Supporting the transition from conventional plastics to more environmentally sustainable alternatives

Action Plan

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Executive summary

Marine plastics pollution is an issue of global concern. The Japanese government's "Osaka Blue Ocean Vision" seeks to reduce additional pollution by marine plastic litter to zero by 2050. Therefore, Japan has committed support for developing countries to combat marine litter through capacity building and waste management infrastructure development with a specific focus on plastic waste. This project, funded by the Government of Japan, and implemented through the United National Industrial Development Organisation (UNIDO) was a partnership with the Council for Scientific and Industrial Research (CSIR) and the University of the Witwatersrand in South Africa to support South Africa's transitioning from conventional plastics to more environmentally sustainable alternatives.

The objectives of this research were to develop an evidence-based Action Plan for South Africa's transition and to provide support for increased collection of recyclable plastics by strengthening the capacity for waste picker integration. Other important issues that were considered include the identification of products suitable for replacement, assessment of the environmental sustainability of materials, end-of-life treatment requirements for alternative materials and the potential for local production and conversion of biobased material alternatives to support local economic growth.

This document provides a summary of the research findings and an evidence-based Action Plan detailing key actions that need to be taken to ensure that South Africa's transition from conventional plastics is indeed more environmentally sustainable in the long term. The required actions are grouped into the following four interventions as follows:

Decisions Support focusing on awareness campaigns conveying accurate messages on alternative materials, updated datasets for life cycle assessments (LCA) to ensure that future assessments are considering local South African conditions, and further development of the life cycle sustainability assessment (LCSA) methodology towards a standardized approach.

Gate keeping through the introduction of standards, certification, and labelling as well as establishing testing capacity to verify compostability claims.

Support for local production through confirmation of available feedstock, markets, incentives and continued research and development.

Investment in end-of-life treatment infrastructure to ensure that the alternative materials are indeed managed in an environmentally sustainable way. This includes development of extended producer responsibility schemes for alternative materials, establishment of industrial composting facilities, improved waste separation at source and waste picker integration to reduce material leakage into the environment while optimising recycling opportunities.

Responsibility for each intervention is assigned at high level with proposed time frames. Lastly the action plan also provides comments on progress where activities have already started.

Acronyms

CSIR	Council for Scientific and Industrial research
DST	Department of Science and Technology
EPR	Extended Producer Responsibility
G20	Group of 20 Countries including: Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Republic of Korea, Mexico, Russia, Saudi Arabia, South Africa, Turkey, the United Kingdom, the United States, and the European Union.
HDPE	High Density Polyethylene
LCA	Life Cycle Assessment
LCSA	Life Cycle Sustainability Assessment
LDPE	Low Density Polyethylene
LLDPE	Linear Low-density Polyethylene
Mt	Million Tonne
PAGE	Partnership for Action on Green Economy
PBAT	Polybutylene Adipate Terephthalate
PBS	Poly(butylene succinate)
PE	Polyethylene
PET	Polyethylene Terephthalate
PHA	Polyhydroxyalkanoates
PHBH	P-Hydroxy-Benzoate Hydroxylase
PLA	Poly(lactic acid)
PP	Polypropylene
PRO	Product Responsibility Organisation
PS	Polystyrene
PSM	Plastarch Material
PVC	Polyvinyl chloride

the dtic	Department of Trade, Industry, and Competition of South Africa
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organisation
WEF	World Economic Forum

CONTENTS

1 Background

Nearly every person, everywhere around the world encounters plastics daily. “Plastics are the workhorse material of the modern economy” owing to its unique combination of unrivalled properties and low cost (WEF, 2016). Global production of virgin plastics increased from 15 Mt in 1964 (WEF, 2016) to 368 Mt in 2019 (Plastics Europe, 2021). While plastics started off as a by-product of fuel production, today 90% of plastics are derived from virgin fossil feedstocks accounting for 6% of global oil consumption (WEF, 2016). At this growth rate, the plastics sector will by 2050 be responsible for 20% of the total global oil consumption and 15% of the global annual carbon budget[1] (WEF, 2016). However, simply replacing conventional plastics with alternative materials does not guarantee a lower carbon budget. Choi, et al. (2018) found that blended bioplastics with PLA, such as PLA/PBAT, can be more harmful to the environment in terms of carbon dioxide emissions than existing materials, such as LDPE.

According to the World Economic Forum (WEF, 2016) plastic packaging is at 26%, the largest application of plastics globally. After a single first use, 95% of plastic packaging material is lost to the economy despite having a collection rate of 14% for recycling. Value losses during sorting and reprocessing result in only 5% of material value being retained for subsequent use. While delivering many benefits, plastics have become a very visible source of environmental pollution. It is estimated that 32% of plastic packaging escapes global collection systems (WEF, 2016) and contributes to open burning or simply leak into the environment.

In South Africa, packaging accounts for 52% of all plastics consumed (The DTIC, 2020). Plastics consumption in South Africa stood at 1,443,000 tonnes of virgin plastics and 296,480 tonnes of recycled plastics in 2020 (Plastics SA, 2021). The formal and informal sector combined collected 43.2% percent of the recyclable plastics in the waste stream for recycling which resulting in 312,600 tonnes of recyclate produced in 2020 (PlasticsSA, 2021).

The scale of plastics leaking into the oceans are putting the world’s oceans at risk. The global marine plastic litter challenge can be summarised as follows:

1) Current stock of accumulated plastics in oceans is estimated at 75-199 million tonnes (UNEP, 2021);
2) Up to 80% of marine plastic debris is believed to originate from land-based sources (Li *et al*., 2016);
3) Leakage of plastics into the ocean is about 12 million tonnes per annum (Boucher et al., 2020); and
4) Annual leakage will nearly triple by 2040 if no action is taken (Lau *et al.*, 2020).

Jambeck et al. (2015), ranked South Africa as 11th in terms of mismanaged plastic with 90,000-250,000 tonnes of plastic estimated to enter the oceans from land-based sources each year. A more recent local study by Verster and Bouwman (2020) has shown that the amount of land-based plastic reaching the ocean is somewhat lower, in the range of 15,000 – 40,000 tonnes per year. Lebreton and Andrady (2019) have mapped mismanaged plastic waste generation globally as illustrated in Figure 1.

[1] This is the budget that must be adhered to in order to achieve the internationally accepted goal to remain below a 2˚C increase in global warming.

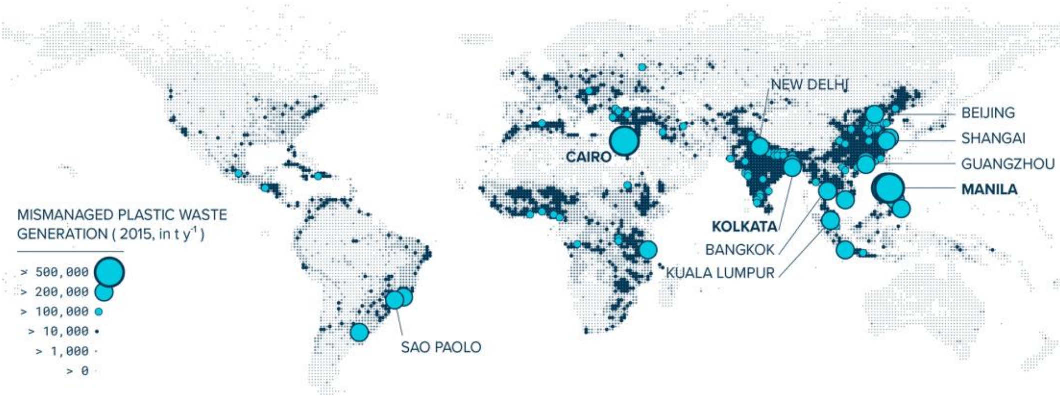

Figure 1: Global mismanaged plastics waste generation in 2015, with the 10 largest producing urban centres labelled on the map (Lebreton and Andrady, 2019)

Although South Africa is not home to one of the ten largest waste plastics producing urban centres, large amounts of mismanaged plastics are generated in coastal areas with a high possibility of leaking into the ocean. Oceanographic models predict that more than 60% of floating plastic entering the ocean from local land-based sources, wash up on South African beaches (Collins and Hermes, 2019) leaving the remaining 40% of debris to drift further offshore and contribute to the global challenge.

The G20 member states have mobilized to put a stop to the global marine plastic litter challenge. At the G20 Leaders' Summit in Hamburg (2017) the G20 Action Plan on Marine Litter[2] was formulated and further discussed the following year in Argentina. The Japanese government, who took the Presidency of the G20 Summit in 2019, has prioritized the global marine litter challenge and shared the "Osaka Blue Ocean Vision" to reduce additional pollution by marine plastic litter to zero by 2050. Japan also committed to support developing countries in their efforts to combat marine litter through capacity building and waste management infrastructure development focussing on plastic waste.

The marine plastic litter challenges could be addressed through implementing circular economy practices. This will require **innovations in recovery** of all waste materials (not only conventional plastics) and treatment technologies, development of new materials, product designs that better facilitate reuse or recycling, adoption of alternative packaging solutions, and adherence to the broader principles of circularity to ensure a more sustainable plastic life cycle (Oceans Conservancy, 2015). Implementing these practices, require supporting policy frameworks including to create incentives for economic actors, such as industry and consumers, to increase the productivity of resources used. This will only be realized through maintaining the value of every product and its materials at any point of its life cycle and avoiding premature discarding of products and/or materials, including plastics. This, in conjunction with **optimizing collection** of all waste streams and improving landfill management to avoid post-collection leakage, will help to substantially reduce the volume of plastics most likely to end up as marine plastic litter (Oceans Conservancy, 2015). Together with measures to tighten the management of marine-based sources of marine litter, and with clean-up operations where feasible, increased plastic pollution of oceans may be slowed down and eventually prevented.

The United Nations Industrial Development Organisation (UNIDO), as a leading UN agency promoting circular economy and resource efficiency in industry, supports African countries to deal with plastic waste leaking to the environment. With funding from the Government of Japan, UNIDO implemented a project "Support for transitioning from conventional plastics to more environmentally sustainable

[2] https://www.mofa.go.jp/mofaj/files/000272290.pdf

alternatives" in partnership with the Council for Scientific and Industrial Research (CSIR) and the University of the Witwatersrand in South Africa with two distinct components:

Component 1 focussed on identifying and implementing opportunities for local production and management of sustainable alternative materials to replace the use of conventional plastics in specific applications, including biodegradable plastics and their end-of-life treatment requirements, if feasible.

Component 2 supported the plastic and packaging industry in their recycling efforts by **strengthening capacity for plastics collection** and through the integration of the informal waste sector. The focus of the project was on the implementation of capacity building activities, including procurement of necessary equipment, and training to enhance the capabilities and capacity of informal collectors for waste separation and recycling.

The main output of the project is this Action Plan which has been compiled based on the evidence collected in component 1. The Action plan outline the activities that are required to support South Africa's transitioning from conventional plastics to more sustainable alternatives.

2 Purpose and goal

The purpose of the action plan is to provide evidence-based support for South Africa's transitioning from conventional plastics to more sustainable alternatives while strengthening the local bio- (and biodegradable) plastics and sustainable[3] alternative materials industry and building up capacities for plastics recycling.

The Goal is twofold:

1. To reduce plastic leakage to the environment and marine plastic litter; and
2. To unlock new economic opportunities in the bio- and biodegradable plastics industry in South Africa.

3 Evidence collected through research

This section summarises the findings from the background research informing the Action Plan presented in Section 4.

3.1 Identified products for replacement

Identifying products for replacement is not as easy as one would expect. Plastic products often move through global supply chains and support global companies. Addressing plastics leakage from global supply chains require a globally harmonised approach that considers region-specific solutions (Ocean Conservancy, 2015). However, this project focussed on identifying plastic products that are of concern in the South African context and for which replacement could potentially contribute to the South African economy through local manufacturing.

Material leakage into the environment will not miraculously be stopped by replacing plastic with another material. **Careful consideration is therefore required to ensure that replacement materials are indeed more environmentally sustainable throughout the product's life cycle** and not only when persistence in the environment is measured. The criteria used to identify the products with potential for replacement are the following:

[3] Sustainability of alternatives are measured here using standard LCA methodologies and additional indicators, namely 1) Persistence and 2) Material Pollution to assess the pollution potential of materials in the environment.

- *Is the product currently being recycled?* - to ensure that current recycling industries are not displaced by replacement. If the product is currently recycled, then the focus should be on increasing collection and recycling rates rather than replacement.
- *Is it likely to be recycled in the near future?* – to ensure that research and development investment as a result of extended producer responsibility (EPR) or other policy changes are not unduly interrupted.
- *Does the relevant product responsibility organisation (PRO) identify the product as suitable for material replacement?* – PROs as industry champions for EPR has an important coordination role to play to limit unintended consequences of uncoordinated replacement efforts.
- *Are there commercially available alternative materials to allow for rapid uptake and implementation by manufacturers?* – Many innovations and improvement efforts that show potential have proven to be too fragmented and uncoordinated to have impact at scale. Furthermore, drop-in solutions that can be used in existing manufacturing processes with limited to no adverse effects on business should be favoured over disruptive technologies. **Although drop-in solutions would be ideal for local product manufacturers, there is a possibility that they will need different technologies to form, shape and recycle the alternative materials.**

Products with a high likelihood of leaking into the environment and that are not generally recycled at scale could therefore be potential candidates for replacement as listed in Table 1. The first filter that was applied is to look at commercially available alternatives. The list of products for which alternatives exist in the market is provided in

Table 2.

Table 1: Priority plastics products that could be considered for replacement

Sector/Application	Product
Packaging/food services	Straws
	Cutlery
	Candy wrappers
	Chip packs
	Biscuit wrappers
	Lollipop sticks
	Cling wrap (household)
	Take-out containers
Health/hygiene	Earbuds
	Condoms
	Nappies
	Sanitary pads
	Plasters
Agriculture	Plastic mulch
Other	Cigarette butts
	Balloons
	Bin liners

Table 2: Products for which alternatives are available in the market

Product	Polymers used	Commercially available alternatives
Biscuit wrappers	PP	Starch based PLA based PBAT based
Candy wrappers	Multi-layered CPP BOPP	Solanyl – potato starch-based packaging
Chip packs	Multi-layered BOPP CPP	Natureflex from Futumura (laminate of two compostable materials) PHA based laminate
Cling wrap (household)	PVC LDPE LLDPE	PLA based Parchment paper Beeswax paper
Cutlery	HDPE PP PS	Biopolymer (PLA, Starch) Bamboo
Earbuds	Composites	Bamboo PLA based
Take-out containers	PS PET PP	Paper Bagasse PLA PBS PBAT or PSM
Straws	PP	PLA Bamboo Paper Stainless steel (Reusable)

As an example of how the sustainability of alternative materials should be considered to inform decision making, the environmental sustainability of polystyrene take-out containers and cups and its various alternatives were evaluated as detailed in Section 3.2.

3.2 Life cycle assessment of polystyrene take-out containers and cups

The life cycle impacts of polystyrene take-out containers and cups (meal-kit) and various alternatives were assessed using attributional life-cycle assessment (LCA) and the ReCiPe 2016 Midpoint(H) method, that considers 18 environmental impact categories. Given the lack of a plastic pollution impact category in existing methods, we have developed two additional indicators, namely 1) Persistence and 2) Material Pollution to assess the pollution potential of plastic (and other materials) in the environment. The functional unit was based on the estimated consumption of take-out meals in South Africa and attention was placed in modelling the end-of-life stage to represent the South African context. Economic-based allocation was applied to ensure correct allotment of burdens to products and recyclate production was modelled using system expansion.

The main findings from the LCA study are as follows:

- Raw material extraction and polymer production stages in the product life cycle are responsible for the bulk of the environmental impacts associated with the meal-kit use in South Africa.
- Polystyrene came out as the preferred option from a pure LCA perspective, followed by paper/cardboard and bagasse.
- Adding persistence and material pollution as indicators, biodegradable plastics, biobased plastics, bagasse, and paper are all less persistent in the environment than conventional plastics.
- Polystyrene is at least four hundred times worse in terms of material pollution than paper.
- Local production and conversion of all investigated options performs worse from an environmental perspective in LCA, due to the use of fossil fuel generated electricity for conversion and the Coal 2-liquid production processes for PP monomers.
- Alternatives to conventional plastic with lower environmental burdens are paper/cardboard (locally produced/manufactured), bagasse and PBS (both imported as finished products), with the latter showing potential for organic recycling in industrial composting facilities.
- Increasing recycling rates of current available meal-kits will improve the overall environmental performance of all conventional plastic alternatives by about 30% over a 5-year period (as per EPR Regulations targets)
- Increased recycling of biodegradable and compostable alternative materials will improve the environmental performance by 40% over the same period.
- Using different coating material than PE show a further improvement on the overall environmental performances of both the Bagasse and Paper meal-kit material alternatives.
- Moving away from conventional plastic coating barriers can improve the natural biodegradability of Bagasse and Paper from a persistence and material pollution perspective.
- Choosing the coating agent carefully may positively impact on the production of the meal-kit (less resource intensive) and at the End-of-Life when organic recycling can be implemented.

These results are well aligned with those from international LCA studies on single-use and re-usable cup and take-out containers, which showed that single-use cups have similar environmental impacts regardless of the material they are made of, with paper to be preferred also to re-usable alternatives if recycling rates can be increased (up to 80%). On single-use food-packaging made of polystyrene (PS), extruded polystyrene (XPS) and paper have often a better environmental performance than packaging alternatives of other materials (PET, PLA, PP and Aluminium) and packaging lightweight (without compromising its functionality) also show improvements on the environmental performance. However, a main limitation of this study is the lack of South African specific data in the LCA datasets.

Since commercially available alternative materials are already applied in South Africa by different users, it is also important to evaluate the availability and location of appropriate treatment technologies in the South African context.

3.3 End-of-life treatment options

Alternative materials require different end-of-life treatment options as compared to conventional plastics. The typical treatment options are mechanical recycling, composting, anaerobic digestion, chemical recycling, pyrolysis, thermal destruction, and landfill. Since South Africa is transitioning to a circular economy, landfilling is no longer a feasible option.

All the recycling solutions rely on collection and the current "broken system" is a handicap for all of these. For example, there is a huge demand for PS recyclable waste, but it does not get collected while compostable alternatives will never be in demand due to a total lack of resource value for industrial composting facilities. Composting of biodegradable plastics requires additional treatment at composting sites to ensure that it does not negatively impact on the end-products. Treatment of biodegradable plastics at composting plants therefore increase the operational costs. Whereas petrochemical plastics have a resource value for recycling, the same is not the case for composting of biodegradable plastics. Composting plants may therefore require incentives to accept these plastics for treatment.

An additional limitation is that some biodegradable plastics are reported to come with an expiry date. This means that treatment facilities should also be able to accept and manage large batches of pre-consumer expired product. Composting facilities may therefore be reluctant to accept relative high volumes of expired batch products as it may impact on the quality of their end-product. Therefore, an alternative management option such as recycling or incineration would be advisable.

The main finding from the research is that the end-of-life treatment for most of the biodegradable alternative materials require industrial scale facilities with standard operations (i.e. temperature controlled) which are currently in short supply in South Africa. It is important to note that the correct blend of materials is required to ensure proper degradation without negatively impacting on compost quality. Furthermore, there is high risk of contamination with non-biodegradable plastics and therefore separation **at source and accurate sorting is a requirement**. If this is in place, conventional plastics can slot in with other mechanical recycling systems while incentives will be required for the collection and treatment of biodegradable alternatives.

Although some biodegradable alternatives may also be recyclable, critical mass will be required to justify investment in recycling facilities, but biodegradability could also negatively impact on the quality of the recyclate if degradation have started. It is therefore advisable to focus on biodegradation as end-of-life solution.

The end-of-life treatment options per alternative material are summarised in **Error! Not a valid bookmark self-reference.**.

Table 3: Summary of treatment options available for plastic alternatives from literature

Alternatives	Alternative treatment Options
PLASTIC ALTERNATIVES	
Poly butylene adipate-co-terephthalate (PBAT)	**Mechanical Recycling:** Prescence of moisture interferes with the recycling due to hydrolysis of the PBAT. Pre-drying mitigates this. **Composting:** Will compost under both Home and Industrial conditions. Microbial degradation using *P. mendocina* and *A. elegans* synergistically degrade PBAT. **Anaerobic conditions:** Does break down under anaerobic conditions however, only very slowly. This could be enhanced sped up by *Clostidium botulinum.*
Poly lactic acid (PLA)	**Mechanical Recycling:** Maximises energy saving. **Composting:** Only under thermophilic environment conditions, this is easier achieved under Industrial Conditions. Home composting unable to achieve high temperatures required. **Anaerobic conditions:** Possible under mesophilic but better under thermophilic temperatures of 55°C. **Chemical recycling:** Catalysis (tin II octanoate) and at temperatures of 120°C (or higher) with a solvent (i.e. xylene) is also possible.
Poly butylene succinate (PBS)	**Mechanical Recycling:** The polymer can be manually recycled and extruded. **Industrial Composting:** Will degrade under industrial composting conditions in approximately 90 days. **Home composting:** Will degrade but slowly up to 12 months to breakdown. **Anaerobic conditions:** Degrades very slowly, however if blended with PLA this could be improved.
Mylar ™ (PET)	**Recycling**: Most favoured treatment option in use in South Africa. **Pyrolysis**: especially for contaminated feedstock but it is complex. **Co-pyrolysis**: using Zeolite and Red Mud. **Microwave pyrolysis**: Between temperatures of 500°C to 900°C to produce a mixture of alkanes and alkenes the proportion is dependent on the temperature.
Latex	**Landfilling:** From a resource recovery and waste hierarchy position this is the least preferred option. **Chemical Disposal**: De-vulcanization is using tetra methyl thiuram di-sulphide in presence of spindle oil at approximately ambient temperature. **Ultrasonic-based**: Using a frequency of at 40 kHz and ultrasonic amplitudes from 5 to 13 µm. **Microwave treatment**: Sulphur bonds can be broken or formed by microwaves treatment. **Biological de-vulcanization**: Possible using a number of bacterial species.
NON-PLASTIC ALTERNATIVES	
Bamboo	**Landfilling**: Not recommended due to ongoing ban on organics to landfill. **Thermal destruction**: As a green energy resource. Composting in home and industrial conditions
Beeswax paper (reusable)	**Landfilling**: Not recommended due to ongoing ban on organics to landfill. **Thermal destruction**: As a green energy resource.
Smokey treats ™ – biodegradable cigarette filters	Unknown
Natureflex ™	Unknown
Solanyl ™	Unknown
Paper Substitutes	**Mechanical Recycling**: Mature industry in South Africa. **Thermal combustion**: usually reserved for soiled feed stock material.
Steel Substitutes and Aluminium	**Mechanical Recycling**: Mature industry in South Africa.

Lastly, investment in treatment infrastructure for alternative materials will require economies of scale and therefore coordinated interventions is required when transitioning from conventional plastics to alternatives.

3.4 Localisation of alternative materials production

In line with the Plastics Industry 2020 Master Plan's (The DTIC, 2020) quest for value chain localisation, the transition from conventional plastics to more sustainable alternatives also considered the possibility for local production of bio-based polymeres which are not biodegradable but can be mechanically recycled.

Most of the companies trading in bio-based plastic products in South Africa are importing finished biopolymer products. However, at the Industry-meets-Science Series workshop on bio-based plastics (DST, 2016) there was general consensus that establishing a local bio-based plastics industry in South Africa is feasible, given the availability of abundant biomass feedstock [saw dust, forestry waste, sugarcane (molasses and bagasse), agricultural residues (maize and wheat)]. The main challenges identified for establishment of a local biopolymer production (DST, 2016) include the following:

- Lack of systems to categorise and record available biomass;
- Market competitiveness of bio-based materials (PAGE, 2019); and
- Perceived absence of economic incentives and legislative drivers

Targeting high-value markets (biomedical, personal hygiene) may provide a logical first step towards a local industry (DST, 2016). Noting, that it is critical to establish demand and market before capacity, given the significant level of investment required for setting up full-scale plants for biopolymer production.

3.5 Localisation of processing using biopolymers

As mentioned in Section 4, localisation of biopolymer production is feasible in South Africa. Furthermore, demonstration of technologies has confirmed that there is potential for converting of biopolymers locally. Trials done using three different grades of PHBH concluded that one grade (PHBH-151C) is suitable for flexible product applications and the other two grades (X331N and 080X) are suitable for injection molding of rigid products. These two grades were further used for prototype development by the CSIR.

4 Identified actions

This section provides a summary of the identified key actions that needs to be taken to ensure that South Africa's transition from conventional plastics is indeed more environmentally sustainable in the long term.

4.1 Decision support

Alternative materials are being introduced into the market through imports. Decisions on products to be replaced are often based on propaganda and emotional reactions to pictures of strangled or impacted wildlife by end-of-life plastics. The choice of replacement material on the other hand is informed by perceptions and assumptions rather than on scientific evidence. To address these issues, decision support tools informed by scientific evidence is required. The following actions are required to improve decision making in the South African context:

- National public awareness campaigns on:
    - Responsible waste management to prevent waste leakage into the environment.

  - Confirmed facts on sustainability of commercially available alternative materials and product options i.e., is the cost and environmental impact associated with the logistics of imported feedstock.
- The official LCA datasets must be updated with South African data to ensure that future LCA studies are reflective of the South African situation.
- The methodology for LCSA must be further developed and tested to ensure that indicators such as persistence and environmental pollution are included in sustainability assessments.

4.2 Gate keeping

Commercially available alternative material options exist for all identified products, and these have already found its way into the South African waste stream. Proper gate keeping require the following to be in place:

- Testing capacity to verify claims of biodegradability; and
- Standards for alternative materials are required to prevent green washing.

4.3 Support for local production

In line with the Plastics Industry 2020 Master Plan (the DTIC, 2020), it is imperative to localise the plastics but also alternative materials value chain to support economic growth and job creation for South Africa. The following actions are required to facilitate local production of biopolymers:

- Confirmation of available feedstock (sources, characteristics, location)
- Creation of competitive markets
- Development of economic incentives for industry to produce locally
- Development of legislative drivers to support local production

4.4 Investment in end-of-life infrastructure

The limited availability of appropriate treatment infrastructure for dealing with alternative materials needs to be addressed to avoid unintended consequences of transitioning to biodegradable plastics alternatives. Proper end-of-life treatment require the following to be in place:

- Extended producer responsibility schemes for all products.
- Strategically located industrial composting facilities to deal adequately with all end-of-life biodegradable polymers.
- Increased and adequate waste separation at source to optimize the appropriate end-of-life treatment of all materials.
- Optimised waste collection systems including waste picker integration to maximise collection of all conventional and alternative materials.
- Optimised recycling of all recyclable materials.

5 Action Plan

This section aims to provide actions, associated timeframes, and allocated responsibility to support South Africa's transitioning from conventional plastics to more sustainable alternative. The actions are summarised in Table 4. The time frames as indicated in the plan should be interpreted as follows:

- Short term: 0-4 years
- Medium term: 5-10 years
- Long term: 11-15 years

Table 4: Action plan summary

INTERVENTION	ACTIONS	TIME FRAME	RESPONSIBILITY	COMMENTS
Decision support	• Update of the official LCA datasets with RSA data. • LCSA methodology development and testing	Short term	CSIR	• The CSIR have initiated engagements for the update of the datasets • LCSA methodology is under development but must be published in a peer reviewed journal before it can be applied as accepted method
Gate keeping	• Increasing testing capacity to verify claims of biodegradability. • Development of standards for alternative materials to prevent green washing. • Establishment of a certification body for compostable products • Promote labelling requirements for biodegradable products	Short term	CSIR NRCS/SABS	• CSIR testing labs have been upgraded with UNIDO support. The accreditation of the biodegradation testing laboratory is in process. • NRCS and SABS have initiated the process to develop relevant South African Standards • CSIR and SABS are in discussion to establish a body for certification of locally produced and imported products claiming to be compostable • CSIR and SABS are in discussion about labelling requirements specifying time-frames and conditions of biodegradation
Support for local production	• Confirmation of available feedstock (sources, characteristics, location)	Medium term	DFFE/DTIC	•

	• Access to renewable energy sources to reduce the reliance on coal-based energy for the production of bio-polymers. • Creation of competitive markets • Development of economic incentives for industry to produce locally • Development of legislative drivers to support local production • Research and development support for development of novel biomass-based materials and product designed for enhanced circularity			
Investment in end-of-life infrastructure	• Extended producer responsibility schemes for all products. • Strategically located industrial composting facilities to deal adequately with all end-of-life biodegradable polymers. • Increased and adequate integrated waste separation at source (separation at source that integrates waste pickers and adheres to the Waste Picker Integration Guideline and Integration Principles) to optimize the appropriate end-of-life treatment of all materials. • Optimised waste collection systems that build from waste pickers' existing system and integrate	Short term	DFFE, Local government, Relevant PROs	• The Compostable Plastics Council (COPCO) was formed in 2020 and is working towards establishing an EPR scheme for post-consumer waste management of compostable plastics • Refer to the waste picker integration guideline at https://wasteroadmap.co.za/wp-content/uploads/2021/02/Waste-Picker-Integration-Guidelines.pdf • Output 2 of this project have developed training and capacity building materials to support waste picker integration.

	waste pickers to maximise collection of all conventional and alternative materials. • Expanded waste collection services to include all communities • Implementing waste collection services that meet the needs of community. • Optimised recycling of all recyclable materials.			

6 References

Boucher, J., Billard, G., Simeone, E. and Sousa, J. (2020). The marine plastic footprint. Gland, Switzerland: IUCN. viii+69 pp.

Choi, B., Yoo, S., and Park,S. (2018) Carbon footprint of packaging films made from LDPE, PLA, and PLA/PBAT blends in South Korea. *Sustainability*, 10, 2369. https://doi.org/10.3390/su10072369

Collins, C., and Hermes, J.C., (2019) Modelling the accumulation and transport of floating marine micro-plastics around South Africa. *Mar Pollut Bull.* 139:46–58. https://doi.org/10.1016/j.marpolbul.2018.12.028

DST (Department of Science and Technology) (2016) Waste Research, Development and Innovation Roadmap: Industry-meets-Science Series on Bioplastics.

Lau, W.W.Y., Shiran, Y., Bailey, R.M., Cook, E., Stuchtey, M.R., Koskella, J., Velis, C.A., Godfrey, L., Boucher, J., Murphy, M.B, Thompson, R.C., Jankowska, E., Castillo, A.C., Pilditch, T.D., Dixon, B., Koerselman, L., Kosior, E., Favoino, E., Gutberlet,J., Palardy, J.E. (2020). Evaluating scenarios toward zero plastic pollution. *Science* 369, 1455–1461. https://doi.org/10.1126/science.aba9475.

Lebreton, L and Andrady, A. 2019. Future scenarios of global plastic waste generation and disposal. *Palgrave Communications*. 5, 6. https://doi.org/10.1057/s41599-018-0212-7.

Li, W., Tse, H.F., Fok, L., (2016) Plastic waste in the marine environment: A review of sources, occurrence, and effects. *Sci Total Environ*. 566-567:333-349. https://doi.org/10.1016/j.scitotenv.2016.05.084

Oceans Conservancy (2015) Stemming the tide: Land-based strategies for a plastic-free ocean. https://oceanconservancy.org/wp-content/uploads/2017/04/full-report-stemming-the.pdf

PAGE (2019) Developing a Biomaterials Industry in South Africa: Action Plan and Implementation Strategy.https://www.un-age.org/files/public/developing_a_biomaterials_industry_in_south_africa-print.pdf

Plastics Europe (2021) Plastics—The facts, 2021. An analysis of European plastics production, demand and waste data. https://plasticseurope.org/wp-content/uploads/2021/12/AF-Plastics-the-facts-2021_250122.pdf

Plastics SA (2021) Plastics – 2020: An analysis of South Africa's plastics production and waste data. Published November 2021. https://www.plasticsinfo.co.za/wp-content/uploads/2021/11/Recycling-Survey-2020-Executive-Summary3.pdf.

The DTIC (Department of Trade, Industry and Competition) (2020) Plastics Industry 2020 Master Plan for growth. Draft 3 published in July 2020. 82p. https://www.plasticsinfo.co.za/wp-content/uploads/2020/08/Master-Plan-for-Growth-Draft-Jun-30_2020.pdf

United Nations Environment Programme (UNEP) (2021). From Pollution to Solution: A global assessment of marine litter and plastic pollution. Nairobi.

Verster, C., and Bouwman, H. (2020) Landbased sources and pathways of marine plastics in a South African context. *S Afr J Sci*. 116(5/6), Art. #7700, 9 pages. https://doi.org/10.17159/sajs.2020/7700

WEF (World Economic Forum), (2016). The New Plastics Economy: Rethinking the future of plastics 36p. https://www3.weforum.org/docs/WEF_The_New_Plastics_Economy.pdf