycling by returning the plastics to molecules with shorter carbon chains or even back to monomers.

In spite of significant investment, most technologies are in pilot stage, with limited operating plants globally, and very little data available on the economic viability of such plants.

In a middle-income country setting, where the potential of government to subsidise industry growth is limited, and investment into, and growth of, mechanical recycling capacity is likely to be more environmentally and economically beneficial, investment into advanced recycling technologies is unlikely to be realised in the near future.

That said, there are a few local developers of pyrolysis technology in South Africa for waste to fuel applications, that have lower capital and operating costs than reported in international data. However, for there to be scope for these technologies to play a role in enabling circularity in the plastics value chain, an assessment of the potential for, and costs of, additional steps to further process the resulting fuel to plastics is needed.

This summary is an extract from the report "*Market assessment of circular plastics opportunities in packaging, construction, agriculture and the automotive industry*", which forms part of a series "*Circularity in the plastics value chain in South Africa – opportunities and barriers*". The reports in the series are:

- **Part 1:** The Plastics Landscape in South Africa – Mapping value chains and key players.
- **Part 2:** South African enabling environment for a circular economy for plastics – a scan of best practice and current local and international policies and legislation.
- **Part 3:** Market assessment of circular plastics opportunities in packaging, construction, agriculture and the automotive industry.
- **Part 4:** A focus on increasing recycled content in packaging through multi-layer conversion.
- **Part 5:** Advanced recycling technologies in South Africa – status quo and potential.
- **Part 6:** Alternatives to problematic plastic packaging in South Africa.
- **Part 7:** The current state of waste plastics management in South Africa.
- **Part 8:** Realising opportunities for a circular economy for plastics in South Africa: actions for the short, medium- and long-term.

The individual reports and a summary of the entire series can be accessed by contacting the GreenCape Circular Economy team via **circulareconomy@greencape.co.za**.

The series is a product of the staff of the World Bank in collaboration with a research and analysis team comprising of GreenCape, the African Circular Economy Network (ACEN) Foundation, the South African Plastics Recyclers' Organisation (SAPRO), WRAP, and WWF South Africa. Financing for this work comes from the **PROBLUE Trust Fund**.

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