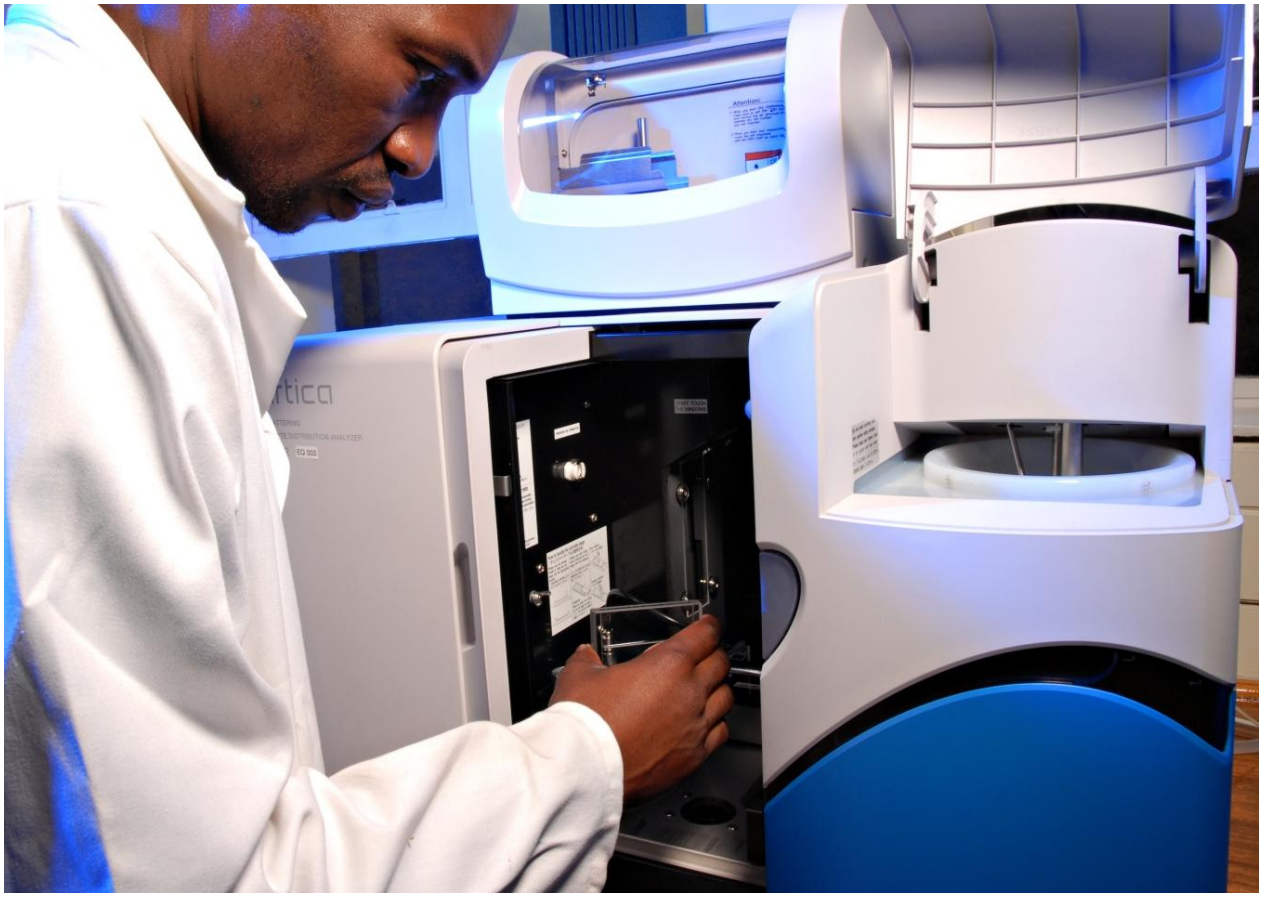
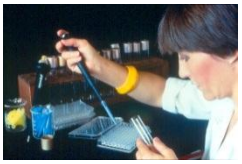
A National Waste Research, Development (R&D) and Innovation Roadmap for South Africa: Phase 2 Waste RDI Roadmap





Waste Research, Development and Innovation (RDI) Capabilities at South African Universities and Science Councils (2014)

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DST/CSIR Waste RDI Roadmap, Phase 2

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DOCUMENT INDEX

Reports as part of this project include:

2012:

REPORT NUMBER	REPORT TITLE	AUTHORS
CSIR/NRE/SUSET/ER/ 2012/0045/A	Phase 1 - HCD: Skills for an Innovative Waste Sector: Workshop Report (11-12 July 2012)	Lombard, R.K., Lombard, J., Godfrey, L. and Roman, H.
CSIR/NRE/PW/ER/ 2012/0052/A	Phase 1 - HCD: Current waste HCD initiatives in South Africa	Lombard, J., Lombard, R.K. Godfrey, L. and Roman, H.
CSIR/NRE/SUSET/ER/ 2012/0053/A	Phase 1 - HCD: Core waste management skills and implementation modalities	Lombard, J., Lombard, R.K., Godfrey, L. and Roman, H.
CSIR/NRE/SUSET/ER/ 2012/0063/A	Phase 1 - Institutional framework: Current and required institutional mechanisms to support waste innovation	Schoeman, C., Mapako, M., Kalan, S., Godfrey, L. and Roman, H.

2013:

REPORT NUMBER	REPORT TITLE	AUTHORS
CSIR/NRE/GES/IR/201 3/0078/A	South African Waste Sector – 2012: An analysis of the formal private and public waste sectors in South Africa	Godfrey, L., Strydom, W., Muswema, A. and Oelofse, S.

2014:

REPORT NUMBER	REPORT TITLE	AUTHORS
CSIR/NRE/GES/ER/201 4/0015/A	The economic benefits of moving up the waste management hierarchy in South Africa: The value of resources lost through landfilling	Nahman, A. and Godfrey, L.
CSIR/NRE/GES/ER/201 4/0016/A	Trends in waste management and priority waste streams for the Waste RDI Roadmap	Godfrey, L., Rivers, M. and Jindal, N.
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1 INTRODUCTION AND BACKGROUND

As the waste sector becomes more technologically demanding in response to the shift up the waste hierarchy away from landfilling towards prevention, reuse, recycling and recovery, so greater waste capabilities (depth and diversity) will be needed (DST, 2012). However, research conducted for the Department of Science and Technology (DST) on the status quo of waste management in South Africa, highlighted that while opportunities for economic growth exist within the waste sector, "*the National System of Innovation (NSI) appears to have not yet responded, with no focused waste innovation programmes or incentives in place to stimulate technological and non-technological innovation*" (DST, 2012b:iv). Both the Audit of Skills in the Waste Sector, as well as the Waste Sector Survey, highlighted that as at 2012, there was very little investment in waste research, development and innovation (RDI) or in human capital development (HCD) within the NSI in South Africa (DST, 2012; 2013).

The Department of Environmental Affairs (DEA) in their Environmental Sector Skills Plan also noted that "*environmental skills planning in South Africa is currently ad hoc, fragmented, and re-active, and is characterised by inefficiency*" (DEA, 2010:5). Therefore, as part of the development of the Waste RDI Roadmap, the DST aims to take a strategic and directed approach to the development of waste capabilities that will directly support development of the South African waste sector. For the purposes of this report, capabilities are seen to include waste RDI people, infrastructure, investment, and outputs within the South African National System of Innovation (NSI). In addition, the alignment of these capabilities with current waste sector needs (market orientation), or the ability of the NSI to respond to sector needs, is mapped.

As background to current waste RDI capabilities, the report reflects on the skills and investment in the waste sector during the period 2010-2012, with reference to the Environmental Sector Skills Plan, an analysis of the HCD pipeline from South African universities, and the baseline of waste sector R&D and HCD investment from the Sector Survey (Chapter 1). The report, then presents a baseline of South Africa's waste RDI capabilities as at May/June 2014 (Chapter 2).

1.1 Skills in Waste RDI (2010-2012)

The following section presents the state of waste skills, waste RDI, and waste human capital development (HCD) during the period 2010-2012.

1.1.1 Environmental Sector Skills Plan (2010)

The Environmental Sector Skills Plan (ESSP) for South Africa (DEA, 2010) was the culmination of a process aimed at evaluating the demand and supply of environmental skills in South Africa, in order to identify scarce and critical skills in the sector, and in so doing, influence and inform wider skills planning processes in South Africa. The demand for skills was determined by –

- scarce and critical skills,
- new trends influencing skills needs, and
- new policy drivers, such as the National Environmental Management: Waste Act.

All three of the above factors are applicable to the South African waste sector. As noted in the ESSP "*the new Waste Management Act requires a re-skilling of all waste practitioners in the country to adopt a 'cradle to cradle approach' to waste management*" (DEA, 2010:12).

Shortages in technical skills in waste management (i.e. waste management technicians), in particular waste management specialist technical skills in municipalities, were identified within the ESSP (DEA, 2010). Demand for new skills were recognised in the Green Economy Skills Development Planning and Provisioning process, to be in, amongst others, new energy technologies (production and installation) and waste reduction (DEA, 2010).

The ESSP identified the following scarce skills[1] in relation to waste management (as at 2009/10):

High skills (Management)	• Senior managers • Middle managers in public sector
High skills (Specialist Professionals)	• Waste researchers and scientists • Toxicologists • Soil geochemists • Remediation specialists • Landfill designers and managers
Intermediate Skills	• Environmental science technicians (with specialist competence for waste management)
Elementary occupation skills	• Waste recyclers (relative scarcity, related to formalisation of recycling industry and new Waste Management Act)

While the ESSP looks at high (NQF 7-10), intermediate (NQF 2-6), and entry level skills (NQF ≤ 1), the Waste RDI Roadmap will focus on supporting the development of 'high' skills, in this case NQF level 8 and higher (honours, masters and doctorate). This is in line with the mandate of the DST and is believed to provide a level of graduate that can unlock innovation and enterprise development opportunities most effectively (DST, 2012). However, it is emphasized that this will be done in parallel with other training and HCD activities in the waste sector aimed at developing skills across all NQF levels.

1.1.2 Human Capital Pipeline (2012)

The pipeline of human capital (with an understanding of waste management) was assessed by evaluating data from the Department of Higher Education and Training's Higher Education Management Information System (HEMIS). Enrollment and graduate data for the period 2006-2011 was extracted and analyzed. Since waste management is not a major area of specialization and qualification within the HEMIS (2nd Order CESM Category), the exact number of students undergoing training in waste management could not be determined.

Waste management is typically embedded in natural science, engineering and public health degrees, however, components of waste management can also be found in the social, agricultural, built environment, geological and biological sciences, amongst others. This point was also noted in the

[1] **Scarce skills** are defined by the Department of Labour, as occupations in which there is a scarcity of qualified and experienced people, currently or in the future, either because such people are not available (absolute scarcity), or because they are available but do not meet the employment criteria (relative scarcity) (DEA, 2010).

ESSP for the broader environmental sector – "*environmental specialisms are very poorly captured in national datasets. This effectively renders environmental qualifications 'invisible' in national data capturing systems*" (DEA, 2010:31). To overcome this problem, the handbooks of a number of South African Universities were searched to determine which courses contain (and at what level) aspects of waste management. These courses (and corresponding levels) were then related back to the HEMIS 2nd Order CESM Categories to determine the number of students potentially exposed to waste management content during their degrees.

Table 1. Enrolments and graduations in courses potentially containing waste management subject matter.

All races		2006	2007	2008	2009	2010	2011	2012
Bachelors	Enrol	11 006	11 895	13 088	13 370	8 554	8 351	10 214
	Graduate	2 110	2 307	2 393	2 571	1 782	1 727	1 945
Honours	Enrol	3 007	3 367	3 195	3 409	2 216	2 622	3 404
	Graduate	1 366	1 536	1 584	1 707	1 105	1 250	1 501
Masters	Enrol	4 558	4 408	4 838	5 022	5 415	5 846	6 137
	Graduate	946	885	972	994	1 005	1 183	1 333
PhD	Enrol	1 812	1 883	1 935	2 059	1 783	2 151	2 203
	Graduate	239	219	249	293	237	280	287

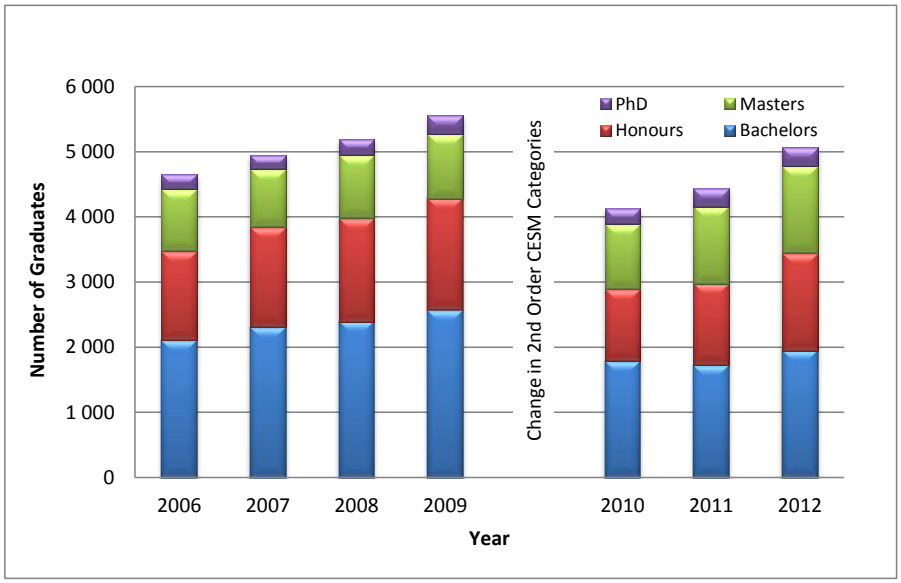

Figure 1. Number of under-graduate and post-graduate students potentially exposed to waste management content or modules during their degree

CESM Categories were adjusted by the Department of Higher Education in 2010. As such, selected categories needed to be matched to pre- and post- 2010 codes. The discrepancy in the number of graduates between 2009 and 2010 may be the result of this change in CESM Categories, however, the most noticeable changes, especially in under-graduates were noted for Environmental design/Architecture, Public Health, and Geography/Cartography, which did not experience reclassification or fragmentation in codes.

While the number of graduates receiving training in some aspect of waste management during their degree is likely to be significantly less than that reflected in **Table 1** and **Figure 1**, it is still a relatively small number of graduates when compared to the estimated 90,000 graduates participating in environmental related study fields (as at 2006) (DEA, 2010).

The results show a gap between the numbers of graduates completing degrees and diplomas and the number of honours, masters and doctorate graduates. This low transition from under-graduate to post-graduate (higher degrees) was also highlighted in the ESSP, where it was found that not enough people are entering the environmental sector with higher degrees (DEA, 2010).

1.1.3 Graduates in the waste sector (2012)

Of the 29,833 people employed in the formal waste sector in 2012 (minimum number), only a small percentage had post-graduate degrees (**Table 2, Figure 2**). What was not determined during the Waste Sector Survey was the type of post-graduate degree held. As such, there is no information available on the relevance of these 1324 diplomas and 1199 degrees held by professionals in the waste sector. Only a small percentage of graduates potentially exposed to waste management content during their degrees are working in the formal waste sector.

Table 2. Diplomas and degrees held by professionals in the South African waste sector (2012)

Waste Sector	Diploma	Degree	Masters	PhD
Private	468	456	102	13
Municipalities	856	610	17	1
Total	**1 324**	**1 066**	**119**	**14**

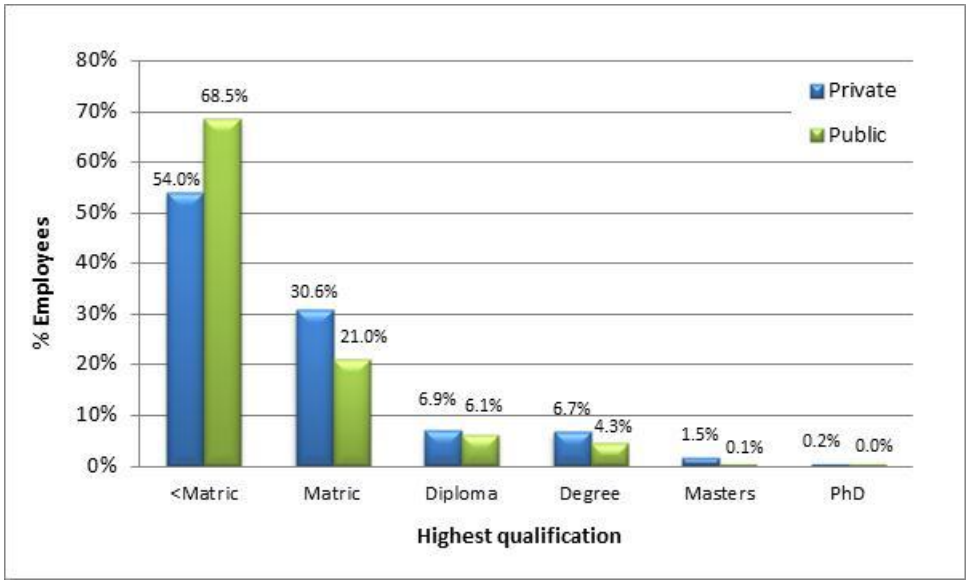

Figure 2. Highest qualifications of employees within the public and private waste sectors (2012)

The Waste Sector Survey noted that industry and Government will need to look at how it attracts and retains highly qualified graduates in the waste sector, to stimulate technological and non-technological innovations.

1.2 Investment in Waste RDI (2010-2012)

1.2.1 Spend on Waste RDI (2012)

The Waste Sector Survey (DST, 2013) showed that investment in Waste RDI, as at 2012, was low. The minimum spend on waste RDI for 2012 was R50.2m, approximately 0.33% of the value of the waste sector. Spend on waste HCD for 2012 was R429m, approximately 2.8% of the value of the sector. In terms of rand value, the private sector spends approximately 2.9 times more on waste R&D than the public sector. However, R&D spend as a percentage of each sector's available revenue (value), suggests a 3.4 times higher spend on waste R&D by the private sector than the public sector (**Table 3**).

Table 3. Minimum spend on waste R&D and HCD as a percentage of sector value (2012)

Waste Sector	Waste R&D [R]	Waste R&D as % of sector value	Waste HCD [R]	Waste HCD as % of sector value
Private	37,251,663	0.54%	84,396,037	1.21%
Public	12,996,567	0.16%	344,166,234	4.13%
Total	50,248,230	0.33%	428,562,271	2.80%

1.2.2 Funding for Waste RDI (2012)

An audit of waste HCD activities conducted as part of the Waste HCD Status Quo Analysis (DEA, 2012a, b, c), highlighted that the majority of respondents funded their learning programs and research partly or wholly through their own resources (**Figure 3**). Other significant sources of funding included the NRF and industry, and, to a lesser extent other waste-related government departments.

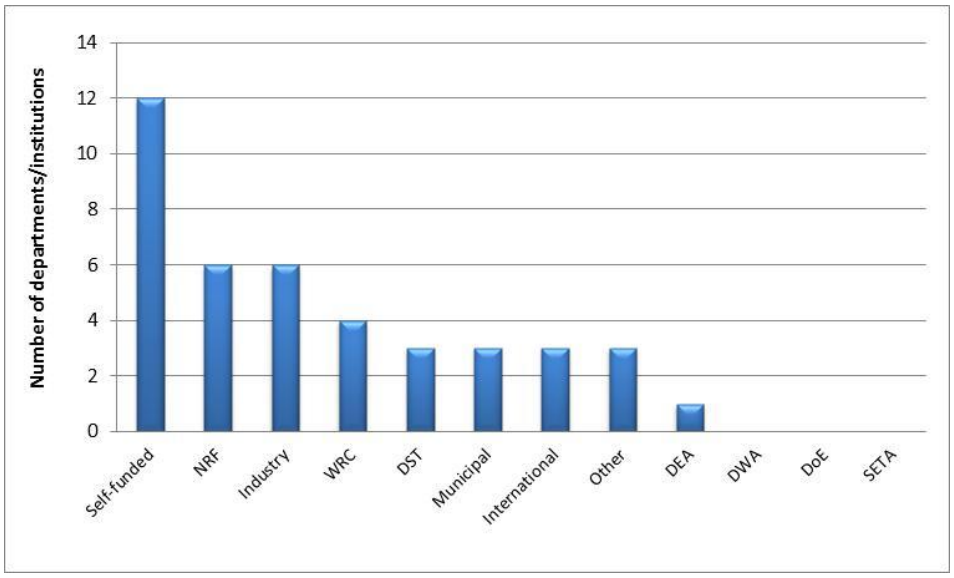

Figure 3. Source of waste RDI funding (2012) (from DST, 2012a)

The main challenges hampering waste RDI, as at 2012, included lack of directed funding in waste, lack of leadership in waste RDI priorities, and lack of waste RDI capacity (skills) (**Figure 4**).

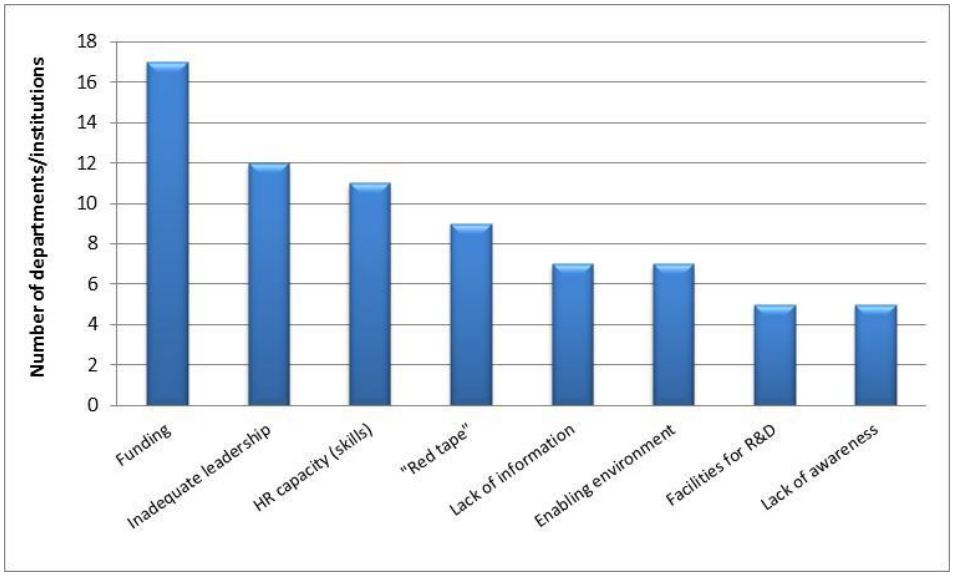

Figure 4. Challenges to Waste RDI (2012) (adapted from DEA, 2012a)

The audit of waste HCD initiatives conducted as part of the Waste HCD Status Quo Analysis (DEA, 2012a, b, c), concluded that:

- There were no diploma or degree qualifications focussed solely on waste management at a tertiary level in South Africa. Waste management was typically addressed as modules of environmental science, engineering, or public health. This differs from what is found internationally.
- A waste management professional skills development programme (at university level) is required to –
    - enable graduates of tertiary institutions to enter the waste industry well-versed and prepared to contribute effectively (public or private sector)
    - to up-skill persons already working within the waste sector, and
    - to develop waste educators at all levels so as to increase supervisory capacity.
- Skills required for innovation are not only technical, as there is growing interest in research in the socio-economic aspects of the waste sector. There is therefore a need for a strong multi-disciplinary approach to waste management skills development.
- The learning program must be structured to have strong links with the workplace, and should support both full-time and part-time learning.

The findings of the Waste HCD Status Quo Analysis has led the DST to engage with two universities to develop an honours and masters degree in waste management, ready for student enrolments in 2015 and 2016 respectively.

2 WASTE CAPABILITIES (2014)

To support the implementation of the Waste RDI Roadmap (2014-2024), a capability mapping exercise was conducted of all South African Universities and Science Councils. The purpose of this capability mapping exercise was to determine current waste RDI capabilities within the NSI and to match this to expected future waste RDI needs for the country. Gaps between current capabilities and future needs will identify priority areas for e.g. investment, capacity development, focussed research, technology development, etc.

2.1 Methodology

Information on current waste RDI capabilities was obtained by means of a self-administered questionnaire. The questionnaire was sent to all university Deputy Vice-Chancellors for Research, and the Deans of Engineering and Science. The questionnaire was also sent to specific researchers working in waste RDI to ensure both a top-down and bottom-up approach to questionnaire completion. It is also ensured that researchers working in the faculties of Social Science and Economics were included.

The following Maturity Assessment Frameworks were used to define the maturity of Waste RDI capabilities in South Africa Universities and Science Councils as at 2014. The methodology adopted for the DST ICT Roadmap was used, but the ranges were adjusted for the smaller waste RDI sector.

Maturity Assessment Framework: Universities

	WASTE RDI Capability - Maturity		
Maturity	**Faculty**	**PhD students**	**MSc students**
Subcritical	Single faculty member	0-1	0-3
Emerging	Dedicated Professorship	1-3	3-5
Building	Dedicated Professorship with small Research Group OR Research Chair or Centre of Excellence	3-5	5-10
Mature	Established Research Chair or Centre of Excellence with professors, senior lecturers, lecturers and admin staff	>5	>10

Maturity Assessment Framework: Science Councils

	WASTE RDI Capability - Maturity		
Maturity	**Staff**	**Senior Staff**	**Junior staff or Students**
Subcritical	Single researcher	0-1	0-3
Emerging	Dedicated Senior researcher	1-3	3-5
Building	Dedicated Principal or Chief researcher with a small Research Group OR Centre of Excellence or Competence	3-5	5-10
Mature	Established Centre of Excellence or Competence with Principal/Chief researchers, Senior researchers, Junior staff and admin staff	>5	>10

Of the 26 Universities and Science Councils approached, 22 completed questionnaires were returned, representing 13 organisational responses. Unlike the 2012 DST Waste Audit, the results presented below are presented at an organisational level and not at a department or faculty level.

2.2 People in Waste RDI

The results show that only 50% of South African universities and Science Councils are currently actively engaged in waste RDI (**Figure 5**). And of those 13 institutions undertaking waste RDI, 46% have less than 5 researchers. The results confirm that waste RDI is a young, emerging discipline within the NSI.

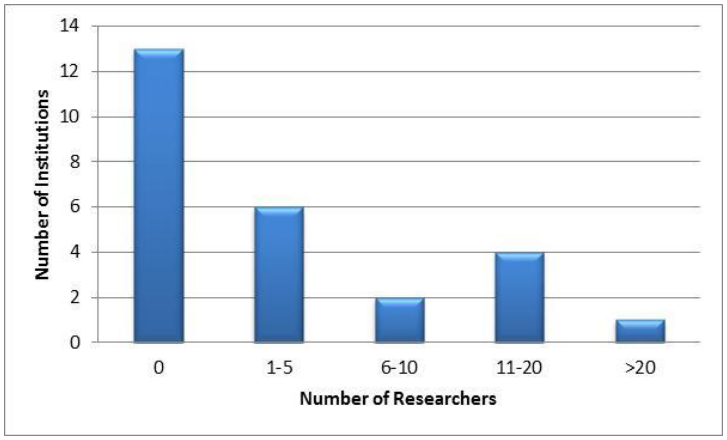

Figure 5. Number of NSI institutions with active waste RDI researchers

Of the 13 institutions active in waste RDI, 92% have less than 10 researchers with a PhD degree (**Figure 6**). There are between 49-76 researchers with PhDs currently working in Waste-related RDI and 40-61 researchers with a Masters degree.

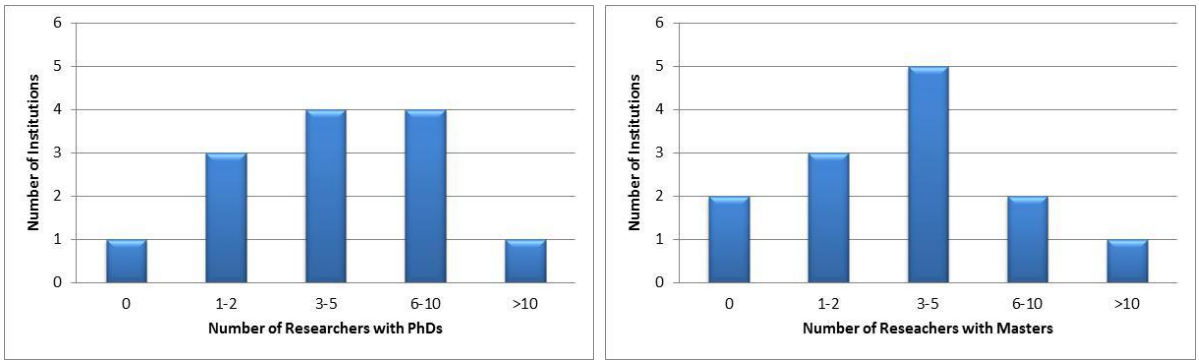

Figure 6. Number of researchers with PhDs and Masters degrees active in waste RDI

2.3 Investment in Waste RDI

2.3.1 Investment in students (bursaries and scholarships)

Of the institutions active in waste-related RDI, only 31% offered bursaries for waste-related bachelors and honours degrees. This increased to 54% of institutions which offered Masters and PhD scholarships (**Figure 7**).

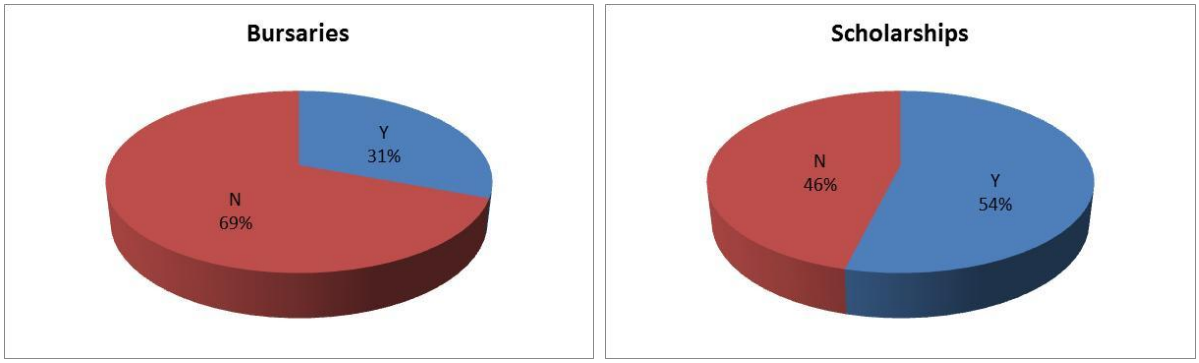

Figure 7. Percentage of institutions awarding bursaries (bachelors/honours) and scholarships (M/PhD)

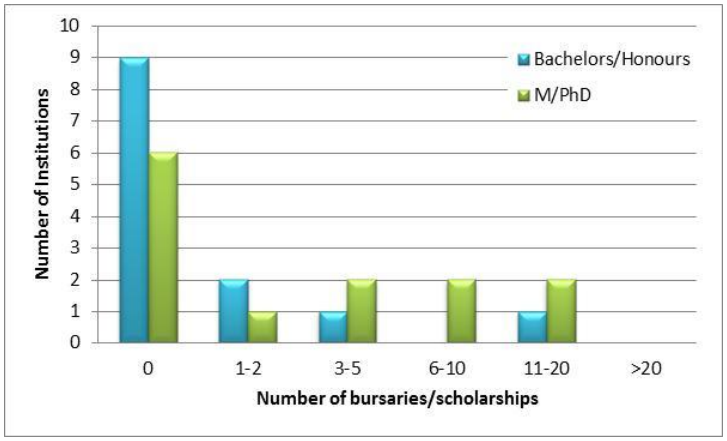

Figure 8. Number of institutions awarding waste-related under-graduate and post-graduate bursaries

2.3.2 Investment in research

Current expenditure on waste RDI (salaries, equipment, laboratories, students, etc) is generally low, with 77% of institutions investing less than R10m per annum (**Figure 9**). Of the three institutions investing more than R10m per annum, two are Science Councils. Two institutions do not incur any direct expenditure on waste RDI.

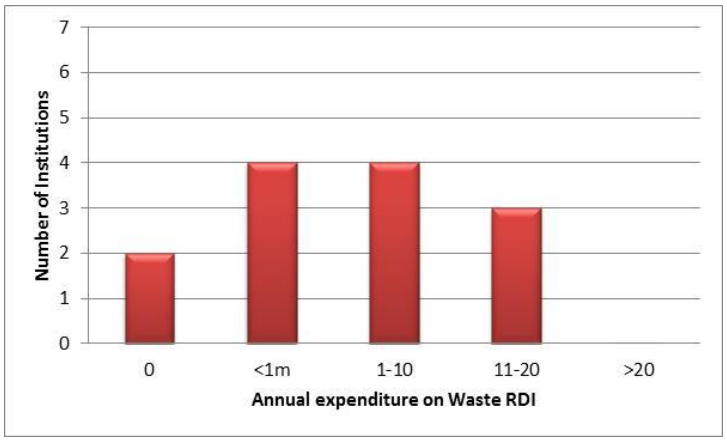

Figure 9. Total annual expenditure on waste RDI (personnel and equipment)

The low expenditure on waste and waste-related RDI may be due to the low levels of funding currently available in the field (**Figure 10**). Five institutions (38%) involved in waste RDI, report no external funding for their activities (i.e. self-funded). The majority of funding for waste RDI comes

from other Government departments (e.g. DEA, DWA, DST), self-funded and private sector/industry funded. The comment raised by the sector (DST, 2012b) that "*the NSI appears to have not yet responded, with no focused waste innovation programmes or incentives in place to stimulate technological and non-technological innovation*" remains relevant, given that only a small number of institutions receive their funding from NSI Funding Agencies (NRF, THRIP or TIA) (**Figure 10**). The waste sector appears not to have tapped into funding opportunities from NGO/donor organisations.

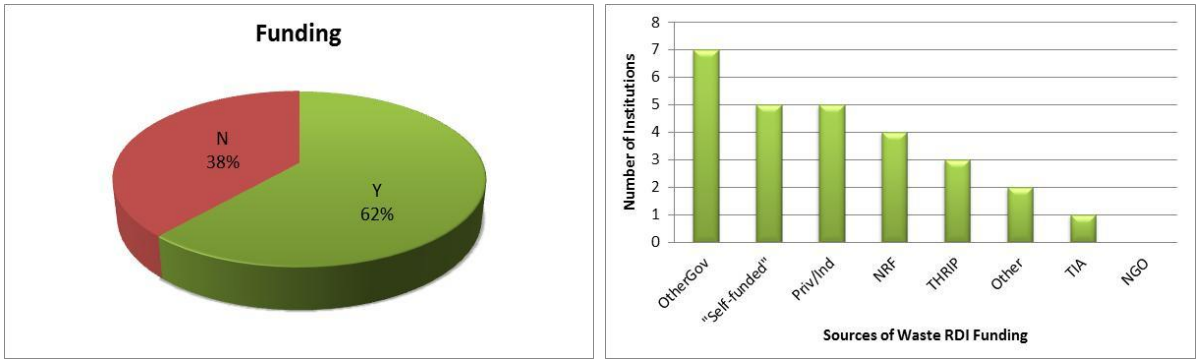

Figure 10. Percentage of institutions receiving funding for Waste RDI and the sources of funding

2.3.3 Investment in infrastructure

77% of respondents indicated that they require specialist equipment for their research (Section 2.4). However, capital expenditure on equipment to support waste RDI remains low, with 53% of institutions reporting that they spend less than R1m on equipment (Figure 11).

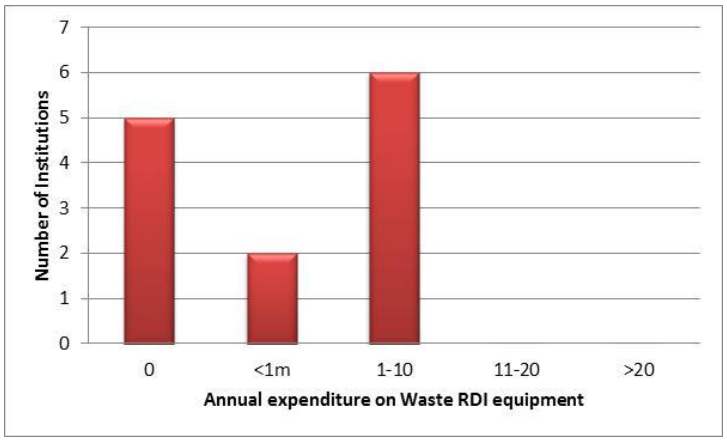

Figure 11. Total annual capital expenditure on waste RDI equipment

2.4 Waste RDI Infrastructure

Three of the 13 institutions active in waste RDI indicated that they have Centres of Excellence or specialised Research Centres related to waste. Of those involved in waste RDI, 77% indicated that they require specialised equipment to undertake their research. Only one institution (8%) indicated that they had manufacturing/production facilities to support development of waste-specific products or technologies (**Figure 12**).

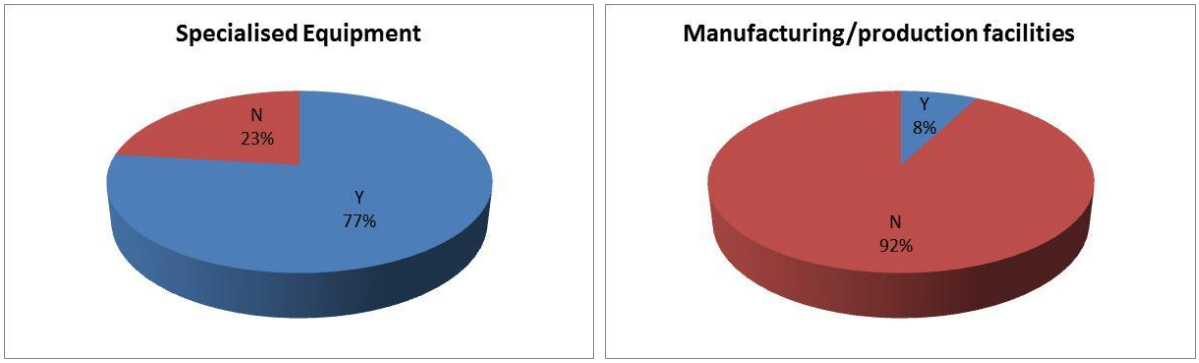

Figure 12. Waste RDI infrastructure (equipment and manufacturing facilities)

2.5 Waste RDI Outputs

What is interesting, given the low investment in waste RDI and the relatively low levels of waste RDI maturity (Section 2.6) is the output of scientific publications and new products/technologies (**Figures 13 and 14**). Only one institution indicated that while active in waste RDI, they were not publishing scientific publications. Three institutions (23%) publish between 11-20 waste-related publications per annum (**Figure 13**), two being universities and one a Science Council.

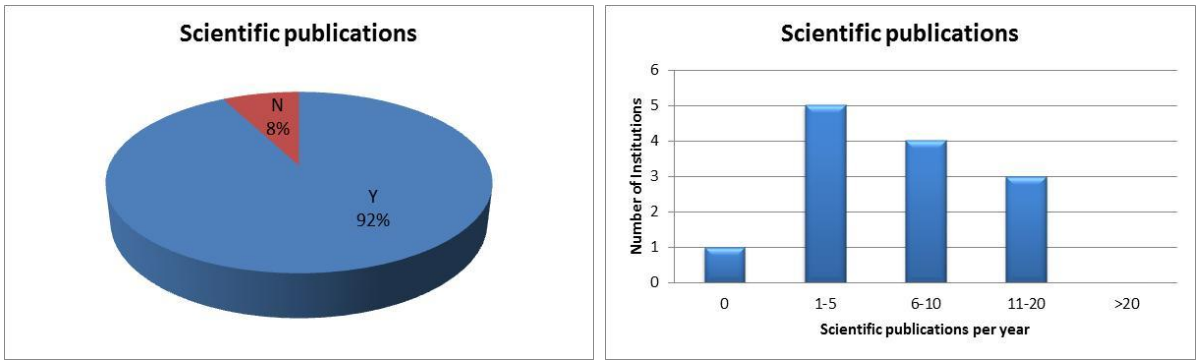

Figure 13. Scientific publications (journal and conference papers, books)

However, the number of waste-related scientific publications is small when compared to the total number of scientific publications by South African research institutions. According to Scopus, 15 891 scientific publications were published by South African institutions in 2013 (*compared to 14 848 in 2012*). While 2 829 (17.8%) of these publications were in the fields of engineering and environmental science (*most likely fields for waste R&D*), waste R&D is multi-disciplinary with the result that the waste RDI outputs could have been published across numerous fields (from social science to chemistry). **Figure 14** highlights this multi-disciplinary nature of waste R&D, with Scopus showing waste-related publications in almost all of the publication areas, but with the majority being published in environmental sciences and engineering (77.3%).

Waste RDI Outputs given during the capability mapping exercise closely match the number of waste-related scientific publications published by Scopus (**Figure 14**) (*with 'waste' as keyword, excluding wastewater*). Waste RDI outputs represent ~0.4% of total South African scientific publications for 2013.

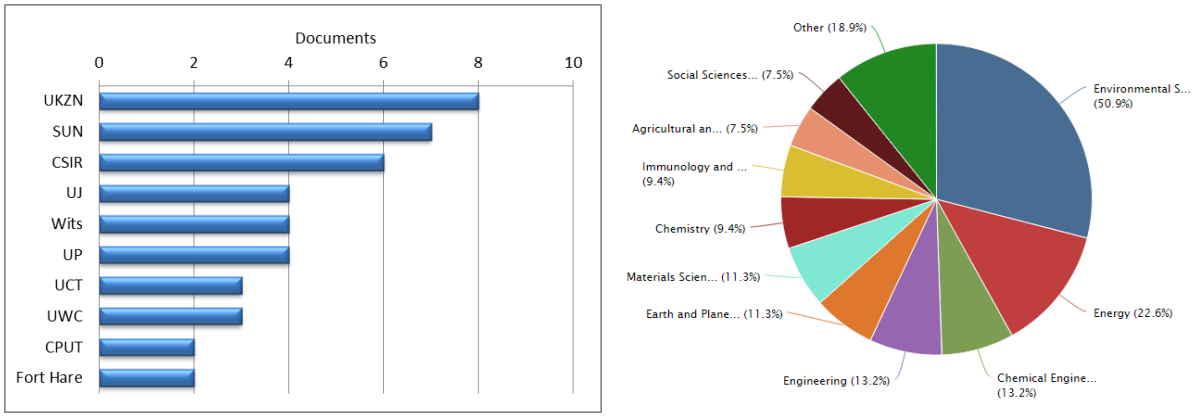

Figure 14. Waste-related scientific publications by Institution (a) and by Subject Area (b) (for 2013) (from Scopus) (*with 'waste' as keyword, excluding 'wastewater'*)

61% of respondents indicated that they have some new products/technologies/patents developed in waste RDI (**Figure 15**), which is very encouraging.

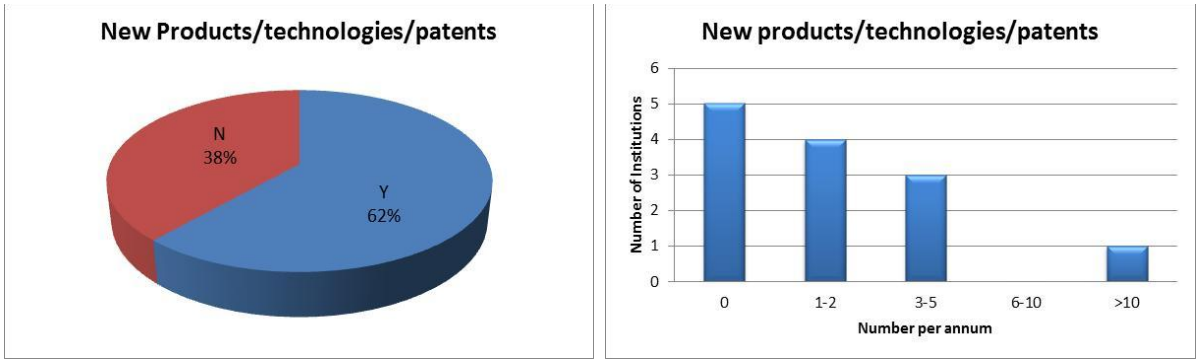

Figure 15. Development of new waste-related products, technologies, patents

2.6 Alignment with sector needs (Market Orientation)

Tables 4-8 capture the current level of maturity of waste RDI capabilities in relation to the sector needs, i.e. the alignment of the NSI with the market orientation.

Alignment with sector needs was evaluated based on –

- Research across the waste hierarchy
- Research across various disciplines or fields of waste RDI
- Research on the different waste streams
- Research on the different technologies

Interestingly, in the absence of any national leadership in waste RDI, the sector has 'organically' responded to growing local and international interest in the waste sector. The South African waste sector can be described as "Emerging", considering the current levels of maturity across all South African Universities and Science Councils.

There are already prominent levels of waste RDI in reuse, recycling and recovery which will provide the foundation for the research necessary to support the move up the waste management

hierarchy, away from landfilling, as required by national policy (**Table 5**). This corresponds with the waste types (**Table 7**) and the waste technologies (**Table 8**) being researched.

With the exception of waste logistics and waste information and information systems, there is good coverage across all fields of waste research (**Table 6**). However, these are two particular areas which will require attention, given the growing demand for waste materials and the associated increasing costs of transportation. The lack of reliable waste information has been recognised as a constraint within the South African waste sector for a number of years now. The results show the high levels of research activity in waste & the environment and waste & society (and supporting waste technologies), the two areas that are exposed to the greatest impact from the improper management of waste. The growing interest in social science research and waste highlights that waste issues cannot be solved only through technological innovations. The role of society is critical in addressing South Africa's current waste challenges. This includes the role of the informal sector, on which a substantial amount of adhoc research is being conducted.

In terms of waste streams, the focus is mainly on general waste streams, with fewer institutions currently involved in hazardous waste research. Prominent types of wastes being researched, include – municipal waste; organic waste; commercial and industrial waste; and fly ash and dust. Mainline recyclables (paper, plastic, glass, metal) and waste tyres are also areas of research focus (**Table 7**).

The focus of technology research is predominantly on pyrolysis/gasification, aerobic digestion/composting and anaerobic digestion (**Table 8**). This is largely in support of the research on organic waste, waste tyres, and municipal waste (**Table 7**).

Key stakeholders in the South African waste sector prioritised eight waste streams which require increased research, development and innovation –

- organic waste
- municipal waste
- waste tyres
- plastic waste
- waste of electric and electronic equipment (WEEE)
- mineral waste
- construction & demolition waste
- ash

The first five will be expanded on in the Waste RDI Roadmap 2014-2024. While all five waste streams will require strengthening of waste RDI capabilities, with the exception of WEEE, all have nodes of at least 'building' capability. WEEE, plastics and tyres currently have lower levels of research activity than municipal and organic waste. Research on WEEE, the fastest growing waste stream in South Africa, is considered sub-critical.

2.6.1 Multi-disciplinary nature of waste RDI

While formal waste RDI capability exists within the NSI (**Tables 4-8**), there are also instances where researchers (usually PhD students) are applying their domain expertise within the field of waste management. Examples include criminology and waste; labour and enterprise policy and waste, polymer science and waste. These instances are not mature enough to reflect as current levels of capability and as such are not captured in the capability tables, but it highlights the multi-disciplinary nature of waste RDI and the application of very diverse fields of research within the waste sector. This is particularly evident in the application of the social sciences to waste management.

It will be important to identify these fields of R&D which may be applied within the field of waste R&D, and to provide mechanisms to support integration of disciplines through practical research projects. This will be particularly relevant within the context of the Waste RDI clusters, e.g. mathematics and modelling under the Analytics & Modelling Cluster; social sciences under the Waste & Society Cluster; physics, chemistry and engineering under the Waste Technologies Cluster.

Table 4. Waste RDI Capability

LEGEND:
- Subcritical
- Emerging
- Building
- Mature

	Waste RDI
	Overall rating
Cape Peninsula University of Technology	
University of Cape Town	
Central University of Technology	
Durban Institute of Technology	
University of Fort Hare	□
University of the Free State	
University of Johannesburg	
University of KwaZulu-Natal	
University of Limpopo	
Mangosuthu University of Technology	
Nelson Mandela Metropolitan University	
North-West University	
University of Pretoria	□
Rhodes University	
University of South Africa	
University of Stellenbosch	
Tshwane University of Technology	
Vaal University of Technology	
University of Venda	
Walter Sisulu University	
University of the Western Cape	
University of the Witwatersrand	□
University of Zululand	
CSIR	
HSRC	
Mintek	
SA Waste Sector RDI Maturity	*Emerging*

□ *Known capability, but no response from Institution*

Table 5. Waste hierarchy

LEGEND:
- Subcritical
- Emerging
- Building
- Mature

	Waste Hierarchy					
	Prevention	Reuse	Recycling	Recovery	Treatment	Disposal
Cape Peninsula University of Technology				Emerging	Subcritical	
University of Cape Town	Subcritical	Subcritical	Subcritical	Subcritical	Subcritical	
Central University of Technology	Subcritical	Subcritical	Subcritical	Subcritical	Subcritical	Subcritical
Durban Institute of Technology						
University of Fort Hare						
University of the Free State						
University of Johannesburg	Subcritical			Subcritical		Subcritical
University of KwaZulu-Natal	Mature	Mature	Mature	Mature	Mature	Mature
University of Limpopo	Emerging	Emerging	Subcritical	Subcritical	Subcritical	Subcritical
Mangosuthu University of Technology						
Nelson Mandela Metropolitan University						
North-West University		Emerging	Subcritical	Emerging		Subcritical
University of Pretoria						
Rhodes University						
University of South Africa	Subcritical		Subcritical			
University of Stellenbosch		Subcritical	Building	Building	Subcritical	
Tshwane University of Technology	Subcritical	Emerging	Emerging	Emerging	Emerging	Emerging
Vaal University of Technology						
University of Venda						
Walter Sisulu University						
University of the Western Cape		Building	Subcritical	Building		
University of the Witwatersrand						
University of Zululand						
CSIR	Building	Building	Building	Building	Building	Building
HSRC		Subcritical	Subcritical	Subcritical		
Mintek		Building	Building		Building	
Research activity level	*7*	*10*	*11*	*11*	*8*	*7*

Table 6. Fields of waste RDI

LEGEND:
- Subcritical
- Emerging
- Building
- Mature

	Fields of waste research											
	Waste technologies	Waste & environment (impacts)	Waste & human health (impacts)	Waste & climate change	Waste & resource economics	Waste behaviour	Waste & society	Waste governance and legislation	Waste strategy and planning	Waste information and systems	Waste classification and analysis	Transportation of wastes / logistics
Cape Peninsula University of Technology	Subcritical										Subcritical	
University of Cape Town	Subcritical	Subcritical	Subcritical	Emerging	Emerging	Subcritical	Subcritical	Subcritical	Subcritical	Subcritical	Subcritical	
Central University of Technology	Subcritical	Subcritical	Subcritical					Subcritical	Subcritical			
Durban Institute of Technology												
University of Fort Hare												
University of the Free State												
University of Johannesburg		Subcritical		Subcritical	Subcritical		Subcritical	Subcritical				
University of KwaZulu-Natal	Mature	Emerging	Subcritical	Subcritical	Subcritical	Mature	Emerging	Emerging	Mature	Subcritical	Mature	
University of Limpopo	Subcritical	Building	Emerging	Building	Emerging	Emerging	Building	Subcritical	Subcritical	Subcritical	Building	
Mangosuthu University of Technology												
Nelson Mandela Metropolitan University												
North-West University	Emerging	Subcritical	Subcritical		Subcritical	Emerging	Emerging	Subcritical	Subcritical		Emerging	
University of Pretoria												
Rhodes University												
University of South Africa		Subcritical				Subcritical	Subcritical					
University of Stellenbosch	Building			Subcritical	Building						Building	
Tshwane University of Technology	Building	Emerging	Emerging				Subcritical					
Vaal University of Technology												
University of Venda												
Walter Sisulu University												
University of the Western Cape	Building	Building	Subcritical	Building	Subcritical	Subcritical	Subcritical				Building	
University of the Witwatersrand												
University of Zululand												
CSIR	Building	Mature	Building	Building	Emerging	Emerging	Emerging	Building	Building	Emerging	Emerging	Subcritical
HSRC		Subcritical	Subcritical	Subcritical	Subcritical	Subcritical	Subcritical	Subcritical	Subcritical			
Mintek	Building	Building			Emerging		Emerging		Emerging	Emerging	Emerging	
Research activity level	*10*	*11*	*8*	*7*	*9*	*8*	*11*	*8*	*7*	*4*	*8*	*1*

Table 7. Waste Types

LEGEND:
- Subcritical
- Emerging
- Building
- Mature

	Waste Types																																
	General and unclassified waste streams																	Hazardous waste streams															
	Municipal waste	Commercial and industrial waste	Brine	Fly ash and dust	Bottom ash	Slag	Mineral waste	Waste of Electric and Electronic Equipment	Organic waste	Sewage sludge	Construction and demolition waste	Paper	Plastic	Glass	Metals	Tyres	Other	Gaseous waste	Mercury containing waste	Batteries	POP Waste	Inorganic waste	Asbestos containing waste	Waste Oils	Organic halogenated and /or sulphur containing solvents	Organic halogenated and/or sulphur containing waste	Organic solvents without halogens and sulphur	Other organic waste without halogen or sulphur	Tarry and Bituminous waste	Health Care Risk Waste	Miscellaneous	Radioactive/Nuclear waste
Cape Peninsula University of Technology	■			■												■																	
University of Cape Town	■	■	■	■		■	■		■			■	■		■		■	■				■											
Central University of Technology	■	■		■					■		■	■	■	■	■		■					■								■	■		
Durban Institute of Technology																																	
University of Fort Hare																																	
University of the Free State																																	
University of Johannesburg	■								■																								
University of KwaZulu-Natal	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
University of Limpopo	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
Mangosuthu University of Technology																																	
Nelson Mandela Metropolitan University																																	
North-West University									■							■																	■
University of Pretoria																																	
Rhodes University																																	
University of South Africa																																	
University of Stellenbosch	■	■						■	■	■		■	■			■																	
Tshwane University of Technology	■	■	■	■	■	■	■	■	■	■								■	■	■													
Vaal University of Technology																																	
University of Venda																																	
Walter Sisulu University																																	
University of the Western Cape		■	■	■					■			■	■	■	■						■	■											
University of the Witwatersrand																																	
University of Zululand																																	
CSIR	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■		■		■						■			■	■			
HSRC																																	
Mintek		■		■		■	■	■						■	■					■			■										
Research activity level	*8*	*8*	*5*	*8*	*4*	*5*	*5*	*5*	*9*	*5*	*4*	*6*	*6*	*6*	*6*	*6*	*3*	*4*	*3*	*5*	*3*	*4*	*3*	*2*	*2*	*3*	*2*	*2*	*3*	*3*	*3*	*2*

Table 8. Waste Technologies

LEGEND:
- Subcritical
- Emerging
- Building
- Mature

	Waste Technologies																												
	Thermal					Biological/chemical															Mechanical/Physical						Landfill		
	Advanced Thermal Recycling	Plasma Arc Gasification	Pyrolysis	Pyrolysis/Gasification	Pyrolysis/Steam Reforming	Acid leaching	Advanced oxidation	Aerobic Digestion/Composting	Anaerobic Digestion	Arthropods	Bio-conversion to biocomposites	Biodiesel	Bioleaching/Chemical leaching	Biorefinery	Catalytic Cracking	Compressed biogenic gas	Enzymatic protein hydrolysis	Ethanol Fermentation	Syngas-to-Ethanol	Thermal Depolymerization	Alternative construction materials	Densification/pelletization	Encapsulation of nuclear waste	Recycling of nuclear fuel	Refuse -derived fuel (RDF)	Sorting/Classification	Landfill engineering	Landfill gas recovery	Landfill mining (sludge)
Cape Peninsula University of Technology																													
University of Cape Town																													
Central University of Technology																													
Durban Institute of Technology																													
University of Fort Hare																													
University of the Free State																													
University of Johannesburg																													
University of KwaZulu-Natal																													
University of Limpopo																													
Mangosuthu University of Technology																													
Nelson Mandela Metropolitan University																													
North-West University																													
University of Pretoria																													
Rhodes University																													
University of South Africa																													
University of Stellenbosch																													
Tshwane University of Technology																													
Vaal University of Technology																													
University of Venda																													
Walter Sisulu University																													
University of the Western Cape																													
University of the Witwatersrand																													
University of Zululand																													
CSIR																													
HSRC																													
Mintek																													
Research activity level	*5*	*3*	*6*	*7*	*3*	*1*	*1*	*6*	*6*	*1*	*1*	*5*	*1*	*1*	*3*	*1*	*1*	*3*	*3*	*3*	*2*	*3*	*1*	*1*	*6*	*1*	*4*	*3*	*1*

3 CONCLUSIONS AND RECOMMENDATIONS

The results of the capability mapping have revealed that the maturity of the South African waste research, development and innovation (RDI) community within the National System of Innovation (NSI) can still be considered as 'emerging'. Research on waste is being conducted across the NSI in multiple Universities and Science Councils, and in the absence of national leadership in Waste RDI (up until now) the sector has established nodes of excellence in certain areas (represented by mature levels of capability). There is evidence of both specialisation (depth of maturity) as well as diversity across fields of waste RDI at the various institutions. The waste RDI community have responded, in part, to the sector needs (market orientation), both in terms of waste streams, as well as supporting waste technologies. This is evident in the levels of research activity in recycling and recovery; waste & the environment and waste & society; municipal solid waste, organic waste and the mainline recyclables (with the exception of WEEE); and pyrolysis/gasification, aerobic and anaerobic digestion. Research in the hazardous waste streams though is under-represented.

Given the size of the South African waste sector, funding to waste RDI remains small, with many institutions indicating that they self-fund their waste research. The result is limited investment currently in waste RDI infrastructure. Given these funding constraints there is still very positive outputs in terms of the number of scientific publications and products/technologies/patents generated by the sector.

While the pipeline of students potentially exposed to waste content during their degrees both at under-graduate and post-graduate levels is encouraging, low numbers of post-graduates are entering the waste sector. Waste management is currently imbedded in environmental sciences and engineering. This will be addressed through the development of two new degrees – an Honours and a Masters degree in Waste Management – currently financed by the Department of Science and Technology.

The capability mapping exercise provides a baseline of waste RDI capability within the NSI in South Africa. The results will be used to support the development of the Waste RDI Roadmap. The current capabilities (supply) within Universities and Science Councils will be matched to the demand, based on the identified opportunities for waste RDI in the Waste RDI Roadmap. Gaps between current capabilities (supply) and future needs (demand) will identify priority areas for e.g. investment, capacity development, focussed research, technology development, etc. The Waste RDI Roadmap provides the opportunity to strengthen current waste RDI capabilities through directed investment.

Finally, the multi-disciplinary nature of waste RDI means that while RDI in the field is considered 'emerging', mature levels of capability may exist in other fields which could be applied into the waste sector (e.g. social sciences, polymer sciences, chemistry, physics, etc.) to strengthen current research. It also makes reporting for the waste sector challenging, e.g. scientific publications in the field of waste can be published across numerous domains, as shown, making it difficult to obtain accurate information for sector RDI (e.g. students, scientific outputs, investment, etc).

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