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A GREEN ECONOMY INDUSTRY AND TRADE ANALYSIS:

ASSESSING SOUTH AFRICA’S POTENTIAL

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INDUSTRY AND TRADE ANALYSIS:

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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, Shakespear Mudombi and Bhavna Deonarain.

TRADE & INDUSTRIAL POLICY STRATEGIES

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ACRONYMS AND ABBREVIATIONS

AMD	Acid Mine Drainage
APEC	Asia-Pacific Economic Cooperation
ASSAf	Academy of Science of South Africa
BRICS	Brazil, Russia, India, China, South Africa
BRT	Bus rapid transit
CAGR	Compound annual growth rate
CBG	Compressed biogas
CIPC	Companies and Intellectual Property Commission
CNG	Compressed natural gas
CRG	Composites Research Group
CSIR	Council for Scientific and Industrial Research
DBSA	Development Bank of Southern Africa
DEA	Department of Environmental Affairs (South Africa)
DoE	Department of Energy (South Africa)
DST	Department of Science and Technology (South Africa)
DWA	Department of Water Affairs
DWS	Department of Water and Sanitation
EDD	Economic Development Department (South Africa)
EGA	Environmental Goods Agreement
EGSs	Environmental goods and services
ESTs	Environmentally sound technologies
GEITA	Green Economy Industry and Trade Analysis
GHG	Greenhouse Gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
HS	Harmonized System
ICTs	Information and communication technologies
IDC	Industrial Development Corporation of South Africa
IEC	International Electrotechnical Commission
IPAP	Industrial Policy Action Plan
IPC	International Patent Classification
IRP	Integrated Resource Plan for Electricity 2010-2030
ITP	Indicative Trade Potential
MBCC	Mandela Bay Composites Cluster

MTSF	Medium-Term Strategic Framework
NATMAP	National Transport Master Plan
NCCRWP	National Climate Change Response White Paper
NPC	National Planning Commission
NDP	National Development Plan: Vision for 2030
NEDP	National Exporter Development Programme
NERSA	National Energy Regulator of South Africa
NSSD1	National Strategy for Sustainable Development and Action Plan 2011-2014
NT	National Treasury (South Africa)
NTB	Non-tariff barrier
OECD	Organisation for Economic Co-operation and Development
PAGE	Partnership for Action on Green Economy
PGMs	Platinum group metals
PV	Photovoltaic
QOS	Quality of Supply
R&D	Research and development
RCA	Revealed Comparative Advantage
REIPPPP	Renewable Energy Independent Power Producers Procurement Programme
SABOA	Southern African Bus Operators Association
SABS	South African Bureau of Standards
SDGs	Sustainable Development Goals
SEZ	Special Economic Zone
SMME	Small, Medium and Micro-sized Enterprise
SSEG	Small Scale Embedded Generation
STEP-Bio	Sugarcane Technology Enabling Programme for Bio-Energy
SWM	Smart Water Metering
the dti	Department of Trade and Industry (South Africa)
TIPS	Trade & Industrial Policy Strategies
UNFCCC	United Nations Framework Convention on Climate Change
USA	United States of America
USD	United States Dollar
WIPO	World Intellectual Property Organization
WTO	World Trade Organization
WWAP	World Water Assessment Programme

EXECUTIVE SUMMARY

A global transition to sustainable development is currently under way, as a response to multiple environmental crises, including the widespread impacts of climate change. South Africa has embraced the shift to a green economy to attain inclusive, equitable and sustainable growth and development. The desire to transition to a green economy has been declared at the highest political level, and the articulation of the green economy agenda is evident in the South African policy framework.

From a trade and industry perspective specifically, the transition materializes through two complementary streams, which go hand in hand: the development of new, green industries and the greening of existing, traditional industries. Within this framework, this analysis focuses on the development of new trade opportunities for green industries in South Africa, both for import substitution and for exports.

The main objectives are to identify and assess economic sectors that offer particular trade opportunities from the perspective of green industrial development; inform a subsequent sector-specific assessment of opportunities at the green industry and trade nexus; and provide recommendations for policymakers on how to further harness the identified opportunities in key sectors. The research followed a two-stage approach, structured against an exploratory phase and, subsequently, targeted case studies.

EXPLORING GREEN TRADE OPPORTUNITIES FOR SOUTH AFRICA

While no international definition has been agreed to, green trade can be defined as the import and export of goods and services that are produced using value chains with enhanced sustainability of transport, production, use, maintenance and end-of-life cycling. Several lists of green goods have been developed, generally as an instrument of trade negotiations, often in line with the World Trade Organisation's Environmental Goods Agreement. Drawing on these lists, a composite list of 161 products indicates that global trade in green goods grew rapidly between 2001 and 2015, with global demand increasing 307%, compared to a total trade demand rising 160%. This trend was mainly driven by wastewater treatment and renewable energy technologies. Global market opportunities have been partially offset by expanding barriers to trade in green goods, although tariffs barriers are only reaching worrying heights in lower-income and low-income countries.

Exports of green goods remain a small part of South Africa's broader export basket and are dominated by catalytic converters. More broadly, South Africa's most prominent green exports are linked to more conventional (not green-focused) industries with a strong presence in the country. These include lead products (linked to the chemicals sector), cleaner paints and varnishes (linked to the paint sector), and, potentially, incinerators (linked to the electro-technical and energy sectors).

South Africa's imports of green goods have grown rapidly from a low base, driven by renewable energy technologies. Control equipment for electrical power, which includes smart meters and other monitoring systems, and a variety of waste management technologies, make up the remainder of the list.

South Africa's greatest green trade opportunity seems to be in import-substitution of products sourced for large government-led programmes (for example, renewable energy and public transport) as well as conventional "dirty" products (such as biogas and bio-composite materials). On the export side, while the dynamic global market is booming, competing in this market will require creating local demand for green products, as well as helping exporters navigate the complexities of a global marketplace distorted by multiple government interventions and trade barriers.

Against this trade background, local dynamics in South Africa play a driving force in developing green industrial and trade capacity. South Africa's transition to a green economy has largely been supported by imports. In the longer run, it is critical that the transition relies, as much as possible, on domestic manufacturing and triggers some exports.

Various government policies have been put in place to support the transition to a green economy. The extent to which they refer to the development of local green industries and exports, however, varies. National policies that are not specific to green industries but have a potential bearing on their growth, such as the National Development Plan (NDP) and the New Growth Path, look at the development of all sectors and do not prescribe specific products or technologies for industrial development. The Industrial Policy Action Plan (IPAP) is an exception, with a dedicated focus area on developing green industries. Policies focusing on or including green economy-related issues, such as the National Strategy for Sustainable Development and Action Plan 2011-2014 and the National Climate Change Response White Paper, generally acknowledge the need to harness the transition as an industrial development opportunity, but do not identify specific products beyond renewable energy technologies. At the disaggregated level, some sectoral strategies, generally linked to the IPAP, are more precise in their industrial development prescription.

In the absence of industry data, an analysis of South African patenting activity provides a complementary angle, helping inform the level of local capabilities in the country. This approach is particularly relevant in South Africa, where technology needs are of significance. Using the patent class list for green products and services of the International Patent Classification (IPC) Green Inventory of the World Intellectual Property Organisation (WIPO), South African patenting data show that there is significant R&D in green technologies. Over the 1977-2016 period, a total of 100,442 green related patent applications were registered in South Africa. The category with the highest number of patents is alternative energy, with more than 57,000 relevant patents, followed by waste management, with more than 36,000.

In sum, the development of green industries and related trade flows appears to be booming, globally. Despite the persistence of trade barriers limiting market access, this trend suggests the existence of numerous opportunities. From a South African perspective, this has not yet been translated into substantial exports, except for traditional exporting sectors. By contrast, the rollout of renewable energy technologies has triggered large imports into the country. South Africa's trade performance, government policy priorities and research and development capabilities do, however, offer interesting insight into possible green industrial and trade development opportunities.

To better understand such potential, a more in-depth analysis of specific opportunities was conducted: the development of embedded generation technologies, the promotion of manufacturing opportunities related to the biogas-to-transport value chain, and in biocomposite materials, and opportunities linked to water-related technologies, in both water management and treatment, respectively.

EMBEDDED GENERATION TECHNOLOGIES

The rollout of smart grids, in which end users both draw on, and feed electricity back into the grid using embedded generation sources like solar panels, is rapidly gathering speed around the world. Developing these smart systems will require changes to the infrastructure underpinning the grid, and represents substantial manufacturing opportunities for well-positioned firms.

The analysis of the two core components of a small-scale embedded generation system, namely solar power systems and smart meters, reveals a large but complex global market. Rapid trade growth is counterbalanced by a strong role for the state in the rollout of small-scale embedded generation systems, which results in a market distorted by serious non-tariff barriers like local procurement programmes and subsidies. These distortions, combined with an extremely competitive global market, limit (but do not close) export opportunities for South African firms, and demand careful targeting of export promotion strategies. Import substitution is likely the greater opportunity for South Africa, underpinned by local content designation already being in place for solar power systems and smart meters.

Unlocking this potential will require completing the regulatory framework for small-scale embedded generation, including developing national policies for municipalities to promote renewable energy technologies, aligning standards for installation and for meters, and adjusting planning processes to create a stable market for embedded generation. On the manufacturing side, resolving the impasse over utility-scale procurement is essential to stabilising a solar market that is currently in crisis.

WATER TECHNOLOGIES

Water demand has increasingly been exceeding supply in South Africa and this gap is projected to grow. Water technologies, both for water treatment and conservation, have a significant role to play in ensuring water security. Despite some local capabilities, South Africa's imports of water technologies are higher than respective exports, presenting opportunities to expand the local manufacturing capability for import substitution as well as exports.

Locally appropriate, efficient, and affordable water technologies need to be promoted in South Africa. The limited funding for research and development and technology commercialisation appears as a key barrier for advancing water efficient technologies in the country. Demand for local technologies must be boosted through local content requirements in the procurement of water technology components.

The export market for South African firms can be expanded. South Africa already has the research and development and technological capacity for most water technologies. The government must provide more incentives and support to grow the sector. The action programmes outlined in the Industrial Policy Action Plan should be fully implemented to develop local manufacturing capability and competitiveness.

THE BIOGAS-TO-TRANSPORT VALUE CHAIN

Compressed biogas and compressed natural gas have been identified as an economically feasible means to reduce the dependence on (imported) crude oil while decreasing greenhouse gas emissions. In 2015, revenues from biogas production reached approximately $24.5 billion globally, with biogas technology production dominated by European and Chinese multinationals and approximately 22.3 million gas-based vehicles and 27,000 natural gas fuelling stations across the world.

In South Africa, most vehicles use petrol and diesel. The market for compressed natural gas and or compressed biogas as a transport fuel remains nascent, due to insufficient infrastructure and a lack of demand for gas as a transport fuel. To date initiatives for vehicular biogas have been limited. Nevertheless, municipal solid waste has been identified as a significant possible source of biogas, indicating an opportunity to enhance economic, environmental, and human development, while tackling waste management issues and creating additional jobs.

The South African biogas-to-transport value chain requires tremendous investment from government as well as favourable regulatory and legislative frameworks to transition the industry from its infancy into a thriving local manufacturing base. Incentives play a pivotal role in promoting biogas uptake. Government can drive the growth of the industry through the conversion of state-owned fleets, while collaborating with the taxi industry and donor agencies to promote the conversion of private vehicles and public transport and to develop the required infrastructure.

BIO-COMPOSITE MATERIALS

Biocomposites, materials made from natural plant and animal materials, represent a broad and rapidly developing set of interrelated technologies with a vast range of applications. Focusing on only one of these applications, the rollout of biopolymers, would allow biocomposite manufacturers to tap into a global market valued at $175 billion. While the market in itself is attractive, as interesting are the possible benefits for industrial competitiveness of the broad range of manufacturing industries that rely on polymers.

For biocomposites to become competitive in a global plastics market that is highly efficient and underpinned by low petroleum prices, investment in the various biocomposite technologies will be needed. For South Africa, foreign ownership of leading intellectual property complicates this, as does a technological pipeline that often fails to support products to commercialisation.

The vast range of biocomposite technologies, all of which are at different stages of efficiency, will require targeted and long-term research support to manage the high risks intrinsic to a technology at an early stage in its development. Investment in technology needs to be aligned with efforts to develop a viable supply of inputs from agricultural or waste sources. The biocomposite market is unlikely to be able to support a large input market on its own, so this may require alignment with efforts to develop the biogas market, or with other efforts in the agricultural space. All these initiatives could be aided by a partnership with South Africa's large and efficient plastics sector, which has substantial industrial complementarities with biocomposite manufacture.

CONCLUSIONS

Ultimately, the opportunity to develop green industries and trade-related opportunities in South Africa, both for import substitution and export purposes, is promising. Ensuring that these opportunities materialize and translate into local economic development will, however, require substantial support from the South African government and active collaboration between public and private entities.

From a trade and industrial policy perspective, the growth of water technology manufacturing arises as the most favourable opportunity for the country in the short term. In the longer run, establishing local expertise and capabilities in biocomposites emerges as a key opportunity, provided Government and the private sector commit to long-term action. By contrast, developing the biogas-to-transport value chain and manufacturing embedded generation technologies are less an industrial policy problem than a case of unlocking demand through state procurement and by enabling regulatory frameworks. The nascent and rapidly changing nature of green goods markets warrants actively pursuing multiple opportunities.

1. INTRODUCTION

A global transition to sustainable development is under way, as a response to multiple environmental crises, including the global impacts of climate change. The Paris Agreement, reached in 2015 under the auspices of the United Nations Framework Convention on Climate Change (UNFCCC) has created a global framework indicating the direction of travel for all economies.

South Africa has embraced the shift to a green economy as a path to inclusive, equitable and sustainable growth and development. A green economy can be broadly described as a set of economic activities that result in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities (UN Environment, 2011). The term highlights the economic dimension of sustainability or, stated differently, shows that sustainability relies on aligning market dynamics and incentives with social and environmental objectives. A green economy can be seen as an enabling tool for achieving resource efficiency and clean production, and for reaching the overarching goal of sustainable development with its three pillars (economy, environment, society), and as enshrined in the Sustainable Development Goals (SDGs).

The desire to transition to a green economy has been declared at the highest political level, and the articulation of the green economy agenda is evident in the South African policy framework. A number of broad policy documents have called for the transition to a more sustainable development path (Montmasson-Clair, 2017, 2013). A commitment to a low-carbon, resource-efficient and pro-employment development path has been made in the government's long-term development policy, the National Development Plan: Vision for 2030 (NDP) (NPC, 2011). The transition was also enacted by all social partners with the signature of the Green Economy Accord in 2011 (EDD, 2011). Sustainability-related documents, such as the National Strategy for Sustainable Development and Action Plan 2011-2014 (NSSD1) (DEA, 2011a) and the National Climate Change Response White Paper (NCCRWP) (DEA, 2011b), also make the case for a new model of development. Economic policy documents are

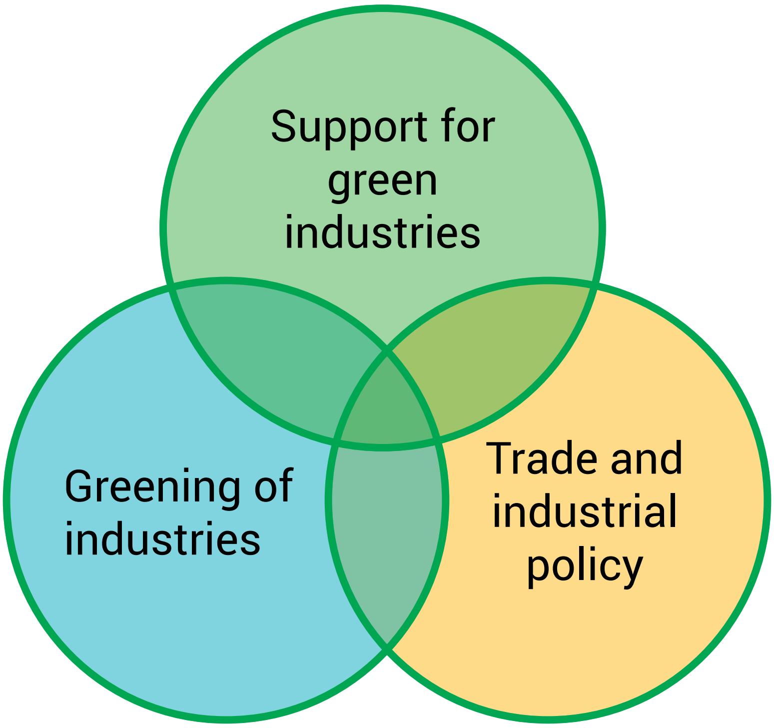


Figure 1: The interplay between the transition to a green economy and trade and industrial policy (Authors' composition)

increasingly incorporating the transition in their core. The Innovation Plan, for example, identifies climate change as one of the key "grand challenges" of the coming decades (DST, 2008). The Industrial Policy Action Plan (IPAP), in its 2017/2018 – 2019/2020 iteration, also stresses the necessity to design a policy roadmap for climate-compatible industrial development in South Africa. Acknowledging the heterogeneity of firm-level situations vis-à-vis the transition, the IPAP aims to build action-orientated strategies that are explicitly based on differentiated and dynamic roadmaps for sectors (the dti, 2017). Furthermore, a multitude of strategies are emerging for specific sectors (renewable energy, transport, waste, water, etc.) throughout the three spheres of government (i.e. national, provincial and municipal levels).

The transition to a sustainable development pathway is an all-encompassing endeavour, cutting across all spheres of government and policy. It is not only an environmental issue but a socio-economic challenge which has ramifications at all levels of economic development, notably trade and industrial development (Montmasson-Clair, 2016).

From a trade and industry perspective specifically, the transition has implications for what is produced as well as how goods are produced. In other words, the transition materializes through two complementary streams, as shown in Figure 1: the development of new, green industries and the greening of existing, traditional industries.

The nexus of green industry and trade, and the identification and assessment of sectors that offer opportunities for green industrial development and trade-related opportunities, is core to this transition. Trade and industrial policies need to be adequately designed and aligned to include environmental objectives to serve as an engine for sustainable economic growth and development. The creation of resource-efficient, low-carbon and competitive industries can strategically position countries, including South Africa, to develop green technologies, reduce dependencies on imports (of green technologies and the conventional technologies they replace) and related ancillary services, and replace or leapfrog brown technology segments, with immense environmental, social and economic benefits (Bucher et al., 2014; du Plooy and Jooste, 2011; Tamiotti et al., 2009). Beyond the sustainability aspects, the increase in trade and investment in environmental goods and services, including environmentally sound technologies (ESTs), provides an opportunity for firms to integrate these into production and related value chains.

Within this framework, the analysis focuses on developing new trade opportunities for green industries in South Africa, both for import substitution and for exports. It is structured as a broad scoping exercise, which aims to contribute to identifying challenges and opportunities to advance green industries and related trade opportunities for South Africa. The main objectives are to identify and assess economic sectors that offer trade opportunities from the perspective of green industrial development; inform a subsequent sector-specific assessment of opportunities at the green industry and trade nexus; and provide recommendations for policymakers on how to further take advantage of the identified opportunities in key sectors.

Section 2 details the methodology followed to achieve these objectives. Section 3 explores key global and South African dynamics related to green trade, identifying five sectoral opportunities. Section 4 analyses these opportunities through dedicated case studies, namely embedded generation technologies (Section 4.1), the biogas-to-transport value chain (Section 4.2), biocomposite materials (Section 4.3), and water treatment and water conservation technologies (Section 4.4). Section 5 concludes the analysis.

2. METHODOLOGY

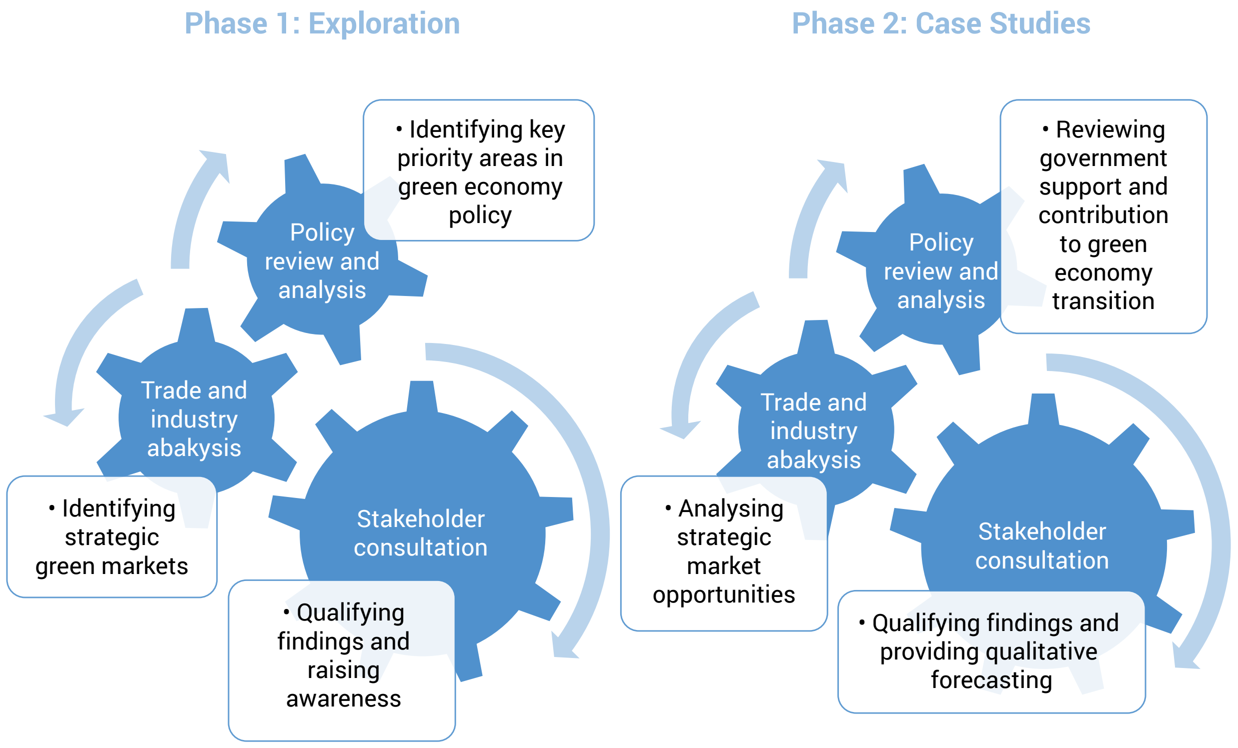
The research followed a two-stage approach, structured against an exploratory phase and, subsequently, targeted case studies. The approach, based on policy review and analysis, stakeholder consultation, and trade and industry data analysis, is schematically represented in Figure 2.

Figure 3 further details the process. The first phase aimed to identify a short list of sectors with high potential. It combined five research components, namely:

- An analysis of global opportunities, through trends in global green trade and trade barriers.
- South Africa's green trade performance (based on a methodology detailed in Figure 2).
- South Africa's technology development capacity, proxied by patent data from the Companies and Intellectual Property Commission (CIPC).
- South Africa's policy priorities, based on a review of the country's relevant policy documents, and
- stakeholder consultation through interviews and workshops with key informants.

A tailor-made methodology was adopted to analyse South Africa's trade in green goods, and extract as much information as possible on opportunities. A composite list of 161 green goods was generated by combining the three most prominent green trade lists, respectively developed by the Organisation for Economic Co-operation and Development (OECD), the Asia-Pacific Economic Cooperation, and the World Bank (refer to Section 3.2 for more detail on the respective lists and the Annexure for the full comparison).

Export and import data was examined for all 161 products identified in the composite list. This list was then analysed across a selection of five metrics: rank of product in South Africa's green goods exports by value; share of South Africa's green goods exports; product growth of South African green good exports; Revealed Comparative Advantage (RCA);[1] and Indicative Trade Potential (ITP).[2] These data points were used to reduce the


Phase 1: Exploration

Phase 2: Case Studies

Figure 2: Schematic representation of the methodology (Authors' composition)

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[1] The RCA is calculated as a given product's share in the country's exports compared to its share in world trade.RCA is a rough indicator of how competitive a country is in producing a given export.

[2] The ITP is a measure of the potential trade between two countries, and offers some guidance on which products have the highest potential for export for a given market. ITP calculates the amount the importing country couldabsorb if it absorbed all imports from the exporter.

selection to a high potential list of 21 products. That list itself was shortened, based on the researchers' judgement of the environmental impact of the goods, to create a final short list of 12 products. This process is shown in Figure 4.

Based on this first phase and the shortlist, five case studies (developed in Section 4) were selected in a second phase to deepen the analysis. The case studies were chosen for their trade potential as well as their under-researched nature. Case studies followed an approach similar to the one adopted in the first phase, merging industry and trade data analysis, policy review and stakeholder consultation. After introducing the technologies (and if needed, the value chain), each case study analysed global market trends as well as the domestic market. The local manufacturing base was then explored to gain an understanding of South Africa's capacity to produce and possibly export the identified technologies, before formulating recommendations on how to grow the local industry.

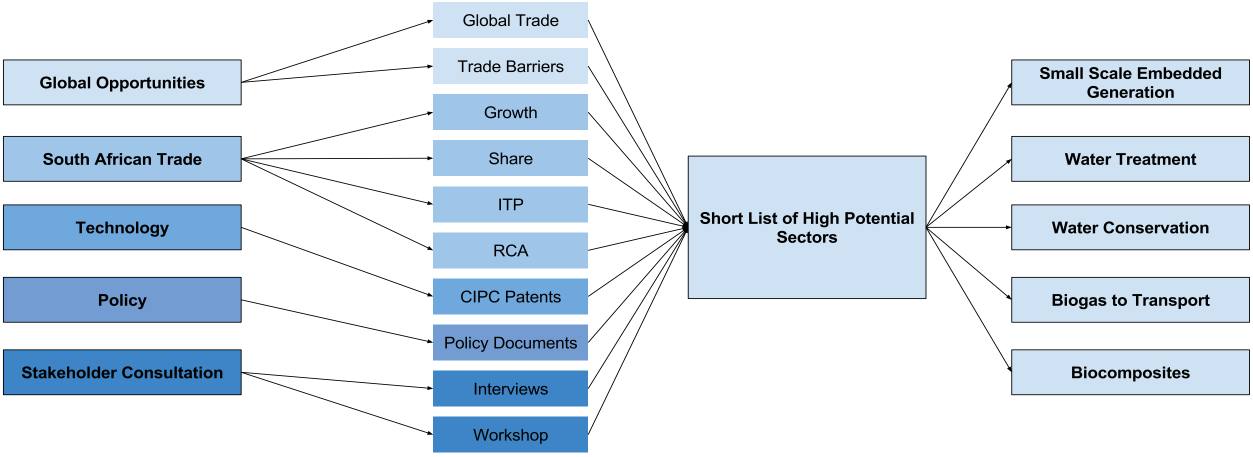

Figure 3: Process flow of the methodology (Authors' composition)

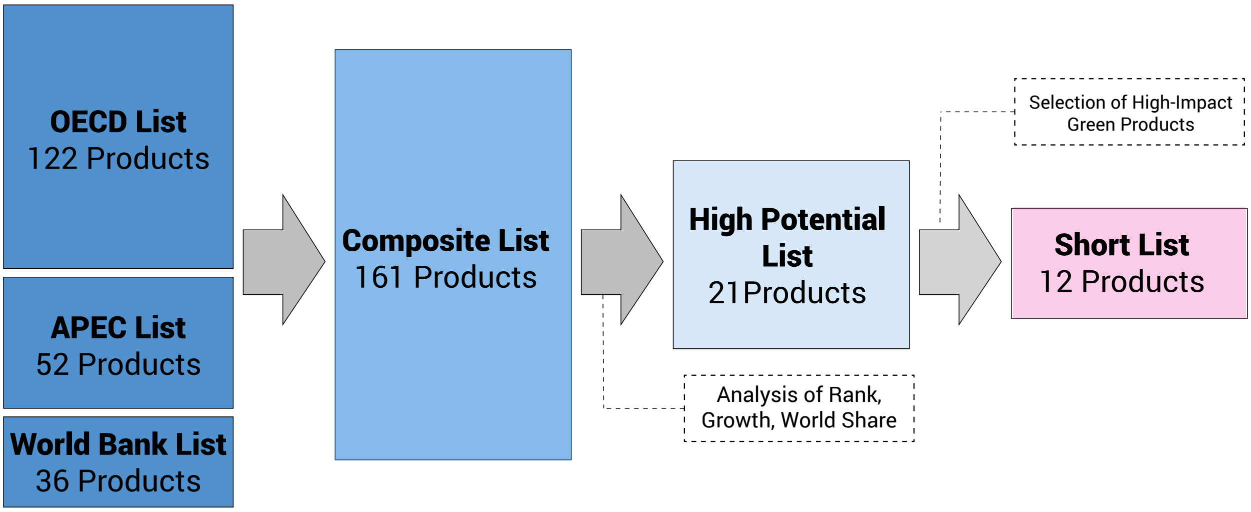

Figure 4: Flow chart guiding the selection of green trade goods (Authors' composition)

3. EXPLORING GREEN TRADE OPPORTUNITIES FOR SOUTH AFRICA: AN OVERVIEW

Before delving into specific case studies in Section 4, this section provides important underlying background on green trade development globally and in South Africa. The section reviews key global dynamics and market trends related to green trade. It then highlights South Africa's green trade performance, domestic policy priorities, and local capabilities.

KEY FINDINGS

- No agreed-upon international definition exists on what constitutes green trade and industry.
- Global trade in green goods has grown rapidly, driven by wastewater treatment and renewable energy technologies.
- Traditional trade barriers to green goods are low, with tariffs barriers only reaching worrying heights in lower- and low-income countries; non-tariff barriers pose a more serious challenge.
- Exports of green goods remain a small part of South Africa's broader export basket and are dominated by catalytic converters.
- South Africa's import of green goods has grown off a low base, driven by renewable energy technologies.
- South Africa's best green trade opportunity seems to be in import-substitution of products sourced for large government programmes as well as conventional "dirty" products.
- Various government policies support the transition to a green economy in South Africa, but the growth of green industries (and associated trade opportunities) remains an underdeveloped policy area.
- South Africa has strong R&D capability in green technologies, notably in energy and waste management.

3.1. GLOBAL DYNAMICS

Green trade can be defined as the import and export of goods and services that are produced using value chains with enhanced sustainability of transport, production, use, maintenance and end-of-life cycling. Broadly, green trade includes environmental goods and services (EGSs), a segment which constitutes the focus of this research. It includes products for energy efficiency, renewable energy, pollution control, water and wastewater, and organic agriculture (PAGE, 2015).

However, it is important to note that there is no agreed upon international definition on what constitutes green trade and industry (the same applies to EGSs and ESTs). Many different understandings of green trade and industry exist globally. Lists of green goods that have been developed are generally created as an instrument of trade negotiations, often in line with the World Trade Organisation's (WTO) Environmental Goods Agreement (EGA), which aims to liberalize trade in green goods, and thus lower barriers to the greening process. All these lists are the product of political negotiation, and thus are not only reflective of neutral technocratic considerations, but also of political manoeuvring and trade interests, leading to somewhat suboptimal outcomes from a sustainability perspective.

Three lists, respectively developed by the Organisation for Economic Co-operation and Development (OECD), as listed in Sugathan (2013), Asia-Pacific Economic Cooperation (APEC, 2012), and the World Bank, (2007) represent the most advanced attempts. As illustrated in Figure 5, such lists differ dramatically in their scope and coverage, with only 38 products appearing on more than one list, and only four items appearing on all three, out of 161 green products covered between those three lists. See the Annexure for the full comparison.

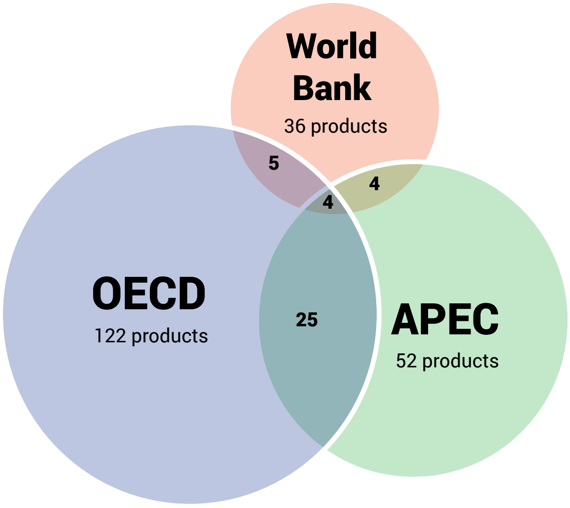

Figure 5: Overlap of selected green goods (Authors' composition, based on APEC, 2012; Sugathan, 2013; World Bank, 2007)

From a technical perspective, tracking green trade, i.e. categorising green goods, presents additional complications. Green goods span a wide variety of products, and do not fit neatly into the Harmonised System (HS) of customs classification. Specific green versions of products (for example, smart meters) are often not distinguished from their broader goods category (metering systems) in the trade data.

Nevertheless, trade analysis remains reliant on the established system of HS codes. In that respect, existing lists form a useful baseline for further analysis. To circumvent the problem of bias, a composite list of trade goods was created, based on multiple lists. The composite list combines the three main lists (OECD, APEC and World Bank) and removes duplicate products, to form an initial composite list of 161 products. The sectoral dimensions of these products can be seen in Table 1 below.

Table 1: Combined list of green goods, by product type (Author's Composition)

Product	No.items
Cleaner technologies and products	4
Environmental monitoring, analysis and assessment	34
Heat/energy savings and management	10
Noise and vibration abatement	1
Pollution management	26
Remediation and clean-up	4
Renewable energy	30
Solid waste management	22
Wastewater management	68
Water supply	5

Note: The total number of items in all categories does not add up the total number of items in the composite list, as some items appear in more than one category.

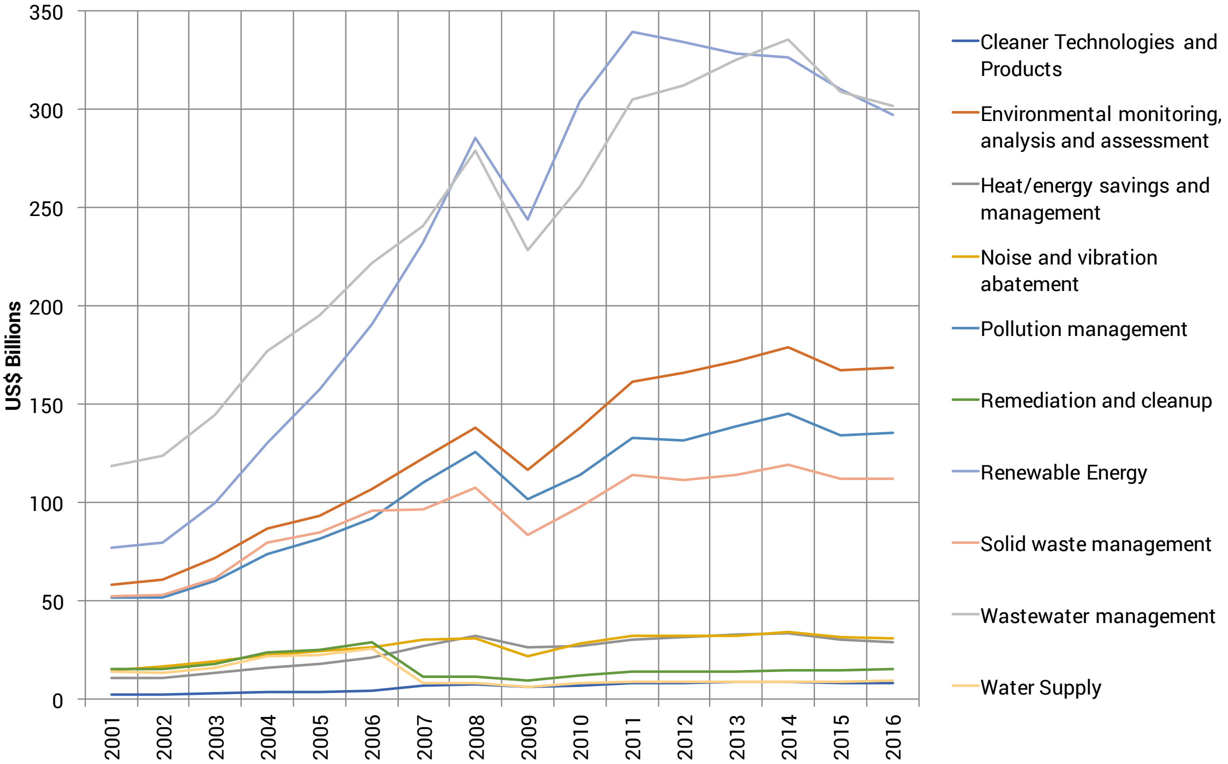

Figure 6: Global imports of green goods, from 2001 to 2015 (Authors' calculations, based on Trade Map data).

The composite list captures a snapshot of the global demand for green goods, providing some insights into dynamics of global markets and the changing marketplace, with some newer products growing rapidly.

The data nevertheless has serious limitations. The green trade space is new and underdeveloped, and in addition is subject to continuous and rapid technological changes. As a result, the static picture of trade data does not provide a comprehensive and accurate insight into what global trade patterns will look like in 10 years' time. The strong role played by governments around the world introduces a complicated set of non-tariff barriers (NTBs), such as local content requirements and various conditions on procurement systems, implying that trade growth does not necessarily represent a trade opportunity.

Despite these limitations, as illustrated in Figure 6, the trends in global imports of green goods are clear. Global trade in green goods grew rapidly between 2001 and 2015, with global demand up by 307%, compared to a total trade demand increase of 160%.

The surge in renewable energy is evident, as renewable energy technologies averaged annual trade growth of 14.5% between 2002 and 2015, the fastest rate of any green good examined. Solar power is at the core of global demand for renewable energy technologies, with solar photovoltaic units and control units accounting for over half of global demand in 2015. More surprisingly, growth in renewable energy technologies was largely matched by growth in wastewater management technologies, which closely followed the rise of renewable energy technologies. A cluster of three groups, namely environmental monitoring, pollution management, and solid waste management products, follow as rapid growers, while remediation and clean-up products and water supply goods saw a minor contraction in global demand.

Global market opportunities have been partially offset by expanding barriers to trade in green goods. As may be observed in Figure 7, formal tariff barriers to green goods[3] are low, and are easily

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[3] Note this graph's definition of environmental goods differs from that used elsewhere. For the specific definition, please see de Melo & Vijil, 2014.

outstripped by NTBs. NTBs themselves, however, are not excessively high, only reaching worrying heights in lower-income and low-income countries, a concern for prospective export markets in Africa, for example.

More worrying are beyond-the-border trade restrictions, which are largely uncaptured in the NTB measure. Green industry programmes, particularly in the renewable energy space, often feature procurement restrictions, local content requirements, and subsidies, grants, and preferential loans to local manufacturers.

This has resulted in at least 12 trade disputes being lodged and 41 trade remedies being applied between 2010 and 2014, across major renewable energy manufacturering economies like the United States of America (USA), China and India (Lewis, 2014). Most of the world's largest generators of renewable energy (China, the USA, India, France, Italy, Spain, and Brazil, but also South Africa) have local content provisions on renewable energy sources. These initiatives may block access to these markets for small and developing countries, making it difficult for their economies to develop green industries of adequate scale, and may boost the most efficient firms in lead markets, strengthening their already competitive position in global trade.

Barriers to other green goods are more complex and less uniform, with goods often captured under trade barriers intended for the broader industry under which they are classified. Exports of water strainers, for example, often face higher export tariffs, because the product is bundled into the same customs category as a range of plastics goods.

3.2. SOUTH AFRICA'S GREEN TRADE PERFORMANCE

While it is clear from global trends that multiple green trade opportunities exist, identifying which products could constitute a trade-related opportunity for South Africa is a challenging exercise. Analysing South Africa's green trade performance, with the aim of identifying opportunities in recent trade flows, offers one useful angle.

Based on the methodology described in Section 2, a shortlist of 12 products with trade potential was identified. The shortlisted products, along with their performance, are shown in Table 2. When using these results, it is important to note that the structure of the data means that the product listed is occasionally bundled with other products in the data. Data on biomass boilers, for example, may include other types of boilers that would be inappropriate for biomass applications.

Overall, exports of green goods remain a small part of South Africa's broader export basket. Of the

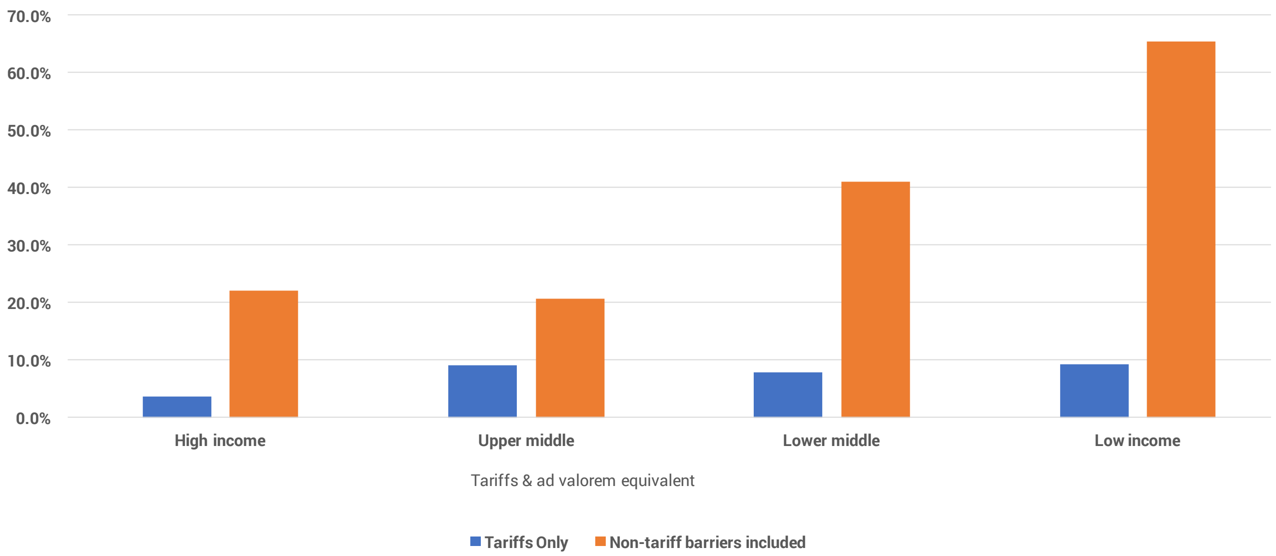

Figure 7: Trade restrictiveness index of environmental goods (de Melo & Vijil, 2014)

Table 2: Metrics of South Africa's exports of select green goods (authors' calculations, based on Trade Map data)

Trade in Green Goods, Short List	RCA[a]	Share[b]	Growth[c]	Rank[d]
Catalytic converters	17.3	11.20%	1.00%	1
Lead products (often for waste storage)	6.4	3.80%	9.60%	6
Fuel cells	4.7	2.80%	-1.80%	4
Sewage treatment equipment	4	2.60%	7.50%	10
Pumps for liquids	3.9	2.30%	8.20%	2
Recycling equipment	2.8	1.60%	11.00%	8
AC generator for renewable energy	1.5	0.80%	7.90%	9
Tanks for sewage treatment	1.4	0.90%	9.60%	3
Cleaner paints and varnishes	1.3	0.80%	12.00%	5
Parts for incinerators	1.2	0.70%	14.90%	7
Incinerators	1	0.60%	27.80%	12
Biomass boilers	0.8	0.50%	37.40%	11

Notes:
[a] RCA refers to revealed comparative advantage of South Africa's green trade exports, where RCA is defined as RCAij = (xij/Xit) / (xwj/Xwt), and xij and xwj are the values of country i's exports of product j and world exports of product j and where Xit and Xwt refer to the country's total exports and world total exports
[b] Share refers to the share of South Africa's green trade exports.
[c] Growth refers to average annual South African export growth between 2010 and 2015.
[d] Rank refers to the position of the product's export value in relation to the green trade list.

group, only catalytic converters are a significant export commodity, a result of the strength of South Africa's platinum industry and large-scale support from government. Similar factors drive the strength of fuel cell exports. The technology is heavily supported by the South African government, notably through the programmes of the Department of Science and Technology (DST) for rural electrification, forklifts and stationary fuel cells and proposed Platinum Special Economic Zone (SEZ) of the Department of Trade and Industry (the dti), and local mining companies (through a development fund) on the back of the country's comparative advantage in mining platinum group metals. As the main use of platinum is threatened eventually, due to the progressive reduction of the platinum content in catalytic converters and the phasing out of internal combustion engines, the sector is investing heavily in developing new technologies, primarily for energy and transport, using platinum group metals. This is a global trend. However, the competitive advantage of South Africa's industries in tapping into these dynamics, over and beyond the mining stage, remains unclear and uncertain.

Many other EGSs reflect their relationship with more conventional (not green-focused) industries with a strong presence in the country. These include lead products (linked to the chemicals sector), cleaner paints and varnishes (linked to the paint sector), and, potentially, incinerators (linked to the electro-technical and energy sectors).

These results differ somewhat from a study by Van Niekerk & Viviers (2014), the only study to date that has been identified as dealing specifically with the export of green goods from a South African perspective. Van Niekerk and Viviers employ three criteria namely the impact on carbon emissions, the ability of South Africa to produce the good (measured by RCA) and the potential economic benefit of producing the good, to identify five high potential products, and then employs a quantitative Decision Support Model to establish high potential markets for those goods.[4] The top five export opportunities identified are found in Table 3. The results indicate a far greater role for exporting renewable energy goods than the list in Table 2 indicates, including solar systems, wind power components, and supporting components like control boards. The distinction is likely due to the greater weight given by the paper to the capacity of the selected goods to reduce carbon emissions, and the greater weight given to the potential economic benefits of South Africa being able to produce them.

On the import side, rapid growth from a low base has resulted in several products growing at extremely high rates. Renewable energy components account for at least 50 per cent of the products listed in Table 4, as sourcing for the Renewable Energy Independent Power Producers Procurement Programme (REIPPPP), initiated in 2011, has driven a spike in demand for solar and wind power equipment. While the high growth figures seen in Table 4 partly represent development from a low base, they are still indicative of significant import dependence. Indeed, despite the REIPPPP's local content requirements creating some local manufacturing capacity, South Africa's development of renewable energy-based electricity has been largely driven by imported products from China, the USA and the European Union. Control equipment for electrical power, which includes smart meters and other monitoring systems, and a variety of waste management technologies make up the remainder of the list.

Table 3: Top five low-carbon environmental goods (van Niekerk & Viviers, 2014)

Product	Use
Photosensitive/ photovoltaic/LED semiconductors	Generate electricity from solar power
Towers and lattice masts	Elevate the blades of wind turbines
Electrical control and distribution boards, < 1kV	Control the functioning of the photovoltaic system
Gearing and screws	Convert slow rotation of blades of wind turbines to a sufficient speed to generate electricity
Static converters	Convert solar energy into electricity

Table 4: Growth in South Africa's import of select green goods (Authors' calculations, based on Trade Map data)

Select green goods	Medium-term growth 1991 - 2015	Short-term growth 2010 - 2015
Steam turbines	272,491%	-78%
Photovoltaic semiconductors	2,087%	241%
Waste handling equipment	296%	71%
Recycling equipment	281%	198%
Wind turbine generators	239,557%	50,757%
Wind turbine generator parts	12,358%	2,276%
Wastewater screens/strainers	432%	101%
Wind turbine gearing	351%	74%
Steam turbine parts	2,346%	8%
Filtration/purification system parts	695%	119%
Monitoring/regulating equipment (manostats)	220%	68%
Monitoring/regulating equipment (other)	140%	7%

Note: The list and order in this table refer to South Africa's largest green imports by USD value, averaged over the period from 2010-2015.

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[4] The Decision Support Model is an export market selection tool. It incorporates a screening process that facilitates export market selection through the identification of realistic export opportunities in the form of product-country combinations.

In summary, South Africa's best green trade opportunity seems to be in import-substitution of products sourced for large government programmes, with the REIPPPP being the prime example. The current uncertainty about the future of the REIPPPP, however, threatens the existing manufacturing base, with local plants closing down.

Substantial opportunities exist for import substitution of "dirty" conventional products, despite not being captured in Table 4. The biogas-to-transport value chain, which aims to replace petroleum with waste-based gas, appears as a strong opportunity. The local manufacturing potential remains uncertain but promising, given the opportunity to leverage a shift of government and public transportation fleets to biogas, the significant sources of feedstock (i.e. waste), and the local experience from a growing number of biogas-to-power sites in South Africa.

More broadly, the development of new, innovative, sustainable, biocomposite materials arises as a potential opportunity across numerous industries, substituting chemicals with natural inputs. Biomaterials, including bioceramics, biopolymers/bioplastics and biometals, drug delivery systems, nano-enabled biomaterials, regenerative tissue engineering, stem cells, medical devices, and biomechanics are but a few examples. South Africa displays some local capabilities, such as in bioplastics and biocements. The uptake of industrial symbiosis in the country is also a trend that could support developing waste-based products.

The export side seems substantially more complex. While there is still potential in a booming and dynamic global market, competing in this market will require first creating local demand for locally manufactured green products, and then helping manufacturers navigate the complexities of exporting in a global marketplace distorted by multiple government interventions and trade barriers.

3.3. DOMESTIC POLICY PRIORITIES

Against this trade background, local dynamics in South Africa play a driving force in developing green industrial and trade capacity. South Africa's transition to a green economy has largely been supported by imports. It is critical that the transition relies, as much as possible, on domestic manufacturing and triggers some exports in the longer run. To better understand future green trade and industry opportunities in South Africa, domestic policy priorities provide a second angle for analysis.

Various government policies have been put in place to support the growth of industry, and subsequently, exports. Local manufacturing and assembly is critical for building productive capacity. The extent to which these policies highlight green or environmental goods varies. While some simply highlight the need to adopt green technologies and products, others stress the need to enhance the local industry to produce for the local market as well as the global market.

Three broad categories of policies can be identified: firstly, general national policies, such as the NDP, which may have an impact on green industries; second, sustainability-orientated national policies, such as the NSSD1 and the NCCRWP; and thirdly, sectoral policy documents that are specific to particular sectors, such as solar, wind, waste and transport. Some of the specific products mentioned in the policies are presented in Table 5. A summary of each policy in relation to promotion of green industry, localisation and export potential is presented below.

National policies that are not specific to green industries but have a potential bearing on their growth include the NDP, the Medium-Term Strategic Framework (MTSF), the Ten-Year Innovation Plan, the Industrial Policy Action Plans (IPAPs), the National Export Strategy, the New Growth Path, and the National Exporter Development Programme (NEDP). In general, with the exception of the IPAPs, these policies look at the development of all sectors and do not prescribe particular products or technologies for industrial development.

The policies that focus on, or include, green economy-related issues are the NSSD1, the NCCRWP, and the New Growth Path (Green Economy Accord). These focus primarily on the transition of the country to a sustainable development pathway. While they generally acknowledge the need to harness the transition as an industrial development opportunity, these documents do not identify specific products beyond renewable energy technologies.

A complete analysis of the country's numerous sectoral policies is beyond the scope of this research. An analysis of selected policy documents, however, shows that some sectoral strategies, generally linked to the IPAP, such as for solar and wind, are more precise in their industrial development prescription. Others policies, such

Table 5: Scoping of green trade and industry policy priorities (Authors' composition)

Document	Promotion of green industries / technologies	Promotion of green import-substitution industrialisation	Promotion of green export potential
National Development Plan	Supports industrial manufacturing towards greener industries over time.	Aims to leverage public and private procurement to promote localisation and industrial diversification, particularly renewable energy technologies and bio-fuels.	Aims to tap into niche markets where South Africa has, or can develop, a competitive advantage for green products and services, including renewable energy technologies.
Ten Year Innovation Plan	Supports the development of R&D for a green economy.	Aims to build local technological capabilities to reduce importation of green technologies or products.	Targets a 25% global market share by 2018 for hydrogen and fuel cells.
New Growth Path	Identifies green industries and technologies as a growth and employment driver.	Supports local procurement of inputs, including energy efficiency and renewable energy technologies (starting with solar water heaters).	Aims to widen the market for South African goods and services through a stronger focus on exports to the region and other rapidly growing economies.
Medium-term Strategic Framework 2014 – 2019	Highlights the need to take advantage of the green economy and growing industries.	Identifies products and components that are being imported which can be produced locally (solar water heaters, power generation equipment, and rail locomotives and carriages).	Highlights the need to increase exports, though not specific on which products.
Industrial Policy Action Plans (IPAP)	Targets the promotion of green industries.	Identifies renewable energy, organic agriculture (agro-processing), biofuels, buses and electric vehicles, biogas, waste management and nuclear energy (advanced manufacturing), biocomposites, water and sanitation, and platinum-related opportunities as key sectors.	Targets the growth of exports and regional integration, through the implementation of the Integrated National Export Strategy (INES) and exploiting regional value chains. Seeks to develop and position South African businesses for increased export opportunities for many products including advanced water technologies.
National Export Strategy	Highlights the need to identify green sectors offering the most diversification and potential for growth.	Does not highlight issues relating to localisation of particular green products.	Targets the diversification of the export basket and the growth of exports, although not specific to green products.

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Table 5: Scoping of green trade and industry policy priorities (continued)

Document	Promotion of green industries / technologies	Promotion of green import-substitution industrialisation	Promotion of green export potential
National Export Strategy	Highlights the need to identify green sectors offering the most diversification and potential for growth.	Does not highlight issues relating to localisation of particular green products.	Targets the diversification of the export basket and the growth of exports, although not specific to green products.
The National Exporter Development Programme (NEDP)	Seeks to contribute to the growth of exports, including from green industries.	Mentions the use of trade policies to support job creation and significant import substitution, but is not product specific.	Aims to increase exports in general, including from green industries, but is not product specific.
The National Strategy for Sustainable Development and Action Plan	Identifies the need to promote the development of green industries.	Stresses the need to implement the Industrial Policy Action Plan, focusing on green economy interventions (particularly renewable energy and industrial energy efficiency) and greater localisation and manufacture of environmental goods and services.	Does not highlight export of green products.
Green Economy Accord	Acknowledges that opportunities in the green economy are many and varied.	Aims to promote local manufacturing, assembly, construction and installation of renewable energy plant and equipment (solar panels, trackers, mirrors, metal frames, glass, wind-turbine blades, towers, turbines and turbine components, electricity inverters, solar water heaters), energy efficient lighting, electric vehicle and its batteries, bio-gas retrofitted public transport vehicles, solar-powered street and traffic lights.	Does not specify any green products but mentions that the viability of local manufacturing capacity should be enhanced for export.
National Climate Change Response White paper	Emphasizes the need to exploit opportunities offered by the green economy and green industries.	Targets the development of the EGSs sector, notably the local manufacturing potential of solar heating products (through the Renewable Energy Flagship Programme). It also highlights other Near-term Priority Flagship Programmes that focus on water conservation and demand management, energy efficiency and energy demand management, transport, waste management, carbon capture and sequestration, and adaptation research.	Acknowledges that there are economic opportunities from new or expanded markets, though not product specific.

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Table 5: Scoping of green trade and industry policy priorities (continued)

Document	Promotion of green industries / technologies	Promotion of green import-substitution industrialisation	Promotion of green export potential
Integrated Resource Plan 2010 – 2030	Promotes renewable energy technologies.	Brings forward the rollout of renewable energy (particularly solar and wind), with the aim of developing a local industry.	Does not mention export of green products.
The Energy Security Master Plan – Liquid fuels	Does not specifically mention green industry.	Does not specifically mention green industry.	Does not mention export of green products.
Draft Position Paper on the South African Biofuels Regulatory Framework	Aims to develop the biofuels industry.	Discusses the regulations for introducing mandatory blending of biofuels with petrol and diesel and the licensing of local manufacturers of biofuels.	Does not mention export of green products.
Draft Position Paper on the South African Biofuels Regulatory Framework	Aims to develop the biofuels industry.	Discusses the regulations for introducing mandatory blending of biofuels with petrol and diesel and the licensing of local manufacturers of biofuels.	Does not mention export of green products.
Sector strategies: wind and solar	Aims to develop green industries, notably by enhancing relevant R&D skills.	Identifies numerous technologies (concentrated PV, thin film PV, central receivers, and concentrated systems for industrial process heat application) and components (modules, inverters, tracking systems, steel structures, cabling and transformers) with potential for local manufacturing.	Stresses the need to grow the export market share in the global solar and wind power sector value chains. Highlights regional export opportunities in Africa's infrastructure and energy access backlog.
National Transport Master Plan	Includes the development of the green economy, though it is not very explicit.	Identifies high-speed rail, new locomotives and coaches, electric multiple unit, light rail/tram train, Bus Rapid Transit (BRT), and light rapid transit, as public transport options. However, issues of import substitution of these products and their components is not explicit.	Emphasizes the need for an efficient transport system to facilitate growth in trade. No reference to the export of green transport products.
Green Transport Strategy (draft)	Highlights the importance of moving towards a green economy. a	Aims to offer electric vehicle manufacturers trade incentives to both produce and sell affordable EVs in South Africa, for the local and export markets. Promotes work by the CSIR and other local research institutions to manufacture EV batteries at a reduced cost.	Highlights the need to grow local production and the subsequent ability to export.

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Table 5: Scoping of green trade and industry policy priorities (continued)

Document	Promotion of green industries / technologies	Promotion of green import-substitution industrialisation	Promotion of green export potential
National Climate Change Response Strategy for the Water Sector	Does not highlight green economy development.	Does not highlight issues relating to the localisation of green products.	Does not highlight issues relating to the export potential of green products.
National Waste Management Strategy	Aims to grow the contribution of the waste sector to the green economy.	Highlights various measures and conventions in place that control the import of chemicals and hazardous waste. No reference to localisation.	Highlights the various measures and conventions in place that control the export of chemicals and hazardous waste. No reference to technology exports.
National Biodiversity Strategy and Action Plan	Does not highlight green economy development.	Does not highlight issues relating to the localisation of green products.	Does not highlight issues relating to the export potential for green products.
Integrated Growth and Development Plan (IGDP) - Agriculture, Forestry, and Fisheries	Highlights the need to take advantage of the green economy. Seeks to increase the productivity of the sectors.	Considers trade flows, with the aim of developing an import substitution plan, though not specific on any green product.	Considers trade flows, and identifies priority commodities that defend a net export position, though not specific on any green products.
Agricultural Policy Action Plan	Does not mention the green economy or green industries development, though it highlights the need to grow certain green trade-related products.	Seeks to support local production of biofuels and climate-smart agriculture, based on organic farming, agro-ecology and conservation agriculture.	Aims to increase market access for agriculture, forestry, and fisheries products in both domestic and international markets through targeted/product specific interventions.

as the National Waste Management Strategy and National Climate Change Response Strategy for the Water Sector, remain vague on the industrial development and trade aspects of their sectors, despite some clear potential due to the extent of the challenges in these sectors. Key examples include the Water Conservation and Demand Management and Waste Management Flagship Programmes included in the NCCRWP.

Institutionally, this situation reflects the diversity of entities involved in supporting the transition. The Department of Environmental Affairs (DEA) has undertaken several key initiatives in driving the country's transition to a green economy, although the implementation is conducted by a wide range of entities. Direct support for industries falls under the dti, notably through the South African Bureau of Standards and the National Regulator for Compulsory Specifications (for standards and labelling) and through the National Cleaner Production Centre (for training, capacity building and implementation support). Fiscal incentives, i.e. taxes and subsidies, are under the mandate of the National Treasury, although various entities implement them. DST is responsible for technology policy and fostering R&D in all sectors of the green economy. The Economic Development Department (EDD) supervises the Industrial Development Corporation (IDC), one of the two main state-run development finance institutions while the National Treasury governs the other main development finance institution, the Development Bank of Southern Africa (DBSA). A variety of other national departments, such as energy, transport, agriculture and water, are also critical in developing green industries.

3.4. LOCAL CAPABILITIES

While South Africa's trade performance and policy priorities provide two important angles in identifying future green trade opportunities, they only paint a partial picture. As the green industries are still nascent and subject to rapid technological changes, existing trade flows do not provide a comprehensive understanding of future trade opportunities. Similarly, policy priorities are useful to understand the overarching development approach framing South Africa's transition to a green economy, although are limited on manufacturing and trade-related capabilities.

In the absence of industry data, an analysis of South African patenting activity provides a complementary angle, which helps inform the level of local capabilities in the country. R&D is indeed a vital component in the industrialisation value chain. It is the basis on which new products and services are conceptualized and realized. An important output of R&D are research outputs that can be patented. While not every research output, including patented ones, results in a successful commercial product,[5] this output can be used as a proxy for the potential development of new products.

This approach is particularly relevant in a developing country like South Africa, where technology needs are important. As demonstrated by South Africa's Climate Change Technology Needs Assessment (DST, 2007a), the country's successful transition to a green economy relies on the development (through R&D as well as knowledge transfer) of numerous technologies. The provision of water supply and sanitation, new crop species and cultivars, energy efficiency incentives, the control of the spread of vector-borne disease, information technology, solar power, and the promotion of the source reduction, recycle, and reuse were the priority areas identified for technology and knowledge needs in 2007.

Using the patent class list for green products and services of the International Patent Classification (IPC) Green Inventory[6] of the World Intellectual Property Organisation (WIPO), South African patenting data show that there is significant R&D undertaken in green technologies.

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[5] Failure of the new technologies can be associated with challenges relating to the 'valley of death' (ASSAF, 2014) and the 'innovation chasm' (DST, 2008).

[6] The "IPC Green Inventory" was developed by the IPC Committee of Experts to facilitate searches for patent information relating to Environmentally Sound Technologies (ESTs), as listed by the United Nations Framework Convention on Climate Change (UNFCCC) (WIPO, http://www.wipo.int/).

Figure 8 illustrates the total number of patents from 1977 to 2016 for each technology category, whilst Figure 9 depicts the general trend of the total number of patents for each technology category per year from 1977 to 2016. The numbers presented are for both granted and pending patent applications from each year.[7] Over this period, a total of 100,442 green patent applications were registered in South Africa.

The category with the highest number of patents is alternative energy, with more than 57,000 relevant patents, followed by waste management, with more than 36,000. Importantly, the sum of the categories is larger than the total number of patents due to numerous patents featuring in more than one category. Over time, annual patent registrations have only evolved marginally, although the increase in the two leading categories, i.e. alternative energy and waste management, is notable.

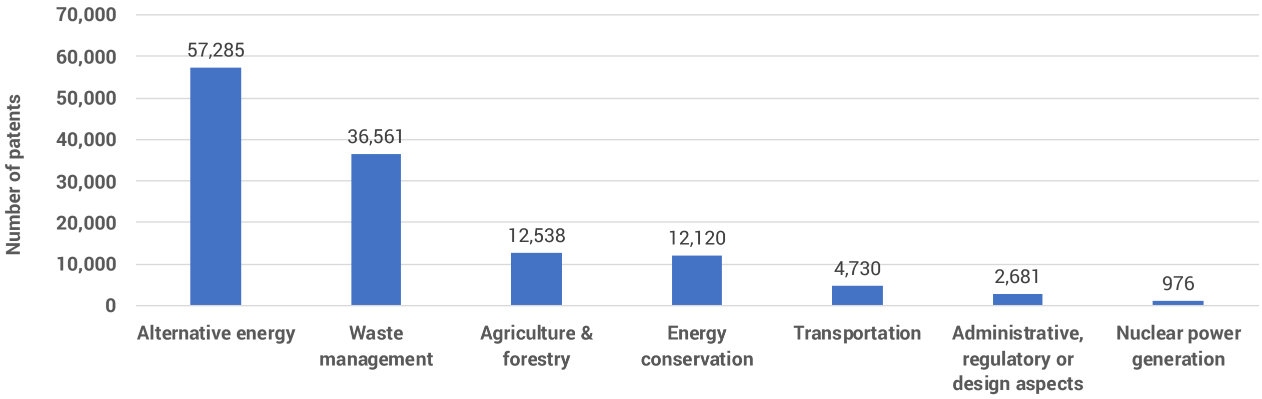

Figure 8: Numbers of patents (granted and pending) for green technologies across sectors in South Africa from 1977 to 2016 (Authors' composition, based on data from the CIPC)

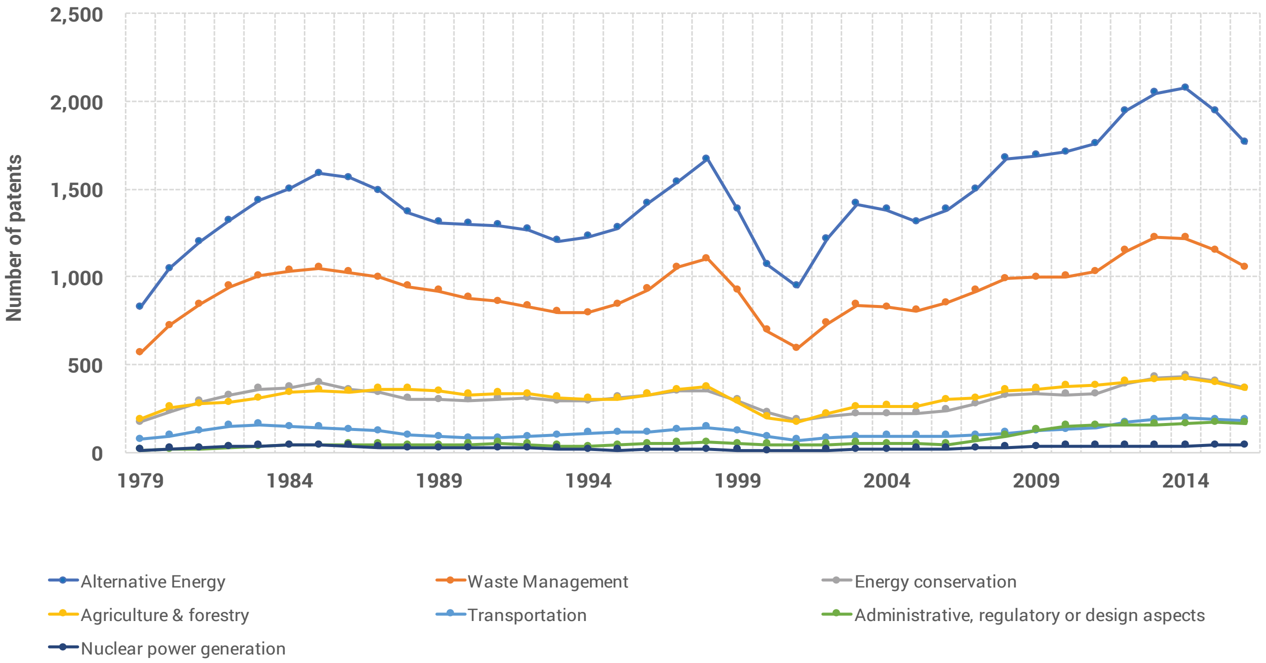

Figure 9: Annual numbers of patents (granted and pending) for green technologies across sectors in South Africa (three-year moving averages) (Authors' composition, based on data from the CIPC)

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[7] It is important to note that while the IPC Green inventory is specific on the class and subclass for each green technology, the data used does not go up to the subclass level, hence the number of patents shown is not exactly the total for that technology but is the total for the class in which the technology belongs. As some of the technology classes apply to several technologies, effort was taken to avoid the likely overlap and double counting in the patents classes for each of the technology categories. However, the broad categories should not be interpreted as mutually exclusive, as some of them have patent classes that overlap.

The alternative energy category is dominated by patents related to biofuels, followed by solar energy, waste-to-energy and waste heat recovery (Figure 10). Insulation technologies and storage technologies (for electricity and heat) dominate energy conservation patents (Figure 11).

Waste management covers patents for air pollution (for carbon capture and storage, and air quality), the disposal, re-use and treatment of waste, and water pollution (Figure 12). In the agriculture and forestry sector, patenting is focused predominantly on pesticide alternatives, with activity in soil improvement, forestry techniques, alternative irrigation techniques, and organic fertilisers. Other sectors are smaller in terms of patent activity but show some areas of interest, such as clean vehicles and static structure design for buildings.

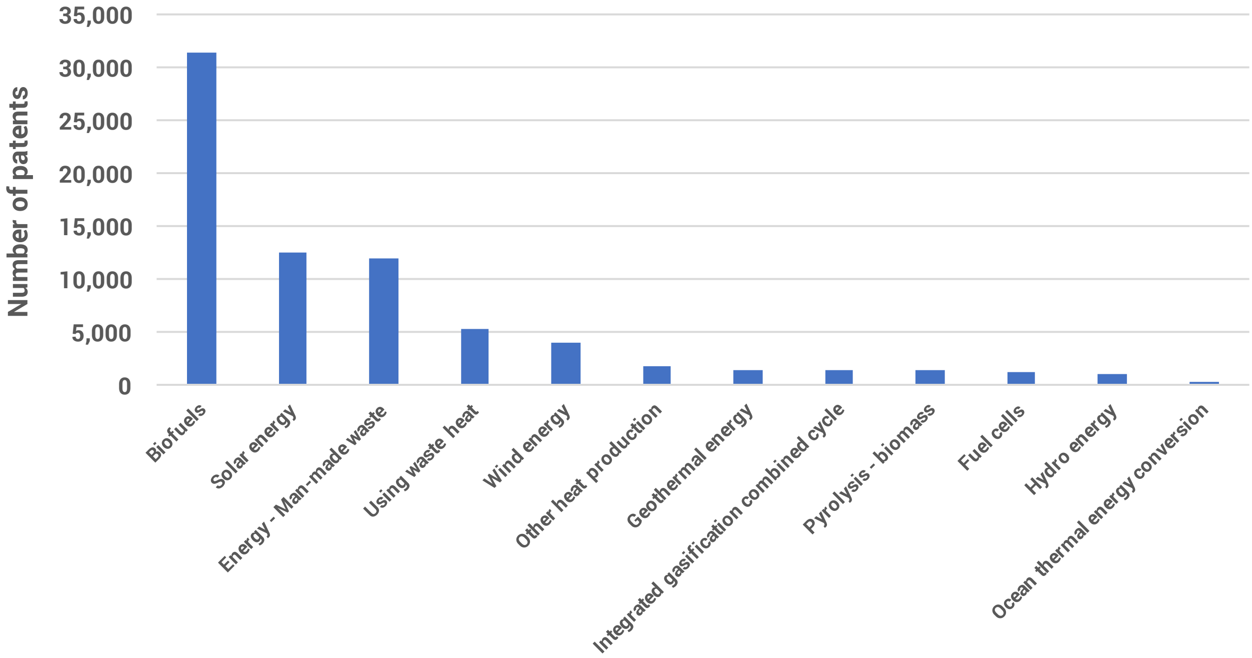

Figure 10: Numbers of patents (granted and pending) for alternative energy production technologies in South Africa from 1977 to 2016 (Authors' composition, based on data from the CIPC)

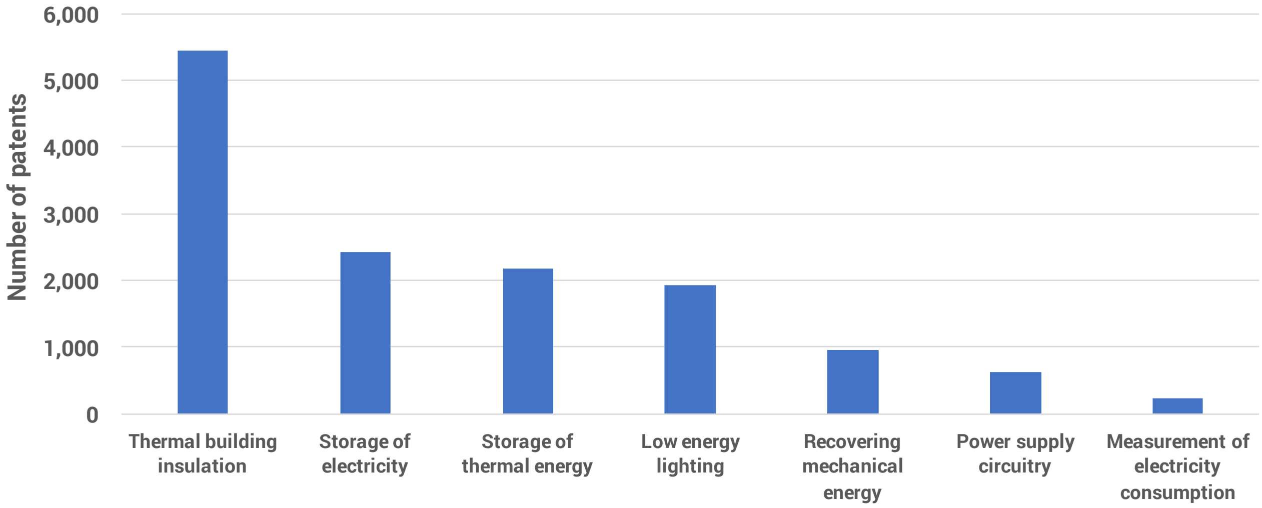

Figure 11: Numbers of patents (granted and pending) for energy conservation technologies in South Africa from 1977 to 2016 (Authors' composition, based on data from the CIPC)

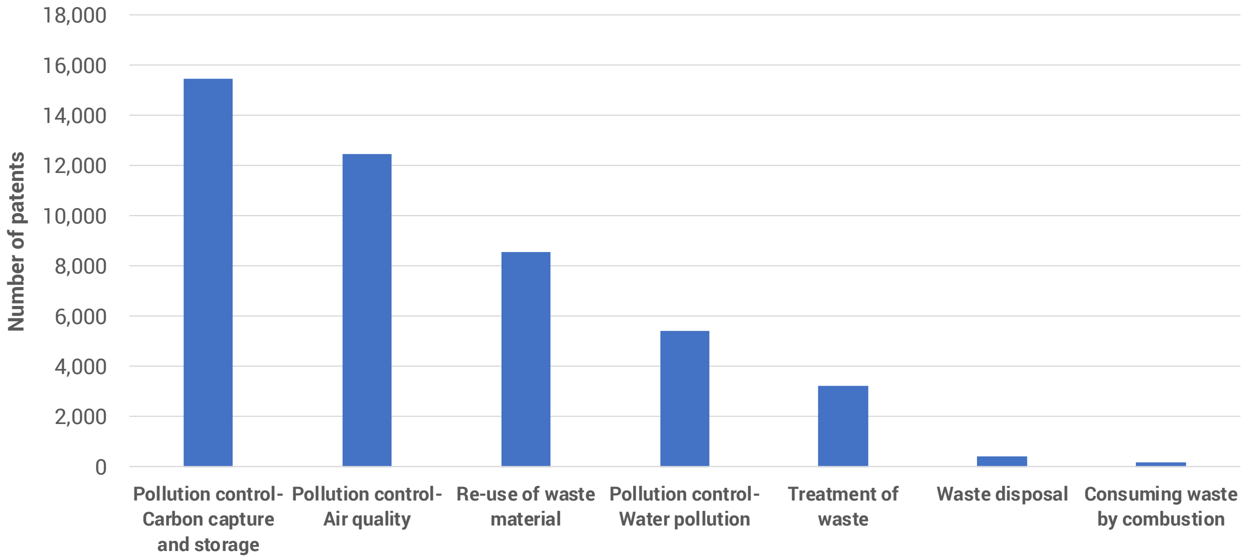

Figure 12: Numbers of patents (granted and pending) for waste management technologies in South Africa from 1977 to 2016 (Authors' composition, based on data from the CIPC)

3.5. PRELIMINARY CONCLUSIONS

The development of green industries and related trade flows appears to be booming globally. Despite the persistence of trade barriers limiting market access, this trend suggests the existence of numerous opportunities. From a South African perspective, this has not yet been translated in substantial exports, apart from traditional strongholds, such as catalytic converters. By contrast, the rollout of renewable energy technologies has triggered large imports into the country. South Africa's trade performance, government policy priorities and R&D capabilities do, however, offer interesting insight into possible green industrial and trade development opportunities.

To better understand such potential, a more in-depth analysis of specific opportunities is conducted in Section 4. Five opportunities are further investigated. Firstly, developing small-scale solar-related technologies, i.e. manufacturing solar power systems and smart meters, is envisaged. Existing manufacturing capacity, developed off the back of the REIPPPP, and the leadership demonstrated in smart meters are two key reasons justifying further investigation. Further, the promotion of manufacturing opportunities around the biogas-to-transport value chain and biocomposite materials are investigated respectively. Both opportunities, while distinct, have a strong import substitution potential, by replacing traditional imports such as fossil fuels, and display sufficient feedstocks, such as organic waste, and local pockets of excellence. In addition, significant local and regional markets justify exploring opportunities linked to water-related technologies, both in water conservation and water treatment. The existence of local capabilities in these sectors also suggests the possibility of further developing South African exports.

4. UNPACKING POTENTIAL GREEN TRADE OPPORTUNITIES FOR SOUTH AFRICA: SELECTED CASE STUDIES

Based on Section 3, which identifies green trade and industrial development opportunities in South Africa, this section narrows the analysis to a selection of those opportunities. These select opportunities, primarily chosen because of their perceived potential and their under-researched nature, are as follows: small-scale solar technologies, biocomposite materials, the biogas-to-transport value chain, and water-related technologies (both water conservation and water treatment segments). While much research has been done on the technical or rollout aspects of these technologies, this analysis focuses on understanding how these opportunities may advance trade and industrial development in South Africa.

4.1. EMBEDDED GENERATION TECHNOLOGIES

KEY FINDINGS

- The global rollout of smart grids will contribute to the already rapid rise of trade in solar panels and smart meters, among other components.
- Export opportunities are, however, limited by a complex global market, distorted by strong non-tariff barriers, such as local content requirements and the provision of subsidies.
- In summary, import substitution seems a greater opportunity for South Africa, leveraging off local content designation for both solar panels and smart meters.
- However, it is unclear if solar panel manufacture and assembly can continue until greater certainty is provided on utility-scale procurement.
- While industrial and trade policy interventions may be needed at a later stage, the immediate priority should be setting up a regulatory framework that may create a small-scale embedded generation (SSEG) market.

4.1.1. BACKGROUND

South Africa's efforts to transition to renewable energy alternatives has thus far focused on attempts to roll out large-scale projects. A more comprehensive transition to sustainable energy, however, requires fundamentally rethinking how the national grid functions. Smart grids, featuring electrical meters intertwined with information technology, offer one means to do so, introducing three key changes.

Firstly, smart grids would allow for differentiated tariffs (known as time-of-use tariffs), with higher tariffs during peak periods and lower tariffs during periods of excess capacity. Secondly, smart grids would enable more targeted load-shedding in times of crisis, with a central user or utility able to reduce the load on the grid by shutting off non-essential uses, such as geysers, whilst keeping more sensitive uses, such as refrigerators, intact. Thirdly, and perhaps most importantly for the purpose of fostering the development of green industries, smart grids would facilitate and enhance the rollout of embedded generation. Embedded generation refers to a grid in which end users also produce their own energy, such as houses with solar panels on the roofs. Such small-scale producers can sell the energy they generate back into the grid, either receiving a tariff as a result, or receiving discounts from their electric bill. The potential of SSEG in South Africa is immense, with a network of solar panels mounted on houses and buildings offering a way to cost-effectively transform the structure of energy generation in the country.

Yet extensive issues remain to be resolved before such a transformation could take place. Regulations remain in draft form and need to be confirmed, and greater uptake of recently-developed standards needs to be promoted. The Internet infrastructure requires upgrading to manage the demands of a reliable communications system for bidirectional smart meters with integrated IT capabilities, which are an essential part of smart grid infrastructure, and a range of municipal and national codes and systems must be amended to allow sourcing energy from a wide variety of dispersed sources. Crucial stakeholders, notably the national utility Eskom, need to be brought on board. Additionally, the rollout of SSEG will require large-scale changes to the electrical infrastructure, most pressing being the rollout of smart meters and small-scale solar power systems. A working smart-meter system with regulation for feed-in tariffs would then create a much larger market for small-scale solar generation.

The dual demands, for smart meters and small-scale solar systems, offer new and exciting manufacturing opportunities for South African firms. While extensive research has been conducted on the ways to roll out SSEG in South Africa, less has been undertaken on supporting policy to encourage local manufacturing and assembly of both smart grids and small-scale solar power systems. Even less has been completed on an assessment of the potential market for export. As is detailed below, the manufacture of smart meters and assembly of solar power systems are integrated into thinking on SSEG, with components already designated for local procurement. Much of the debate around SSEG therefore revolves around improving the regulatory infrastructure, in the belief that the resulting private sector installation of meters and panels, and related manufacturing, does not require support beyond local procurement designation.

With extensive literature exploring the question of how to get the system working, this section therefore considers two less examined questions. Firstly, is local procurement enough to create local manufacturing opportunities off the back of an enabling SSEG framework? Secondly, is there space for South African firms to compete in the global market for smart meters and/or solar power systems?

4.1.2. GLOBAL MARKET TRENDS

Data on smart grids is generally bundled into the broader energy services market, which includes functions like energy efficiency and various consulting services. Smart grid technologies themselves are drawn from different industries, including information technologies and, increasingly, energy-efficiency products. As a result, it is difficult to find specific data on smart grid products in isolation from the broader services market.

In any case, SSEG is expanding rapidly across the world, with the global market for energy services companies expected to reach $14 billion by 2024 (Navigant Research, 2015). Estimates of the value of the global smart grid market range between $15 billion to 500 billion annually (depending on which components are included), with the market expected to grow between 5% and 18% annually over the coming decade (ITA, 2016). To analyse the trading dynamics in smart grids, two core components, i.e. smart meters and solar power systems, are explored in further detail.

Global trade in renewable energy products has boomed in recent years, with the global market growing by a factor of 5.3 between 2001 and 2015, whilst the market for solar energy components has grown by a factor of nearly 10 over the same period, as can be seen in Figure 13. Nevertheless, it is difficult to isolate the SSEG elements in this growth, with much of it being driven by the demand for utility-scale solar installations.

A combination of government policies, large investment in innovative technology, and the opportunities created by renewable energy programmes in large economies has led to a global solar manufacturing space clustered within a few major countries, as indicated in Table 6. The market is, however, extremely fluid. For example, more recent reports show that Yingli Green Energy and First Solar have slipped down the list, while Trina Solar and Canadian Solar have moved up the list. Regardless of the exact positioning of various companies, the global market place is competitive and crowded.

The global market for smart meters is expected to expand from $4 billion (2011) to $20 billion by 2018 (Alejandro et al, 2014). More than 11 European countries have begun rolling out smart meters, with Sweden being the first to reach 100% smart-meter penetration (in 2009) (Rank et al., 2010). Trade data on smart meters is difficult to find, since smart meters and their components are classified in different broad categories, which also include traditional meters and prepaid meters. Using the most common codes for smart meter classification,[8] shows evidence of strong growth, as illustrated in Figure 14.

The smart meter space remains slightly less developed. Most smart meter manufacturers are traditional, diversified precision electronics companies, that have added smart meter production to an already established base. These traditional players tend to be clustered in the USA and Europe, although some are challenged by the rise of Chinese manufacturers, notably Holley Metering. The largest smart meter manufacturers are identified in Table 7. A range of other countries outside the few core meter manufacturers have begun initiatives aimed at promoting the local production of smart meters. While some, like Slovenia's Iskraemeco, are involved

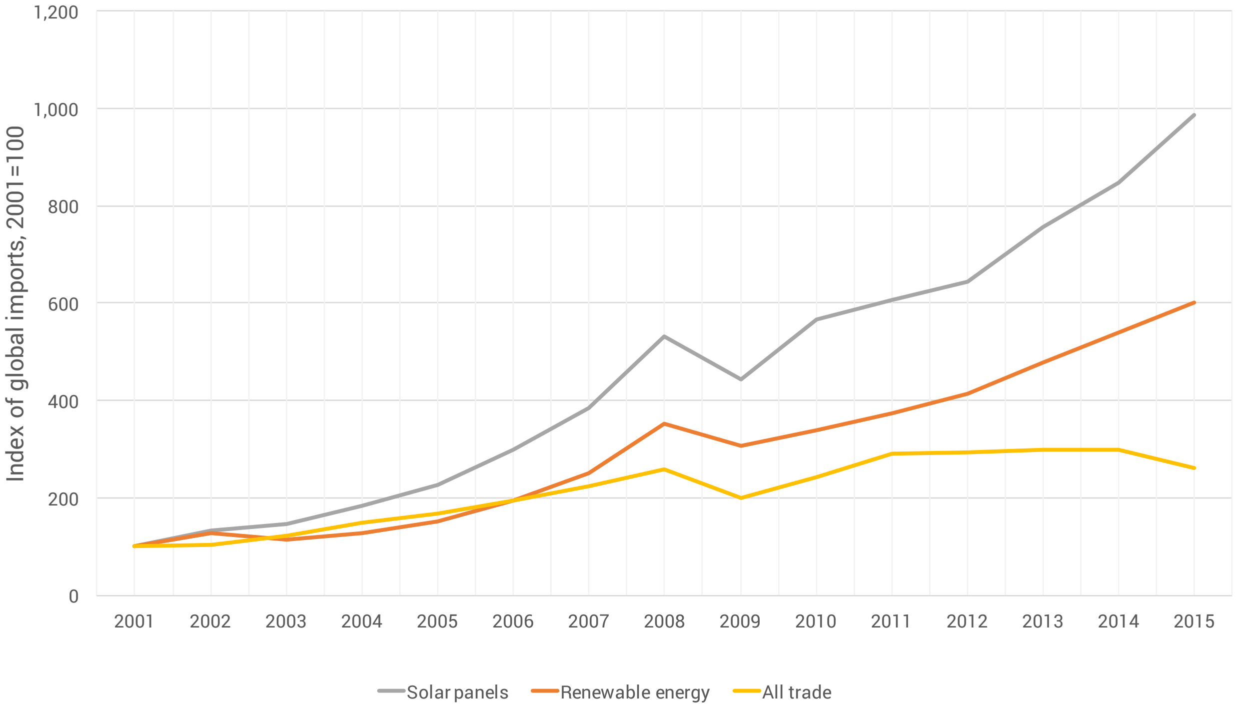

Figure 13: Global trade in solar panels, from 2001 to 2015 (Authors' calculations, based on Trade Map data)

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[8] Codes for smart meters are based on a definition by the US International Trade Commission, which identified the following key categories: "Harmonized System (HS) heading 902830 (Electricity Supply or Production Meters). Parts and subassemblies of smart meters fall under HS 902890 (Parts and Accessories of Gas, Liquid, or Electricity Supply or Production Meters, Including Calibrating Meters)."

Table 6: Leading solar manufacturers by global market share of megawatt-peak (Renewable Energy World, 2016)

2010	2011	2012	2013	2014	2015	Share in 2015
Suntech	Suntech	Yingli	Yingli	Trina	Trina	7.15%
JA Solar	First Solar	First Solar	Trina Solar	JA Solar	JA Solar	7.12%
First Solar	JA Solar	JA Solar	JA Solar	Hanwha Q-Cells	Hanwha Q-Cells	6.69%
Yingli	Yingli	Suntech	Canadian Solar	Yingli	Canadian Solar	5.30%
Q-Cells	Gintech	Trina	First Solar	NeoSolar	First Solar	4.96%
Sharp	Trina	Canadian Solar	Hareon	Jinko Solar	Jinko Solar	4.72%
Trina	Motech	Motech	Motech	Motech	Yingli	4.70%
Motech	Canadian Solar	Gintech	NeoSolar	First Solar	Motech	4.13%
Gintech	Sharp Solar	Sharp Solar	Jinko Solar	Canadian Solar	Neosolar	4.13%
Kyocera	Jinko Solar	NeoSolar	Gintech	Kyocera	Shungfeng-Suntech	3.88%

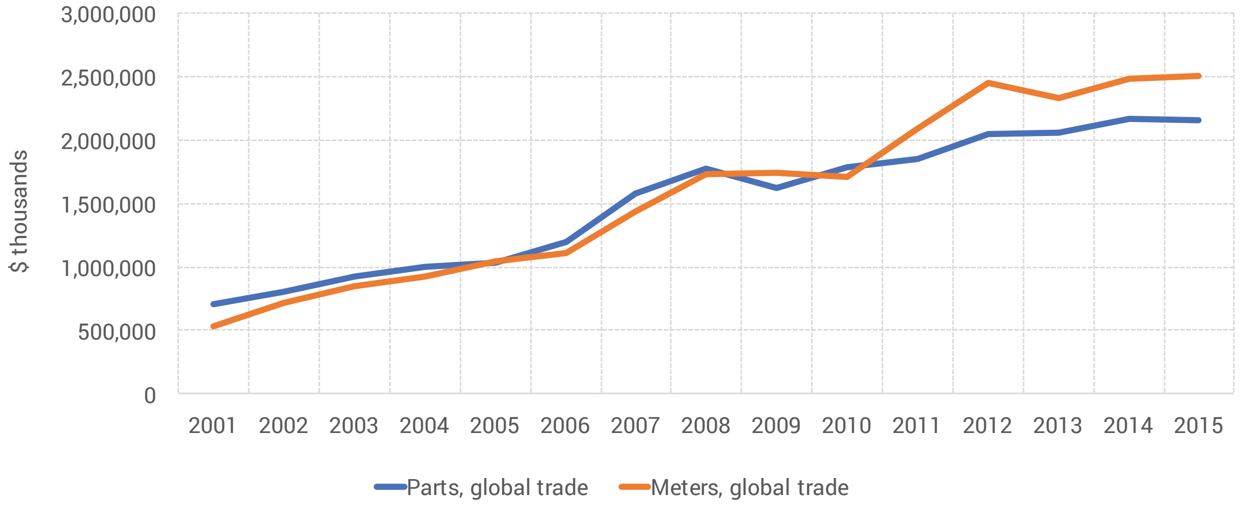

Figure 14: Global trade in meters and parts (Authors' calculations, based on Trade Map data)
Note: To date, data on smart meters alone does not exist.

Table 7: Select leading global smart meter manufacturers (Alejandro, et al., 2014)

Company	Country of origin	Presence in South Africa
Sensus	USA	Yes
Elster	Germany	Yes
Itron	USA	Yes
Echelon	USA	Agent
Holley	China	No
Landis+Gyr	Switzerland	Yes
General Electric	USA	Yes

in primary manufacture of their own products, most others are principally involved in assembly. India, for example, is establishing a five-acre assembly plant in Andhra Pradesh, with the capacity to produce 150,000 smart meters per month (Metering & Smart Energy International, 2010), while an undisclosed Chinese firm will be developing a smart and prepaid meter manufacturing plant in Kenya, as part of a procurement deal with Kenya Power (Daily Nation, 2016).

Beyond the competitiveness of these global players, trade in smart meters is complicated by two main factors. The first is a lack of a global standard for smart meters, with different utilities using different specifications. The global standard-setting body, the International Electrotechnical Commission, has identified over 100 (voluntary) standards that are relevant to smart grids, but the plethora of national standards requires firms to be able to adapt their products to specific export markets (IEC, 2010). Many standards globally require manufacturers to constantly adjust their product offering based on their target market. This makes it difficult to achieve economies of scale in manufacturing, and can create higher entry costs for foreign firms, as companies must adapt their product to each new market. These costs may be prohibitive, particularly for small firms. The second is the widespread occurrence of local procurement and other regulations, in a similar fashion to the solar PV issues, as detailed below (De Melo & Vijil, 2014).

While growth trends in both solar panels and electrical meters are encouraging, another two factors present hurdles for potential exporters: firstly, the high protection in these sectors, and secondly, the high level of competitiveness of a few global manufacturers of these products.

Formal protectionism is low. Exporters do not face tariffs in most developed economies, including the USA, Japan, and the largest European countries. Emerging economies have slightly higher tariffs, particularly for meters, as can be seen in Figure 15.

Despite this low formal protectionism, as mentioned in Section 3.1, NTBs remain high, in a large part because the rollout of SSEG systems is often state-led, creating local procurement requirements and subsidies, among other barriers. These programmes are vitally important to countries like South Africa, in their ability to create local manufacturing where the sector might otherwise rely solely on imports. They nevertheless have the potential to restrict access to important export markets, and also have a general trade-distorting effect. Domestic subsidies often indirectly affect exports. Direct export subsidies are nothing new in the global solar market, having driven China's solar boom, which

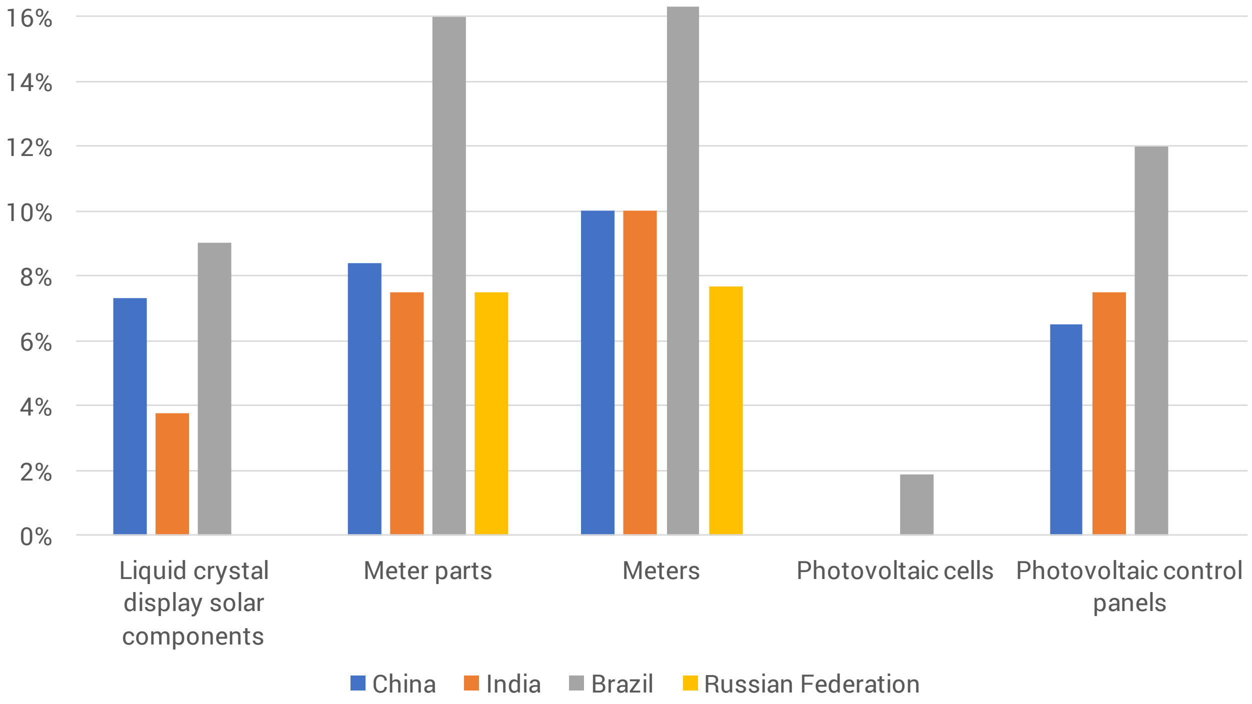

Figure 15: BRICS tariffs faced by South Africa for SSEG components (Authors' calculations based on Market Access Map data)

saw Chinese manufacturing capacity grow tenfold between 2008 and 2013 (Haley & Haley, 2013). More subtle subsidies, such as high feed-in tariffs for solar power, are also in place in many countries. These tariffs are essential to attracting investment to the solar space and to improving the efficiency of the technology, helping rapidly create large market opportunities. The net result has however, been the clustering of industries around government interventions, and as a result, scale efficiency gains can make it hard for newer manufacturers, like South African firms, to access the market.

Overall, the global market for both small-scale solar units and metering systems is attractive and likely to keep growing exponentially as SSEG systems are rolled out across the globe. Yet the market space is extremely competitive, distorted by government policies, and complicated by various standards and other technological issues.

4.1.3. THE DOMESTIC MARKET

Given intense competition in the global market, the core opportunities for South African firms are likely to be local manufacturing and assembly as substitution for imports of smart meters and small-scale generation units. South Africa's import of solar units has been growing rapidly, spurred by the REIPPPP. The demand from SSEG is estimated to be a small component, although it is impossible to distinguish in the trade data. Similarly, the trade data does not provide an accurate picture of the import of smart meters, since they are bundled together with other meters. Nevertheless, the trend has been stable, with imports edging upwards progressively from 2003, as can be seen in Figure 16.

As of December 2016, roughly 100,000 solar PV units were estimated to be privately installed in South Africa, which, when combined, had a capacity of 159 megawatt-peak (GreenCape, 2017). It is difficult to confirm how many smart meters installed, although City Power rolled out approximately 52,653 units in Johannesburg in 2013, and a range of initiatives have been undertaken by other municipalities (Eskom, 2015). Since "smart meters" is a broad term which could be applied equally to meters that enable demand management but not two-way energy supply and these meters predate the development of standards for smart meters, it remains unclear in some cases whether these pre-existing meters are of a type suited to SSEG.

The existing market for small-scale solar power

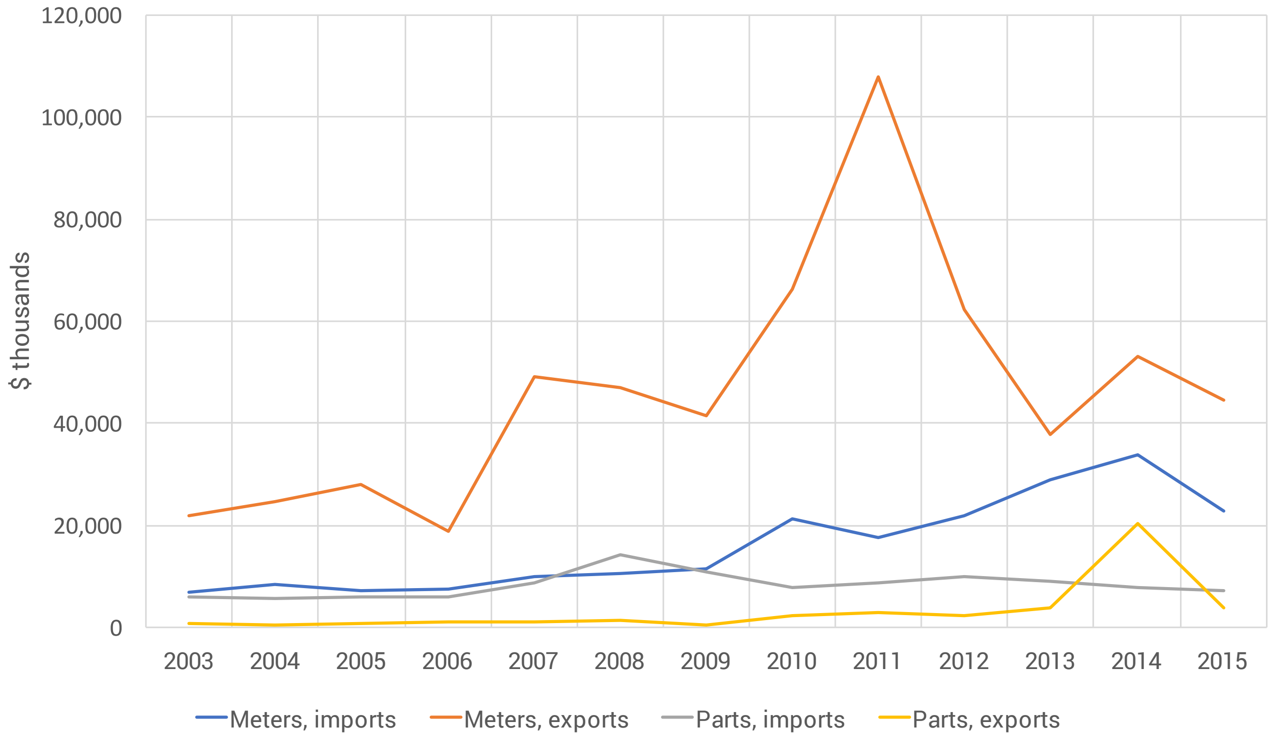

Figure 16: South Africa's trade in meters and parts, from 2003 to 2015 (Authors' calculations, based on Trade Map data)
Note: To date, data on smart meters alone does not exist.

systems and smart meters therefore remains small, but with impressive potential if embedded generation systems are rolled out nationally. One estimate claims that "residential and commercial PV could reach 22.5 gigawatt by 2030 based on Living Standard Measure 7 households9 with 5kWp PV household installations" (NERSA, 2015).

Two factors that would unlock the full potential of SSEG in South Africa include: establishing a successful regulatory environment, and implementing local content requirements that facilitate local production. Other barriers, such as upgrading the aging distribution infrastructure and physically installing the meters, are important, but are generally regarded as open to being solved naturally so long as the regulatory environment creates a compelling case for investment in SSEG through a favourable feed-in tariff. The identified barriers are inclusive of:

- A decrease in the municipality revenue base as, in some cases, electricity sales provide up to 70% of municipal income.
- Municipalities' ability to cross-subsidize other municipal services using electricity revenue will be reduced.
- There is a risk of low-voltage and medium-voltage system overload from high simultaneous SSEG generation into the local grid at, for example, midday.
- Lack of controls threaten the safety of utility personnel.
- The lack of pre-approved, generic standards for the SSEG/utility interface.
- Regulatory and legal obstacles.
- The quality of supply (QOS) impact of PV equipment. Quality of Supply is a broad term referring to metrics like the stability of energy supply, the continuity of supply, and the relationship between energy customers and suppliers (Tuson, 2014).

The regulatory process for establishing an SSEG system began with the draft regulations compiled by the National Energy Regulator of South Africa (NERSA), entitled "Small-Scale Embedded Generation: Regulatory Rules" (NERSA, 2015). These have since been abandoned in favour of regulatory amendments put forward by the Department of Energy under a Draft Licensing and Registration Notice, which went out for public comment in December 2016 (DoE, 2016). Both aim to reform the licensing regulations for potential energy generators. As it stands, a small-scale power generator looking to sell back into the grid would have to go through the same costly process of applying for a licence as a large-scale utility generator. This is, of course, prohibitively expensive for a model that relies on multiple small generators dispersed across the grid. The proposed amendment would exempt certain generators from licensing requirements, provided that the generator is (1) connected on the load side of the grid, (2) serves to supply an end user, and (3) is under 1 MW in size.

A major restriction on these exemptions, however, is that they would only be in place until the Minister of Energy determines that the amount of power generated fills the quota prescribed by the IRP (GreenCape, 2017). Since embedded generation is not allocated under the current plan, it remains unclear how this would work in practice. Even if an allocation was in place, the ceiling on how much energy could be drawn from SSEG could raise serious uncertainty in the industry. Industry would probably work towards filling the ceiling, but once that is reached, little further work could be done until the minister defines a new ceiling. If this process of redefining how much SSEG energy can be provided is not fixed to a clear, transparent timeline, then industry would face an unpredictable cycle of boom and bust, which may undermine planning and investment in the sector. Such an approach would likely not provide the market demand required to trigger long-term manufacturing investment. Unless this instability is managed by clarifying the quantity of energy sourced over a prolonged period, it seems to be a prohibitive restriction.

The licensing rules are a vital part of SSEG regulation, but they only cover the supply side of embedded generation. Regulations governing the demand side are complex, with the uptake processes and monitoring structures governed by municipalities, and the price dictated by the regulator. Although the Western Cape's sectoral promotion agency, GreenCape, has developed a widely-used set of standards for municipalities, no universal set of regulations guide municipalities' efforts to establish SSEG systems.

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9. The Living Standard Measure is a private market segmentation system that divides the population into various groups based on their access to certain goods, such as hot water or ownership of a car. A Living Standard Measure 7 household would represent a household with a consumption profile in the upper-middle of the range.

As illustrated in Figure 17, progress on municipal regulation is unbalanced, with much of the progress clustered in the Western Cape. While this is partly due to the work of GreenCape, the ambiguous relationship municipalities have with SSEG is also to blame. While the price municipalities pay for electricity should be equal regardless of whether they buy from embedded generation or the national utility Eskom, the State-owned company offers large lines of credit on which in recent years the municipalities have been extremely dependent. In addition, the complexity of administering an SSEG system remains daunting, particularly for smaller municipalities, requiring extensive refurbishment of municipal billing systems and energy planning.

A final, but rapidly closing, gap in the smart grid space is the roll-out of common standards, both for the infrastructure (the smart meters) and the installation process. An existing standard, largely developed by GreenCape, applies to the infrastructure. More challenging is the creation of standards for the private installation of solar panels. This is critical. Poor installation of meters can be a serious safety hazard, and while this is bad in itself, it is equally a concern for an industry that will need to prove itself to a public unused to working as its own electrical generator. One high-profile fault that leads to severe damage could set the industry back by decades. A South African Bureau of Standards (SABS) technical committee has been working on developing such a standard, although the process has been slow and dogged by instability, due to internal institutional challenges. Given the lengthy SABS process, the South African Photovoltaic Industry Association (SAPVIA) has been drafting its own set of private standards, to act as a place holder. The private standards were released in May 2017, with the launch of the PV Green Card, a voluntary certification system for PV system installers and an accompanying database of those installers. While the SABS standard was scheduled to be completed by June 2017, the process was still not complete at the time of writing.

If the regulation and standards are set in place, and the industry begins to move forward in earnest, the most likely route for potential suppliers will be to import both solar panels and smart meters. This is particularly true given the decline of solar assembly plants as a result of the uncertainty around the REIPPPP. Existing smart-meter programmes have partnered with foreign suppliers, with Eskom procuring the meters for its 2011 pilot programme from German multinational Landis+Gys (Eskom, 2015). Local procurement policies have been put in place, with both solar PV systems and smart meters receiving designation.[10]

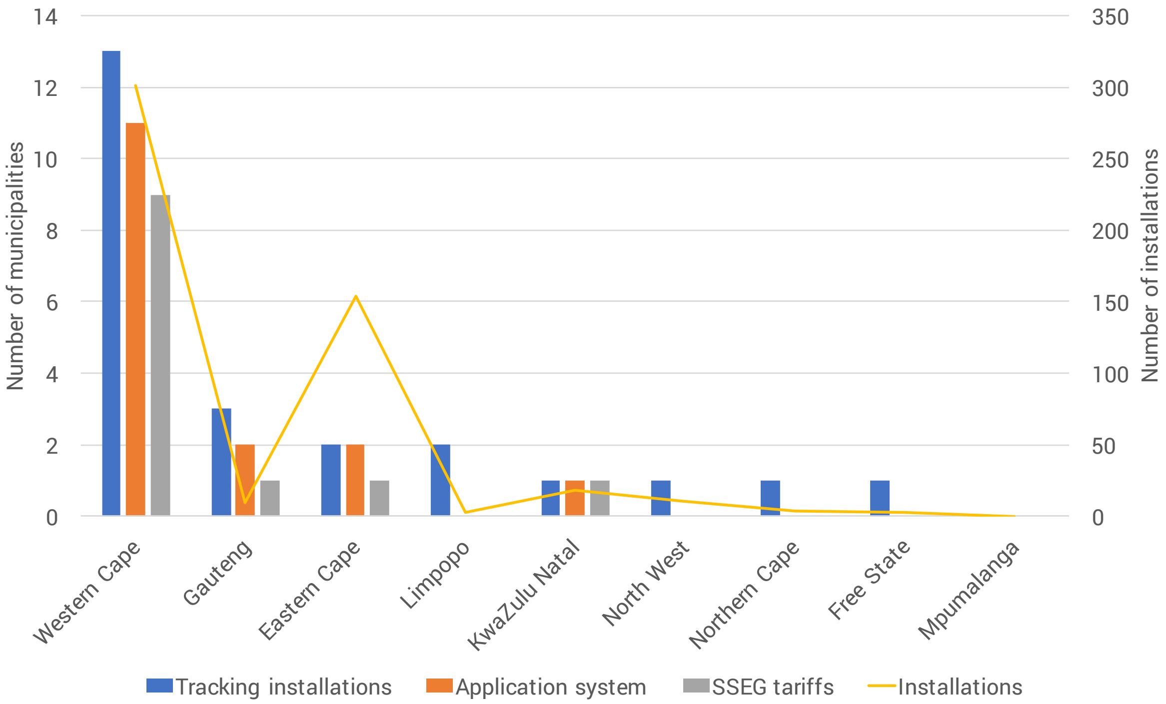

Figure 17: Municipal regulatory systems for SSEG in South Africa (GreenCape 2016)

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[10] Designation refers to industries, sectors and subsectors where a specific level of local content is required when procuring from the state.

Table 8: Local content provisions for designated solar PV systems (Renewable Energy World, 2016)

Component	Minimum local content	Conditionality
Laminated solar PV modules	15%	The local process will include tabbing and stringing of cells, encapsulation and lamination, final assembly and testing in compliance with International Electrotechnical Commission standards.
Module frame	65%	Aluminium components: all aluminium PV module frames, PV mounting structures/racks, clamps, brackets, foundation components and fasteners are to be manufactured from locally produced extruded, rolled, cast or forged products.
DC combiner box	65%	Direct current combiner boxes: enclosures must be made from sheet moulding compound and moulded in South Africa.
Mounting structure	90%	All aluminium PV module frames, PV mounting structures/racks, clamps, brackets, foundation components and fasteners are to be manufactured from locally produced extruded, rolled, cast or forged products.
Inverter	40%	Must be assembled locally.

Table 9: Local content provisions for smart meters (Eskom, 2015)

Local content provisions	Weight
Local content to South Africa	50%
Local content to site (within 50km from project location)	0%
Procurement from large black suppliers	15%
Procurement from black women-owned suppliers	10%
Procurement from small black enterprises	0%
Skills development	**25%**
Smart meter information technology trainee - 25% Meter quality controller - 25% Trainee safety, health and environmental officer - 25% Trainee meter technicians - 25%	

Designation in the case of solar PV focuses on the more standard parts of the unit, rather than the PV module, as can be seen in Table 8. As currently defined, a supplier would have to undertake some basic fabrication of the mounting structure and other parts, while also assembling the unit locally. In the case of smart meters, the scorecard seen in Table 9 features 50% pure local content, with the remainder comprising a selection of empowerment initiatives and training programmes. Designation may be accompanied by proposed tariffs on a range of environmental goods, including solar cells (15% proposed tariff) and solar glass (10% - 15% proposed tariff), both of which now enter the country duty free.

While designation is a positive step for the local industry, it is not clear how effective it will prove in the broader SSEG market. A SSEG rollout is understood to be efficient as there is no central procurement body, but rather a fragmented market of households and service providers with an interest in acquiring meters and panels that will reduce their electrical bill. These individual buyers will not be subject to any procurement restrictions, and even if the local municipality or Eskom is the end user of the energy generated by those units, they will not have a clear lever to encourage local procurement of those products, unless they put in place a set of regulations limiting the units from which they are willing to accept energy.

While local procurement could be effective in promoting local manufacturing off the back of a wide-scale rollout of smart meters by Eskom and/or municipalities, and this local manufacturing would surely spill over to the private domestic market, it nevertheless compels government to take the lead in installing an SSEG system, which may not be the most efficient model. Regardless, problems with the local procurement system would need to first be corrected. Most pressing is the need to fix the local content standards programme, which remains prohibitively expensive for most projects. Local procurement of SSEG would also need to be backed up by credible guarantees from the government, to reassure a market made wary by the recent REIPPPP fallout. The REIPPPP is dependent on a system in which national utility Eskom contracted independent power producers after a bidding process co-managed by the National Treasury and Department of Energy. For various reasons, Eskom refused to sign the contracts emerging from the most recent bidding rounds, and has fought back against plans for future rounds. While the Department of Energy still supports the programme, no progress can be made until Eskom commits to connecting contracted independent power producers to the grid. The result has been an open-ended stasis in the rollout of renewable energy in South Africa. Given this experience, and if possible, Eskom needs to be brought on as a willing partner or, failing that, the Department of Energy will need to exert its authority over the sector and assure protection for a renewable energy technology market that Eskom largely opposes (Creamer 2016).

4.1.4. THE LOCAL MANUFACTURING BASE

The local manufacturing bases for meters and for solar panels differ, but share two important joint characteristics. Firstly, they remain dependent on local procurement off the back of large-scale government programmes. For solar systems, the REIPPPP is the main driving force, whilst with reference to meters, Eskom's ongoing upgrading programmes for metering technologies constitutes the core demand pull. Secondly, the local manufacturing bases for both solar systems and smart meters are focused on assembling imported products. As such, surveying the broader landscape is challenging, as the presence of local manufacturing capacity says little to none on the actual local benefits or the depth of manufacturing activity being undertaken. As discussed earlier, the local procurement policies that drive most local investments, for the majority, focus on assembly and fabrication of simpler parts, such as module frames for solar panels.

Notably, these factors point to a sector that does not have substantial roots in the South African market. With firms undertaking simple assembly activities and remaining reliant on government programmes, shifts in the policy environment can very easily alter the state of the local industry. This has two core implications. Firstly, the industry remains reliant on credible state support for the renewable energy sector, which is growing increasingly tenuous after the showdown with Eskom over the REIPPPP. Secondly, there is little in the way of industrial policy support beyond local procurement. Supporting policies that enable a more fundamental shift in the competitiveness of the sector may be required if there are to be sustained attempts to develop the industry.

Given this fluid space, it is challenging to determine the exact manufacturing base of the sectors, although some data is available. For potential smart meter manufacturers, the basis of their business is in producing more traditional meters, but a range of newer firms are focusing almost solely on smart meter manufacturing. A limited number of original manufacturers exist, with much of the focus on assembly. Leading meter manufacturers tend to focus their local production on standard or prepaid meters, with no smart meter assembly present among a representative selection of firms as listed in Table 10. The weakness of local manufacturing is fundamentally connected to the underdeveloped nature of the broader electro-technical industry in the country, which is large and sophisticated, but which often does not undertake primary manufacturing of crucial electrical components, preferring to import more complex items (the dti, 2010).

Firms in the metering space are divided into two types. A first group consists of large multinationals or South African firms under contract to assemble for large multinationals. As mentioned earlier, most

Table 10: Selected local manufacturers among leading meter providers (GreenCape, 2014)

Firm	Origin	Local manufacturing
Itron	USA	Yes, but for pre-paid meters only
Aurecon	South Africa	No
Siemens	Germany	No
Alstom	France	No
Actom	South Africa	Yes
Powertech	South Africa	Yes, but not smart meters
CTLab	South Africa	Some assembly
ABB	Swiss	Yes

major international smart-meter manufacturers have some presence in South Africa, but as noted in Table 10, few companies have local manufacturing capacity. Complementing these established players is a second group of emerging South African firms, who often focus on smart-meter manufacturing. Data is limited on these firms, and while a limited sample is shown in Table 11, it remains difficult to distinguish between primary manufacturers and those who assemble or resell foreign products.

Data on South African firms' participation in the global smart meter market is also limited. The only identified exporter, Conlog, a Durban-based meter manufacturer, exports its products to over 20 countries, mostly in developing markets like Colombia, Indonesia, and a range of African countries (Potgieter, 2014). However, most of this trade appears clustered in the prepaid-meter market, with the smart-meter market remaining underdeveloped.

On the solar power systems side, the industry has traditionally been far more established, albeit with a focus on utility-scale solar power for the REIPPPP. Local procurement requirements under the REIPPPP meant that the local content share of projects ranged between 23.7% for the first bidding round, to 49.2% for the fourth bidding round (Department of Energy, 2015). While most solar manufacturers in South Africa are concentrated on assembly activities, one firm, Photovoltaic Technology Intellectual Property (PTiP), undertakes primary manufacture of PV cells (Barbee, 2016).[11]

Table 11: South African smart meter firms (Authors' compilation)

Firm	Location	Smart Meters
PMT (Power Meter Technics)	Gauteng	Yes
Meter Mate	Gauteng	Yes
Power Star	Western Cape	Yes
PEC Utility Management	Gauteng	Yes
PPS (Power Process Systems)	Gauteng	No
Conlog	KwaZulu-Natal	Yes

Figure 18 illustrates the value shares for various components does not differ much between residential PV units connected to the grid and utility-scale solar PV panels. The most substantial difference is in the weaker role for mounting hardware and the greater role for inverters in residential units. This therefore implies some limitations, given the large role for manufacturers

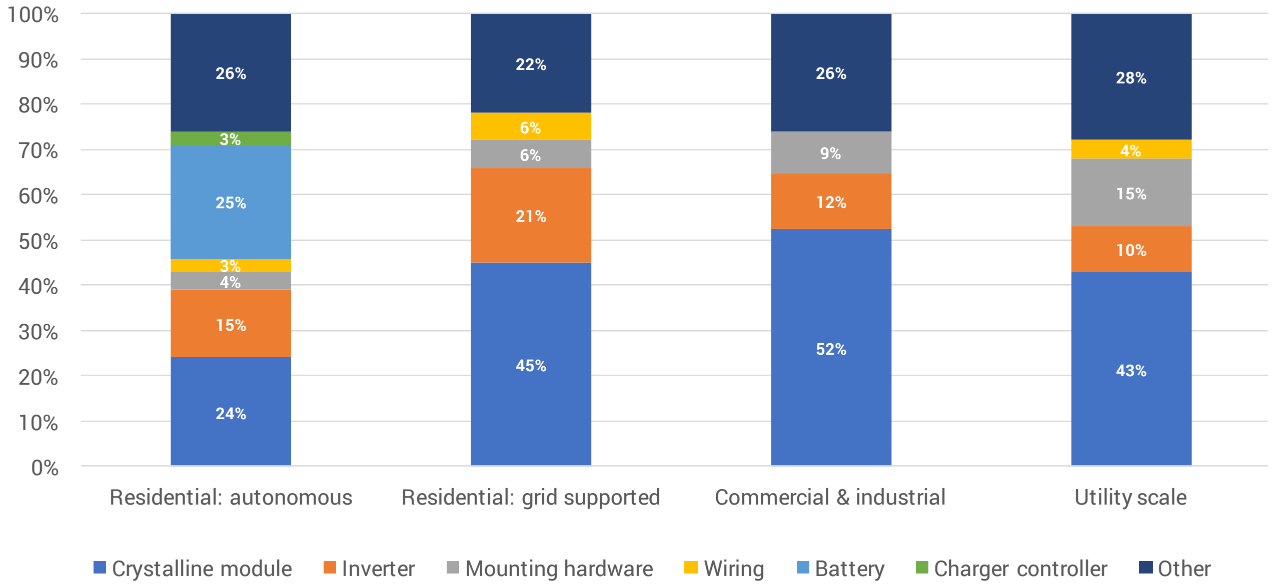

Figure 18: Share of value by component for various solar PV systems (Maphelele, 2013)

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[11] Production is based on local innovations by Professor Vivian Alberts in the field of thin-film technology. More traditional silicon solar panel manufacturers all rely on imported cells.

of solar mounting hardware. Nevertheless, the local manufacturing base established for the REIPPPP should be able to serve the small-scale market.

Unfortunately, South Africa's local manufacturing base has been decimated by the standoff over the future of REIPPPP. At the height of the success of REIPPPP, a wide range of local assemblers operated in the country, facilitated by local content regulations, but the stalling of the REIPPPP has starved these companies of business. Only two local manufacturers remain in South Africa, both reliant on exports to remain afloat. The factories are not considered internationally competitive, and are expected to close if no progress is made on resolving the impasse around the REIPPPP.

While local manufacturing could return to South Africa given a revitalised market linked to SSEG, this seems unlikely to happen soon. Doubts about the South African renewable energy market, combined with the continued reliance of the SSEG market on the same state actors that generated and oversaw the problems with the REIPPPP, mean that overcoming the lack of faith in the market will be a challenge.

Despite the many barriers to export South African solar firms face, two firms are undertaking assembly for the foreign market. Unfortunately, these firms are only doing so to compensate for the stasis in the domestic market after the stalling of the REIPPPP. South Africa's solar assembly is not considered internationally competitive, and industry representatives attribute the existence of exports to the need to recoup sunk costs. Industry experts noted that, should the REIPPPP issue not be resolved, one of these manufacturers was likely to close its doors by mid-2017.

4.1.5. RECOMMENDATIONS

The SSEG sector has high potential, albeit with greater opportunities in import substitution than in exports. However, smart meters seem far more promising than small-scale solar system development. Tapping into this will require leveraging off three core areas.

Firstly, support for developing smart meters should be undertaken in partnership with the established base of local manufacturers and assemblers. These firms are strong partners in their own right, but also benefit from the fact that their success is not solely reliant on the rollout of SSEG, since they have a diversified product base set in an established market for traditional and prepaid meters. Local demand for solar products, by contrast, will be limited so long as the REIPPPP remains suspended, and the market may struggle if solely reliant on SSEG.

Secondly, to the extent that exports are possible, smart meters appear better placed than solar systems, and should perhaps be the core focus of export-oriented support policies. On the one hand, there are some established export capabilities for meters, and more scope to adapt smart-meter technologies to the developing country market, and this might offer a competitive edge. The global solar market, on the other hand, is brutally competitive and highly distorted, and appears an extremely complex undertaking for would-be exporters. While the export success of both products, and other components in smart grids, can be boosted through import substitution that helps local firms build competitive scale, export initiatives will have to be more targeted on specific products like smart meters.

Thirdly, if solar and other renewable energy technologies are to be pursued as a realistic manufacturing opportunity, then greater certainty is needed on the future of the utility-scale market. The impasse over the REIPPPP has devastated the market for solar power, and while the future market for SSEG could alleviate some of the collapse in demand, the scale and pace of a SSEG rollout is currently too uncertain for firms to consider investing in local manufacturing capacity. A large rollout of SSEG seems possible, but the dispensation granted to the Minister of Energy to control the procurement of embedded generation, and the uncertainty from the lack of SSEG allocations in the IRP, mean that the market is likely to be too unpredictable for manufacturing investment planning. Given the close interdependence of the solar market with the REIPPPP programme, the current impasse either needs to be resolved or the SSEG market needs a clear, credible signal from government on how much will be procured and when. Otherwise, industrial policy focus should shift away from solar manufacturers, perhaps towards smart meters. Smart meters are desirable regardless of what happens with the REIPPPP or with the rollout of SSEG, since they allow Eskom to manage its load more effectively, and better manage any potential future crises. SSEG would create vastly more opportunities for smart meters, but the smart-meter market seems more assured regardless of what happens.

The broader question for both sectors, however, is whether they would need additional industrial policy support to succeed. It seems the core issues at stake for both are in getting the SSEG regulatory framework in order. With local procurement designation already in place, and proven manufacturing capabilities in both sectors, getting the demand side going seems the most pressing issue for the sector. Extensive work has been done, including draft regulatory frameworks and emerging standards, and much of the success depends on moving that work forward. With the regulatory framework put in place, municipal bylaws clarified, and standards more fully developed, the SSEG sector is then likely to take off. Until this happens, however, few policy interventions in the sector seem pressing. Once the policy framework is clearer, particularly on how much energy the DoE is willing to procure through SSEG, then supporting interventions like assistance for expanding manufacturing capacity and deepening localisation may be needed.

4.2. WATER TECHNOLOGIES

KEY FINDINGS

- South Africa, like many other countries, faces growing water security concerns, due to increased use and threatened water supply, and growing water demand.
- Water technologies, both for water treatment and water conservation, have a significant role of play.
- Despite some local capabilities, South Africa's imports of water technologies are higher than respective exports, presenting opportunities to expand the local manufacturing capability for import substitution as well as exports.
- For most water technologies, the country already has research and development and technological capacity.
- The limited funding for research and development and technology commercialisation is a key barrier to promote locally appropriate, efficient, and affordable water technologies in South Africa.
- Increased promotion of the demand for local technologies through local procurement of water technology components is required.
- The action programmes outlined in the Industrial Policy Action Plan should be fully implemented to develop local manufacturing capability and competitiveness.

4.2.1. BACKGROUND

Globally, more than 2.4 billion people do not have proper access to improved sanitation (Creamer Media, 2016) and more than a billion lack access to improved water (ActionAid, 2016; WEF, 2016). Many of the people without access are in sub-Saharan Africa (ActionAid, 2016) and, in South Africa, a significant proportion of the population lacks modern access to water and associated services, resulting in detrimental socio-economic effects. Violent protests regularly occur in the country as a result of poor water service delivery by municipalities, posing serious and immediate risk to the economy and to social stability (ActionAid, 2016). For example, a total of 538 water and sanitation-related protest events were recorded countrywide in the 2016/2017 period (DWS, 2017).

The frequency of droughts and dry spells affects South Africa like many other countries, with notable impacts on agriculture, industries and households. Climate change is likely to make water availability less reliable, and some areas are likely to become drier. South Africa also faces many other water-related challenges, such as algal blooms (i.e. a quick increase in the algae population) on dams, and acid mine drainage (AMD) (ASSAF, 2014), further worsening water scarcity problems.

At the same time, water demand in South Africa is likely to grow at a rate of approximately 1.2% over the next 10 years, which creates a need to explore new approaches to improve availability while reducing demand (DWA, 2013). The growing competition for water is expected to result in more tensions within the country and the region (WEF, 2016).

In the context of these challenges, water technologies can play an important role in improving the water value chain (ASSAF, 2014), categorized by the following stages: basin/catchment management; abstraction; storage; treatment; distribution; use; wastewater treatment; and discharge (GreenCape, 2016). The same value chain can be viewed from the desired impact outcomes perspective, as shown in Table 12.

Furthermore, the United Nations World Water Development Report 2015 notes that only about 5% of the Africa's potential water resources are developed, with an average per capita storage of 200 m^3, which is extremely low compared to 6,000 m^3 in North America (WWAP, 2015). The various hitches along the water value chain create opportunities to create solutions and economic benefits. There are huge investment opportunities (ActionAid, 2016) that offer financially competitive returns (Sonen Capital, 2016). Some of the generic investment opportunities in the water sector are presented in Table 13. On a broader note, technologies can be separated into two groups, those for water management (water conservation, water harvesting, water efficiency) and those for water treatment (desalination, wastewater treatment, recycling and re-use).

4.2.2. WATER TREATMENT TECHNOLOGIES

Wastewater treatment has several benefits. Firstly, it reduces the negative impact of untreated wastewater on the environment. Secondly, it contributes to conserving water and enables the proper re-use of treated water. Furthermore, wastewater

Table 12: Water supply chain (Sonen Capital, 2016)

Component	Definition
Supply	Water collection Water rights Wastewater
Treatment	Water cleansing and rescue Desalination
Distribution	Water infrastructure (utilities) Water services (i.e. engineering & construction) Technologies (i.e. smart meters)
Consumption	Retail (i.e. bottled water)

Table 13: Summary of water investment sectors (Sonen Capital, 2016)

	Types of Investment
Technology	Equipment Water treatment Chemicals Smart meters
Utilities/ Infrastructure	Regulated utilities Non-regulated utilities Emerging market utilities
Industrial	Pipes and plumbing Pumps and fluid control Irrigation equipment Construction Engineering and consulting
Commodities	Water rights Water allocations

treatment technologies can be integrated with other technologies to realise additional benefits, such as energy recovery and resource extraction. Wastewater can be used as a cost-efficient and sustainable source of energy, nutrients, organic matter and other useful by-products (WWAP, 2017). The benefits encompass human and environmental health, food and energy security, and also climate change adaptation and mitigation (Figure 19).

Since most of the large wastewater treatment processes, such as desalination, consume a vast amount of energy, hence options that generate or reduce energy use, need to be explored (DWA 2013). Renewable energy can cater for some of the energy needs. Options include recovering energy from sludge and converting it into biogas (as discussed in Section 4.3), and hydropower that involves extracting available energy from existing water supply and distribution systems i.e. harnessing excess energy in pressurised conduits to produce hydroelectric power (GreenCape, 2016). However, the viability of the renewable energy option remains dependent on whether enough energy can be produced to meet high energy demand.

Water re-use uptake is growing due to increasing water shortages and, at the same time, is becoming more feasible due to better purification technology, such as membrane technology, and decreasing treatment costs (DWA, 2013). Opportunities for water treatment are increasing as a result of the availability of large quantities of industrial wastewater, currently not optimally treated, rising water and wastewater costs, increasing water scarcity, stricter discharge and treatment standards, pressures to reduce energy and greenhouse gas (GHG) emissions relating to water and wastewater management, and new and niche technologies (Cohen et al., n.d.).

The choice of water treatment technology depends on the nature of the pollutants in the water and the required quality of the re-use water (DWA, 2011a), as well as the appropriateness of the technology in a particular setting. A selection of water treatment technologies that can be applied to water re-use are shown in Table 14.

Generally, treating water to the quality necessary for re-use requires secondary treatment through advanced treatment technologies (Cañeque et al., 2015). Where secondary treatment entails the biological removal of biodegradable organic matter and suspended solids, two broad categories of processes can be used, namely membrane and non–membrane. Then, advanced water treatment that involves the removal of total dissolved solids and/or trace constituents is employed depending on the final application of the treated water.

Membrane technologies are important in wastewater treatment. The use of membrane technologies is becoming increasingly common for tertiary or advanced treatment, especially in developed countries, as membranes continue to improve and operational costs decrease (WWAP, 2016).

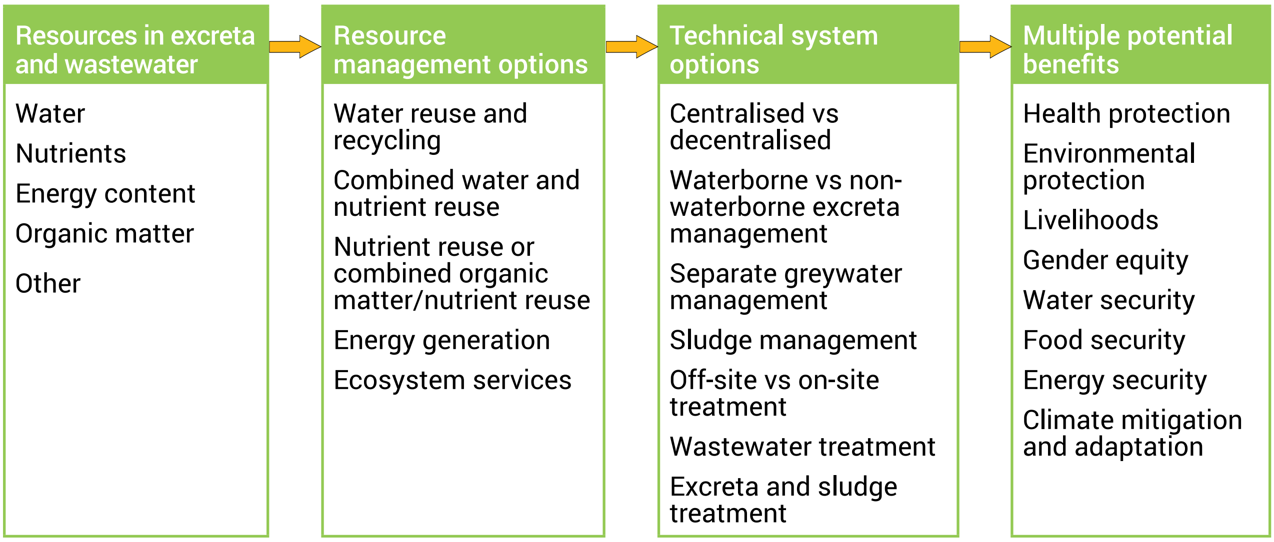

Figure 19: Framing wastewater management from a resource perspective and potential benefits (Andersson et al., 2016 and WWAP, 2017)

Table 14: Applicable water treatment technologies for water re-use (DWA, 2011a)

Category of Pollutants	Types of Investment
Macro-organics, chemical oxygen demand and biochemical oxygen demand	• Biological treatment (activated sludge, trickling filtration, fixed film reactors, membrane bioreactors) • Chemical coagulation/flocculation and clarification
Particulate and suspended solids	• Chemical coagulation/flocculation and clarification • Granular media filtration • Membrane filtration
Nutrients – Nitrogen	• Biological nitrogen removal (nitrification/denitrification) • Air stripping (ammonia) • Chemical coagulation/flocculation and solids separation
Nutrients – Phosphorus	• Biological phosphorous removal (enhanced biological phosphorus uptake) • Chemical precipitation (typically metal salt addition) • Chemical precipitation (packed bed reactors)
Microbiological agents, such as bacteria, viruses and parasites	• Membrane filtration • Chemical disinfection (chlorine, bromine compounds etc.) • Ultra Violet radiation
Salinity, inorganic salts	• Precipitation • Ion exchange • Membrane desalination (nanofiltration /reverse osmosis)
Metals	• Precipitation • Chemical adsorption • Membrane separation
Micro-organics, such as volatile organics, pesticides, pharmaceuticals and endocrine disruptors	• Advanced oxidation (H_2O_2/UV) • Adsorption by activated carbon (granular/powder) • Membrane separation (nanofiltration /reverse osmosis) • Biologically enhanced adsorption (BAC)
Disinfection by-products	• Modified disinfection agent in upstream processes • Advanced oxidation • Adsorption by activated carbon (PAC/GAC) • Membrane separation (nanofiltration /reverse osmosis)
Radionuclides	• Precipitation • Chemically enhanced adsorption • Membrane separation (nanofiltration /reverse osmosis)

Advances in membrane filtration technology have reduced human and environmental health risks and have opened new opportunities for wastewater use including potable re-use.

Membrane filtration technology has two main types, namely ultrafiltration and microfiltration (Cañeque et al., 2015). Membrane technologies have advanced markedly, with many new membrane materials, such as polymeric and ceramic membranes being introduced (Deloitte, 2016). Other associated technologies include membrane bioreactors being developed from innovations to intensify the membrane separation by incorporating it with the activated sludge process (WWAP, 2017).

Desalination converts salt water into usable water. Some of the proven water desalination treatment technologies are: distillation, membrane-based, ion-exchange and precipitation (DWA, 2011b).

The last group of water treatment technologies focus on the specific issue of AMD,12 an acute problem in South Africa principally. The collection, treatment and re-use of AMD converts the negative impacts into positive beneficial water use (DWA, 2011a). Use of the treated water depends on the degree of treatment and cost implications.

The need to ensure that water treatment infrastructure is suited to the local context and be of right size has spurred development of small-scale systems. Small-scale wastewater treatment technologies, also called package plants, refer to any onsite, waterborne, domestic wastewater treatment system with a total capacity less than 2,000 m^3/day. They may consist of one or many modules and are generally based on equipment mostly constructed and packaged off site and brought onsite for installation (van Niekerk et al., 2009).

Package plant technology is suitable in different contexts, such as remote areas, where the existing municipal sewer/municipal wastewater treatment works do not have adequate capacity, and in cases where the re-use of treated effluent needs to be explored (van Niekerk et al., 2009). Small-scale distributed solutions are also suited to urban fringe areas, especially where it is costly to connect to the large sewerage infrastructure (GreenCape, 2016). The smaller plants have a lower cost of pumping, and are easy to set up. These have also allowed for private sector participation in complementing municipalities in wastewater treatment. The types of package plants are shown in Table 15. The pre-treatment stage of the package plants usually has the following options: purely anaerobic systems; pond systems; and constructed wetlands.

Table 15: Categorisation of typical package plants (van Niekerk et al., 2009)

Type	Technology
General	• Anaerobic treatment • Wetlands
Suspended biomass	• Activated sludge systems
Fixed film biomass	• Rotating Bio-contactors • Submersed bio-contactors • Trickling filters
Membrane systems	• Membrane bioreactor

Nanotechnology can be also used for advanced filtration materials that can be applied to water re-use, recycling, and desalination (ASSAF, 2014). However, most such technologies are at an experimental stage.

4.2.3. WATER CONSERVATION TECHNOLOGIES

Water conservation and demand management are considered low-hanging fruits and are increasingly prioritized by consumers and policymakers alike. The use of new and improved water and sanitation technologies, as well as the better management of such infrastructure are key to realising potential savings. Mechanisms to implement water conservation and demand management are highlighted as follows.

Efforts have been directed to developing technologies to reduce persistent high-water losses. Many companies and utilities are already using technology that enables remote detection of leaks in pipelines. Some of the commonly used technologies are metal detection, tracer gas, acoustic systems, thermal imaging, smoke generation, fluorescent dyes and "crawler" or push cameras (GreenCape, 2016).

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[12] AMD involves the production of effluents containing high concentrations of sulphate and heavy metals, and having a low pH. If left to decant and flow, the acidic effluent ends up polluting the environment including both underground and above-ground water sources.

Smart water metering (SWM) and the application of information and communication technologies (ICTs) in water management have many benefits, including saving water and reducing costs. These metering systems enable electronic recording of water consumption information and its transmission to a remote location without human intervention (Champanis et al., 2013). The recorded water consumption data allows customers and utilities to assess usage patterns and monitor any abnormal usage behaviours. Better monitoring and analysing irregularities in water meter data can also improve utility cash flows, by accounting for unbilled water, identifying technical issues early as well as payment challenges (Deloitte, 2016). This contributes to promoting conservation habits (Sonen Capital, 2016). Smart water delivery systems using tailor-made software enable sustainable access to water for many people (ASSAF, 2014). Champanis et al. (2013) note that though SWM has many benefits, the high cost to implement it is a key barrier.

Rainwater harvesting techniques are also important for improving water availability both among rural and urban users (Viljoen et al., 2012). Different technologies suit various user needs and vary from small-scale systems designed for households to those that suited for big industries.

4.2.4. GLOBAL MARKET TRENDS

Water treatment works and water utilities have been identified as being among the largest markets in environmental goods and services (Bucher et al., 2014). The international policy framework has been an important driver of the global market for water technologies. Water was one of the Millennium Development Goals, which embraced access to water as a critical component of development. Clean water and sanitation now constitutes one of the Sustainable Development Goals (SDGs), seeking to ensure the availability and sustainable management of water and sanitation for all (SDG 6) (UN, 2015). These goals can boost demand for water technologies both in South Africa and elsewhere.

In addition, global challenges, such asclimate change, stimulate investment in, and demand for, water technologies to counter the likely adverse effects on water availability. Climate change scenarios project an exacerbation of the spatial and temporal variations of water cycle dynamics, thereby increasing the mismatch between water supply and demand (WWAP, 2017). At the international level, several initiatives mobilize stakeholders to adopt measure that ensure water security for their operations as well as the environments in which they operate in. The Paris Pact on Water and Adaptation[13] seeks to mobilize international stakeholders and member countries to enhance climate change adaptation in basins of rivers, lakes and aquifers, through joint, participative, integrated and sustainable water resources management. The Megacities Alliance for Water and Climate initiative[14] aims to enhance capacity building between megacities so that they can adapt better to climate change. It includes setting up a world-wide cooperation platform, to facilitate action to counter the effects of climate change related to water in megacities. In addition, the Business Alliance for Water and Climate Initiative,[15] launched in 2015, seeks broad action on improving water security. The initiative aims to promote analysis and sharing of water-related risks, implement collaborative response strategies, measure water footprint with existing standards, and reduce impacts on water availability and quality in direct operations and all along the value chain. Related to this, LaFon (2016) observed that climate change phenomenon was already stimulating investment in the stocks of water technology companies in the United States of America.

Estimates of the size of the global water treatment market vary, but point to a huge market. Grand View Research (2016) valued the market at $50.65 billion in 2015, while Sonen Capital (2016) cited Global Water Intelligence estimates of $178 billion. Investment in water and wastewater treatment is high priority in many developing countries (Bucher et al., 2014) as they strive to boost their socio-economic development. Globally, the desalination market has also started to grow after a period of decline (GreenCape, 2016). Deloitte (2016) observed strong worldwide growth in membrane technologies, such as membrane bioreactors, particularly in large-scale applications, due to their increasing affordability, efficiency and effectiveness.

Increasing global water scarcity is driving the growth in the desalination market. The demand for desalination and re-use is set to grow by up to 10% in 2017, as municipalities and industries are diversifying their water supply options (GWI, 2017). More than 17,000 desalination plants are in

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[13] See http://newsroom.unfccc.int/ for more information.

[14] See http://newsroom.unfccc.int/ for more details.

[15] See http://newsroom.unfccc.int/ for more information.

operation in 150 countries worldwide, a capacity that is expected to double by 2020 (Hardcastle, 2015, citing a Frost & Sullivan report). The market earned revenues of $11.66 billion in 2015 and this figure is estimated to reach $19.08 billion in 2019. Globally, countries with persistently inadequate water supplies, such as Israel and the Gulf States, have been the world's leaders in water re-use technologies (Deloitte, 2016). Figure 20 shows that Israel is well advanced in terms of water re-use, recycling about 70% of its treated wastewater. These countries play an important role in the development and transfer of such technologies to many other countries. Other regions are still behind in water re-use. Exton (2015) highlights a huge gap in North America, where about 75% of wastewater is treated (16 trillion gallons of water a year), but only 4% of that water is reused (600 million gallons per year). In Africa, there is a low adoption of wastewater treatment as well as water re-use. The continent presents a good market opportunity. Africa has many rapidly growing economies, coupled with increasing urbanization, and these factors demand increased investment in water infrastructure (the dti, 2017; WWAP, 2017).

Deloitte (2016) also noted a likely growth in demand for water treatment technologies that involve fewer costly and polluting chemicals. This is particularly so in the oil and gas sector, where there is an increasing need to reduce the amount of chemicals used in hydraulic fracturing.

McKinsey identified three opportunity areas for new products and services in the water sector, namely improving the productivity of water treatment and distribution, of waterintensive industrial and power processes, and of water usage in agriculture (Boccaletti et al., 2010).

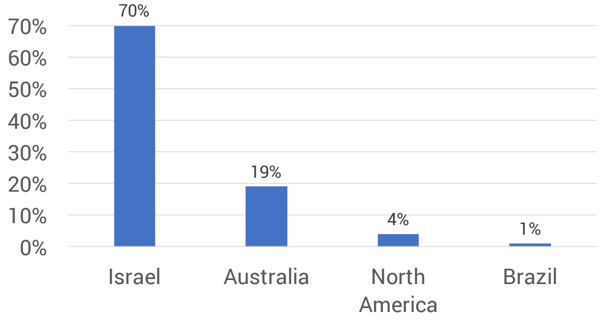

Figure 20: Share of treated wastewater reused in selected countries in 2015 (Deloitte, 2016 and Exton, 2015)

Rainwater is increasingly being harvested using "source control" technologies that handle storm water near the point of generation (decentralized storm water drainage, such as green roofs or pervious surfaces) and alleviate peak flows and flood risk (WWAP, 2017). Dennehy (2013) predicted that, in the coming two decades, the demand for storm water technology and infrastructure in the US municipal sector will surpass $105 billion, while the demand is also expected to grow in commercial, industrial and residential markets. The increasing demand for storm water control technology is being driven by increased urbanisation, more frequent and intense rainfall events, the continued deterioration of old infrastructure, and regulatory requirements. Control measures have become a standard requirement in urban planning and building guidelines in almost all developed countries (Dennehy, 2013).

4.2.5. THE DOMESTIC MARKET

South Africa is a water-scarce country, receiving a yearly rainfall average of 450 mm, compared to the global average of 860 mm (Creamer Media, 2016). South Africa's water utilities industry had total revenues of $3.5 billion in 2011, representing a compound annual growth rate (CAGR) of 8.1% between 2007-2011; the country has the largest water industry (in terms of water and wastewater treatment equipment sales) on the continent (Deloitte, 2014). The water sector infrastructure in the country consists of water resources and water services infrastructure. Water resources infrastructure refers to infrastructure to cater for raw water resources while water services infrastructure refers to bulk water, that is supplied to domestic and commercial water users (DBSA, 2012).

The South African policy framework aims at stimulating and providing an enabling environment for the development and the adoption of water technologies. Government policies and programmes likely to have a bearing on their development and usage are briefly outlined as follows.

The National Water Resource Strategy (Second edition - NWRS2) seeks to ensure that the water sector supports development, economic growth and job creation (DWA, 2013). The strategy indicates that to meet growing demand and ensure that water is protected, used, developed, conserved, managed and controlled sustainably and equitably, efforts should go beyond "traditional engineering solutions" of infrastructure development. Some of the strategies that should be explored are water conservation and water demand management, as well as utilisation of groundwater, desalination, water re-use, and rainwater harvesting. Improving efficiency and reducing water losses are also key priorities.

The NWRS2 also points to the need to develop and deploy appropriate technologies in the water sector. It notes, for instance, that building large, complex energy-intensive water treatment works for under-resourced rural municipalities that lack the necessary technical and skills capacity to manage them is not appropriate. The department stipulates that any future water infrastructure projects will have to comply with specific energy guidelines and their technical design should be appropriate for conditions in that project area. It also emphasizes that for equitable maximum benefits to be realized from water resources, opportunities need to be harnessed through renewing infrastructure, developing human capabilities, and enhancing technological development.

Desalination has been identified as one option for overcoming the problem of limited water supply. The government's National Desalination Strategy outlines the main applications of desalination in the country as follows: using brackish (saline) surface/ground/sea water, and treating mining and industrial effluents.

Desalination offers a promising opportunity to provide water for industrial and household use. The strategy seeks to further develop and commercialise local desalination technologies, as well as enhancing the industrial localisation of desalination projects. The export potential of desalination, mine water, and industrial effluents treatment technology is identified, with the strategy asserting that associated research and development is worth pursuing and that adequate support should be availed (DWA, 2011b). GreenCape (2016) notes that projections indicate that by 2030, water desalination plants could supply close to 10% of the country's urban water supply.

On the water management side, the Water Conservation and Water Demand Management Strategy seeks to promote water use efficiency in several ways, including avoiding using water at all where possible, minimising water use through process optimisation, and re-using and recycling water. The strategy emphasizes the need to reduce leaks in the water reticulation system through adequate and technically-correct operating and maintenance measures (DWAF, 2004). This includes pipe network replacement or rehabilitation, leak detection and repair, pressure management, effective zoning of the distribution system, cathodic protection of pipelines, and meter management programmes.

Water is a basic commodity, and as such, various stakeholders, including government, donors and non-government organisations, are working to improve access to water in South Africa, especially for poor communities. Such programmes present big opportunities for South African companies to provide the relevant technologies.

Water is generally considered inexpensive in South Africa, hence companies have less incentive to invest in water conservation technologies. However, while this argument holds true to some extent, other associated factors might drive companies to invest in such technologies. Deloitte (2016) notes that while water constitutes a minor business expense, the disruption in its supply can have enormous consequences for the business. Scarcity of water supplies can disrupt daily operations, might affect the social license to operate, especially where the water basin is shared by many local stakeholders, and the inability to operate sustainably can damage the brand value. Water efficiency is therefore becoming a long-term requirement for business survival, as many companies are struggling to get the water they need for their operations (Boccaletti et al., 2010). In this regard, the use of water conservation technologies is progressively increasing, presenting an opportunity for the development of innovative, low-cost technologies (ASSAF, 2014).

According to ActionAid (2016), improving water use efficiency (through investing in more efficient irrigation and by stopping leaks) could reduce water usage of the agricultural sector by 30%-40%. Similarly, increasing water efficiency could decrease water consumption by 12%-30% for municipal and domestic users, and by 10% in the industrial sector.

Significant strides are also being made in the power generation sector in water saving and re-use. Power generation uses copious quantities of fresh water, which is problematic in a water-stressed environment. The National Strategy for Water Reuse notes that the power generation sector in the country continues to improve its water use efficiency, including by exploring dry cooling technologies. Coal-fired power stations in the country use zero effluent discharge facilities. However, as the country considers adopting nuclear power generation and other energy options, water re-use and efficiency opportunities in those sectors will have to be explored (DWA, 2011a).

One notable effort to improve water usage and efficiency is the Strategic Water Partners Network South Africa (SWPN-SA), which is a collaboration between national government, private sector companies, civil society organisations and municipalities. It aims to reduce the water demand-supply gap through projects that seek to conserve water, reduce leakages, improve the capacity of local municipalities, and incentivise the private sector to enhance effluent treatment and re-use (SWPNSA, n.d.). This platform has three working groups that focus on effluent and wastewater management, water efficiency and leakage reduction, and agriculture and supply chains. Such an initiative stimulates demand for water technologies as it encourages companies to implement water management and conservation strategies along their value chains.

Water losses, known as non-revenue water, are high in the South African water system (DWS, 2015). The loss in revenue for the country at the municipal level is estimated to about R11 billion annually (ActionAid, 2016). Creamer Media (2016) notes that 36.8% of all water supplied in the country is categorised as non-revenue (about 1,580 million m^3 a year), of which 25.4% is lost through inefficiencies, including physical leaks due to ageing infrastructure and poorly maintained equipment. On the Infrastructure Leakage Index, which compares the leakage rate to a benchmark, South Africa has a national average of about 5.3 against a benchmark value of 3 (on a scale of 1 to 10, 1 representing best practice while a value of 10 show that losses are 10 times the benchmark value) (DWS, 2015). Government efforts to improve the country's dire water efficiency situation stimulate the demand for water conservation and management products. Indeed, though some municipalities have been implementing water conservation and demand management, most have yet to do so.

For the agricultural sector, the strategy highlights the need to adopt efficient irrigation systems. Improving irrigation efficiency is necessary because the sector is largest consumer of water (DST, 2007b). The South African government has been rolling out water harvesting technology to resource poor farmers. This has boosted demand for the various components, such as water tanks. About R33.5 million was allocated for rainwater harvesting in the 2016/2017 national budget to help less resourced farmers (Creamer Media, 2016). Organisations like ActionAid have also been supporting farmers in various provinces through the provision of water-efficient irrigation systems (ActionAid, 2016).

More broadly, rooftop rainwater harvesting (RWH) could play a significant role in sustainable water provision and conservation in South Africa (ASSAF, 2014). Rainwater harvesting can provide water for irrigation and household use, with the potential to contribute to 30% of domestic usage, providing that adequate designs (i.e. portable systems) are available (GreenCape, 2016). Opportunities also exist in the design, manufacture, installation and maintenance of local water harvesting systems for rainwater, greywater or storm water, including the increasing adoption of water-sensitive design (WSD) (GreenCape, 2017).

All of these initiatives can create demand for water technologies. While the strategy calls for creating an enabling environment to facilitate technology transfer for water use efficiency and productivity improvement, it does not make the source (imports and exports) of the water technologies that will contribute to water conservation and demand management objectives.

Water re-use is then embraced as one of the strategies to balance water supply and demand, as stated in the National Strategy for Water Reuse. The strategy aims to promote water re-use in a sustainable fashion, to avoid unintended consequences.[16] It seeks to ensure that water re-use projects are consistent with the National Water Resource Strategy, and national water policy and legislation. The National Strategy for Water Reuse acknowledges the enormous local capacity in wastewater and effluent treatment technologies. It calls for the South African water industry to enhance its capacity to implement some of the more advanced water re-use technologies (DWA, 2011a). The strategy further notes that the country could be a leading innovator in water re-use technology, especially in AMD treatment.

In response, various research institutions, such as the Water Research Commission (WRC), the Council for Scientific and Industrial Research (CSIR) and many other companies have focused on developing technologies that can help solve this problem (ASSAF, 2014). The South African government prioritises treating AMD to augment fresh-water resources. In May 2016, the government committed to providing R600 million every year towards treating AMD. This amount will be complemented by a certain percentage from users and mining companies (Creamer Media, 2016). The low use of AMD treatment is primarily due to its high cost,

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[16] The consequences of releasing untreated or inadequately treated wastewater can be categorised into three groups namely: harmful effects on human health and safety; negative environmental impacts; and adverse repercussions on economic activities (WWAP, 2017).

efforts to find cheaper alternatives are being made. GreenCape (2016) asserts that South Africa could become a leader in developing water reclamation technology, such as AMD, though it remains an area still growing in terms of knowledge and expertise.

ActionAid (2016) estimates that 30% of wastewater treatment facilities in South Africa are in poor condition. This has both detrimental effects on the environment and wastes precious water. Some of the infrastructure is dilapidated and old. These facilities operate over their capacity, are not maintained properly, and are operated by poorly trained operators (DWS, 2015).

Accordingly, the National Strategy for Water Reuse recognises the importance of legislation in maintaining (environmental) standards and notes that "strict enforcement of discharge standards, and addressing the management and performance failures of municipal wastewater treatment plans is therefore critical to the future of indirect water reuse" (DWA, 2011a, p. 13). Such regulatory requirements are increasingly driving the demand for wastewater treatment and re-use (Grand View Research, 2016). Increased enforcement of legislation and standards could stimulate demand for specific technologies, as users will have to buy such technology to adhere to the requirements.

Water re-use in South Africa is approximately 14% of total water use (DWA, 2011a), indicating a strong potential to further increase the treatment and re-use of effluent and wastewater. For example, opportunities exist for water treatment and re-use technologies related to industrial symbiosis (GreenCape, 2017), with room for partnerships and synergy between municipalities and large private sector companies (SWPNSA, n.d.). For example, the market size of the industrial water re-use industry in the Western Cape is estimated at R600 million and it is expected to continue growing (GreenCape, 2017).

On the technology development side, two key policy documents, namely the Bio-economy Strategy and the National Water Research, Development and Innovation Roadmap, aim to promote new, innovative water technologies.

The Bio-economy Strategy (also discussed in Section 4.4) identifies two areas, namely industry, which targets bio-based chemicals, biomaterials and bio-energy, and sustainable environmental management, which targets water and waste. It seeks to "prioritise and support research, development and innovation in biological processes for the production of goods and services, while enhancing water and waste management practices in support of a green economy" (DST, 2013, p. 31). Water resource management is a critical component of the strategy. In particular, it notes that agricultural intensification requires research into and support for optimal management practices for irrigation and recycling, as well as improving efficiency in municipal and industrial wastewater treatment. One of the thematic focus areas for the industrial bio-economy is bioremediation of domestic and industrial wastewater. The strategy promotes the use of microorganisms and other biologics (such as enzymes) as catalysts in many processes including water treatment and waste minimisation. The strategy further calls for strengthening wastewater research, development and innovation, including setting up pilot and demonstration wastewater treatment facilities to test and market larger-scale treatment facilities.

This call is echoed by the Water Roadmap, which seeks to position South Africa as a leading water technology development and deployment player by facilitating a more effective water innovation system. The roadmap has seven plans which will be implemented over a 10-year period from 2015-2025 (WRC et al., 2015). It aims to promote research, development, testing, demonstration, and deployment of new technologies and know-how, and to help create at least one breakthrough technology every five years. The roadmap seeks to create synergies between research institutions, academic institutions, industry and government in the development and deployment of technologies, while exploring export opportunities in Africa and other markets.

In line with the policy documents introduced above, the Department of Water and Sanitation (DWS) has three programmes aimed at fostering the rollout of water-related technologies, namely the No Drop, the Blue Drop, and the Green Drop. The No Drop programme focuses on water conservation (targeting use efficiency and loss), the Blue Drop programme focuses on drinking water quality, while the Green Drop programme focuses on wastewater quality compliance (DWS, 2014).

These programmes cover the whole country and their implementation has strong implications for the demand for water technologies. They can provide impetus for the demand of respective water technologies. For instance, the Green Drop programme targets wastewater systems controlled by municipalities, private owners, and the Department of Public Works. According to DWS

(2014), 152 municipalities provide wastewater services via a network of 824 wastewater treatment systems,[17] and of these only 24 systems had retained Green Drop status from 2011 to 2013. In terms of privately-owned wastewater systems, four of the five systems that were assessed had achieved Green Drop Certification. However, none of the 121 Department of Public Works systems assessed had achieved Green Drop Certification.

The National Infrastructure Plan (2012), which identified 18 Strategic Integrated Projects (SIPs) that seek to implement large-scale infrastructural developments, includes two SIPS relevant to the water and sanitation sector. SIP 6 aims to develop an integrated municipal infrastructure, including municipal water and sanitation. Meanwhile, SIP 18 focuses on water and sanitation infrastructure. Over a 10 year period, the plan aims to provide adequate water supply to 1.4 million households and basic sanitation to 2.1 million households that currently do not have proper access to such services. These projects will involve maintaining and building wastewater treatment works to solve the water leakage problem. Inherently, these programmes create substantial demand for water technologies.

4.2.5.1 Local Demands and Needs

In line with the policy priorities discussed above, GreenCape (2016) identified the following market opportunities in the South African water sector: precision agricultural irrigation, rainwater harvesting, groundwater and artificial recharge, desalination, end-user efficiency, reducing municipal losses, small or decentralised treatment, resource recovery from wastewater, water reclamation, energy and water, and smart metering and information and communications technology (ICT) in water. In the last five years, a significant increase in ICT usage in the South African water sector has been observed, with applications in customer management, operational management, and financial and control management (Champanis et al., 2013; GreenCape, 2016). There has also been substantial progress in smart metering, with the deployment of advanced water meters (intelligent meters) that are capable of relaying important information, including monitoring consumption patterns, prepaid systems, and detecting leakages. A general increase in demand for smart meters in all urban markets is apparent (GreenCape, 2017).

Trade missions from South Africa's trading partners have also identified a strong water-related market in the country. For example, in 2012, the Danish Government produced a growth strategy with the objective of increasing their exports of water-related products to South Africa (Ministry of Foreign Affairs of Denmark, n.d.). The strategy notes that there are "ample opportunities for Danish companies providing smart solutions to manage water resources, including water and wastewater treatment, groundwater mapping and management, urban water services, water conservation and demand management" (Ministry of Foreign Affairs of Denmark, n.d., p. 7).

Similarly, there have been efforts to explore the South African market potential by Dutch water technology companies targeting the mining, agriculture and horticulture, and food processing sectors (Netherlands Water Partnership, n.d.). Another study (Cohen et al., n.d.) assessed business opportunities in the South African water sector focusing on industrial processing for Dutch companies. This study notes that there might be opportunities for Dutch companies offering new efficient and cost-effective technologies, which can include sterilization using ozone or UV, reverse osmosis systems and ultrafiltration.

Furthermore, the African continent offers an untapped export market for South Africa (IDC, 2014), especially due to the potential creation of the Tripartite Free Trade Area that will comprise Southern African Development community (SADC), the Common Market for Eastern and Southern Africa (COMESA) and the East African Community (EAC) (IDC, 2014). The African Water Facility (AWF) estimates that about $20 billion should be invested yearly to cover the infrastructure gap on the continent (Creamer Media, 2016).

South Africa's imports of water technologies (Figure 21) are generally higher than respective exports. The greatest proportion of imports are in the water handling goods and equipment, followed by aeration systems/air-handling equipment, sewage treatment/incineration equipment, chemical recovery/water separation systems, chemicals, and measuring and monitoring equipment.

Technology imports are nevertheless important in meeting water demand and management needs, especially when the local technological capabilities are limited. However, it tends to further crowd out local capacity. This has negative impacts on

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[17] They receive a total of 5,000 million litres of wastewater per day or 1,825,000 million litres/year (DWS, 2014).

technology generation, ownership and production, and is undesirable, particularly in the long run, as local capacity and the associated industries could contribute immensely to creating jobs.

Still, there are opportunities for technological learning, transfer and cooperation. In this context, the government has been entering into cooperation agreements with other governments with the aim of enhancing local technological capabilities. For instance, the government signed a water co-operation agreement with Italy to work on joint projects that seek to enhance capacity building, technology transfer and technical assistance in the fields of water quality enhancement, water resource management, water service management and rural sanitation technology (TMG Digital, 2016). Another significant programme is the Danish-South African collaboration in the water sector programme, which targeted the demonstration of and collaboration for water technology development and skills enhancement in the water sector (WWF-SA, 2015).

4.2.6. THE LOCAL MANUFACTURING BASE

4.2.6.1 Technology Development

South Africa has well-established local capacity in the water sector, with many firms involved in the research, development and production of water technologies in the country. Competitiveness in various water technologies differs but local industry has the capacity to develop and produce most technologies. The Water Roadmap, introduced in Section 4.2.5, assessed the capacity of R&D in the water sector in South Africa. Some of the areas identified as having notable capacity include process automation and control, civil engineering aspects of the water cycle, wastewater and potable water treatment (domestic and industrial, including using biological processes), mine water desalination, catchment hydrology, water quality monitoring, ecosystem functioning, and environmental water quality (WRC et al., 2015). It is unfortunate that the country has slowly been losing some of its capability. For instance, the dti (2017) notes that 20 years ago, the country had a vibrant pump manufacturing industry, but that local capability has increasingly been replaced by local subsidiaries of foreign multinationals.

However, efforts are being made to enhance technology development in the country. An important initiative in the water technology development value chain is the Water Technologies Demonstration Programme (WADER). The WADER is a collaborative initiative between the Department of Science and Technology (DST) and the WRC. This programme seeks to promote applied R&D and the commercialisation stages of the water innovation continuum, thereby bridging the gap between research and the market. Demonstration projects aim to assess the performance, installation procedures, operations, and maintenance attributes of water technologies. The information from these

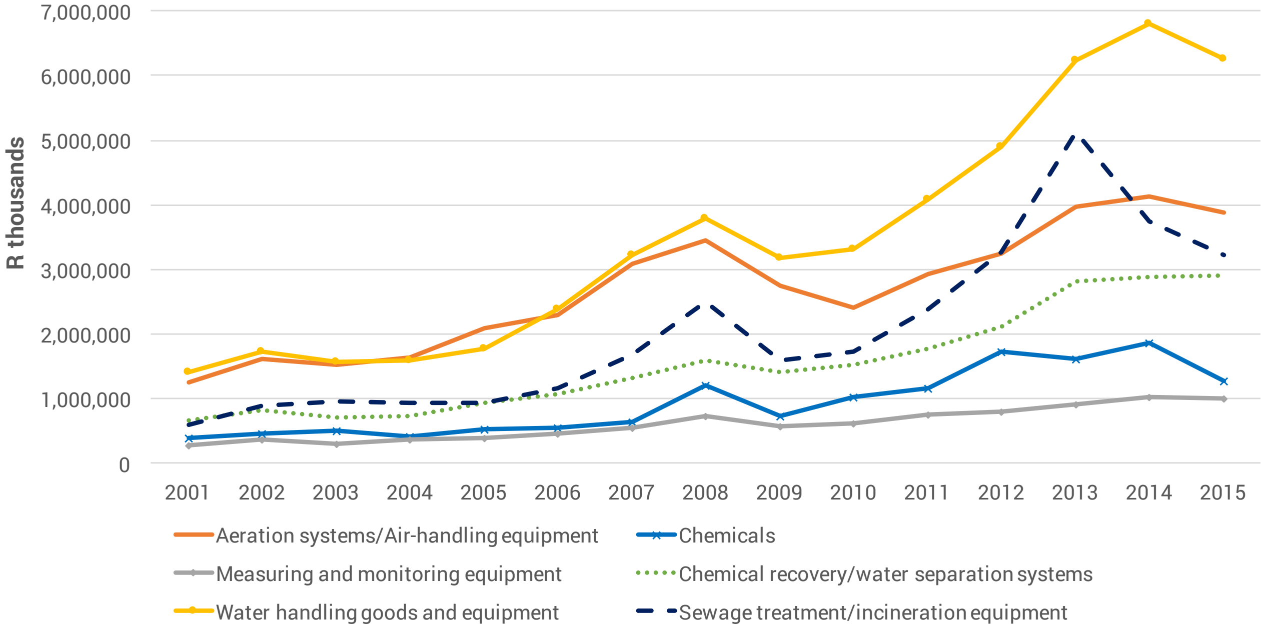

Figure 21: South African imports of various water technologies, from 2001 to 2016 (Authors' composition, based on data from Trade Map)

demonstrations is made public to help consumers make informed decisions about the technologies, promote market awareness and confidence, attract potential funders, speed-up technology adoption, communicate gaps in research, and help South African researchers and technology developers/ manufacturers legitimise the performance of their products. The programme is structured around the following objectives:

- Build a pipeline of water technology demonstrators for potential commercialisation.
- Promote early adoption of innovative water technologies.
- Leverage funds and other resources to support technology demonstrators.
- Centralise coordination of funding and other resources for technology demonstrators.
- Establish and maintain relevant guidelines and tools for technology demonstrations and technology assessments.
- Build multi-sectoral and cross-disciplinary relationships and networks with and among various role-players.
- Promote the post-demonstration "ownership" of successful demonstrators to help ensure market deployment/commercial sustainability.
- Assess inbound and local technologies to determine they are "fit-for-purpose".
- Information sharing and knowledge transfer.
- Promote water entrepreneurship and skills development in the water technologies space Institutionalise WADER to support optimisation and sustainability of the water innovation continuum (DST and WRC, 2014).

Private sector activities are led by various companies seeking to develop profitable water technologies that can enhance their national and global competitiveness. One notable company pioneering innovation in wastewater treatment is GrahamTek. This company launched an integrated waste and water technology solution18 that offers a commercially viable and sustainable solution for the treatment of AMD toxic wastewater and seawater desalination while generating its own electricity from brine reject water that can be combined with municipal waste.

4.2.6.2 Water Treatment

Technologies and technological components treating input water in the industrial sector are already available from well-established local manufacturers as well as agents for imported products. The existence of an association that represents suppliers of package plants in the water treatment industry in the country, the Small Wastewater Treatment Works Suppliers Association,[19] shows the extent of local capability in the provision of package plants. A specific Code of Conduct binds its members to certain guidelines that seek to ensure a good reputation is maintained in the industry. The most common package technologies installed in South Africa are activated sludge, extended aeration plant, trickling filter, submerged bio-contactors and rotating bio-contactors.

In terms of desalination technology, local capabilities (knowledge, skills and implementation) are still limited (DWA, 2011b). To enhance local expertise, the DWS, WRC, the DST, the dti and the private sector are collaborating to support the development of desalination technologies in areas where the country has a comparative advantage (DWA, 2013). In addition, partnerships at the international level are crucial. Creamer Media (2016) has reported that South Africa has partnered with Iran to develop desalination plants in some coastal municipalities. Due to the limited capability, most of the desalination technology is imported. In this context, it would require implementing a local content requirement for those components that South African companies can produce, as well as facilitating technological learning and knowledge transfer (GreenCape, 2016).

South African companies possess well-developed capabilities in water and wastewater treatment. The country is endowed with world-class expertise in wastewater research at universities, research councils and large industrial players (DST, 2013). Swartz et al (2014) report that both conventional and advanced treatment technologies for water reclamation have been tested and proven for South African conditions. For example, the CSIR has been studying water reclamation since the 1960s. The local knowledge base spans a wide range of treatment technologies, with some local projects also applying sophisticated technologies, such as advanced oxidation and membrane treatment.

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18. See http://www.gtek.org.za/ for more information.

19. See http://www.sewpacksa.co.za/ for more information.

South African companies are already making great strides in both the domestic and global market. For instance, South Africa-based VWS Envig (now Veolia Water Solutions & Technologies South Africa), a subsidiary of French company Veolia Environnement, was awarded the 2008 Frost & Sullivan Market Leadership Award in the water and wastewater services market in South Africa. The company had achieved the highest market share in the water and wastewater services market. It caters to a variety of industrial end-users in a number of countries including Namibia, Botswana, Mozambique, Nigeria, Kenya and Mauritius (Frost & Sullivan, 2009). The company is supported by its global parent company, which provides an opportunity for technology transfer and learning.

Exporting various water technologies (Figure 22), the largest export category in South Africa is water handling goods and equipment, followed by sewage treatment/incineration equipment, chemicals, chemical recovery/water separation systems; aeration systems/air-handling equipment, and measuring and monitoring equipment.

4.2.6.3 Water Conservation

There are a number of local companies in South Africa that are involved in developing and supplying water conservation technologies; some of them are shown in Table 16.

The developments in the ICT sector also benefit the water sector. Water utility companies increasingly use big data and analytics in decision-making processes, resulting in improvement in the efficiency of their operations, asset maintenance programmes, and planning (Deloitte, 2016). Invariably, they are providing better, faster and more efficient capabilities to gain insight into the root cause of leaks or pollution and remediation issues, and enhancing demand prediction capabilities. Deloitte (2016, p.9) states that "…data-driven business intelligence has the potential to radically transform the way water and water infrastructure is understood, managed and used".

South African companies are also visible in the ICT-based water technology space. For example, XLink Communications received the 2014 South African Frost & Sullivan award for Technology Leadership

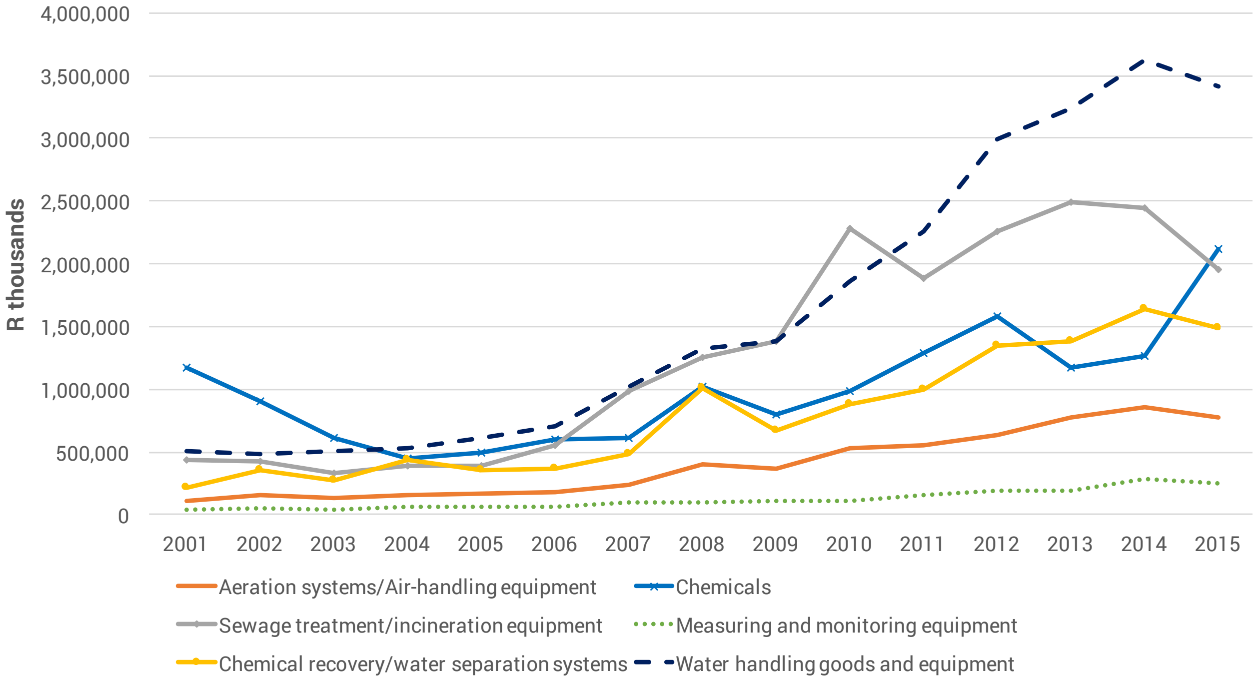


Figure 22: South African export of various water technologies, from 2001 to 2016 (Authors' composition, based on data from Trade Map)

(Kilian, 2015). The company offers a variety of products that help municipalities and companies detect water leaks, and improve efficiency using a machine-to-machine service. Headquartered in Johannesburg, the company has operations in 10 African countries and is set to expand.

Table 16: Selected South Africa-based companies supplying water conservation technologies (Authors' composition)

Firm	Focus
AquaTrip South Africa	Water-leak detection and control systems technology
SBS Tanks	Water storage reservoirs & tanks
Water Rhapsody	Rainwater harvesting systems, greywater systems, tanks
Water Conservation Systems	Grey water systems, rainwater harvesting & water saving products
Urban Rain Systems	Urban rainwater harvesting solutions, tanks
Water and Sanitation Services South Africa	Management, operation, maintenance, construction, refurbishment and upgrade of all water and waste water treatment, distribution, collection and storage infrastructures
Free Rain Conservation	Rain water harvesting, grey water systems, water storage, irrigation systems
JoJo Tanks	Water storage tanks

Another example that highlights the strides being made is the development of a pipe condition assessment device by Professor Kobus van Zyl of the University of Cape Town. This technology can detect the leakage rate with improved accuracy (Oosthuizen, 2016). Also, AquaTrip South Africa has been considering localizing its water-leak detection and control system technology, an important element in conserving water (Solomons, 2013).

Increasingly, the government is working towards fully harnessing manufacturing opportunities presented by the water sector. The country's water sector is mainly driven by state procurement through DWS, which presents an opportunity to strengthen the country's economy through designation of components within the water sector (the dti, 2013). The Industrial Policy Action Plan (2017/18 – 19/20) has water and sanitation as a key sector that needs to be leveraged. Some of the main manufacturing opportunities and programmes intended to contribute to the development of the sector are presented in Table 17.

4.2.7. RECOMMENDATIONS

Locally appropriate, efficient, and affordable water technologies need to be promoted in South Africa. Such technologies should seek to contribute to improved water conservation as well as water treatment. The technology should be more efficient

Table 17: Key action programmes for water and sanitation in the IPAP (the dti, 2017)

Key Action Programmes	Summary
Water Industrialisation Development Plan	To provide a pathway towards integrated water management and sustainable industrialisation.
Innovative Desalination and Water Manufacturing Programme	To develop local manufacturing capability and competitiveness to service the public and industrial sectors in their efforts to implement effective water reclamation and reuse solutions for South African and regional markets.
Next Generation Sanitation Cluster Development Programme	To promote off-grid sanitation technologies that will lower water requirements for sanitation to improve service delivery in rural, peri-urban and water-scarce areas. The off-grid sanitation market presents an expansion opportunity for manufacturing, service and supply sectors.
Modular and Advanced Wastewater Technologies Manufacturing and Capability Build Programme	Could decrease technology cost, enhance competitiveness through new solutions, and develop and position South African businesses for increased export opportunities. This includes developing advanced technology competitiveness, stimulating innovation and capability development for bulk, advanced and modular technologies for industrial and public markets. This will also target participation of SMMEs through enhancing their competitiveness and market participation.

through reducing water losses and usage along the value chain while also requiring less energy.

One barrier to the growth of the water sector is the limited funding for R&D and commercialisation. That water is a basic need has a bearing on the pricing and competitiveness of some of the technologies. In other words, pricing has to be affordable for the majority to have access to water. Hence, the government should continue to provide R&D funding as well as increasing support for commercialisation.

There is also a need for greater demand for local technologies through enhancing local procurement of water technology components. This is particularly relevant as national or local government funds most water infrastructure development. Without demand for local products, it will be difficult to sustain the manufacturing industry.

To further grow their export market, South African firms must position themselves to grasp the export opportunities that will arise from projected growth in many African countries. However, for this to happen, the firms have to provide the products/ technology at competitive prices as well to meet the needs of the consumers.

For most technologies, the R&D capacity already exists: what needs to be strengthened is commercialisation. The government, through the dti, should provide more incentives to grow the water sector. The action programmes outlined in the IPAP (2017/18 – 19/20) should be fully implemented to develop local manufacturing capability and competitiveness.

4.3. THE BIOGAS-TO-TRANSPORT VALUE CHAIN

KEY FINDINGS

- Compressed biogas and compressed natural gas has been identified as an economically feasible means to reduce dependence on (imported) crude oil while decreasing GHG emissions.
- In South Africa, petrol and diesel continue to dominate the fuelling space, and the market for CNG/CBG as a transport fuel remains stagnant due to insufficient infrastructure and a lack of demand for gases as a transport fuel.
- Municipal solid waste has been identified as a significant possible source of biogas.
- The South African biogas-to-transport value chain requires tremendous investment from government as well as favourable regulatory and legislative frameworks to transition the industry from its infancy into a thriving local manufacturing base.
- The government can drive the growth of the industry through the conversion of state-owned fleets while collaborating with the taxi industry and donor agencies to promote the conversion of vehicles and develop the required infrastructure.

4.3.1. BACKGROUND

A global shift towards sustainable transport systems is taking place, spurred by the imminent threat of a changing climate in tandem with energy security concerns and fluctuations in the price of crude oil. In attempts to diversify energy sources and move away from traditional, carbon-intensive fuels, such as diesel and petroleum, biogas has been identified as a valuable alternative to fossil fuels, along with the introduction of electric vehicles.

The development of biogas is considered a means to reduce the dependence on (imported) crude oil and to decrease GHG emissions. Transport is the second largest emitter of GHG, after electricity generation. The combustion of biogas is cleaner than conventional fuels and can also help to improve air quality, particularly in urban areas where pollution levels are hazardous. In addition, the production and utilisation of biogas has been identified as a sustainable means to address waste management issues while securing renewable energy-based electricity and vehicular fuel supply. Biogas is, moreover, seen as a flexible source of renewable energy, due to its storage capacity. Furthermore, biogas can be injected into a gas grid, stored and used when required, either for electricity generation or as a transport fuel (Hofmann and Findeisen, 2017).

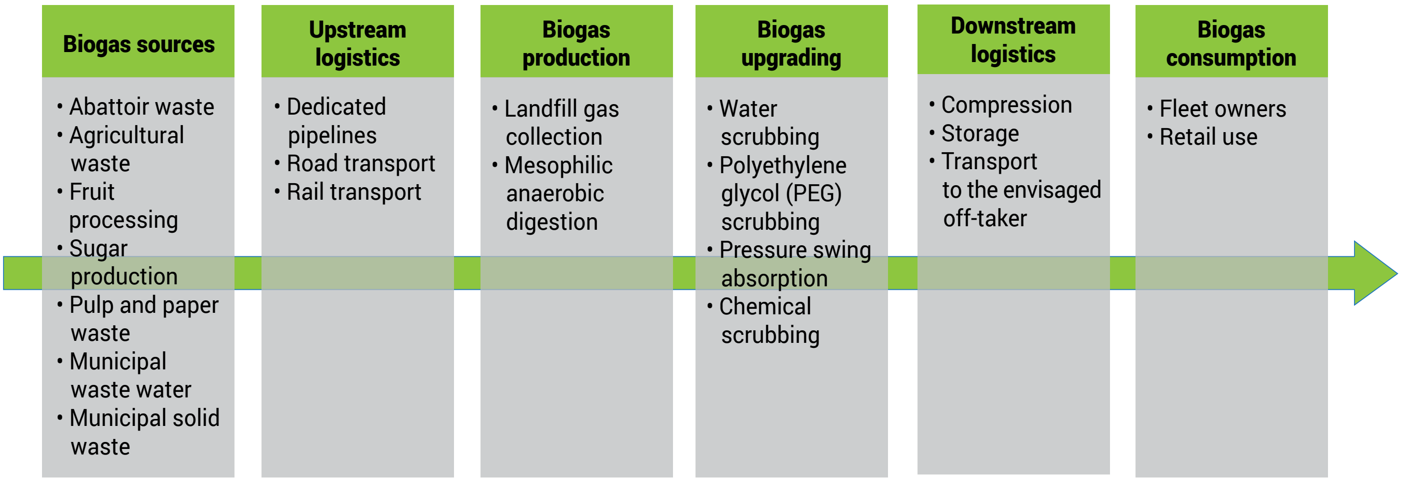
Although biogas is primarily produced for electricity and heat generation (EcoMetrix Africa 2016a), the use of biogas for transport has proven to be economically feasible, as gas is a cheaper vehicular fuel than petrol or diesel. This is particularly the case for public transportation systems (such as buses) and centralised fleet (like for hospital vehicles) with fixed routes and/or stationary points.

This section seeks to identify the industrial development opportunities and benefits of biogas as a vehicular fuel in South Africa. Firstly, this section examines the links required to establish a biogas-to-transport value chain in South Africa. Secondly, it analyses global biogas production and gas-based vehicle trends, including policies and incentives to promote the uptake of biogas in various countries. Then, the state of the biogas-to-transport value chain in South Africa is explored, looking at the availability of biomass inputs, local production initiatives and the end-use markets. This section concludes with recommendations for developing a local biogas-to-transport manufacturing base and the subsequent policies or incentives required for promoting and using biogas as a vehicular fuel.

4.3.2. THE VALUE CHAIN

The biogas-to-transport value chain consists of a number of stages, as depicted in Figure 23: identifying sources of biomass; determining logistical arrangements from on-site collection to production plants; producing biogas via anaerobic digestion or flaring capture from landfill sites; upgrading the gas, thereby making it suitable as a fuel; compressing, storing and transporting the gas to off-takers (filling stations); and, finally, the end-use consumption by retailers and fleet owners (EcoMetrix Africa 2016a).

The first stage of the value chain consists of sourcing adequate feedstock. Biogas is a product of anaerobic digestion, which occurs naturally



Biogas sources	Upstream logistics	Biogas production	Biogas upgrading	Downstream logistics	Biogas consumption
• Abattoir waste • Agricultural waste • Fruit processing • Sugar production • Pulp and paper waste • Municipal waste water • Municipal solid waste	• Dedicated pipelines • Road transport • Rail transport	• Landfill gas collection • Mesophilic anaerobic digestion	• Water scrubbing • Polyethylene glycol (PEG) scrubbing • Pressure swing absorption • Chemical scrubbing	• Compression • Storage • Transport to the envisaged off-taker	• Fleet owners • Retail use

Figure 23: The biogas-to-transport value chain (EcoMetrix Africa, 2016)

during processes where organic matter is broken down by micro-organisms in the absence of oxygen. Methane, carbon dioxide and other trace gases form the chemical composition of biogas. 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 (EcoMetrix Africa 2016a). Biogas is also derived from landfill gas flaring and food crops, such as sugarcane, although these are not included in this research, due to food and water security issues as well as technological differences.

The second stage of the biogas-to-transport value chain involves the logistics required to transport biomass from various sources of origin to biogas production plants. This includes infrastructure, such as pipelines, and road and rail transport. Due to transport costs linked to the distance of biomass sources to the production plants, as well as the high cost of transportation and storage (EcoMetrix Africa 2016a), biogas production facilities located near to, or at, the actual sites of biomass sources, such as landfills or cattle farms, are favoured.

The third stage is the production of biogas. As aforementioned, biogas production results from anaerobic digestion occurring when feedstock is fed into airtight technologies, such as digesters. Controlled temperature conditions, namely psychrophilic (<20 °C), mesophilic (35-40 °C) or thermophilic (50-60 °C) determines the rate of digestion (Chen et al., 2008). Mesophilic anaerobic digestion is the most frequently-used temperature regime due to ease of control and operation (EcoMetrix Africa 2016a). Although thermophilic anaerobic digestion produces biogas at a higher yield and faster rate, this type of digestion is limited due to massive input requirements (Kim et al., 2002).

Upgrading biogas constitutes the fourth stage of the biogas-to-transport value chain. In this phase of the value chain, biogas is upgraded to bio-methane, a composition similar to natural gas, by increasing the methane content and removing carbon dioxide and impurities using technological processes, namely chemical scrubbing, polyethylene glycol scrubbing, water scrubbing and pressure swing absorption. It is at this precise stage that biogas becomes suitable for use as a transport fuel. Achieving a level similar to natural gas ensures that technology, infrastructure and vehicles designed to produce and receive natural gas can also use biogas, which is advantageous as there are already numerous technologies available on the market to convert vehicles to receive natural gas (DEA, 2016; Hofmann and Findeisen, 2017). However, this stage, which is the main difference between the biogas-to-transport value chain and the biogas-to-power value chain, makes transport usage more technology and capital intensive.

After the process of upgrading, bio-methane can be compressed, stored in gas cylinders at a typical pressure (between 172 and 248 bar) and thereafter transported to off-takers, such as retailers and filling stations, via pipelines, railroads or trucks (EcoMetrix Africa 2016a).

Finally, the last stage of the value chain is the consumption of the upgraded biogas. The envisaged off-takers of compressed biogas (CBG) are the same as for compressed natural gas (CNG), i.e. fleet owners whose vehicles operate on fixed routes and retailers, such as fuelling stations that provide fuel to private and fleet vehicles. Vehicles with regular internal combustion engines need to be converted to use gas as a fuel. Alternately, dual fuel engines are also on the market, offering the ability to operate on both petrol/diesel and natural gas/biogas. Due to the density of compressed gas, CNG/CBG tanks are larger and more expensive compared to conventional fuel tanks. Cheaper fuel costs, however, compensate for this.

Each stage of the value chain is significant for the overall production of biogas, but from an industrial development and trade perspective, three key avenues are important and henceforth structure the analysis going forward: the input/feedstock stage, the technology stage (i.e. digesters and the gas infrastructure), and the end-use/biogas consumption (i.e. converted vehicles and fuelling stations).

4.3.3. GLOBAL MARKET TRENDS

4.3.3.1 Biogas Market Trends

In 2015, revenues from biogas production reached approximately $24.5 billion globally, with the market expected to grow at a compound annual growth rate of 6.5% between 2016-2026, reaching nearly $50 billion by 2026 (Future Market Insights, 2017). Concerns over environmental impacts of fossil fuels and uncertainties in the crude oil markets are forecast to drive government initiatives promoting the uptake of biogas for electricity and transport.

As shown in Table 18, Germany, China, Sweden, France and the United Kingdom dominate global biogas production, and the main use of biogas is for cogeneration, i.e. electricity and heat generation. For instance, Germany produces 28,270 gigawatt-hours per year of electricity from biogas. The average plant produces 200 m^3/h of biogas, requiring 11,000 tonnes of energy crops, 110,000 tonnes of manure or 16,000 tonnes of organic household waste per year (Hofmann and Findeisen, 2017). Most biogas production is derived from agricultural feedstocks, landfills and sewage sludge.

Despite most biogas being used for electricity and heat generation, over 500 biogas upgrading plants globally produce high quality bio-methane, the bulk of which is found in Europe (Hofmann and Findeisen, 2017). Sweden is a notable example (IEA, 2015). On average, Sweden produces 1.7 terawatt-hours of biogas annually, 50% of which is converted to bio-methane (IGU, 2015). Sweden is among the leading countries developing biogas for use as a vehicle fuel, aiming to achieve a carbon-neutral vehicle fleet by the year 2030. Government subsidies, incentives and investments have been instrumental in supporting growth in the sector (IGU, 2015). Recently, demand for biogas has been so high that Sweden has had to import waste from neighbouring countries to meet feedstock supply requirements (Shayon, 2017).

In addition, numerous initiatives promise to expand biogas for transport in the future, with countries adopting legislation and regulations. For example, the United Kingdom's Renewable Transport Fuel Obligation, adopted in 2007, stipulates that transport fuel suppliers must commit to procuring 4.75% of their fuel from renewable and sustainable sources, such as biofuels (House of Commons, 2016). In Tanzania, the Domestic Biogas Partnership Programme has installed more than 12,000 biogas digesters to date, providing much needed sustainable energy, particularly to those residing in rural areas, and resulting in an annual reduction of 60,000 tCO_2eq (SNV, n.d.). In addition, technical and business assistance has contributed to developing over 60 local bio-digester construction companies.

Levels of financial assistance vary between countries with support mechanisms. Tax incentives and exemptions, project grants and subsidies have played an essential role in the development of global biogas industries. In Germany for instance, feed-in tariffs have propelled the use of biogas for electricity generation, whereas in Sweden, biogas as a vehicle fuel is not only preferred due to tax exemptions, but also thanks to additional incentives enticing customers to convert, such as free parking and exclusion from road tolls (IEA, 2015).

Table 18: Biogas production in leading countries in 2014 (Authors' compilation, based on IEA, 2015)

Country	Plant type	Number of electricity generation plants	Energy production (GWh/year)	Measures promoting biogas
Austria	Waste water treatment and landfills	44	26	Green Energy Law Tax incentives Biofuel blending quota
	Agriculture and bio-waste	293	544	
Brazil	Sewage sludge	5	42	Biogas subsidies and credit National Programme on Biogas and Biomethane
	Bio-waste	1	1	
	Agriculture	9	10	
	Industrial	2	8	
	Landfills	8	552	
Denmark	Sewage sludge	57	250	Promotion of Renewable Energy Act Tax incentives Biofuel blending quotas
	Agriculture	67	861	
	Industrial	5	51	
	Landfills	25	56	

Table 18: Biogas production in leading countries in 2014 (continued)

Country	Plant type	Number of electricity generation plants	Energy production (GWh/year)	Measures promoting biogas
Finland	Sewage sludge	16	126	Feed-in tariff Project grants Tax incentives
	Bio-waste	11	124	
	Agriculture	12	4	
	Industrial wastewater	3	7	
	Landfills	40	295	
France	Sewage sludge	60	97	Feed-in tariff Project subsidies Upgrading tariffs
	Bio-waste from municipal solid waste	11	51	
	Industrial	80	7	
	On-farm and centralized plants	105	260	
	Landfills	80	858	
Germany	Sewage sludge	1,400	1,310	Biofuel quota Subsidies Tax incentives
	Bio-waste	180	850	
	Agriculture	7,960	25,120	
	Industrial	80	450	
	Landfills	400	540	
Norway	Sewage sludge	25	164	Tax incentives and exemptions Project grants
	Bio-waste	11	63	
	Agriculture	4	3	
	Industrial	3	n/d	
		85	270	
Republic of Korea	Sewage sludge	38	969	Renewable Fuel Standard
	Bio-waste	16	249	
	Agriculture	7	9	
	Landfills	21	1,350	
Sweden	Sewage sludge	137	672	Tax incentives and exemptions Project grants
	Bio-waste	23	580	
	Agriculture	39	77	
	Industrial	5	117	
	Landfills	60	240	
Switzerland	Sewage sludge	465	550	Feed-in tariff Project fund
	Bio-waste	29	275	
	Agriculture	96	226	
	Industrial wastewater	22	67	
	Landfills	6	11	
United Kingdom	Sewage sludge	146	761	Feed-in tariff Renewable Transport Fuel Obligation
	Bio-waste	55	707	
	Landfills	345	5,169	

4.3.3.2 Technology

Globally, biogas technology production is dominated by European and Chinese multinational firms operating across the globe. Table 19 provides an overview of companies paving the way in biogas production plants and plant components.

4.3.3.3 Gas-Based Vehicles

There are approximately 22.3 million gas-based vehicles and 27,000 natural gas fuelling stations in the world (NGV Journal, 2016). Importantly, nearly all of these vehicles rely on CNG rather than CBG. Countries, such as Argentina, Brazil, China, Iran and Pakistan, are far ahead of the pack, as illustrated in Figure 24. China is at the forefront with approximately four million vehicles and over 6,500 fuelling stations in use in 2016. As the number of gas-based vehicles has been rising over the past years, Pakistan has also made headway in converting conventional internal combustion engines, with over 3.5 million vehicles and 3,000 natural gas fuelling stations in country. Iran's performance must also be stressed upon, with more than four million gas-based vehicles on the road, and 2,500 natural gas fuelling stations (NGV Journal, 2016).

As shown in Table 19, China, India, Germany, France, Italy, Japan and the United States are among the leading countries manufacturing CNG vehicles (passenger cars, mini-buses and buses). In terms of vehicle conversion technologies, such as CNG conversion kits as a whole or individual components, China is a world leader, with a number of firms exporting their products globally.

4.3.4. THE DOMESTIC MARKET

The first experiment with anaerobic digestion using animal manure in the world was developed in South Africa during the 1950s, signalling a potentially lucrative biogas industry in the country. However, contrary to predictions, the biogas industry and market in South Africa have remained in their infancy over the past decades (GIZ, 2016).

South Africa can produce and use CBG locally as a sustainable alternative transport fuel, reducing harmful environmental impacts (transport accounts for about 13% of GHG emissions in South Africa (DoT, 2016)) and the country's reliance on imported fossil fuels. As in the rest of the world, petrol and diesel still dominate the fuelling space in South Africa (EcoMetrix Africa 2016a).

Since South Africa does not possess any proven oil deposits, the country spends colossal resources on importing petroleum products, with a peak of more than $16 billion in 2014 for crude oil only,

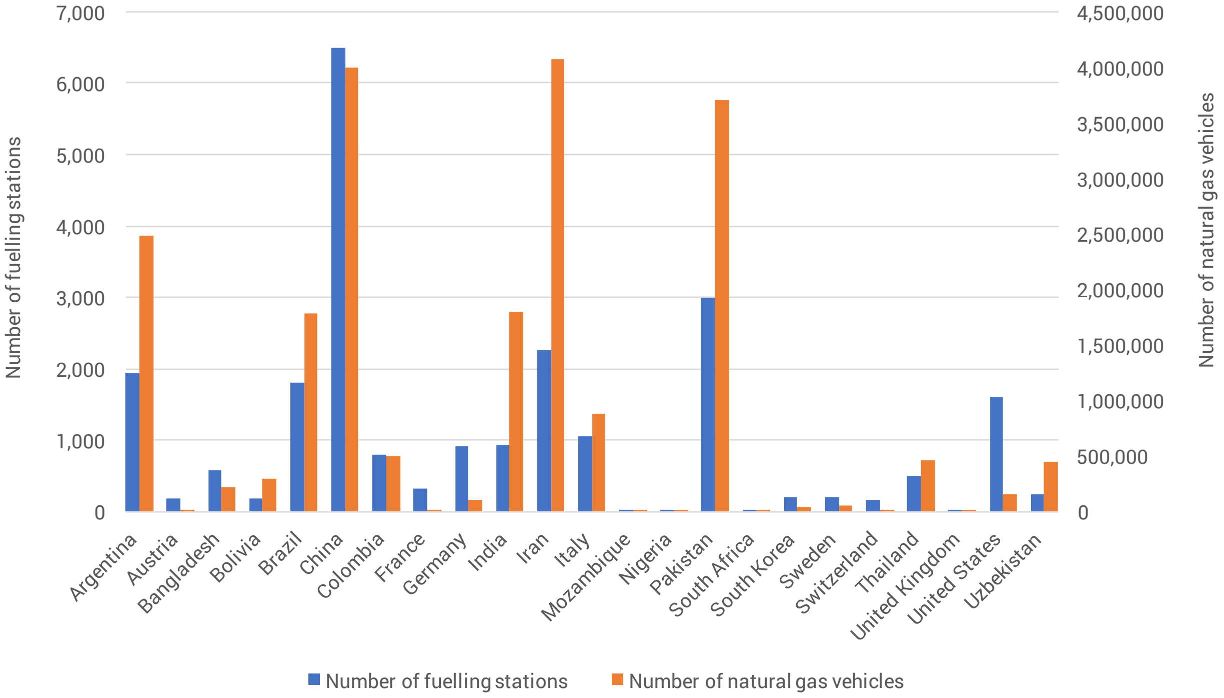


Figure 24: Number of natural gas vehicles and fuelling stations in selected countries in 2016 (Authors' compilation, based on NGV Journal, 2016)

Table 19: Overview of leading European biogas technology companies (Authors' composition, based on data from European Biogas Association, 2017 and company profiles)

Company Name	Countries active (sales and offices)	Planners, manufacturers of plants	Operators	Manufacturers, suppliers of plant components	Total Turnover	Number of employees
AB Energy (Gruppo AB) – Italy	Italy, Romania, Serbia, Poland, Austria, UK, Germany, France, Czech Republic, Croatia, Spain, Turkey, USA, Canada, Mexico, Brazil	X		X	€230 million ($245 million)	600
Agraferm Technologies AG – Germany	Germany	X	X		n/d	90
AGP GAS CONVERSIONS PVT LTD- India	North America, South America, Western Europe, Asia			X	n/d	n/d
APROVIS Energy Systems GmbH - Germany	Worldwide			X	n/d	100
Biogest Energie und Wassertechnik GmbH – Austria	Austria, Bulgaria, Croatia, Czech Republic, Hungary, Italy, Poland, Ireland, Romania, Serbia, Slovakia, UK, USA, France, Thailand	X	X	X	n/d	50
BTS Biogas – Italy	Italy, UK, France, USA, Germany, Czech Republic, Poland, Canada, Japan, Thailand, South Korea	X	X	X	n/d	>100
Chengdu Laida Mechanical & Electronics Co., Ltd – China	China, Central Asia, Middle-East, South America			X	>$100 Million	500-100
DMT Environmental Technology - Netherlands	Netherlands, USA, Malaysia, France	X		X	€15 Million ($16 million)	50
DONG Energy - Denmark	Denmark	X	X		kr71 billion ($10.1 billion)	6,500
DSM - Netherlands	The Netherlands, Germany, Austria, France, UK, Czech Republic, Slovenia, Italy, USA, Canada, India, China	X		X	€9 Billion ($9.6 billion)	22,000

(continued next page) ➡

Table 19: Overview of leading European biogas technology companies (continued)

Company Name	Countries active (sales and offices)	Planners, manufacturers of plants	Operators	Manufacturers, suppliers of plant components	Total Turnover	Number of employees
Evonik Resource Efficiency GmbH – Germany	USA, China, Malaysia, Japan, South Korea, Brazil, Europe			X	n/d	35,000
Franz Eisele u. Sohne GmbH u. Co. KG – Germany	Worldwide			X	n/d	80
Gasunie – Netherlands	n/d	X		X	€1.6 billion ($1.7 billion)	1,700
Geotech – United Kingdom	UK, Austria, Belgium, Bulgaria, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, The Netherlands, Norway, Poland, Portugal, Romania, Slovenia, Spain, Sweden, Switzerland, Turkey			X	£6.9 million ($10.1 million)	51
GRDF (Gaz Réseau Distribution France) – France	France			X	€3 billion ($3.2 billion)	11,431
Henan Ouyi Autogas Equipment Co., Ltd.- China	USA, Russia, Japan, Thailand, Malaysia, India, Philippines, Georgia, Bolivia, etc.			X	$50-100 million	50-200
IES BIOGAS s.r.l – Italy	Italy, Czech Republic, Romania, Serbia, Croatia, Poland, Bulgaria, Slovakia, Argentina	X	X	X	€100 million ($106 million)	40
Jiaxing Lixun Automotive Electronic Co., Ltd –China	China, Russian Federation			X	$10-50 million	<500
Landwärme GmbH - Italy	Germany, Austria, Benelux, Switzerland, Denmark, Sweden, Hungary	X	X		€120 million ($128 million)	20
PAN Fueltech (P) Ltd - India	India			X	$4.6 million	50

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Table 19: Overview of leading European biogas technology companies (continued)

Company Name	Countries active (sales and offices)	Planners, manufacturers of plants	Operators	Manufacturers, suppliers of plant components	Total Turnover	Number of employees
Parker Hannifin Corporation, Hiross Zander Filtration Division - Germany	Worldwide		X		n/d	55,000
Pentair Haffmans - Netherlands	Worldwide	X		X	$6.4 billion	28,195
Sattler Ceno TOP-TEX GmbH – Austria	Worldwide			X	€126 million ($134 million)	669
Sichuan Aonengjia Gas Vehicle Technology Co., Ltd - China	North America, South America, Eastern Europe, Southeast Asia, Africa			X	$50-100 million	51-200
Schmack Biogas GmbH – Germany	Worldwide	X	X	X	n/d	330
Xylem Water Solutions - Sweden	Worldwide			X	€3.5 billion ($3.7 billion)	12,900
Zhongyou Tongyong Luxi Natural Gas Equipment Co., Ltd - China	China, Armenia, Colombia, Malaysia, India, Indonesia, Iran, Peru, Russia, Thailand, Uzbekistan, etc.			X	> $100 million	> 1,000

Note: n/d indicates the absence of available data

exacerbating the negative balance of trade (see Figure 25).

The priority policies and regulations related to biogas production and adoption are the National Environmental Management Waste Act of 2008, which provides the framework for waste management licenses and the treatment of waste to combat harmful environmental and health impacts and ensure sustainable development (DEAT, 2008) and the Gas Act of 2001, which is geared towards "promoting the efficient, effective, sustainable and orderly development and operation of gas transmission, storage, distribution and liquefaction" (DoE, 2002). On the procurement side, 110 MW of electricity generation capacity has been allocated to large-scale biogas projects as part of the REIPPPP, although, to date, no project has been successfully selected.

To displace some of the demand for conventional fuels, CNG/CBG will need to be priced competitively. The South African government, through the Department of Energy, regulates the price of petrol and diesel. Prices are based on a range of factors including, but not limited to, the exchange rate, global crude oil prices and transportation costs associated with imports and inland transport (EcoMetrix Africa 2016a). In addition, various fuel levies and taxes make up the composition of the domestic petrol price. The situation differs for bio-methane, as the National Treasury has yet to determine a tax and levy structure. At the moment, VAT of 14% is levied on CNG (EcoMetrix Africa 2016a). As of May 2017, the pump price of 93 and 95 unleaded petrol in the reef region stood at R13.57 ($1.02) and R13.79 ($1.04) per litre respectively, while a litre of diesel cost R11.81 ($0.89) (AA, 2017). In comparison, the price of natural gas at filling stations is lower, at R8.99 ($0.68) per litre equivalent (CNG Holdings, 2017).

Furthermore, Suleman et al., (2015) established that all of the gas-to-transport value chain links are already present in the country. The three key stages, namely inputs/feedstock, technology development, and end-use/consumption, are discussed below.

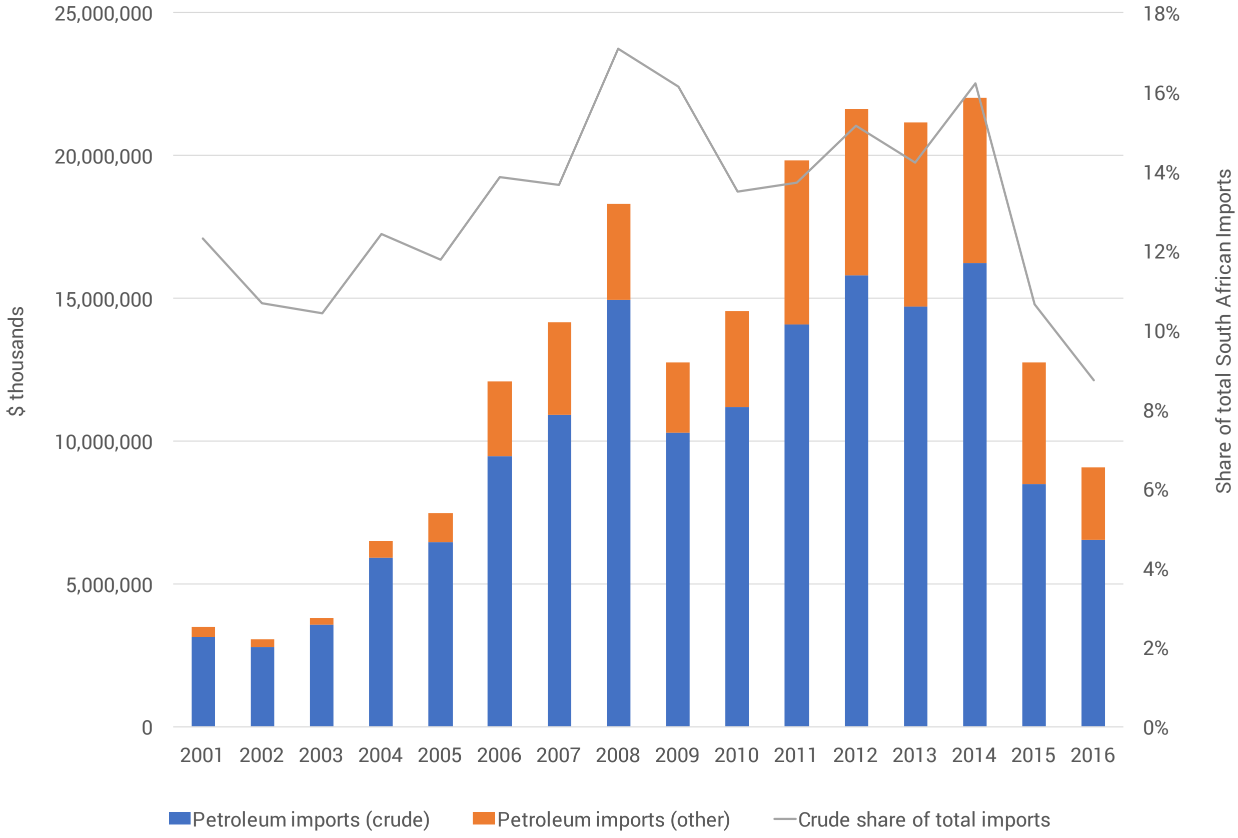


Figure 25: South Africa's petroleum imports from 2001 to 2016 (Authors' compilation, based on Trade Map data)

4.3.4.1 Inputs

According to the Biogas Inventory (EcoMetrix Africa 2016a), South Africa could produce 3 million normal cubic metres (Nm³) of biogas per day, most which is located around Gauteng, the coastal regions of KwaZulu-Natal and the Western Cape. Despite this significant potential, biogas production in the country continues to lag behind the rest of the world.

Biogas is derived from various sources of agricultural and municipal waste feedstocks, as illustrated in Figure 26. 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. The agricultural feedstocks required for biogas production include wet and dry animal manure, although this type of biomass produces low yields. During production, fermentation, and storage processes, breweries collect water waste used to generate biogas that amounts to the proportion of organic waste inputted. The waste from fruit processing and sugarcane has proven to provide high yields, but seasonal production raises doubts about reliability (EcoMetrix Africa 2016a).

Municipal solid waste has been identified as a significant source of biogas, contributing 1,136,450 Nm³, as evident from Figure 26. Most of the 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.

The issue of food security has been viewed as a challenge to biogas development in South Africa, as growing crops for fuel and gas competes with agricultural land, skills and water – an already stressed resource. However, since municipal solid waste has been identified as potentially the largest source of biogas in the country, the focus should shift to waste-based generation.

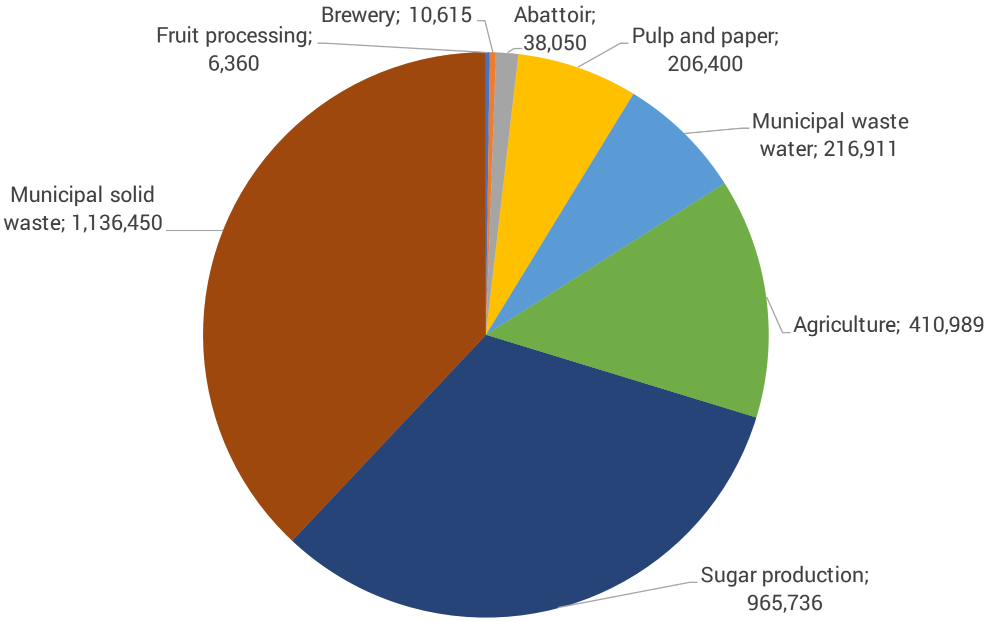


Figure 26: Potential sources of biogas in South Africa (in Nm³ per day) (Authors' compilation, EcoMetrix Africa, 2016)

4.3.4.2 Technology

There are approximately 700 biogas digesters installed in South Africa, most of which are domestic/rural digesters, small- to medium-scale commercial digesters and large-scale industrial/agricultural digesters (EcoMetrix Africa 2016a). Typical domestic and rural digesters include fixed dome digesters (with the dome usually imported from China, while the digester is constructed on site using bricks and mortar), Do-It-Yourself "DIY" Biobag digester kits, plastic rotor moulded digesters, and concrete digesters cast on-site.

Most biogas facilities focus on electricity and heat generation, mirroring the global situation (Masebinu et al., 2015). Table 20 provides an overview of the main biogas projects in the country. As of May 2017, only one large-scale, commercial biogas-to-fuel project was established in the country, the New Horizons Energy facility in Cape Town. Waste management in Cape Town has been a daunting task not only for the municipality, but also for leading retailers producing waste as well as waste collection services, with waste generation exceeding the city's capacity to efficiently manage waste sources. The city produces approximately 2 million tonnes of waste annually, rotting at landfill sites and emitting harmful gases into the atmosphere. As a result, New Horizons Energy identified a promising opportunity to derive economic and social benefits while tackling waste management issues and reducing environmental impacts in the process (Clean Energy Africa, 2017).

Prior attempts by project developers to access municipal waste streams have been discouraged by legislation. The Municipal Finance Management Act of 2003, for example, limits contract periods to three years (EcoMetrix Africa 2016a). Furthermore, municipalities tend to secure projects dedicated to electricity generation with the eThekwini municipality, the City of Cape Town and the City of Johannesburg focusing on establishing waste-to-electricity projects, such as the landfill gas to electricity programme at Mariannhill and Bisasar Road (Africa's largest landfill site) (EcoMetrix Africa 2016a).

Trade data for CNG conversion kits, biogas digesters and related components is difficult to access, as disaggregated data is not available, with biogas technologies clustered under a broad grouping of a particular HS code. Nevertheless, data on the imports of biomass boiler components provide an idea of the local demand for such products, as illustrated in Figure 27.

Overall, the dissemination of biogas technologies has been impeded over the past years by a lack of research, particularly on biogas as a vehicular fuel (Mukumba et al., 2016). Furthermore, funding mechanisms from project conception to the feasibility stage are virtually non-existent, with experts citing that it costs between R2 million-R6 million ($136,000-$408,000) to undertake full feasibility studies, including environmental impact assessments. However, once projects are proven to be bankable, finance can be acquired from South African commercial banks and government funds.

These challenges are exacerbated by a lack of integration between various government departments, though the DEA, the dti, DST, the Department of Transport (DoT) and the DoE have been collaborating on measures to promote a biogas industry in South Africa, and jointly convened the first National Biogas Conference held in 2013 (DoE, 2015). The DoT's draft Green Transport Strategy also proposes projects to convert and test dual-fuel public fleets (DoE, 2015). The DEA identified CNG as having significant pollution mitigation potential (DEA, 2014). Additionally, the dti has partnered with the Industrial Development Corporation (IDC) to undertake various studies and tests on the use of CNG as a vehicle fuel, by conducting feasibility studies and converting taxi fleets.

4.3.4.3 Vehicles and Fuelling Stations

Dedicated CNG/CBG vehicles operate solely on gas and are suitable for those using fixed routes where refuelling infrastructure is easily available. Dual or bi-fuel vehicles can operate on either CNG/CBG or petrol/diesel. (South African Cities Network et al., 2015).

The uptake of gas-based transport in South Africa lags behind other developing countries, such as Pakistan and Argentina, mainly due to lack of demand and insufficient infrastructure. It is estimated that only 1,000 CNG taxis operate in Johannesburg, Ekurhuleni and Tshwane (South African Cities Network et al., 2015). In 2016, there were also fewer than 10 CNG/CBG filling stations in South Africa, probably accounting for slow adoption of biogas for transport usage (EcoMetrix Africa, 2016). Yet dual-fuel vehicles taxis operating on

Table 20: Biogas-related projects in South Africa (Authors' compilation, based on data from the Southern African Biogas Industry Association)

Province	Project	Location	Owner	Developer	Input	Output
Gauteng	Bronkhorstspruit Biogas Plan	Bronkhorstspruit	Bio2Watt	Bosch Projects	manure	4.6MW
	Northern Works Waste Water Treatment Works	Johannesburg	Johannesburg Water	WEC Projects	waste water	1.2MW
	Driefontein Waste Water Treatment Works	Johannesburg	Johannesburg Water	WEC Projects	waste water	0.75MW
	Morgan Abattoir	Springs	Morgan Abattoir	Biogas SA/WEC Projects	slaughter waste and organic waste	0.4MW
	Cavalier Abattoir	Cullinan	Calaier Group	iBert	slaughter waste	495kW
KwaZulu-Natal	Bisasar Road LFG	Durban	eThekwini Municipality DSW	n/d	3,500-5,000 tons of refuse per day	6MW
	Mariannhill LFG	Durban	eThekwini Municipality DSW	n/d	550-850 tons of refuse per day	1.5MW
	Sucro Power	Durban	Sucro Power	iBert	napier grass	16kW
Western Cape	Hessequa Abattoir Riversdale	Riversdale	Hessequa Abattoir	iBert	slaughter waste	50kW
	PetroSA	Mossel Bay	PetroSA	Biotherm	refinery waste water	4.2MW
	Elgin Fruit Juices	Grabouw	Elgin Fruit Juices	Elgin Fruit Juices	5 tons of fruit waste per day	500kW
	Distell Stellenbosch	Stellenbosch	Distell	Veolia Water	waste water	Boiler Fuel
	SAB Miller	Newlands	SAB Miller	SAB Miller	waste water	Boiler Fuel
	Uilenkraal Dairy Farm	Darling	Uilenkraal Dairy Farm	CAE	bovine manure	600kW
	Zandam Cheese and Piggery	Durbanville	Zandam	iBert	pig manure	75kW
Northern Cape	Meat to Market	Jan Kempdorp	Meat to Market	iBert	slaughter waste	135kW

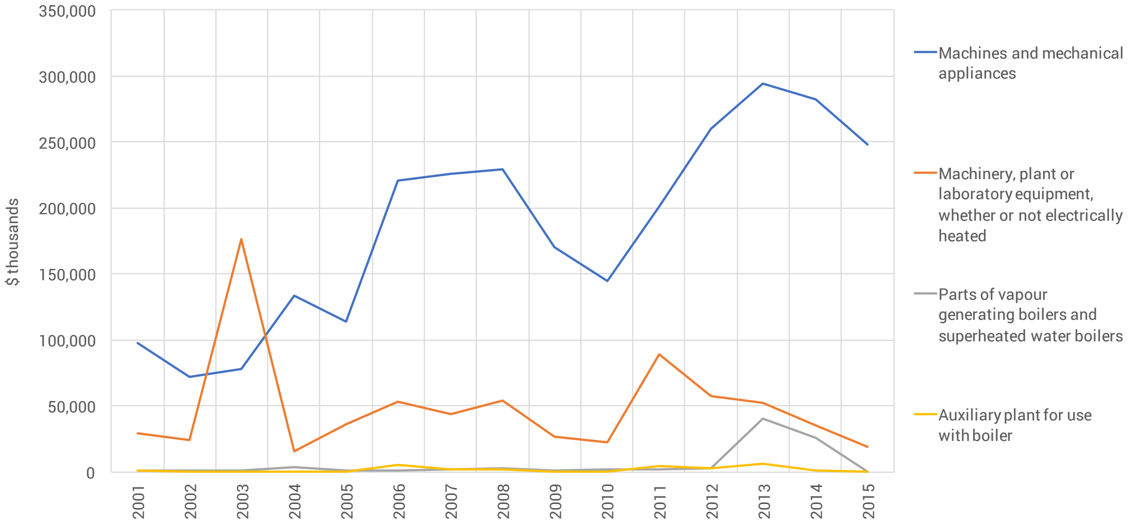


Figure 27: South African imports of biomass boiler components, from 2001 to 2015 (Authors' compostition, based on Trade Map data)

CNG achieved an average cost saving of 24% of fuel cost or R0.35 per km travelled (South African Cities Network et al., 2015).

Converting the public bus fleet and mini-bus taxis to gas-based systems could spur industrial growth in the local biogas-to-transport fuel sector. South Africa has 130,000 legally-operational mini-bus taxis, a third of them in Gauteng (SANTACO, 2017), and 25,000 buses (SABOA, n.d.). The cost of converting a taxi to use CNG amounts to R20,000 ($1,569) and or a private vehicle R16,500 ($1,255) (South African Cities Network et al., 2015). In addition, municipal dump trucks constitute another key opportunity for the government to save on fuel costs, by retrofitting trucks at a once-off cost of R8,000 ($628), to receive biogas derived from municipal solid waste.

Funding mechanisms are available for taxi owners aiming to convert their fleets. Owners buying kits of their own accord are offered lower CNG prices per litre, and can recover costs of conversion within 13 months. Alternately, gas retailers can fund taxi conversions and recover costs by increasing the price of gas at the pump. In both cases, CNG as a fuel remains cheaper than petrol or diesel (South African Cities Network et al., 2015).

Similarly, the fuel cost for dual-fuel CNG/diesel buses drops by an estimated 20% compared to standalone diesel buses (South African Cities Network et al., 2015). The financial, social and environmental benefits of using gas as a fuel have led a number of local municipalities across the country to express their intention to procure gas-based buses in the coming years, generating some level of local demand. The city of Johannesburg acquired and converted a total of 70 dual-fuel CNG buses to add to their fleet. Similarly, the Tshwane municipality bought 40 CNG buses operating within the A Re Yeng BRT fleet in 2015. A study undertaken by the IDC (South African Cities Network et al., 2015) showed that if household waste were to be collected, separated and fed into compressed biogas plants, more than 7,100 municipal busses could be converted to received CNG/CBG, creating an estimated 1,000 to 10,000 jobs if such programmes are applied across South Africa.

For a mass roll-out of CNG taxi and municipal bus fleets, key processes need to be put in place, such as gas production and distribution infrastructure,

Table 21: Targets for planned gas-based bus procurements over the 2015-2022 period (South African Cities Network, et al., 2015)

Municipality	Planned order
Johannesburg BRT/Metrobus	402
Cape Town BRT	320
Tshwane BRT	130
Ekurhuleni	50
eThekwini	60
Rustenburg	25
Total	977

manufacturing or procuring vehicle conversion kits, and complementary fiscal and legislative mechanisms to support the adoption of biogas transport fuel.

Currently, bio-methane for use as a vehicle fuel has not penetrated the South African market (DEA, 2016), with the lack of demand for biogas and insufficient infrastructure to promote uptake in South Africa viewed as major obstacles hindering its development. These barriers have spurred constant chicken-and-egg debates around whether the government should invest in infrastructure to stimulate demand, or rather wait for growth in the market before injecting capital into infrastructure development.

4.3.5. THE LOCAL MANUFACTURING BASE

Trade and manufacturing-related data on the state of South Africa's biogas industry is not available. Nevertheless, industry experts have provided information on the various local and international products available on the South African market.

The South African biogas industry can be classified according to three broad clusters: government-funded and donor-funded initiatives that seek to promote the biogas-to-transport industry; existing and emerging small-scale to medium-scale firms that locally produce a limited range of products related to biogas digester technologies; and government-supported, large-scale commercial biogas and bio-methane production facilities producing gas for designated off-takers.

The first group is structured around two key initiatives, namely the Southern African Biogas Industry Association (SABIA) and the National Biogas Platform. The local industry has made significant strides to create awareness and promote biogas in the country through the creation of the SABIA. The industry body was formed in 2014 by a core group of interested parties out of a common need for active representation of the biogas industry in South Africa (SABIA, n.d.).

The National Biogas Platform is a multi-stakeholder forum on biogas, convened by the Department of Energy and SABIA and hosted by the Deutsche Gesellschaft für Internationale Zusammenarbeit, better known in South Africa as GIZ, which serves as a secretariat and facilitator for the platform. The platform comprises representatives of different government departments, private sector companies, investors, financiers, academics, research institutes and civil society. It aims to serve as a sounding board for policy development on biogas and to promote the biogas industry in South Africa, through stakeholder engagement, lessons learned, as well as research and advocacy on policy and financing issues. The National Biogas Platform has six working groups which provide technical inputs, research support and continuous feedback on developments in their respective focal areas. These are the Commercial Viability, the Licensing and Technical Standards, the Vehicular Biogas, the Rural Digesters, the Information Gathering and Communication, and the Use of Digestate working groups) (SABIA, n.d.).

The second group, made of small-scale to medium-scale, innovative and dedicated South African firms largely focuses on specific products and markets. Table 22 provides a brief overview of the local biogas firms, products and providers.

A representative example is Cape Town-based Agama, which focuses on the small-scale digester market (residential and commercial complexes, schools, and farms). The company, which has a manufacturing plant in Cape Town, assembles locally-designed and engineered products. It also exports to numerous markets, including Europe and Australia. The company offers three main products, namely 'BiogasPro', 'Smart Top' and 'Light Top'. The BiogasPro can sustain from 5 kg to 40 kg of waste per day. The Smart Top is a hydraulic fibre-glass chamber, which fits on top of a dome style digester that is constructed on site by local workers. The 'Light Top' is another small-scale product, which can produce 1.9 Nm^3 of biogas per day, equivalent to 0.8 kg of LPG or 3.5 kWh of electricity. In addition to producing biogas technologies, Agama also provides training to local semi-skilled and unskilled workers and students who have gone on to create SMMEs that then can install their products at various sites, facilitating knowledge transfer and scale-up of the sector.

The third and last group consists of government-supported, large-scale projects. New Horizons Energy's R400-million ($31 million) biogas plant in Cape Town, largely funded by the Industrial Development Corporation, is South Africa's first, large-scale waste-to-biogas plant. It became active in the beginning of 2017, producing CNG for vehicular use, which Afrox has agreed to offtake. Around 10% of the city's municipal solid waste is expected to be diverted to the plant, as opposed to landfill, in attempts to provide renewable sources of energy and products, such as compressed bio-methane and organic fertilizers (Cloete, 2017). The plant will create around an estimated 80 full-time and 100 indirect jobs.

Table 22: Overview of leading biogas firms, products and services in South Africa (Authors' composition)

Existing firms	Products and services
	Small-scale market
Agama Biogas	• BiogasPro • Smart Top • Light Top
Aquadam	• Muleby System Tank for storage
Biogas SA	• Small-scale domestic/rural Biobag DIY Digester kit • The in-situ cast concrete Puxin Digester • Biogas flares and gas conditioning equipment
Novo Energy	• Bio-methane production • Gas infrastructure • Filling Stations
Re-energise Africa	• Biogas production, upgrading and storage
Selectra	• Anaerobic digestion solutions
Trade Plus Aid	• Biogas Alternative Energy Programme • Concrete Dome Digesters • Lagoon Digesters
WEC Projects	• Gas scrubbing solutions • Upgrading • Rebuilds and operation and maintenance
	Large-scale market
Bio2Watt (large-scale)	• First South African industrial scale waste-to-energy commercial biogas plant, in Bronkhorstspruit • Supplies electricity to off-takers (BMW)
CNG Holdings (large-scale)	• Fleet conversion • CNG filling stations
New Horizons CNG Plant (large-scale)	• Waste to CBG vehicle fuel production

Expanding small-scale existing South African firms into thriving mass-market biogas producers and distributors is achievable, Industry experts agree, however, that without government financial and policy support, biogas for vehicular use could prove commercially uncompetitive, because CNG/CBG may not remain exempt from fuel taxes and levies. No legislation at present favours the use of biogas. Nevertheless, the industry association SABIA is working to overcome this, with constant stakeholder engagement, research studies, the creation of biogas working groups and awareness campaigns.

Although gas is produced from local feedstocks and, in some cases, locally-designed technologies, digesters are only assembled in South Africa, with the bulk of biogas digesters, vehicle conversion kits or related components (such as plastics, pipes and gas stoves) imported from international companies based mainly in China or European countries, such as Germany.

4.3.6. RECOMMENDATIONS

Vehicular biogas production presents an untapped socio-economic opportunity. It can bring about cross-sectoral benefits by reducing vulnerability from energy costs and supply (foreign exchange expenditure), ensuring carbon mitigation, managing municipal, agricultural and human waste, recycling already stressed water resources, creating job opportunities, enhancing the circular economy and stimulating the local industry.

To take off, the South African biogas-to-transport value chain requires tremendous investment from government as well as favourable regulatory and legislative frameworks to transition the industry from its infancy into a thriving local manufacturing base. The South African government should set standards for the operation and production of biogas across the industry, ensuring that generation and the quality of products produced are safe and reliable. To encourage localisation of biogas technologies and create a domestic manufacturing base, the state should provide conditional funding that stipulates a percentage of local content.

Incentives play a pivotal role in promoting biogas uptake. Existing biogas markets flourished in other countries through government assistance, such as incentives, subsidies and tax reductions/exemptions (EcoMetrix Africa 2016a). In South Africa, a Biogas Bonus Scheme is being developed, and driven by SABIA. The aim is to promote developing biogas projects by assisting in feasibility studies, to stimulate the uptake of biogas outside electricity and heat generation, and eventually to provide rebates and monetary support for local biogas manufacturers (SABIA, 2016). However, outside of SABIA's reach, the South African government has done little, to date, to ensure the transition to CNG/CBG based fleets. For instance, incentives could include pricing regulations to ensure that CNG prices continue to remain lower than those of petrol and diesel, tax reductions or exemptions on biogas digesters, CNG conversion kits or related components, or mandatory blending requirements to promote initial uptake.

Furthermore, municipalities, biogas companies and funding institutions should collaborate with relevant parties (such as taxi/bus associations and fleet owners), through stakeholder engagement and workshops highlighting the wide range of benefits arising from CBG/CNG to encourage uptake. To ensure cooperation from the taxi industry, operators should be incentivised to procure or convert vehicles that can use CNG/CBG. Aside from the regular subsidies and fuel levy exemptions for gas, taxi operators can establish gas re-fuelling businesses at taxi ranks, thereby ensuring constant supply.

The government should provide leadership by driving the growth of the industry through converting state-owned fleets. CNG or CBG could be combined with electric motors, thereby lessening the environmental burden and promoting local content in terms of CNG and CBG production. Although still a non-renewable resource, natural gas emits 30% less GHG than diesel and petroleum, when used as a vehicular fuel (Suleman et al., 2015).

Moreover, more CNG/CBG fuelling infrastructure should be rolled out on routes travelled by these fleets, so that drivers of dual-fuel vehicles are not tempted to fill their tanks with conventional fuel because of its ready availability.

Since municipal solid waste is the largest source of potential feedstock, local governments are in prime positions to partner with companies to transform waste management into a lucrative industry that provides cross-cutting benefits not only for the municipality but for the country as a whole. Since it is cheaper to fuel buses with CNG/CBG, passenger transport fares could also be lowered, ensuring added social benefits of switching to gas-based fleets.

4.4. BIO-COMPOSITE MATERIALS

KEY FINDINGS

- Biocomposities are diverse and therefore require grouping by product technology, in order to effectively target policies.
- Correctly targeted, products like biopolymers with large established markets could improve industrial competitiveness through the role they play in the supply chain of many manufacturing activities.
- Biocomposite technologies cannot yet compete on cost and effectiveness with established, petroleum-based alternatives.
- Bringing the technology to maturation will require targeted, long-term support.
- Commercialising this technology will then further rely on adequate supplies of feedstock, which may require leveraging off biogas or agricultural development programmes.
- All these efforts should be conducted in partnership with South Africa's strong plastics sector, to take advantage of existing industrial complementarities.

4.4.1. BACKGROUND

Bio-composite materials (biocomposites) refer to a broad category of goods produced from natural, renewable resources, most commonly agricultural goods or agricultural waste. The range of products captured under biocomposites is vast, and includes simple panel boards, fibres and yarn, and goods similar to plastics products, like water bottles and car panelling. This last category, bioplastics, is the most interesting, with biomaterials having the potential to replace unsustainable and carbon-intensive petroleum-based products. Throughout this section, bioplastics is the most prominent type of biocomposite considered.

Biocomposites differ from many of the products examined in this paper, in that both the market and the technology remains underdeveloped. In many ways, biocomposites mirror the situation in the market for renewable energy technologies a few years ago, when there was still limited demand, but large (often publicly-funded) investment, preceding rapid growth in product efficiency and competitiveness.

Establishing South Africa as a producer of biocomposite materials therefore requires positioning the country for rapid change over the next decade. Doing so is difficult, because of extreme uncertainty in the technology and market, which makes it hard to meaningfully assess many core data points, like global trade patterns, or to determine which are the most efficient firms.

This section begins with a broad exploration of the universe of biocomposites, before focusing in on the global and local market for bioplastics. While South African biocomposite manufacturing activities are limited, three core areas are examined, namely: the availability of appropriate feedstock, the availability of appropriate technology, and the state of matching industrial capacity, i.e. firms that are close in their operations to biocomposite manufacturers and could be leveraged to drive the rollout of biocomposite technology.

4.4.2. TYPES OF BIOCOMPOSITES

Biocomposites are a category of goods, unified by their use of sustainable resources as inputs. As a result, there is an extreme diversity in both the inputs and the types of products created. In this sense, biocomposites closely mirror the plastics industry, which creates a base product from a range of inputs, and uses the base product to create everything from clothing fibres to large building materials.

Across the diverse inputs and outputs in biocomposites, levels of technological development vary. Some products, such as clothing made from hemp, are well established, and have been around for decades (Biocomposites, 2014). Others, such as making chipboard from cassava, are underdeveloped, and do not yet meet standards of rigidity and durability that enjoyed by wood products (Baharuddin et al, 2016). Figure 28 offers a snapshot of various biocomposites.

Broadly speaking, the two core types of biocomposites are fibres and polymers. Bio-fibres aim to offer alternatives to traditional sources, notably animal-based fibres, and focus on plant-based fibres. Polymers aim to challenge the dominance of petroleum-derived plastic products in a wide range of sectors. Within this broad division, there are many distinctive types, defined effectively by three characteristics: input, base chemical, and mix, as depicted in Figure 29.

The input refers to the plants and waste from which the product is derived. Often this is cross-cutting, with sugarcane bagasse, for example, able to feed-in to almost every type of polymer (though only truly marketable and efficient in certain types). This multi-use is primarily the result of the second factor, the chemical base. Generally, processing of biomaterials reduces them to core inputs, like cellulose or starch, which are chemically similar after processing from various sources. The transition from these base materials to a finished product is, however, based on what production technologies are available, and how usable certain inputs are for a given product. The third component is the mix of the product. Many biocomposites do not yet meet standards for products like hard plastics on their own, requiring a mix with traditional polymers or binding agents. These mix products are still more sustainable than their conventional alternative. Moreover, mixed products often make use of petroleum-based products that are biodegradable, like polycaprolactone, further improving their

Figure 29: The biocomposite components lifecycle (Authors' composition)

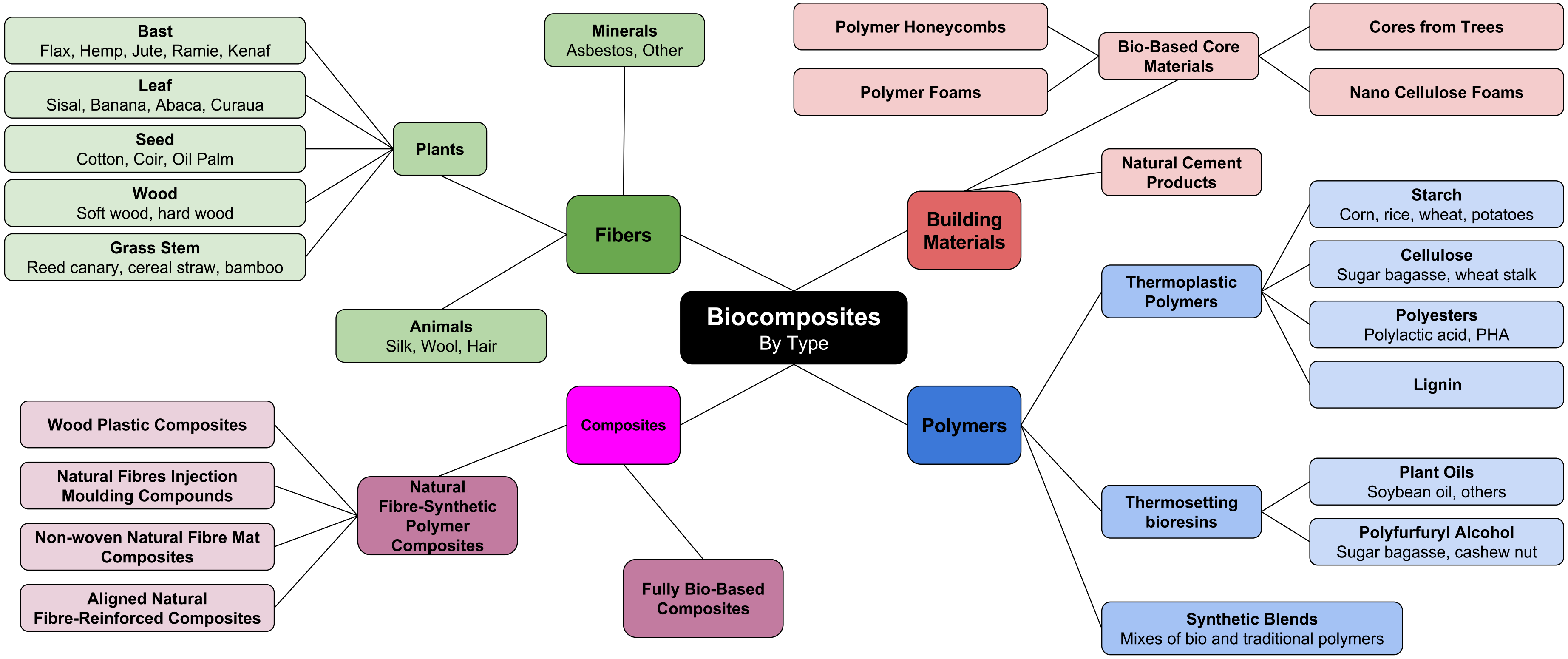


Figure 28: Typology of biocomposite products (Authors' composition, adapted from NetComposites, 2014)

performance in terms of sustainability. Others mix multiple types of bio-composites, combining bio-fibres that are bound by bio-polymers. While this technology is less advanced, it will likely become more viable as individual technologies progress.

All of these characteristics are perhaps less important than their end use, which are even more diverse. Fibres feed into a range of products, including clothing, medical fibres (like stitches), automotive mats, alternatives for construction of traditional glass-fibre products, and as inputs to mixes for polymer products. Polymer products have a broad range of applications that closely mirror those of plastic polymers. They can be used for simple consumer products, like plastic containers, and in heavy industrial products, like automotive panelling. Beyond fibres and polymers, there is a diverse range of other products, notably in the construction industry.

Globally, this often refers to the creation of softer core building materials, which when used alongside traditional materials, allows for a more flexible and resilient structure. The level of complexity within the biocomposite product space can be witnessed by looking at one type of product, biopolymers, as seen in Figure 30. The multiple types of polymers differ in the inputs and technologies they use, but also vary in the extent to which they are biodegradable, and the extent to which they are viable without a mix of petroleum products.

4.4.3. GLOBAL MARKET TRENDS

The global market for biocomposites can be analysed in two distinct ways. The first is to examine the actual market, the current state of biocomposites. This, however, can be misleading, as the sector is still underdeveloped, and many of the most promising products are not at a stage of development where they compete with traditional manufactures. The second technique is to examine the product categories that biocomposite materials are likely to compete with or replace in the future, notably plastics. Again, this may be misleading, as biocomposite materials may be usable in some industries (for example, interior car panelling) but not in others (such as highly-stressed airplane panels). Nevertheless, both tell a partial but complementary story about the state of the industry.

Growth estimates in the global market are unreliable, and dependent on developments in the technology, but are impressive. The EU's trade group, European Bioplastics, has predicted that the global market for biopolymers will grow from 1.4 million tonnes in 2015 to 6.2 million tonnes in 2019 (European

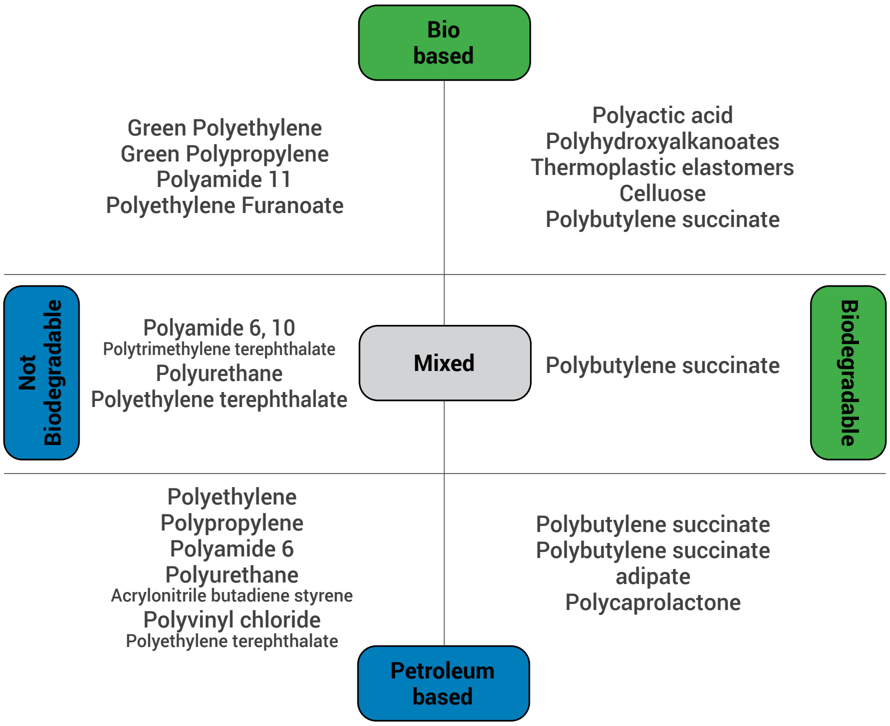


Figure 30: The universe of bio- and traditional polymers (Authors' composition, based on Black, 2015)

Bioplastics, 2017). Meanwhile, the global natural fibre composites market is expected to expand by 11% annually between 2017 and 2022.

The growth in bioplastics is set to be complemented by commitments from several countries to expand their use of renewable resources in production processes. The Japanese government has set a goal that 20% of plastics consumed in Japan should be from renewable resources by 2020. Japanese automotive manufacturer Toyota has set a similar 20% goal for the use of renewable or recycled material in resin parts by 2015 (Muniyasamy, 2016). Coca-Cola aims to manufacture all new bottles using its 'PlantBottle' technology, in which 30% of the material is made from bioplastic derived from sugarcane, by 2020 (Durandt, 2016).

The company has already produced 35 billion bottles across 40 countries, and the technology is being used to package food products, like Heinz Ketchup, and in more advanced applications for seat interiors for Ford's hybrid car the Fusion (Coca-Cola, 2016).

As can be seen in Figure 31, much of the current biocomposites industry is clustered in low-end, mass-scale production of packaging goods. Biocomposite materials have proven successful in packaging, with many of the other technologies still reaching viable levels of strength and quality in this market segment.

While examining the plastics industry broadly is not helpful, given its immense diversity, an analysis of plastics polymers, the raw form of plastics that biocomposites can feed into, offers some useful insights.

In general, ethylene and propylene polymers feed into the textiles industry (for polyester) and the packaging industry (bottles and food containers). Vinyl chloride and vinyl acetate polymers are used in a wide-variety of products, including similar packaging to the above, but are also used in industrial contexts, such as piping and cable insulation. Styrene polymers are used for lightweight packing material (polystyrene), while acrylic polymers offer more stretch than other polymers and are used in specialised contexts, such as the medical industry (Ibid). All the above have major environmental implications, as most polymers have an extremely long life and are difficult to dispose of. While the likes of ethylene polymers are non-toxic, a range of health concerns are associated with other polymers, with vinyl polymers often containing a wide range of dangerous toxins, and styrene being a known carcinogen when degraded (Brinson & Brinson, 2008). A brief overview of core polymers is featured in Figure 32.

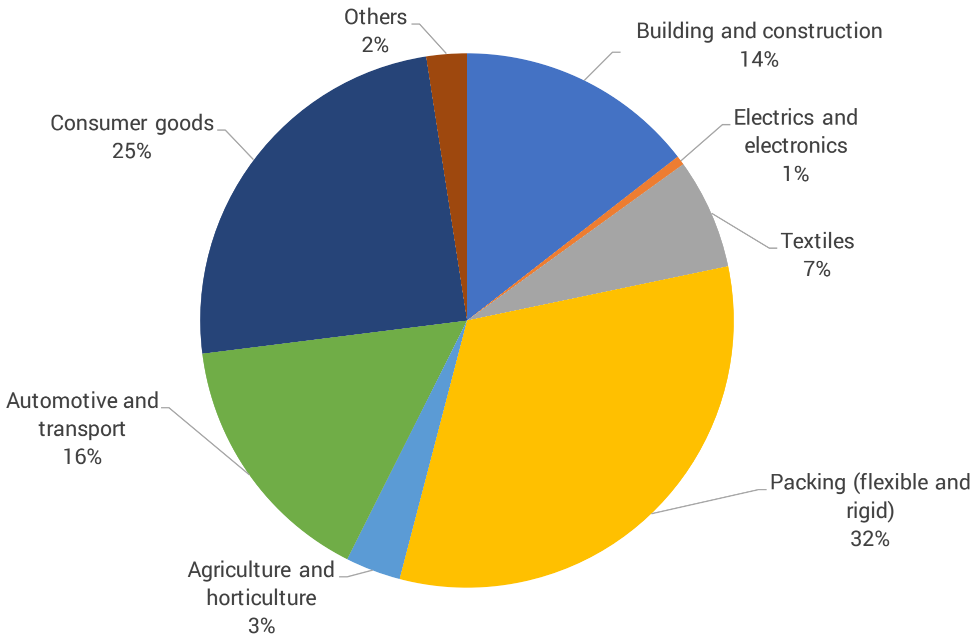
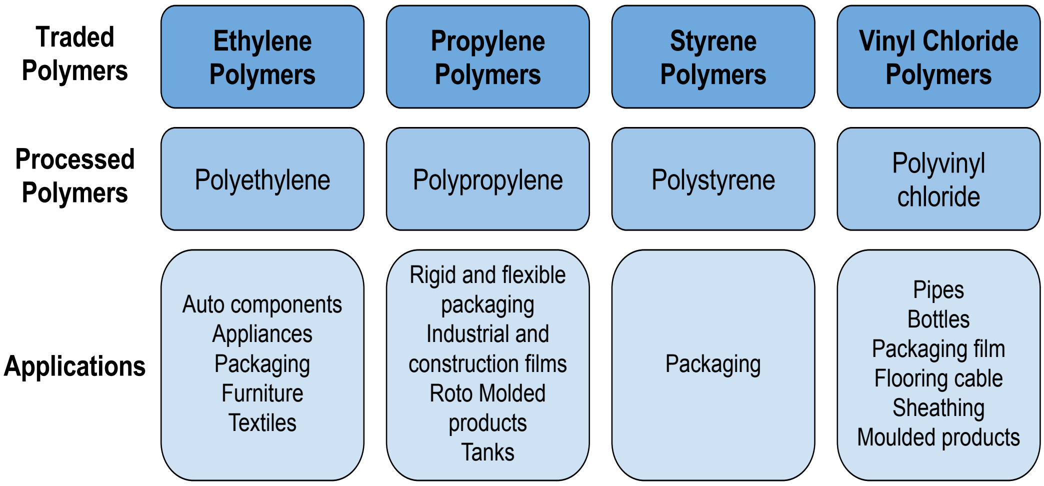


Figure 31: Global production capacities of bioplastics in 2016, by market segment (Authors' composition)

The global market for trade in polymers is valued at $175 billion, and has experienced solid growth, as can be seen in Figure 33, with fortunes differing depending on the type of polymer in question, and polymer growth dependent on the common types of products into which a given polymer feeds.

4.4.4. THE DOMESTIC MARKET

Since biocomposites represent more of a change in production processes rather than in the type of products sold, the market potential for the product is well proven. One can infer that the demand for bioplastics should resemble the demand for plastics, and the demand for bio-cement not unlike that of cement. The extent to which biocomposites can access that market, however, is dependent on the development of the technology and building a supporting environment that can make biocomposites viable alternatives to traditional inputs. Given this, the domestic market demand is not as important as developing the supporting environment to allow for the products to access a proven and established market.



Traded Polymers	**Ethylene Polymers**	**Propylene Polymers**	**Styrene Polymers**	**Vinyl Chloride Polymers**
Processed Polymers	Polyethylene	Polypropylene	Polystyrene	Polyvinyl chloride
Applications	Auto components Appliances Packaging Furniture Textiles	Rigid and flexible packaging Industrial and construction films Roto Molded products Tanks	Packaging	Pipes Bottles Packaging film Flooring cable Sheathing Moulded products

Figure 32: Types of polymers and applications (Authors' composition, based on Young, 2015)

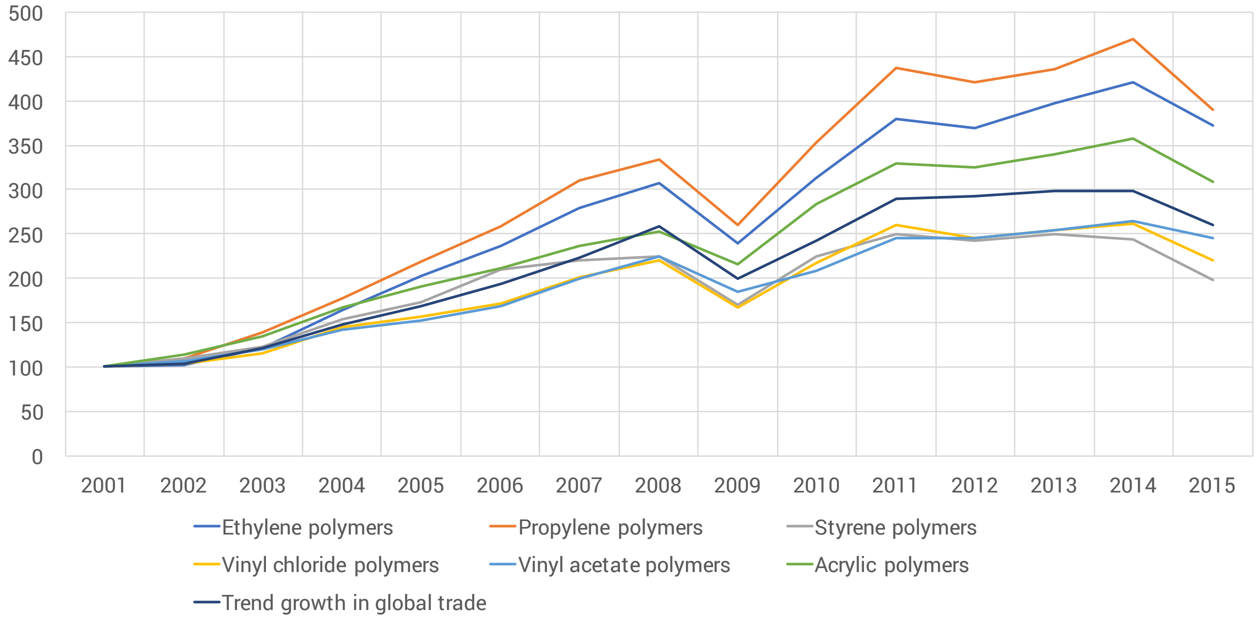


Figure 33: Index of global trade in plastics polymers, from 2001 to 2015 (2001 = 100) (Authors' calculations, based on Trade Map data)

Nevertheless, it is worthwhile examining some of this existing market, particularly for the plastics sector. South Africa's plastics sector is valued at R50.4 billion ($5.22 billion at 2013 middle-rates) in 2013 and employs approximately 60,000 people (Young, 2015). Most of the industry (53%) is concentrated in the packaging sector, while the rest is divided between a wide range of other applications (such as in the construction, automotive, electrical and other industries).

South Africa's plastic sector is unusual by global standards, due to the nature of refinery capacity in the local market. Whereas most plastics products are derived from chemicals produced by a naphtha cracker attached to a petroleum refinery, no such plant exists in South Africa. Instead, South Africa draws the bulk of its plastics and chemicals from by-products of the petrochemical company Sasol's coal-to-liquid technology. This produces an atypical mix of chemical outputs. The result is an unusual trade mix, in which the country is a net exporter of propylene polymers, but a large net importer of ethylene polymers. Indeed, the South African plastics industry exported $576 million in polymers, and imported $700 million in 2016 (Trade Map, 2017). Further detail is illustrated in Figure 34.

While the local plastics manufacturing industry is strong, the unusual chemicals market has long been identified as a major weakness. The reliance on imported basic chemicals and inertia in the petroleum industry, where the construction of a new naphtha cracker would take decades and cost billions of dollars, mean that there does seem to be market space for alternative sources of basic polymer inputs – notably for ethylene polymers – provided these are of comparable quality and cost.

4.4.5. THE LOCAL MANUFACTURING BASE

South Africa does produce and market some biocomposites, but as with the global market, the sector is underdeveloped. Even getting information on the sector is challenging, with production capacity disbursed among diversified firms, and few stand-alone biocomposites manufacturers. As the head of the South African Composites Association explains: "[b]asic information, such as industry stakeholders, employment figures and its contribution to the economy, is not known. Insufficient industry information makes it difficult to attract students to this field, consequently further restricting innovation and advancement in composites" (Booysens, 2015).

Because of the limited industrial base for biocomposites in the country, it is necessary to look beyond the existing infrastructure to assess the potential for the sector in South Africa. Three factors are particularly important. Firstly, inputs are required, notably a stable supply of adequate quantities of feedstock that will not disrupt food production. Secondly, it is important to consider

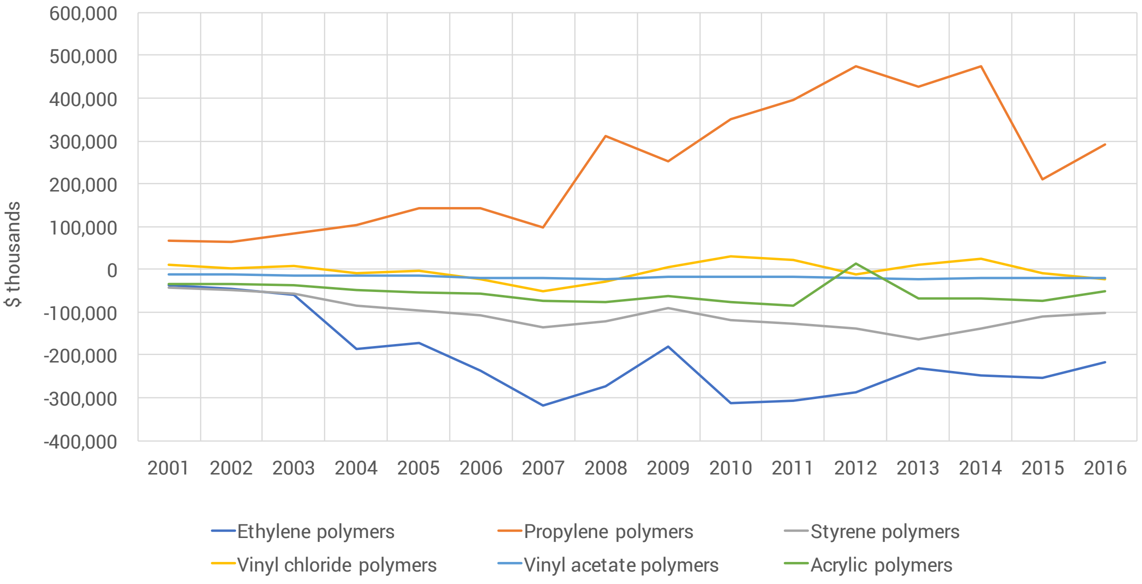


Figure 34: Net South African trade in plastics polymers (Authors' calculations, based on Trade Map data)

the state of biocomposite technologies in South Africa, both in terms of the existence of viable and competitive technologies, and in terms of South African firms' access to potentially proprietary methods and technologies. The third component is the identification of industrial complementarities with existing firms in South Africa. As mentioned above, most of the existing biocomposite capacity is found in firms that are diversified into varied types of polymers. Leveraging this market may provide the best avenue for promoting production of biocomposites.

4.4.5.1 Inputs

Assessing potential inputs for biocomposites is a complex proposition, since biocomposite technologies can have varied inputs. Inputs can be categorised by two broad metrics: whether they are waste or agricultural inputs and the proven suitability of the technology. Sugarcane and maize, for example, are established and well-researched inputs for biocomposites, while cassava and sorghum are high-potential inputs that require more investment. Underlying this dynamic is the complication of intellectual property rights, which, in the case of foreign firms, is clustered into more established technologies based on inputs like sugarcane and maize. The intellectual property rights for less-developed inputs, like sorghum for example, are locally owned (in this case, by the University of Pretoria) and are more easily available.

Much of the focus in South Africa has been on the cluster of inputs identified as high potential for bioethanol production. Indeed, an overarching issue for the development of inputs is their relationship to biofuels (including bioethanol, biogas and biodiesel). Bioplastics application is not regarded as large enough to develop a stable supply of inputs for economies of scale. Building a competitive supply chain is therefore dependent on either the established existence of available inputs (notably waste goods), or a setting up a bioethanol supply chain that could act as a driving force for developing appropriate feedstock.

In the case of the established supply of goods, three high-potential options are often discussed, namely the use of sugarcane bagasse, maize and agro-processing waste.

Sugarcane bagasse, which is the waste product left after the production of sugar from cane, constitutes the first option. There is a large supply of bagasse off the back of the sugar industry, with 22 million tonnes of sugarcane grown annually, from which mills produce 3 tonnes of wet bagasse per 10 tonnes of crushed sugarcane (Muniyasamy, 2016). Bagasse has no resale value, but is used internally by the mills, as a source of power. Research on sugarcane beneficiation is supported through the Sugarcane Technology Enabling Programme for Bio-Energy (STEP-Bio), which is a three-year, R19 million initiative funded by both industry and the Department of Science and Technology, and largely implemented by the Sugar Milling Research Institute (Davis, 2016).

Maize constitutes the second option. In this case, the technology drives the discussion, as maize is among the most frequently studied and well-understood agricultural products, and is therefore well suited to the production of derivatives, like biocomposites. For its use as an input in products like bioethanol, maize itself is a controversial proposition, since it tends to raise serious food security concerns. Nevertheless, biocomposite production could make use of by-products from flour grinding. For every 1 kg of dry corn processed, 0.87 kg of waste products remain. Half of this waste is from maize stalks, of which 40% are used as animal feed (Muniyasamy, 2016). With an average maize production of 8 million tonnes per annum, this would leave unused domestic maize waste at 4.96 million tonnes per year. Using this waste remains difficult, as the most established technologies typically make use of the maize itself, rather than the waste products.

A selection of other waste products, particularly those derived from the agro-processing sector, form the last group of high-potential possibilities. Traditional wastestreams of the type that feeds bio-digesters (as discussed in Section 4.3 on the biogas-to-transport value chain) are difficult to use for bioplastics, as they require the complex extraction of component proteins and fibres, demanding greater specialisation in the type of waste input provided. Nevertheless, some mixed waste products do have potential. Fruit waste, for example, is a high potential stream, as is the use of waste water from cleaning fruit (Khan et al, 2015). Mill sludge from paper and pulp processing could similarly be used, with applications for both bioplastics and construction materials (Sithole, 2014).

Beyond these core streams, a diverse number of other options are available, though a full mapping lies beyond the scope of this research. Nevertheless, two additional feedstocks are worth mentioning

Firstly, the production of biocomposites from cassava could tie into pre-existing state-led efforts to promote the growing cassava for processing into starch. Cassava is not consumed in South Africa and therefore offers no threat to domestic food security. 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).

Secondly, sorghum could be used, despitefacing similar problems. The technology remains underdeveloped and the level of domestic production is too low to support an industry, particularly since the stalling of plans to produce bioethanol, which had driven development of a nascent sorghum industry that has since died out. Nevertheless, sorghum is of interest as many of the innovations and their intellectual property 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.

4.4.5.2 Technology

Establishing a working supply system is essential, as the production of biocomposites is likely to follow the availability of high quality and well-controlled agricultural and waste products. Nevertheless, access to appropriate technologies is the essential precondition before the supply chain can reach fruition.

Given that most biocomposite technologies are still in the development stage, and the more developed technologies are subject to stringent intellectual property right protections, local capacity development plays a key role in this nascent phase of South Africa's industry. These development efforts are guided by three key policy documents.

The first is the national Bio-economy strategy, which sketches a broad framework for using biomaterials, as seen in Figure 35 (DST, 2013). The strategy defines the bio-economy as "activities that make use of bio-innovations, based on biological sources, materials and processes to generate sustainable economic, social and environmental development. In the bio-economy, the entire innovation system/network, ranging from ideas, research, development, productisation and manufacturing to commercialisation, should be used to its full potential in a coordinated manner." More broadly, the idea usually refers to an economy that makes use of natural, renewable inputs, often stemming from agricultural sources. The bio-economy strategy updates the 2001 biotechnology strategy, which did not make explicit mention of bioplastics or biocomposites, but rather made recommendations on the institutional structure underpinning research

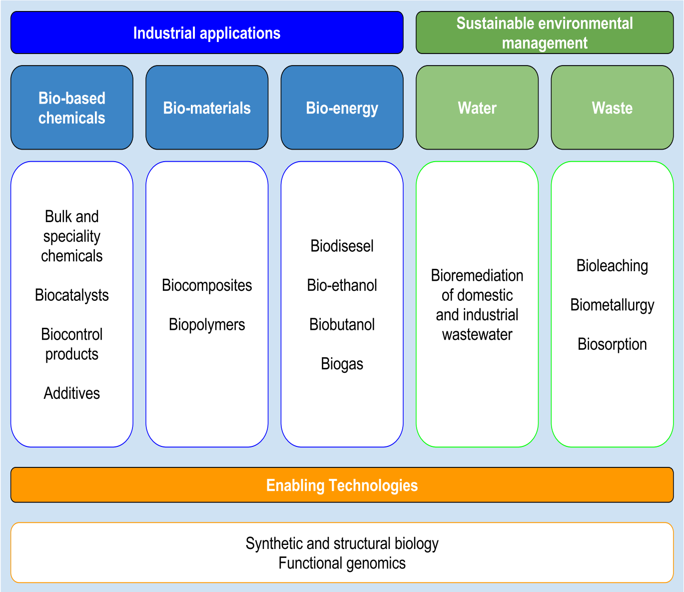


Figure 35: Thematic focus areas in the Bio-economy Strategy (DST, 2013)

and development, in particular promoting the creation of a number of regional innovation centres (DST, 2001). Secondly, the National Advanced Manufacturing Technology Strategy sketches the research underpinnings of efforts to promote advanced manufacturing industries (DST, 2005). While biocomposites are not mentioned in detail, the report identified promotion of an Advanced Materials Network, which includes biomaterials, as a part of the strategy.

4.4.5.3 Bio-Materials Work

Activities on bio-materials are led by the Council for Scientific and Industrial Research (CSIR), which has a history of work in the biocomposite space dating back to at least the 1990s. The CSIR's capacity in the sector was expanded with the creation of a Biocomposites Centre of Competence in Port Elizabeth in 2011 (CSIR, 2012). The 4,300m^2 facility has been driven by R10.8-million ($1.49 million at 2011 rates) invested by the Department of Science and Technology, and aims to create biocomposites 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, 2012). The centre lists partnerships and initiatives with a range of industry clients, as can be seen in Table 23.

The CSIR centre's location is part of a broader attempt to create a dti-supported biocomposite cluster in Port Elizabeth, known as the Mandela Bay Composites Cluster (MBCC). The MBCC bills itself as a partnership between the private sector, government and academia, and aims to "establish a composites eco-system in which R&D, skills development and industrialisation efforts are coordinated to activate and strengthen value chains" (MBCC, 2016). The MBCC aims to promote composites broadly, with biocomposites only a part of the plan. This dual focus is true for the industry more widely, with the relevant industry body for biocomposites, Composites SA (formerly the Polymeric Composites Institute of South Africa), representing both traditional and biocomposite manufactures (Booysens, 2013). There is a substantial overlap between Composites SA and the MBCC, with the president of the former serving as Executive Director of the latter. An international industry group, the Roundtable on Sustainable Biomaterials, has a small presence in the country, but primarily focuses on the biofuels sector.

Table 23: CSIR's Biocomposites Centre of Competence partnerships (Anandjiwala, 2012)

Client and partnerships	Initiatives
Airbus	Interior panels for airplanes
BIRN	International Biocomposites Network
Bombardier	Interior panels for train carriages
Chemcity	Biocomposites for construction industry
De Gama, Frame, Brits Textiles	Natural fibre composites
Experico	Packaging
IDC	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

Research efforts underpin these programmes and groups, which are vital in a field that relies on improving technology and gaining access to intellectual property. Initiatives outside of the CSIR tend to be clustered into universities, which include: The Plant Protein Biopolymers and Biomaterials research group at the University of Pretoria, the Composites Research Group (CRG) at the Durban University of Technology, the Materials Engineering team at the University of Stellenbosch, the Centre for Nanomaterials Science Research at the University of Johannesburg, as well as a range of other projects. Table 24 lists partnerships for the various research projects.

While these research initiatives are encouraging, care needs to be taken in assuring that state investment in research and development feeds through to industry. South Africa has a bad record of successful investment in promising technologies

Table 24: Main biocomposite research projects and partnerships in South Africa (Authors' composition)

Project	Institution	Local Partnerships
Biocomposites 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, National Research Foundation, CSIR, Kentron, Toyota, Sasol, UEC
Materials Engineering team	University of Stellenbosch	Roundtable for Sustainable Biomaterials
Centre for Nanomaterials Science Research	University of Johannesburg	South African Chemical Institute, the Water Institute of Southern Africa, the South African Nanotechnology Initiative, Mintek
Biocomposites – Natural Fibre Research	Nelson Mandela Metropolitan University	CSIR

that nevertheless do not reach marketability. This has been witnessed in green technology, with innovations like thin-film solar panels or the Joule electric car, though the problem is found across the research and development space. One biocomposite researcher interviewed for this research indicated that even when they had a proven technology and registered patents, there was inadequate support in getting the innovation to market, as the research team felt they did not have the skills or knowledge needed to complete this step themselves. With biocomposites still at an early stage of development, it is difficult to gauge the extent to which the aforementioned research initiatives will overcome this marketability hurdle.

4.4.5.4 Production Complementaries

The rollout of bioplastics does not actually involve the creation of a radically new product, but rather the change in the production process of a well-established plastics industry (with the same being true of other industries, like cement). A large car panel manufacturer would not change their final product in the face of biocomposites, but could alter the basic inputs that go into producing that panel. Such a process requires some level of adaption by both the final product fabricator and the manufacturer of the polymers and plastics, but does not substantially change the industry. With the plastics industry already established and competitive in the country, the government has ample capacity to partner with and develop the existing manufacturing capability.

The private sector can be divided into three groups. The first group is made up of global multinational plastics and chemicals companies, such as Dupont, which have a wide range of products on offer, of which biopolymers are one such product. Local polymer and plastics manufacturers form the second group. They are less likely to have biocomposites as part of their range of product offerings, although some do (such as KAP Manufacturing's production of BioPET). Thirdly and finally are a handful of small, specialised firms, focusing on specific biocomposite products. Xyris Technology, for example, is a small firm founded by an ex-CSIR researcher, which produces bioplastics from starch. A non-exhaustive list of firms can be found in Table 25.

The presence of firms with high capacity is positive for efforts to promote biocomposites, but each group has its drawbacks. Most of the large multinational firms do not produce locally. The South African firms do produce many of their products locally, though there is often a mix of locally produced and internationally sourced product offerings. It is not clear whether these firms possess their own intellectual property and engage in their own manufacturing activities, or whether they are simply agents for more established manufacturers. Access to intellectual property, which larger multinational firms usually own, is difficult for many smaller South African firms. When firms have their own

Table 25: Select local plastics and bioplastics firms (Authors' composition, adapted from Young, 2015 and from firm product catalogues)

Company Name	Location	Origin	Biocomposite Products
BASF Holdings South Africa	Gauteng	Germany	Biodegradable plastics ecoflex and ecovio
Bayer (Covestro)	Gauteng	Germany	Polylactic acid used in the creation of bio-based polycarbonate blend resins. Also use of post-consumer recyclates as feedstock.
Chem Systems	Gauteng	South Africa	-
Chemfit	Gauteng	South Africa	-
Chemgrit	Gauteng	South Africa	-
KAP Industrial	Western Cape	South Africa	Biopet made from renewable sugarcane resources
Karbochem	Gauteng	South Africa	-
Lake International Technologies	Gauteng	South Africa	-
Lanxess	Gauteng	Germany	-
Masterbatch South Africa	Gauteng	South Africa	-
NCS Resins	KwaZulu-Natal	South Africa	-
Plastichem	Gauteng	South Africa	Distributor. supplies Bayer (Covestro) composites
Rocbolt Technologies	Gauteng	South Africa	
Safripol	Gauteng	South Africa	Subsidiary of KAP Industrial
Sasol	Gauteng	South Africa	
Bodotex Composites	Eastern Cape	Denmark	BALSA Core, Jute, Flax, Epoxy, and others
Xanita Africa	Western Cape	Sweden	Paper composites
Xyris Technology	Gauteng	South Africa	Maize starch bioplastics

Note: Details on biocomposite products are based on available public information, and may not fully reflect the products on offer by the firm.

intellectual property, it is often specialised, which may not be the most competitive, and furthermore may not be enough to form a sustainable business model without additional activities in other areas. Research on sorghum, for example, has extensive intellectual property development, but remains a less advanced source of biocomposites. Given the highly fragmented product offering and the diverse range of firms working in the space, more information on the biocomposite industry is needed.

Despite the presence of some biocomposite manufacturers, most domestic activity is not predicted to play an increasingly significant role in the coming years and decades. Much local production is focused on mass-produced composites, notably in the packaging sector (such as water bottles and food containers), but with little presence in more advanced fabricated goods like panelling for airplanes or automotives. These applications remain in the early stages, with some

The presence of a strong industry creates a useful partner for the development of biocomposites. However, it also means the job creation potential of biocomposites is likely to be much smaller than truly disruptive new industries like solar panels. This is not to say that biocomposites is a smaller industry, but rather that it would directly displace existing technologies rather than create a new market. Bioplastics are not likely to change the demand for water bottles or car panels. There could still be a job creation effect, but it would work through improving the competitiveness of existing industry, allowing the industry to benefit from environmentally-conscious buyers, and positioning the industry favourably for a shift from petroleum-based plastics to bioplastics. As a result, the sector needs to be approached as a case of industrial upgrading for the plastics industry, demanding a high level of partnership.

4.4.6. RECOMMENDATIONS

While the emerging biocomposites sector offers a great deal of potential, developments within the industry need to be constantly considered against the strength of the established technologies they seek to replace. In the case of plastics, the industry has decades of experience and research, which has resulted in high quality, low-cost products. The industry is highly concentrated, subject to numerous stringent safety and quality standards, and often interlinked with a range of other functions (particularly the processing of by-products from refinery processes). While biocomposites will be one of many technologies plastics manufacturers use, this will be a slow process of gradual development. A commitment by the South African government to invest in biocomposites would need to be one with a long-time horizon, considered over decades rather than years. Uncertainty or instability in that commitment would undermine this long-run process. If the country opts to take on such a long-term commitment, four core issues would need to be addressed.

Firstly, partnerships and coordination mechanisms would have to be effectively developed. Biocomposites remain a fragmented set of only tangentially-related technologies and processes, and are not suitable for concentrated industrial policy interventions in their current state. Basic knowledge of the industry and the technologies available (and their intellectual property) is not presently available. While efforts to build coordinating research bodies (such as the CSIR centre) and industry groups (Composites SA) are encouraging, more would need to be done. The creation of a biocomposites industry group or the building of capacity for biocomposites representation in existing industry groups would go a long way to closing this gap. As a matter of priority, large plastics and chemicals companies should be included in such partnerships, regardless of their present biocomposite manufacturing capacity. These firms are best placed to establish competitive biocomposite processes and, as a corollary, to derail long-term efforts to change production processes. Bringing them in early would help offset this risk.

Secondly, bundling in biocomposites with the broader bio-economy strategy would bring economies to the scale necessary to create a steady supply of inputs. Currently, the supply chain of inputs to the biocomposites sector is not developed enough to roll out large-scale industrial manufacturing. While there are avenues with high potential for sourcing waste products, notably sugar bagasse, the technology for developing biocomposites from waste is less advanced than that for primary agricultural products. The supply chain for those products is not well developed, with established demand patterns difficult to break or involving risk of deepening food insecurity. Biocomposites alone are unlikely to be large enough in the near term to create their own supply of inputs, stifling their development. As such, any efforts to improve the biocomposites supply chain would need to be bundled in with a package of other bio-products that have the scale to drive the supply of feedstock. Core among these are inclusive of biofuels. While the development of biofuels would drastically help the growth of biocomposites, clarity on the issue is a priority. On the one hand, if bioethanol production is no longer being actively supported, this must be made clear. On the other hand, if biofuels remain a priority, it needs a guarantee of support that is credible even in periods of low petroleum costs. Either way, the supply chain for biocomposites urgently needs certainty on the future of bioethanol.

Thirdly, the government should support research and improve the alignment of biocomposites with domestic competitiveness. While some biocomposite technologies are currently viable and in production, many others remain underdeveloped. Given that foreign firms own the established technologies, the biocomposite strategy needs to urgently decide on its approach to support research. Either the strategy would need to abandon hope for locally-developed intellectual property, and concentrate on building a competitive enough supply chain to attract investment by foreign firms, or it would need to provide substantial long-term funding to select research projects. This research support would need to be stable over the long term, and be committed to developing both the science and marketability of a given technology. It would also need to align with the areas in which South Africa remains competitive. Biocomposites for textile manufacturing, for example, would rely on an industry that traditionally struggles, whereas biocomposites for polymers could feed into automotive panelling, building off a strong local industry. Greater focus, while maintaining the flexibility to adapt to a rapidly changing technology, will be needed.

Finally, a number of supporting regulations and standards would need to be adapted and adjusted to the new reality of biocomposites. While many biocomposites can be treated in the same way as general plastics polymers, many others have different physical properties that are atypical for plastics, or which would require wording changes in existing standards and regulation. While general test measures, like brittleness or heat resistance, must be applied universally, specific mentions of petroleum-derived plastics would need to be removed or clarified from relevant standards.

5. CONCLUSIONS

The global transition to a pathway of sustainable development, including through the transition to low-carbon, climate-resilient economies, is already a major driver of trade and industrial development worldwide. Trade in green goods, however defined, has been growing rapidly, primarily supported by the exponential rollout of renewable energy technologies, as illustrated in Section 3. Demand for sustainable substitutes of environmentally-harmful products, as shown in the cases of the biogas-to-transport value chain and biocomposite materials, is also increasing, and could tap into multibillion-dollar industries (such as oil and gas, petrochemicals and building materials). New, disruptive technologies and processes are progressively emerging in other fields, such as water management (conservation) and water treatment, and are experiencing rising global demand.

South Africa follows a similar pattern, with the development of utility-scale renewable energy technologies at the core of the country's sustainability transition. Other areas, such as resource efficiency, sustainable transport, improved waste and water management and the hydrogen economy, also appear as prominent forces in South Africa's shift to a green economy.

Despite these advances, and noteworthy support from the South African government, domestic industrial capacity remains limited. South African industries have not meaningfully tapped into the opportunities arising from the global transition. The nascent stage of the local market (coupled with its small size) appears as a key barrier. Indeed, domestic markets for green technologies are either in early stages (such as for vehicular biogas) or beset by unsettling uncertainty (as in the case of renewable energy). Developing export capacity remains challenging, notably due to the numerous NTBs (such as local content requirements) implemented by major markets, as well as South Africa. Facing these challenges without a strong local market is extremely difficult, and laying the foundation for the growth of local markets for green products, technologies and services is paramount.

In addition, while the country displays significant innovation, as demonstrated by the steady pattern of green patent registrations, the frequent failure to commercialize them into market-ready products remains a hurdle. Nevertheless, pockets of excellence and industrial capacity exist. This is the case in the manufacturing of solar-related components such as smart meters and water-related technologies, as well as the production of biogas and biocomposite materials, as discussed in Section 4. A mix of research capacity, based at universities and research centres, innovation by large groups and market leaders (both South African and foreign) and the rise of innovative, niche-product start-ups form a valuable platform on which to build.

An enabling environment could develop substantial local demand to build upon and further develop the industry. An adequate regulatory framework for the rollout of SSEG would provide a springboard for manufacturing solar components in the country. The same applies to water-related technologies, with the urgency of addressing South Africa's water management and use issues. Coupled with a state-led conversion programme, policy support for the development of the biogas-to-transport value chain could bring massive benefits to the country, displacing the demand for fossil fuels. Global demand for biocomposite materials is rising fast, spurred by commitments from various national governments and international conglomerates. South African innovators and entrepreneurs would require strong and immediate support from local authorities to develop competitive products and services, and tap into this dynamic market.

Ultimately, the opportunity to develop green industries and trade-related opportunities in South Africa, both for import substitution and export purposes, is tangible, as illustrated by the case studies in Section 4. Ensuring that these opportunities materialize and translate into local economic development will, however, entail substantial support from the South African government and active collaboration between public and private entities.

From a trade and industrial policy perspective, the growth of water technology manufacturing appears to be the most favourable opportunity for the country in the short term, out of the options explored. In the medium to long run, the establishment of local expertise and capabilities in biocomposites emerges as a key opportunity, provided that the state and private sector make long-term commitments. By contrast, developing the biogas-to-transport value chain and manufacturing embedded generation technologies are less an industrial policy problem, and more a case of unlocking demand (through state procurement and enabling regulatory frameworks). Opportunities should be explored where possible as the nascent and rapidly changing nature of the market for green goods warrants actively pursuing multiple markets.

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ANNEXURE

Table 26: Comparison of selected lists of green goods (Authors' composition, based on APEC, 2012; Sugathan, 2013; World Bank, 2007)

HS Code	Group	Item	OECD	APEC	WB
220710	Renewable Energy: Other	Ethanol	X		
252100	Pollution management: Chemical recovery systems	Limestone flux	X		
252100	Wastewater management: Chemical recovery systems	Limestone flux	X		
252220	Pollution Management: Chemical recovery systems	Slaked (hydrated) lime	X		
252220	Wastewater management: Chemical recovery systems	Slaked (hydrated) lime	X		
280110	Wastewater management: Water purification systems	Chlorine	X		
280110	Water Supply: Water purification systems	Chlorine	X		
281410	Wastewater management: Chemical recovery systems	Anhydrous ammonia	X		
281511	Wastewater management: Chemical recovery systems	Sodium hydroxide solid	X		
281512	Wastewater management: Chemical recovery systems	Sodium hydroxide in aqueous solution	X		
281610	Pollution Management: Chemical recovery systems	Magnesium hydroxide and peroxide	X		
281610	Wastewater management: Chemical recovery systems	Magnesium hydroxide and peroxide	X		
281830	Wastewater management: Chemical recovery systems	Aluminium hydroxide	X		
282010	Wastewater management: Chemical recovery systems	Manganese dioxide	X		
282090	Wastewater management: Chemical recovery systems	Manganese oxides (other)	X		
282410	Wastewater management: Chemical recovery systems	Lead monoxide	X		
283210	Wastewater management: Chemical recovery systems	Sodium sulphites	X		
283220	Wastewater management: Chemical recovery systems	Other sulphites	X		
283510	Wastewater management: Chemical recovery systems	Phosphinates and phosphonates	X		
283522	Wastewater management: Chemical recovery systems	Phosphates of monosodium or disodium	X		

HS Code	Group	Item	OECD	APEC	WB
283523	Wastewater management: Chemical recovery systems	Phosphates of trisodium	X		
283524	Wastewater management: Chemical recovery systems	Phosphates of potassium	X		
283525	Wastewater management: Chemical recovery systems	Calcium hydrogenorthophosphate	X		
283526	Wastewater management: Chemical recovery systems	Other phosphates of calcium	X		
283529	Wastewater management: Chemical recovery systems	Other phosphates (excl. polyphosphates)	X		
284700	Cleaner Technologies and Products: Cleaner/resource-efficient products	Hydrogen peroxide	X		
285100	Water Supply: Potable water supply and distribution	Distilled and conductivity water	X		
290511	Renewable Energy: Other	Methanol	X		
320910	Cleaner Technologies and Products: Cleaner/resource-efficient products	Paints and varnishes, in aqueous medium, acrylic or vinyl	X		
320990	Cleaner Technologies and Products: Cleaner/resource-efficient products	Other paints and varnishes, in aqueous medium	X		
380210	Wastewater management: Chemical recovery systems	Activated carbon	X		
391400	Water Supply: Potable water supply and distribution	Ion exchangers (polymer)	X		
392010	Solid waste management: Waste disposal equipment	PVC or polyethylene plastic membrane systems to provide an impermeable base for landfill sites and protect soil under gas stations, oil refineries, etc. from infiltration by pollutants and for reinforcement of soil			X
392020	Solid waste management: Waste disposal equipment	Polypropylene sheeting, etc.	X		
392490	Solid waste management: Waste collection equipment	Household & toilet articles of plastic	X		
392690	Wastewater management: Screens/ strainers	Other articles of plastics and articles of other materials of HS 3901 to 3914; other	X		
441872	Cleaner Technologies and Products: Cleaner/resource-efficient products	Flooring panels, multilayer, assembled, of wood (excl. for mosaic floors)		X	
560314	Wastewater management: Screens/ strainers	Non-wovens, whether or not impregnated, coated, covered or laminated: of man-made filaments; weighing more than 150g/m^2			X

HS Code	Group	Item	OECD	APEC	WB
580190	Wastewater management: Sewage treatment	Woven pile & chenille fabrics of other textile materials	X		
681099	Solid waste management: Hazardous waste storage and treatment equipment	Other articles of cement, concrete	X		
700800	Heat/energy savings and management:	Multiple-walled insulating units of glass	X		
701931	Heat/energy savings and management: Separators/ precipitators	Thin sheets (voiles), webs, mats, mattresses, boards, and similar nonwoven products			X
701931	Pollution management: Separators/ precipitators	Thin sheets (voiles), webs, mats, mattresses, boards, and similar nonwoven products			X
701990	Heat/energy savings and management: Separators/ precipitators	Other glass fibre products	X		
701990	Pollution management: Separators/ precipitators	Other glass fibre products	X		
730820	Renewable Energy: Wind energy	Towers and lattice masts for wind turbine			X
730900	Wastewater management: Sewage treatment	Tanks, vats, etc., > 300 litres	X		X
731010	Wastewater management: Sewage treatment	Tanks, drums, etc., >50 litres <300 litres	X		
731021	Wastewater management: Sewage treatment	Cans < 50 litres, closed by soldering or crimping	X		
731029	Wastewater management: Sewage treatment	Other cans < 50 litres	X		
732510	Wastewater management: Water handling goods and equipment	Articles of cast iron	X		
780600	Solid waste management: Hazardous waste storage and treatment equipment	Other articles of lead	X		
840219	Renewable Energy: Biomass boilers	Vapour generating boilers, not elsewhere specified or included hybrid			X
840290	Renewable Energy: Biomass boilers	Parts of vapour generating boilers and superheated water boilers		X	X
840410	Pollution Management: Air pollution control	Auxiliary plant for use with boilers of HS 8402 or 8403 (for example, economisers, super-heaters, soot removers, gas recoverers)		X	X

HS Code	Group	Item	OECD	APEC	WB
840420	Heat/energy savings and management:	Condensers for steam or other vapour power units		X	
840490	Pollution Management: Air pollution control	Parts of auxiliary plant of heading 8402 or 8403 and condensers for steam or other vapour power		X	X
840510	Pollution Management: Air pollution control	Producer gas or water gas generators, with or without their purifiers; acetylene gas generators and similar water process gas generators, with or without their purifiers			X
840681	Renewable Energy:	Turbines, steam and other vapour, over 40 MW, not elsewhere specified or included			X
840690	Renewable Energy: Geothermal energy	Parts of steam and other vapour turbines		X	
840991	Noise and vibration abatement: Mufflers/silencers	Parts suitable for use solely or principally with the engines of HS 8407 or 8408; suitable for use solely or principally with spark ignition internal combustion piston engines	X		
841011	Wastewater management: Sewage treatment	Hydraulic turbines 11	X		X
841012	Wastewater management: Sewage treatment	Hydraulic turbines 12	X		
841013	Wastewater management: Sewage treatment	Hydraulic turbines 13	X		
841090	Wastewater management: Sewage treatment	Parts for hydraulic turbines	X		X
841181	Renewable Energy:	Turbines, steam and other vapour, over 40 MW, not elsewhere specified or included			X
841182	Renewable Energy: Gas generation	Gas turbines of a power > 5.000 kW (excl. turbojets and turbopropellers)		X	X
841199	Renewable Energy: Gas generation	Parts of gas turbines		X	
841290	Renewable Energy: Gas generation	Parts of non-electrical engines and motors		X	
841320	Wastewater management: Water handling goods and equipment	Root-control equipment	X		
841350	Wastewater management: Water handling goods and equipment	Positive displacement pumps, hand-operated [centrifugal pumps]	X		

HS Code	Group	Item	OECD	APEC	WB
841360	Wastewater management: Water handling goods and equipment	Pumps for liquids, whether or not fitted with a measuring device; other rotary positive displacement pumps	X		
841370	Wastewater management: Water handling goods and equipment	Pumps for liquids, whether or not fitted with a measuring device; other centrifugal pumps	X		
841381	Renewable Energy: Water handling goods and equipment/Wind energy		X		
841381	Wastewater management: Water handling goods and equipment/Wind energy		X		
841410	Environmental monitoring, analysis and assessment: Air-handling equipment/Measuring and monitoring equipment	Vacuum pumps	X		
841410	Pollution Management: Air-handling equipment/ Measuring and monitoring equipment	Vacuum pumps	X		
841430	Pollution Management: Aeration systems/ Air-handling equipment	Compressors of a kind used in refrigerating equipment	X		
841430	Wastewater management: Aeration systems/ Air-handling equipment	Compressors of a kind used in refrigerating equipment	X		
841440	Pollution Management: Aeration systems/ Air-handling equipment	Air compressors mounted on a wheeled chassis for towing	X		
841440	Wastewater management: Aeration systems/Air-handling equipment	Air compressors mounted on a wheeled chassis for towing	X		
841459	Pollution Management: Air-handling equipment	Fans (and blowers) other than table, floor, window, ceiling or roof fans with a self-contained electric motor of an output not exceeding 125 W			
841480	Environmental monitoring, analysis and assessment: Air-handling equipment/ Aeration systems/ Measuring and monitoring equipment	Other air or gas compressors or hoods	X		
841480	Pollution Management: Air-handling equipment/ Aeration systems/ Measuring and monitoring equipment	Other air or gas compressors or hoods	X		
841480	Wastewater management: Air-handling equipment/Aeration systems/Measuring and monitoring equipment	Other air or gas compressors or hoods	X		
841490	Pollution Management: Air-handling equipment/Aeration systems	Parts for air or gas compressors, fans or hoods	X		

HS Code	Group	Item	OECD	APEC	WB
841490	Wastewater management: Air-handling equipment/Aeration systems	Parts for air or gas compressors, fans or hoods	X		
841581	Pollution Management: Air-handling equipment/Aeration systems	Compression type refrigerating, freezing equipment incorporating a valve for reversal of cooling/heating cycles (reverse heat pumps)			X
841581	Wastewater management: Air-handling equipment/Aeration systems	Compression type refrigerating, freezing equipment incorporating a valve for reversal of cooling/heating cycles (reverse heat pumps)			X
841780	Pollution Management: Incineration equipment/Incinerators, scrubbers/ Sewage treatment	Industrial or laboratory furnaces and ovens, including incinerators, non-electric; other than bakery ovens and furnaces for treatment of ores	X	X	
841780	Solid waste management: Incineration equipment/Incinerators, scrubbers/Sewage treatment	Industrial or laboratory furnaces and ovens, including incinerators, non-electric; other than bakery ovens and furnaces for treatment of ores	X	X	
841780	Wastewater management: Incineration equipment/Incinerators, scrubbers/Sewage treatment	Industrial or laboratory furnaces and ovens, including incinerators, non-electric; other than bakery ovens and furnaces for treatment of ores	X	X	
841790	Solid waste management: Incineration equipment	Parts of Industrial or laboratory furnaces and ovens, including incinerators, non-electric	X	X	
841861	Pollution Management: Air-handling equipment/Aeration systems	Compression type refrigerating, freezing equipment incorporating a valve for reversal of cooling/heating cycles (reverse heat pumps)			X
841861	Wastewater management: Air-handling equipment/Aeration systems	Compression type refrigerating, freezing equipment incorporating a valve for reversal of cooling/heating cycles (reverse heat pumps)			X
841869	Pollution Management: Air-handling equipment/Aeration systems	Compression type refrigerating, freezing equipment incorporating a valve for reversal of cooling/heating cycles (reverse heat pumps)			X
841869	Wastewater management: Air-handling equipment/Aeration systems	Compression type refrigerating, freezing equipment incorporating a valve for reversal of cooling/heating cycles (reverse heat pumps)			X

HS Code	Group	Item	OECD	APEC	WB
841911	Renewable Energy: Solar energy	Instantaneous gas water heaters	X		
841919	Renewable Energy: Solar energy	Other instantaneous or storage water heaters, nonelectric	X	X	X
841940	Environmental monitoring, analysis and assessment: Measuring and monitoring equipment	Distilling or rectifying plant			X
841950	Heat/energy savings and management:	Heat exchange units	X		X
841960	Pollution Management: Separators/ precipitators/	Machinery for liquefying air or other gases	X	X	
	Measuring and monitoring equipment				
841989	Pollution Management: Separators/ precipitators	Other machinery for treatment of materials by change of temperature	X	X	X
841990	Heat/energy savings and management:	Parts for heat exchange equipment	X	X	X
842119	Environmental monitoring, analysis and assessment: Oil/water separation systems/Measuring and monitoring equipment	Other centrifuges	X		
842119	Wastewater management: Oil/water separation systems/Measuring and monitoring equipment	Other centrifuges	X		
842121	Wastewater management: Screens/ Strainers/ Chemical recovery systems/ Oil/ Water separation systems	Filtering or purifying machinery and apparatus for liquids: for filtering or purifying water	X	X	
842129	Wastewater management: Screens/ Strainers/ Chemical recovery systems/ Oil/ Water separation systems	Filtering or purifying machinery and apparatus for liquids; other	X	X	
842139	Pollution Management: Catalytic converters/Chemical recovery systems/Dust Collectors/ Incinerators, scrubbers	Filtering or purifying machinery and apparatus for gases	X	X	
842191	Environmental monitoring, analysis and assessment: Oil/water separation systems/Measuring and monitoring equipment	Parts of centrifuges	X		
842191	Wastewater management: Oil/water separation systems/Measuring and monitoring equipment	Parts of centrifuges	X		

HS Code	Group	Item	OECD	APEC	WB
842199	Pollution Management: Incinerators, scrubbers/ Catalytic converters/ Chemical recovery systems/ Dust Collectors/ Separators/ Precipitators/ Chemical recovery systems/ Oil/ Water separation systems/ Screens/ Strainers	Parts of filtering or purifying machinery and apparatus for liquids or gases	X	X	
842199	Wastewater management: Incinerators, scrubbers/ Catalytic converters/ Chemical recovery systems/ Dust Collectors/ Separators/ Precipitators/ Chemical recovery systems/ Oil/ Water separation systems/ Screens/ Strainers	Parts of filtering or purifying machinery and apparatus for liquids or gases	X	X	
842220	Solid waste management: Recycling equipment	Machinery for cleaning or drying bottles or other containers	X		
842381	Wastewater management: Sewage treatment	Weighing machines capacity <30 kg	X		
842382	Wastewater management: Sewage treatment	Weighing machines capacity >30 kg <500 kg	X		
842389	Wastewater management: Sewage treatment	Weighing machines	X		
842490	Pollution Management: Odour control equipment/Sewage treatment	Parts for sprayers for powders or liquids	X		
842490	Wastewater management: Odour control equipment/Sewage treatment	Parts for sprayers for powders or liquids	X		
847420	Solid waste management: Recycling equipment	Crushing or grinding machines for solid mineral substances		X	
847439	Solid waste management: Recycling equipment	Other mixing or kneading machines for earth, stone, sand, etc.	X		
847982	Wastewater management: Sewage treatment	Mixing, kneading, crushing, grinding, screening, sifting, homogenising, emulsifying or stirring		X	
847989	Solid waste management: Recycling equipment/Waste disposal equipment	Machines and mechanical appliances having individual functions, not elsewhere specified or included in this chapter, other	X	X	

HS Code	Group	Item	OECD	APEC	WB
847990	Solid waste management: Waste disposal equipment	Parts of machines and mechanical appliances having individual functions, not elsewhere specified or included in this chapter, other		X	
848110	Wastewater management: Water handling goods and equipment	Valves, pressure-reducing	X		
848130	Wastewater management: Water handling goods and equipment	Valves, check	X		
848140	Wastewater management: Water handling goods and equipment	Valves, safety	X		
848180	Wastewater management: Water handling goods and equipment	Other taps, cocks, valves, etc.	X		
848340	Renewable Energy: Wind energy	Gears and gearing and other speed changers (specifically for wind turbines)			X
848360	Renewable Energy: Wind energy	Clutches and universal joints (specifically for wind turbines)			X
850161	Renewable Energy: Parts	AC generators not exceeding 75 kVA (specifically for all electricity generating renewable energy plants)			X
850162	Renewable Energy: Parts	AC generators exceeding 75 kVA but not 375 kVA (specifically for all electricity generating renewable energy plants)			X
850163	Renewable Energy: Parts	AC generators not exceeding 375 kVA but not 750 kVA (specifically for all electricity generating renewable energy plants)			X
850164	Renewable Energy: Parts	AC generators exceeding 750 kVA (specifically for all electricity generating renewable energy plants)			X
850231	Renewable Energy: Wind energy	Generating sets, electric, wind-powered		X	X
850239	Renewable Energy: Parts	Generating sets (excl. wind-powered and powered by spark-ignition internal combustion piston . . .		X	
850300	Renewable Energy: Parts	Parts suitable for use solely or principally with electric motors and generators, electric . . .		X	
850590	Solid waste management: Waste separation equipment	Electromagnets; other, including parts		X	

HS Code	Group	Item	OECD	APEC	WB
850680	Renewable Energy: Fuel Cells	Fuel cells using hydrogen or hydrogen-containing fuels such as methane to produce an electric current, through a electrochemical process rather than combustion			X
850720	Renewable Energy: Fuel Cells	Other lead acid accumulators			X
851410	Pollution Management: Incineration equipment/Incinerators, scrubbers/ Sewage treatment	Industrial or laboratory furnaces and ovens; electric, resistance heated	X	X	
851410	Solid waste management: Incineration equipment/Incinerators, scrubbers/Sewage treatment	Industrial or laboratory furnaces and ovens; electric, resistance heated	X	X	
851410	Wastewater management: Incineration equipment/Incinerators, scrubbers/Sewage treatment	Industrial or laboratory furnaces and ovens; electric, resistance heated	X	X	
851420	Pollution Management: Incineration equipment/Incinerators, scrubbers/ Sewage treatment	Industrial or laboratory furnaces and ovens; electric, induction or dielectric	X	X	
851420	Solid waste management: Incineration equipment/Incinerators, scrubbers/Sewage treatment	Industrial or laboratory furnaces and ovens; electric, induction or dielectric	X	X	
851420	Wastewater management: Incineration equipment/Incinerators, scrubbers/Sewage treatment	Industrial or laboratory furnaces and ovens; electric, induction or dielectric	X	X	
851430	Pollution Management: Incineration equipment/Incinerators, scrubbers/ Sewage treatment	Industrial or laboratory furnaces and ovens, electric, other	X	X	
851430	Solid waste management: Incineration equipment/Incinerators, scrubbers/Sewage treatment	Industrial or laboratory furnaces and ovens, electric, other	X	X	
851430	Wastewater management: Incineration equipment/Incinerators, scrubbers/Sewage treatment	Industrial or laboratory furnaces and ovens, electric, other	X	X	
851490	Solid waste management: Incineration equipment/Sewage treatment	Parts of industrial or laboratory electric furnaces and ovens or other laboratory induction or dielectric heating equipment	X	X	
851490	Wastewater management: Incineration equipment/Sewage treatment	Parts of industrial or laboratory electric furnaces and ovens or other laboratory induction or dielectric heating equipment	X	X	
851629	Remediation and clean-up: Hazardous waste storage and treatment equipment/Clean-up	Other electric space heating and soil heating apparatus	X		

HS Code	Group	Item	OECD	APEC	WB
851629	Solid waste management: Hazardous waste storage and treatment equipment/Clean-up	Other electric space heating and soil heating apparatus	X		
853710	Renewable Energy: Solar energy	Photovoltaic system controller			X
853931	Heat/energy savings and management:	Fluorescent lamps, hot cathode	X		
854140	Renewable Energy: Solar energy	Photosensitive semiconductor devices, including photovoltaic cells whether or not assembled in modules or made up into panels; light-emitting diodes	X	X	X
854389	Remediation and clean-up: Waste treatment equipment/Aeration systems/Water purification systems	Other electrical machines and apparatus with one function	X		
854389	Wastewater management: Waste treatment equipment/Aeration systems/Water purification systems	Other electrical machines and apparatus with one function	X		
854389	Water Supply: Waste treatment equipment/Aeration systems/Water purification systems	Other electrical machines and apparatus with one function	X		
854390	Remediation and clean-up: Waste treatment equipment/Aeration systems/Water purification systems	Parts of electrical machines and apparatus, having individual functions		X	
854390	Wastewater management: Waste treatment equipment/Aeration systems/Water purification systems	Parts of electrical machines and apparatus, having individual functions		X	
854390	Water Supply: Waste treatment equipment/Aeration systems/Water purification systems	Parts of electrical machines and apparatus, having individual functions		X	
900190	Renewable Energy: Solar energy	Mirrors of other than glass (specifically for solar concentrator systems)			X
901320	Remediation and clean-up: Hazardous waste storage and treatment equipment/Clean-up	Lasers	X		
901320	Solid waste management: Hazardous waste storage and treatment equipment/Clean-up	Lasers	X		
901380	Renewable Energy: Solar energy	Liquid crystal devices, and other optical appliances and instruments not elsewhere specified		X	

HS Code	Group	Item	OECD	APEC	WB
901390	Renewable Energy: Solar energy	Parts and accessories for liquid crystal devices "LCD", lasers and other appliances		X	
901580	Environmental monitoring, analysis and assessment: Measuring and monitoring equipment	Other surveying, hydrographic, oceanographic, hydrological, meteorological or geophysical instruments and appliances, excluding compasses		X	
902511	Environmental monitoring, analysis and assessment: Measuring and monitoring equipment	Thermometers and pyrometers, not combined with other instruments: liquid-filled, for direct reading	X		
902519	Environmental monitoring, analysis and assessment: Measuring and monitoring equipment	Thermometers and pyrometers, not combined with other instruments: other than liquid-filled, for direct reading	X		
902580	Environmental monitoring, analysis and assessment: Measuring and monitoring equipment	Hydrometers and similar floating instruments, thermometers, pyrometers, barometers, hygrometers and psychrometers, recording or not, and any combination of these instruments	X		
902610	Environmental monitoring, analysis and assessment: Water handling goods and equipment/Measuring and monitoring equipment	Instruments for measuring the flow or level of liquids	X	X	
902610	Wastewater management: Water handling goods and equipment/ Measuring and monitoring equipment	Instruments for measuring the flow or level of liquids	X	X	
902620	Environmental monitoring, analysis and assessment: Water handling goods and equipment/Measuring and monitoring equipment	Instruments for measuring or checking pressure	X	X	
902620	Wastewater management: Water handling goods and equipment/ Measuring and monitoring equipment	Instruments for measuring or checking pressure	X	X	
902680	Environmental monitoring, analysis and assessment: Measuring and monitoring equipment	Other instruments and apparatus	X	X	
902690	Environmental monitoring, analysis and assessment: Measuring and monitoring equipment	Parts and accessories for articles of HS 9026	X	X	
902710	Environmental monitoring, analysis and assessment: Measuring and monitoring equipment	Gas or smoke analysis apparatus	X	X	

HS Code	Group	Item	OECD	APEC	WB
902720	Environmental monitoring, analysis and assessment: Measuring and monitoring equipment	Chromatographs and electrophoresis instruments	X	X	
902730	Environmental monitoring, analysis and assessment: Measuring and monitoring equipment	Spectrometers, spectrophotometers and spectrographs using optical radiations (ultraviolet, visible, infrared)	X	X	
902740	Environmental monitoring, analysis and assessment: Measuring and monitoring equipment	Exposure meters [including sound-level meters]	X		
902750	Environmental monitoring, analysis and assessment: Measuring and monitoring equipment	Other instruments and apparatus using optical radiations (ultraviolet, visible, infrared)	X	X	
902780	Environmental monitoring, analysis and assessment: Measuring and monitoring equipment	Other instruments and apparatus for physical or chemical analysis	X	X	
902790	Environmental monitoring, analysis and assessment: Measuring and monitoring equipment	Microtomes; parts and accessories	X	X	
902810	Environmental monitoring, analysis and assessment: Measuring and monitoring equipment	Gas supply, production and calibrating meters	X		
902810	Heat/energy savings and management: Measuring and monitoring equipment	Gas supply, production and calibrating meters	X		
902820	Environmental monitoring, analysis and assessment: Measuring and monitoring equipment	Liquid supply, production and calibrating meters	X		
902820	Heat/energy savings and management: Measuring and monitoring equipment	Liquid supply, production and calibrating meters	X		
903010	Environmental monitoring, analysis and assessment: Measuring and monitoring equipment	Instruments and apparatus for measuring or detecting ionising radiations	X		
903130	Environmental monitoring, analysis and assessment: Measuring and monitoring equipment	Other measuring or checking instruments, appliances and machines, not elsewhere specified in this chapter	X		
903149	Environmental monitoring, analysis and assessment: Measuring and monitoring equipment	Other optical instruments	X	X	
903180	Environmental monitoring, analysis and assessment: Measuring and monitoring equipment	Manostats	X	X	
903190	Environmental monitoring, analysis and assessment: Measuring and monitoring equipment	Parts and accessories for instruments, appliances and machines for measuring and checking		X	

HS Code	Group	Item	OECD	APEC	WB
903210	Heat/energy savings and management: Process and control equipment	Thermostats	X		
903220	Environmental monitoring, analysis and assessment: Measuring and monitoring equipment	Manostats			X
903281	Environmental monitoring, analysis and assessment: Measuring and monitoring equipment	Hydraulic and pneumatic instruments and apparatus	X		
903289	Environmental monitoring, analysis and assessment: Measuring and monitoring equipment	Automatic regulating or controlling instruments, other	X	X	
903290	Environmental monitoring, analysis and assessment: Measuring and monitoring equipment	Parts and accessories		X	
903300	Environmental monitoring, analysis and assessment: Measuring and monitoring equipment	Parts and accessories (not specified or included elsewhere in this chapter) for machines, appliances, instruments or apparatus of Ch. 90		X	
960310	Solid waste management: Waste collection equipment	Brooms, hand	X		
960350	Solid waste management: Waste collection equipment	Brushes as parts of machines, appliances	X		
960390	Solid waste management: Waste collection equipment	Mechanical floor sweepers	X		

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PAGE PARTNERSHIP FOR ACTION ON GREEN ECONOMY

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