THE FUTURE OF THE WESTERN CAPE AGRICULTURAL SECTOR IN THE CONTEXT OF THE 4TH INDUSTRIAL REVOLUTION

Review: Waste Management and Recycling

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1. Technology Overview and Detailed Description

Waste can be described as any matter, whether gaseous, liquid or solid, originating from any residential, commercial or industrial area, which is superfluous to requirements and has no further intrinsic or commercial value[1].

In South Africa, the Department of Environmental Affairs defines waste as:
"… any substance, whether or not that substance can be reduced, re-used, recycled or recovered:

- *That is surplus, unwanted, rejected, discarded, abandoned or disposed of*
- *Which the generator has no further use of for the purposes of production*
- *That must be treated or disposed of"*

Table 1 below is a classification of waste streams.

Table 1: Waste stream classification2

Residential	Single-family and multifamily dwellings; low-, medium-, and high-density apartments.	Food wastes, paper, cardboard, plastics, textiles, yard wastes, wood, ashes, street leaves, special wastes (including bulky items, consumer electronics, white goods, universal waste) and household hazardous waste.
Commercial	Stores, restaurants, markets, office buildings, hotels, motels, print shops, service stations, auto repair shops.	Paper, cardboard, plastics, wood, food wastes, glass, metal wastes, ashes, special wastes, hazardous wastes
Institutional	Schools, universities, hospitals, prisons, governmental centres	Same as commercial, plus biomedical
Industrial (non-process wastes)	Construction, fabrication, light and heavy manufacturing, refineries, chemical plants, power plants, demolition	Same as commercial
Municipal Solid waste	All the preceding	All the preceding
Construction and Demolition	New construction sites, road repair, renovation sites, razing of buildings, broken pavement	Wood, steel, concrete, asphalt paving, asphalt roofing, gypsum board, rocks and soils.
Industrial	Construction, fabrication, light and heavy manufacturing, refineries, chemical plants, power plants, demolition	Same as commercial, plus industrial process wastes, scrap materials
Agricultural	Field and row crops, orchards, vineyards, dairies, feedlots, farms	Spoiled food, agricultural waste, hazardous waste

Agricultural waste

Agricultural wastes can be defined as the residues from the growing and first processing of raw agricultural products such as fruits, vegetables, meat, poultry, and crops. This includes natural (organic) and non-natural wastes produced from arming activities such as dairy farming, horticulture, seed growing, livestock breeding, grazing land, market gardens, nursery plots and forestry.

The agricultural waste can come in several forms, such as slurries or sludge, solids, and liquids. Because agricultural and food industry residues and wastes are seasonal care should be taken to dispose of this waste from the environment, or have in place systems to manage the waste from interfering with other environmental and ecological systems. This is because the pollution potential of agricultural waste is high over an extended period, contaminating water (surface and underground) and soil resources with a host of contents, some of which are organic chemicals and pathogens from animal excrement[3].

Agricultural waste has been characterised according to the agricultural activity undertaken, and this is summarised in Table 2 below.

Table 2: Characterisation of agricultural waste according to agricultural activity[4]

Agricultural activity	Wastes
Crop production and harvest	Straw, stover
Fruit and vegetable processing	Biological sludges, trimmings, peels, leaves, stems, soil, seeds and pits
Sugar processing	Biological sludges, pulp, lime mud
Animal production	Blood, bones, feather, litter, manures, liquid effluents
Dairy product processing	Biological sludges
Leather tanning	Fleshings, hair, raw and tanned trimmings, lime and chrome sludge, grease
Rice production	Bran, straw, hull
Coconut production	Stover, cobs, husk, leaves, coco meal

A brief description of all available agricultural waste treatment technologies was published, and these technologies were described according to treatment methodology, final products, cost and environmental impacts. Of the 50 projects described, 5 (olive industry, wine, animal waste, rice and swine industry) were discussed in detail, and will not be detailed here. The reader is referred to this reference[5].

Intellectual property of waste technologies in South Africa

Waste patents registered in South Africa provide an indication of new waste technology trends which may emerge in the future, as companies begin to protect their intellectual property. A review of registered patents (2007-2012) shows that the portfolio is comprised primarily of Waste to Energy technologies ('fuel', 'incineration', 'combustion', 'anaerobic digestion' and 'pyrolysis') and recycling, which is like global trends. Most of these patents (86%) are foreign-owned, suggesting that South Africa may be an opportune destination for the commercialization of waste technologies[6].

2. Application Examples and Case Studies

The global drivers of waste management are increasing population growth and rapid urbanisation, increasing volume and complexity of waste, climate change effects, scarcity of resources, stricter regulations, amongst others. In South Africa however, the drivers are increased legislation, the desire to reduce unemployment and the need to secure energy[7]. As such, illustrative examples of waste management technologies have been selected to illustrate South Africa's initiatives in waste management.

Bio-composite materials development

The agricultural sector is one of the largest contributors to waste in South Africa, threatening surface water and groundwater sources from agroprocessing activities.

Sugarcane bagasse is residual waste from the sugarcane stalks juice extraction process. Historically, bagasse has been used as a biofuel, in the paper and pulp industry, as well as a component of building material. The burning of bagasse fibre was unpopular as it contributed to air pollution. The CSIR has studied the value-added applications of bagasse polymers in automotive, building, and environmental applications[8].

The value-added use of agricultural biomass residues derived from the sugarcane processing industry, namely bagasse and maize stalks were studied for the development of sustainable bio based polymer and bio-composite materials. These materials were investigated for applications in automotive parts, green buildings and green packaging applications[9].

Waste to fuel technology

A process for the development of a fast pyrolysis unit that can convert dry biomass into crude oil in a single reactor was developed by the University of Pretoria, South Africa. By using local agriculture and forestry waste, and converting it to fuel, all (100%) of the national demand for petrol could be met, reducing South Africa's dependence on non-renewable fossil fuel reserves. The advantages of this technology are the following:

1. The char can be recovered and returned to the soil as mineral-rich fertilizer and mulch;
2. The reactor can be scaled up;
3. The design of the reactor allows for conversion of the oil product in a single step to specifications close to those required for transportation fuels.
4. Rural communities and farmers can produce biofuels themselves.
5. The pyrolyser is small and simple enough for portable units to be built and sold or licensed for use by local SMMEs.

Agricultural waste composting

Agricultural waste composting is a method of aerobically digesting the solids portion of cattle, horse and other livestock manure. Manure contains organic matter and nutrients such as nitrogen, phosphorous and potassium, and can be a useful source of fertilizer.

The main objectives of agricultural waste composting are to reduce threats to the environment, for instance the discharge of excessive nutrients, odours and leachate that can lead to groundwater contamination, and to produce a stable material that can be used on the farm or sold to the community.

3. Technology or Application Life Cycle: Current Status and Expected Development in 2020 and 2025

Table 3: Life Cycle

Technology Area	Current application in agriculture	Expected applications in agriculture by 2020	Expected applications in agriculture by 2025
Waste management and recycling	Fuel production, Food processing	Bio composites	Fully integrated circular economy

4. Business Eco-System View

Waste management and recycling overlaps with:

- Bi-refinery
- Renewable energy
- Biorefinery and biofuels

5. Benefits and Risks

Benefits

- The benefits of finished compost include:
  - reduced soil erosion, particularly in areas of exposed soils;
  - increased water retention in the upper soil profile, thus reducing the frequency of watering;
  - release of nutrients for plant growth, reducing the need for fertilizers;
  - suppression of soil borne plant pathogens, reducing the need for fungicides and bactericides[10].
- Opportunities for immediate job creation in the waste sector have been identified in:
  - Open-spaces cleaning (e.g. clearing of illegal dumping sites, street cleaning and sweeping, litter picking)
  - Waste collection
  - Sorting of recyclables
  - Labour intensive activities that require low skills[11]
- Contribution to Gross Domestic Product (GDP), enterprise development (resource beneficiation) and job creation (the estimated employment by the total waste sector in South Africa is 113,505[12]
- Reduced emissions like Greenhouse Gasses, less landfill leachate, land availability for other uses

Risks

The South African Department of Environmental Affairs identified challenges in the waste management sector, and these would be addressed through the National Waste Management Strategy (NWMS). The main challenges (which can also be the socio-economic drivers of waste management) are:[13]

- A growing population and economy, which means increased volumes of waste generated puts pressure on waste management facilities which are already limited in number and capacity;
- Increased complexity of the composition of the waste stream due to urbanization and industrialization results in increased complexity of its management, exacerbated by the introduction of hazardous and general waste mixes;
- A historical backlog of waste services for urban informal areas, tribal areas and rural formal areas due to these services being made readily accessible to affluent and urban communities;
- Poor waste data management (unreliable and contradictory) resulting in limited comprehension of the main waste flows and national waste balance;

- A policy and regulatory environment that does not actively promote the waste management hierarchy;
- Absence of a recycling infrastructure to support waste separation at collection, and buy-back models;
- Ageing waste management infrastructure, and declining quantum of capital investment and maintenance;
- Waste disposal is preferred over other options;
- Few waste treatment options are available to manage waste and therefore more expensive than landfill costs and,
- Too few adequate and compliant landfills and hazardous waste management facilities

The development of policy, legislation, stakeholder facilitation, implementation strategies, facilities/infrastructure, monitoring and evaluation strategies would begin to reverse these challenges. The absence of a coordinated response to these challenges poses a significant risk to the implementation of waste management technologies

6. Potential Economic, Social, Ecological and Political Developments and Impacts

Economic Developments and Impacts

- The minimum financial value of the formal South African waste sector (public and private) was R15.3 billion, or 0.51% of GDP as at 2012, with possible increase to R30 billion[14].
- Materials and energy recovered from waste management creates opportunities for local economic development
- More Public-Private Partnerships between municipalities and private entities are forged to exploit opportunities presented in waste management

Social Developments and Impacts

Composting at the farm level has several advantages, especially for rural communities. These include:

- Maintenance of soil fertility
- Reduction in the the amount of on-farm organic waste that would have been destined for disposal, and thus a reduction in the costs of waste collection (transport and disposal costs)
- The sale of organic waste as a source of cash revenues.

Ecological (Environmental) Developments and Impacts

- Long term environmental impacts of applied waste management technologies are:
  - Reduced generation of waste lifts pressure on land resources available for disposal, and promotes the preservation of biodiversity;
  - The protection of water resources such as rivers and wetlands from waste and pollutants
  - Less pollution of surface and groundwater resources and soil especially at poorly managed waste sites;
  - Less air pollution by dust or windblown litter as well as emissions such as methane gas from landfill sites, and
- A decrease in odours and preservation of biodiversity
- A reduction in the total water loss because of the implementation of waste management technologies - the overall water footprint for agricultural production in South Africa is estimated at 58, 853 million m^3, and the total water loss because of food waste is approximately 12,854 million m^3 (almost 22% of the total water footprint of agricultural production in South Africa)[15].

Political Developments and Impacts

The South African Department of Science and Technology (DST) and Trade & Industry (the dti) are two Government Departments tasked with elucidating industrial commercial opportunities from bio-based materials. Furthermore, two key pieces of legislation have been promulgated to address waste in South Africa. These are:

1. The National Environmental Management Act (No. 107 of 1998) (NEMA), and
2. The National Environment Management Waste Act (No. 59 of 2008) (NEMWA). (National Environmental Management: Waste Amendment Act (26 of 2014) and the National Environmental Management Laws Amendment Act (25 of 2014)).

These acts are underpinned by:

- The South African Constitution (Act 108 of 1996)
- Hazardous Substances Act (Act 5 of 1973)
- Health Act (Act 63 of 1977)
- Environment Conservation Act (Act 73 of 1989)
- Occupational Health and Safety Act (Act 85 of 1993)
- National Water Act (Act 36 of 1998)
- Municipal Structures Act (Act 117 of 1998)
- Municipal Systems Act (Act 32 of 2000)
- Mineral and Petroleum Resources Development Act (Act 28 of 2002)

- Air Quality Act (Act 39 of 2004)

Both acts (NEMA and NEMWA) together serve to ensure that waste production activities in South Africa are managed, so that the production of waste is minimised, waste is recycled or re-used, and that waste is disposed of safely. Government Notice No. 718 of 2009, recently amended by No. 921 of 2013, identifies which activities will have a negative effect on the environment, and any entity wishing to engage in such activities would need to be issued a license by government.

Recent legislative changes relate to waste management pricing set by government, as well as the requirement for waste management strategies of selected industries to be approved by government. These are:

(i) The National Waste Management Strategy (NWMS)
The aim of the National Waste Management Strategy (NWMS) is to achieve the objectives of the National Environmental Management: Waste Act 2008 (Act 59 of 2008) and provide a plan to address challenges associated with waste management in South Africa16.
The NWMS has identified eight priority goals, accompanying objectives to achieve these goals and indicators to measure the achievements against targets, which are to be met within a five-year timeframe.

(ii) Waste Research, Development and Innovation (RDI) Roadmap
The Department of Science & Technology (DST) initiated a Waste RDI Roadmap for South Africa, in line with its 10-year national Waste Research, Development and Innovation (RDI) Roadmap, which supports the goals of the National Waste Management Strategy (NWMS), National Development Plan (NDP), Industrial Policy Action Plan (IPAP), and Green Economy Accord through recent technology development.

The vision of the Roadmap is to develop South Africa's circular economy, by stimulating waste innovation (technological and non-technological), R&D, and skills development through investments in science and technology for economic, social and environmental benefit.

Annexure 1 illustrates the alignment of Waste Management and Recycling with the key policy mandates of DAFF, articulated in the NDP, and APAP, and illustrates where Waste Management and Recycling and possibly technologies of the future may be used to support the delivery of the South African government's proposed interventions as articulated in the APAP.

7. Conclusions

- The South African wine industry should adopt renewable energy technologies and integrate these into wine waste processing.
- Government and industry need to make a concerted effort to prevent contamination of the environment and risk to human health trough the management of pesticides use and disposal into natural resources by implementing the following[16]:
  - Training / workshops in the field of pesticide application.
  - Promotion of Integrated Pest Management.
  - Training for the evaluation of exposure and risks.
  - Incentives to the farmer to use less pesticides.
  - Controlling pesticide quality and quantity
  - Adoption of stringent and effective monitoring programs to evaluate soil and groundwater contamination.
  - Provision of disposal options to the user.
  - Creation of a hazard ranking system for contaminated sites in South Africa
  - Provision of options for treatment of soil or groundwater contamination.
- To implement the National Waste Management Strategy, the following roles and responsibilities are suggested by the South African government
  - The role of the private sector:
    - apply clean technology practices
    - adopt modern technologies in waste processing and treatment, and develop capacity in these areas
    - apply for licenses and comply with terms of licenses
    - collect information and report on waste information
  - The role of civil society:
    - reduce, re-use and recycle, and dispose of waste responsibly
    - increase awareness of the environmental impact of products they consume
  - The role of government:
    - Forge partnerships with communities and the private sector
    - Provide waste management services,
    - Municipalities should co-operate with industry and other stakeholders to extend recycling at the municipal level, by providing bins and incentives for recycling, provide standards for waste processing.
    - Implement Ministerial and MEC responsibilities and administrative responsibilities as stipulated in the National Waste Management Strategy

Other national departments play important regulatory and supportive roles in implementing the Waste Act, and waste management more broadly. Their roles and responsibilities, as documented in the National Waste Management Strategy of the Department of Environmental Affairs are tabulated below (Table 4).

Table 4: Roles and responsibilities of other South African government departments in waste management

Department	Area of responsibility	Description
Department of Co-operative Governance	Waste services planning, delivery and infrastructure	Support municipalities to prepare IWMPs and integrate with IDPs. Make MIG funds accessible for development and upgrading of municipal landfill sites.
Department of Trade and Industry	Industry regulation and norms and standards	Manage the overall system of industry regulation. Apply Consumer Protection Act. Develop norms and standards using the Technical Infrastructure. Support the development of markets for recycled materials. Support the establishment of SMEs for waste collection services and recycling.
National Treasury	Fiscal regulation and funding mechanisms	Oversee financial integrity of intergovernmental transfers to provincial and local government. Manage the overall system of taxation and implement tax measures that support the goals and objectives of the NWMS. Determine budget allocations for waste management functions at national level.
Department of International Relations	International agreements	Give effect to Multilateral Environmental Agreements.
South African Revenue Services	Import and export control	Ensure waste management measures are aligned with the product codes in the Schedules to the Customs and Excise Acts.
Department of Water Affairs	Water quality and licensing	Collaborate with DEA in issuing integrated waste disposal licences.
Department of Mineral Resources	Waste management in the mining sector	Regulate waste management in the mining sector that falls outside the ambit of the Waste Act (including residue deposits and stockpiles), and remediate land that mining activities have contaminated.
Department of Health	Health care risk waste	Address health care risk waste and advise DEA and provincial departments on the appropriate standards and measures for the sector.
Department of Defence	Contaminated land	Remediate land contaminated by explosives

8. Synthesis and key trends from the literature

- The focus of global waste management projects is largely on organic waste (agricultural, municipal/ household, wood/paper, food and sewage), and recyclables (metals, plastic, e-waste)[17]. This shown in Figure 1 below.

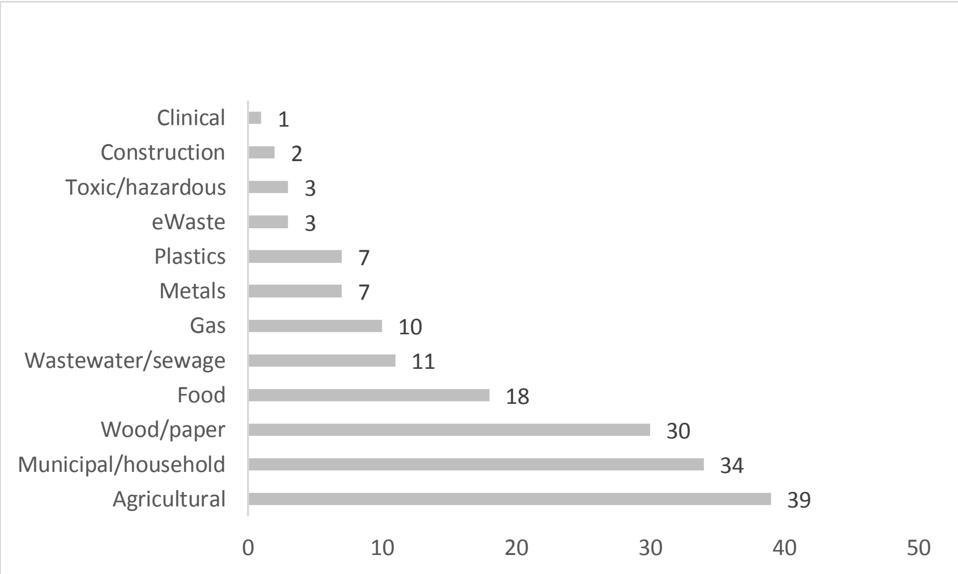

Figure 1: Number of global waste projects by waste type

- Developing and emerging countries face similar waste management challenges as developed countries[18,19,20,21,22,23,24,25.] These are
  - Poor infrastructure to deal with large volumes of waste (recycling levels are therefore low)
  - Changing socio-economic conditions means waste stream types and volumes will changes as well;
  - The major waste stream management techniques are open dumps and burning
  - The most prevalent and problematic waste stream types are organic waste (60-70%), hazardous waste and construction waste
  - Inadequate environmental legislation on waste management
- China
  - Has developed strategic emerging industries (energy conservation and environmental protection and recycling)
  - Has developed a circular economy (production methods, use of resources and recycling systems, green consumption, policy and technical support)
- South Africa has not yet implemented a fully functional circular economy in waste management. For example, as at 2011, about 90% of waste in South Africa is disposed of in landfills, only about 10% of waste is recycled, thermal and biological technologies

are poorly developed and used, although significant amounts of biomass waste are produced[26].

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