Biomaterials in South Africa

Action plan and implementation strategy

07 September 2018

PAGE PARTNERSHIP FOR ACTION ON GREEN ECONOMY

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1. Introduction

- Initial scoping of green trade opportunities identified four high-potential areas:
  - Embedded generation technologies
  - Water technologies
  - Biogas-to-transport
  - Biocomposites

- Biocomposites were selected for further research – and then evolved to a broader focus on biomaterials

- Two core outcomes
  - Action plan: detailing interventions in the biomaterial space
  - Implementation strategy: including responsibility, timelines/sequencing, rough costing, etc.

1. Introduction

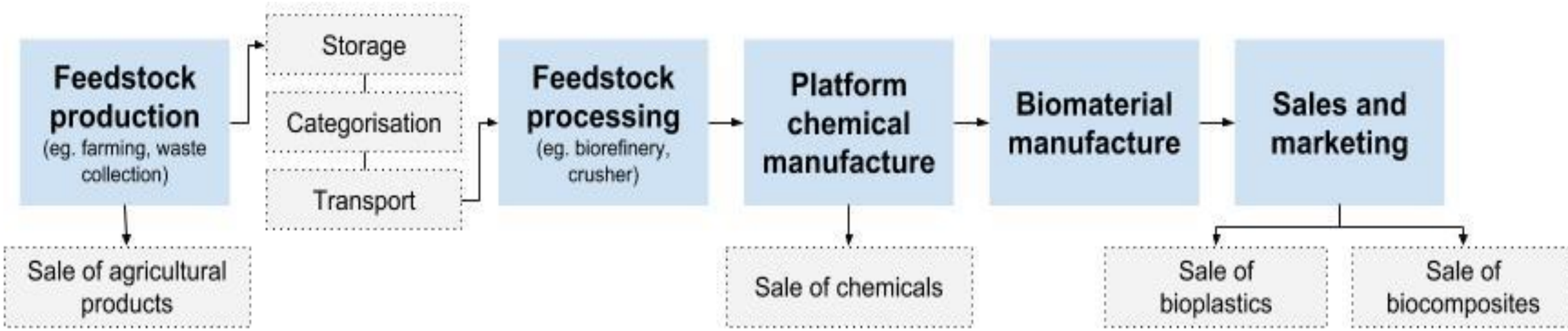
Defining biomaterials

- Materials made by processing agricultural goods or waste
- Includes bioplastics, natural fibers, and the combination of the two in biocomposites
- Biomaterials are better 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

Why biomaterials?

1. Large established market for plastics and composites, with the potential to drop-in new biotechnologies
2. Opportunity to close gaps in the South African plastics/chemicals space
3. Long-term adjustment for plastics industry as petroleum declines
4. Localising supply to strategic industries, notably autos
5. Potential to better share value in the plastics space, through agriculture
6. Strong feedstock potential
7. Greening of plastics

1. Introduction



Approach to action plan

1. Identify major barriers to developing the biomaterials industry
2. Identify policy interventions to target those barriers
3. Set those interventions to a comprehensive implementation plan

Problem statements will identify major barriers around three core issues

1. **Innovation:** supporting access to appropriate biomaterial technology
2. **Feedstock:** access to adequate scale of appropriate feedstock materials
3. **Competitiveness:** ability to compete with traditional plastics and materials

2. Barriers

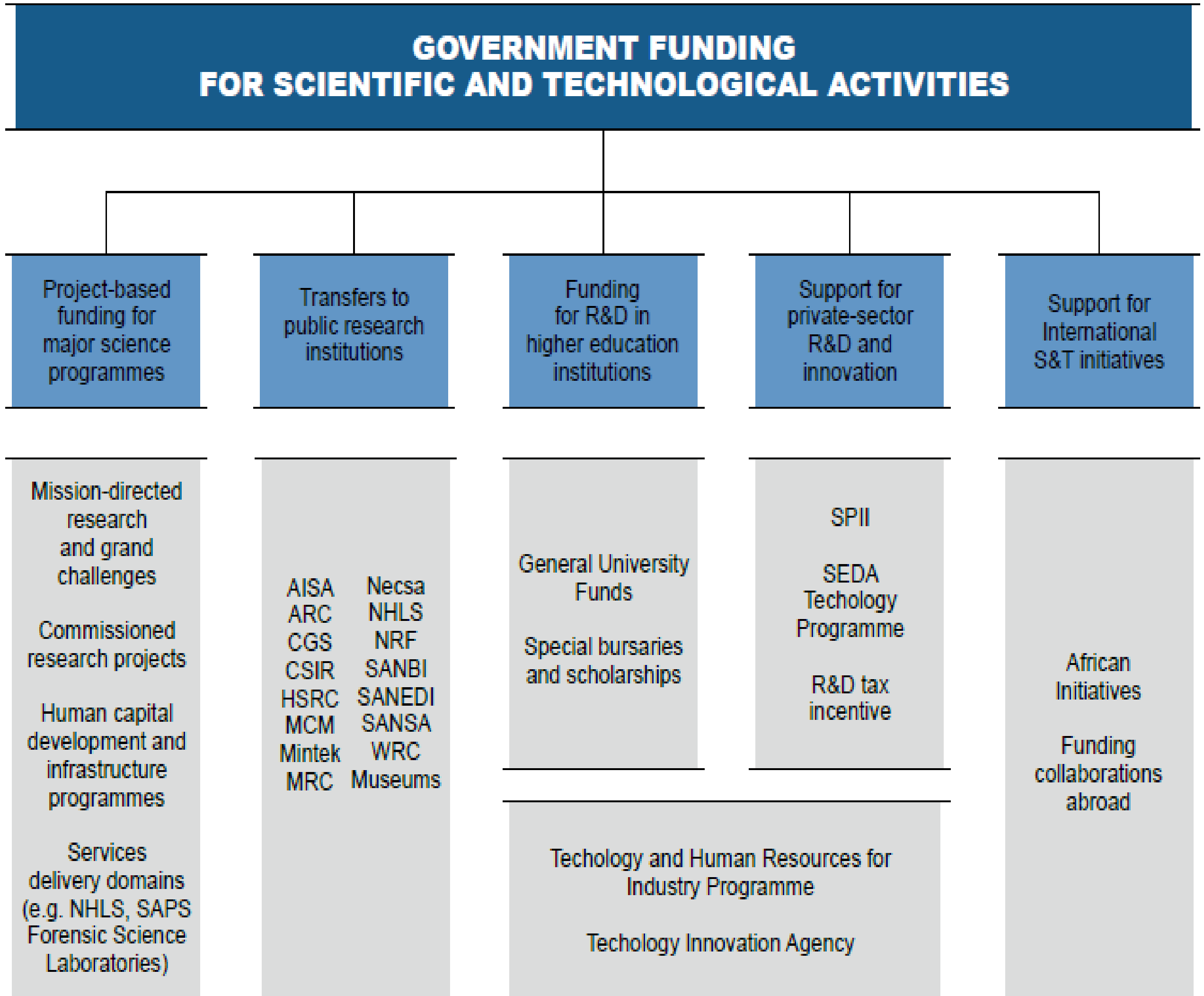
2. Barriers

Area	Barrier
Innovation environment	Deficiencies in the **broader innovation environmen**t: including poor commercialisation and limited and unstable pool of funding
	Selection of high potential biomaterials: extreme diversity of technology risks diluting available support across many technologies
	Institutional environment: innovation is almost entirely state-led and will require ongoing support
	Importing available technology: lack of education initiatives and readiness support make it difficult to import existing production technology
Feed stock	Uncertainty on **feed stock availability**: including a lack of systems to categorise and record available biomass
	Accessing **leading feed stocks**: which are restricted by alternate uses for biomass (such as energy generation) and regulations
	Developing **new feed stocks**: of which many of the most innovative crops are not yet at commercial viable levels of production
	Waste management: in which poor waste collection and management systems limit the use of non-agriculture feed stocks
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 ubiquities of plastics means few productive niches exist
	Enterprise development: High upfront costs and large-scale economies complicate efforts to diversify the sector

2.1 Technology

Managing deficiencies in the broader innovation environment

- Biomaterials cannot be separated from the broader innovation environment in SA, which offers a number of challenges:
- Poor commercialisation, with substantial gap between businesspeople and researchers
- Instability in funding, particularly in the long-term
- Challenges in selecting appropriate technologies, particularly in new areas



Source: TIPS

2.1 Technology

	Scenario 1 Prioritises expert opinion	Scenario 2 Prioritises technological readiness	Scenario 3 Equal weighting	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

Source: UCT CeBER

Selection of high potential biomaterials

- Selection problems are always a challenge in emergent technologies, but particularly for biomaterials
- There is a high degree of diversity in biomaterial technology, ranging from feedstock used to the nature of the process, end use applications, and the environmental impact of the biomaterial

2.1 Technology

Strengthing the institutional infrastructure for innovation

- Existing innovation infrastructure around three pillars: a CSIR centre, CSIR bio-refinery pilots, and university projects
- Some private sector work, but mainly on feedstock categorisation by the likes of Illovo and Sappi
- Currently limited commercialisation of innovations, with the major complaint being a lack of anchor clients
- Few complaints on funding, beyond the usual

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

Source: TIPS

2.1 Technology

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

Source: Nova institute

Supporting the import of established technologies

- Much of the existing IP is based outside of South Africa
- Foreign investment in centres of excellence, general research far outpaces South Africa
- High risk that South Africa becomes an exporter of raw materials – which is already the case for dissolving wood pulp
- Weak support exists for localisation of foreign technologies or the targeting of investors in the biomaterials space

2.2 Feed stock

Diversity in feed stock materials

Biomaterials are produced utilizing a variety of biomass from forestry, agricultural, aquatic sectors and waste feedstocks, the nature of feedstocks makes biomaterials a sustainable, renewable and biodegradable alternative to petroleum based products

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

- Organic inputs such as starches, natural fibres and waste are used to produce plastics and chemicals.
- These natural based inputs, considered to be carbon neutral, absorbing CO2 from the atmosphere, are favoured for lower energy requirements during production processes

2.2 Feed stock

Agricultural feedstock

- 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
- 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.
- An opportunity exists to utilize residues and by-products from the aforementioned crops to establish and produce bio-based composites in the country

Aquatic feedstock

- Biomaterials are produced from aquatic feedstock such as algae and seaweed. Testing and piloting of these materials are already underway in South Africa
- In contrast to maize, wheat and sugar, aquatic feedstocks can been grown under dry weather conditions on arid land using limited amounts of water, 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 social and economic benefits, in terms of job creation and community development.

2.2 Feed stock

Processed Feedstock

- Processed feedstocks aim to maximize potential value by utilizing waste such as pulp and paper, bagasse, and chicken feathers from the poultry sector, to extract materials to produce HVC and fibres for biomaterials
- Such initiatives are viewed as sustainable strategies to revive and revitalize industries in the country, aiding competitiveness and contributing to employment generation within struggling sectors

Barriers

- Due to food security, arable land availability and water scarcity, the use of maize and wheat as a feedstock has previously been discouraged by the South African government.
- Food, fodder, fuel nexus- companies preferring to use waste for energy generation
  - from a waste hierarchy perspective: using waste for energy is the last option, waste should be used to produce high value materials and products that offer a better price: fibre, hvc, composites
  - Although some companies are looking to diversify, feedstock for energy generation remains prevalent
- Resource security: feedstock availability may be dependent on monopoly companies (forestry sector where sawdust becomes stock-pilled)-market control
- Logistics: costs of transporting feedstock to extraction and production facilities-where to locate facilities
- Challenges arise around the definitions and regulation of waste, limiting waste from these agricultural crops for food and fodder purposes
- Aquatic feedstocks face competitiveness difficulties from established Asian industries

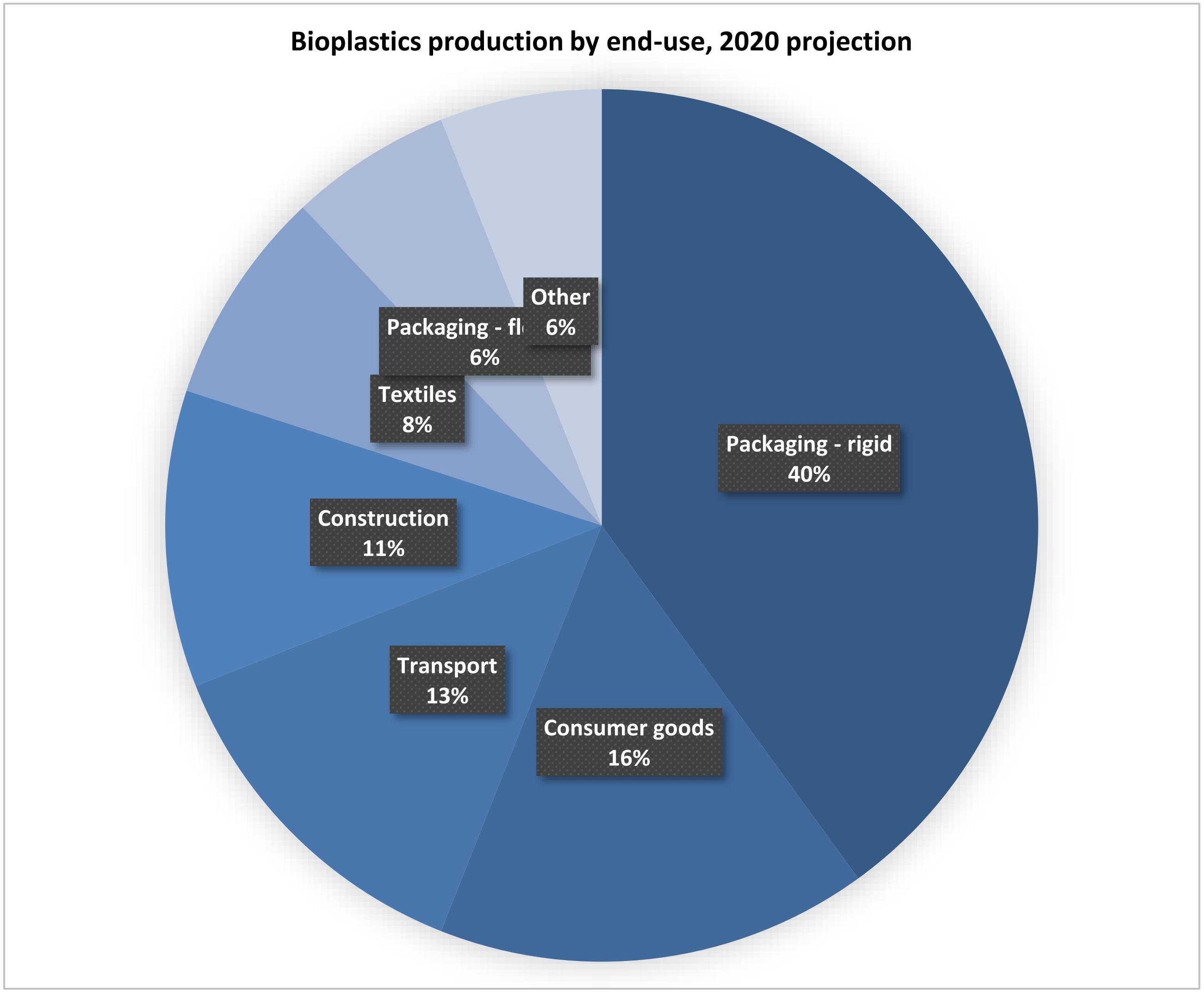
2.3 Competitiveness

Short-term development of efficiencies and scale.

- Recent experience with renewables/other green technologies show a period of support may be needed to build scale and competitiveness
- Few (perhaps no) biomaterials are cost competitive with traditional plastics, particularly at lower oil prices
- Likely to change both as technology improves, and as petroleum declines and by-products become more expensive
- Green premium may be needed in the short term

Stage	Potential for value chain optimisation
Crop to feedstock	14,3%
Feedstock to building block	35,7%
Other routes (eg crops to chemical directly)	7,1%
Building block to chemical product	28,6%
Getting products to end market	14,3%

2.3 Competitiveness



Source: Nova institute

Identifying gaps in the existing market

- Plastics and composites are so ubiquitous that finding gaps is difficult
- Green premium marketing may help, but costs have to be at least generally comparable
- This is more difficult in more high volume industries, such as packaging
- Chemicals may be a useful way to spread the revenue base, notably by filling gaps such as South Africa's underproduction of ethylene

2.3 Competitiveness

New enterprise development

- With small existing biomaterial industry, and little established technology, there are few small or black-owned firms
- Private sector players tend to be either large feed stock suppliers (such as Sappi) and niche manufacturers (such as RCL Foods)
- Question of whether small industry has a role to play in bio-refining or plastic manufacturing, which tends to be highly sensitive to scale
- Many opportunities in agriculture, but farmers have been put off by unstable policy – such as in kenaf (which saw a collapsed IDC programme) and sorghum (which was promoted under the bioethanol programme)

Long-term competitiveness

- Beyond the scope of this plan, there is a need to consider where South Africa is positioned long-term
- As petroleum use declines, the refinery by-products that underpin the plastics industry will become increasingly expensive
- If bio-refineries replace the traditional model for plastics, there will likely be patterns similar to what we see today: where production of inputs is not fundamentally connected to value-addition
- Existing investment patterns in the technology risk setting up a pattern where developing countries provide raw materials, cost-competitive manufacturers do bio-refinery, and developed countries undertake high-end manufacture

3. Action plan

4. Action Plan

Category	Intervention	Type of Intervention
Feedstock	**The creation of a matching programme for feedstock**	**Priority**
Innovation	**Bridge funding for biomaterials research**	**Priority**
Cross-cutting	**Identification of priority clusters of platform biochemicals**	**Priority**
Innovation	**Development of a biomaterials centre of excellence, focused on testing**	**Priority**
Innovation	**Reinforcing support to pilot biorefineries**	**Priority**
Competitiveness	**Development of a task team to lead on industry partnerships**	**Priority**
Cross-cutting	Establish biomaterials training programmes at universities and colleges	Secondary
Innovation	Reinforcing research funding	Secondary
Competitiveness	Promoting the green premium	Secondary
Feedstock	Creating new standards for biomaterials and Feedstock	Secondary
Competitiveness	Adapting existing standards for biomaterials	Secondary
Feedstock	Facilitating cross-border movement of Feedstock	Secondary
Competitiveness	Facilitate engagements with existing industrial policy	Secondary
Cross-cutting	Further research	Secondary

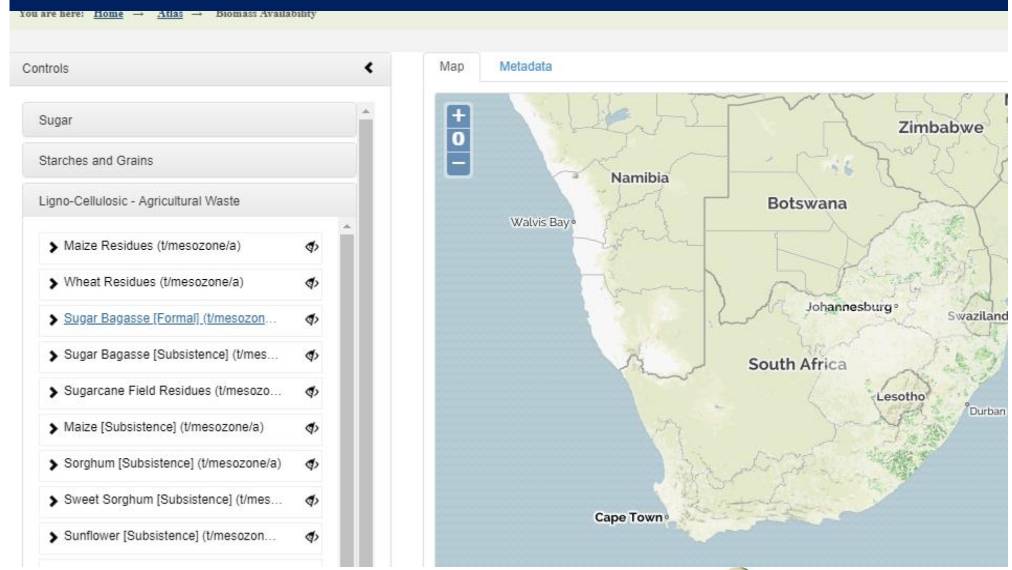
3. Action plan

Priority intervention 1: The creation of a matching programme for feed stock

- Availability of appropriate feed stock is a **key barrier** to reaching scale in bio-materials production
- Views differ on **whether current stocks are adequate**, and the extent to which new feedstocks will be needed
- It is very difficult for policymakers to identity **which feed stocks to support**, as the industry has not yet developed around a few core technologies
- Feed stocks also require **appropriate pricing**, based on their current use – such as sugarcane bagasse for energy
- A matching programme would **close gaps** in the availability of feed stocks, **without requiring very difficult decisions** on selection or pricing

Some existing initiatives

1. **Industrial symbiosis programmes**
   - NCCP
   - Greencape
   - Industrial parks
2. **Bio-atlas**
   - Maps availability of biomass, primarily for energy use
   - Could be expanded to include biomaterials feedstock



3. Action plan

Priority intervention 2: Bridge funding for biomaterials research

- Biomaterials funding cannot be easily detached from the **broader innovation funding** space
- With biomaterials not a major priority, the creation of an adequately **large fund is unlikely**
- A fund that **closes gaps** in the broader innovation funding space could be smaller and more effective than general funding
- **Bridge funding** would help proven technologies that are in funding gaps – offering support during the gap and assistance in receiving additional funding
- Any funding system would have to be accompanied by continuity in current R&D funding

Priority intervention 3: Biomaterials centre of excellence

- Current biomaterial initiatives are constrained by challenges involving **technology testing**
- Agencies, universities and the private sector have cited that **technologies are readily available**, however **complications around the various testing procedures** prevent technologies from reaching piloting and commercialization
- Numerous stakeholder engagements have reinforced the need for a biomaterials centre of excellence, or **one-stop-shop.**
- The creation of a centre of excellence – a facility where **prototype, feasibility, business model development, manufacturing, testing and demonstration** takes place could minimize current complexities around producing and testing biomaterial technologies

3. Action plan

Priority intervention 4: Reinforcing support to pilot biorefineries

- Biorefineries are essential to the biomaterials value chain – converting biomass into chemicals, biomaterials and fuels.
- They are also **highly capital intensive**, with **weak offtake opportunities** in an underdeveloped biomaterials market
- Currently, the core of biorefinery developments are **state-led**, notably by the CSIR
- **Deepening support** to these facilities, and **increasing collaboration** between key agencies, can foster the development and expansion of biorefineries in SA, by ensuring that mechanisms for the growth and use of feedstocks are made available.

Biorefinery Industry Development Facility

- The R 37.5 million Biorefinery Industry Development Facility in Durban was established to extract maximum value from biomass waste: primary function of the facility is for upscaling and piloting technologies
- In the forestry industry: there are numerous inefficiencies: 60-75% of a tree is lost as waste. The sector is currently constrained, the BIDF maximizes on the potential of the raw material, where up to 90% of a tree is used
- High-value speciality chemicals can be extracted from sawmill and dust shavings, while mill sludge can be converted into nanocrystalline cellulose, biopolymers and biogas

The Department of Science and Technology (DST) has identified 5 biorefinery opportunities for South Africa based on the following inputs and areas: forestry, sugar, algae, non-food crop plant oils and microbial biorefineries based in rural areas

3. Action plan

Priority intervention 5: Support to clusters of platform chemicals

- **Extreme diversity** in biomaterials limits the capacity of policymakers to intervene
- Current policy takes a broad approach, but some level of focus – particularly at the chemicals production level – may be needed
- **Risk of diluting interventions** across multiple technologies, with weak linkages
- The selection of a few **clusters based on chemical composition** would enable better policy, and easier identification of linkages among biomaterials technologies
- Chemicals focus creates **diversified sources of revenue** for bio-refineries

Sample of three biomaterials clusters

1. Ethylene cluster:
   - Vital component in many plastics, notably PET.
   - South Africa's plastics industry is almost entirely reliant on the import of ethylene
   - Shares a production process with bio-ethanol
2. Butane cluster
   - 1,4-butanediol is used to produce PBT
   - Butanol and n-butanol have a range of uses as a chemical
   - Feedstock for the cluster is varied, and can include sugar, starches and waste.
3. Acid cluster:
   - Focus on lactic and succinic acids, which are used to produce PLA and PBS plastics respectively.
   - Lactic acid can also be used to make lactate esters; while succinic acid has a number of applications.
   - Succinic acid has importantly 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.

3. Action plan

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 fiber composites
Experico	Packaging
IDC	Sisal fiber 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	Characterization

Priority intervention 6: Task team to lead on industry partnerships

- Researchers note that a key barrier to commercialising innovations is the **lack of industry support and interest**
- Off-take agreements from industry **de-risk investments**, allow production to reach **appropriate scale**, and underpin the development of **feedstock production**
- Scientists and researchers are not well placed to build such partnerships without support
- A task team – or some **appropriate institutional structure** – should lead on building industry partnerships

TIPS

3. Action plan

Secondary Interventions

- Secondary Intervention 1: Establish biomaterials training programmes or modules at universities and colleges
- Secondary Intervention 2: Reinforcing research funding
- Secondary Intervention 3: Promoting the green premium
- Secondary Intervention 4: Creating new standards for biomaterials and feed stock
- Secondary Intervention 5: Adapting existing standards for biomaterials
- Secondary Intervention 6: Facilitating cross-border movement of feed stock
- Secondary Intervention 7: Facilitate engagements with existing industrial policy
- Secondary Intervention 8: Further research

Risk assessment

- Risk 1: Efforts to combat plastics undermine the market for bioplastics
- Risk 2: High cost base prevents the achievement of adequate minimum scale
- Risk 3: Failure to compete with better positioned international rivals
- Risk 4: Coordination failures undermine market growth
- Risk 5: Unsustainable and inequitable industry growth

TIPS

4. Feedback and discussion

4. Way forward

Category	Intervention	Type of Intervention
Competitiveness	**Development of a task team to lead on industry partnerships**	**Priority**
	Promoting the green premium	Secondary
	Adapting existing standards for biomaterials	Secondary
	Facilitate engagements with existing industrial policy	Secondary
Feedstock	**The creation of a matching programme for Feedstock**	**Priority**
	Facilitating cross-border movement of Feedstock	Secondary
	Creating new standards for biomaterials and Feedstock	Secondary
Innovation	**Bridge funding for biomaterials research**	**Priority**
	Development of a biomaterials centre of excellence, focused on testing	**Priority**
	Reinforcing research funding	Secondary
Cross-cutting	**Reinforcing support to pilot biorefineries**	**Priority**
	Identification of priority clusters of platform biochemicals	**Priority**
	Establish biomaterials training programmes at universities and colleges	Secondary
	Further research	Secondary

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