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PAGE PARTNERSHIP FOR ACTION ON GREEN ECONOMY

DEVELOPING A BIOMATERIALS INDUSTRY IN SOUTH AFRICA: ACTION PLAN AND IMPLEMENTATION STRATEGY

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DISCLAIMER

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The Biomaterials Action Plan and Implementation Strategy was undertaken on request by the South African Government and was commissioned as a joint initiative by the United Nations Partnership for Action on Green Economy (PAGE) in collaboration with the United Nations Industrial Development Organization (UNIDO) and the South African Government.

The Action Plan Task Team consisted of representatives from government departments as well as relevant PAGE agencies. From PAGE, the task team supported the development of the terms of reference for this study and was responsible for overseeing the implementation of the study and the completion of the report. Representatives included Ozunimi Iti, UNIDO Industrial Development Officer, Abu Saieed, UNIDO Green Industry Expert, Siyanda Siko (International Labour Organisation), Cecilia Njenga and Taylor Clayton (United Nations Environment Programme). From the South African government, the Task Team provided valuable inputs into the study and included Jenitha Badul, Leanne Richards and Devina Naidoo (Department of Environmental Affairs), Gerhard Fourie and Ilze Baron (Department of Trade and Industry), Henry Roman and Magamase Mange (Department of Science and Technology) and Christian Prins (Economic Development Department). Furthermore, the PAGE National Steering Committee had the opportunity to put forward inputs to the analysis and the report.

Trade & Industrial Policy Strategies (TIPS), a not-for-profit economic research organisation based in Pretoria, South Africa, authored the report. TIPS led the research process, collected data, drafted the report, and managed stakeholder consultations. The research team was composed of the following economists and industrial policy specialists: Gaylor Montmasson-Clair, Christopher Wood, and Bhavna Deonarain.

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ABBREVIATIONS

APDP	Automotive Production and Development Programme
BIDF	Biorefinery Industry Development Facility
CeBER	Centre for Bioprocess Engineering Research
CSIR	Centre for Scientific and Industrial Research
DAFF	Department of Agriculture, Forestry and Fisheries
DEA	Department of Environmental Affairs
DST	Department of Science and Technology
the dti	Department of Trade and Industry
DUT	Durban University of Technology
DWP	Dissolving wood pulp
GHG	Greenhouse gas
IDC	Industrial Development Corporation
IPAP	Industrial Policy Action Plan
NCPC	National Cleaner Production Centre
NMMU	Nelson Mandela Metropolitan University
NRCS	National Regulator of Compulsory Specifications
NRF	National Research Fund
PAGE	Partnership for Action on the Green Economy
PBS	Polybutylene succinate
PBT	Polybutylene terephthalate

PET	Polyethylene terephthalate
PHAs	Polyhydroxyalkanoates
RSB	Roundtable on Sustainable Biomaterials
SABS	South African Bureau of Standards
SACU	Southern African Customs Unio
SMMEs	Small, Medium and Micro Enterprises
SEZ	Special Economic Zone
TIA	Technology Innovation Centre
UNIDO	United Nations Industrial Development Organization
WISP	Western Cape Industrial Symbiosis Programme

EXECUTIVE SUMMARY

Biomaterial industry and market have been developing faster in meeting environmental concerns worldwide. Biomaterials – plastics and composite-like technologies derived from waste and plant matter – offer an opportunity to help reduce the environmental impact of traditional plastics, while safeguarding the economic contribution made by the plastics and chemicals industry. And because most biomaterials are produced using a set of platform chemicals and fibres, the industry can further reinforce the chemicals sector, and meet the changing demands of high-technology composites fabrication in the automotive and aerospace industries.

However, biomaterials are a category of goods, rather than a specific product. Individual biomaterials can differ markedly, in everything from material inputs, production process, and end-use. This diversity complicates efforts to construct a focused set of policy interventions, as individual biomaterials differ in their stage of technological development, the raw materials they use as feedstock, and the supporting industrial policies they require. Within this complex context, early investment in the technology and productive environment is crucial to develop the industry and to maintain pace with early adopters.

For South Africa, biomaterials offer an opportunity to leverage a strong technological base and a rich agricultural environment to position the country for the long-term development of a biomaterials sector. Biomaterial research efforts in South Africa are primarily driven by the Centre for Scientific and Industrial Research (CSIR) and a collection of university initiatives, with overarching support from the Department of Science and Technology (DST). The CSIR's efforts can broadly be grouped into two streams. First is a Biocomposites Centre of Competence in Port Elizabeth, which aims to create biomaterials. The second stream includes biorefinery pilot projects, which aim to process various biomass sources to produce a spectrum of products. The private sector is also active in the biomaterials space, but less so on primary technology development or prototyping of new technologies.

Barriers to developing a competitive South African biomaterials industry nevertheless persist. As summarise in Table 1, three broad challenges along the biomaterials value chain can be identified: the creation of viable technology; the availability of affordable and reliable feedstocks; and the core productive competitiveness of biomaterial manufacturing.

Table 1: Barriers along the biomaterials value chain in South Africa

Source: Authors' composition

Area	Barrier
Innovation environment	Deficiencies in the broader innovation environment, including poor commercialisation and limited and unstable pool of funding
	Selection of high potential biomaterials: extreme diversity of technology risks makes targeted support difficult
	Institutional environment: innovation is almost entirely state-led and will require ongoing support
	Importing available technology: lack of education initiatives and readiness support makes it difficult to import existing production technology

Area	Barrier
Feedstock	**Uncertainty on feedstock availability,** including a lack of systems to categorise and record available biomass
	Accessing leading feedstocks: restricted by alternate uses for biomass (such as energy generation) and regulations
	Developing new feedstocks: many of the most innovative crops are not yet at commercially viable levels of production
	Waste management: poor waste collection and management systems limit the use of non-agriculture feedstocks
Competitivenes	**Short-term efficiencies:** biomaterials are not competitive on a cost-basis against traditional plastics, and are unlikely to be so until appropriate scale is achieved
	Few gaps or product niches: outside of the green premium and some chemicals imbalances, the ubiquity of plastics means few productive niches exist
	Enterprise development: high upfront costs and large-scale economies complicate efforts to diversify the sector

In light of these challenges, this report proposes an action plan and implementation strategy to further the development of the sector in South Africa. It aims to both reinforce existing initiatives, and offer suggestions for new approaches, with the goal of deepening the value chain and removing barriers. It takes a problem-solving approach, which involves identifying barriers and gaps in the market for biomaterials and identifying government policies that can fill these gaps.

Removing these barriers and improving general support for biomaterials in South Africa would need a multitude of small interventions, implemented by a wide range of departments and agencies. Six priority projects are highlighted first, to better enable focus in the implementation of the action plan. Thereafter, a number of supporting interventions are explored. Table 2 provides an overview of key interventions.

Implementing the action plan would require specific planning and coordination by the government agencies assigned to the various action items. To aid this planning process, a draft implementation plan has been compiled. This plan should not be considered in any way final, but rather as a guideline to the sequencing and linkages between the various components.

The implementation plan is divided in two ways. First is a set of workstreams, which target key gaps according to the barriers identified (feedstock, innovation, and competitiveness) and the administrative requirements that underpin them, as reflected in Table 2. Second, while each of the four workstreams targets a specific set of problems, the implementation of the action items is linked, particularly via a set of institutional arrangements that oversees the action plan. This includes four new structures – a liaison committee in the Department of Trade and Industry (the dti), an industry partnership team developed by the dti and the Department of Agriculture, Forestry and Fisheries (DAFF), a feedstock matching team in the NCPC, and a biomaterials expert committee overseen by DST. The remaining initiatives are overseen by existing programmes, namely the Technology Innovation Agency (TIA) and the CSIR's Biorefinery Development Facility.

Table 2: Summary of key interventions

Source: Authors' composition

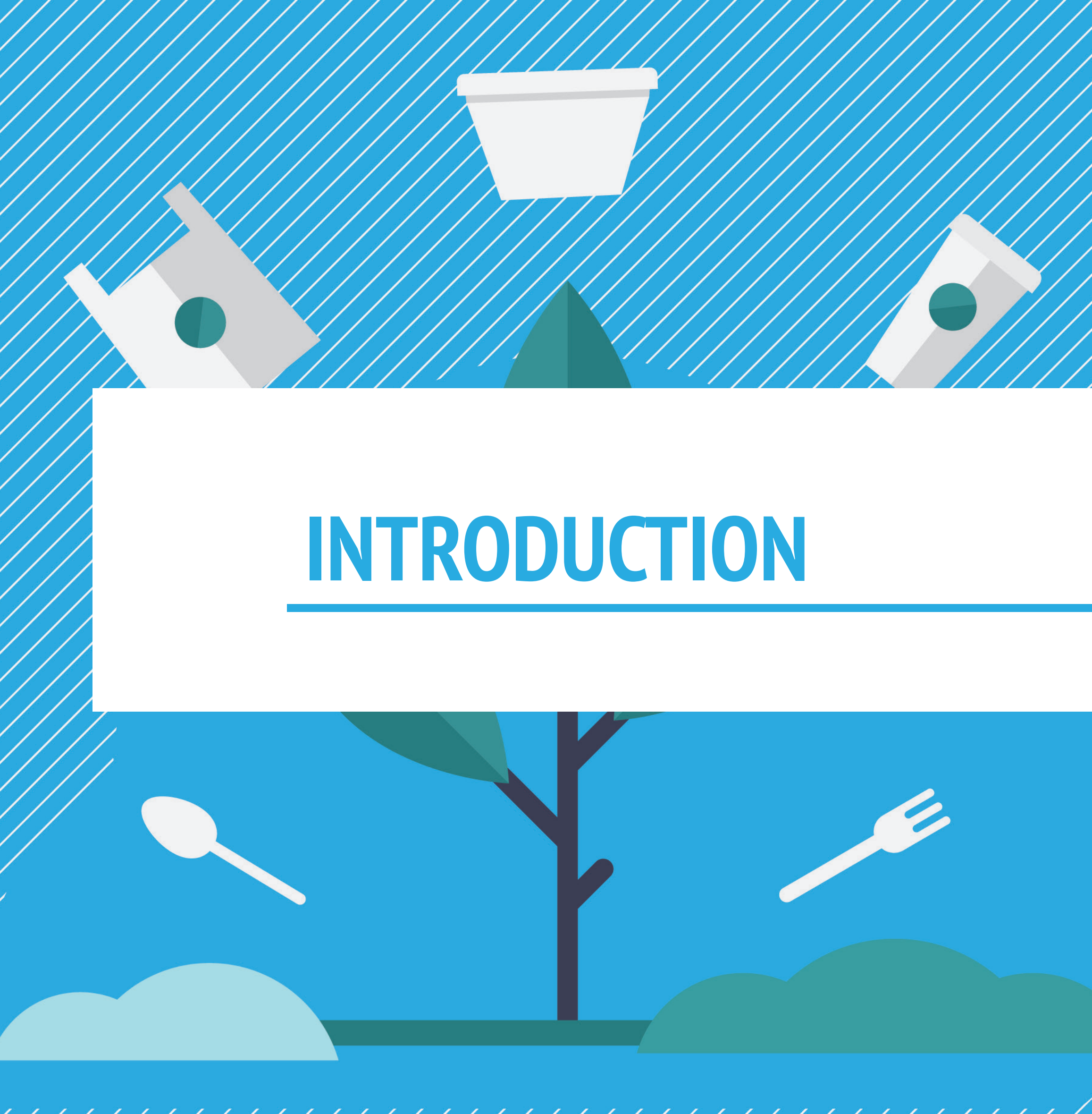
Intervention	Lead agency
Priority 1: The creation of a matching programme for feedstock	NCPC
Priority 2: Bridge funding for biomaterials research	TIA
Priority 3: Identification of priority clusters of platform biochemicals	The dti
Priority 4: Development of a biomaterials centre of excellence	CSIR
Priority 5: Reinforcing support to pilot biorefineries	CSIR
Priority 6: Development of a task team to lead on industry partnerships	The dti
Secondary 1: Promote training programmes at universities and colleges	DHET
Secondary 2: Reinforcing existing research infrastructure	All
Secondary 3: Awareness programmes and promoting the green premium	DEA
Secondary 4: Creating new standards for biomaterials and feedstock	DAFF
Secondary 5: Adapting existing standards for biomaterials	SABS
Secondary 6: Facilitating cross-border movement of feedstock	The dti
Secondary 7: Facilitate engagements with existing industrial policy	The dti
Secondary 8: Further research and ongoing support	CSIR

Support	Timeframe	Cost range	Workstream
GreenCape, the dti	44 months	Mid	Feedstock
DST, IDC	51 months	High	Innovation
DST	21 months	Low	Administration
DST, universities	42 months	High	Innovation
DST, the dti	60 months	High	Competitiveness
CSIR, IDC	55 months	Low	Competitiveness
Universities	27 months	Low	Innovation
All	n/a	n/a	Innovation
The dti, DAFF	12 months	Mid	Competitiveness
DEA, SABS	55 months	Mid	Feedstock
The dti	12 months	Low	Competitiveness
SARS, DAFF	54 months	Low	Competitiveness
Investment agencies	33 months	Variable	Competitiveness
PAGE, TIPS	n/a	Variable	Administration

These institutions oversee six branches of the implementation plan and are each assigned a set of milestones that should be achieved sequentially:

1) a dti biomaterials liaison group, in charge of three initiatives, namely the integration into existing industrial policy, adapting standards for biomaterials, and creating new standards for feedstock and unique materials;
2) an industry partnership programme, led by the dti and DAFF, to partner with end-users of biomaterials and match them with local production capacity;
3) a feedstock programme, managed by the NCPC, to match the demand and supply of feedstock in South Africa and ultimately the region;
4) a biomaterials expert group, composed of universities, the CSIR and DST, to provide expert technical guidance and lead on action items that require more technical support and develop a centre of excellence;
5) the further development of biorefineries under the leadership of the CSIR and DST; and
6) the creation of a bridge funding facility under the auspices of TIA.

INTRODUCTION



Managing the widespread use of plastics products is a pressing environmental issue, with important considerations for trade and industrial policy. Plastics are famously difficult to dispose of in an environmentally conscious manner and involve a dirty and carbon-intensive production process. Efforts to manage the ubiquitous use of plastics has seen pledges to combat single-use plastics, the promotion of biodegradable plastics, efforts to clean and recycle areas impacted by plastics, and – in some cases – moves to ban plastics altogether. At the same time, next-generation transportation technologies like electric vehicles look set to radically alter the operations of petroleum refineries and, in so doing, undermine the steady supply of large-scale petroleum by-products that underpin both the plastics and the chemicals industries.

Biomaterials – plastics and composite-like technologies derived from waste and plant matter – offer an opportunity to help reduce the environmental impact of traditional plastics, while safeguarding the economic contribution made by the plastics and chemicals industry. And because most biomaterials are produced using a set of platform chemicals and fibres, the industry can further reinforce the chemicals sector, and meet the changing demands of high-technology composites fabrication in the automotive and aerospace industries.

While biomaterials require substantial work to reach competitiveness and scale, early investment in the technology and productive environment is crucial to develop the industry and to maintain pace with early adopters. For South Africa, biomaterials offer an opportunity to leverage a strong technological base and a rich agricultural environment to position the country for the long-term development of a biomaterials sector. The government's Bioeconomy Strategy and the basket of interventions that fall under it form a solid basis on which to build. Previous work by PAGE aimed at identifying high priority green trade opportunities for South Africa highlighted the potential for biocomposites and serves as the initial research for this report.

This document proposes an action plan and implementation strategy to further the development of the sector in South Africa. It aims to both reinforce existing initiatives, and offer suggestions for new approaches, with the goal of deepening the sector and removing barriers.

The action plan proceeds in four parts. Part 1 offers an overview of biomaterials, reviewing both the technology and the state of biomaterials production in South Africa. Part 2 identifies crucial barriers to developing the biomaterials space, structured around three topics: the creation of an enabling environment for innovation, the availability of reliable and affordable feedstocks, and the market competitiveness of biomaterials. These barriers directly guide a set of interventions, which aim to remove or lessen these constraints. The interventions themselves are detailed in Part 3, which includes an initial assessment of some implementation details for each action item, including previous initiatives that the work should build on, the responsible entities, and initial costing of initiatives. Finally, Part 4 maps these interventions to an implementation strategy.

Methodology

The set of interventions chosen to promote the growth of biomaterials depends on government's objective. The biomaterial industry can be developed to various levels: with biomaterials working as a niche product stream, a large-scale industrial product that fills gaps left by petroleum-based plastics, or as a leading product with global reach. Setting an appropriate target is vital to developing the industry, and the action plan should be aligned to that target. Such a target cannot be set in the course of this research and is not available. The South African bio-economy strategy, developed by DST, includes a list of indicators for the development of the industrial bio-economy, but most focus on general policy approaches, such as improving research and development, rather than a targeted end state.

Because of this gap in clear objective, the action plan takes a problem-solving approach. This involves identifying barriers and gaps in the market for biomaterials and identifying government policies that can fill these gaps. In this case, barriers were identified in the problem statements above, using both research and engagement with stakeholders. These identified barriers guide many of the core interventions identified.

Removing these barriers and improving general support for biomaterials in South Africa will need a multitude of small interventions, implemented by a wide range of departments and agencies. While these interventions are detailed in the action plan, six priority projects are highlighted first, to better enable focus in the implementation of the action plan. Thereafter, a number of supporting interventions are briefly explored, but may require further study to ascertain their feasibility and potential impact.

These interventions are split into a number of smaller stepping-stones, known as implementation milestones. These milestones are mapped to a broad overarching implementation plan, which can be found attached as Annex 1. The linkages between the action plan (Part 3) and the implementation strategy (part 4) can be seen in Figure 1.

Figure 1: Linkages between the action plan and implementation strategy

ACTION PLAN

Priority intervention 4

Development of a biomaterials center of excellence

INNOVATION WORKSTREAM

LEAD AGENCY: CSIR	SUPPORT: DST, Universities	TIME: 42 months	COST: High

While the South African community of biomaterials researchers is small and close-knit, the enabling infrastructure for that research is fragmented across centres and universities around the country. Many of the instruments are multi-use and are part of broader laboratory or testing structures. While this backbone of infrastructure plays a vital role in strengthening the biomaterials space, its fragmentation adds time and cost barriers to efforts to develop new technologies.

A common approach to solving this problem would be creating a centre of excellence in biomaterials. While the traditional approach under the DST-NRF centres of excellence programme is to create virtual centres, which are effectively coordinating bodies for the research ecosystem, a more comprehensive approach would be to create a physical centre that is equipped with appropriate instruments, focused primarily on testing.

In terms of the process in building the center of excellence, four key milestones are important in building the centre of excellence. First would be establishing a traditional, virtual centre of excellence. This would begin building the appropriate institutional infrastructure for further work and would have positive spill-over benefits for other initiatives, such as improving training of biomaterials experts (discussed below). This centre should be based on existing infrastructure, of which the CSIR's Biorefinery Industry Development Facility would appear to be the most suitable candidate.

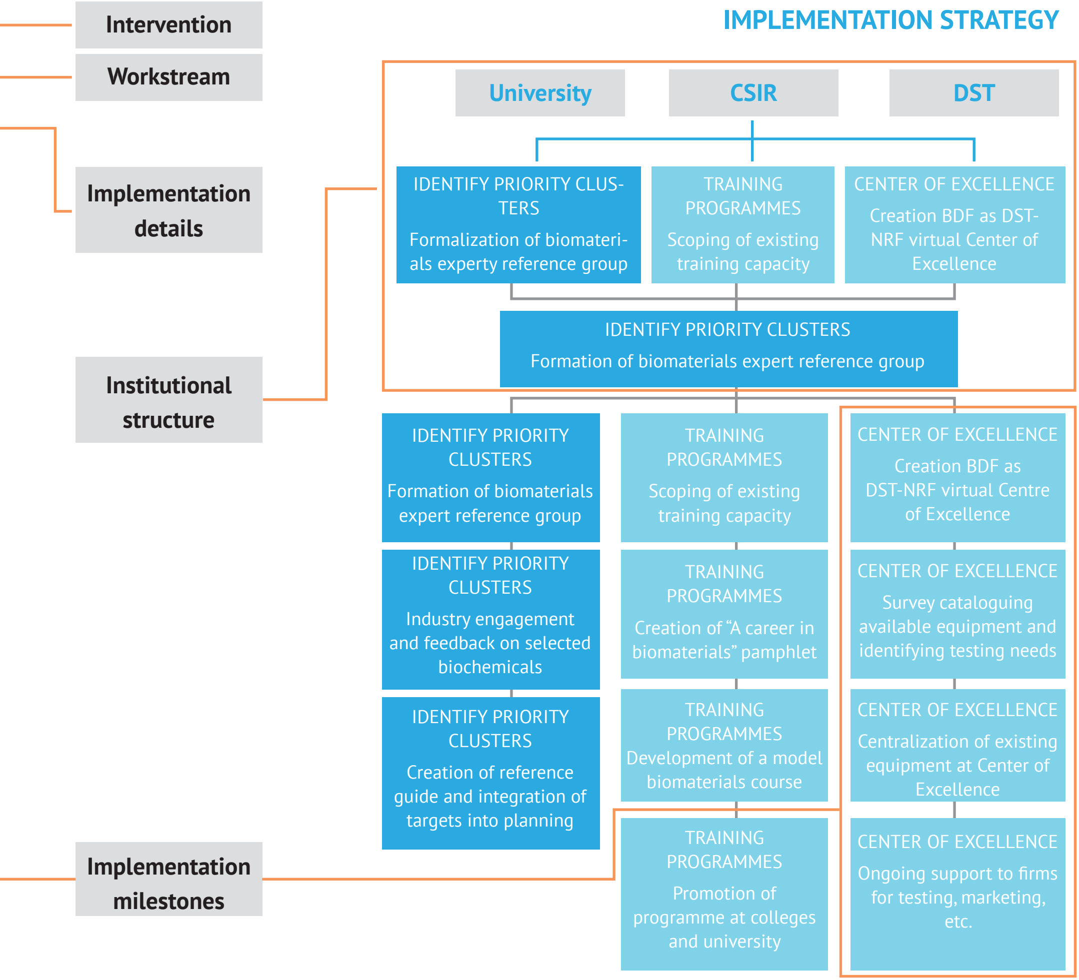
Second would be a survey by the centre of excellence, creating a catalogue of facilities that can perform testing of biomaterials, and detailing what tests must be completed. This would lay out the full spectrum of tests needed for new biomaterials, which can include a vast array of tests on strength, flexibility, heat-resistance, biodegradability, toxicity, and many others. Technical testing needs can be supplemented by forming a better understanding of the needs for support for prototyping, feasibility studies, business model development, manufacturing, and demonstration.

Third, the centre would then need to begin a process of, as much as possible, centralising its resources to a single testing facility or handful of testing facilities. This would need to be guided by the scoping study above, and perhaps facilitated by additional support from the state, whether through funding to buy appropriate equipment, or through partnerships with state bodies like the South African Bureau of Standard (SABS).

Additional supporting work on a centre of excellence could be facilitated by greater understanding of similar centres elsewhere in the world. Centres of excellence (or similar centres) are common across the world, and partnerships or learning exercises with these centres could help in setting up the South African centre.

Implementation plan milestones	
Creation of BDF as DST-NRF virtual Centre of Excellence	6 months
Survey cataloguing available equipment and identifying testing needs	6 months
Guided by scoping study, process of centralising	6 months
Ongoing support to entrepreneurs for testing, product prototypes, etc.	24 months

IMPLEMENTATION STRATEGY



1. OVERVIEW OF BIOMATERIALS

1.1 Defining biomaterials

Biomaterials are best understood as a category of goods, rather than a specific product. Individual biomaterials can differ markedly, in everything from material inputs, production process, and end-use. This diversity complicates efforts to construct a focused set of policy interventions, as individual biomaterials differ in their stage of technological development, the raw materials they use as feedstock, and the supporting industrial policies they require.

Simplifying greatly, biomaterials in this context refers to two broad categories of goods: bioplastics and biocomposites. Bioplastics refer to plastics produced from plant or waste matter. Composites refer to more complex industrial materials made from a combination of technical fibres and plastics products, and are commonly used in, for example, making automotive panels or airplane interiors. Biocomposites in this context refer to composite materials in which at least the fibre or plastic component is wholly or partially derived from plant or waste matter. Because both technologies rely on the production of platform chemicals, which are used in the production of bioplastics and as standalone chemicals in their own rights, biochemicals are included in the scope of the action plan.

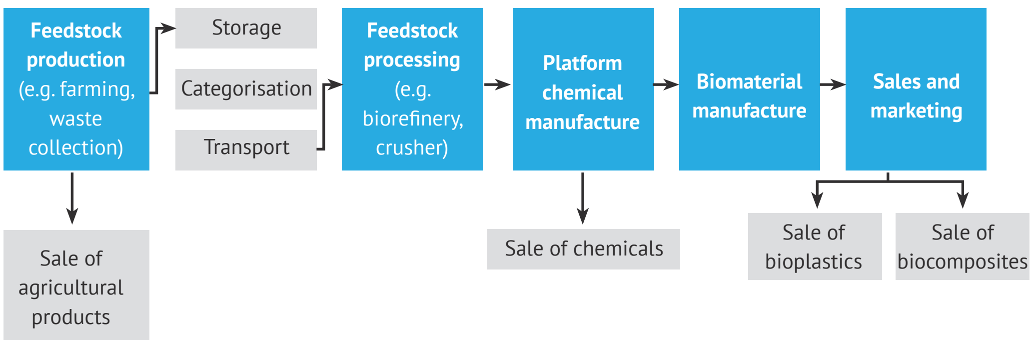
1.2 Technology

Most biomaterials technologies require four productive stages.

First is the collection of appropriate feedstock. Feedstock can include primary agricultural products (such as sugar cane or maize), agricultural waste (such as sugar cane bagasse or maize stalks), or other waste (such as municipal solid waste and waste water). These feedstock materials need to be carefully collected, stored, and categorised, with needs differing by type of feedstock and production process. Second, feedstock is broken down to its constituent components. This is most commonly basic chemical parts, such as starch, cellulose, and sacchrose. Feedstock can be broken down in several ways. Most common is the biorefinery approach, in which feedstocks are fed into specialised boilers to extract their components. Third, these basic components are then combined into various platform chemicals. Many of these are chemically identical to petroleum-based chemicals and can be dropped in to existing production process for plastics or related products. Finally, these chemicals are processed to produce a finished product. A sample of a simple biomaterial value chain is illustrated in Figure 2.

Figure 2: Simplified biomaterial value chain

Source: Authors' composition



Scoping specific biomaterial technologies is complicated by a high degree of diversity in the sector. This diversity is reflected in the production process, base chemicals and plastic types, bio-content, bio-degradability, and so on. A scoping of the leading bioplastics can be found in Table 1, highlighting the competitive nature of the global bioplastics space.

Table 1: Global bioplastics market by bio-based polymer, 2013
Source: Nova Institute, 2015

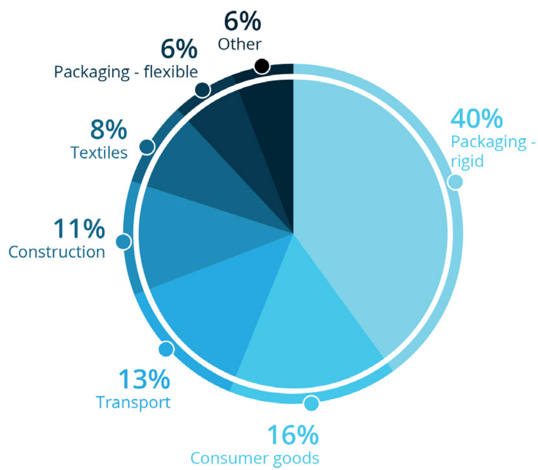
Structural polymers		Bio-based carbon content	Producing companies (2013-2020)	Production locations (2013-2020)	Production capacity (tonnes, 2013)
Technical title	Abbr.				
Epoxies	–	30%	–	–	1 210 000
Polyurethanes	PUR	10% to 100%	7	7	1 200 000
Cellulose acetate	CA	50%	17	20	850 000
Polyethylene terephtalate	PET	20%	5	5	600 000
Starch Blends	–	25% to 100%	15	16	430 000
Polylactic acid	PLA	100%	28	34	195 000
Polytrimethylene terephthalate	PTT	27%	1	2	110 000
Polybutylene succinate	PBS	Up to 100%**	10	11	100 000
Polyamides	PA	40% to 100%	9	11	85 000
Polybutylene adipate-co- terephthalate	PBAT	Up to 50%**	4	5	75 000
Ethylene propylene diene monomer rubber	EPDM	50% to 70%	1	1	45 000
Polyhydroxyalkanoates	PHA	100%	14	16	32 000
Polyethylene	PE	100%	1	1	20 000

As can be seen by the differing production levels in Table 1, biomaterial technologies remain at divergent stages of development. Some biopolymer offerings already compete with established plastics processes, while others are far from being realistically marketable. Various applications, notably in packaging and bottling, are competitive when allied to the marketability of being environmentally friendly (the 'green premium'), even if they are not yet competitive on a simple price-point basis. Cost-competitive biomaterial technologies can reach marketability relatively early, as they can be combined with traditional plastics to counteract any weaknesses or deficiencies in the technology. The capacity to combine biomaterials with traditional petroleum-based materials allows the product to leave the lab more quickly than otherwise might be the case and facilitates the development of scale in the production of newer technologies.

Because of the interchangeability of bio-based plastics and chemicals, the potential market for biomaterials closely resembles the market for traditional plastics and composites. The first wave of biopolymers was used in light packaging materials, with traditional plastics mixed with plant-based biomaterials to create more environmentally friendly bottles and containers. The current generation of biomaterials targets more durable applications, such as hard plastics for consumer goods and some industrial

Figure 3: Global bioplastics production by end-use, 2020 projection

Source: Nova institute, 2015



applications, like car interiors and panelling. As can be seen in Figure 3, packaging, consumer goods, and transport equipment are projected to make up 73% of the 17 million tonne global market for bioplastics by 2020.

Internationally, interventions are notable in the biomaterials space. These include national programmes in countries such as China, Japan, Germany and Thailand to promote innovation in the field by opening biomaterials, or more commonly bioplastics, centres of excellence. Major companies have made pledges on biomaterials, with Coca-Cola a prominent example through the development of its partially bio-based PlantBottle technology. Coca-Cola, together with four other large American companies (Ford, Heinz, Nike and P&G) have created a working group to develop bio-PET technologies (Kaye, 2012), and major automotive companies like Toyota (Dang, 2011) and Mercedes (Venter, 2017) have made efforts to introduce biomaterials into car interiors and panelling.

1.3 Biomaterials in South Africa

Biomaterial research efforts in South Africa are primarily driven by the Centre for Scientific and Industrial Research (CSIR) and a collection of university initiatives, with overarching support from the Department of Science and Technology (DST). The CSIR's efforts can broadly be grouped into two streams. First is a 4 300m2 Biocomposites Centre of Competence in Port Elizabeth. The centre aims to create biomaterials derived from "natural fibres such as flax, hemp, kenaf and agave; thermoplastic and thermoset resins; as well as biopolymers such as soy protein, polylactic acid and polyfurfuryl alcohol. The mechanical, thermal, thermo-mechanical and fire-retardant properties of fibre-reinforced composites are optimised for application in the automotive and aerospace industries" (Anandjiwala, n.d.). The centre lists partnerships and initiatives with a range of industry clients, as can be seen in Table 2.

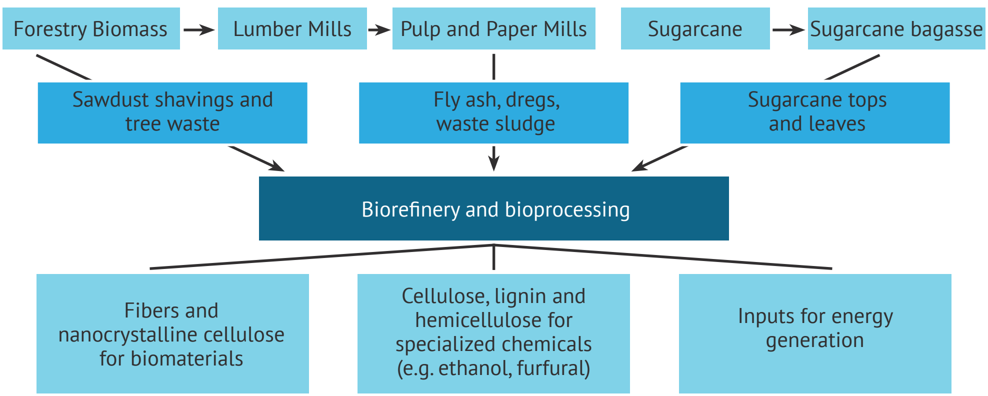
Table 2: CSIR's Biomaterials Centre of Competence partnerships
Source: Anandjiwala, 2012

Client and partnerships	Initiatives
Airbus	Interior panels for airplanes
BIRN	International Biomaterials Network
Bombardier	Interior panels for train carriages
Chemcity	Biomaterials for construction industry
De Gama, Frame, Brits Textiles	Natural fibre composites
Experico	Packaging
Industrial Development Corporation	Sisal fibre production
Sustainable Fibre Solutions	Kenaf processing
The House of Hemp and Hemporium	Establishment of hemp industry
University of Delaware	Biopolymers for housing
Volkswagen	Parcel tray
Woolworths and suppliers	Characterisation

The second stream includes biorefinery pilot projects. Biorefineries aim to process "various biomass sources to produce a spectrum of products, such as value-added chemicals, fuels, and agricultural products", and form a vital part of the value chain for biomaterials, as illustrated in Figure 4 (Bennett and Page, 2017). The CSIR opened a R37.5 million Biorefinery Industry Development Facility (BIDF) in Durban in 2017, which primarily aims to serve as a venue for piloting and upscaling technologies. The BIDF is one part of a large work plan aimed at creating biorefineries, with the DST targeting refineries in five areas: forestry, sugar, algae, non-food crop plant oils and microbial biorefineries based in rural areas[1]. This biorefinery work is supported by a number of additional initiatives, such as the creation of a biorefinery research consortium; involving the CSIR, bioenterprise Sekolong Sa Dimelana, Tshwane University of Technology, and the University of the Witwatersrand (Arnoldi, 2018).

Figure 4: Simplified representation of forestry and sugarcane biorefinery processes and products[2]

Source: Authors' composition based on Federal Government of Germany, 2012; Sithole, 2017



[1] Interviews

[2] Fly ash is a by-product of the pulp and paper industry and is produced when woody materials are burned. Dregs are alkaline residues generated by the pulp and paper industry.

Outside of the CSIR, a wide range of biomaterials research is being done in several university-led initiatives. Table 3 lists some of these initiatives and provides some details on their partnership work with local firms.

Table 3: Selected biomaterial research projects in South Africa
Source: Authors' composition

Institution	Project	Local Partnerships
University of Pretoria	Plant Protein Biopolymers and Biomaterials research group	Blue Sky Venture Partners
Durban University of Technology	Composite Research Group	Mintek, National Research fund (NRF), CSIR, Kentron, Toyota, Sasol, Altech UEC
University of Stellenbosch	Materials Engineering team	Roundtable for Sustainable Biomaterials, Airbus
University of Johannesburg	Centre for Nanomaterials Science Research	South African Chemical Institute, the Water Institute of Southern Africa, the South African Nanotechnology Initiative, Mintek
Nelson Mandela Metropolitan University	Biomaterials – Natural Fibre Research	CSIR

Sugar (and related sugar research and industry groups) and Sappi have done extensive work on the categorisation of feedstock. Sappi is actively involved in basic processing, through the sale of dissolving wood pulp, primarily for export. KwaZulu-Natal-based agro processing company RCL foods is involved in the production of a succinate monomer. The community of firms working directly on biomaterials is small. A far larger and more well-developed set of firms operate in composites, plastics, and chemicals. Biomaterial development would certainly benefit from their active involvement in the industry. Sasol is the key player. While experts report Sasol is undertaking work on biomaterials, little information on these projects is publicly available. Sasol does have some experience in biomaterials, through a distribution agreement between the company's Chinese joint venture Wesco, and Australian bioplastics firm Cardia Bioplastics, but its biomaterials operation otherwise remains confidential.

2. BARRIERS TO BIOMATERIALS INDUSTRY GROWTH

This action plan proposes a set of practical interventions to unblock barriers to developing a competitive South African biomaterials industry. Some interventions offer broad support to the industry. Many others will more narrowly target existing barriers to the natural development of the industry and technology. As such, this section identifies problems or challenges that may restrain the biomaterials industry, and thus may require policy intervention.

The problem statements consider three broad stages along the biomaterials value chain: the creation of viable technology, the availability of affordable and reliable feedstocks, and the core productive competitiveness of biomaterial manufacturing. For each stage, a mixed research methodology was used. This methodology included a review of the relevant literature, interviews with stakeholders, and data analysis. Stakeholder engagement was accomplished by primary interviews with biomaterials researchers, government officials, and the private sector, and was supplemented by a workshop of biomaterials experts, who provided feedback into a draft version of the report.

Selected barriers are summarised in Table 4.

Table 4: Barriers along the biomaterials value chain
Source: Authors' composition

Area	Barrier
Innovation environment	Deficiencies in the broader innovation environment, including poor commercialisation and limited and unstable pool of funding
	Selection of high potential biomaterials: extreme diversity of technology risks makes targeted support difficult
	Institutional environment: innovation is almost entirely state-led and will require ongoing support
	Importing available technology: lack of education initiatives and readiness support makes it difficult to import existing production technology
Feedstock	Uncertainty on feedstock availability, including a lack of systems to categorise and record available biomass
	Accessing leading feedstocks: restricted by alternate uses for biomass (such as energy generation) and regulations
	Developing new feedstocks: many of the most innovative crops are not yet at commercially viable levels of production
	Waste management: poor waste collection and management systems limit the use of non-agriculture feedstocks

Competitiveness	Short-term efficiencies: biomaterials are not competitive on a cost-basis against traditional plastics, and are unlikely to be so until appropriate scale is achieved
	Few gaps or product niches: outside of the green premium and some chemicals imbalances, the ubiquity of plastics means few productive niches exist
	Enterprise development: high upfront costs and large-scale economies complicate efforts to diversify the sector

2.1 Creating an enabling innovation environment

Biomaterials technology is still in the early stages of its development. While some technologies, particularly in the packaging industry, have reached commercial viability, untapped potential exists in industrial and other applications.

Four core problem areas must be overcome to enable an innovation environment for biomaterials:

1. Deficiencies in the broader innovation space
2. Selection of high potential biomaterials
3. Strengthening the institutional infrastructure for biomaterials
4. Supporting the import of established technologies

2.1.1 Addressing deficiencies in the broader innovation space

South Africa's innovation environment features well-established barriers, including: inadequate long-term support (including financing and other intiatives) for promising technologies, difficulties in the targeting of technologies, and poor commercialisation of developed products. It is impossible to disconnect biomaterials from these challenges, and it is well beyond the scope of this strategy to correct them. As such, a biomaterials innovation strategy must try to manage broader challenges in the innovation environment.

Innovation support to biomaterials must, in particular, focus on managing instability in funding provided to innovation, particularly during the later stages of development. While numerous technologies have been successfully incubated in universities or state research centres in the early years of their life, support for these technologies has often weakened over the long term, particularly as the technology reaches the difficult and expensive stage of commercialisation. Famous cases of premature withdrawal of public funding support include the Joule electric car and thin-film solar panels. Furthermore, the problem goes beyond these high-profile examples, and into the nature of innovation funding environment underpinned by a fiscally-constrained state, with many pressing spending priorities, and short-term planning horizons.

While the weakness of commercialisation is partly a funding problem, it also stems from a gap between scientists and business people. Numerous interventions have attempted to bridge the gap between the science world and the commercial space. Among these have been integrating intellectual property (IP) offices into universities and building commercialisation offices. The leap from scientist to entrepreneur, however, is still a difficult one. One innovative sorghum biomaterial, for example, was registered by a local university's intellectual property office, but was owned by two scientists with little interest or knowledge in business, and who did not wish to pursue the technology. Both scientists are approaching retirement, and the technology is likely to leave the university along with them.

The innovator-entrepreneur is idealised, but it is not a model suited to the sort of high-scale, chemical-plastics sector that biomaterials will need to enter. This is particularly so when one considers that the technologies will likely be loss-making for a long time, under pressure from the established petrochemical industry. As such, developers of biomaterials may be better served by building partnerships with established industrial players, who can incubate and develop the technology for market.

2.1.2 Selection of high potential biomaterials

With a limited pool of resources to support biomaterials technologies, some level of selection will need to take place. This is so even if government policy tries to avoid "choosing winners," because the distribution of instruments like funding or incubation support means choosing who gets support and who does not. Careful assessment of individual initiatives is the vital stage in choosing which projects to support. However, this needs to be set in a context that understands which biomaterial technologies are most likely to work in the South African commercial environment, with adequate enabling conditions like appropriate feedstock and a market for uptake of the technology.

Assessing which biomaterials to support is complex. Biomaterial technology is highly diverse, ranging from feedstock used to the nature of the process, end-use applications, and the environmental impact of the biomaterial (with some not being biodegradable, for example). Policy support would need to decide, first, whether to target a broad range of useful technologies, or to be more focused. One option would be to target the development of biomaterial platform chemicals, which can be used in multiple value chains. A more disaggregated approach would need to consider various biomaterial technologies and develop some form of rubric to score the viability of potential technologies.

Perhaps the most impressive scoping study of this type was undertaken by the University of Cape Town's Centre for Bioprocess Engineering Research (CeBER). The CeBER study ranked the viability of a wide selection of platform chemicals, assessing expert opinion, technological readiness, and the market for the chemical. The results can be seen in Table 5.

Table 5: Ranking of viability of leading platform chemicals
Source: Harrison et al, 2017.

	Scenario 1 Prioritises expert opinion	Scenario 2 Prioritises technological readiness	Scenario 3 Equal weighting of expert opinion, technological readiness, and market demand	Scenario 4 Prioritises market demand
1	Citric acid	Citric acid	Citric acid	Citric acid
2	Lactic acid	Lactic acid	n-Butanol	n-Butanol
3	Iso-butanol	Iso-butanol	Glutamic acid	Glutamic acid
4	n-Butanol	n-Butanol	Lactic acid	Isoprene
5	Butanediol	Butanediol	Iso-butanol	Acetic acid
6	Ethanol	Ethanol	Butanediol	Iso-butanol
7	Isoprene	Isoprene	Ethanol	Butanediol
8	Glutamic acid	Glutamic acid	Acetic acid	Lysine
9	Acetic acid	Acetic acid	Isoprene	Furfural
10	Algal lipids	Algal lipids	Furfural	Lactic acid
11	Ethylene	Ethylene	Lysine	Ethanol
12	Furfural	Furfural	Glycerol	Glycerol
13	Adipic acid	Adipic acid	Adipic acid	Ethylene glycol
14	Polylactic acid	Polylactic acid	Polylactic acid	Butyric acid
15	Succinic acid	Succinic acid	Ethylene	Sorbitol
16	Lactate esters	Lactate esters	Algal lipids	Isobutene
17	Famesene	Famesene	Sorbitol	Acrylic acid
18	Levulinic acid	Levulinic acid	Butyric acid	Adipic acid
19	PHAs	PHAs	Ethylene glycol	Polylactic acid
20	Malic acid	Malic acid	Succinic acid	1,3-Propanediol

Careful analysis of this kind is important to act as a guideline for policymakers, but innovation policy will need to coalesce around a focused set of chemicals or plastic types to facilitate effective and focused support to the industry.

2.1.3 Strengthening the institutional infrastructure for innovation

The CSIR and the university ecosystem (discussed in 1.3 Biomaterials in South Africa above) will likely need to continue to lead on biomaterials technology development in the immediate future, and ongoing support to existing initiatives will need to remain, at least until broader uptake by industry. Researchers highlight the need not only for sustained financial support but also for support focused on commercialisation. The core challenge is the lack of uptake agreements from commercial partners. Even when viable technology has been delivered, bringing it to market has proven challenging without close partnership. Research initiatives can drive such partnerships themselves, but researchers are not experts in marketing or partnership development, and additional support during this stage appears to be needed.

2.1.4 Supporting the import of established technologies

Finally, while supporting local innovation is important, much of any new technology will be developed elsewhere. The development of these technologies requires similar innovation to support successful local use of that technology. Establishing readiness among local firms for large technological changes, facilitating access to IP, and training engineers in new technologies should be an essential part of any innovation strategy.

South Africa is well positioned to take advantage of technological advances elsewhere in the world, through the presence of multiple foreign investors who are leaders in the biomaterials space. These include large petroleum, chemicals, and plastics firms, which tend to include biomaterials as a secondary product line. Production of these more advanced product lines, however, tends to take place in more developed countries, with most of the processing in South Africa being based on locally available petrochemical by-products. Encouraging the localisation of production of foreign IP both would position the South African industry for changes in technologies and create a pool of expertise vital to promoting domestic innovation.

2.2 Reliable and affordable sources of suitable feedstock

Feedstocks form the basis for the entirety of the biomaterials value chain. As with petroleum in traditional biomaterials, the cost and accessibility of feedstock is a key determinant of the resultant cost structure of the rest of the industry, and fluctuations or shocks to the supply of feedstock can destabilise fragile early adopters of the technology.

While South Africa has the potential to be a strong feedstock producer, four primary challenges must be addressed to assure the reliability of the feedstock environment:

1. Uncertainty on feedstock availability,
2. Accessing major agricultural feedstocks,
3. Developing promising new feedstocks, and
4. Waste management and long-term planning.

2.2.1 Uncertainty on feedstock availability

A wide number of biomass feedstocks are available for use in biomaterials, with a selection of the most prominent options outlined in Table 6.

Table 6: Biomass feedstock options

Source: Authors' compilation based on Harrison et al, 2017; Quarshie and Carruthers, 2014.

Raw Feedstock		**Processed Feedstock**	
Agriculture	Maize	Solid	Bagasse
	Wheat		Woody Biomass
	Sugarcane		Pulp and Paper
	Sorghum		Food waste
	Fruit and Vegetables		Municipal Solid Waste
	Soya		Abattoir
	Sunflower		Agricultural Residue
	Canola		Confectionery
	Agave	Liquid	Vinasse
	Flax		Confectionery
	Jute		Molasses
	Hemp		Brewery/Winery
	Cassava		Fertilizer
Aquatic	Seaweed		Food waste
	Algae		Abattoir
			Municipal waste water

Favourable climatic conditions coupled with a well-positioned forestry and agricultural sector enables South Africa to seize opportunities to produce suitable feedstocks required for a competitive biomaterials industry (Harrison et al, 2017). The variety of potential agricultural feedstocks in South Africa is, however, also a challenge, in that policy support needs to manage different types of feedstocks. Understanding where focus should lie is complicated by limited information on the availability of feedstock materials. While some estimates, such as Table 7, are available, a great deal of uncertainty remains on the quality and suitability of feedstock materials for use in biomaterials manufacture.

Table 7: Potential biomass residues and yields available in South Africa for the year 2014
Source: Harrison et al, 2017

Exploitable dry biomass	Tonnes per annum (millions)	Petajoule per annum
Agricultural		
Maize stover	6.7	118
Sugarcane bagasse	3.3	58
Wheat straw	1.6	28
Sunflower stalks	0.6	11
Forestry Industry		
Residues left in forest	4	69
Sawmill residue	0.9	16
Paper and board mill sludge	0.1	2
Subtotal	17.2	302

Efforts to map biomass availability, such as the BioEnergy Atlas (BioEnergy Atlas for South Africa, n.d), are a promising step forward, but remain focused on marco-level data, that is useful in guiding policy decisions, but is more limited for a single firm in search of a specific feedstock. It does not necessarily empower a potential biorefinery to find appropriate feedstocks to purchase. The lack of knowledge of appropriate biomaterials, and the lack of standards that could help companies understand what is available, makes it difficult to match biomass sellers with buyers.

This overarching challenge is present across all major biomass types, although the specific barriers faced by feedstock providers differ. Three categories of biomass are useful to conceptualise the challenges – major agricultural feedstocks (such as sugar cane bagasse, maize stover, and wood pulp), new feedstocks (such as algae and sorghum), and waste feedstocks – which forms the basis for the remainder of this section.

2.2.2 Accessing major agricultural feedstocks

Agricultural crops, such as maize, wheat, sugar and soybean, have formed the backbone of South Africa's food crop production, for domestic consumption and export purposes. Agricultural feedstock offers the potential to produce biomaterials, biofuels and platform chemicals in a sustainable and renewable manner. Maize, South Africa's largest export crop, has a starch content suitable for adhesives, chemicals and bioplastics. Maize is cultivated on 3 million hectares of land in South Africa, producing approximately 8 million tonnes of the crop and 6.7 million tonnes of maize stover (cobs, leaves and stalks) a year, with a gross value of R29.66 billion in 2016/2017 (DAFF, 2018). The abundant supply of waste residues from maize (cobs, leaves, stalk) remain under-utilised, yet could displace petroleum-based products such as polypropylene (PP).

South Africa's sugar industry annually contributes R12 billion to the economy, with an average sugarcane production of 17.5 million tonnes annually, placing the country as the 13th largest producer of sugar in the world and second largest export crop (DAFF, 2018; Harrison et al, 2017). From a socio-economic perspective, the sugarcane sector has contributed to community development, in particular the growth of small-scale farmers, who comprised 95% of overall sugarcane growers in 2011, providing 8.6% of the total crop yield (Harrison et al, 2017). Sugar has been used mainly in the production of biofuels, ethanol as well as platform (alcohol, carboxylic acid) and fine chemicals (food, pharmaceuticals).

In recent years, various factors have caused a decline in the production of sugarcane.

Among these, has been a surplus of sugar at a global level and local conditions such as crop infestation resulting in increased costs for pesticides, price hikes in fertilisers and fuels, and as well as prolonged drought in major growing provinces (Harrison et al, 2017). To sustain the sugar industry in South Africa, the sector could focus on the value-add products emanating from sugarcane processing, such as bagasse, a fibrous by-product, which can be used to produce platform chemicals, biofuels and the manufacturing of building materials. The sugar industry produces a great deal of bagasse as a by-product (Montmasson-Clair et al, 2017). For every 10 tonnes of crushed sugarcane, 3 tonnes of bagasse are produced at South African sugar mills (Muniyasamy, 2015). Currently, the majority of bagasse is used for the production of energy, which complicated efforts to utilise bagasse for other purposes.

For reasons of food security, arable land availability and water scarcity, the use of maize, wheat and sugar as feedstock has previously been discouraged by the South African government. However, the residues and by-products from these crops can be used to make bio-based composites in the country.

South Africa produced 1 316 million tonnes of soybeans in 2017 with an estimated annual average gross value of R6 billion a year (DAFF, 2018). Soybeans are primarily grown in water-scarce areas of the country, and most are processed into oil and soya feed for animals, while 3% is directly consumed by humans (Harrison et al, 2017). Soybean oil has to some extent been used in the production of chemicals for cleaning products and solvents as well as lubricants and biodiesel. Other notable feedstocks include flax, hemp, jute and kenaf. Due to high mechanical property values, hemp, flax and jute are the most common plant-derived natural fibres used to commercially improve polymers and provide a 40% lighter, high-strength alternative to conventional fibres from glass, for example. Harvesting and processing methods have been employed to improve the quality and cost-efficiency of these natural fibres through treatments that reinforce compatibility with synthetic polymers and reduce the moisture content of the feedstock (Quarshie and Carruthers, 2014). Flax and hemp plants provide both fibres from the stem as well as oil from the plant seed. In addition, hemp has higher drought-resistant properties.

2.2.3 Developing new feedstocks

In the South African context, in consideration of the current water crisis, the cultivation of algal biomass, agave, cactus pear, seaweed and sorghum presents a promising opportunity for arid land use, particularity in the driest parts of the country, because these agricultural crops require limited fresh water for growth (Harrison et al, 2017).

Sorghum requires half the water content of sugar-based crops and hence is a viable candidate for expanding feedstock production in the country. The high biomass and sugar content of sorghum has been used across the globe to produce biofuels, platform chemicals and biopolymers, resins, rubber and various solvents (Harrison et al, 2017). Sorghum production in 2017 in South Africa reached 151 335 tonnes, up from 70 500 in the previous year, with a gross value of R467 million (DAFF, 2018). The technology remains underdeveloped and the level of domestic production is too low to support sorghum biomaterial processing, particularly since the stalling of plans to produce bioethanol, which had driven development of a nascent industry that has since died out (Montmasson-Clair et al, 2017).

Nevertheless, sorghum is of interest as many of the innovations and their IP are locally owned, notably by researchers at the University of Pretoria, and also because the protein structure of sorghum is chemically similar to maize, promising high efficiency in the future. Sweet sorghum cultivation is under development in the Eastern Cape, largely for the production of bioethanol (Harrison et al, 2017).

The production of biomaterials from cassava could tie into pre-existing state-led efforts to promote growing cassava for processing into starch. Current cassava statistics are not captured in the Department of Agriculture, Forestries and Fisheries databases (Chigumira et al, n.d), but it has been estimated that only 40 000 tonnes of cassava starch was produced in 2012. Cassava is not consumed in South Africa and therefore offers less of a threat to domestic food security (although it may still use land that could be otherwise employed for the growing of food). The two major barriers to promoting cassava would be, firstly, deepening local agricultural production, which remains low, and secondly, improving technological applications, which are proven in the production of certain products, like construction boards, but tend not to meet global standards (Baharuddin, et al, 2016).

Research into biomaterials produced from aquatic feedstock, such as algae and seaweed, is already under way in South Africa. In contrast to agricultural feedstocks (maize, wheat and sugar), aquatic feedstocks can be grown under dry weather conditions on arid land using limited amounts of freshwater, seawater and wastewater, proving promising for resource-stressed regions of the country. Aside from the environmental benefits, cultivation of aquatic feedstock in secluded areas of South Africa offers opportunities for job creation and community development (Sithole, 2017).

Algae gained popularity in recent years owing to numerous environmental, health and medicinal benefits. However, globally the cultivation of algae is nascent compared to agricultural crops, such as maize, wheat and sugar, with South African imports reaching approximately 2 600 tonnes in 2011 (Harrison et al, 2017). Recent studies have shown the numerous benefits of algae cultivation as an alternative to fossil-based oils. Small-scale pilot projects are being rolled out at production facilities including; BioDelta in Franschoek, Musina Spirulina Plant in Limpopo and Natural carotenoids of South Africa in Upington (Harrison et al, 2017). The use of microalgal biomass as feedstock to generate crude oil via pyrolysis is now undergoing feasibility studies at InnoVention, a subsidiary company of Nelson Mandela Metropolitan University (NMMU).

Agave, a type of agricultural crop, can be grown throughout the year on eroded and non-arable land, for producing sisal (the primary product of agave), fibre, paper and high-value compounds such as sweeteners, and hecogenin for the pharmaceutical sectors (Harrison et al, 2017). Sisal production in South Africa was 0.5% of the world's share in 2013, with 1 360 tonnes produced compared to peak production of 8 000 tonnes in the 1970s (Harrison et al, 2017). Agave cultivation is labour intensive; expansion of the industry provides a platform to boost employment, particularly in communities where arid land is plentiful, such as the Karoo. Due to low resource requirements, agave cultivation could be actively pursued in resource-stressed regions of the country.

2.2.4 Waste management and the long-term development of waste feedstocks

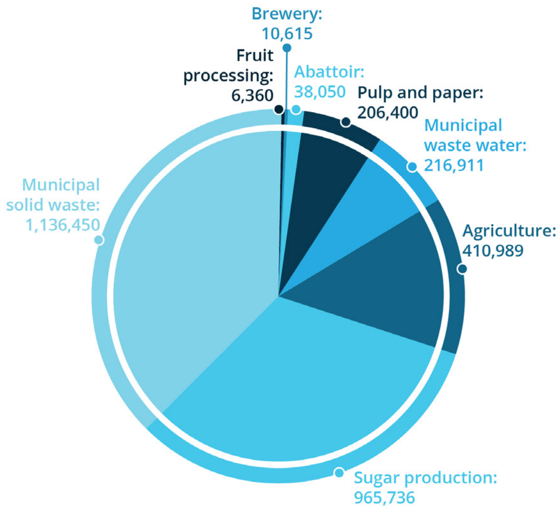
With South Africa taking steps to phase out landfilling of waste, industries will be forced to be more proactive in waste management. Waste products emanating from municipal solid waste and various industrial wastes are used to produce biogas and other chemicals. The development of biogas is considered a means to reduce the dependence on (imported) crude oil and to decrease greenhouse gas (GHG) emissions. Biogas and biomethane can produce fuel for transport and supply sustainable inputs for chemical production. Biogas is a product of anaerobic digestion, which occurs naturally during processes where organic matter is broken down by micro-organisms in the absence of oxygen. Biogas is derived from biomass sources, such as agricultural residues (fruit processing and sugar production), animal waste (abattoir slaughter waste and manure), wastewater treatment (sewage sludge), brewery, pulp and paper wastewater and, predominately, municipal solid waste from landfill sites, as illustrated in Figure 5 (EcoMetrix Africa 2016a). Biogas is also derived from landfill gas flaring and food crops, such as sugarcane.

As a by-product of municipal waste water treatment, sewage sludge can serve as a functional biomass input for gas generation, though concerns over levels of toxic matter in the sludge often deter production. To generate biogas, abattoirs use rumen, manure, selected animal trimmings and blood, producing high yields during digestion, but stringent health and safety requirements apply to slaughter waste, particularly as related to possibilities of contamination.

According to the Biogas Inventory (EcoMetrix Africa 2016a), South Africa could produce 3 million normal cubic metres (Nm3, a standard unit of measurement for the volume of a gas) of biogas per day, mostly around Gauteng, and the coastal regions of KwaZulu-Natal and the Western Cape. Despite this significant potential, biogas production in the country continues to lag the rest of the world.

Figure 5: Biogas gas potential in South Africa (nm3 per day)

Source: Montmasson-Clair et al, 2017



Populous municipalities (such as Johannesburg, Cape Town and eThekwini) are therefore presented with favourable opportunities to enhance economic, environmental and human development, while tackling waste management issues and creating additional jobs through waste-to-fuel initiatives.

Unfortunately, the country has yet to seize the opportunities arising from a wide range of unused municipal and commercial feedstocks. Meanwhile, the stored organic matter, particularly at landfill sites, continues to emit copious amounts of harmful methane emissions, counteracting the country's efforts to transition to a low-carbon economy. However, since municipal solid waste has been identified as potentially the largest source of biogas in the country, the focus could shift to waste-based generation.

2.3 Support to bring products to market and to compete

While technology commercialisation and the creation of a suitable supply of feedstock are vital to fashioning an enabling environment for a biomaterial industry, a core question of competitiveness is overarching for the industry. The competitiveness challenge is daunting. Biomaterials face competition from the extremely sophisticated petrochemical and traditional plastics industry. The type of mass-produced plastics products that biomaterials are most suited to are extremely price sensitive, and small differences in cost in the context of large production runs can be prohibitive. More high-end, high-durability plastics have larger margins and may offer some promise on a cost basis, but many biomaterial technologies are not yet of a quality to match these products and may be difficult to seamlessly integrate into existing production processes. Low (albeit rising) oil prices and a sophisticated local base in plastics and chemicals manufacture mean traditional production processes are well positioned to combat the rise of biomaterials, if the industry was so inclined.

At least three challenges need to be considered when increasing the competitiveness of biomaterials:

1. Short-term development of efficiencies and scale;
2. Identifying gaps in the existing market; and
3. Enterprise development.

2.3.1 Short-term development of efficiencies and scale

Recent experience with green technologies, notably in renewable energy, demonstrates that they require a period of support when the technology is not cost competitive. This period of development allows for learning and refinement of the technology and achieving a scale of production that facilitates competitiveness. Such support is feasible for energy, because of large state procurement dynamics, but is complex for biomaterials. Experts interviewed for the research argue that few, if any, biomaterials are cost competitive with traditional materials at present.

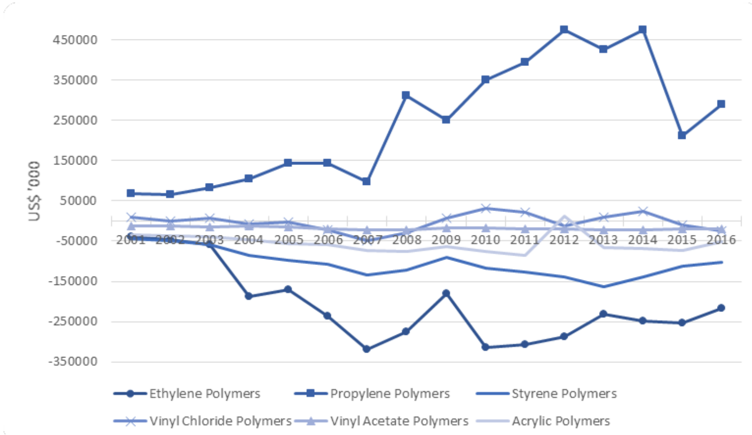
In the short term, strategies that rely on biomaterials displacing traditional plastics are misguided. Rather, biomaterial technologies need to be integrated alongside traditional plastics, in a parallel process. Biomaterials can be easily combined with traditional plastics to form a mix-polymer that allows improvements in the technology while making use of more established processes. This is particularly so for biocomposites, where combining of technical fibres and plastics allows for a mix of bio-based and traditional sources. There is high capacity for this type of parallel process to work (as discussed in the interventions below), but it would require a level of deep cooperation and support between government and the industry, because government innovation support alone cannot create this type of incubating environment. Especially crucial are partnerships with anchor clients, particularly in high-volume industries like plastics, and in sectors with high levels of pre-existing government partnership, such as automobiles.

2.3.2 Identifying gaps in the existing market

Identifying gaps in the market for biomaterials is a complex proposition, particularly considering the ubiquities of plastics products, and the versatility of the industry in adapting to market needs. The easy answer to this question, marketing off the greenness of biomaterials, is an option, and one that must be exploited. But often this is not as straightforward as one might expect, with, for example, many petroleum-based plastics products being biodegradable, whereas some biomaterials are not. The "greenness" of products is also more of a selling point in some cases than others, with the argument working for common commodities like packaging, but proving more complex in industrial applications like car panelling.

Nevertheless, niches are available. For example, one core niche in the South African industry is to try to mitigate imbalances in the plastics and chemicals sector resulting from Sasol's unique production processes. Sasol is by far the largest supplier of chemicals used in plastics in the South African market, but the company's coal-to-liquid production process produces a highly atypical mix of by-products relative to traditional naphtha crackers. In particular, South Africa under-produces ethylene (which can be produced from bio feedstocks) and overproduces propylene, as can be seen in Figure 6. Both are used in relatively fixed ratios in the production of plastics and chemicals and closing this gap would offer a potential market for local production, displacing imports and strengthening the downstream industry.

Figure 6: South African net trade in polymers, 2001 - 2016
Source: Author's calculations based on ITC Trade Map data



Other niches are of course available, but careful surveying of these would be important in identifying key points of support in the industry. This would allow planning to look beyond the technology and the broader market to areas that can be successful alongside the existing plastics and chemicals sector.

Identifying niches is also important to cope with existing competition from international biomaterials producers. Certain product areas, notably in packaging, are already well established, with the technologies integrated into large companies. Coca-Cola, for example, aims to produce all bottles using its biomaterial "PlantBottle" technology, in which 30% of the material is made from bioplastic derived from sugarcane, by 2020 (Durandt, 2016). The integration of these technologies in large firms results in production being determined by the location of basic manufacturing, rather than any unique competitiveness in biomaterials.

2.3.3 Enterprise development

The development of new firms, particularly for black entrepreneurs and in the form of small, medium, and micro enterprises (SMMEs), is a priority for the South African government, and must be carefully considered when developing a biomaterials industry. New technologies often hold significant potential for small, new entrants that are nimble enough to respond to changes in the market and that could become potential early-adopters of new technology.

Nevertheless, the challenge for biomaterials is considerable. The traditional linkage between plastics and petrochemicals means that most of the dominant players in the plastics and polymer market are extremely large firms that benefit from substantial scale advantages, in terms of both production and their capacity for investment in new technologies. Integrating new entrants into the biomaterial market will require proactive planning, and careful sequencing of initiatives in a way that acknowledges that small firms can best be supported once South Africa has an established presence in the biomaterials industry, and the technology itself is competitive.

The potential for new enterprise development may be strongest in the feedstock phase. Feedstocks for traditional plastics and materials have come from a handful of large petroleum companies, but biomaterials could expand this to a vast network of farmers and waste recyclers. Actively promoting development in this area will be crucial to creating a plastics and composite industry that is inclusive and shares benefits widely.

ACTION PLAN

3. ACTION PLAN

FEEDSTOCK WORKSTREAM

Priority intervention 1

The creation of a matching programme for feedstock

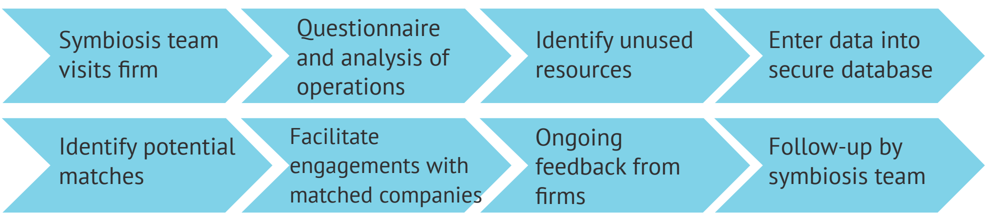
LEAD AGENCY | NCPC	SUPPORT | GreenCape, the dti	TIME | 44 months	COST | Mid

The most fundamental problem facing the development of biomaterials manufacturing on an industrial scale is the uncertainty around the market for feedstock. Studies and respondents diverge substantially on the state of feedstock for biomaterials. One respondent noted that, even if all the agricultural waste feedstock in the region could be collected, it would still be inadequate to supply manufacturing on an industrial scale. Other respondents claim there is enough available feedstock, but that it is highly fragmented and difficult to access. In some cases, high potential feedstock, such as sugarcane bagasse, is used for other purposes, such as energy generation. This creates uncertainties about the willingness of firms to sell their feedstock, and on the effective price that would need to be paid to access that feedstock. Understanding the appropriateness of feedstock is equally complex, with waste in particular requiring careful handling and sorting to be viable for further production. These complexities undermine the development of offtake options for existing feedstock, and in so doing prevent the development of new, innovative feedstock types such as cactus pear or algae. Inadequate feedstock systems risk leading to the South African biomaterials market becoming increasingly reliant on the import of intermediate bio-chemicals for plastics production.

As an urgent priority, a programme is needed that systematically identifies feedstock, appropriately categorises it for end use, and links feedstock holders with firms that can process that feedstock. It is therefore suggested that a programme of industrial matching for feedstock be created. This would draw on the experience of the various industrial symbiosis programmes in the country, which match industrial waste with other firms that can beneficiate that waste. The focus here would be on agricultural by-products and waste, with offtake targeting firms processing to high-value products like bioplastics.

Such matching can be facilitated at numerous levels. As a low-cost option, a digital platform could be established, in which feedstock owners and processors can post available products and needs, and thus be matched with little input needed from government. The state would likely have to undertake some initial input to such a platform, registering a number of firms to bring it to operational scale, but costs would nevertheless remain low. The system could also build on pre-existing initiatives like the Bioenergy Atlas. The trade-off would be the risk of an online system not being widely used – a problem highlighted by the poor experience of such a system in industrial symbiosis – and perhaps seeming too costly a barrier for firms with pre-existing uses for waste products and little desire to seek other uses.

Figure 7: A typical industrial symbiosis model
Source: Western Cape Industrial Symbiosis Programme (WISP), 2018



A preferable option would be to establish the matching agency as either an independent body or a dedicated team in a relevant institution, such as the National Cleaner Production Centre. Institutionalising the matching would raise costs, but would create a more focused implementation arm, which could assist both in the matching programme and provide a base of operations for further biomaterials projects. This approach would follow an industrial symbiosis model, in which outreach to firms that both have and need feedstock is undertaken by officials, and appropriate linkages are then made between them. The institutional specifics of this programme would need to be decided separately, but an overview of the approach taken by the Western Cape's industrial symbiosis programme is provided in Figure 7.

Implementation plan milestones	**Timeline (months)**					
	6	12	18	24	30	Ongoing
Establish a biomass matching team at the NCPC	■					
Scoping of priority biomass and existing knowledge on location of feedstock		■	■			
Register anchor biomass providers				■		
Register anchor clients for the supply and off-take of feedstock				■		
Programme launch, including launch of online platform					■	
Ongoing registration of small-scale biomass providers and end-use firms						■
Ongoing evaluation and feedback						■

Priority intervention 2

INNOVATION WORKSTREAM

Bridge funding for biomaterials research

LEAD AGENCY | TIA	SUPPORT | DST, IDC	TIME | 51 months	COST | High

Research funding has been consistently noted as a priority for biomaterials. The most pressing issue identified, both in biomaterials and in the broader innovation environment, was the difficulty in bringing promising laboratory research to market. Similarly, innovative feedstocks often suffer from a lack of funding support, and newer biochemical opportunities are often under-supported.

While there is clearly need for funding for biomaterials, the way this funding is structured and conceived needs to be carefully considered. Virtually every new technology or industry will stress the need for financing, with funding serving as a proxy for every conceivable barrier. In a resource-scarce environment, action plans proclaiming the need for funding risk not being supported with adequate resources in practice. Even if some resources can be made available, the scope and diversity of biomaterials raises questions on whether funding of adequate scale can be directed to the best possible technologies, or whether the sprawl will result in a dilution of resources across multiple research initiatives. For this reason, simply planning for more funding is not an adequate approach. In all likelihood, it will not be possible to disconnect biomaterials development from the broader innovation funding environment, and while lobby efforts might direct greater attention to this area, they cannot break entirely with what exists.

Nevertheless, it is recommended that a fund be created, with a more targeted mandate that allows a smaller pool of funds to have a large impact. Researchers typically identify unstable funding as a greater problem than the absolute lack of funding. In the most common example, funding is available for pure research, but is not adequately provided when it comes to bringing the technology to market. Over the span of the innovation cycle from conceptualisation to market, there are significant gaps where funding is not adequately provided or not appropriate to the specific stage in question.

A bridge fund would aim to close this gap. The fund would be made available to proven technologies that have previously received funding and are making efforts to attract more funding but have fallen into one of these funding gaps. The fund would aim to provide a level of short-term funding (as defined during the fund's inception) during this period, which would facilitate additional work on the technology, whether that be additional research or support for marketing and commercialisation. The long-term aim of the fund would be to ensure the research project is sustainably financed – whether through the awarding of further research funding from elsewhere, or the development of a commercialised product offering.

The fund would need to be managed under a competitive bid system, in which projects submit both details of their technologies and a funding strategy, including proof of attempting to find funding for the next phase and failing to do so. The management of the bridge fund and the sources of financial backing would need to be identified by the appropriate government agencies, with the DST's oversight role in innovation support making it the best placed department to lead on these efforts. It is recommended that private sector funding be used where possible, to more closely integrate private firms into the process and assure the financial sustainability of the project in a resource-constrained fiscal environment.

Implementation plan milestones	Timeline (months)					
	6	12	18	24	30	Ongoing
Outreach to funding partners						
Appropriation of funding						
Request for proposals						
Selection of projects						
Review of projects and selection processes						
Ongoing recurrent of steps 4 – 5						

Priority intervention 3

ADMIN
WORKSTREAM

Identification of priority clusters of platform biochemicals

LEAD AGENCY | the dti	SUPPORT | DST	TIME | 21 months	COST | Low

Both feedstock matching and the provision of bridge funding benefit from being relatively neutral in their applicability to various biomaterial technologies, with broad relevance to a number of different types of biomaterials. However, core support to promote industry competitiveness and bring key technologies to market will require identifying priority areas that guide government policy. These areas are needed because of the sheer scope of the biomaterials industry, where there are multiple feedstocks, technologies, conversion techniques, steps of processing, and end uses. The vast diversity of biomaterials can make for unwieldy policymaking and requires a more focused approach.

This can be facilitated by selecting a few key product areas to focus on but doing so comes with risks. Government is often poorly placed to identify promising new technologies in the early stages when they most need support. Structural problems also risk undermining selective focus. Most notably, creating demand for adequately scaled feedstocks entails a large amount of processing, and small niche products often do not have the scale to crowd in the needed inputs.

As such, it is suggested that focus areas be identified with the emphasis on high potential intermediary chemicals rather than directly on biomaterials. Potential in this case would be defined by the capacity of these chemicals to be used for higher value-added applications – most notably plastics and composites – but also to feed into other offtake markets (across a wide range of industries that use chemicals), close market gaps, displace imports, or simply compete on a relatively equal footing with traditional plastics.

While the selection of targeted chemical clusters would need to be undertaken by a more comprehensive process of oversight and discussion, an illustrative sample set of clusters can be found in Box 1.

Box 1: A sample set of biomaterial clusters

1. **Ethylene cluster:** Ethylene is a vital component in many plastics, notably PET. South Africa's plastics industry is almost entirely reliant on the import of ethylene, providing opportunities for import substitution. Ethylene chemicals also share a production process with bio-ethanol and have the potential to leverage off biofuel production.
2. **Butane cluster:** 1,4-butanediol is used to produce PBT plastics, while butanol and n-butanol have a range of uses as chemicals, such as in the "manufacture of acrylates, used in paints, detergents, adhesives and textiles". Feedstock for the cluster is varied, and can include sugar, starches and waste.
3. **Acid cluster:** Lactic and succinic acids, which are used to produce PLA and PBS plastics respectively. Lactic acid can also be used to make lactate esters, which are used in many industries; succinic acid similarly has various applications. Succinic acid also has important linkages to the butane cluster since it can be produced by processing n-butane, and PBS plastics can be made by using butanediol and succinic acid. Both derive from sugars and some other feedstocks.

Clusters can be used in numerous ways and at different levels of intensity of policy support. At the low end, clusters could be purely informative, acting as a guideline for making decisions on other mechanisms, such as financing and firm support. On the more ambitious front, clusters could be the subject of specific, focused support in terms of improving research funding, building pilot bio-refineries producing the target chemicals, and inviting bids for funding support to firms operating in this field.

Implementation plan milestones	**Timeline (months)**			
	6	12	18	24
Formation of biomaterials expert reference group	■			
Draft of target biochemicals clusters		■		
Industry engagement and feedback on selected biochemical			■	
Creation of reference guide, and integration of targets into existing policy documents (such as the Industrial Policy Action Plan (IPAP), sectoral targets)				■

Priority intervention 4

INNOVATION
WORKSTREAM

Development of a biomaterials centre of excellence

LEAD AGENCY | CSIR	SUPPORT | DST, universities	TIME | 42 months	COST | High

While the South African community of biomaterials researchers is small and close-knit, the enabling infrastructure for that research is fragmented across centres and universities around the country. Many of the instruments are multi-use and are part of broader laboratory or testing structures. While this backbone of infrastructure plays a vital role in strengthening the biomaterials space, its fragmentation adds time and cost barriers to efforts to develop new technologies.

A common approach to solving this problem would be creating a centre of excellence in biomaterials. While the traditional approach under the DST-NRF centres of excellence programme is to create virtual centres, which are effectively coordinating bodies for the research ecosystem, a more comprehensive approach would be to create a physical centre that is equipped with appropriate instruments, focused primarily on testing.

Four key milestones are important in building the centre of excellence. First would be establishing a traditional, virtual centre of excellence. This would begin building the appropriate institutional infrastructure for further work and would have positive spill-over benefits for other initiatives, such as improving training of biomaterials experts (discussed below). This centre should be based on existing infrastructure, of which the CSIR's Biorefinery Industry Development Facility would appear to be the most suitable candidate.

Second would be a survey by the centre of excellence, creating a catalogue of facilities that can perform testing of biomaterials, and detailing what tests must be completed.

This would lay out the full spectrum of tests needed for new biomaterials, which can include a vast array of tests on strength, flexibility, heat-resistance, biodegradability, toxicity, and many others. Technical testing needs can be supplemented by forming a better understanding of the needs for support for prototyping, feasibility studies, business model development, manufacturing, and demonstration.

Third, the centre would then need to begin a process of, as much as possible, centralising its resources to a single testing facility or handful of testing facilities. This would need to be guided by the scoping study above, and perhaps facilitated by additional support from the state, whether through funding to buy appropriate equipment, or through partnerships with state bodies like the South African Bureau of Standard (SABS).

Fourth would be the development of a programme to provide ongoing support to entrepreneurs and innovators with new biomaterials products or new applications for existing technologies. Emphasis should be on both technology-development (testing, design, etc.) and commercialisation (marketing support, network development, etc.). This could, in the long term, be supported by some form of local certification scheme, but that would need to be assessed once the initiative is established.

Additional supporting work on a centre of excellence could be facilitated by greater understanding of similar centres elsewhere in the world. Centres of excellence (or similar centres) are common across the world, and partnerships or learning exercises with these centres could help in setting up the South African centre.

Implementation plan milestones	Timeline (months)				
	6	12	18	24	Ongoing
Establishment of BIDF as DST-NRF virtual Centre of Excellence					
Survey cataloguing available equipment and identifying testing needs					
Guided by scoping study, process of centralising					
Ongoing support to entrepreneurs for testing, product prototypes, etc.					

Priority intervention 5

COMPETITIVENESS
WORKSTREAM

Reinforcing support to pilot biorefineries

LEAD AGENCY | CSIR	SUPPORT | DST, the dti	TIME | 60 months	COST | High

The domination of fossil fuel-derived products continues to hamper efforts to carve more sustainable growth pathways. Currently, bio-based feedstocks cannot compete with the abundance of cheap fossil-fuel based inputs for composites and plastics. However, stringent environmental legislation and the global transition away from traditional plastic products will contribute to the search for alternative feedstocks. With major companies, such as Coca-Cola, Toyota, Mercedes and Woolworths, committing to, and actively seeking, bio-based alternatives, the demand for petroleum-based chemicals and plastic is increasingly uncertain. Similarly, increasing awareness of sustainability and environmental issues is rapidly changing consumer preferences.

Biorefineries allow for the extraction of materials, such as cellulose, fibres, lignin, starches and biogas. These materials then undergo refining to culminate in inputs that feed into biocomposite, biochemicals and bioplastics production, as well as energy generation. South Africa generates 26 million tonnes of second-generation waste residues emanating from agricultural and forestry biomass residues. Biorefineries can aid the creation of a sustainable, waste-free South African bioeconomy. Furthermore, biorefinery strategies can be implemented in existing production plants in South Africa.

Although the government has identified lightweight materials as a critical area for growth, substantial room for further policy support remains. Nevertheless, the DST has identified five biorefinery opportunities for the country based on the following inputs and areas: forestry, sugar, algae, non-food crop plant oils and microbial biorefineries, with a focus on biorefinery development in rural areas. Initiatives are under way to make use of agricultural and livestock waste in South Africa. The CSIR has launched a biorefinery in Durban. The facility is overseeing pilot projects using pulp and paper waste as well as chicken feathers from the poultry sector to extract materials for high-value chemicals and fibres for biomaterials.

Life cycle assessments have indicated that aside from environmental and economic efficiency gains, biorefineries contribute to local social development and transformation through the creation of jobs and support for small-scale farmers. Maximising the potential of waste residues from the forestry and sugar industries, for example, could help stimulate the creation of biorefineries in South Africa. Sappi is the world's largest producer and exporter of dissolving wood pulp (DWP). Strengthening support for biorefineries could help the local beneficiation of DWP, while revitalising agricultural sectors and improving socio-economic development in South Africa.

Biorefineries can be implemented through a top-down or bottom-up approach. With a top-down approach, a biorefinery is created to make use of feedstocks such as biomass and associated waste residues. The bottom-up approach involves the expansion and integration of biorefineries into existing biomass production industries, such as sugar or pulp and paper processing. Biorefineries can also be integrated into industries relying heavily on crude oil or fossil fuels inputs, such as Sasol's petrochemical production facilities.

Strengthening support for biorefineries is a priority if efforts to transition away from the dependence on petroleum-based inputs are to materialise in the country. Increased collaboration between DST, DAFF, DEA, the dti and supporting agencies, such as the CSIR and IDC, and the private sector, would foster the development and expansion of biorefineries in South Africa, by ensuring that mechanisms for the growth and use of feedstocks are made available. Public and private sector funding for securing appropriate technologies required for biorefining would help accelerate uptake and implementation.

Furthermore, since the forestry-based biorefinery is operational, additional support should be provided to the remaining four biorefinery initiatives proposed by the DST. Feasibility studies and business model development should be prioritised to ensure the viability of biorefineries for the identified sectors.

Implementation plan milestones	Timeline (months)							
	6	12	18	24	30	36	42	48
Maintain existing support								
Undertake feasibility studies for sugar, non-food crop and microbial biorefineries	■	■						
Develop business models for sugar, non-food crop oil, and microbial biorefineries		■						
Further engagement with sugar industry to expand production by integrating biorefineries into existing plants		■						
Engage with stakeholders in the agricultural sector		■						
Support for the creation of sugarcane biorefinery capacity			■	■				
Support for the creation of non-food crop oil biorefinery capacity					■	■		
Support for the creation of microbial biorefinery capacity							■	■

Priority intervention 6

COMPETITIVENESS WORKSTREAM

Development of a task team to lead on industry partnerships

LEAD AGENCY | the dti	SUPPORT | CSIR, IDC	TIME | 55 months	COST | Low

The private sector will have to be the ultimate custodian of biomaterials technologies, ramping them up to production and driving the market for the products. At present, the South African biomaterials industry is largely state-led, with the government playing the central role in product development, training technicians, support to feedstock producers, and the establishment of biorefineries. The main area in which the government cannot stand in for the private sector is in creating a market for biomaterials.

Existing efforts have shown that having private sector off-take partners can be vital to the success of a project. The IDC's kenaf biocomposites project found initial success through its partnership with Mercedes-Benz, which underpinned the subsequent creation of the rest of the value chain, from farm to processing to end use. The global Bio-PET industry was driven substantially by Coca-Cola's PlantBottle efforts, and similar commitments by major multi-nationals hold significant potential for suitably prepared entrants to displace traditional materials from global value chains.

The challenge, however, is that the centrality of end-demand for bioplastics makes it difficult to develop scale and efficiencies in the industry prior to a commitment from industry clients, which in turn makes it hard to develop clients themselves. The state can help, to some extent, by acting as an anchor client through procurement or by offering incentives to nascent biomaterials industries. A lower-cost and more sustainable route would be to support building partnerships with business.

This can be facilitated by the creation of a structure aimed specifically at marketing partnerships with major plastics users – such as retailers (like Pick n Pay, Checkers, Woolworths), consumer goods producers (such as P&G, Unilever), and processed-food producers. The structure would need to be flexible and relatively independent. A multi-departmental task team may face coordination challenges that could limit its ability to play this role, but a special unit housed in any of a number of institutes (IDC, the dti, NCPC, InvestSA, Proudly SA, etc.) could offer a single point of contact for firms looking to green their packaging and plastics usage.

Implementation plan milestones	**Timeline (months)**				
	6	12	18	24	Ongoing
Appropriation and recruitment for an industry support team	■				
Development of relationship with core manufacturing team: producers, feedstock partners, and state partners (IDC, etc.)		■	■		
Roadshow of visits to major plastics users - including retailers, etc.		■	■		
Launch of major partnership initiatives				■	
Ongoing problem solving and marketing support					■

Secondary intervention 1

INNOVATION
WORKSTREAM

Promote training programmes at universities and colleges

LEAD AGENCY |	SUPPORT | DHET, universities	TIME | 27 months	COST | Low

Biomaterials cross specialised education areas – including agro-science, bio-science, chemistry, and materials sciences – almost all of which are in short supply at the domestic level and exist in a highly competitive labour market environment. Developing appropriate skills for the biomaterials industry requires promoting interdisciplinary training that links the various fields involved in biomaterials into overarching courses or accreditations. A dedicated biomaterials degree would be too narrow and unlikely to attract graduates to a still-developing job market, but support initiatives should still be considered. This can include scoping and marketing existing training options for a career in biomaterials, and the development of a template, which can be adopted by interested universities, for biomaterials courses.

Implementation plan milestones	Timeline (months)				
	6	12	18	24	30
Engagement with university and college departments and scoping of existing capacity	■				
Creation of 'A career in biomaterials' pamphlet		■			
Development of model course structure			■		
Promotion of programme at colleges and university				■	■

Secondary intervention 2

INNOVATION WORKSTREAM

Reinforcing existing research infrastructure

LEAD AGENCY | All	SUPPORT | All	TIME | n/a	COST | n/a

As already mentioned, funding for innovation generally is always scarce, and newer technologies often struggle to find adequate support. While the primary recommendation is the creation of a bridge fund, equally important is maintaining what already exists. The efforts of the CSIR centre of competence in biocomposites, the CSIR and DST's work on biorefinery, and the various university initiatives are essential for laying the foundations upon which the industry can be built. The funding that supports these initiatives would need to be maintained (in real terms), and ideally set to a long-term funding vision. This vision would clarify financing ranges for a long period, to facilitate planning and additional work at the various centres, as well as build the capacity to develop partnerships with the private sector. This intervention is limited by budgeting cycles, and a clear commitment on the role of biomaterials in the innovation agenda would help stabilise the existing infrastructure across the uncertainty of the budget process.

Secondary intervention 3

COMPETITIVENESS WORKSTREAM

Awareness programmes and promoting the green premium

LEAD AGENCY | DEA	SUPPORT | the dti, DAFF	TIME | 12 months	COST | Mid

In the short term, competitiveness deficiencies in biomaterials can be somewhat lessened by promoting the "green premium" – the environmentally conscious nature of the production of biomaterials. Thus far, most of the major commercial successes for biomaterials – such as Coca-Cola's bio-PET programme – have been driven by promoting the green premium. While the private sector is best placed to assess the environmental sensitivity of their client base, and respond with appropriate marketing, government can help by publicising the broader concepts involved, notably around the risks of traditional plastics. Several initiatives are available to do so. Labelling requirements, including the creation of special signage for bio-plastics, would help empower consumers to distinguish between otherwise identical products. Marketing campaigns, particularly those that include lifecycle thinking and build awareness about multiple production processes, would help in distinguishing biomaterials from their carbon-based counterparts. Other approaches, such as industry partnerships or educational initiatives, are available and would need to be led on an ongoing basis by a set agency, of which the industry support team (established in priority intervention 6) would be most suitable.

Implementation plan milestones	**Timeline (months)**		
	6	12	18
Establishment of marketing capacity in industry support team	■		
Integration of biomaterials into existing green branding		■	
Production of logo/symbol for green plastics and chemicals			■

Secondary intervention 4

COMPETITIVENESS WORKSTREAM

Creating new standards for biomaterials and feedstock

LEAD AGENCY | DAFF	SUPPORT | DEA, SABS	TIME | 55 months	COST | Mid

Feedstock categorisation refers to a broad category of activities that assure that feedstocks are of an adequate quality for use in biorefining, and that they are handled and stored appropriately. Developing standardisation programmes for categorisation, and then expanding that into standards for the biomaterials themselves, would help create a consistent quality measure for the industry. Good quality standards do already exist, both internally in major companies, and through the work of the Roundtable on Sustainable Biomaterials (RSB). The RSB certifies for a number of its own standards, including for biofuels and smallholder farms, but most importantly with the RSB-STD-02-001 standard for the certification of Bio-Products. While the standard would need to undergo a review and consultation process, it is a good starting point for the development of local standards for the industry as a whole. More specific standards may be needed for waste in particular. This could be a general set of standards but could simply be a qualification standard for participation in the government matching programme (priority intervention 1), which would assure the reliability of the matching programme.

Implementation plan milestones	Timeline (months)					
	6	12	18	24	30	36
Outreach to RSB, and feedstock producers; and formation of working group	■					
Study to identify standards gaps		■				
If necessary, development of new feedstock standards			■	■		
Assistance to accreditation firms to equip them for testing to new standards				■		
Support to feedstock firms in meeting new standards				■		
If necessary, development of manufacturing standards					■	■
Assistance to accreditation firms to equip them for testing to new manufacturing standards						■
Support to feedstock firms in meeting new manufacturing standards						■

Secondary intervention 5

COMPETITIVENESS WORKSTREAM

Adapting existing standards for biomaterials

LEAD AGENCY | SABS	SUPPORT | the dti	TIME | 12 months	COST | Low

Most product standards will not need adaptation for biomaterials. Bioplastics and composite materials often have consistent chemical inputs to traditional materials, and should not differ substantially from existing standards. No compulsory specifications exist for plastics or chemicals products, although some do exist for products of both industries, but again are unlikely to be affected. Accordingly, efforts should be directed to ongoing communication with the SABS and the National Regulator for Compulsory Specifications (NRCS). A contact person, perhaps based at the dti, should be appointed to play a dual role. First would be to provide information on biomaterials to the two organisations, both in the form of a briefing on the new industry and as an ongoing point of reference for further queries. Second would be to act as a contact point for industry, who could respond to issues regarding certification to key standards. Should issues arise, the point person could then communicate directly with the SABS and the relevant technical committee to close gaps in the standards coverage.

Implementation plan milestones	**Timeline (months)**	
	6	12
Outreach to SABS		
Selection of key Technical Committees potentially affected by biomaterials		
Presentation to Technical Committees to raise awareness of biomaterial requirements		

Secondary intervention 6

COMPETITIVENESS
WORKSTREAM

Facilitating cross-border movement of feedstock

LEAD AGENCY | | the dti	SUPPORT | SARS, DAFF	TIME | 54 months	COST | Low

While the short-term focus must be on using South African feedstock sources, unlocking agricultural waste in the region would present an important future source of feedstock for the nascent South African industry, and one that may face an array of trade barriers. While formal tariff barriers apply to appropriate feedstocks, many biomass materials require rapid processing to remain viable for use in biomaterials. Long wait times at the border and slow movement of freight may be prohibitive in the short term. Support for the development of regional linkages should be led by the matching programme (established as priority intervention 1) and supported by a team of relevant agencies working in trade (such as the dti, South African Revenue Service (SARS), DAFF, and the NRCS).

While long-term changes may unlock this waste, in the medium term, the focus should be on supporting the development of regional biorefineries that facilitate primary processing of feedstocks into a form that is easier and more stable to transport. In the near term, this can be facilitated by engagement with high-potential neighbouring counties – including major sugar producers like Swaziland and Zambia – on their planning processes around bio-refining, and the exploration of potential collaboration with existing South African capacity.

Implementation plan milestones	Timeline (months)								
	6	12	18	24	30	36	42	48	54
Registration of one or two pilot feedstock providers from Southern African Customs Union (SACU) countries	■	■							
Formation of cross-border task team with DAFF, SARS, Health, and the dti		■							
Support to regional feedstock providers and monitoring of barriers			■						
Reporting on experiences to task team				■					
Refinement of process, and support to further consignments from regional providers					■				
If appropriate, support to regional biorefineries						■	■	■	■

Secondary intervention 7

COMPETITIVENESS WORKSTREAM

Facilitate engagements with existing industrial policy

LEAD AGENCY | | the dti	SUPPORT | Invest. agencies	TIME | 33 months	COST | Variable

As a cross-cutting intervention, biomaterials need to take advantage of the full range of industrial policy tools now on offer. This can include the Special Economic Zone project (including eco-industrial parks and the green economy-focused Atlantis SEZ), the black entrepreneur's fund, the innovation hubs system, the development of agriparks, the Blue Economy Phakisa; the Waste and Chemicals Phakisa, and a range of other initiatives. For this to work, biomaterials will have to be integrated into the dti planning process and the work of product desks, and supporting contacts created in the dti for government partners or firms seeking assistance.

Implementation plan milestones	Timeline (months)					
	6	12	18	24	30	36
Formation of internal dti liaison group for biomaterials	■					
Ongoing meetings on a quarterly basis - first meeting		■				
Ongoing meetings on a quarterly basis - second meeting				■		
Ongoing meetings on a quarterly basis - third meeting						■

Secondary intervention 8

Further research and ongoing support

ADMIN
WORKSTREAM

LEAD AGENCY | CSIR	**SUPPORT | PAGE, TIPS**	**TIME | n/a**	**COST | n/a**

Finally, this plan could be strengthened by additional research, which was beyond the scope of this project. Research could include: a thorough scoping of international biomaterials initiatives, additional technical background on the technology, further analysis of industry's infrastructure and human resource needs, integration of biomaterials into agricultural policy and planning, an exploration of regional dynamics (notably around the region as a supplier of feedstock), and details of how to strengthen links between public and private parts of the sector.

4. IMPLEMENTATION STRATEGY

Using the action plan

Implementing the action plan will require specific planning and coordination by the government agencies assigned to the various action items. To aid this planning process, a draft implementation plan has been compiled. This plan should not be considered in any way final, but rather as a guideline to the sequencing and linkages between the various workstreams.

Elements of the implementation plan are integrated into the preceding details of the action plan. These elements include responsible agencies, estimated timespan, cost range, workstream, and key milestones. The milestones are a set of key targets that should be achieved in sequence and form the base of the implementation plan.

The full implementation plan can be found in the attached flowchart in Annex 1.

The implementation plan is divided in two ways. First is a set of workstreams, which are colour coded as defined below. The workstreams target key gaps according to the barriers identified above (feedstock, innovation, and competitiveness) and the administrative requirements that underpin them.

Figure 8: Implementation plan workstreams

- **COMPETITIVENESS WORKSTREAM**
- **FEEDSTOCK WORKSTREAM**
- **INNOVATION WORKSTREAM**
- **ADMINITRATION WORKSTREAM**

While each of the four workstreams targets a specific set of problems, the implementation of the action items is linked, particularly via a set of institutional arrangements that oversees the action plan. This includes four new structures – a liaison committee in the dti, an industry partnership team developed by the dti and DAFF, a feedstock matching team in the NCPC, and a biomaterials expert committee overseen by DST. The remaining initiatives are overseen by existing programmes, namely the Technology Innovation Agency and the CSIR's Biorefinery Development Facility.

These institutions oversee six branches of the implementation plan and are each assigned a set of milestones that should be achieved sequentially. These six branches are detailed below.

Branch 1: the dti biomaterials liaison group

A collection of three initiatives - integration into existing industrial policy, adapting standards for biomaterials, and creating new standards for feedstock and unique materials - require ongoing responsive policy making that answers the evolving needs of the biomaterials sector. The three action items are therefore bundled under a liaison group established in the dti. The liaison group will meet on a regular basis, and will include representatives from the industry, the relevant dti sector desks, the dti's technical infrastructure team, technical bodies such as SABS, and any other relevant players, such as the Roundtable on Sustainable Biomaterials.

The liaison group will undertake three workstreams. First will be to offer ongoing advice on and assistance in accessing industrial policy tools, including incentives, investment support, and assistance in overcoming regulatory barriers. There is no set work plan for this initiative, but rather ongoing meetings and assessment as needs arise.

Second is a programme of outreach to SABS, to make standards makers aware of biomaterials and the evolving needs of new product standards. This will primarily require the identification of relevant technical committees, and the presentation of details on the industry to those committees.

Third, and the most intensive workstream, will be to attempt to establish new standards, with a focus on feedstock categorisation. This work would need to be guided by a study aimed at identifying standards gaps, as well as partnership development with existing standards creators like the RSB. In the long term, support to make testing accessible and cost effective for feedstock producers and manufactures may be needed. Partnership with established quality promotion programmes, such as the Global Quality and Standards programme of the United Nations Industrial Development Organization (UNIDO), could help streamline implementation.

EXISTING INDUSTRIAL POLICY

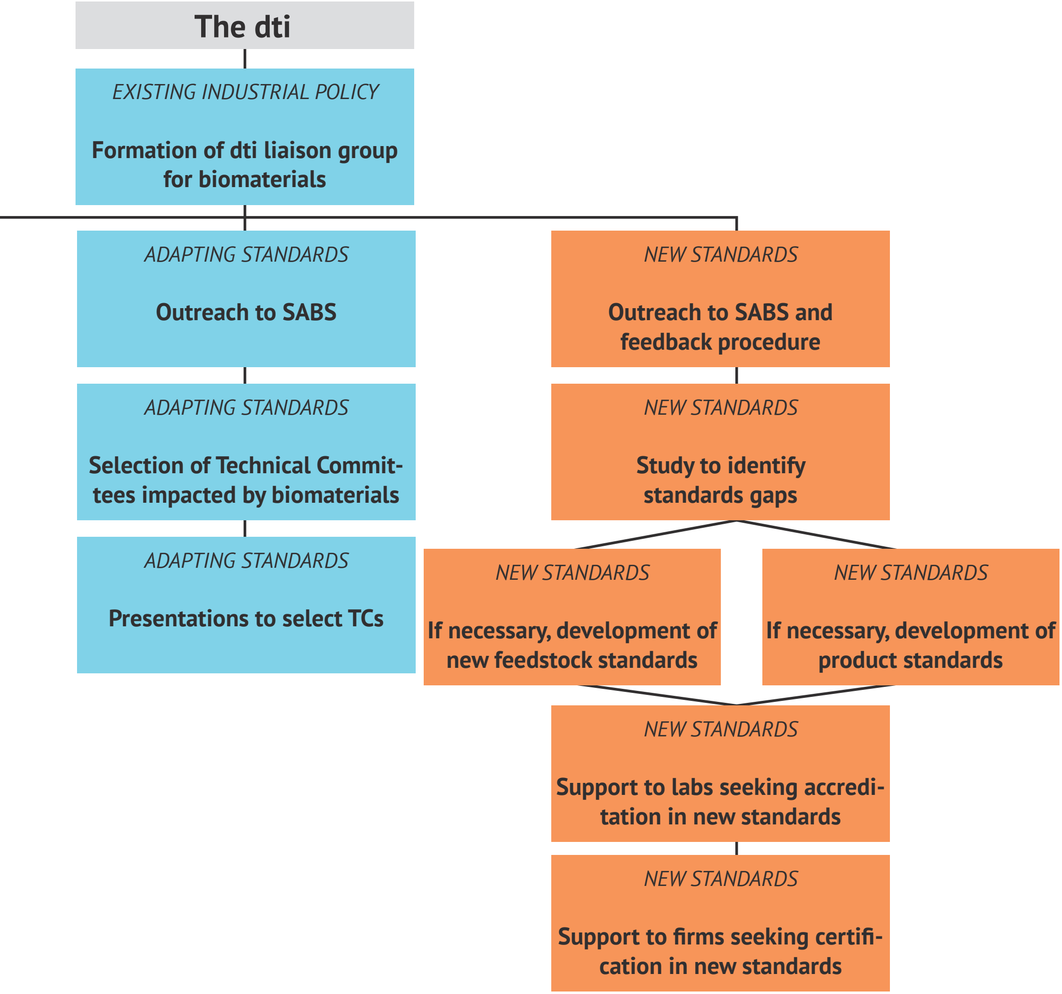
Ongoing meetings on an annual basis – first meeting

EXISTING INDUSTRIAL POLICY

Ongoing meetings on an annual basis – second meeting

EXISTING INDUSTRIAL POLICY

Ongoing meetings on an annual basis – third meeting


The dti
EXISTING INDUSTRIAL POLICY
Formation of dti liaison group for biomaterials
ADAPTING STANDARDS
Outreach to SABS
ADAPTING STANDARDS
Selection of Technical Committees impacted by biomaterials
ADAPTING STANDARDS
Presentations to select TCs
NEW STANDARDS
Outreach to SABS and feedback procedure
NEW STANDARDS
Study to identify standards gaps
NEW STANDARDS
If necessary, development of new feedstock standards
NEW STANDARDS
If necessary, development of product standards
NEW STANDARDS
Support to labs seeking accreditation in new standards
NEW STANDARDS
Support to firms seeking certification in new standards

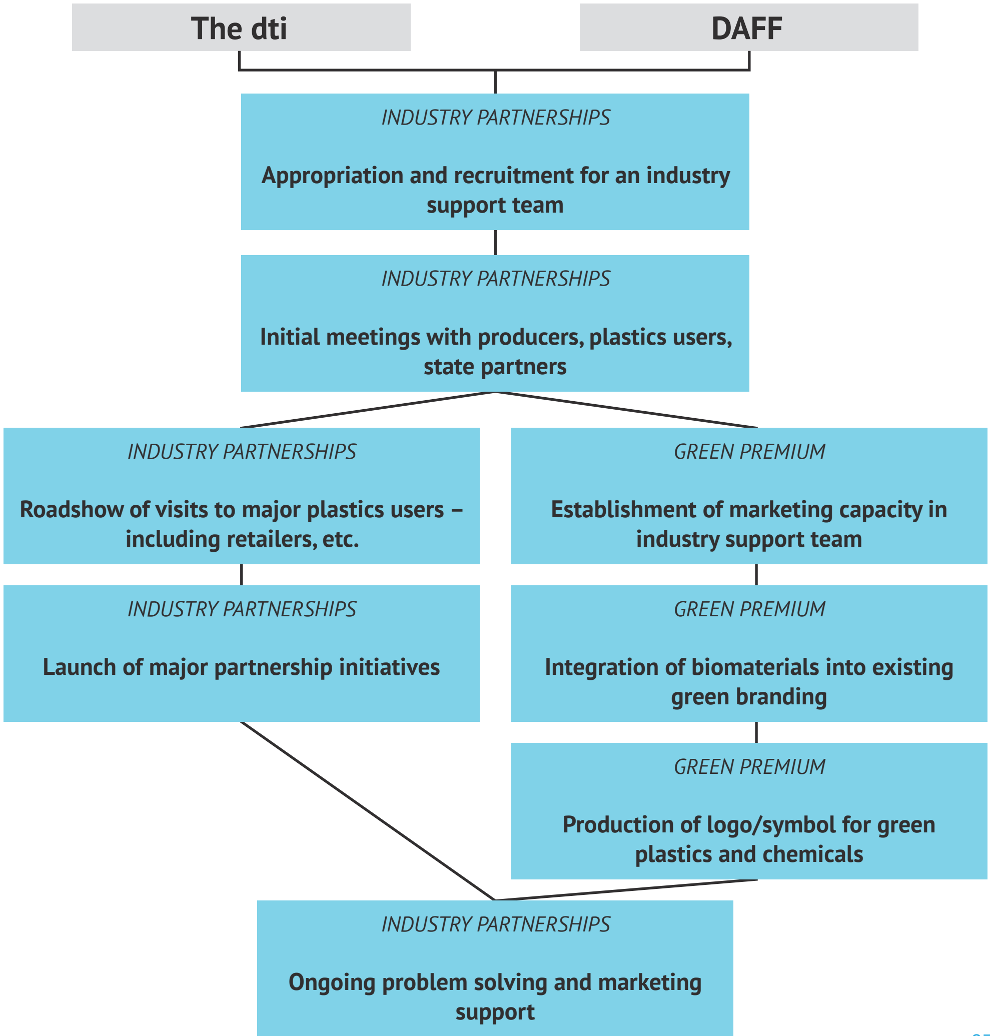
Branch 2: Industry partnership programme

The development of offtake opportunities and demand creation is perhaps the essential change required for the development of a biomaterials value chain. This would require the creation of established capacity that can work on a consistent basis to partner with end-users of biomaterials and match them with local production capacity.

The location of the industry support team should be decided by government, based on the availability of resources and capacity. Ideally, the industry support team should be placed in an agency or division that has experience working with the private sector and maintains influence with policymakers. The dti's InvestSA may be a suitable candidate, but for the time-being the implementation plan assigns responsibility to a collaborative effort by the dti and DAFF.

The work of the team will need to involve both direct partnership development and the hosting of roadshows to major end-users. Focus should be on major users, such as retailers, the packaging industry, the automotive industry, and others as identified by the team; and the development of two or three anchor clients to support the development of initial commercial value chains.

Once work is advanced on partnership development, more general support can be offered through the creation of branding and marketing that promotes the environmental impact of using biomaterials, as opposed to traditional fossil fuel-based plastics, chemicals or composites. This can include the development of branding – such as a bioplastics logo – as well as general marketing that informs the public about the distinction between biomaterials and other production processes.

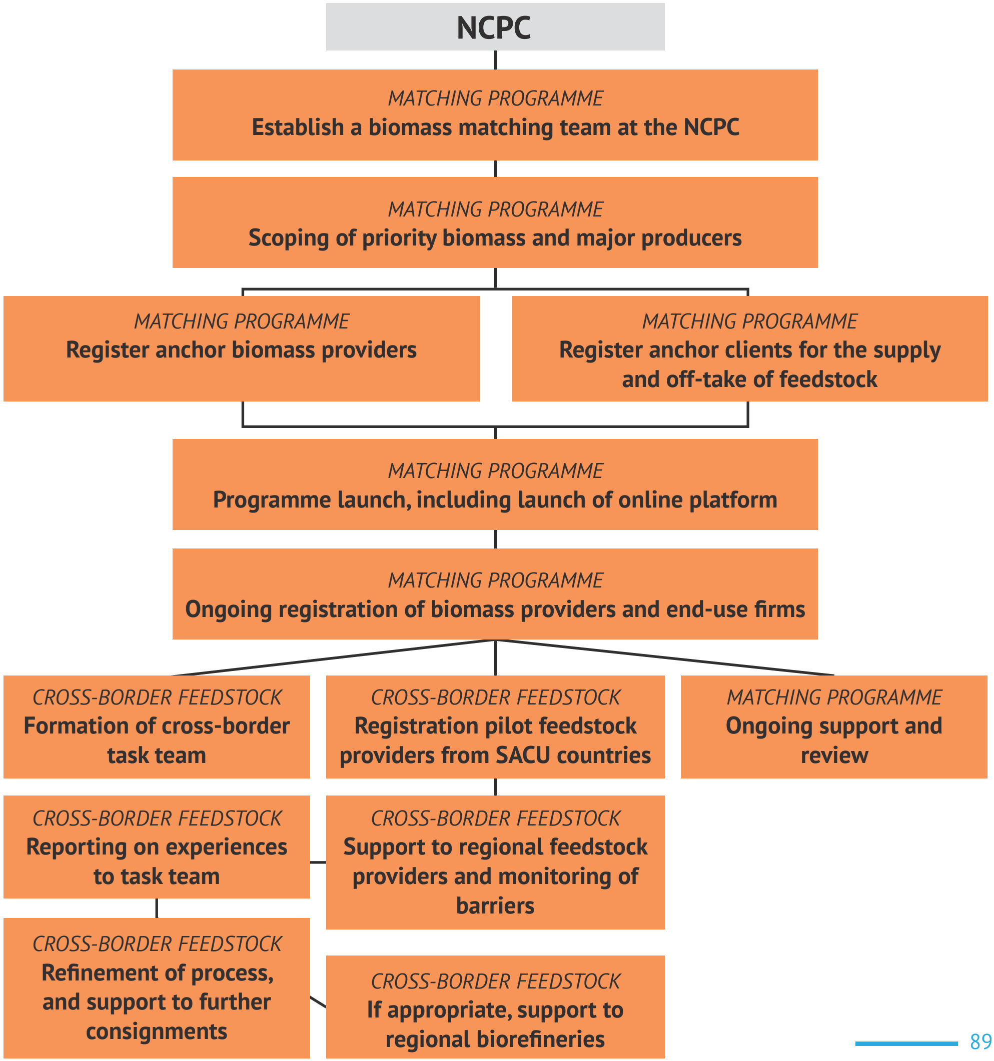

The dti
DAFF
INDUSTRY PARTNERSHIPS
Appropriation and recruitment for an industry support team
INDUSTRY PARTNERSHIPS
Initial meetings with producers, plastics users, state partners
INDUSTRY PARTNERSHIPS
Roadshow of visits to major plastics users – including retailers, etc.
GREEN PREMIUM
Establishment of marketing capacity in industry support team
INDUSTRY PARTNERSHIPS
Launch of major partnership initiatives
GREEN PREMIUM
Integration of biomaterials into existing green branding
GREEN PREMIUM
Production of logo/symbol for green plastics and chemicals
INDUSTRY PARTNERSHIPS
Ongoing problem solving and marketing support

Branch 3: NCPC feedstock programme

The National Cleaner Production Centre (NCPC) will lead on the creation of a feedstock programme and, based on the experience with that programme, launch an initiative to support the cross-border movement of feedstock. The NCPC has extensive experience in industrial symbiosis, and will employ a similar process, as outlined in priority intervention 1.

The milestones outlined here are based on an initial focus on linking a handful of anchor firms on both the feedstock side and basic processing of either chemicals or more advanced biomaterials. On the feedstock side, this can include major producers of more established feedstocks, notably in the wood pulp and sugar industries, with similar linkages on the manufacturing side.

The cross-border promotion of feedstock is a late-stage intervention that should only be considered once an established set of linkages have been established and the industry has begun to develop. The cross-border strategy should, at first, follow the same approach as the rest of the matching programme, only with partners in countries outside South Africa. Transactions will, however, be closely monitored, and barriers identified and reported back to a cross-border task team made up of the team from NCPC and the dti's internal liaison group. Based on the experience of cross-border movement, the task team will work to overcome barriers, either through changes to remove established regulatory impediments or through the creation of specific support measures to enable logistics despite those barriers.


NCPC
MATCHING PROGRAMME
Establish a biomass matching team at the NCPC
MATCHING PROGRAMME
Scoping of priority biomass and major producers
MATCHING PROGRAMME
Register anchor biomass providers
MATCHING PROGRAMME
Register anchor clients for the supply and off-take of feedstock
MATCHING PROGRAMME
Programme launch, including launch of online platform
MATCHING PROGRAMME
Ongoing registration of biomass providers and end-use firms
CROSS-BORDER FEEDSTOCK
Formation of cross-border task team
CROSS-BORDER FEEDSTOCK
Registration pilot feedstock providers from SACU countries
MATCHING PROGRAMME
Ongoing support and review
CROSS-BORDER FEEDSTOCK
Reporting on experiences to task team
CROSS-BORDER FEEDSTOCK
Support to regional feedstock providers and monitoring of barriers
CROSS-BORDER FEEDSTOCK
Refinement of process, and support to further consignments
CROSS-BORDER FEEDSTOCK
If appropriate, support to regional biorefineries

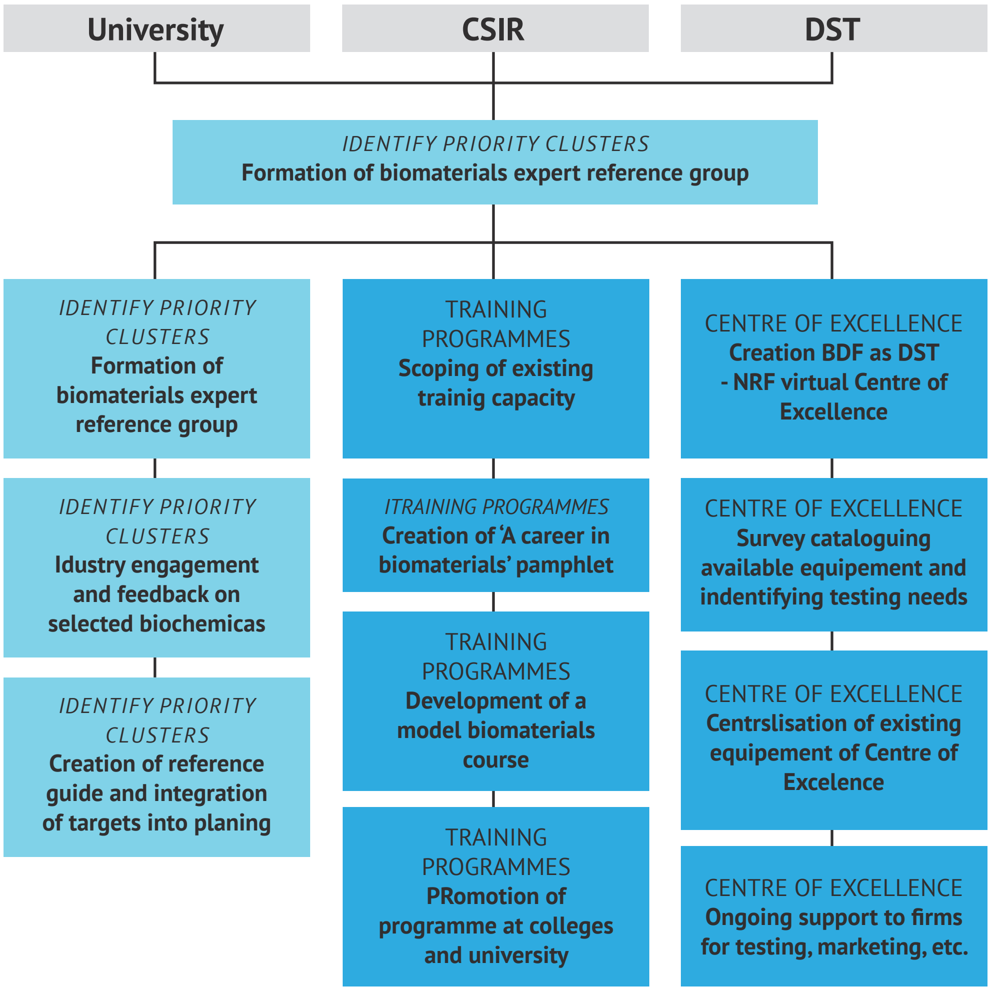
Branch 4: Biomaterials expert group

A biomaterials expert reference group, made up mainly of university professionals, the CSIR, and the DST, will provide expert technical guidance and lead on action items that require more technical support. The expert reference group will have three workstreams.

The first will be to lead on the identification of priority biochemicals, and to take the identified chemicals through a validation process with industry and other stakeholders.

Second, will be to conduct a scoping study on biomaterials training initiatives, and identify what exists and what gaps require further investment. While the expert reference group likely will not have capacity to create training programmes, it can offer support by both promoting existing programmes and offering guidance on the creation of future programmes. The milestones for the creation of a brochure or similar reference materials, and the creation of a draft model course syllabus, will help achieve these ends.

Finally, and most ambitiously, the CSIR will lead on an expert group initiative to develop a Centre of Excellence. The Biomaterials Industry Development Facility in Durban should serve as a basis from which to develop further capacity, guided by a relevant scoping study, and involving the creation of linked testing capacity. Further development focused on creating marketing support for biomaterials firms should follow once centralised testing infrastructure is established and the centre of excellence is up and running.


University
CSIR
DST
IDENTIFY PRIORITY CLUSTERS
Formation of biomaterials expert reference group
IDENTIFY PRIORITY CLUSTERS
Formation of biomaterials expert reference group
IDENTIFY PRIORITY CLUSTERS
Idustry engagement and feedback on selected biochemicas
IDENTIFY PRIORITY CLUSTERS
Creation of reference guide and integration of targets into planing
TRAINING PROGRAMMES
Scoping of existing trainig capacity
ITRAINING PROGRAMMES
Creation of 'A career in biomaterials' pamphlet
TRAINING PROGRAMMES
Development of a model biomaterials course
TRAINING PROGRAMMES
PRomotion of programme at colleges and university
CENTRE OF EXCELLENCE
Creation BDF as DST - NRF virtual Centre of Excellence
CENTRE OF EXCELLENCE
Survey cataloguing available equipement and indentifying testing needs
CENTRE OF EXCELLENCE
Centrslisation of existing equipement of Centre of Excelence
CENTRE OF EXCELLENCE
Ongoing support to firms for testing, marketing, etc.

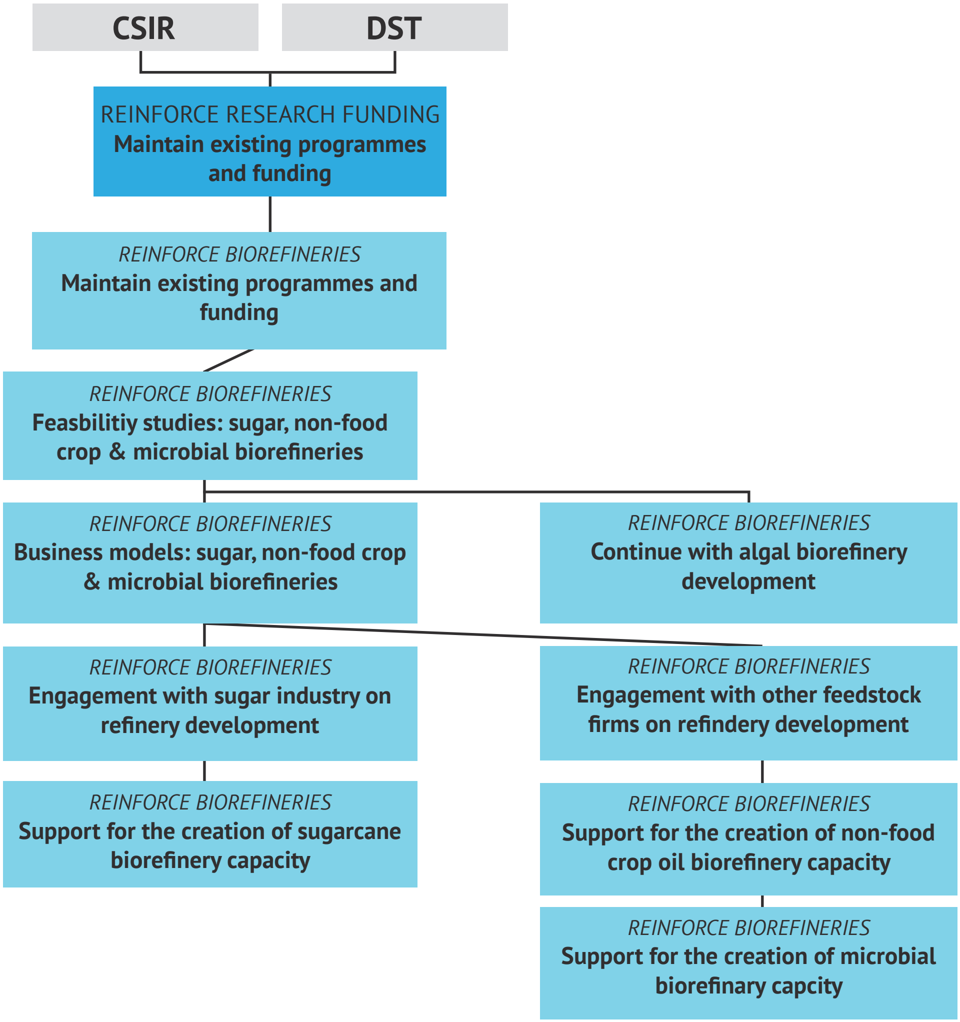
Branch 5: CSIR biorefinery development

The CSIR and DST will similarly maintain work on the development of biorefinery capacity. The first crucial step will be to maintain what already exists, and then to expand into new or already planned areas. In the short term, focus should be on the development of both feasibility studies and the relevant business cases.

Focus should specifically be on two streams. First is a sugarcane-focused biorefinery, which would aim to complement the wood pulp biorefinery, and complete the development of capacity in the two major high-potential feedstock areas.

Second is to expand into more innovative feedstock streams, notably in non-food feedstocks, and then into more innovative types like algae and microbial biorefinery.

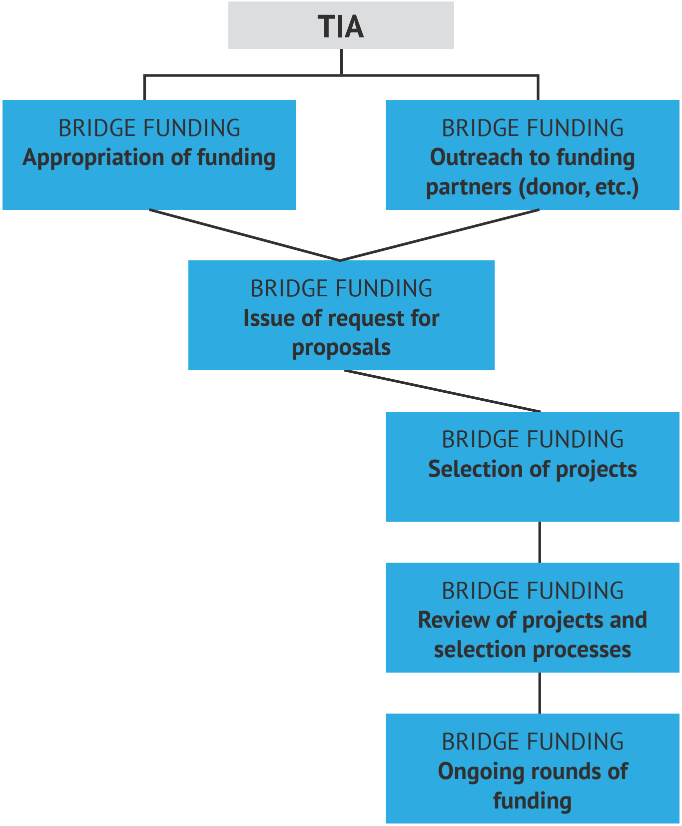
Many of these initiatives are already ongoing at the DST, and simply consolidating what exists will form a solid base for new initiatives to build on.


CSIR
DST
REINFORCE RESEARCH FUNDING
Maintain existing programmes and funding
REINFORCE BIOREFINERIES
Maintain existing programmes and funding
REINFORCE BIOREFINERIES
Feasbilitiy studies: sugar, non-food crop & microbial biorefineries
REINFORCE BIOREFINERIES
Business models: sugar, non-food crop & microbial biorefineries
REINFORCE BIOREFINERIES
Continue with algal biorefinery development
REINFORCE BIOREFINERIES
Engagement with sugar industry on refinery development
REINFORCE BIOREFINERIES
Engagement with other feedstock firms on refindery development
REINFORCE BIOREFINERIES
Support for the creation of sugarcane biorefinery capacity
REINFORCE BIOREFINERIES
Support for the creation of non-food crop oil biorefinery capacity
REINFORCE BIOREFINERIES
Support for the creation of microbial biorefinary capcity

Branch 6: TIA funding

The proposed bridge funding action item is entirely reliant on accessing suitable funding. This should be managed both by internal appropriation of funding, and outreach to funding partners in the donor community and through any private sector partners. Administration of the bridge fund should be managed through the Technology Innovation Agency (TIA), which has the most suitable expertise and experience to handle the funding.

The exact design of the fund is left open-ended, to best reflect the mix of funders that are identified. For this reason, the implementation plan includes only a general outline of the activities in this branch.


TIA
BRIDGE FUNDING
Appropriation of funding
BRIDGE FUNDING
Outreach to funding partners (donor, etc.)
BRIDGE FUNDING
Issue of request for proposals
BRIDGE FUNDING
Selection of projects
BRIDGE FUNDING
Review of projects and selection processes
BRIDGE FUNDING
Ongoing rounds of funding

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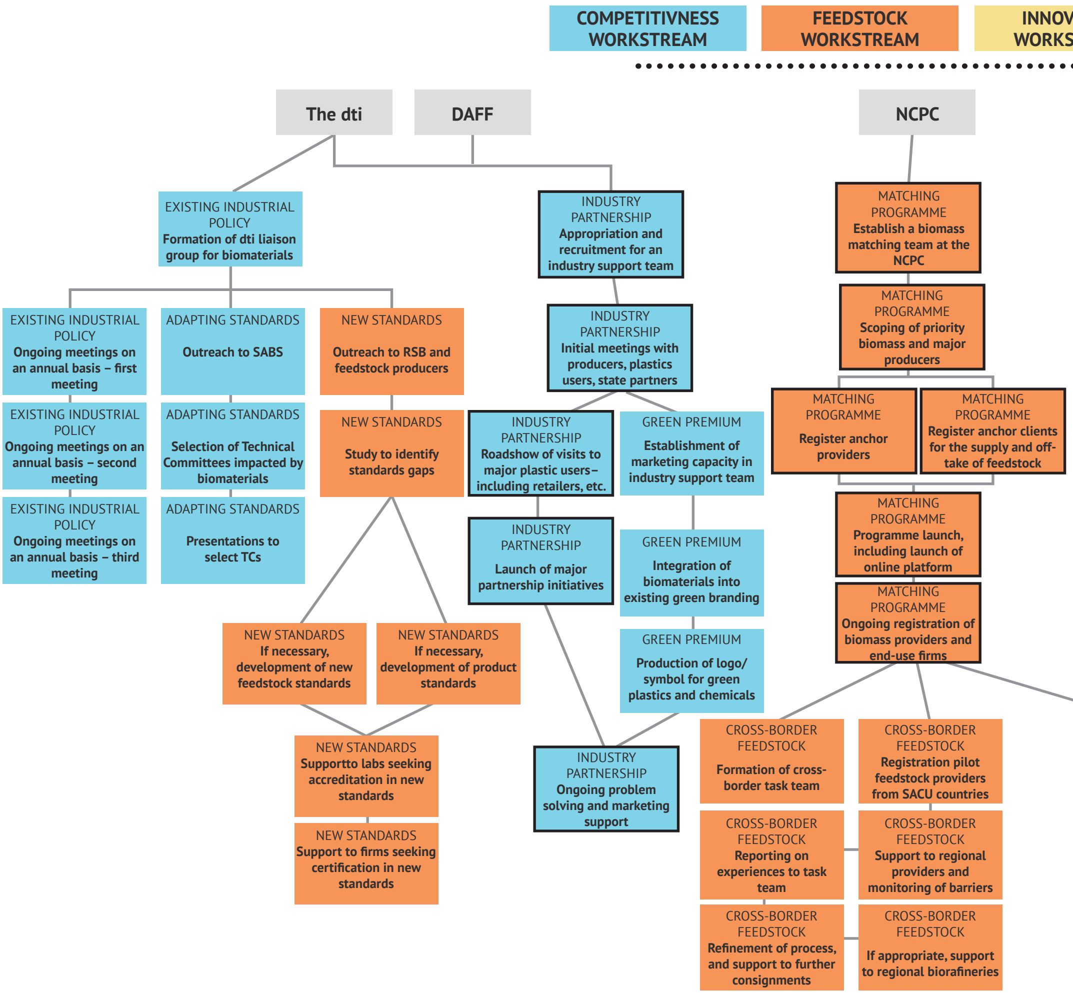
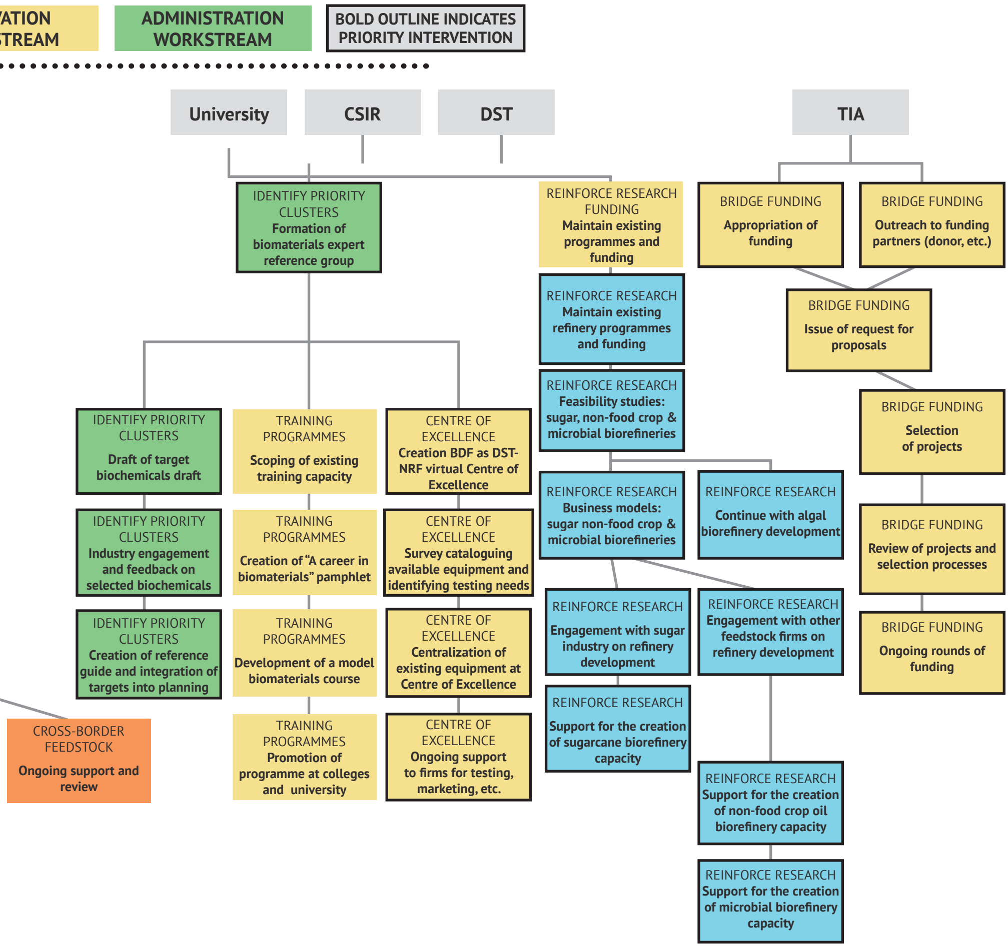
ANNEX 1: IMPLEMENTATION STRATEGY FLOWCHART





ATION
TREAM
ADMINISTRATION WORKSTREAM
BOLD OUTLINE INDICATES PRIORITY INTERVENTION
University
CSIR
DST
TIA
IDENTIFY PRIORITY CLUSTERS Formation of biomaterials expert reference group
REINFORCE RESEARCH FUNDING Maintain existing programmes and funding
BRIDGE FUNDING Appropriation of funding
BRIDGE FUNDING Outreach to funding partners (donor, etc.)
REINFORCE RESEARCH Maintain existing refinery programmes and funding
BRIDGE FUNDING Issue of request for proposals
REINFORCE RESEARCH Feasibility studies: sugar, non-food crop & microbial biorefineries
BRIDGE FUNDING Selection of projects
IDENTIFY PRIORITY CLUSTERS Draft of target biochemicals draft
TRAINING PROGRAMMES Scoping of existing training capacity
CENTRE OF EXCELLENCE Creation BDF as DST-NRF virtual Centre of Excellence
REINFORCE RESEARCH Business models: sugar non-food crop & microbial biorefineries
REINFORCE RESEARCH Continue with algal biorefinery development
BRIDGE FUNDING Review of projects and selection processes
IDENTIFY PRIORITY CLUSTERS Industry engagement and feedback on selected biochemicals
TRAINING PROGRAMMES Creation of "A career in biomaterials" pamphlet
CENTRE OF EXCELLENCE Survey cataloguing available equipment and identifying testing needs
REINFORCE RESEARCH Engagement with sugar industry on refinery development
REINFORCE RESEARCH Engagement with other feedstock firms on refinery development
BRIDGE FUNDING Ongoing rounds of funding
IDENTIFY PRIORITY CLUSTERS Creation of reference guide and integration of targets into planning
TRAINING PROGRAMMES Development of a model biomaterials course
CENTRE OF EXCELLENCE Centralization of existing equipment at Centre of Excellence
REINFORCE RESEARCH Support for the creation of sugarcane biorefinery capacity
CROSS-BORDER FEEDSTOCK Ongoing support and review
TRAINING PROGRAMMES Promotion of programme at colleges and university
CENTRE OF EXCELLENCE Ongoing support to firms for testing, marketing, etc.
REINFORCE RESEARCH Support for the creation of non-food crop oil biorefinery capacity
REINFORCE RESEARCH Support for the creation of microbial biorefinery capacity

PAGE PARTNERSHIP FOR ACTION ON GREEN ECONOMY

The Partnership for Action on Green Economy (PAGE) was launched in 2013 as a response to the call at Rio+20 to support those countries wishing to embark on greener and more inclusive growth trajectories.

PAGE brings together five UN agencies – UN Environment, International Labour Organization, UN Development Programme, UN Industrial Development Organization, and UN Institute for Training and Research – whose mandates, expertises and networks combined can offer integrated and holistic support to countries on inclusive green economy, ensuring coherence and avoiding duplication.

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State Secretariat for Economic Affairs SECO