MOTIVATION FOR THE DEVELOPMENT OF NORMS & STANDARDS FOR THE TREATMENT OF ORGANIC WASTE IN SOUTH AFRICA

DRAFT REPORT FOR STAKEHOLDER REVIEW AND COMMENT

16 OCTOBER TO 16 NOVEMBER 2017

12 October 2017

Commissioned by: **Deutsche Gesellschaft für InternationaleZusammenarbeit (GIZ) GmbH**

South African – German Energy Programme (SAGEN)

Hatfield Gardens

333 Grosvenor Street

Pretoria 0028

South Africa

Contact: Dr Sascha Thielmann (sascha.thielmann@giz.de)

Website: www.giz.de

Consultant:

Cape Environmental Assessment Practitioners (Pty) Ltd

Reg. No. 2008/004627/07

Telephone: (044) 874 0365 17 Progress Street, George
Facsimile: (044) 874 0432 PO Box 2070, George 6530
Web: www.cape-eaprac.co.za

APPOINTED ENVIRONMENTAL ASSESSMENT PRACTITIONER:

***Cape EAPrac* Environmental Assessment Practitioners**

PO Box 2070

George

6530

Tel: 044-874 0365

Fax: 044-874 0432

Report written & compiled by: **Melissa Mackay** (BTech & ND Nature Conservation), who has eleven years' experience as an environmental practitioner.

Report reviewed by: **Louise-Mari van Zyl** (MA Geography & Environmental Science [US]; Registered Environmental Assessment Practitioner with the Interim Certification Board for Environmental Assessment Practitioners of South Africa, EAPSA). Ms van Zyl has over fifteen years' experience as an environmental practitioner.

PURPOSE OF THIS REPORT:

Motivation for the development of Norms & Standards for the treatment of organic waste in South Africa

CLIENT:

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

CAPE EAPRAC REFERENCE NO:

NAT414/08

SUBMISSION DATE

12 October 2017

"There is no such thing as organic waste, only wasted organics." (Vermi~BIOLOGICALS)

ACKNOWLEDGEMENTS & TASK TEAM PROFILES

Sincere thanks to the following Task Team members for their active support and constructive input during the process of investigating and developing these draft norms and standards:

Mr Stephen Brown

Stephen Brown is a Control Veterinary Public Health Officer with the national Department of Agriculture, Forestry & Fisheries (DAFF) and has been with the department for 20 years. His current portfolio includes Abattoir by-products and Waste Management. He has a National Diploma in Public Health from the Peninsula Technikon, Cape Town. Stephen has been working in the veterinary public health environment for the past 28 years.

Email: stephenb@daff.gov.za

Ms Sayuri Chetty

Sayuri Chetty is a BSc-Hons Environmental Science graduate from the University of KwaZulu-Natal. Since graduating, she obtained three years of experience in the energy and waste sector, of which the last two has been with the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, as a Renewable Energy Advisor. Her main focus at GIZ is on technical advice, knowledge management and improving on market and investment related conditions for the promotion of embedded generation from biogas and solar rooftop PV in South Africa.

Contact information:

Email: sayuri.chetty@giz.de

Mr Jason Gifford

Jason Gifford has spent the better part of the past 15 years developing biogas to energy solutions and technology and up until recently was the Business Unit Manager of the WEC Projects Biogas to Energy division. He spent 5 years working on biodiesel projects in East Africa and the Philippines as a solution for the biodiesel process waste products. He is currently the chairman of the South African Biogas Industry Association (SABIA).

One of his highlights was being instrumental in the success of South Africa's only operational biogas to energy on a municipal wastewater treatment installation.

Email: Jason@logicalwaste.co.za

Sofja Giljova

Sofja Giljova is renewable energy advisor at the Deutsche Gesellschaft fuer International Zusammenarbeit, (GIZ) GmbH, based in Pretoria. She has been working in the field of Biogas for four years focusing on commercial and regulatory technology aspects. She holds a diploma degree (master's equivalent) in Economics with the Focus on Energy Economics from the University of Cologne, Germany. Before joining GIZ South Africa Sofja was working for a large German Energy Utility and as a consultant for small and medium German municipal utilities.

Email: sofja.giljova@giz.de

Mr Paul Hoffman

Paul Hoffman has a qualification in M.Com Marketing Management and has spent 29 years working across sectors. Paul has extensive experience in business and marketing strategies,

export development, enterprise development and other disciplines, including corporate organisations, managing his own business and an academic background as lecturer. He is a specialist in developing Business and Marketing Strategies, Export Capacity Building and Development, as well as creating access to and implementation of funding programmes and other financing opportunities. He is currently Project Manager of the South Cape Economic Partnership in the Eden District Municipality, and as a partnership he is presiding over 8 task teams that look to implement projects in various sectors, including Waste Management and solutions from waste, Oil, Gas and Marine, amongst others. He has recently been part of a delegation to Sweden to investigate energy from waste solutions

Email: paul@wcedp.co.za

Ms Melissa Mackay

Melissa Mackay obtained her National Diploma Nature Conservation from PE Technicon in 2006 and a BTech from NMMU in 2014. She spent time travelling abroad from 1997 to 1999, gaining experience in various fields, including a position as animal handler & farm manager in the United Arab Emirates. She worked as Tourism Manager for Western Cape Nature Conservation Board from 2000-2004. Other experience includes a contract position as an on-board observer on commercial fishing vessels, pro bono Environmental Impact Assessment for Odzala-Koukoua National Park in the Republic of Congo, facilitator of the Southern Cape Weeds Forum and a participant in the Operation Phakisa for the Waste Economy in 2017. She has worked as an Environmental Practitioner since October 2006. Her main duties at Cape EAPrac include: Process Management for Environmental Impact Assessments, GIS and mapping, Damage Assessments, Environmental Management Plans, Environmental Control & Public Participation.

Email: mel@cape-eaprac.co.za

Ms Lebogang Mosenthal

Lebogang Mosenthal is in possession of Honours in Energy studies from University of Johannesburg and honours in Chemistry from North West University. She obtained 8 years' experience in energy sector. Her previous experience has been in natural gas policy and is currently working as a Project Manager in Renewable Energy Initiatives. Her main focus is in facilitating the implementation of biogas related activities and liaising with stakeholders in order to create an enabling environment for biogas industry.

Email: Lebogang.Mosenthal@energy.gov.za

Ms Lerato Pilane

Lerato Pilane obtained her B Tech Environmental Health qualification from Tshwane University of Technology. She has 15 years' experience in both Environmental Health and Veterinary Public Health fraternities. She is currently Veterinary Public Health Officer at DAFF providing technical support to provinces on abattoir waste management.

Email: leratop@daff.gov.za

Dr Jaisheila Rajput

As Founder and CEO of Toma-Now, Jaisheila Rajput is passionate about developing economic models for sustainability and transforming the way we do business. Jaisheila obtained a PhD in Chemistry from the University of Cape Town. From the beginning, she has leveraged her research and innovation capabilities into developing practical, industry relevant solutions. She has a career spanning over a decade in large corporates in the automotive, chemicals and construction industries.

Her rich background includes technical, management systems, strategy and sustainability. She has worked in several countries including South Africa, Germany and Hong Kong. Jaisheila brings a fresh global perspective to the development of solutions for companies doing business in Africa.

Email: jaisheila.rajput@toma-now.com

Prof. William Stafford

William Stafford is a life scientist with twenty one years of R&D experience in diverse fields of biochemistry, microbial ecology, systems biology, bioenergy, permaculture, holistic resource management, industrial ecology and sustainability science. William is a researcher in the Green Economy Solutions competency area at the Council for Scientific and Industrial Research (CSIR), and an extraordinary associate professor in the Department of Industrial Engineering at Stellenbosch University.

Email: wstafford@csir.co.za

Dr Walter Stinner

Walter Stinner obtained his PhD in Agricultural Sciences at the University of Giessen in Germany, with a dissertation topic of “Influence of biogas production on yields and environmental effects in organic cash crop farms”. Since 2008, he has been working as a Scientist at the German biomass research center (DBFZ). Walter has more than 18 years of experience in the area of biogas technology, mass flow management, project development and business model creation in the framework of biogas projects. This includes nutrient cycling, hygiene chains and legal aspects of the option of fertilizer creation via anaerobic treatment of organic wastes of different origin.

Email: Walter.Stinner@dbfz.de

Mr Mark Tiepelt

Mark Tiepelt is a qualified civil engineer with 26 years’ experience in construction, alternative building and sustainable energy technologies. Mark established his company BiogasSA in 2009 and has built over 150 domestic scale digesters as well as a 400kW commercial biogas plant at an abattoir in Springs in South Africa. Mark has conducted numerous biogas related feasibility studies and reports and consults regularly to the biogas industry. Over the years Mark has been actively involved in developing the biogas industry in SA by organizing the first biogas workshop back in Nov 2012, was instrumental in the formation of SABIA (served as chairman for 3 years), played a key role in the establishment of the National Biogas Platform and was appointed in July 2017 by UNIDO as administrator for SABIA.

Contact information:

Email: mark@biogassa.co.za

Mr Horst Unterlechner

Horst Unterlechner holds a degree in Civil Environmental Engineering (Ing.) from HTL Innsbruck, Austria. He has over 25 years of experience in design, planning and development specialising in the abattoir, deboning, cold storage and food processing projects, with over 15 years in renewable energy projects, specialising in small scale biogas systems. He is the owner and founder of iBert (Pty) Ltd who specialise in biogas development in South Africa and is a steering committee member of the South African Biogas Industria Association (SABIA).

Email: horst@ibert.co.za

Ms Louise-Mari van Zyl

Louise-Mari van Zyl holds a Masters degree in Geography & Environmental Sciences from the University of Stellenbosch. She has worked as an Environmental Assessment Practitioner (EAP) since 2002 on projects in the Eastern, Southern, Western & Northern Cape provinces. She is a registered Environmental Assessment Practitioner with the Interim Certification Board for Environmental Assessment Practitioners of South Africa

Email: louise@cape-eaprac.co.za

MOTIVATION FOR THE DEVELOPMENT OF NORMS & STANDARDS FOR THE TREATMENT OF ORGANIC WASTE IN SOUTH AFRICA

Submitted for:
Stakeholder Review & Comment

Report Issued by:
Cape Environmental Assessment Practitioners

Tel: 044 874 0365
Fax: 044 874 0432
Web: www.cape-eaprac.co.za

PO Box 2070
17 Progress Street
George 6530

ORDER OF REPORT

Motivation Report

Appendix 1 : National Greenhouse Gas Emission Reporting Regulations

Appendix 2 : National Dust Control Regulations

Appendix 3 : Revision of General Authorisations Section 39 of the NWA

Appendix 4 : Regulations Regarding Fertilisers

Appendix 5 : Draft Norms & Standards for Treatment of Organic Waste

Appendix 6 : Public Participation Report (Pending)

TABLE OF CONTENTS

ABBREVIATIONS AND ACRONYMS XIII

1 INTRODUCTION 16

1.1 FRAMEWORK OF THE REPORT 21

2 LEGISLATIVE REVIEW 21

2.1 DEFINITIONS OF WASTE 22

2.2 NATIONAL ENVIRONMENTAL MANAGEMENT ACT 107 OF 1998 (NEMA) 27

2.2.1 Applicability of NEMA Chapter 5 to SEMAs 29

2.3 NATIONAL ENVIRONMENTAL MANAGEMENT: WASTE ACT 59 OF 2008 (NEM: WA) 32

2.4 NATIONAL ENVIRONMENTAL MANAGEMENT: WASTE AMENDMENT ACT 26 OF 2014 (NEM: WAA) 33

2.5 NATIONAL ENVIRONMENTAL MANAGEMENT: AIR QUALITY ACT 39 OF 2004 (NEM:AQA) 33

2.6 NATIONAL WATER ACT 36 OF 1998 (NWA) 34

2.6.1 South African Water Quality Guidelines 34

2.7 FERTILISER, FARM FEEDS, AGRICULTURAL REMEDIES AND STOCK REMEDIES ACT (ACT 36 OF 1947) 35

2.8 NATIONAL GAS ACT (ACT 48 OF 2001) 36

2.9 ELECTRICITY REGULATION ACT (ACT 4 OF 2006) 36

2.10 SPATIAL PLANNING AND LAND USE MANAGEMENT ACT (SPLUMA, ACT 16 OF 2013) 37

2.11 BY-LAWS 37

3 NORMS & STANDARDS DEVELOPMENT 37

3.1.1 Norms & Standards Registration Process 40

4 SENSITIVE ENVIRONMENTS 40

5 ORGANIC WASTE STREAMS / FEEDSTOCKS 42

6 TECHNOLOGIES 48

6.1 MECHANICAL 49

6.1.1 Briquetting 50
6.1.2 Centrifuge 53
6.1.3 Chipping 56
6.1.4 Pelleting 57
6.1.5 Sonification 59
6.2 CHEMICAL 60
6.2.1 Chemical hydrolysis 61
6.2.2 Chemical oxidation 62
6.2.3 Transesterification 64
6.2.4 Saponification 66
6.3 ANAEROBIC 68
6.3.1 Anaerobic digestion 68
6.4 AEROBIC 73
6.4.1 Aerobic digestion 74
6.4.2 Black Soldier Fly Larvae 77
6.4.3 Composting 80
6.4.4 Vermicomposting 82
6.5 THERMAL 84
6.5.1 Aqueous Phase Reforming (APR) 87
6.5.2 Combustion 89
6.5.3 Drying 90
6.5.4 Gasification 92
6.5.5 Hydrothermal Carbonization (HTC) 95
6.5.6 Hydrothermal Liquefaction (HTL) 97
6.5.7 Pressure Heating / Supercritical Water Gasification 98
6.5.8 Pyrolysis 101
6.5.9 Rendering 102
6.5.10 Torrefaction 105

7 ENVIRONMENTAL IMPACTS 107
7.1 AIR QUALITY IMPACTS 118
7.2 ODOUR AND DUST IMPACTS...... 120
7.3 WATER QUALITY IMPACTS 121
7.4 SOIL QUALITY IMPACTS 124
7.5 POSITIVE ENVIRONMENTAL IMPACTS...... 125
7.6 ECONOMIC IMPACTS 126
8 MITIGATION AND MANAGEMENT 127
9 BIOENERGY 135
10 USE OF PRODUCT MATERIAL 137
10.1 PRION AND PATHOGEN DEACTIVATION...... 138
10.2 COMMERICAL PRODUCTS CONTAINING SLUDGE...... 140
11 CONCLUSION......141
12 BIBLIOGRAPHY 143
13 GLOSSARY OF TERMS 152

TYPES OF FEEDSTOCK 164

DEFINITIONS OF TECHNOLOGIES......166

TABLES

Table 1: Types of Feedstocks......23
Table 2: Categories of organics (Department of Environment and Conservation (NSW), 2004)......26
Table 3: List of environmentally inappropriate areas for composting and related organics processing facilities (Department of Environment and Conservation (NSW), 2004).......41
Table 4: Task Team proposed list of environmentally sensitive exclusionary sites. 42
Table 5: Feedstock uses and problems (Department of Environment and Conservation (NSW), 2004) 44
Table 6: Organic waste categorisation (Department of Environment and Conservation (NSW), 2004) 48
Table 7: Summary of mechanical technologies 49

Table 8: Summary of chemical technologies 60

Table 9: Summary of anaerobic digestion technology 68

Table 10: Summary of aerobic technologies...73

Table 11: Summary of thermal technologies...85

Table 12: Environmental impacts related to the collection and transport of organic feedstock (COWI, 2004) 108

Table 13: Emissions and related impacts from various waste treatment options (COWI, 2004) 108

Table 14: Typical impacts and potential mitigation measures for a composting operation (Department of Environmental Affairs, 2013)..110

Table 15: Typical impacts associated with compost and related organics processing facilities 113

Table 16: Potential impacts per technology 117

Table 17 : Wastewater limit values applicable to the irrigation of any land or property up to 2000m3 (Department of Water & Sanitation, 2013) 123

Table 18: Wastewater limit values applicable to the irrigation of any land or property up to 500m^3 (Department of Water & Sanitation, 2013)...124

Table 19: Wastewater limit values applicable to the irrigation of any land or property up to 50m^3 (Department of Water & Sanitation, 2013) 124

Table 20: Management requirements per technology type 128

FIGURES

Figure 1: Classification of total waste generated in South Africa in 2011 16

Figure 2: Waste composition for general waste (Mosia, Laugesen, Pillay, & Tsikata, 2012) .17

Figure 3: Composition of solid wastes generated in East African urban centres (Bello, Ismail, & Kabbashi, 2016)...18

Figure 4: Total waste generation EU (Eurostat, Waste indicators on generation and landfilling measuring sustainable development 2004-2010, 2013)...19

Figure 5: USA municipal solid waste (US Environmental Protection Agency, 2016) 19

Figure 6: Waste hierarchy (DST, 2014) 21

Figure 7: Sources of biomass (Ahmed, Nasri, & Hamza, 2012) 42

Figure 8: Mechanised briquette maker (Source: Kefan Machinery) 51

Figure 9: Manual briquette maker (Source: Multimate Designs) 52

Figure 10: Centrifuge decanter using wastewater (Source: Sinoped) 54

Figure 11: Biomass chipping (Source: Eden Woodlands) 56

Figure 12: Cornstalk pellets (Gemco Energy, 2017) 58

Figure 13: Sonification process (Sonotronic, 2017) 59

Figure 14: General process for production of biofuels (Tatsis & O'Connor, 2016) 62

Figure 15: Ethanol reservoirs at the Arcis-sur-Aube sugar refinery and distillery in eastern France © AFP 63

Figure 16: Transesterification process (Minerals Processing Research Institute, 2017) 65

Figure 17: Saponification process (University of Notre Dame, 2017) 67

Figure 18: Bio2watt plant near Bronkhorstpruit, South Africa 69

Figure 19: Typical small scale biogas process (Muvhiiwa, Hildebrandt, Chimwani, Ngubevana, & Matambo, 2017) 69

Figure 20: Biogas yields of various substrates in m3/tonne (Kigozi, Aboyade, & Muzenda, 2014) 71

Figure 21: Small scale biodigester in Muldersdrift, Johannesburg, South Africa (Muvhiiwa, Hildebrandt, Chimwani, Ngubevana, & Matambo, 2017) 71

Figure 22: AB treatment at Garmerwolde WWTP in the Netherlands (Pronk, de Kreuk, de Bruin, Kamminga, Kleerebezem, & van Loosdrecht, 2015) 75

Figure 23: Composting toilet system (clivusmultrum Incorpporated, 2010) 76

Figure 24: Black soldier fly larvae composting concept (Lalander, Fidjeland, Diener, Eriksson, & Vinnerås, 2015) 79

Figure 25: The biomass is aerated to ensure aerobic composting, resulting in the production of carbon dioxide and heat rather than methane (myclimate, 2017) 81

Figure 26: Vermicomposting (ecoideaz, 2016) 83

Figure 27: Bioforming process (New Energy and Fuel, 2009) 87

Figure 28: Biomass combustion (Minh, 2013) 89

Figure 29: Wood chip dryer (Nexus Energy, 2017) 91

Figure 30: Process of gasification (All Power Labs, 2017) 93

Figure 31: Biomass gasification (WPP Energy Corp, 2010) 94

Figure 32: Cascade use of HTC (Kopinke, 2016) 95

Figure 33: Effect of pressure and temperature over time on biomass (Lachos-Perez , Juliana , Torres-Mayanga , Forster-Carneiro, & Meireles, 2015) 99

Figure 34: Co-pyrolysis and products (Abnisa & Daud, 2014) 101

Figure 35: Historical rendering process (Mavitec, 2017) 103

Figure 36: Micro rendering plant outside of an abattoir (WRT, 2017) 104

Figure 37: Torrefaction of biomass (Indiamart, 2017) 105

Figure 38: Banding of the SA AQI (Department of Environmental Affairs, 2012) 119

Figure 39: Diagrammatic representation of the performance of biofuels compared to petroleum fuels in terms of global effect (greenhouse gas emissions) and local emissions (air pollutants) (Stafford, Lotter, von Maltitz, & Brent, 2017) 120

Figure 40: Odour compounds (Department of Environment and Conservation (NSW), 2004) 121

Figure 41: Acceptable dust fall rates (Department of Environmental Affairs, 2013) 121

Figure 42: Value of selected wastes (Department of Science & Technology, 2014) 126

Figure 43: What is Bioenergy? (Schubert, et al., 2009) 136

Figure 44: Biofuel technologies (Norton, 2009) 137

Figure 45: Summary of inactivation of different pathogens by different treatments (Franke-Whittle, 2011) 139

Figure 46: Regulatory requirements for the commercial use of sludge (Department of Water Affairs , 2008) 140

ABBREVIATIONS AND ACRONYMS

AC	Aerobic Composting
AEL	Air Emissions License
AD	Anaerobic Digestion
APR	Aqueous Phase Reforming
BAR	Basic Assessment Report
BPEO	Best Practicable Environmental Option
CA	Competent Authority
CHP	Combined heat and power generator
COD	Chemical Oxygen Demand
Cu	Cattle unit
DAFF	Department of Agriculture, Forestry & Fisheries
DEA	Department of Environmental Affairs
DEC	Department of Environment and Conservation
DOE	Department of Energy
DWS	Department of Water & Sanitation
EA	Environmental Authorisation
EAP	Environmental Assessment Practitioner
EHS	Environmental, Health & Safety
EIA	Environmental Impact Assessment
EIR	Environmental Impact Report
EU	European Union
GIS	Geographic Information System
GWh	Giga Watt hour
HTC	Hydrothermal carbonisation
HTL	Hydrothermal liquefaction
I&APs	Interested and Affected Parties

IDP	Integrated Development Plan
IEM	Integrated Environmental Management
ISO	International Organisation for Standardisation
kV	Kilo Volt
MEC	Minister of the Executive Committee
MSW	Municipal Solid Waste
MW	Mega Watt
N&S	Norms and Standards
NAQI	National Air Quality Indicator
NEMA	National Environmental Management Act 107 of 1998
NEM:AQA	National Environmental Management: Air Quality Act 39 of 2004
NEM:BA	National Environmental Management: Biodiversity Act 10 of 2004
NEM:ICMA	National Environmental Management: Integrated Coastal Management Act 24 of 2008
NEM:PAA	National Environmental Management : Protected Areas Act 57 of 2003
NEM:WA	National Environmental Management: Waste Act 59 of 2008
NERSA	National Energy Regulator of South Africa
NHRA	National Heritage Resources Act
NID	Notice of Intent to Develop
NOWCS	National Organic Waste Composting Strategy
NSBA	National Spatial Biodiversity Assessment
NSW	New South Wales
NWA	National Water Act 36 of 1998
OFMSW	Organic Fraction of Municipal Solid Waste
OHSA	Occupational Health and Safety Act
S&EIR	Scoping & Environmental Impact Report
SAHRA	South African National Heritage Resources Agency
SANBI	South Africa National Biodiversity Institute

SANS	South Africa National Standards
SCWG	Supercritical water gasification
SDF	Spatial Development Framework
SEMA	Special Environmental Management Acts
SPLUMA	Spatial Planning and Land Use Management Act
SSO	Source Separated Organics
WML	Waste Management License

1 INTRODUCTION

Cape Environmental Assessment Practitioners (*Cape EAPrac*) has been appointed by the **Deutsche Gesellschaft für Internationale Zusammenarbeit** (GIZ) to facilitate the development of a Motivation for Norms & Standards document for the treatment of organic waste in South Africa. This process is being undertaken in terms of Chapter 5 of the National Environmental Management Act (NEMA, Act 107 of 1998 as amended), the National Environmental Management: Waste Act (Act 59 of 2008), Regulation 9 of GN 634 dated 23 August 2013 and the National Environmental Management: Air Quality Act (NEM:AQA, Act 39 of 2004).

This motivation report serves to provide information to the national Department of Environmental Affairs (DEA) in support of the development of a Norms & Standards document which will provide a legal framework for operators for the treatment of organic waste without having to undertake potentially onerous and expensive licensing / permitting processes. The intent is not to avoid regulation but rather to apply the same standards across the board for treatment / technologies which have similar environmental impacts without putting undue pressure on the departmental capacity, whilst stimulating private sector involvement in the green economy and help reduce waste to landfill.

According to the National Waste Information Baseline (NWIB), South Africa generated approximately 108 million tonnes[1] of waste in 2011, consisting of 59 million tonnes of general[2] waste; 48 million tonnes of unclassified waste[3]; and 1 million tonnes of hazardous waste (see Figure 1 for the split in terms of percentage of total waste) (GreenCape, 2016; Department of Environmental Affairs, 2012).

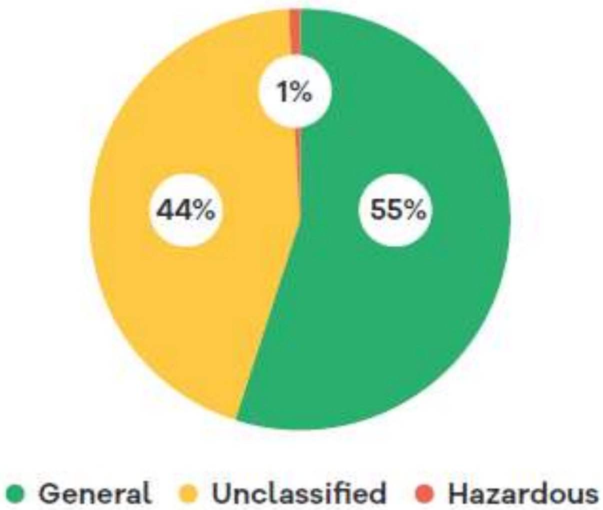


Figure 1: Classification of total waste generated in South Africa in 2011

[1] This volume was calculated at 111 million tonnes in 2017
[2] "general waste" means waste that does not pose an immediate hazard or threat to health or to the environment, and includes non-hazardous substances, materials or objects within business, domestic, inert, building and demolition wastes as outlined in Schedule 3 of Act 26 of 2014, National Environmental Management: Waste Amendment Act.
[3] These are wastes that are listed under both general and hazardous waste and will require further classification, in terms of the Waste Classification and Management Regulations (GNR 634).

The current status of waste management in South Africa illustrates a culture of generation and disposal, as only 10% of waste is recovered to be reprocessed / repurposed. It is estimated that 65% of the classified waste (around 38 million tonnes) is classified as recyclable[4], and therefore could theoretically be diverted from landfill and recovered to be reprocessed/repurposed (GreenCape, 2016; Department of Environmental Affairs, 2012). It is a widely acknowledged premise both nationally and internationally that efforts must be increased to reduce the volume of waste that is directed to landfill sites.

According to the 2012 data (Department of Environmental Affairs, 2012), 13% of recorded South African organic municipal waste is generated in municipal areas and currently landfilled. This figure is only for municipal waste and the volume increases significantly when considering agricultural, food processing and biomass that does not enter the municipal waste stream. The waste streams (or feedstocks) are expanded on in Section 2.1 of the report.

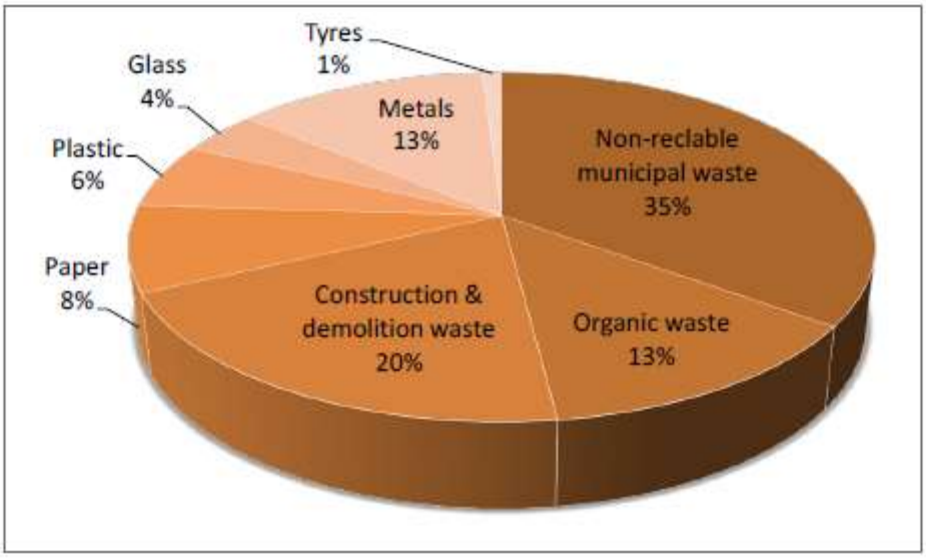


Figure 2: Waste composition for general waste (Mosia, Laugesen, Pillay, & Tsikata, 2012)

It must be noted that using the data from the South African Waste Information Centre (SAWIC) collated for 2016, organic waste was only identified as making up 5.61% of the general waste recorded. The records however also include “General: Municipal Waste” as a category and it is not clear if unsorted household organic waste make up part of that category and as such was not included in the calculation. In addition, not all volumes are necessarily captured onto SAWIC, and as such, the estimation of organic waste used will remain that by DEA in 2012. Better database evaluation and reporting is strongly recommended and it will be a requirement of the Norms & Standards to ensure that organic waste facilities fulfil reporting requirements.

The commonly adopted ‘waste management hierarchy’ prioritises source reduction, followed by reuse and recycling. Treatment or processing of waste is considered only once waste

[4] Recyclable materials include construction and demolition waste (20%), metals (13%), organic waste (13%) and common dry recyclables (including paper, plastics, glass and tyres) (19%).

minimisation techniques have been explored whilst disposal is considered as a last option. Efforts to reuse and recycle alone will not achieve the Department's 'zero-to-landfill' initiative, therefore it is important to also focus on treatment of organic wastes because of its potential for deriving useful products and energy.

In Africa waste related problems are not uncommon. Cities such as Accra in Ghana only manages a 55% collection which leads to an excess of 1 700 000 tonnes of waste accumulating in the core city areas (Agbelie, Bawakyillenuo, & Lemaire, 2015). The majority of waste generated in most parts of Africa is organic, associated with peoples consumption relating mostly to kitchen and compounds as opposed to e-waste for example (Bello, Ismail, & Kabbashi, 2016). Given the health risks associated with uncollected and untreated waste and the energy demand in African cities, attention is being directed to developing energy recovery facilities from waste, thus improving lives and providing jobs within the green economy (United Nations, 2009).

Waste Composition (%)	Dar es Salaam	Moshi	Kampala	Jinja	Lira	Nairobi
Bio-waste	71	65	77.2	78.6	68.7	65
Paper	9	9	8.3	8	5.5	6
Plastic	9	9	9.5	7.9	6.8	12
Glass	4	3	1.3	0.7	1.9	2
Metal	3	2	0.3	0.5	2.2	1
Others	4	12	3.4	4.3	14.9	14
Kg/cap/day	0.4	0.9.	0.59	0.55	0.5	0.6
Percent collection	40	61	60	55	43	65
Population	3,070,060	183,520	1,700,850	91,153	107,809	4,000,000
Population paying for collection(% of total population		35	ND	ND	ND	45

Figure 3: Composition of solid wastes generated in East African urban centres (Bello, Ismail, & Kabbashi, 2016)

Comparisons of organic waste content of municipal waste outside of South Africa, particularly the European Union (EU) (Eurostat, 2017), Australia (MRA Consulting, 2016) and the United States of America (USA) (US Environmental Protection Agency, 2016) show volume percentages of organic waste closer to 40% and some as high as 45%. This indicates a significantly larger portion of waste is recycled as organic waste internationally than locally, although there does seem to be some differentiation in the various classifications by different countries. It would then be reasonable to assume that South Africa's organic waste volumes should be estimated to be between 40 and 70% and probably more comparable with those of Nairobi at 65% as shown in the figure above.

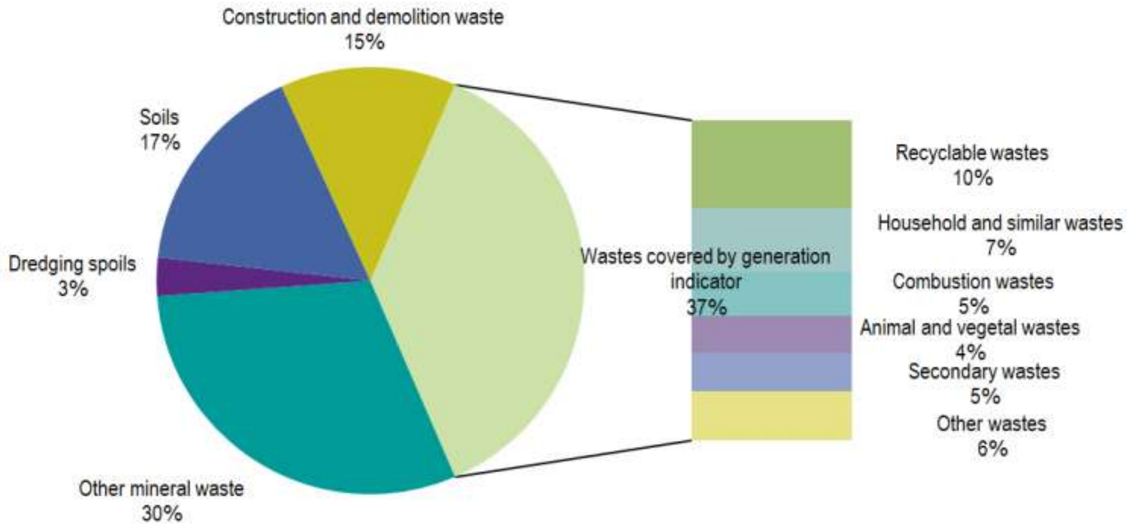


Figure 4: Total waste generation EU (Eurostat, Waste indicators on generation and landfilling measuring sustainable development 2004-2010, 2013)

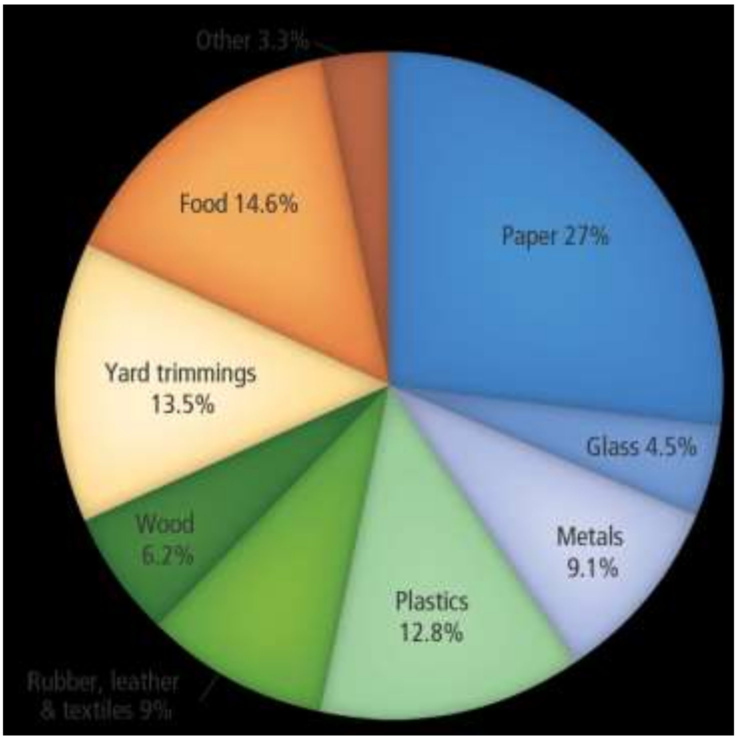


Figure 5: USA municipal solid waste (US Environmental Protection Agency, 2016)

The EU (Council of the European Union, 1999) identified organic or biodegradable waste as a low hanging fruit for removal from landfill sites when drafting the directive specifying landfill wastes. This was then further quantified (COWI, 2004) with targets set for member states aimed at significantly reducing the disposal of waste to landfill and in support of greenhouse gas reduction and renewable energy strategies.

In 2016 Australia identified the most important infrastructure opportunities for waste management which included organics facilities that convert food and garden waste into compost or energy from waste (pyrolysis, gasification, incineration and anaerobic digestion) for renewable energy solutions (MRA Consulting, 2016).

In the USA, waste volumes have decreased significantly from 1970 to 2011 due to the increase in recycling, composting and combustion for energy recovery (US Environmental Protection Agency, 2014). In response to the greenhouse gas emissions, the US EPA has undertaken extensive work implementing Landfill to Gas (LFG) on existing landfill sites whilst encouraging source separation for recycling and composting to improve quantities of waste going to landfill.

Given the available volumes of organic waste in Africa and South Africa, the UN Economic Commission for Africa identified waste management coupled with energy recovery as a high priority to address economic issues on the continent (United Nations, 2009). Biogas and composting were rated as most successful of technologies that have been implemented to date, with particular reference to private sector involvement to lessen capacity constraints on local governments.

Global trends in waste management are showing a shift from “end of pipe” waste management (mostly landfilling) to a circular economy approach, recognizing that many waste streams are resources rather than waste (Department of Science & Technology (DST), 2014). This approach led to research by the CSIR to examine the current waste hierarchy approach and suggest moving waste up the hierarchy towards reuse, recycling and recovery (DST, 2014). The value of this approach is the development of a “green economy” supporting the following principles:

- Re-introduction of resources back into the economy
- Contribution to economic growth and job creation, and
- Reducing social and environmental costs

The national ‘waste hierarchy’ currently shows preference for opportunities aimed at prevention or reduction followed by reuse, recycling, recovery and only then disposal. This model however, does not take into account the potential economic value recovering waste streams as resources (DST, 2014). Furthermore, when taking into account organic waste, it is unlikely that prevention or reduction is likely to occur successfully, as much of the waste comes from food supply and the value in beneficiating the material as a primary resource is quite significant.

Figure 6: Waste hierarchy (DST, 2014)

This report therefore provides the necessary information required for the DEA to establish Norms & Standards for the treatment of organic waste that alleviates issues with institutional capacity, promotes the green economy and the development of South Africans, improves waste management and provides for development of energy recovery.

1.1 FRAMEWORK OF THE REPORT

The overall objective of this report is described as follows:

- get an understanding of the waste streams, technologies and operational processes for the treatment of organic waste,
- understand infrastructure and location requirements for the treatment options,
- identify impacts associated with the various treatment options,
- identify “listed activities” associated with current legislation that would be applicable to these treatment options;
- drafting norms & guidelines for organic waste treatment that can be effectively implemented, measured and monitored.

2 LEGISLATIVE REVIEW

The management and treatment of waste is predominantly legislated by the National Environmental Management (NEMA, Act 107 of 1998, as amended) and the Specific Environmental Management Act (SEMA), the National Environmental Management: Waste Act (NEM:WA, Act 59 of 2008) and the National Environmental Management: Air Quality Act (NEM:AQA, Act 39 of 2004). There are some additional pieces of legislation that may play a supporting or corresponding role and these have been referred in the review below.

It must be noted that NEMA provides the basis for the development of Norms & Standards in Chapter 5 where it provides for Integrated Environmental Management. In terms of Chapter 5, specifically sections 24(2)(a) and 24(10) and the NEMA definitions of "*activities*", "*environmental authorisation*", "*Minister*" and "*norms and standards*", it is clear that NEMA provides for the development of Norms & Standards that include any activities identified in terms of the SEMA's (in this case NEM:WA and NEM:AQA) that follow the objectives of integrated environmental management. This stance is expanded on in Sections 2.2 and 2.5 below.

Since this document relates to the organic waste stream, it is important to fully understand the definitions of what constitutes a "waste" in terms of the current relevant legislation.

2.1 DEFINITIONS OF WASTE

National Environmental Management: Waste Amendment Act, 2014 (Act 26 of 2014):

"Waste" means -

a) Any substance, material or object that is unwanted, rejected, abandoned, discarded or disposed of[5] or is intended or required to be discarded or disposed of, by the holder of that substance, material or object whether or not such substance, material or object can be re-used, recycled or recovered and includes all wastes as defined by Schedule 3 of the Act;

b) Any other substance, material or object that is not included in Schedule 3 that may be defined as a waste by the Minister by notice in the Gazette.

National Water Act, 1998 (Act 36 of 1998):

"Waste" includes any solid material or material that is suspended, dissolved or transported in water (including sediment) and which is spilled or deposited on land or into a water resource in such volume, composition or manner as to cause, or to be reasonably likely to cause, the water source[6] to be polluted".

When considering the organic waste stream in terms of the definitions above it is clear that in South Africa it (organic waste) is legally considered to be a "waste" and thus its disposal and treatment is regulated. The organic waste component in waste streams has been documented extensively in many countries globally and the principal motivation in its classification is its level of biodegradability and the positive impacts which result as a removal of organic wastes from landfill sites[7]. Since organic waste is by its very nature biodegradable and thus has further value in its

[5] Our emphasis.
[6] Our emphasis.
[7] DEFRA, 2004; COWI A/S, 2004; Eunomia, 2002; Arthurson, 2009; European Union Directive 2008/98/EC; Hugo, 2016

decomposition and subsequent controlled reuse, this report uses the term “feedstock” to refer to this type of waste material.

The Task Team involved with developing the draft Norms & Standards for Organic Composting in South Africa identified five (5) classes of feedstock which align with the Bioenergy Atlas for South Africa (2016) as a minimum, but included specific feedstocks that are organic and biodegradable but are not necessarily considered as biofuel in the Atlas.

One of the most important criteria in determining the inclusion of an organic waste into this report is its biodegradability. Biodegradable is defined by the following sources as:

- Oxford English Dictionary (Oxford University Press, 2017) - “*A substance or object capable of being decomposed by bacteria or other living organisms and thereby avoiding pollution*[8]”;
- EU Landfill Directive ((Council of the European Union, 1999) as “*any waste that is capable of undergoing anaerobic or aerobic decomposition*[9]*, such as food and green waste, and paper and paperboard”;*
- (Department of Environment and Conservation (NSW), 2004)- “*able to be transformed to a lower state by environmentally significant biological processes*”.

Thus from these definitions, the feedstocks below have been identified based on their ability to decompose and in doing so avoid pollution by means of a natural process and most importantly, remove a significant amount of waste from landfill sites that are unable to beneficiate them as feedstocks.

The norms & standards are aimed at providing an enabling environment to encourage the use of technologies for the treatment of organic feedstocks. It is advisable for the business cases for facilities that make use of the feedstocks must take into consideration the need to act / treat (i.e. pollution potential), the need for hygienisation / pasteurisation (prevention of vector spread), economy of scale, effort required for collection, harvest and pre-treatment and the connection with the product needs post treatment.

Table 1: Types of Feedstocks

TYPES OF FEEDSTOCK	
Agriculture:	
Manure	Animal dung or slurry.
Mortalities	Used in relation to agricultural livestock, this refers to animals that have died on site due to natural causes and excludes mortalities due

[8] Our emphasis
[9] Our emphasis

	to infectious diseases as identified by DAFF that requires hazardous treatment / intervention. These are specifically animals that have died before intentional slaughter, or from injury or old age.
Biomass: Lignocellulose (woody)	
Agricultural crop residue	Woody plant material remaining after harvesting, including bark, stalks, roots, offcuts, etc.
Invasive plant species	Woody plant species identified as invasive species in terms of the NEM:BA and requiring management actions to remove / destroy. In many instances the material may not remain in situ to prevent ongoing spread and must be removed.
Plantation residue	Branches, bark, stumps, prunings and any part of the tree discarded after harvesting has taken place.
Sawmill residue	This includes sawdust, woodchip, bark, planer shavings, and pole shavings that accumulate at milling sites.
Biomass: Low Lignocellulose (non woody)	
Agricultural crop residue	Residue from low lignocellulose crops such as maize, sweet sorghum, groundnuts, soybeans, cane straw and sunflowers.
Invasive plant species	Non-woody plant species identified as invasive species in terms of the NEM:BA and requiring management actions to remove / destroy. In many instances the material may not remain in situ to prevent ongoing spread and must be removed.
Sugar bagasse	Bagasse is the fibrous matter that remains after sugarcane or sorghum stalks are crushed to extract their juice. It is dry pulpy residue left after the extraction of juice from sugar cane. Bagasse is used as a biofuel and in the manufacture of pulp and building materials.
Processing:	
Abattoir	Abattoir waste can be defined as waste or waste water from an abattoir which could consist of the pollutants such as animal faeces, blood, fat, animal trimmings, paunch content and urine.

Food Oils	Food oils used for human consumption are generally plant oils and extracts and animal fats and oils. Vegetable oils include extracts from olives, palm, soybean, rapeseed / canola, sunflower seed, peanuts, coconuts and avocado to name a few, whilst animal oils include fish oil (omega 3 oil), lard and lanolin. As waste products these are characterised by high salinity, low pH values, high contents in phenol derivates and organic matter and nutrients.
Organic Fraction of Municipal Solid Waste (MSW)	Biodegradable organic waste produced by residential, commercial and industrial activities and disposed of at municipal landfill sites. In 2011, South Africa generated 59 million tons of municipal waste of which 13% was classified as organic waste.
Restaurant / kitchen	Food left overs such as fish, beef cooked or fresh, chicken cooked or fresh, potato fried fresh, vegetable, beans, cake and bread as an mixer or single waste
Food processing	Residues from the processing of agricultural and food products and includes whey, fruit and vegetable pulp, dairy products, wind and beer manufacturing.
Sewage:	
Sludge	Sewage sludge refers to the residual, semi-solid material that is removed and produced as a by-product during the treatment of sewage. There are two basic forms of sewage sludge - raw or primary sludge and secondary sludge, also known as activated sludge or waste activated sludge in the case of the activated sludge process. Sewage sludge is usually treated by one or several of the following treatment steps: lime stabilization, thickening, dewatering, drying, anaerobic digestion or composting.

The Department of Environment and Conservation (NSW) in Australia identified three main factors in determining categories for organic waste. These are:

- Category 1: Potential to generate offensive odours
- Category 2: Potential to attract vermin and vectors
- Category 3: Potential to generate harmful leachate, which could contaminate surface water, groundwater and soil.

Category 1 organics have the lowest potential environmental impact, Category 2 organics have a greater impact and Category 3 organics have the greatest potential to seriously affect the receiving environment. Although the potential impact of each category is different, the environmental performance requirements are the same for facilities processing any category of organics. Thus environmental performance requirements or Norms & Standards can be applied to ensure management of potential impacts.

Table 2: Categories of organics (Department of Environment and Conservation (NSW), 2004)

Potential to have environmental impact	Organics category	Types of organics permitted in categories[1] (Categories with larger numbers may contain types from classes with smaller numbers.)	
		Type	Examples of organics
Lowest potential environmental impact	Category 1	Garden and landscaping organics	Grass[2]; leaves; plants; loppings; branches; tree trunks and stumps.
		Untreated timber	Sawdust; shavings; timber offcuts; crates; pallets; wood packaging.
		Natural organic fibrous organics	Peat; seed hulls/husks; straw; bagasse and other natural organic fibrous organics.
		Processed fibrous organics	Paper; cardboard; paper-processing sludge; non-synthetic textiles.
Greater potential environmental impact than Category 1, less potential impact than Category 3.	Category 2	Other natural or processed vegetable organics	Vegetables; fruit and seeds and processing sludges and wastes; winery, brewery and distillery wastes; food organics excluding organics in Category 3.
		Biosolids[3] and manures	Sewage biosolids, animal manure and mixtures of manure and biodegradable animal bedding organics.
Greatest potential environmental impact	Category 3	Meat, fish and fatty foods	Carcasses and parts of carcasses; blood; bone; fish; fatty processing or food.
		Fatty and oily sludges and organics of animal and vegetable origin	Dewatered grease trap; fatty and oily sludges of animal and vegetable origin.
		Mixed residual waste containing putrescible organics	Wastes containing putrescible organics, including household domestic waste that is set aside for kerbside collection or delivered by the householder directly to a processing facility, and waste from commerce and industry.

Notes:

1. These categories are used only to facilitate reference to these groupings of waste and organics (with different potential environmental impacts) in these guidelines and in environment protection licences: they are **not** used in waste legislation.
2. Particular care should be taken when grass clippings are present in the feedstock. It is well known that careful process management is required to mitigate odour and leachate problems when processing grass clippings (e.g. Buckner 2002). High moisture content, high nitrogen levels, abundance of readily available organic matter and poor structure and tendency to mat mean that grass can easily become anaerobic and odorous.
3. Conditions applying to processing and use can be found in *Environmental Guidelines: Use and Disposal of Biosolids Products* (EPA 1997).

As can be seen in Table 2 above, the identification of organic waste by the DEC (NSW) is compatible with those identified by the Task Team. It must also be noted at this point, that the National Organic Waste Composting Strategy (NOWCS, 2013) which has subsequently led to the Draft Norms & Standards for Organic Waste Composting (2014), utilised a very similar approach given the development of regulation that has taken place in Australia and the EU to date.

2.2 NATIONAL ENVIRONMENTAL MANAGEMENT ACT 107 OF 1998 (NEMA)

The NEMA is the framework Act dealing with environmental management in South Africa. It covers pollution prevention, environmental management principles, incident management, and environmental authorisations.

NEMA is a national Act and as such the national Department of Environmental Affairs (DEA) is the competent authority for authorising applications.

NEMA enables a series of Acts known as the Special Environmental Management Acts (SEMA's). These focus on specific facets of environmental management that fall under the umbrella of NEMA but are not identified specifically in NEMA, e.g. in specific regions (coastal zone or for specific types of industry, waste management or air emissions). The following are considered SEMA's:

- National Environmental Management: Waste Act (NEM:WA)
- National Environmental Management: Air Quality Act (NEM:AQA)
- National Environmental Management: Biodiversity Act (NEM:BA)
- National Environmental Management: Protected Areas Act (NEM:PAA)
- National Environmental Management: Integrated Coastal Management Act (NEM:ICMA)

In terms of Chapter 5 of NEMA, any activities identified in the EIA Regulations[10], the **NEM: WA Waste Management Regulations** or the **NEM: AQA Regulations** must undertake either a **Basic Assessment (BA) Process** or a **Scoping & Environmental Impact Reporting (S&EIR)** for specific 'listed activities.

These statutory processes must comply with the requirements prescribed in the relevant regulations and must be completed before the competent authorities are able to issue a decision either authorising or rejecting the proposal. An Application for authorisation may require multiple listed activities for a single development proposal. These are captured in one Application.

In terms of Chapter 5 of NEMA, a Basic Assessment is required for any listed activities gazetted in terms of the National Environmental Management Act (NEMA) 2014 EIA Regulations, the National Environmental Management: Waste Act (NEM:WA) Category A and the National Environmental Management: Air Quality Act (NEM:AQA) Air Quality Schedule of 22 November 2013. These activities are those whose thresholds and extents are considered to have potentially negative impacts on the environment. Only activities which trigger a Basic Assessment may be considered for Norms & Standards. Activities that require Scoping & Environmental Impact Assessment Reporting must comply with the NEMA and undertake an EIA process as prescribed in the EIA Regulations.

---

[10] The Environmental Impact Assessment (EIA) Regulations are a series of legal documents providing details on the required processes for authorisation for activities that are deemed to have potentially negative impacts on the environment. Listed activities are described in terms of specific thresholds related to location and extent.

In many instances it is the need for the undertaking of these regulatory processes, as well as the associated cost and timing associated with them that discourages potential operators/investors from pursuing waste treatment projects. The CSIR has conducted extensive research showing that the current low costs for landfill and high costs of EIA's are one of the fundamental barriers that prevent innovative waste management projects (Department of Science & Technology, 2014).

The exception to these processes is if the activity, even though it does trigger a listed activity as determined above, is regulated in terms of a gazetted Norms & Standards, in which case the environmental requirements specified in the Norms & Standards must be applied. It is believed once Norms & Standards are adopted for organic waste streams the 'green economy' will be unlocked to a large degree which in turn will have an immediate impact on the volume of waste that (still) goes to landfill.

An important section of NEMA is Section 28 that prescribes certain actions in terms of the "Duty of Care and Remediation of Environmental Damage" and requires persons that cause significant degradation of the environment to take reasonable measures to prevent the pollution or degradation from occurring, continuing or recurring.

The general objective of integrated environmental management is to-

(a) promote the integration of the principles of environmental management set out in section 2 into the making of all decisions which may have a significant effect on the environment;

(b) identify, predict and evaluate the actual and potential impact on the environment, socio-economic conditions and cultural heritage, the risks and consequences and alternatives and options for mitigation of activities, with a view to minimising negative impacts, maximising Prepared by:

In partnership with:

benefits, and promoting compliance with the principles of environmental management set out in section 2;

(c) ensure that the effects of activities on the environment receive adequate consideration before actions are taken in connection with them;

(d) ensure adequate and appropriate opportunity for public participation in decisions that may affect the environment;

(e) ensure the consideration of environmental attributes in management and decision-making which may have a significant effect on the environment; and

(f) identify and employ the modes of environmental management best suited to ensuring that a particular activity is pursued in accordance with the principles of environmental management set out in section 2.

These principles form a fundamental basis in the development of Norms & Standards.

2.2.1 Applicability of NEMA Chapter 5 to SEMAs

Chapter 5 of NEMA makes provisions for Integrated Environmental Management which includes the development of Norms & Standards across all of the SEMAs. The implication of this is that activities such as mechanism to treat organic waste which may under normal circumstances require authorisation in terms of both NEM:WA and NEM:AQA for example, can be regulated in terms of Norms & Standards provided that sufficient environmental performance requirements are implemented to address the relevant impacts.

This is evident when considering the various sections written into the NEMA.

"activities", when used in Chapter 5, means policies, programmes, processes, plans and projects identified in terms of section 24(2)(a) and (b)

24(2) The Minister, or an MEC with the concurrence of the Minister, may identify—

(a) activities which may not commence without environmental authorisation[11] from the competent authority;

(b) geographical areas based on environmental attributes, and as specified in spatial development tools adopted in the prescribed manner by the Minister or MEC, with the concurrence of the Minister, in which specified activities may not commence without environmental authorisation from the competent authority;

The important reference in this instance is that certain activities may not commence without environmental authorisation from the competent authority[12]. Any competent authority of a SEMA is deemed to have been mandated that authority from NEMA.

"environmental authorisation", when used in Chapter 5, means the authorisation by a competent authority of a listed activity or specified activity in terms of this Act, and includes a similar authorisation contemplated in a specific environmental management Act[13]

The definition provided above very clearly identifies authorisations that are required by SEMAs. Section 24(2) further provides the following:

24(2) The Minister, or an MEC with the concurrence of the Minister, may identify—

c) geographical areas based on environmental attributes, and specified in spatial tools or environmental management instruments, adopted in the prescribed manner by the Minister or

[11] Our emphasis
[12] **"competent authority"** in respect of a listed activity or specified activity, means the organ of state charged by this Act (NEMA) with evaluating the environmental impact of that activity and, where appropriate, with granting or refusing an environmental authorisation in respect of that activity.
[13] Our emphasis

MEC, with the concurrence of the Minister, in which specified activities may be excluded from the requirement to obtain an environmental authorisation[14] *from the competent authority;*

(d) activities contemplated in paragraphs (a) and (b) that may be excluded from the requirement to obtain an environmental authorisation from the competent authority, but that must comply with prescribed norms or standards;

Provided that where an activity falls under the jurisdiction of another Minister or MEC, a decision in respect of paragraphs (a) to (d) must be taken after consultation with such other Minister or MEC.

At this point it is important to clarify the definition of who the Minister or MEC is.

> **"Minister**" means the Minister responsible for environmental matters.
>
> **"MEC**" means the Member of the Executive Council to whom the Premier has assigned responsibility for environmental affairs.

It is thus clear that NEMA and all related SEMA's fall under the responsibility of the Minister for environmental matters and as such, the Minister can authorise environmental performance requirements in the form of Norms & Standards for NEMA and the SEMA's together.

24(5) The Minister, or an MEC with the concurrence of the Minister, may make regulations consistent with subsection (4) –

(bA) laying down the procedure to be followed for the preparation, evaluation, adoption and review of prescribed environmental management instruments, including—

(vii) norms or standards.

> **"norms or standards"**, when used in Chapter 5, means any norm or standard contemplated in section 24(10).

The prescriptions for the development of Norms & Standards as per Section 24(10) relate back to the consideration of the identified listed activities as well as authorisation provided the Minister.

Government Notice R634 in terms of NEM:WA of 2013, specifically Chapter 4 Regulation 9 expands on Section 24(10) in the mechanism for removing a waste management activity from the waste management activity classification. Since NEM:WA is a SEMA, it is again clear that the Chapter 5 of NEMA provides for all activities identified in terms of the SEMAs to be managed by means of Norms & Standards.

24(10)

(a) The Minister, or an MEC with the concurrence of the Minister, may—

[14] Our emphasis

(i) develop or adopt norms or standards for-

(aa) a listed activity or specified activity contemplated in subsection 24(2)(a) and (b);

(bb) any part of the listed of specified activity referred to in item (aa);

(cc) any sector relating to item (aa);

(dd) any geographical area relating to item (aa); or

(ee) any combination of the activities, sectors, geographical areas, listed activities or specified activities referred to in items (aa), (bb), (cc) and (dd);

(ii) prescribe the use of the developed or adopted norms or standards in order to meet the requirements of this Act;

(iii) prescribe reporting and monitoring requirements; and

(iv) prescribe procedures and criteria to be used by the competent authority for the monitoring of such activities in order to determine compliance with the prescribed norms or standards.

(b) Norms or standards contemplated in paragraph (a) must provide for rules, guidelines or characteristics—

(i) that may commonly and repeatedly be used; and

(ii) against which the performance of activities or the results of those activities may be measured for the purposes of achieving the objects of this Act.

(c) The process of developing norms or standards contemplated in paragraph (a) must, as a minimum, include—

(i) publication of the draft norms or standards for comment in the relevant Gazette;

(ii) consideration of comments received; and

(iii) publication of the norms or standards to be prescribed.

(d) The process of adopting norms or standards contemplated in paragraph (a) must, as a minimum, include—

(i) publication of the intention to adopt existing norms or standards in order to meet the requirements of this Act for comment in the relevant Gazette;

(ii) consideration of comments received; and

(iii) publication of the norms or standards to be prescribed.

The specific roles of all the spheres of government are also clearly outlined in the 2011 Municipal Waste Sector Plan (Mosia, Laugesen, Pillay, & Tsikata, 2012). The DEA is the lead agent for waste management-related functions including:

- <u>Development of policy, strategy and legislation</u>;

- Co-ordination;
- Enforcement;
- Dissemination of information;
- Participation in appeals (against government decisions, authorizations, etc.);
- Monitoring, auditing and review; and,
- Capacity building.

It is thus clear that the DEA Minister should and is enabled to provide for an integrated Norms & Standards in order to address the critical waste management concerns and assist in developing the green economy.

2.3 NATIONAL ENVIRONMENTAL MANAGEMENT: WASTE ACT 59 OF 2008 (NEM: WA)

The White Paper on Integrated Waste Management and Pollution Control of 2000 best sums up the change in thinking of government from a historic "end-of-pipe" approach to pollution to a framework of preventative strategies that's aimed at waste minimization and pollution prevention. The National Waste Management Strategy (NWMS) and the Polokwane Declaration of 2001 further illustrated the intention of Government to follow in the direction of waste reduction. These have led to the development of the **National Environmental Management: Waste Act** (Act 59 of 2008 as amended) and the waste management hierarchy which implicates waste reduction.

The NEM: WA makes provision for the identification and assessment of activities that are associated with the management of 'waste related' activities and which require authorisation from the relevant authorities based on the findings of an environmental assessment. The Act aims to protect health and the environment by providing reasonable measures for the prevention of pollution and ecological degradation, thus securing ecologically sustainable development.

The Act deals with the licensing of waste activities, priority wastes, establishment of norms and standards, requirements for storage, transport and disposal of waste, assessment and clean-up of contaminated land, establishment of a waste information system. This is the current legislative instrument which guides and regulates all waste management activities. The NEM:WA lists waste activities which require licensing in Government Notice 921 as well as the licensing requirements to ensure that all waste treatment facilities operate legally.

When considering waste facilities it is the *'treatment'* and *'disposal'* of **'general'** and **'hazardous'** waste materials that require prior approval. Of importance is the type of waste classification for feedstock material that determines the process that should be followed to obtain the necessary approvals and the time it will take for such approval processes. Organic waste is still classified as "waste" in terms of the NEM:WA.

2.4 NATIONAL ENVIRONMENTAL MANAGEMENT: WASTE AMENDMENT ACT 26 OF 2014 (NEM: WAA)

NEM: WAA came into effect on the 2nd June 2014 and includes among others, the substitution and deletion of certain definitions contained in NEM: WA (2008) and the inclusion of Schedule 3:

The defining changes in this Act also included substitution and deletion of definitions, various administrative requirements, enabling of a pricing structure for applications and fines and to establish a Waste Management Bureau.

The importance of this Act for the organic feedstock industry relates to the definition of what constitutes waste[15] and the understanding of Schedule 3 identified in this Act is critical in determining whether or not a Waste Management License (WML) is required for all types of facilities. The definitions do not allow for any beneficial use of organic material and enforce a stringent definition of what waste is regardless of the level of beneficiation available. Furthermore the definition of re-use prevents an beneficiation, including natural decomposition due its specificity.

The Amendment Act does not change the process requirements for authorisation.

2.5 NATIONAL ENVIRONMENTAL MANAGEMENT: AIR QUALITY ACT 39 OF 2004 (NEM:AQA)

NEM: AQA was introduced as a replacement to the Atmospheric Pollution Prevention Act (APPA, Act 45 of 1965) in order to protect the environment by providing reasonable measures for the prevention of pollution and ecological degradation and for securing ecologically sustainable development while promoting justifiable economic and social development. It also allows for the development of national norms and standards regulating air quality monitoring, management and control.

In the context of organic waste treatment facilities, it is important to note the provisions in NEM:AQA relating to **thermal treatment of waste**[16]**, odour control**[17], **boiler heat output exceeding 50MW**[18] and **engine heat input exceeding 10MW**[19] may require an Atmospheric Emissions License (AEL). It must be noted that odour control remains a subjective matter on the whole but section 35(2) imposes an obligation on the occupier of any premises to take all reasonable steps to prevent the emission of any offensive odour caused by any activity on such premises. 'Offensive odour' means any smell which is considered to be malodorous or a nuisance to a reasonable person (DEA, 2004).

---

[15] See definition of "waste" provided in Section 3.1 above.
[16] Sub Category 8.1 – Thermal treatment of general and hazardous waste
[17] Category 10 – Animal matter processing
[18] Sub category 1.4 – Gas Combustion Installations
[19] Sub category 1.5 – Reciprocating Engines

It is unlikely that organic feedstock treatment facilities will reach the thresholds for boiler heat output of 10 or 50MW, leaving the odour and thermal treatment of waste activities potentially applicable.

2.6 NATIONAL WATER ACT 36 OF 1998 (NWA)

The NWA was instituted to ensure that sustainability and equity are identified as central guiding principles in the protection, use, development, conservation, management and control of water resources. These guiding principles recognise the basic human needs of present and future generations, the need to protect water resources, the need to share some water resources with other countries, the need to promote social and economic development through the use of water and the need to establish suitable institutions in order to achieve the purpose of the Act.

Section 20 of the NWA deals with the control of emergency incidents and Section 21 describes a number of water uses that are applicable to waste management practices.

- Section 21(f) Discharging waste or water containing waste into a water resource through a pipe, canal, sewer or sea outfall or other conduit - this water use includes discharging waste or wastewater directly into a river. A permit to discharge waste effluent and the need to comply with prescribed discharge standards is required.
- Section 21 (g) Discharging of waste in a manner which may detrimentally impact on a water resource - this water use applies where waste disposal takes place into facilities on-site, e.g. French drains, Oxidation ponds, evaporation dams, and landfill sites.

In general the NWA thus covers pollution prevention, incident management, water use and licensing. In relation to organic waste treatment facilities this applies to the abstraction and use of water in the facility, as well as the discharge or irrigation of wastewater and the application of sludge to land.

portrayal

2.6.1 South African Water Quality Guidelines

The Department of Water and Sanitation (DWS) has provided comprehensive water quality guidelines and targets associated with all types of water use. The water quality guideline is a set of information provided for a specific water quality constituent. It consists of the water quality criteria, including the Target Water Quality Range, for that constituent together with other support information such as the occurrence of the constituent in the aquatic environment, the norms used to assess its effects on water uses, how these effects may be mitigated, possible treatment options, etc.

The South African Water Quality Guidelines consists of guidelines for domestic, recreational, industrial and agricultural water uses, guidelines for the protection of aquatic ecosystems as well as guidelines for the protection of the health and integrity of aquatic ecosystems and guidelines for the protection of the marine environment. Each of these guidelines provides scientific and technical information for a particular water quality constituent in the form of numerical data and/or narrative descriptions of its effects on the fitness of water for a particular use or on the health of aquatic ecosystems.

The following South African Water Quality Guidelines are recognised by the National Water Act:

- Volume 1: Domestic Water Use:
- Volume 2: Recreational Water Use;
- Volume 3: Industrial Water Use;
- Volume 4: Agricultural Water Use: Irrigation;
- Volume 5: Agricultural Water Use: Livestock Watering;
- Volume 6: Agricultural Water Use: Aquaculture;
- Volume 7: Aquatic Ecosystems; and
- Volume 8: Field Guide.

In addition to this series, the DWS also provides a document series for the utilisation and disposal of wastewater sludge. This includes sludge from any treatment process that included domestic and industrial wastewater. The management of sludge on land is related to the criteria identified in the SAWQ Guidelines. The series consists of the following volumes:

- Volume 1: Selection of management options;
- Volume 2: Requirements for the agricultural use of sludge
- Volume 3: Requirements for the on-site and off-site disposal of sludge;
- Volume 4: Requirements for the beneficial use of sludge; and
- Volume 5: Requirements for thermal sludge management practices and for commercial products containing sludge.

The re-use of wastewater and sludge from digestate / residue must comply with the target quality for each criteria as identified in these guides. This can be seen as a form of Norms & Standards already in effect and should just be expanded to include other feedstock types. All registered laboratories will use the valued determined by DWS and should be utilised by industry role players.

2.7 FERTILISER, FARM FEEDS, AGRICULTURAL REMEDIES AND STOCK REMEDIES ACT (ACT 36 OF 1947)

The Act aims to control the sale and use of substances that may prove detrimental to livestock and the environment. Its main functions are:

- to provide for the appointment of a Registrar of Fertilizers, Farm Feeds and Agricultural Remedies;
- it allows for the registration of fertilizers, farm feeds, agricultural remedies, stock remedies, sterilizing plants and pest control operators;

- to regulate or prohibit the importation, sale, acquisition, disposal or use of fertilizers, farm feeds, agricultural remedies and stock remedies; and
- to provide for the designation of technical advisers and analysts.

In 2012, the Minister for DAFF signed into effect Regulation 732 in terms of this Act. This regulation has specific references to the creation, use and sale of organic fertilisers. Any fertiliser that contains organic and plant material that is sold on to another party must be registered as a fertiliser with the department. The use of digestate / residue / product of organic waste treatment facilities, if sold, will require authorisation in terms of these Regulation.

2.8 NATIONAL GAS ACT (ACT 48 OF 2001)

The Act undertakes the following aims:

- To promote the orderly development of the piped gas industry;
- to establish a national regulatory framework;
- to establish a National Gas Regulator as the custodian and enforcer of the national regulatory framework; and to provide for matters connected therewith.

Although mainly responsible for piped gas developments, the NGA does provide for the development of alternative gas sources and to facilitate investment in the gas industry. Registration with the National Energy Regulator of South Africa (NERSA) is required in terms of the Gas Act (Act 48 of 2001) for the following activities:

1. production of gas;
2. importation of gas;
3. transmission of gas for own exclusive use; and
4. Small biogas projects not connected to the national gas pipeline grid.

Any organic waste treatment facilities that are aimed at capturing biogas are required to register with NERSA.

2.9 ELECTRICITY REGULATION ACT (ACT 4 OF 2006)

The Act undertakes the following:

- To establish a national regulatory framework for the electricity supply industry;
- To make the National Energy Regulator the custodian and enforcer of the national electricity regulatory framework;
- To provide for licences and registration as the manner in which generation, transmission, distribution, trading and the import and export of electricity are regulated; and
- To provide for matters connected therewith.

The applicability of this Act to organic waste treatment facilities relates directly to the use of the generated electricity by means of energy recovery. Certain exemptions are identified in the Act with regard to the obligation of a generator to apply for and hold a license. These are:

- Any generation plant constructed and operated for demonstration purposes only and not connected to an inter connected power supply;
- Any generation plant constructed and operated for **own use**; and
- **Non-grid connected supply of electricity** except for commercial use.

Thus any facility generating electricity that is not connected to the grid and is for own use consumption does not require a license in terms of this Act. It must be noted that the Minister may determine that a person identified in this Act who does not necessarily have to obtain a license may be required to register with NERSA. This registration process is similar to that of the National Gas Act but has not yet been implemented for biogas generators.

2.10 SPATIAL PLANNING AND LAND USE MANAGEMENT ACT (SPLUMA, ACT 16 OF 2013)

The Spatial Planning and Land Use Management Act, 2013 (SPLUMA) was assented to by the President of the Republic of South Africa on 5 August 2013 and assented on 2 August 2013. SPLUMA is a framework act for all spatial planning and land use management legislation in South Africa. It seeks to promote consistency and uniformity in procedures and decision-making in this field. The other objects include addressing historical spatial imbalances and the integration of the principles of sustainable development into land use and planning regulatory tools and legislative instruments.

Land use planning is necessary to ensure that activities take place on properties with the appropriate land use zoning. As a minimum any organic waste treatment facility is likely to require Building Plan Approvals from the local municipality and must comply with any of their other requirements.

2.11 BY-LAWS

Each local and district municipality has by-laws in place for their jurisdiction. These address activities such as storage, registration of waste contractors, flammable substances storage and transport, permitting of scheduled trades, trade effluent discharge. Municipal permits do not necessarily require authorisation in terms of national legislation, but are still a requirement in the event that no Environmental Authorisation is necessary.

3 NORMS & STANDARDS DEVELOPMENT

Only the national DEA may authorise or implement Norms & Standards.

In 2008 NEMA was amended by providing an enabling provision that allows Ministers and MECs to adopt or develop norms or standards for any NEMA or associated SEMA Basic Assessment listed activities, parts of listed activities of combinations of listed activities, and prescribe such norms or standards in order to meet the requirements of NEMA.

As such, NEMA allows a person/entity to commence and continue with a listed activity without prior environmental authorisation, on condition that the conduct of such listed activity is compliant with a standard. Standards therefore are an additional tool for Integrated Environmental Management (IEM) in South Africa and an alternative to the EIA process. Only activities requiring a **Basic Assessment** process in terms of the EIA Regulations may be considered for the development of standards.

The required characteristics of a standard are not defined per se in NEMA but are rather contained within certain sections of NEMA. The following characteristics of standards have been identified based on the provision of NEMA (DEA&DP, 2012)):

1. **Standards are enforceable** - The use of the word "comply" in section 24(2)(d) of NEMA implies that standards must contain clear compliance obligations that can be enforced. The wording of section 24(10)(b)(ii) 17 and section 24F(1)(b)18 provides further support for the view that standards are intended to be enforceable rules. Standards can therefore be used to regulate activities directly.

2. **Standards are inflexible rules which can be uniformly applied –** Section 24(10)(b)(i) indicates the standards must provide "rules, guidelines or characteristics that may be commonly and repeatedly used". This clearly requires that the standards be applied uniformly, without flexibility and repeatedly in instances where a listed activity is to be conducted. The words "rules, guidelines or characteristics" are intended to be the instructive elements of the standard and are, as such enforceable. Standards must be written in a clear and unambiguous manner to ensure uniformity in their application. Mandatory terms such as "must", "will" and "shall", are inflexible and obligatory and therefore are used in standards. Discretionary terms such as "may" and "should", allow for ambiguity and do not provide a clear obligation, and therefore cannot be included in standards.

3. **Standards provide specific performance criteria or outcomes which can be measured for compliance purposes** - section 24 (10)(b)(ii) requires that standards provide rules, guidelines or characteristics to measure the performance of activities or results thereof for the purposes of achieving the objects of NEMA. This suggests that standards are essentially environmental performance criteria to monitor the efficacy of the management of an activity and requires that compliance with standards to be measurable or quantifiable.

In order to uphold the objectives of NEMA an activity to which standards are applied will need to fulfil the following assumptions:

a. it must be possible to **predict all environmental impacts** associated with the activity – if not nationally, at least in specific locations to which standards will be made applicable;

b. **mitigation measures** must be known (i.e. known solutions to known problems) and capable of being prescribed clearly and unambiguously; and

c. compliance with respect to **performance criteria** (indicators) can be measured either qualitatively or quantitatively.

It is critical to understand the fundamental difference between an EIA and Standards when drafting standards which may potentially be used as an alternative to the EIA process.

- **EIA** is a process in which **impacts are *predicted* and assessed and mitigations and performance criteria are recommended**. The administrative focus of EIA is on the authorisation process which is based on the prediction of impacts.
- Conversely **standards** can only be developed for activities where the **impacts and mitigation measures are *known***. Standards are **clear, measurable, inflexible rules** which provide performance criteria for proactive environmental management. The administrative focus of standards is on monitoring and compliance which is based on the upfront knowledge of impacts and the measurement of specific performance criteria. Compliance with standards should guarantee the absence of significant impacts associated with a development or activity.

To date the following environmental Norms & Standards have been regulated or gazetted for comment:

- National Environmental Management: Protected Areas Act (57/2003). Norms and standards for the management of protected areas in South Africa. **7 July 2014** (Comment);
- National Environmental Management: Waste Act (59/2008): Draft national norms and standards for organic waste composting. **7 February 2014** (Comment);
- National Environmental Management Act (107/1998): National standards for the extraction, flaring or recovery of landfill gas. **29 November 2013** (Gazetted);
- National Environmental Management: Waste Act (59/2008): National norms and standards for the storage of waste. **29 November 2013** (Gazetted);
- National Environmental Management: Waste Act (59/2008): National norms and standards for the extraction, flaring or recovery of landfill gas. **29 November 2013** (Gazetted);
- National Environmental Management: Waste Act (59/2008). National norms and standards for the scrapping or recovery of motor vehicles. **29 November 2013** (Gazetted);
- National Environmental Management: Waste Act (59/2008): National norms and standards for the assessment of waste for landfill disposal. **23 August 2013** (Gazetted);

- National Environmental Management: Waste Act (59/2008): National norms and standards for the remediation of contaminated land and soil quality in the Republic of South Africa. **10 May 2013** (Gazetted);

The majority of the documents produced to date have been done so in terms of the NEM:WA.

3.1.1 Norms & Standards Registration Process

An activity that can be considered in terms of a Norms & Standards regulation does not require an Environmental Impact Assessment as envisaged by NEMA i.e. no Basic Assessment is required. This is due to the fact that the Norms & Standards are based on predictable impacts, mitigation measures and performance criteria.

An applicant must register a facility contemplated under a Norms & Standards regulation with the national DEA prior to the commencement of construction. A registration application must include as a minimum:

a) The owner of the facility;
b) The area where the facility is situated;
c) The location of the facility in terms of the name of the local municipality, property number and geographical coordinates;
d) The size of the facility;
e) The proximity of the facility to the nearest residential area; and
f) The land use / zoning.

It must be noted that Norms & Standards do not exempt the applicant from complying with any other legislation that may be applicable.

4 SENSITIVE ENVIRONMENTS

Sensitive environments have been defined by the European Environment Agency as "*Any parcel of land, large or small, under public or private control that already has, or with remedial action could achieve, desirable environmental attributes. These attributes contribute to the retention and/or creation of wildlife habitat, soils stability, water retention or recharge, vegetative cover, and similar vital ecological functions. Environmentally sensitive areas range in size from small patches to extensive landscape features. They can include rare or common habitats, plants and animals*. (Source: DUNSTE)

In Chapter 1: National Environmental Management Principles 4(r), NEMA refers to "*Sensitive, vulnerable, highly dynamic or stressed ecosystems, such as coastal shores, estuaries, wetlands, and similar systems require specific attention in management and planning procedures, especially where they are subject to significant human resource usage and development pressure"*.

The Australian Department of Environment and Conservation (NSW) identified areas considered inappropriate for composting and related organics process, see table below.

Table 3: List of environmentally inappropriate areas for composting and related organics processing facilities (Department of Environment and Conservation (NSW), 2004).

Area	Objective
A site located within an area of significant environmental or conservation value identified under relevant legislation or a planning instrument, including: • National Parks • historic and heritage areas, buildings or sites • any reserves for environmental protection, for example, aquatic, marine, nature, karsts • areas covered by a Conservation Agreement • Wilderness Areas identified or declared under the *Wilderness Act 1987* • other areas protected under the *National Parks and Wildlife Act 1974* • World Heritage Areas • areas on the Register of the National Estate • SEPP 14 wetlands, REP 20 wetlands, SEPP 26 Littoral Rainforests • areas zoned under an LEP or REP for environmental protection purposes, for example, high scenic, scientific, cultural or natural heritage.	To avoid the risk of damaging areas of high environmental value
Sites within an identified drinking water catchment (surface water or groundwater), for example, any lands nominated as 'Special or Protected Areas' by local water supply authorities (such as Sydney Water, Hunter Water, Council) or in the vicinity of a groundwater bore used as drinking water.	To avoid the risk of polluting drinking water
Sites located in an area overlying an aquifer that contains drinking-water-quality groundwater that is vulnerable to pollution. (Consult the Department of Infrastructure, Planning and Natural Resources for criteria to determine the vulnerability of groundwater.)	To protect groundwater and surface water resources
Sites where the substrata are prone to landslip or subsidence.	To avoid sites that may have unsuitable substrata
Sites on floodplains that may be subject to washout during major flood events. (Consult councils for information about local flooding characteristics.)	To avoid washout risk if a significant flood event occurs

Taking the above information into consideration, the task team has identified sites that should not be considered for the development of organic waste treatment facilities in the proposed Norms & Standards document. It must be noted that although the table above exclude the development of organic waste sites in *protected areas*[20], the Task Team is of the opinion that excluding beneficiation of organic waste in declared protected areas such as nature reserves, national or provincial parks, biospheres or heritage sites will not benefit communities, businesses and tourism facilities. It is more likely that not allowing such beneficiation may lead to negative impacts in these

[20] A protected area in terms of the NEM:PAA is an area declared, or regarded as having been declared, in terms of section 28 as a protected environment; an area which before or after the commencement of the Act was or is declared or designated in terms of provincial legislation for a purpose for which that area could in terms of section 28(2) be declared as a protected environment; or an area which was a lake area in terms of the Lake Areas Development Act, 1975 (Act No. 39 of 1975), immediately before the repeal of that Act by section 90(1) of the NEM:PAA

special environments and as such they have not been included in the proposed list of *exclusionary* places.

Table 4: Task Team proposed list of environmentally sensitive exclusionary sites.

1) An organic waste treatment facility may not be constructed in an environmentally sensitive area such as –
a) Within natural watercourses and within 32m of a natural watercourse, measured from the edge of the watercourse;
b) Within wetlands or floodplains, where the facility will be located outside of the 1 in 100 year floodline;
c) Within estuaries or within 100m inland of the high water mark of the sea or an estuary;
d) On shifting sand dunes or geologically unstable formations;
e) Where the construction of the activity and associated infrastructure requires the removal of more than 300m² of Endangered or Critically Endangered vegetation.

5 ORGANIC WASTE STREAMS / FEEDSTOCKS

Organic waste (or feedstock) is determined by its biodegradability. Simply put biodegradable matter is any organic matter in waste which can be broken down into carbon dioxide, water, methane or simple organic molecules by micro-organisms and other living things using composting, aerobic digestion, anaerobic digestion or similar processes.

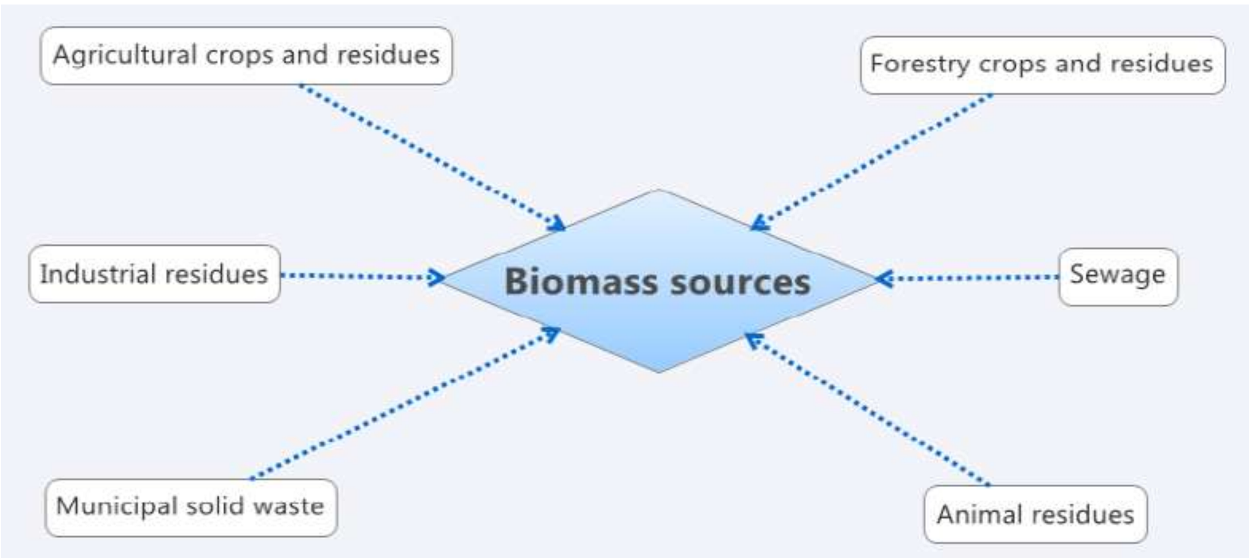


Figure 7: Sources of biomass (Ahmed, Nasri, & Hamza, 2012)

Biomass is a renewable resource derived from agricultural or forestry sector which has been estimated to provide about 25% of global energy requirements (James and Fabien 2008; Briens et al 2008). In addition, biomass can also be the starting raw materials for a lot of valuable chemicals, pharmaceuticals and food additives from multiple other sources of organic materials other than woody biomass alone. The applications of new and advanced technologies in chemical processing provide new opportunities for the conversion of these natural resources (biomass) which were often restricted to woody biomass only.

The German Advisory Council on Global Change (WBGU) (Schubert, et al., 2009) attaches a higher priority on the recycling of biogenic / biodegradable waste for energy (including cascade use[21]), and to the use of residues, than to the use of energy crops. The use of biogenic wastes and residues has the advantage of causing very little competition with existing land uses. It involves no greenhouse gas emissions from land-use changes and cultivation, so that the contribution to climate change mitigation is determined primarily by the conversion into bioenergy carriers and their application in energy systems. When undertaken correctly, this leads to improved food production where for waste-to-energy improves land-use efficiency and post-harvest processes whilst organic fertilisers improve soil and crop potentials.

When using residues, care must be taken to meet soil protection standards – and hence ensure climate change mitigation – and that pollutant emissions are avoided. The standards recommended by the WBGU have also been taken into account for this report.

According to (Huang, 2014), moisture content, calorific value and chemical composition of the wastes determines the value of a waste for recycling or removal from landfill sites.

Moisture content

Moisture content directly influences the disposal of the wastes. Moisture content will decide whether they will be converting into compost or biogas or into solid fuel or be used as landfill fillers. So far, there are various moisture meters available to check the waste moisture content.

Calorific value

Calorific value of wastes determines the energy value. The waste calorific value affected by moisture content and hydrogen content in it.

Chemical composition

Waste chemical composition refers to the elements such as, carbon, oxygen, hydrogen, sulphur, nitrogen, etc. The chemical composition affects the disposal of the wastes.

The Task Team identified five (5) categories of feedstocks from the organic waste stream, these include:

---

[21] Uses downstream of the primary use i.e. waste to energy the primary use is for energy, but cascade use would be digestate for soil enhancement

- Agricultural waste
- Biomass (Lignocellulose / woody)
- Biomass (Low Lignocellulose / non-woody)
- Food processing
- Sewage

Please refer to Section 13 for a description of the feedstock types.

Within each of these categories are feedstocks that are globally recognised as benefitting from treatment to provide soil enhancers, fertilisers, biogas, biochar, high protein food sources and various other usable products.

Table 5: Feedstock uses and problems (Department of Environment and Conservation (NSW), 2004)

Type	Uses and problems	Possible Treatment Types
Agriculture:		
Manure	Source of nitrogen (N), phosphorous (P) and potassium (K) and other micronutrients; Typically used as a soil enhancer untreated but with beneficiation is able to provide a more stable organic fertiliser Over nutrification of soils when applied in large quantities; Nutrification of water sources when incorrectly applied; Can be malodourous; Emits methane if not correctly aerated; Incorrect aerobic treatment can lead to ammonia (NH_3) and nitrous oxide (N_2O) emissions by trying to avoid methane emissions.	Aerobic and anaerobic fermentation
Mortalities	Source of nitrogen (N), phosphorous (P) and potassium (K) and other micronutrients; Over nutrification of soils when applied in large quantities; Possibly hazardous if mortality caused by infectious disease; Nutrification of water sources when incorrectly applied; Can be malodourous; Emits methane if not correctly aerated.	Aerobic, anaerobic, thermal
Biomass: Lignocellulose (woody)		
Agricultural crop residue	Source of organic carbon / CO_2, cellulose, hemicellulose, and lignin	Mechanical, aerobic, thermal, anaerobic after pre-treatment

	Can be chipped and composted	
Invasive plant species	Source of organic carbon / CO_2, cellulose, hemicellulose, and lignin Threatens biodiversity of indigenous vegetation Threatens water security Poses a high fire risk when left on land Can be chipped and composted Used for firewood and furniture	Mechanical, aerobic, thermal
Plantation residue	Source of organic carbon / CO_2, cellulose, hemicellulose, and lignin Poses a high fire risk when left on land Can be chipped and composted Used for firewood and furniture	Mechanical, aerobic, thermal
Sawmill residue	This includes sawdust, woodchip, bark, planer shavings, and pole shavings that accumulate at milling sites. Source of organic carbon / CO_2, cellulose, hemicellulose, and lignin Poses a high fire risk when left on land Emits methane if not correctly aerated.	Mechanical, aerobic, thermal
Biomass: Low Lignocellulose (non woody)		
Agricultural crop residue	Source of organic carbon / CO_2, cellulose, hemicellulose, and lignin Emits methane if not correctly aerated.	Mechanical, aerobic, anaerobic, chemical and thermal
Sugar bagasse	Source of organic carbon / CO_2, cellulose, hemicellulose, and lignin Emits methane if not correctly aerated.	Mechanical, aerobic, anaerobic, chemical and thermal
Food Processing:		
Abattoir Waste	Source of nitrogen (N), phosphorous (P) and potassium (K) and other micronutrients, organic carbon / CO_2 Typically used as a soil enhancer untreated e.g. blood spraying; Over nutrification of soils when applied in large quantities; Nutrification of water sources when incorrectly applied; Can be malodourous; Emits methane if not correctly aerated All protein can be re-used for animal foods or soil enhancers	Aerobic, anaerobic, chemical and thermal

Food Oils	High salinity, low pH values, high contents in phenol derivates and organic matter and nutrients. Can be malodourous Can be carcinogenic if reused too many times By product is glycerol which can be reused	Aerobic, anaerobic, chemical and thermal
Organic Fraction of Municipal Solid Waste (MSW)	Source of nitrogen (N), phosphorous (P) and potassium (K) and other micronutrients, organic carbon / CO_2 Nutrification of water sources when incorrectly applied; Can be malodourous; Emits methane if not correctly aerated	Mechanical, aerobic, anaerobic, chemical and thermal
Restaurant Waste	Source of nitrogen (N), phosphorous (P) and potassium (K) and other micronutrients, organic carbon / CO_2 Nutrification of water sources when incorrectly applied; Can be malodourous; Emits methane if not correctly aerated	Mechanical, aerobic, anaerobic, chemical and thermal
Agro-processing	Source of nitrogen (N), phosphorous (P) and potassium (K) and other micronutrients, organic carbon / CO_2 High source of protein Nutrification of water sources when incorrectly applied; Can be malodourous; Emits methane if not correctly aerated; Incorrect aerobic treatment can lead to ammonia (NH_3) and nitrous oxide (N_2O) emissions by trying to avoid methane emissions.	Mechanical, aerobic, anaerobic, chemical and thermal
Sewage:		
Sludge	Source of nitrogen (N), phosphorous (P) and potassium (K) and other micronutrients, organic carbon / CO_2 Continual supply available Over nutrification / pollution of soils when applied in large quantities or at substandard quality Nutrification / pollution of water sources when incorrectly applied Can be malodourous	Mechanical, aerobic, anaerobic, chemical and thermal

	Incorrect aerobic treatment can lead to ammonia (NH_3) and nitrous oxide (N_2O) emissions by trying to avoid methane emissions.	

As can be seen from the table above, the proposed treatments for the organic feedstocks are cross cutting and it must be noted that some technologies are not effective for any one particular stream.

As an example, the main problem with anaerobic digestion of crop residues is that most of the agricultural residues are lignocellulosic with low nitrogen content. To improve the digestibility of crop residues, pre-treatment methods like size reduction, electron irradiation, heat treatment, enzymatic action etc. are necessary. For optimizing the Carbon / Nitrogen (C/N) ratio of agricultural residues, co-digestion with sewage sludge, animal manure or poultry litter is normally recommended (BioEnergy Consult, 2014).

Crop residues can be digested either alone or in co-digestion with other materials, employing either wet or dry processes. In the agricultural sector one possible solution to processing crop biomass is co-digestion together with animal manure, the largest agricultural waste stream. In addition to the production of renewable energy, controlled anaerobic digestion of animal manure reduces emissions of greenhouse gases, nitrogen and odour from manure management, and intensifies the recycling of nutrients within agriculture.

In co-digestion of plant material and manures, manure provide buffering capacity and a wide range of nutrients, while the addition of plant material with high carbon content balances the carbon to nitrogen (C/N) ratio of the feedstock, thereby decreasing the risk of ammonia inhibition.

Co-digestion offers good opportunity to farmers to treat their own waste together with other organic substrates. As a result, farmers can treat their own residues properly and also generate additional revenues by treating and managing organic waste from other sources and by selling and/or using the products such as heat, electrical power and stabilised biofertiliser (BioEnergy Consult, 2014).

Table 6 below provides a very suitable categorisation of organic waste which has been used later in the report for applying management standards.

Table 6: Organic waste categorisation (Department of Environment and Conservation (NSW), 2004)

Potential to have environmental impact	Organics category	Types of organics permitted in categories[1] (Categories with larger numbers may contain types from classes with smaller numbers.)	
		Type	Examples of organics
Lowest potential environmental impact	Category 1	Garden and landscaping organics	Grass[2]; leaves; plants; loppings; branches; tree trunks and stumps.
		Untreated timber	Sawdust; shavings; timber offcuts; crates; pallets; wood packaging.
		Natural organic fibrous organics	Peat; seed hulls/husks; straw; bagasse and other natural organic fibrous organics.
		Processed fibrous organics	Paper; cardboard; paper-processing sludge; non-synthetic textiles.
Greater potential environmental impact than Category 1, less potential impact than Category 3.	Category 2	Other natural or processed vegetable organics	Vegetables; fruit and seeds and processing sludges and wastes; winery, brewery and distillery wastes; food organics excluding organics in Category 3.
		Biosolids[3] and manures	Sewage biosolids, animal manure and mixtures of manure and biodegradable animal bedding organics.
Greatest potential environmental impact	Category 3	Meat, fish and fatty foods	Carcasses and parts of carcasses; blood; bone; fish; fatty processing or food.
		Fatty and oily sludges and organics of animal and vegetable origin	Dewatered grease trap; fatty and oily sludges of animal and vegetable origin.
		Mixed residual waste containing putrescible organics	Wastes containing putrescible organics, including household domestic waste that is set aside for kerbside collection or delivered by the householder directly to a processing facility, and waste from commerce and industry.

Notes:

1. These categories are used only to facilitate reference to these groupings of waste and organics (with different potential environmental impacts) in these guidelines and in environment protection licences: they are **not** used in waste legislation.
2. Particular care should be taken when grass clippings are present in the feedstock. It is well known that careful process management is required to mitigate odour and leachate problems when processing grass clippings (e.g. Buckner 2002). High moisture content, high nitrogen levels, abundance of readily available organic matter and poor structure and tendency to mat mean that grass can easily become anaerobic and odorous.
3. Conditions applying to processing and use can be found in *Environmental Guidelines: Use and Disposal of Biosolids Products* (EPA 1997).

6 TECHNOLOGIES

There are many technologies available for the treatment of organic waste depending on what waste stream is available and what outcome is required.

Schubert et al (2009) provides a very comprehensive breakdown of bioenergy possibilities from multiple feedstock sources, including biogenic wastes. The necessary conversion technologies are available, albeit it in a limited fashion in South Africa, as is the know-how to operate them: biogas facilities for harvest residues, green cuttings, slurry and food waste, biodiesel facilities for used oil and animal fat, and biomass-fired cogeneration systems or pellet heating systems for ligneous or straw-like wastes and residues.

Based on international and national options available, the Task Team identified the various treatment options that are considered. Many of these technological types are implemented as combinations. These were grouped into the following five categories:

- Mechanical
- Chemical
- Anaerobic
- Aerobic
- Thermal

The categorisation was implemented as the technologies identified for them have similar management requirements and as such similar environmental impacts are associated with them. This could thus provide for future technologies to be included at a later stage as long as they fit into the categories.

6.1 MECHANICAL

Mechanical treatments refer to treatment mechanisms where a component is altered by means of physical force or motion, often by means of machination.

Table 7: Summary of mechanical technologies

Mechanical:	
Briquetting	A briquette (or briquet) is a compressed block of coal dust or other combustible biomass material such as charcoal, sawdust, wood chips, peat, or paper used for fuel and kindling to start a fire. Biomass briquettes are a biofuel substitute to coal and charcoal.
Centrifuge	A centrifuge is a device, which employs a high rotational speed to separate components of different densities. This becomes relevant in the majority of industrial jobs where solids, liquids and gases are merged into a single mixture and the separation of these different phases is necessary. A decanter centrifuge separates solid materials from liquids in slurry and therefore plays an important role in wastewater treatment, chemical, oil and food processing industries. There are several factors that affect the performance of a decanter centrifuge and some design heuristics to be followed which are dependent upon given applications.

Chipping	Chipping is the process of reducing woody waste to smaller pieces mechanically in order to speed up decomposition of the material. Once chipped, the woody material can be used as mulch, for composting, as a fuel source or even compressed for a slower burning fuel source.
Pelleting	Compressing of organic matter to create a dense, low moisture fuel source. Pellets can be made from industrial waste and co-products, food waste, agricultural residues, energy crops, and virgin lumber.
Sonification	Sonication is the act of applying sound energy to agitate particles in a sample, for various purposes. It can aid mixing and particle dispersal as well as perform cell lysis. The process can generate heat which can result in further thermal processing.

6.1.1 Briquetting

Briquetting technology is used to densify the loose combustible materials into solid composites of different shapes and sizes with the presence of pressure and binding agents.

Generally, there are a wide range of materials that can be used to make briquettes, such as waste paper, cardboard, water hyacinth, agricultural residues, charcoal dust, and wood wastes like sawdust, etc.

<u>Briquetting process</u>

Generally, the briquettes are made through the following procedures:

1. Raw materials preparation: mechanical fragmentation of raw materials by a crushing machines (which is up to the quality and size of the materials and the technology applied, and the procedure can be staged).

2. Drying of the crushed materials when the moisture content is too high for briquettes production.

3. Briquette the processed materials by using various types of briquetting machines such as the screw pressing machines, stamping pressing machines and hydraulic briquetting machines). The briquettes are made in the process of pressure agglomeration, in which the loose materials is molded into a permanent , geometrical and defined dimensions by the compaction pressure and intermolecular forces and bonds when necessary.

<u>Briquetting densification technologies</u>

Briquetting is one of the densification technologies for converting biomass wastes into solid and convenient fuel. Briquetting technologies can be classified in the following categories based on the mechanical features and equipment involved: piston press densification, screw press densification, roll press densification and manual presses.

The choice of either mechanical or manual presses is determined on the source of material, logistics to deliver to a fixed position or the need for mobility of the technology to the source of material. As an example, mobile units would be more feasible when the feedstock material is AIS and the processing of the feedstock is more viable at the site of clearing as opposed to a permanent facility adjacent to a sawmill.

Costing of the machinery and maintenance of such will also play a role in the type of equipment required.

Figure 8: Mechanised briquette maker (Source: Kefan Machinery)

Figure 9: Manual briquette maker (Source: Multimate Designs)

Briquettes fuel is usually used in boiler plants, heating plants, power stations and thermal power stations, as well as by individual customers for household use. It is also possible to use fuel briquettes in the fireplaces and conventional boilers that once use coals or woods with or without a little modification. The increase price of the conventional fuels urges the demand for the briquettes fuel and affects briquette fuel price and the briquette machines price as the increased public awareness to the environment protection.

Benefits of converting wastes into fuel briquettes

- Using fuel briquettes means to chop less firewood and less charcoal to buy, saving time and money and do contributions to ease the environment pressures.
- Cheap fuel for cooking if producing briquettes at a household level.
- Opportunities for small business development from making and selling briquettes made from local waste materials.
- Briquettes made from daily wastes such as paper, wood etc. means a reduction of waste at household level.
- Briquettes have a durable quality, high burning efficiency and convenient to be stored and transported.

Challenges associated with briquetting

- Large scale briquetting equipment needs high investment while small scale briquettes production equipment is not widely applied.
- Wet weather may lower the density of briquettes, harming briquette quality.

Potential environmental impact

- Incorrect storage of raw material (feedstock) could lead to fire hazards.
- Incorrect storage of raw material (feedstock) could lead to leachates entering surface or groundwater sources.
- Unmanaged mobile facilities may impact on indigenous vegetation.
- Unmanaged mobile facilities may cause compaction or erosion of soil.
- Reduction in methane and CO_2 emissions due to the diversion from landfill.
- Reduction in used landfill airspace.
- Removal of potential fire hazards left to land.

6.1.2 Centrifuge

A decanter centrifuge separates solids from liquid phase(s) with high efficiency. In the centrifuge the gravitational acceleration is replaced by the much higher centrifugal acceleration (up to 4000 x g). By this high bowl speed the solids (higher density) are separated from liquids (lower density).

Decanter centrifuges can be either 2-phase or 3-phase systems depending on the feedstock that requires processing.

2-phase separation with a decanter

2-phase separation with a press decanter means that the liquid and the solid phases are separated from each other by centrifugal acceleration. The solids particles collect due to their higher density on the bowl wall and are transported with the scroll to the discharge openings. At the same time the cleared liquid flows along the scroll into the liquid discharge zone.

Typical applications of 2-phase separation are waste water clearing, sludge dewatering, but also juice and wine production with decanter centrifuges.

Figure 10: Centrifuge decanter using wastewater (Source: Sinoped)

3-phase separation with a decanter

With these decanters 3 phases can be separated from each other in one process step only. Here two liquids which cannot be mixed and have different densities (e.g. oil and water) are separated from a solids phase. The heavy liquid (water) collects in the middle between the oil and the solids layer. Thus the two liquids separated from each other can be drawn off from the decanter. The solids are transported via the scroll to the discharge openings as it happens also in 2-phase separation.

Typical applications of 3-phase separation are production of edible oils such as olive oil, oil sludge processing, the production of bio diesel etc. This type of technology has been implemented in a tannery in Port Elizabeth to improve the removal of solids from the liquid component thus improving their waste water treatment requirements whilst ensuring recovery of solid material from the stream.

Benefits of using decanters

- Effective solid-liquid or solid-liquid-liquid separation to improve re-use and effective treatment of materials.

- Automatic and continuous operation, screen-free to achieve long-term performance with easy maintenance.
- Wide application range, it can be used in following separation processing.
    - Industrial dewatering. For the separative mixtures, the decanter centrifuge can conduct an effective separation as good as filtering centrifuge, but for the compressible suspension when the filtering centrifuge fail to handle, the decanter centrifuge can still finish the separation.
    - Liquid clarification. The decanter centrifuge can be also used to clarify the liquids, through less efficient than clarifier, it will get more drier sediment and higher-concentration allowable solids.
    - Separation of lighter solids from heavier liquid. Normally, this kind of material is separated by filtering centrifuge, but when the mixture contains of compressible solids or trouble happened to screens, the decanter centrifuge with minor improvement will be the only way to handle.
    - Liquid-liquid-solids separation. For the liquid-liquid-solids mixtures with solids more than 14%, it is quite hard for dish centrifugal separator to conduct an effective separation due to the complex separation process in which liquid-solids separation and liquid-liquid separation is both unavoidable. However, the decanter centrifuge can achieve the one-stage separation of three phase. Particle classification: decanter centrifuge grades the particles based on the sizes.
- Great adaptability of various material, wide range of separating operation, conduct a good operation even for the uneven solids sizes. Used in the separation of suspension with various density.
- Compact structure for easy seal, and can be used in high or low temperature.
- High-capacity of single device with small footprint and high efficiency.

Challenges associated with centrifuge

- Complex structure with higher cost.
- Poor washing effect of sediment, will require additional mechanisms where this is necessary.
- May require additional technology to further treat the separated material depending on the type of feedstock.

Potential environmental impact

- Incorrect storage of raw material (feedstock) could lead to leachates entering surface or groundwater sources.
- Incorrect storage of product material could lead to leachates entering surface or groundwater sources.
- Potential odours.

- Reduction in methane and CO_2 emissions due to the diversion from landfill.
- Reduction in used landfill airspace.

6.1.3 Chipping

Chipping is the process of breaking down woody biomass material into smaller pieces which provides for easier management and further processing of the material.

Figure 11: Biomass chipping (Source: Eden Woodlands)

Chipping can be carried out at a large variety of scales from roadside chipping using a small tractor powered chipper up to large scale fixed site chipping factories.

Disk chipper

Two or four knives are radially mounted on a heavy flywheel. Progressive slices are cut into the wood. Chips of 0.3-4.5 cm.

Drum chipper

This type is bigger and more powerful than disk chippers. Up to 12 knives are mounted tangentially on a drum. More heterogeneous chips with a length up to 6.5 cm.

Feed screw chipper

This chipper type utilises a large conical screw with a sharpened edge. It can process large logs and produce chips up to 8cm.

Benefits of using chippers

- Can be used on site where the material is being cut.
- Effective mechanism to resize woody biomass to allow for better decomposition.
- Multiple feedstock sources such as agricultural waste, wood waste and municipal solid waste
- Multiple uses for product such as mulch, soil stabilisers, weed depressant, compost, thermal treatment of municipal solid waste etc.

Challenges associated with chippers

- Cost of equipment.
- Typical lifespan of a chipper is 5 – 10 years. Maintenance costs are therefore critical for sustainability.
- May require additional technology to further treat the chipped material depending on the type of feedstock.

Potential environmental impact

- Incorrect storage of raw material (feedstock) could lead to leachates (particularly tannins) entering surface or groundwater sources.
- Noise associated with the machinery.
- Unmanaged mobile facilities may impact on indigenous vegetation.
- Unmanaged mobile facilities may cause compaction or erosion of soil.
- Reduction in methane and CO_2 emissions due to the diversion from landfill.
- Reduction in used landfill airspace.
- Removal of potential fire hazards left to land.

6.1.4 Pelleting

The development and spread of modern pelletizing technology reinforces this trend (Thrän et al., 2005; Peksa-Blanchard et al., 2007). Usage has so far been dominated by pellets from wood production. The primary source is wood from short-rotation plantations, but also used are woody biomass arising as a residue of forestry (timber waste), of agriculture (in particular straw), of wood processing (including industrial wood and in particular wood shavings), and end-of-life wood (bulky waste, demolition) (IZT, 2007). Pelletizing of other residues (e.g. press cakes from oil plants) is still under development.

Biomass pellets have been utilized in both residential heating systems and industrial power & heat generation in European countries.

Figure 12: Cornstalk pellets (Gemco Energy, 2017)

Benefits of using pelletisers

- Can be used on site where the material is being cut.
- Effective mechanism to compress woody biomass for use as a fuel.
- Material for pelleting especially alien invasive material is cheaper than coal mining.
- The slight ash that is discharged by the corn stalk-fired boiler can be used as a fertilizer for the crops.
- Wood biomass is lower in sulphur, nitrogen, ash, chlorine, and other chemicals than coal and traditional fossil fuels.

Challenges associated with pelletisers

- Cost of equipment.
- Only waste wood and agricultural biomass should be used for pelleting as a fuel source.

Potential environmental impact

- Incorrect storage of raw material (feedstock) could lead to leachates (particularly tannins) entering surface or groundwater sources.
- Noise associated with the machinery.
- Unmanaged mobile facilities may impact on indigenous vegetation.
- Uncontrolled use of virgin and hardwood trees.
- Unmanaged mobile facilities may cause compaction or erosion of soil.
- Reduction in methane and CO_2 emissions due to the diversion from landfill.
- Reduction in used landfill airspace.
- Produces less ash when combusted than coal, therefore less residue remains.
- Removal of potential fire hazards left to land

6.1.5 Sonification

Sonification is a process that enables the digestion process of biosolids such as sewage sludge and biomass without the need to add chemical agents.

Sonication treatment destroys parts of the cells of the biomass liquefying them. This liquefied material is definitely better decomposable by micro-organisms for example in the digesters of a biogas plant. This means that the digesting process runs off much better, increasing the biogas output by up to 50% and a corresponding reduction of residual substrate as waste. Further positive effects are: an important reduction of digesting-tower volume and an increased dehydration rate of the biomass (Sonotronic, 2017).

One big advantage of ultrasounds in this field is also the possibility to increase production of environmental-friendly energy and to reduce the volume of waste materials (applies for waste water treatment plants) which must be disposed.

The ultrasonic effect is very helpful for the treatment of biosolids because it generates a periodic compression and depression of the sonicated substance. If the ultrasonic intensity is high, the medium in the substance will be torn apart during the depression phase. This generates microscopic bubbles inside the liquid, which are filled with vapour or gas. This generates pressures of over 500 bar and enormous shear forces at temperatures of up to 5,200 Kelvin. These processes tear up the walls of organic cells, bacteria, fungi etc. This is particularly effective for water disinfection (Mason, 2008).

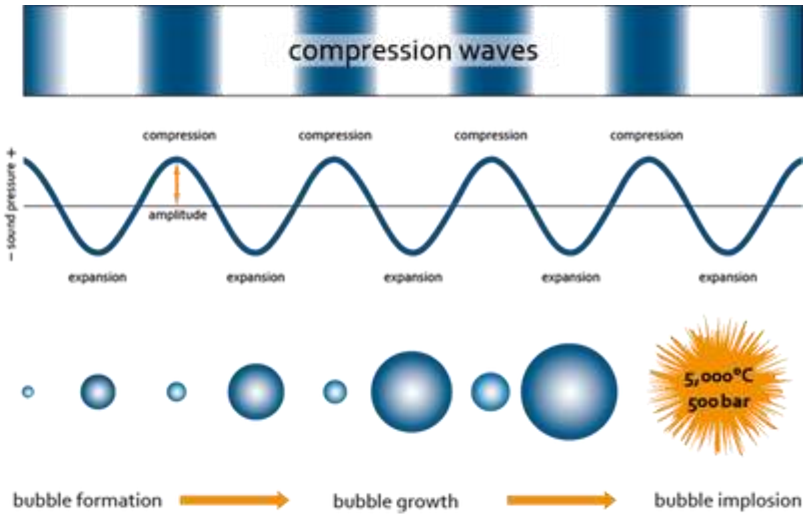


Figure 13: Sonification process (Sonotronic, 2017)

Benefits of using sonification

- Liquefies biosolids to better enable digestion of material by bacteria.
- In biogas digesters, improves gas production.
- Effective for wastewater treatment and biogas digesters for disinfection of liquid feedstock.

- The pressure and heat effectively destroys pathogens and harmful bacteria from the feedstock.

Challenges associated with sonification

- Cost of equipment.
- Very specialised machinery required.
- High energy requirements.

Potential environmental impact

- Incorrect storage of raw material (feedstock) could lead to leachates entering surface or groundwater sources.
- Reduction in methane and CO_2 emissions due to the diversion from landfill.
- Reduction in used landfill airspace.
- Produces less ash when combusted than coal, therefore less residue remains

6.2 CHEMICAL

Chemical treatments refer to the process where a substance is exposed to chemicals or chemical processes in which the reactions modify the chemical properties of the original substance.

Many of the chemical processes require some form of pre-treatment, mostly mechanical.

Table 8: Summary of chemical technologies

Chemical:	
Chemical hydrolysis	Hydrolysis is a type of decomposition reaction where one reactant is water. Typically, water is used to break chemical bonds in the other reactant. Sometimes this addition causes both substance and water molecule to split into two parts. In such reactions, one fragment of the target molecule (or parent molecule) gains a hydrogen ion.
Chemical oxidation	Chemical oxidation is a process involving the transfer of electrons from an oxidising reagent to the chemical species being oxidised. Oxidation chemically converts hazardous contaminants to non-hazardous or less toxic compounds that are more stable, less mobile, and/or inert. The oxidizing agents most commonly used are ozone, hydrogen peroxide, hypochlorites, chlorine, and chlorine dioxide. In water and wastewater engineering, chemical oxidation serves the purpose of converting putrescible pollutant substances to innocuous or stabilised products.

Transesterification	Animal and plant fats and oils are composed of triglycerides, which are esters formed by the reactions of three free fatty acids and the trihydric alcohol, glycerol. In the transesterification process, the alcohol (commonly, methanol) is added to the free fatty acids together with a base that deprotonates the alcohol so that it reacts to form fatty acid methyl ester- the main component of biodiesel.
Saponification	Soaps are sodium or potassium salts of long chain fatty acids. When triglycerides in fat/oil react with aqueous NaOH or KOH, they are converted into soap and glycerol. This is called alkaline hydrolysis of esters. Since this reaction leads to the formation of soap, it is called the Saponification process.

6.2.1 Chemical hydrolysis

Hydrolysis is a type of decomposition reaction where one reactant is water. Typically, water is used to break chemical bonds in the other reactant. Generally, hydrolysis or saccharification[22] is a step in the degradation of a substance.

In the context of biomass, this entails the conversion of lignocellulose into fuels and chemicals from monosaccharides (Binder & Raines, 2010). Adding water gradually to a chloride ionic liquid-containing catalytic acid leads to a nearly 90% yield of glucose from cellulose and 70–80% yield of sugars from untreated corn stover. Ion-exclusion chromatography allows recovery of the ionic liquid and delivers sugar feedstocks that support the vigorous growth of ethanologenic microbes. This simple chemical process, which requires neither an edible plant nor a cellulase, could enable crude biomass to be the sole source of carbon for a scalable biorefinery.

According to Binder & Raines (2010), the estimated global annual production of biomass is 1×10^{11} tons, sequestering 2×10^{21} J. For comparison, annual petroleum production amounts to 2×10^{20} J, whereas the technically recoverable endowment of conventional crude oil is 2×10^{22} J. Hence, in only one decade, Earth's plants can renew in the form of cellulose, hemicellulose, and lignin all of the energy stored as conventional crude oil.

The multistep process balances cellulose solubility and reactivity with water, producing sugars from lignocellulosic biomass. Furthermore, the hydrolyzate products are readily converted into ethanol by microorganisms. Together, these steps comprise an integrated process for chemical hydrolysis of biomass for biofuel production.

[22] When a carbohydrate is broken into its component sugar molecules by hydrolysis (e.g. sucrose being broken down into glucose and fructose), this is termed saccharification.

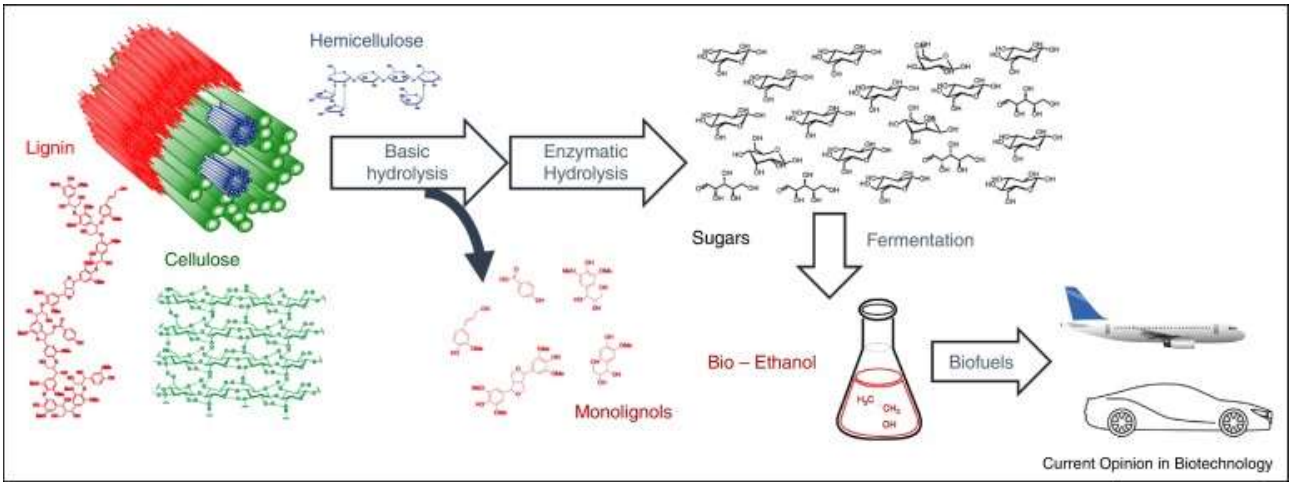


Figure 14: General process for production of biofuels (Tatsis & O'Connor, 2016)

Benefits of using chemical hydrolysis

- Uses inexpensive chemical catalysts rather than enzymes and avoids an independent pre-treatment step.
- In biogas digesters, hydrolysis is the first process of gas production.
- Chemical hydrolysis can be used to destroy pathogens and harmful bacteria.

Challenges associated with hydrolysis

- Highly viscous biomass-ionic-liquid mixtures might require special handling.
- Larger scale fermentation of hydrolyzate sugars might reveal the presence of inhibitors.
- Water evaporation costs associated with certain feedstock materials.

Potential environmental impact

- Incorrect storage of raw material (feedstock) could lead to leachates entering surface or groundwater sources.
- Incorrect storage of feedstock and product could lead to malodours;
- Reduction in methane and CO_2 emissions due to the diversion from landfill.
- Reduction in used landfill airspace.

6.2.2 Chemical oxidation

The aim of chemical oxidation is to oxidise organic pollutants to less dangerous or harmless substances. In the best case scenario, complete oxidisation of organic substances will result in CO_2 and H_2O. It does so by increasing the biodegradability of a substance. Chemical oxidation can be used to remediate a variety of organic compounds, including some that are resistant to natural degradation. It can be applied to the treatment of manufacturing processes that produce wastewater such as the paper industry as well as for sewage wastewater. The conventional ways of treating wastewater such as lagooning, treatment of activated sludge etc. are not necessarily always sufficient to meet regulatory effluent standards. Additionally chemical oxidation is used to produce biofuels from lignin depolymerization and utilization (Ma, Xu, & Zhang, 2014).

Oxidation chemically converts hazardous contaminants to non-hazardous or less toxic compounds that are more stable, less mobile, and/or inert. The oxidizing agents most commonly used are ozone, hydrogen peroxide, hypochlorites, chlorine, and chlorine dioxide (Van Deuren, Lloyd, Chhetry, Liou, & Peck, 2002).

Figure 15: Ethanol reservoirs at the Arcis-sur-Aube sugar refinery and distillery in eastern France © AFP

Benefits of using chemical oxidation

- Proven track record internationally
- In-situ (only requires a small area for unit setup).
- Fast reduction in contaminant concentrations.
- Produces a high quality treated effluent.
- Remediated wide range of contaminants.

Challenges associated with chemical oxidation

- Requirement for handling large quantities of hazardous oxidizing chemicals due to the oxidant demand of the target organic chemicals and the unproductive oxidant consumption of the formation.
- Some COCs are resistant to oxidation and may require multiple applications, thus escalating costs.

- There is a potential for process-induced detrimental effects. Further research and development is ongoing to advance the science and engineering of in situ chemical oxidation and to increase its overall cost effectiveness.
- Expensive.

Potential environmental impact

- Incorrect storage of raw material (feedstock) could lead to leachates entering surface or groundwater sources.
- Additional energy requirements needed for the introduction or generation of oxidants.
- Reduction in methane and CO_2 emissions due to the diversion from landfill.
- Reduction in used landfill airspace.

6.2.3 Transesterification

Transesterification (also called alcoholysis) is the reaction, normally catalized, of a fat or oil with an alcohol to form fatty acid esters (known as FAME when the alcohol is methanol) and glycerol. Transesterification of natural glycerides with methanol to methylesters is a technically important reaction that has been used extensively in the soap and detergent manufacturing industry worldwide for many years. Almost all biodiesel is produced in a similar chemical process using base catalyzed transesterification as it is the most economical process, requiring only low temperatures and pressures while producing a 98% conversion yield (Iowa State University Office of Biotechnology, 2017).

The creation of biofuels has three main processes (Haigh & Görgens, TRANS--1: Transesterfication of Waste Oil to Biodiesel, 2014):

Transesterification section: Conversion of oil to alkyl esters (biodiesel) with methanol. This occurs in the presence of an alkali catalyst. Most of the methanol is then removed and recycled.

Catalyst separation section: The catalyst is removed by first neutralising it and then precipitating it out of the flow.

Product separation section: The glycerol, unreacted oil, unreacted methanol and biodiesel are split by the use of a liquid---liquid extraction column, distillation columns and a precipitate separator.

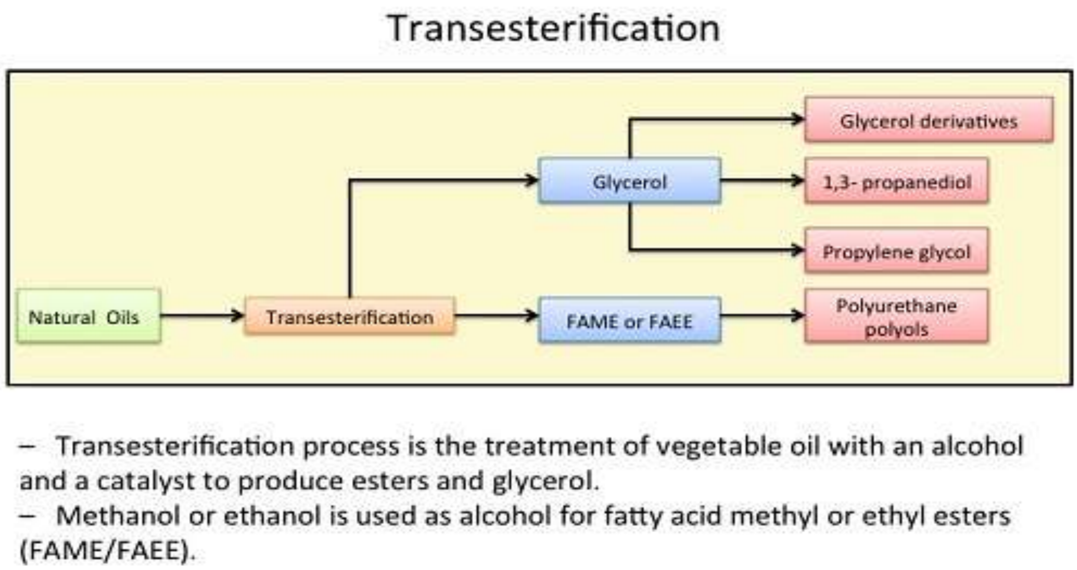


Figure 16: Transesterification process (Minerals Processing Research Institute, 2017)

Benefits of using transesterification[23]

- Proven track record.
- Fast reduction in contaminant concentrations.
- Biodiesel characteristics closely match those of conventional diesel fuel, therefore engine modification is unnecessary.
- Biodiesel is biorenewable. Feedstocks can be renewed one or more times in a generation
- Biodiesel is carbon neutral. Plants use the same amount of CO2 to make the oil that is released when the fuel is burned.
- Biodiesel is rapidly biodegradable and completely nontoxic, meaning spillages represent far less risk than petroleum diesel spillages.
- Biodiesel has a higher flash point than petroleum diesel, making it safer in the event of a crash.
- Biodiesel can be made from recycled vegetable and animal oils or fats.
- Biodiesel is nontoxic and biodegradable. It reduces the emission of harmful pollutants, mainly particulates, from diesel engines (80% less CO2 emissions, 100% less sulphur dioxide). But emissions of nitrogen oxide, the precursor of ozone, are increased
- Continued improvements in pre-treatment and hydrolysis technologies will significantly reduce capital and operating costs, as will opportunities for process integration, such as consolidated bioprocessing that enables hydrolysis and fermentation to occur simultaneously.

[23] (Saifuddin, Samiuddin, & Kumaran, 2015)

- Provides energy security.

Challenges associated with transesterification

- Expensive process.
- Longer reaction time is required.
- High energy consumption for the process.
- Recovery of by-product: purification of glycerol is very difficult.
- Sensitivity to the free fatty acids (FFA) content of the oil reduces biodiesel yield.

Potential environmental impact

- Incorrect storage of raw material (feedstock) could lead to leachates entering surface or groundwater sources.
- Biofuels are biodegradable, non-toxic and have significantly fewer emissions than petroleum-based fuels when burned.
- Reduction in methane and CO_2 emissions due to the diversion from landfill.
- Reduction in used landfill airspace.
- Reduces the use of fossil fuels.
- Reduction of air pollution when burning biofuels.

6.2.4 Saponification

One of the organic chemical reactions known to ancient man was the preparation of soaps through a reaction called saponification. Natural soaps are sodium or potassium salts of fatty acids, originally made by boiling lard or other animal fat together with lye or potash (potassium hydroxide). Hydrolysis of the fats and oils occurs, yielding glycerol and crude soap (Helmenstine, 2015).

Chemically, saponification is a process by which triglycerides are reacted with sodium or potassium hydroxide (lye) to produce glycerol and a fatty acid salt, called 'soap'. The triglycerides are most often animal fats or vegetable oils, however chlorophyll and lipids have been removed from microalgae using saponification to produce oil feedstock (Li, et al., 2016). When sodium hydroxide is used, a hard soap is produced. Using potassium hydroxide results in a soft soap. The chemical reaction between any fat and sodium hydroxide is a saponification reaction. The saponification reaction is exothermic in nature, because heat is liberated during the process. The soap formed remains in suspension form in the mixture. Soap is precipitated as a solid from the suspension by adding common salt to the suspension (Helmenstine, Saponification Definition and Reaction, 2017).

The glycerols produced from saponification have multiple applications including in the food industry, pharmaceutical uses, electronic cigarette liquids, antifreeze, combustion fuels, biodiesels and explosives.

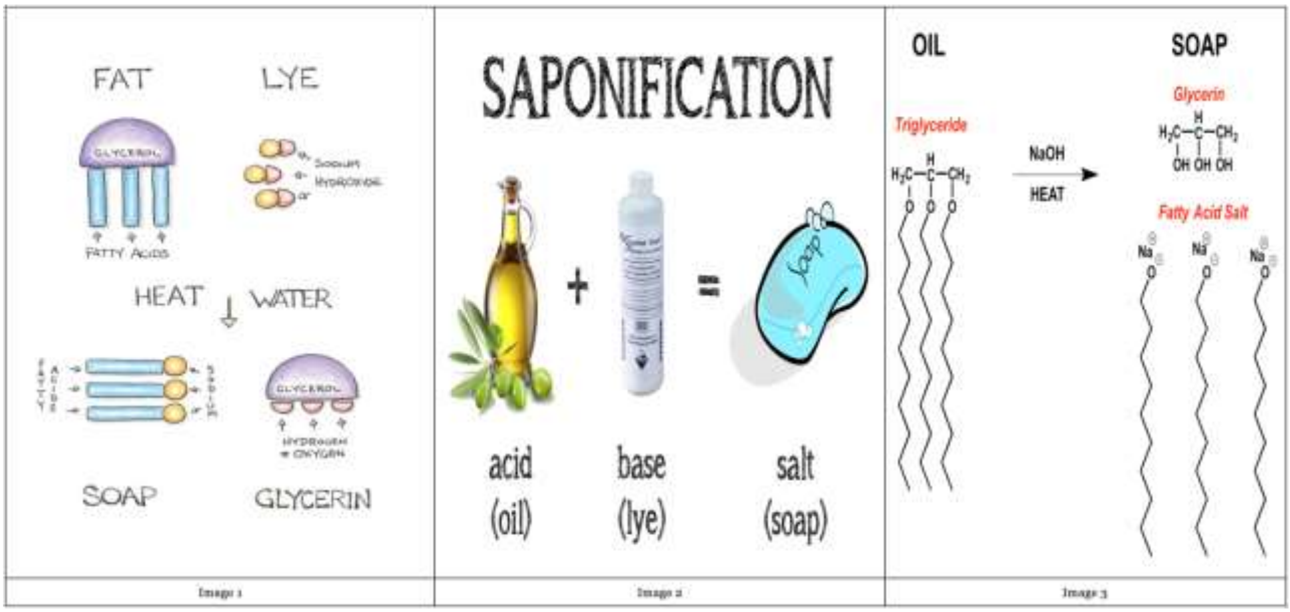


Figure 17: Saponification process (University of Notre Dame, 2017)

Benefits of using saponification

- Proven track record.
- Fast reduction in contaminant concentrations.
- Economically valuable products.
- No residual materials.
- Biodiesel characteristics closely match those of conventional diesel fuel, therefore engine modification is unnecessary.
- Biodiesel is biorenewable. Feedstocks can be renewed one or more times in a generation
- Saponification products are carbon neutral. Plants use the same amount of CO2 to make the oil that is released when the fuel is burned
- Biodiesel is rapidly biodegradable and completely nontoxic, meaning spillages represent far less risk than petroleum diesel spillages
- Biodiesel has a higher flash point than petroleum diesel, making it safer in the event of a crash
- Multiple products can be made from recycled vegetable and animal oils or fats.
- Biodiesel is nontoxic and biodegradable. It reduces the emission of harmful pollutants, mainly particulates, from diesel engines (80% less CO2 emissions, 100% less sulphur dioxide). But emissions of nitrogen oxide, the precursor of ozone, are increased
- Continued improvements in pre-treatment and hydrolysis technologies will significantly reduce capital and operating costs, as will opportunities for process integration, such as consolidated bioprocessing that enables hydrolysis and fermentation to occur simultaneously.
- Provides energy security.

Challenges associated with saponification

- Expensive process.
- Recovery of by-product: purification of glycerol is very difficult.
- Sensitivity to the free fatty acids (FFA) content of the oil reduces biodiesel yield.

Potential environmental impact

- Incorrect storage of raw material (feedstock) could lead to leachates entering surface or groundwater sources.
- Biofuels are biodegradable, non-toxic and have significantly fewer emissions than petroleum-based fuels when burned.
- Reduction in methane and CO_2 emissions due to the diversion from landfill.
- Reduction in used landfill airspace.
- Reduces the use of fossil fuels.
- Reduction of air pollution when burning biofuels

6.3 ANAEROBIC

Anaerobic treatment refers to treatment of biodegradable material where bacteria consume organic matter in an oxygen free environment.

Table 9: Summary of anaerobic digestion technology

Anaerobic:	
Anaerobic digestion	Anaerobic digestion is a fermentation process that causes the breakdown of organic compounds without the presence of oxygen. This process reduces nitrogen to organic acids and ammonia. Carbon from organic compounds is released mainly as methane gas (CH4). A small portion of carbon may be respired as CO_2. The decomposition occurs as four stages namely: hydrolysis, acidogenesis, acetogenesis, and methanogenesis.

6.3.1 Anaerobic digestion

Anaerobic digestion is a decomposition process whereby organic material is broken down into simpler molecules by bacteria in the absence of oxygen, ultimately leading to the formation of carbon dioxide and methane. Traditionally anaerobic digestion is used to treat manure and sewerage. However, the biogas yield can be improved by the addition of other organic material such as food waste, vegetable oil, energy crops and silage.

Typical operating temperatures are mesophillic, 35°C and thermophillic, 55°C. The Bio2watt biogas facility near Bronkhorstspruit in South Africa is an example of a plant that is both mesophililc and thermophilic and uses various sources of organic material to generate a current average of 4MW.

Figure 18: Bio2watt plant near Bronkhorstpruit, South Africa

Anaerobic digestion processes typically incorporate a method to use the produced gas. In the case of the small simple systems, the gas is fed into a domestic cooking and heating system. In the case of the large and more complex plants, a co-generation system is generally incorporated into the plant and part of the produced heat and power is used in the anaerobic digestion plant.

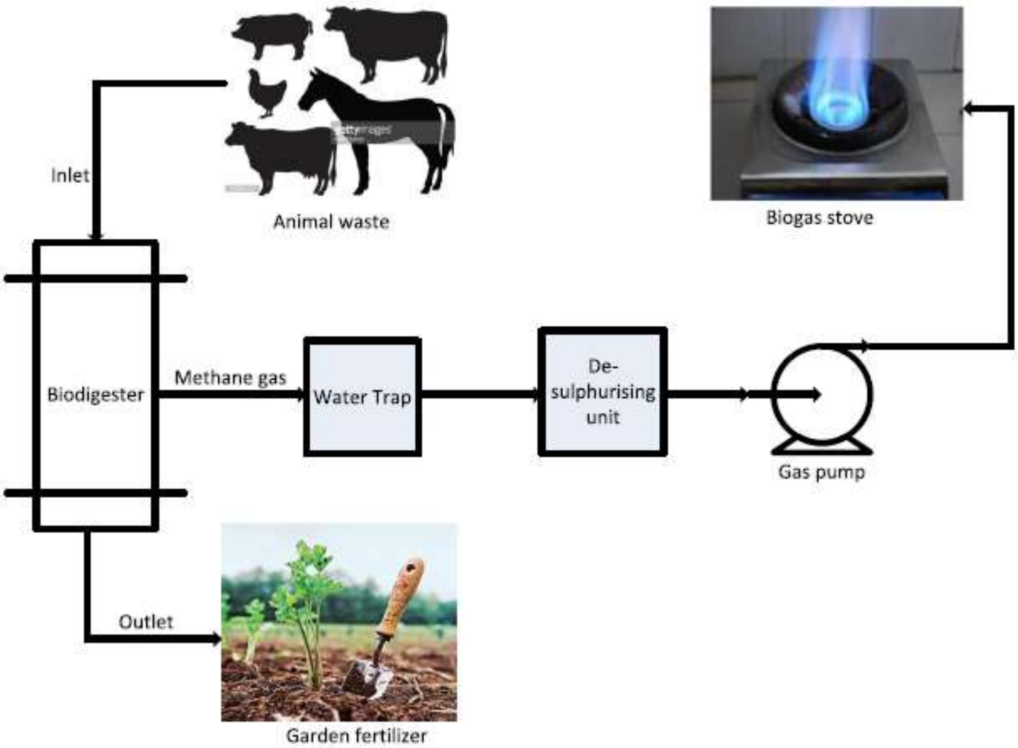


Figure 19: Typical small scale biogas process (Muvhiiwa, Hildebrandt, Chimwani, Ngubevana, & Matambo, 2017)

Biogas consists of methane (CH_4) and carbon dioxide (CO_2) as its main components, plus very small quantities of the compounds H_2O, H_2S, NH_3, N_2 and O_2. The unwanted components can be removed by various processes, such as pressure-swing absorption and amine scrubbing. Membrane separation processes promise increased efficiency, but are at present only at the development stage. In 2009 there were approximately 80 biogas processing facilities in operation in Europe that fed into natural gas networks or provide a natural gas substitute (Schubert, et al., 2009). Depending on the process used, purities in the range of 96–99% methane are achieved.

Synthesis gas is made up of other components. Depending on the gasification process, carbon monoxide (CO) and hydrogen (H_2) form as principal components, while CH_4 and water vapour occur only in small concentrations. This mixture is converted to CH_4 and CO_2 in synthesis reactors and the CO_2 separated off. The process of converting synthesis gas to CH_4 and that of removing the CO_2 are managed on a large scale and both processes have been successfully applied for over 20 years (Schubert, et al., 2009). In contrast to the direct deployment of the biogas or synthesis gas in decentral electricity generation plant, in which waste heat utilization is only partly feasible, the feeding of biomethane into natural gas networks allows more flexible utilization. Biomethane can then be supplied via the network to those users (CHP plant) that can optimally utilize waste heat.

Alternatively the gas network can serve a collecting function, supplying the biomethane product from multiple plant for maximum-efficiency deployment in large combined cycle power plant. When using biomethane it is generally possible to make use of the entire infrastructure developed for natural gas (distribution networks, combined-cycle power plant, gas engines, gas turbines, natural-gas vehicles).

The CO_2 inevitably produced in the gas processing can, at least in larger plant, be captured and stored. This improves the climate change mitigation effect of bioenergy use by approx. 20%. The technology for CO_2 storage is at present being developed. The emissions of CH_4 caused during the gas processing should be considered critical. While they are of the order of only a few percentage points, they cause a distinct reduction in the climate change mitigation effect of biomethane production and utilization owing to the strong global warming potential of CH_4 (Schubert, et al., 2009). The goal of future development must be to drastically reduce these leakages.

Bio-electricity is also generated through the combustion of biogas in gas and combustion engines. Biogas is produced decentrally through fermentation of liquid and solid biomass; the use of waste such as animal dung offers major ecological advantages in this context. In Europe gaseous and solid types of biomass contribute in roughly equal proportions to electricity generation: for example, in Germany in 2006, biogas systems met 0.9% of electricity needs while solid biomass met 1.2% (Schubert, et al., 2009). Alongside biogas systems, gasification and gas power generation in combined-cycle power plants provides a particularly efficient means of converting waste-based biomass into electricity.

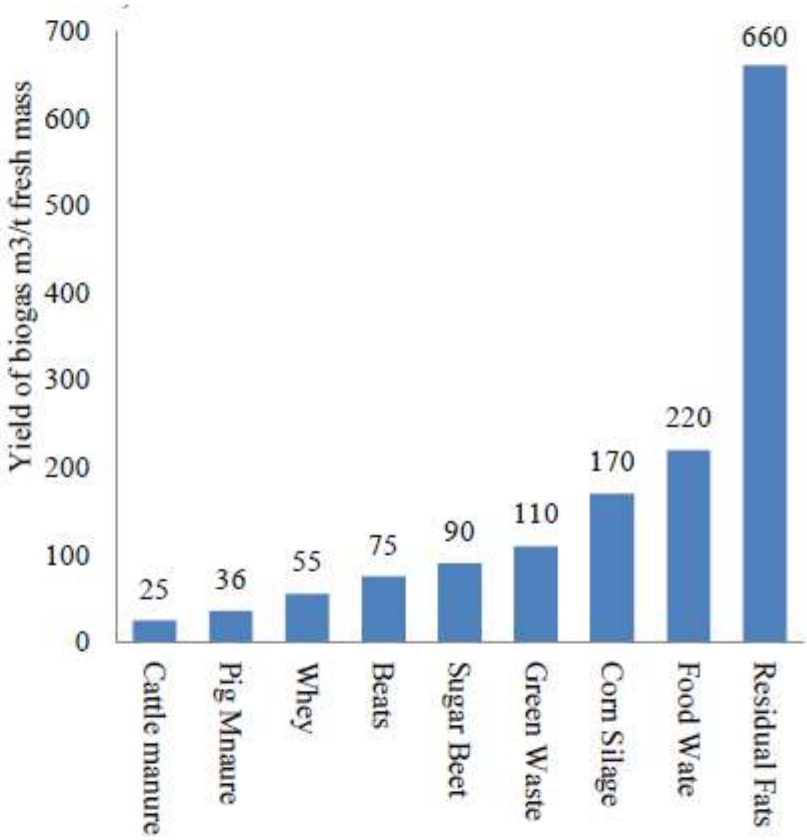


Figure 20: Biogas yields of various substrates in m3/tonne (Kigozi, Aboyade, & Muzenda, 2014)

Levis et al (Levis, Barlaz, Themelis, & Ulloa, 2010)consider AD treatment of MSW SSO to be the most environmentally sound option out of landfilling, aerobic composting and AD. This is due to the production and beneficial use of methane, and after curing, the digestate can be used as a soil amendment.

Traditionally rural households apply raw manure to lands as an organic fertiliser but this tends to have a lower organic nitrogen content than digestate that has gone through an AD treatment, as well as providing a clean source of energy (Muvhiiwa, Hildebrandt, Chimwani, Ngubevana, & Matambo, 2017).

Figure 21: Small scale biodigester in Muldersdrift, Johannesburg, South Africa (Muvhiiwa, Hildebrandt, Chimwani, Ngubevana, & Matambo, 2017)

Benefits of using anaerobic digestion[24]

- Proven track record globally
- Large amount of continually available feedstock.
- Digestion residues are very valuable organic alternatives to chemical fertilisers.
- Organic fertilisers produced by anaerobic digestion offer a considerably cheaper alternative to the chemical fertilisers and agrochemicals used in agriculture.
- Production of methane rich biogas which offers a renewable alternative to the consumption of fossil fuels.
- Carbon neutral process.
- Provides energy security.
- Combined heat and power (CHP) production.
- Reduction in pathogen populations but pasteurisation or sterilisation is necessary to ensure complete annihilation.
- Anaerobic digestion can reduce odour nuisance during land-spreading by up to 80%.
- AD destroys most weed seeds and digested slurry therefore provides organic fertilisation with minimal risk of weed spread, reducing the need for costly herbicides.
- Anaerobic digestion can be performed on many scales from small onsite agricultural projects to large municipal waste disposal facilities.
- Power and heat produced using biogas substantially reduce the energy costs of the facilities at which they are installed.
- Biogas to energy can be used as a base load or at peak demand for electricity.

Challenges associated with anaerobic digestion[25]

- Anaerobic bacteria tend to be slower growing and more sensitive to changes in conditions.
- Waste feed must be strictly managed if digester performance is not to be adversely affected (organic load shock).
- High initial costs to implement.
- Needs specific expertise for the management of the plant.
- Sulphur in waste feeds leads to the production of hydrogen sulphide during digestion so plants need to be robust to prevent corrosion.
- Heavy metals cannot be destroyed by digestion and thus the only way they can be controlled is to ensure that the feedstock is as clean as possible.
- Digestate may need to be dried to address surplus in some cases

Potential environmental impact

[24] (Stuart, Undated)
[25] (Stuart, Undated)

- Incorrect storage of raw material (feedstock) could lead to leachates entering surface or groundwater sources.
- Incorrect storage of raw material (feedstock) could lead to nuisance odours and attract pests.
- Anaerobic digestion reduces the biological oxygen demand (BOD) and chemical oxygen demand (COD) of effluents and therefore decreases the potential pollution dangers of the digestate.
- Significantly fewer emissions than petroleum-based fuels when gas is burned.
- Reduction in methane and CO_2 emissions due to the diversion from landfill.
- Reduction in greenhouse gas by capturing methane for use.
- Reduction in used landfill airspace.
- Reduces the use of fossil fuels.
- Reduction of air pollution when burning biogas.
- Reduction in odour nuisances.
- Reduction in weed seed transfer to land.
- Improvement of soils from organic fertilisers.
- Nutrient recycling.

6.4 AEROBIC

Aerobic decomposition of biodegradable material requires the presence of oxygen for the bacteria or other organisms to function.

Table 10: Summary of aerobic technologies

Aerobic:	
Aerobic digestion	Aerobic digestion is a process typically used in sewage treatment designed to reduce the volume of sewage sludge and make it suitable for subsequent use. The technology can also be applied to other organic wastes; such as food, cardboard and horticultural waste. It is a microbial process occurring in the presence of oxygen. Microbes rapidly consume organic matter and convert it into carbon dioxide, water and a range of lower molecular weight organic compounds. It is an important part of the process in composting and, when carried out optimally can generate sufficient heat to aid in destruction of pathogens (harmful bacteria and pathogens).
Black soldier fly larvae	Valorisation of organic waste through larval feeding activity of the black soldier fly, *Hermetia illucens* provides waste reduction and stabilisation while providing a product in form of the last larval stage,

	the so-called prepupae, which offers a valuable additive in animal feed.
Composting	A controlled biological process in which organic materials are broken down by micro-organisms in the presence of oxygen.
Vermicomposting	Vermicompost (or vermi-compost) is the product of the composting process using various species of worms, usually red wigglers, white worms, and other earthworms, to create a heterogeneous mixture of decomposing vegetable or food waste, bedding materials, and vermicast. This process of producing vermicompost is called vermicomposting.

6.4.1 Aerobic digestion

Aerobic digestion is typically associated with the treatment of wastewater. Aerobic systems are similar to septic systems in that they both use natural processes to treat wastewater (US Environmental Protection Agency, 2014). The basic aerobic treatment process involves providing a suitable oxygen rich environment for organisms that can reduce the organic portion of the waste into carbon dioxide and water in the presence of oxygen. Because aerobic systems use a higher rate process, they are able to achieve superior effluent quality.

Aerobic treatment technologies can act as stand-alone systems for treating the raw wastewater or provide aerobic polishing of anaerobically pre-treated wastewater for further removal of biochemical oxygen demand (BOD), suspended solids (TSS), nitrogen, and phosphorus. Aerobic treatment can also be used specifically to remove nitrogen and phosphorus–also known as BNR, or biological nutrient removal system.

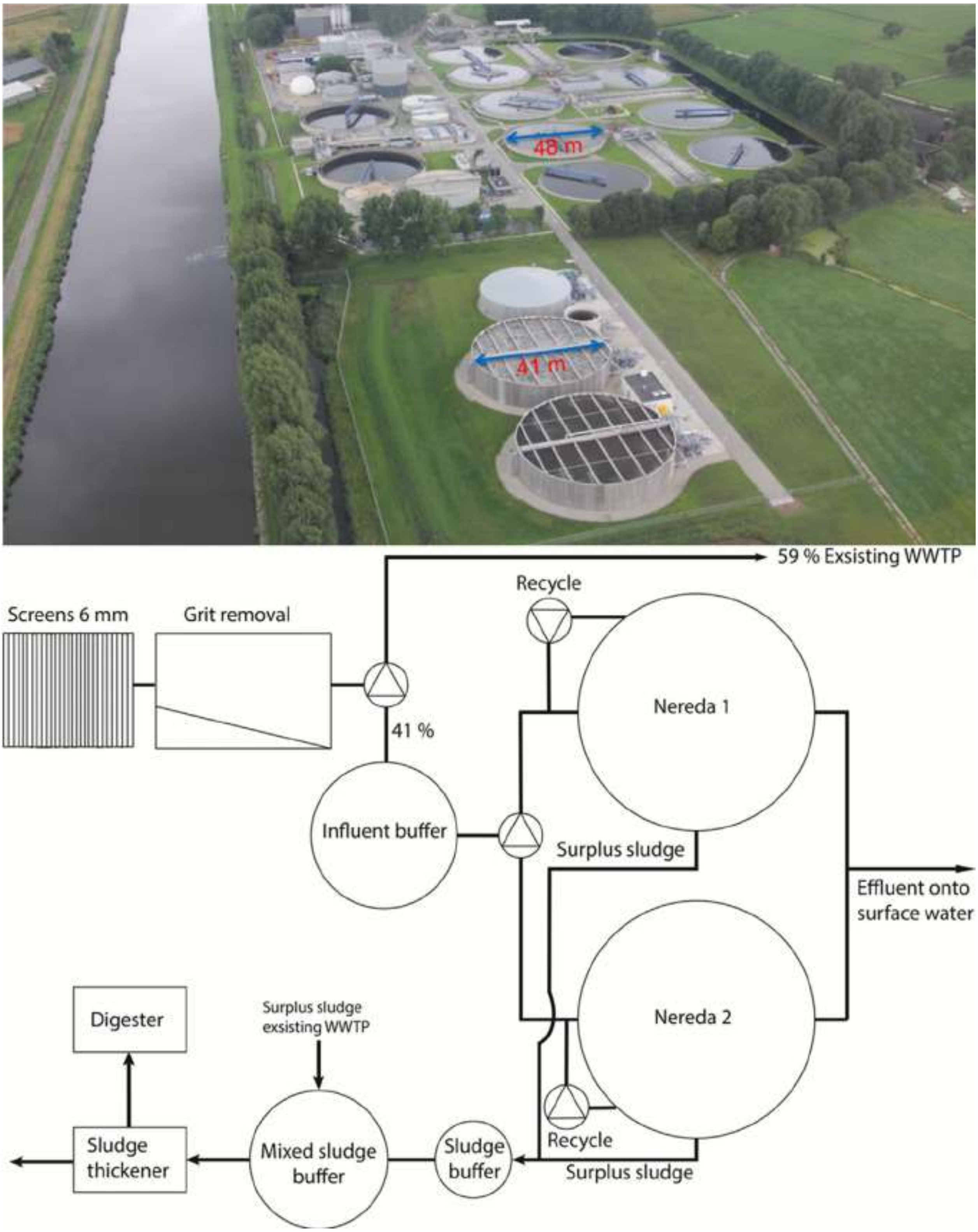


Figure 22: AB treatment at Garmerwolde WWTP in the Netherlands (Pronk, de Kreuk, de Bruin, Kamminga, Kleerebezem, & van Loosdrecht, 2015)

Another form of aerobic digestion is the composting toilet. These systems treat the waste as a moist solid, rather than in liquid suspension, and therefore separate urine from faeces during treatment to maintain the correct moisture content in the system. Treatment times are very long, with a minimum time between removals of solid waste of a year; during treatment the volume of the solid waste is decreased by 90%, with most being converted into water vapour and carbon dioxide.

Pathogens are eliminated from the waste by the long durations in inhospitable conditions in the treatment chamber and not by the mesophilic temperatures achieved in the chamber (clivusmultrum Incorpporated, 2010).

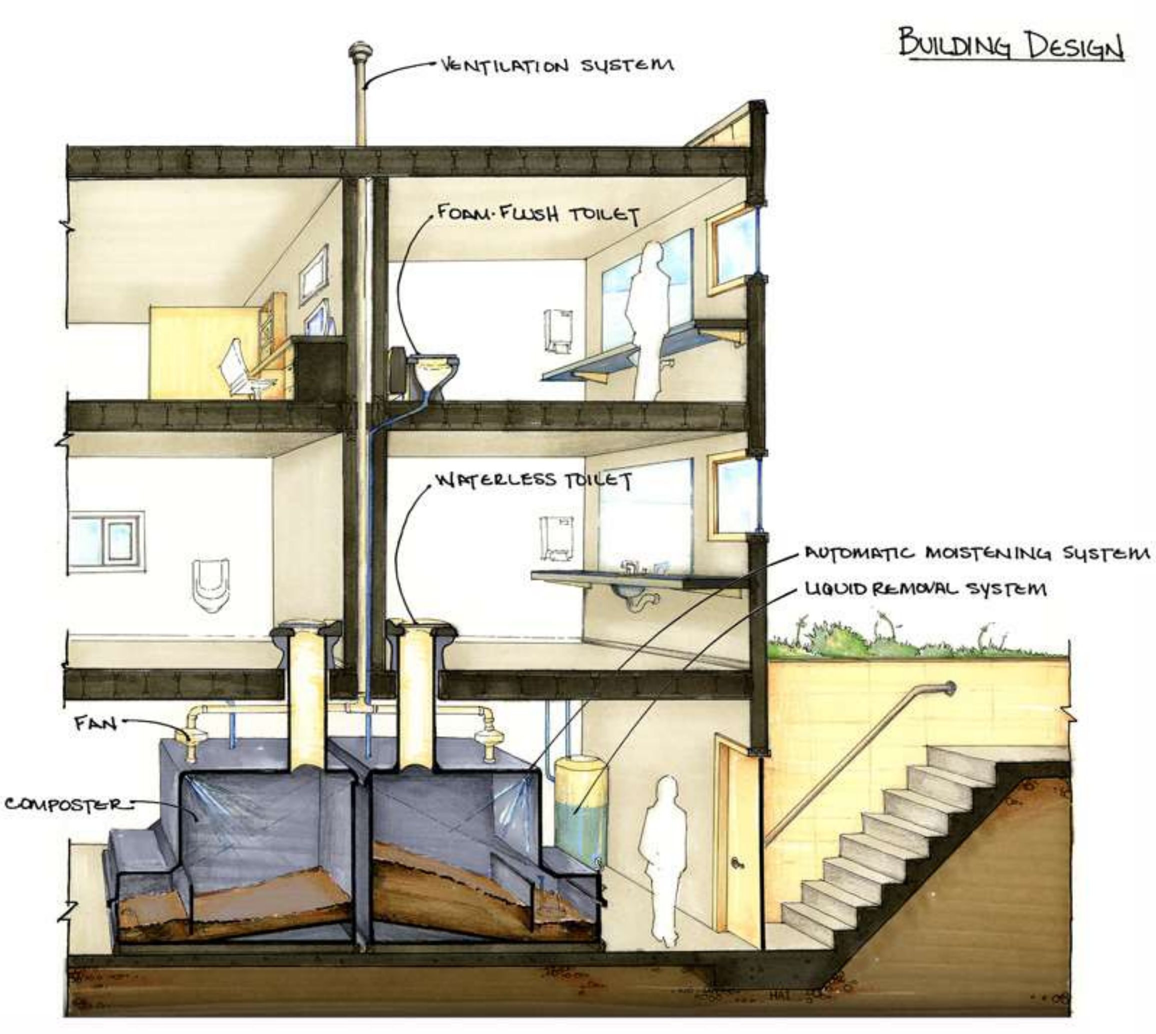


Figure 23: Composting toilet system (clivusmultrum Incorpporated, 2010)

Benefits of using aerobic digestion[26]

- Proven track record.
- Large amount of continually available feedstock.
- Can provide a higher level of treatment than a septic tank.
- Helps protect valuable water resources where septic systems are failing.
- Provides an alternative for sites not suited for septic systems.
- May extend the life of a drain field / leach field.
- May allow for a reduction in soil absorption drain field size.
- Reduces ammonia discharged to receiving waters.
- Typically introduced in more rural environments.

[26] (US Environmental Protection Agency, 2000)

- Composting toilets are more waterwise.

Challenges associated with aerobic digestion[27]

- More expensive to operate than a septic system.
- Requires electricity.
- Includes mechanical parts that can break down.
- Requires more frequent routine maintenance than a septic tank.
- Have site specific requirements to avoid pollution of water resources.
- Can lead to the emissions of CH_4, N_2O and NH_4.

Potential environmental impact

- Incorrect drain field site could lead to leachates entering surface or groundwater sources.
- Incorrect storage of raw material (feedstock) could lead to nuisance odours and attract pests.
- More water efficient.
- Reduction in methane and CO_2 emissions due to the diversion from landfill.
- Reduction in greenhouse gas by capturing methane for use.
- Reduction in used landfill airspace.
- Reduction in odour nuisances when correctly utilised.

6.4.2 Black Soldier Fly Larvae

Conversion of organic waste by larvae of the black soldier fly, *Hermetia illucens* L. (Diptera: Stratiomyidae) into versatile prepupae is an interesting recycling technology, with a potential to give organic waste economic value (Diener, et al., 2011).

Hermetia illucens is widespread in tropical and warmer temperate regions between about 45°N and 40°S. Its larvae feed on different decaying organic material, such as rotting fruits and vegetables, animal manure and human excreta. The last larval stage, the so-called prepupa, migrates from the feed source in search of a dry and protected pupation site. Pupation occurs within the larval skin and the adult emerges after about 14 days. The adults are rather lethargic and poor flyers. Females mate two days after emerging and oviposit into dry cracks and crevices adjacent to a feed source. Due to the relatively long period between oviposition and eclosion (3–4 days), eggs are never laid directly onto the moist rotting material. (Diener, et al., 2011)

During its adult stage, *H. illucens* does not feed and relies solely on its body fat reserve. Consequently, the fly does not come into contact with any degrading or fresh organic material including foodstuffs, and can therefore not be regarded as unsanitary or a vector of diseases. An additional advantage of *H. illucens* is its capacity to repel oviposition of female house flies, a

[27] (US Environmental Protection Agency, 2000)

serious disease vector especially in developing countries, where open defecation and inappropriate sanitation account for dangerous sources of pathogens. (Diener, et al., 2011)

The black soldier fly larvae are a source of protein, fat and chitin and according to Diener et al (2011) have been used to replace up to 50% of the food source for commercial fish production. It has also been suggested that oil from soldier fly prepupae raised on pig manure were converted into biodiesel, it would yield as much energy as methane production from the same amount of manure.

When used in faecal sludge, black soldier fly were not only able to survive and even develop in pure faecal sludge, but were also capable of significantly reducing the sludge biomass. However, their growth was significantly better when a 50:50 combination of faecal sludge and market waste was used (Diener, et al., 2011). Many insects possess a natural detoxification mechanism and results related to the heavy metal accumulation showed that the black solider fly larvae accumulated cadmium, suppressed lead and zinc was kept at a more or less constant level (Diener, et al., 2011). This indicates that the processing of the waste containing heavy metals and is beneficial, but some screening may be required to ensure that bioaccumulation of metals in the body of the larvae and the residue is not transferred along the food chain This can be achieved by a separation process and management of the feedstock used for the larvae.

Apart from the protein, fat and chitin, the black soldier fly produces a digestate which can be used for agricultural application. A study aimed at determining the waste to biomass conversion, found that the material degradation by black solider fly larvae is 55.1% in a continuous fly larvae composting system. The phosphorous and total ammonium nitrogen concentrations increased in the outflow residue material. The hygienic quality of the residual material was found to increase in the fly larvae treatment: the pathogen *Salmonella* spp. and viruses were reduced in the system, while the reduction of the other organisms studied was small or insignificant (Lalander, Fidjeland, Diener, Eriksson, & Vinnerås, 2015). Black soldier fly residue has been found to be comparable to that from vermiculture.

Figure 24: Black soldier fly larvae composting concept (Lalander, Fidjeland, Diener, Eriksson, & Vinnerås, 2015)

Benefits of using black soldier fly larvae

- High potential organic waste reduction and protein production.
- Large amount of continually available feedstock.
- Very quick processing / turnaround time.
- High value protein produced to use in hatcheries, fisheries, for small livestock (chickens and rodents) and potentially for biofuels.
- Replacement for fishmeal which reduces costs.
- Inexpensive to implement.
- Flies have a high tolerance to environmental conditions.
- Can operate from a small space (100,000 tons/yr needs only 2ha).
- Black soldier flies are not considered a serious disease vector.
- Lack of odour and dry to touch when handling.
- Self-harvest by exiting the feedstock at the prepupae stage and can be easily collected.
- Act as a deterrent of the common housefly greatly reducing their number.

Challenges associated with black soldier fly larvae

- Lower levels of omega-3 levels found in fish grown on black soldier fly larvae.
- Need to improve the protein, fat and fibre ratio when used as feed.
- Accumulation of some heavy metals which could continue along the food chain.

- Consumer perceptions.

Potential environmental impact

- Incorrect storage of raw material (feedstock) could lead to leachates entering surface or groundwater sources.
- Incorrect storage of raw material (feedstock) could lead to nuisance odours and attract pests.
- Reduces the demand for fishmeal and on wild fisheries.
- Reduction in methane and CO_2 emissions due to the diversion from landfill.
- Reduction in used landfill airspace.
- Reduction in odour nuisances when correctly utilised.

6.4.3 Composting

Composting is the process of recycling decomposed organic materials into a rich soil (compost). This naturally occurring and environmentally sound process for the disposal of waste products is popular worldwide and is of considerable economic importance. Composting input materials vary, and can include different types of organic and inorganic wastes, sewage sludge, pig, cattle or poultry manure, slaughterhouse waste and the organic fraction of municipal solid waste. The areas of application of the final product range from the restoration of construction sites and gardening, to fertilisers and pathogen-suppressive potting-mixes (Franke-Whittle, 2011).

The benefits of composting are linked to resource recycling. When composting, carbon (C) and nutrients (N, P and K) may be recycled and used again in soils. Composting can potentially help to restore organic matter in soils, reduce the use of mineral fertilisers and peat in growth media, reduce the need for pesticides, improve soil structure, reduce erosion and improve the water holding capacity of soil.

A good aeration system is imperative in the composting process, to ensure uniform temperature and moisture contents throughout the pile during the first and second phases of the composting process. This will minimise the survival of microorganisms such as coliforms, and various pathogens. The first phase is a thermophilic process thus temperatures in compost range between 55 - 70˚C (Franke-Whittle, 2011), with temperatures being observed in some instance exceeding 80˚C. Inactivation of pathogens is temporal and temperature dependant. Pathogen destruction through the composting process can occur either by a thermal kill at a high enough temperature, or by the action of antibiotics produced by microorganisms present in the compost (Wiley in Franke-Whittle, 2011). Achieving an average temperature of 55-60°C for 1-2 days is generally sufficient to reduce pathogenic viruses, bacteria, protozoa, and helminth ova to an acceptably low level. However, the endospores produced by spore-forming bacteria such as Clostridium and Bacillus would not be inactivated under these conditions (Franke-Whittle, 2011). It is thus essential that any feedstock material that may be considered infectious and where the pathogens will not be deactivated by thermophilic treatment, must undergo pasteurisation or similar destruction mechanisms.

Figure 25: The biomass is aerated to ensure aerobic composting, resulting in the production of carbon dioxide and heat rather than methane (myclimate, 2017)

Benefits of using composting

- High potential organic waste reduction and protein production.
- Large amount of continually available feedstock.
- Very quick processing / turnaround time.
- High value protein produced to use in hatcheries, fisheries, for small livestock (chickens and rodents) and potentially for biofuels.
- Replacement for fishmeal which reduces costs.
- Inexpensive to implement.
- Reduction in methane from organic material decomposition.
- Carbon neutral as it does not use virgin materials.
- Introduces beneficial organisms to the soil.
- Improves soil condition, water retention, nutrient stability, prevents soil erosion.
- Labour intensive so could provide entry level job opportunities as well as small SMMEs.

Challenges associated with composting

- Compost must be aerated to avoid creating methane.
- Could be malodourous depending on what materials are being composted.

- Ensure pathogenic compostable materials are pasteurised.
- Consumer perceptions.
- Prevent the spread of alien invasive species seed.
- Avoid leachate run off.

Potential environmental impact

- Incorrect storage of raw material (feedstock) could lead to leachates entering surface or groundwater sources.
- Incorrect storage of raw material (feedstock) could lead to nuisance odours and attract pests.
- Reduction in methane and CO_2 emissions due to the diversion from landfill.
- Reduction in used landfill airspace.
- Reduction in odour nuisances when correctly utilised.
- Improved soil conditioning on agricultural land.

6.4.4 Vermicomposting

Vermicomposting is a composting process that uses worms and micro-organisms to convert organics into nutrient-rich humus. It is similar in many ways to the use of black soldier fly larvae. There are many applications using earthworms, these include vermicomposting, Vermiculture (use of the worm for fish bait), vermimeal production (animal feed protein), vermiceutical production (medical treatment for humans), and vermiremediation (removal of heavy metals and pollutants from soil and sludge).

Earthworms aerate, till and fertilize the soil, breaking down organic waste into plant-available forms, improving the soil structure and nutrient and water-holding qualities of soil. In the past 50 years in particular, the use of chemical fertilizers, over-tillage of the soil and the use of pesticides have killed earthworms and other beneficial organisms, leading to poor soil fertility, loss of soil structure and soil erosion.

As worms move through soil and decaying organic matter, they ingest (eat) and aerate it, depositing castings as they go. These castings are rich in nutrients and beneficial soil organisms. Inside the gut of one worm there are enzymes and masses of bacteria and microbes. Everything that passes through the gut of an earthworm is coated with these beneficial microbes and bacteria.

Although there are several thousand species of earthworms globally, only 6 species have been identified as being suitable for vermiculture systems. These species have the ability to tolerate a wide range of environmental conditions and fluctuations and they are not adversely affected by handling and disruption of their habitat. Other qualities that make these species suitable include relatively short life spans, and rapid growth and reproductive rates.

Eisenia fetida, its close relative, *Eisenia andrei*, and *Lumbricus rubellus* are the earthworm species most commonly used in vermiculture. They are referred to by a variety of common names, including red worms, red wigglers, tiger worms, brandling worms, and manure worms. They are often raised together and are difficult to tell apart. (Vermiculture, 2009). Introduction of species that could be harmful, destructive or invasive must be avoided (Bareja, 2011).

Vermicomposting also can reduce heavy metals and toxins found in sewage sludge. It has also been found that the vermicomposting helps to reduce the presence of pathogens in organic matter significantly. Vermicomposting results in castings or solid residue from the worms and a liquid known as vermitea. These vermi-castings are rich in nitrate and contain minerals like phosphorous, potassium, calcium, and magnesium, which are excellent fertilizers and soil conditioners.

Vermitea has been used as a liquid fertiliser and has shown high potential for improving better soil structure, body and a healthier general appearance, humus content, as well as increasing harvest production. Two additional benefits that were experienced are that livestock preferred plants treated with the vermitea and shelf life of potatoes grown with vermitea were longer (Uys, 2016).

Figure 26: Vermicomposting (ecoideaz, 2016)

Benefits of using vermicomposting

- High potential organic waste reduction and protein production
- Large amount of continually available feedstock
- Natural fertiliser
- Inexpensive to implement

- Can be implemented on small scale up to commercial scale
- Worms are an excellent source of protein, fats and amino acids for animal feeds
- Worms are used for removing soil pollutants through bioremediation. Heavy metals and other pollutants can be taken up by the worms and removed from the soil and sewage sludge
- Improves soil aeration and texture
- Improves soil water retention capabilities
- Labour intensive so could provide entry level job opportunities as well as small SMMEs

Challenges associated with vermicomposting

- Takes up to 6 months to process
- Can become malodorous if not correctly managed
- Requires constant monitoring
- Bioaccumulation of some heavy metals in the work protein which could continue along the food chain
- Consumer perceptions especially for protein use

Potential environmental impact

- Incorrect storage of raw material (feedstock) could lead to leachates entering surface or groundwater sources
- Incorrect storage of raw material (feedstock) could lead to nuisance odours and attract pests
- Introduction of invasive species must be avoided
- Reduction in methane and CO_2 emissions due to the diversion from landfill
- Reduction in used landfill airspace
- Reduction in odour nuisances when correctly utilised

6.5 THERMAL

Thermal treatments refer to the addition of an external heat source to the feedstock which then causes chemical changes to the material. This applied heat source differs from composting for example where the decomposition process generates its own heat until the process is completed. Most of the treatments identified in this category are considered to trigger the listed activities Government Notice R893 of NEM:AQA as well as those of NEM:WA.

It must be noted that many of the thermal technologies identified in this section can be, and often are used in conjuction with each other i.e. drying and pyrolysis are used as part of the gasification process, but can be used on their own for different applications.

Table 11: Summary of thermal technologies

Thermal:	
Aqueous phase reforming	The reaction of biomass-derived oxygenated compounds (e.g. glycerol) in aqueous solution at low temperature in the presence of a platinum catalyst to produce hydrogen and light alkanes. Aqueous oxygenated hydrocarbons are reformed at low temperatures (200–250 °C) and high pressures (1.5–5 MPa).
Combustion	Combustion is a thermal process that produces heat and light energy from fire. Combustion occurs at high temperatures (generally above 1200˚C) when a fuel is oxidised and for complete combustion sufficient aeration is needed to provide an excess of oxygen. For example, when wood burns, oxygen in the air joins with carbon in wood and the carbon is oxidised to carbon-dioxide, leaving only minerals in the ash.
Drying	Application of heat to evaporate water from biosolids. Either direct or indirect heating methods are used. In the most common case, a gas stream, e.g., air, applies the heat by convection and carries away the vapor as humidity. Other possibilities are vacuum drying, where heat is supplied by conduction or radiation (or microwaves), while the vapor thus produced is removed by the vacuum system. Another indirect technique is drum drying (used, for instance, for manufacturing potato flakes), where a heated surface is used to provide the energy, and aspirators draw the vapor outside the room. In contrast, the mechanical extraction of the solvent, e.g., water, by centrifugation, is not considered "drying" but rather "draining".
Gasification	Gasification is a thermal process that converts fuel into energy rich gases; such as carbon monoxide, hydrogen (synthesis gas or syngas). This is achieved by reacting the material at moderate temperatures (>700 °C), with a limited and controlled amount of oxygen and/or steam. The syngas can be burned to produce electricity or further processed to manufacture chemicals, fertilizers, liquid fuels, substitute natural gas (SNG), or hydrogen.
Hydrothermal	HTC is a thermochemical process for the conversion of organic

Carbonisation (HTC)	compounds to structured carbons. It can be used to reduce the water content from the digestate / fertilizer and convert the solid fraction into “green coal” or brown coal formation (coalification). Typical hydrothermal carbonization conditions are 180oC and 1 MPa of pressure.
Hydrothermal Liquefaction (HTL)	Hydrothermal liquefaction of biomass is the thermochemical conversion of biomass into liquid fuels by processing in a hot, pressurized water environment for sufficient time to break down the solid biopolymeric structure to mainly liquid components. Typical hydrothermal processing conditions are 125˚C–374˚C of temperature and operating pressures from 4 to 22 MPa of pressure.
Pressure heating / Supercritical water gasification (SCWG)	Mechanism using heat and pressure to improve char and lighter gases in biomass.
Pyrolysis	Pyrolysis is a thermal process that decomposes of organic material at in the absence of oxygen at temperatures of 300-600oC. It involves the simultaneous change of chemical composition and physical phase, and is derived from the Greek word for "fire separating". Pyrolysis is also known as thermal cracking, cracking, thermolysis, depolymerization, etc.
Rendering	Rendering is a thermal process that converts waste animal tissue into stable, value-added materials. The rendering process simultaneously dries the material and separates the fat from the bone and protein. A rendering process yields a fat commodity (yellow grease, choice white grease, bleachable fancy tallow, etc.) and a protein meal (meat and bone meal, poultry byproduct meal, etc.). Rendering plants often also handle other materials, such as slaughterhouse blood, feathers and hair, but do so using processes distinct from true rendering
Torrefaction	Torrefaction is a thermal process to convert biomass into a more coal-like material through light roast at 200-300˚C, giving it better fuel characteristics than the original biomass. Torrefied biomass is more brittle, making grinding easier and less energy intensive.

6.5.1 Aqueous Phase Reforming (APR)

Aqueous phase reforming is an example of a hydrothermal process for the conversion of biomass. Water is used as a solvent and the reaction is carried out at conditions such that water remains in the liquid phase. Typical reaction conditions are 150---250°C and 1.5---6.0 MPa (15---60 bar) and with a precious metal catalyst. While this process is similar to hydrothermal liquefaction the reaction conditions are generally more benign which favours hydrogen production from the water gas shift reaction. (Haigh & Görgens, APR: Aqueous Phase Reforming, 2014)

The process produces hydrogen and alkanes and is seen as a potential energy technology (Coronado, Stekrova, Reinikainen, Simell, Lefferts, & Lehtonen, 2016).

Owing to the high energy content of hydrogen and the possibility of converting this energy in fuel cell devices into electric power without any pollutant emissions, hydrogen has grown to be one of the most useful sources of energy, especially if it is produced from renewable sources. The primary requirement for the production of hydrogen is the reforming of glycerol which is obtained from biomass by means of transesterification. (Ebshish, Yaakob, Taufiq-Yap, Bshish, & Tasirin, 2012). APR is one of several method used for reforming glycerol.

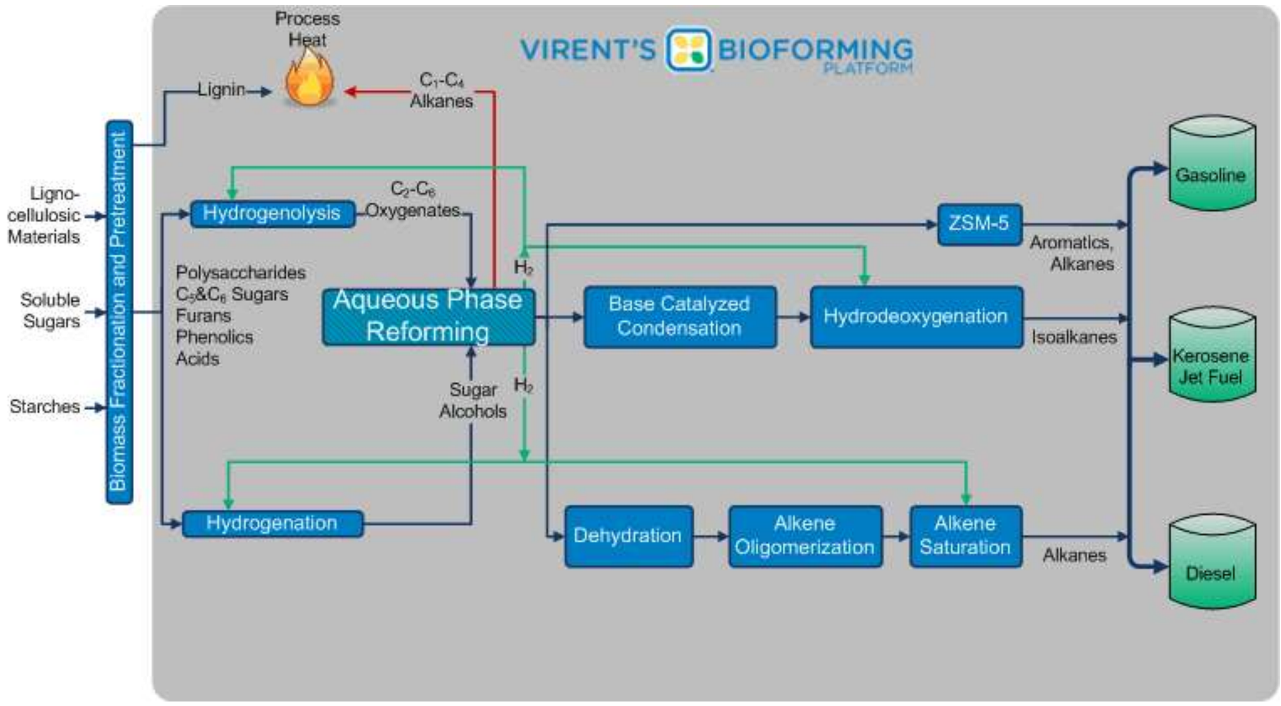


Figure 27: Bioforming process (New Energy and Fuel, 2009)

Benefits of using aqueous phase reforming[28]

- High potential organic waste reduction and hydrogen production
- Large amount of continually available feedstock
- Produces less CO than other reforming technologies

[28] (Ebshish, Yaakob, Taufiq-Yap, Bshish, & Tasirin, 2012) and (Haigh & Görgens, APR: Aqueous Phase Reforming, 2014)

- Because the reactants are in liquid phase, the energy required to vaporise them is eliminated
- The conditions of the process are favourable for the water-gas Shift reaction, which reduces the amount of CO produced
- The high-pressure hydrogen produced in the process can be effectively purified and utilised for further purposes
- The production of hydrogen from hard-to-evaporate polyols at relatively low temperatures can be performed with aqueous-phase reforming in a single-step process, in contrast to steam reforming, which requires multiple steps
- All emissions are captured and used

Challenges associated with aqueous phase reforming[29]

- Technology is very new and assumptions are made regarding emissions and capacity abilities
- Carbon monoxide may be released into the atmosphere as a result of this technology
- Expensive technology (because a noble-metal (Pt) catalyst is used, the cost of hydrogen production using this process is high)
- High water use
- APR requires more time than that needed for steam reforming to perform its reactions
- Operation at high pressures and with dilute feed solutions requires additional energy per unit of hydrogen produced
- To date, APR is only suitable for small-scale hydrogen production

Potential environmental impact

- Incorrect storage of raw material (feedstock) could lead to leachates entering surface or groundwater sources
- Incorrect storage of raw material (feedstock) could lead to nuisance odours and attract pests
- Carbon monoxide may be released into the atmosphere
- Reduction in methane and CO_2 emissions due to the diversion from landfill
- Reduction in used landfill airspace
- Reduces the use of fossil fuels
- Reduction of air pollution when utilising hydrogen

[29] (Ebshish, Yaakob, Taufiq-Yap, Bshish, & Tasirin, 2012) and (Haigh & Görgens, APR: Aqueous Phase Reforming, 2014)

6.5.2 Combustion

Biomass combustion is simply the burning of organic material in the presence of oxygen. Humans have typically burnt biomass to provide heat and light. A biomass combustion system aims to capture the energy produced and utilise it for other uses. Biomass combustion systems can produce hot air, hot water, steam, electricity, or a combination thereof.

Combustion is the process by which more than 90% of the world's primary energy supply is realized in order to provide heat and energy services such as materials processing including food preparation; space heating, ventilation and cooling; electricity, and transportation (Overend, 1999). Only 11% of the total energy supply uses biomass as a combustible source. Typically woody biomass is used, however as long as the material contains carbon, it can be used in combustion.

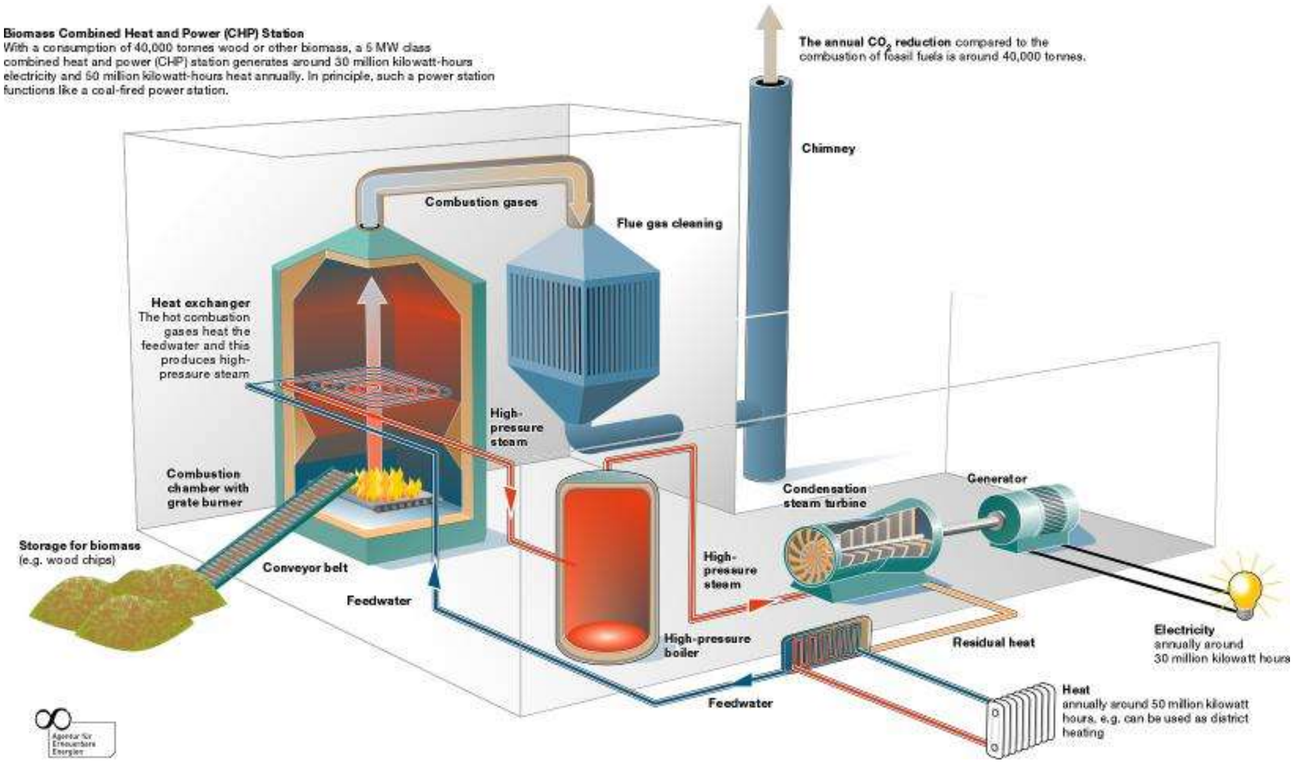


Figure 28: Biomass combustion (Minh, 2013)

Benefits of using combustion

- Proven technologies
- High potential organic waste reduction especially of high lignocellulose material such as woody alien invasive species
- Large amount of continually available feedstock
- Relatively cheap fuel source
- Carbon neutral with respect to greenhouse gas emissions
- Reduces reliance on fossil fuels
- Provides self-sufficiency during blackouts or in areas without conventional electricity

Challenges associated with combustion

- Fuel quality and consistency can vary significantly
- Produces more indoor and outdoor air pollution than conventional heating fuels, even with the use of advanced combustion technology
- Creates the risk of fire and carbon monoxide poisoning
- Can require cutting wood, as well as the skill to lay fires
- Requires regular tending and maintenance
- Fuel storage requires a lot of space
- Risk of deforestation where virgin material is used instead of waste material

Potential environmental impact

- Incorrect storage of raw material (feedstock) could lead to leachates entering surface or groundwater sources
- Incorrect storage of raw material (feedstock) could lead to nuisance odours and attract pests
- Creates smoke and other emissions
- Reduction in methane and CO_2 emissions due to the diversion from landfill
- Reduction in used landfill airspace
- Reduces the use of fossil fuels
- Carbon neutral for emission of greenhouse gases

6.5.3 Drying

Drying of biomass reduces the moisture content of the biomass material, thereby producing a fuel source that is more easily utilised in combustion processes. This leads to increased boiler efficiency, lower air emissions and improved boiler operation due to an increased flame temperature caused by lower moisture content (Amos, 1998). Drying is however an energy-intensive pre-treatment and as such it is often used as a secondary operation to re-use “waste” heat from other industrial processes (Li, Chen, Zhang, Finney, Sharif, & Swithenbank, 2011).

There are various types of dryers commercially available and include rotary dryers, flash dryers and steam dryers. The type of dryer will depend on the type of feedstock material available as well as water capacity (steam dryers require more water than others) (Amos, 1998).

Figure 29: Wood chip dryer (Nexus Energy, 2017)

Benefits of using drying

- Proven technologies
- High potential organic waste reduction especially of high lignocellulose material such as woody alien invasive species
- Large amount of continually available feedstock
- Relatively cheap fuel source
- Carbon neutral with respect to greenhouse gas emissions
- Reduces reliance on fossil fuels
- Lower carbon monoxide level and less fly ash produced when using dry biomass
- Less smoke produced by drier fuels

Challenges associated with drying

- Fuel quality and consistency can vary significantly
- Creates the risk of fire
- Can require cutting wood, as well as the skill to lay fires
- Requires regular tending and maintenance
- Fuel storage requires a lot of space
- Risk of deforestation where virgin material is used instead of waste material
- May require mechanical pre-treatment such as chipping
- Biomass boilers are larger than conventional boilers thus require more space

Potential environmental impact

- Incorrect storage of raw material (feedstock) could lead to leachates entering surface or groundwater sources
- Incorrect storage of raw material (feedstock) could lead to nuisance odours and attract pests

- Reduction in methane and CO_2 emissions due to the diversion from landfill
- Reduction in used landfill airspace
- Reduces the use of fossil fuels
- Carbon neutral for emission of greenhouse gases
- Less smoke produced when using drier fuels

6.5.4 Gasification

Gasification is the process of converting biomass fuel into carbon monoxide, hydrogen and carbon dioxide. This is achieved by reacting the material at high temperatures (>700 °C), without combustion, with a controlled amount of oxygen and/or steam. The resulting gas mixture is called syngas (from synthesis gas) or producer gas and is itself a fuel. The advantage of gasification is that using the syngas (synthesis gas H_2/CO) is potentially more efficient than direct combustion of the original fuel because it can be combusted at higher temperatures or even in fuel cells

The gasification process generally has five stages[30]:

Feed processing / Drying: Wet biomass (30% moisture) is dried using heat produced by gasification.

Pyrolysis: Application of heat to raw biomass, in an absence of air, so as to break it down into charcoal and various tar gasses and liquids. It is essentially the process of charring.

Gasification / thermal cracking: Biomass is thermally cracked in the presence of air into a mixture of H_2, CO (syngas), CO_2 and other by---products.

Reduction: Process stripping of oxygen atoms off combustion products of hydrocarbon (HC) molecules, so as to return the molecules to forms that can burn again.

Gas clean-up: The gas is then treated by direct quench scrubbing and in a WGS reactor.

---

[30] (Haigh & Görgens, Syn-Prd: Syngas Production from Lignocellulose, 2014) and (All Power Labs, 2017)

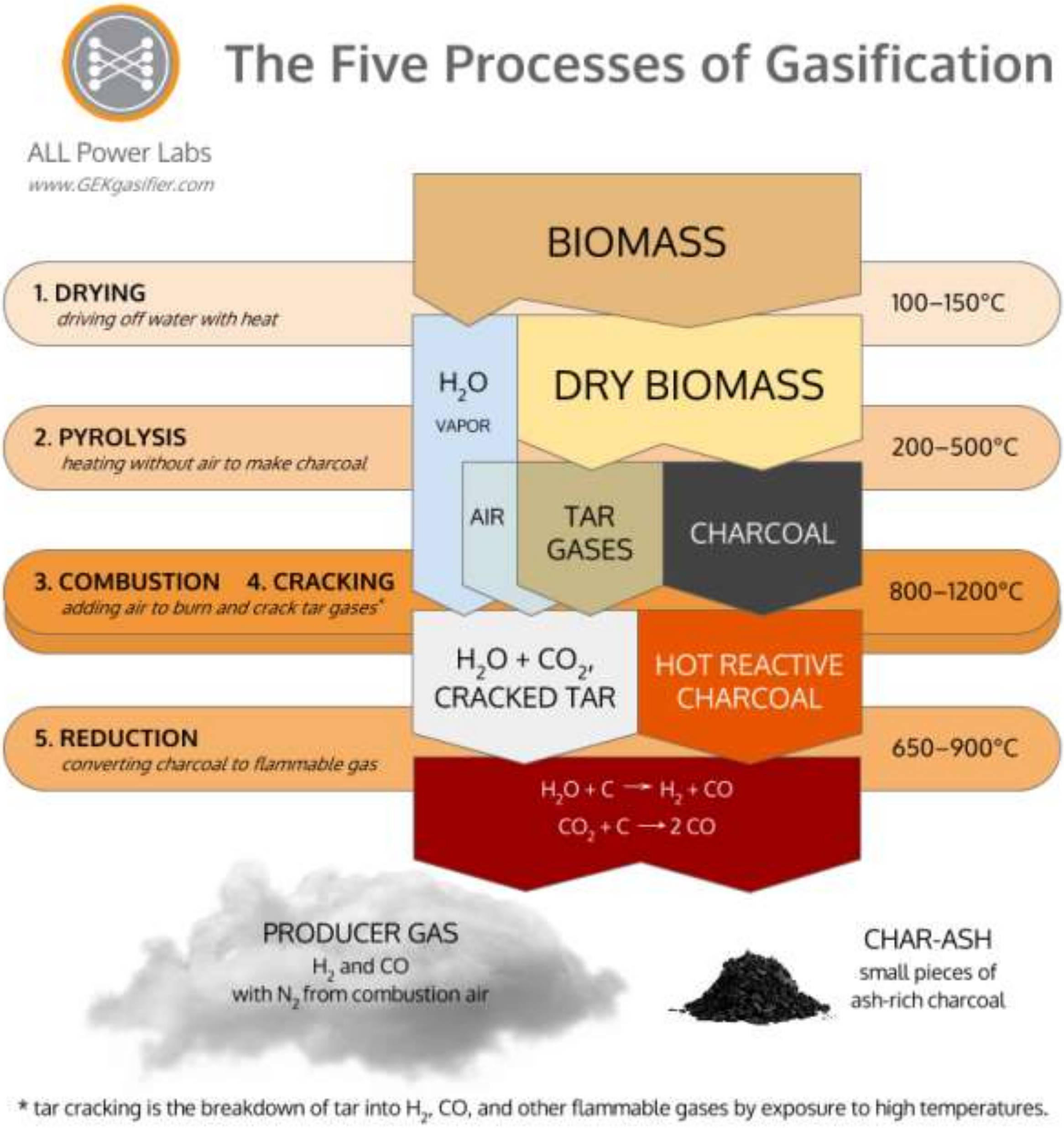


Figure 30: Process of gasification (All Power Labs, 2017)

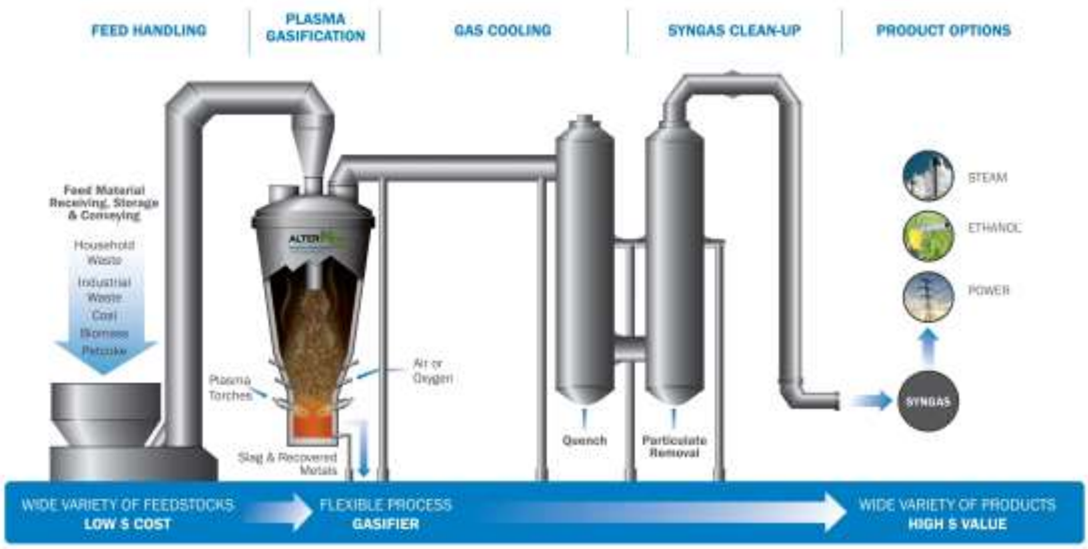


Figure 31: Biomass gasification (WPP Energy Corp, 2010)

Benefits of using gasification[31]

- Proven technologies
- High potential organic waste reduction
- Large amount of continually available feedstock
- Feedstock flexibility – can use multiple types of feedstock
- Relatively cheap fuel source
- Carbon neutral with respect to greenhouse gas emissions
- Reduces reliance on fossil fuels
- Re-use of gases as a renewable fuel source
- Creation of biochar for use as an organic soil enhancer
- Not a water intensive technology
- Improved emissions control due to higher temperatures
- High efficiency
- All emissions are captured and used

Challenges associated with gasification

- Gasification is a complex and sensitive process
- Raw material is bulky and frequent refuelling is often required for continuous running of the system
- Expensive technology
- Requires regular tending and maintenance
- May require mechanical pre-treatment such as chipping
- Poor public-perception and understanding of the technology

[31] (US Department of Energy)

Potential environmental impact

- Incorrect storage of raw material (feedstock) could lead to leachates entering surface or groundwater sources
- Incorrect storage of raw material (feedstock) could lead to nuisance odours and attract pests
- Reduction in methane and CO_2 emissions due to the diversion from landfill
- Reduction in used landfill airspace
- Reduces the use of fossil fuels for energy
- Carbon neutral for emission of greenhouse gases

6.5.5 Hydrothermal Carbonization (HTC)

Hydrothermal carbonization (HTC) is an induced coalification (i.e. it is able to mimic the coal formation process under laboratory conditions) process that converts raw biomass into a coal-like product, called hydrochar, characterized by high carbon content and high calorific value. This type of thermo-chemical conversion, also referred to as wet pyrolysis (or wet torrefaction), can be applied to a variety of non-traditional sources such as the organic fraction of municipal solid waste, wet agricultural residues, sewage sludge, algae and aquaculture residues The process allows for treatment of high moisture content feedstocks without requiring a pre-treatment process. (Lucian & Fiori, 2017)

The products resulting from HTC treatment are primarily a solid phase enriched in carbon (hydrochar), a liquid phase with dissolved organic compounds and a small quantity of a gas phase mainly composed of carbon dioxide, hydrogen and methane. (Basso, Castello, Baratieri, & Fiori, 2013).

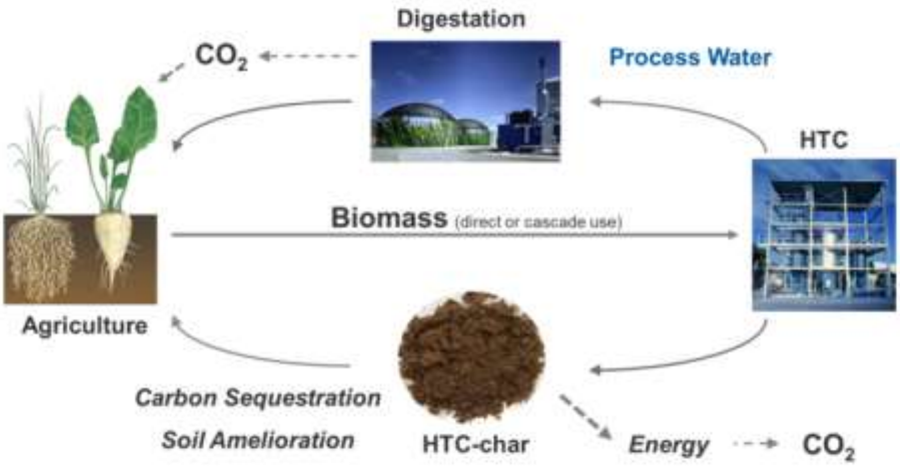


Figure 32: Cascade use of HTC (Kopinke, 2016)

Benefits of using HTC[32]

- Simple, Proven and robust, multi-batch technology
- High potential organic waste reduction
- Large amount of continually available feedstock
- Feedstock flexibility – can use multiple types of feedstock
- Product flexibility – can produce multiple product types
- Can use high moisture content feedstock without pre-treatment
- HTC can also process problem wastes that currently require expensive disposal (e.g. sewage sludge)
- Relatively cheap fuel source
- Carbon neutral with respect to greenhouse gas emissions
- Highest carbon equivalent (CE) value of all technology options (HTC =95% / Biogas = 50%)
- Reduces reliance on fossil fuels
- Re-use of gases as a renewable fuel source
- Low impact technology with very low odour or noise emissions
- Low maintenance costs due to the proven, robust technical implementation
- Creation of biochar for use as an organic soil enhancer
- Not a water intensive technology
- Improved emissions control due to higher temperatures
- High efficiency
- HTC allows for the currently most efficient phosphorous recovery
- All emissions are captured and used

Challenges associated with HTC

- Formation and fate of organic pollutants by using contaminated waste biomass has to be investigated
- Expensive technology
- No commercially operational plants available
- May require mechanical pre-treatment such as chipping
- Poor public-perception and understanding of the technology

Potential environmental impact

- Incorrect storage of raw material (feedstock) could lead to leachates entering surface or groundwater sources
- Incorrect storage of raw material (feedstock) could lead to nuisance odours and attract pests

[32] (R3 Water, 2013)

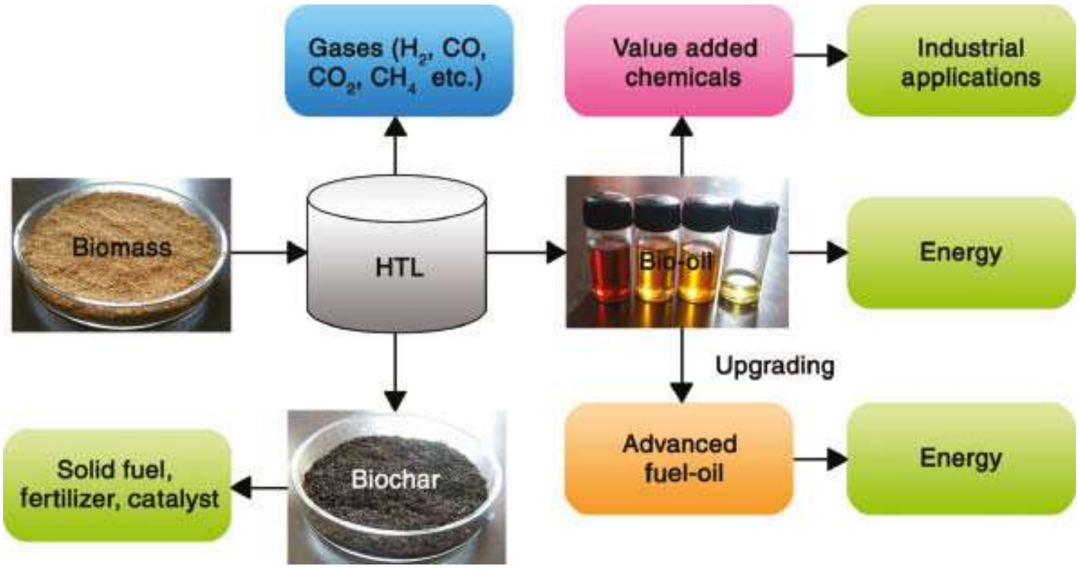
- Reduction in methane and CO_2 emissions due to the diversion from landfill
- Reduction in used landfill airspace
- Reduces the use of fossil fuels for energy
- Carbon neutral for emission of greenhouse gases

6.5.6 Hydrothermal Liquefaction (HTL)

Hydrothermal liquefaction is a medium-temperature, high-pressure thermochemical process (280 - 370 ˚C and between 10 and 25 MPa), which produces a liquid product, often called bio-oil or bi-crude (Toor, Rosendah, & Rudolf, 2011). In hydrothermal liquefaction, water is an important reactant and catalyst, and thus the biomass can be directly converted without an energy consuming drying step, as in the case of pyrolysis.

The HTL process does not use any chemicals and can be done using water alone, although with some feedstocks a catalyst may be required (Toor, Rosendah, & Rudolf, 2011). The bio-crude is very similar to fossil crude oil and as such the processing of the bio-crude can be done using existing refinery technology.

The water that emanates from the HTL process has low carbon contents and can either be recycled into the process or ultimately be purified to attain drinking water quality (Habjanec , 2014).



Benefits of using HTL

- Reduces volumes of biomass to liquid which allows for easier and cheaper transportation (marine algae)
- High potential organic waste reduction
- Large amount of continually available feedstock
- Feedstock flexibility – can use multiple types of feedstock

- Product flexibility – can produce multiple product types
- Can use high moisture content feedstock without pre-treatment
- HTC can also process problem wastes that currently require expensive disposal (e.g. sewage sludge)
- Relatively cheap fuel source
- Carbon neutral with respect to greenhouse gas emissions
- Reduces reliance on fossil fuels
- Re-use of gases as a renewable fuel source
- Creation of biochar for use as an organic soil enhancer
- Improved emissions control due to higher temperatures
- High energy efficiency
- HTC allows for the currently most efficient phosphorous recovery
- All emissions are captured and used

Challenges associated with HTL

- Formation and fate of organic pollutants by using contaminated waste biomass has to be investigated
- Potentially high water usage
- Expensive technology
- No commercially operational plants available
- May require mechanical pre-treatment such as chipping
- Poor public-perception and understanding of the technology

Potential environmental impact

- Incorrect storage of raw material (feedstock) could lead to leachates entering surface or groundwater sources
- Incorrect storage of raw material (feedstock) could lead to nuisance odours and attract pests
- Reduction in methane and CO_2 emissions due to the diversion from landfill
- Reduction in used landfill airspace
- Reduces the use of fossil fuels for energy
- Carbon neutral for emission of greenhouse gases

6.5.7 Pressure Heating / Supercritical Water Gasification

Pressure heating operates similarly to gasification to a large extent by forming hydrogen, methane and carbon dioxide under high temperatures (>374˚C). The difference is that the material is also subjected to pressures above 20MPa. The combination of heat from supercritical water[33] and the pressure causes the biomass to decompose (Wiese-Fales, 2011). The supercritical water gasification (SCWG) process produces hydrogen, carbon dioxide, methane, carbon monoxide and a small amount of ethane and ethylene whilst avoiding biomass drying and allowing maximum conversion for energy purposes.

The gas produced by means of SCWG has almost no NOx and SOx generated and the CO concentration is very low (Lachos-Perez , Juliana , Torres-Mayanga , Forster-Carneiro, & Meireles, 2015).

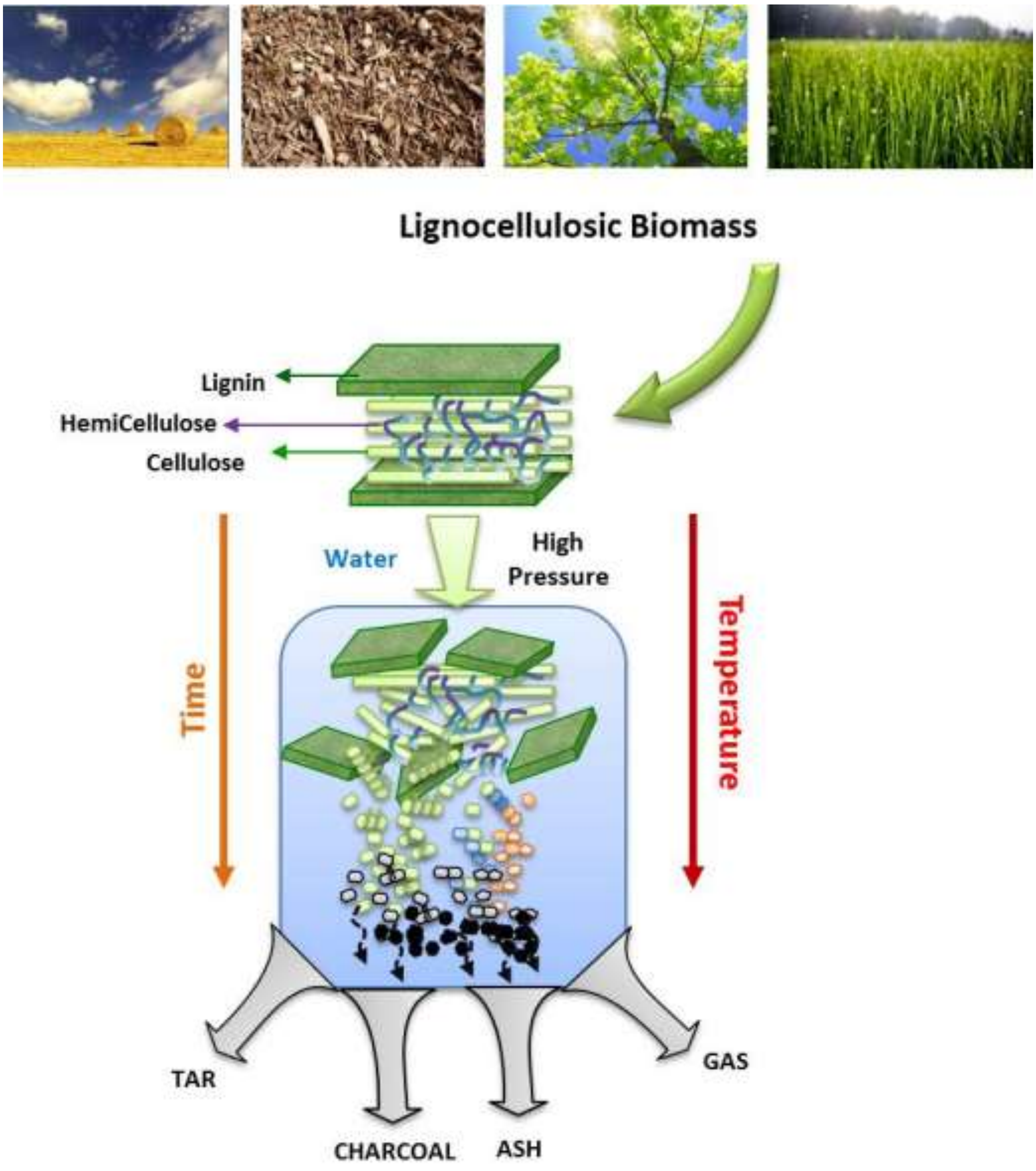


Figure 33: Effect of pressure and temperature over time on biomass (Lachos-Perez , Juliana , Torres-Mayanga , Forster-Carneiro, & Meireles, 2015)

[33] Water in the supercritical state has similar properties of the viscosity as a gas and the density as a liquid and is something halfway between a liquid and a gas. Water becomes supercritical when above its critical temperature, 374.1oC, and critical pressure, 22.1 MPa.

Benefits of using SCWG

- Reduces volumes of biomass to liquid which allows for easier and cheaper transportation (marine algae)
- High potential organic waste reduction
- Large amount of continually available feedstock
- Feedstock flexibility – can use multiple types of feedstock
- Product flexibility – can produce multiple product types
- Can use high moisture content feedstock without pre-treatment
- SCWG can also process problem wastes that currently require expensive disposal (e.g. sewage sludge)
- Relatively cheap fuel source
- Carbon neutral with respect to greenhouse gas emissions
- Reduces reliance on fossil fuels
- Re-use of gases as a renewable fuel source
- Creation of biochar for use as an organic soil enhancer
- Improved emissions control due to higher temperatures
- High energy efficiency
- High pressure of the gaseous product enables the transportation, usage, carbon capture and further purification of the product gas through steam reforming or PSA (pressure swing adsorption)
- The reaction temperature is much lower than that in conventional gasification and pyrolysis
- Gaseous product is very clean
- All emissions are captured and used

Challenges associated with SCWG

- Formation and fate of organic pollutants by using contaminated waste biomass has to be confirmed
- Potentially high water usage
- Expensive technology
- No commercially operational plants available
- May require mechanical pre-treatment such as chipping
- Poor public-perception and understanding of the technology

Potential environmental impact

- Incorrect storage of raw material (feedstock) could lead to leachates entering surface or groundwater sources
- Incorrect storage of raw material (feedstock) could lead to nuisance odours and attract pests

- Reduction in methane and CO_2 emissions due to the diversion from landfill
- Reduction in emissions due to high heat and temperatures
- Reduction in used landfill airspace
- Reduces the use of fossil fuels for energy
- Carbon neutral for emission of greenhouse gases

6.5.8 Pyrolysis

Pyrolysis is the heating of an organic material in the absence of oxygen (sometimes called degasification) (Schubert, et al., 2009). This ensures that combustion does not take place but the chemical compound of the organic material decomposes into combustible gases and charcoal. Most of the combustible gases can be condensed to create bio-oil. Thus pyrolysis produces a liquid, bio-oil and biochar. (United States Department of Agriculture, 2017)

The pyrolysis process can be self-sustained, as combustion of the syngas and a portion of bio-oil or bio-char can provide all the necessary energy to drive the reaction.

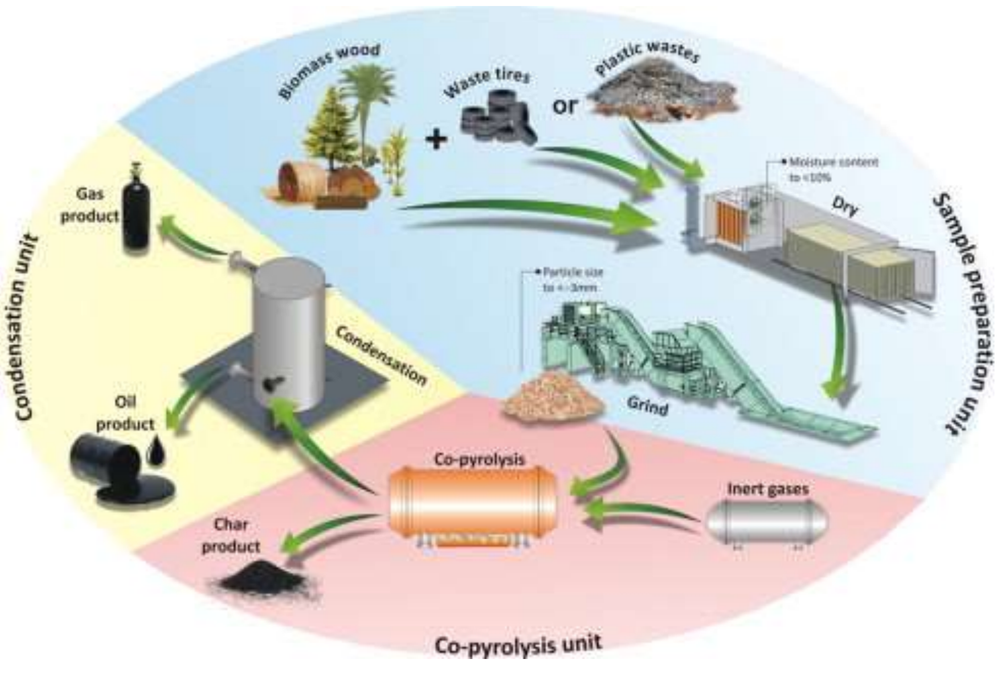


Figure 34: Co-pyrolysis and products (Abnisa & Daud, 2014)

Benefits of using pyrolysis

- High potential organic waste reduction
- Large amount of continually available feedstock
- Feedstock flexibility – can use multiple types of feedstock including inorganic materials such as plastic and tyres
- Product flexibility – can produce multiple product types
- Can use high moisture content feedstock without pre-treatment
- Pyrolysis can also process problem wastes that currently require expensive disposal (e.g. sewage sludge)

- Relatively cheap fuel source
- Carbon neutral with respect to greenhouse gas emissions
- Reduces reliance on fossil fuels
- Re-use of gases as a renewable fuel source
- Creation of biochar for use as an organic soil enhancer
- Improved emissions control due to higher temperatures
- High energy efficiency
- Toxic elements and pathogens in the feedstock are completely destroyed

Challenges associated with pyrolysis

- Expensive technology
- May require mechanical pre-treatment such as chipping
- Poor public-perception and understanding of the technology

Potential environmental impact

- Incorrect storage of raw material (feedstock) could lead to leachates entering surface or groundwater sources
- Incorrect storage of raw material (feedstock) could lead to nuisance odours and attract pests
- Reduction in methane and CO_2 emissions due to the diversion from landfill
- Reduction in emissions due to high heat and temperatures
- All emissions are captured and used
- Reduction in used landfill airspace
- Reduces the use of fossil fuels for energy
- Carbon neutral for emission of greenhouse gases

6.5.9 Rendering

The underlying principles behind any rendering operation, large or small, are exactly the same. Fat is extracted by simply heating fat containing tissue. This material can include the fatty tissue, bones, and offal, as well as entire carcasses of animals condemned at slaughterhouses, and those that have died on farms, in transit, etc.

The rendering process simultaneously dries the material and separates the fat from the bone and protein. A rendering process yields a fat commodity (yellow grease, choice white grease, bleachable fancy tallow, etc.) and a protein meal (meat and bone meal, poultry by-product meal, etc.).

Blood meal is produced in a similar fashion to meat meal but because it contains almost no fat, it is purely a dehydration process with no need for fat removal before milling.

Bones, hair and feathers all require that the product be broken down further i.e. hydrolysed. Hydrolysis is achieved by exposing the product to higher pressure and temperatures in the presence of water which causes bones to become softer and brittle and in the case of hair and feathers, breaks down keratinaceous bonds which in turn improves digestibility when used as protein supplements.

Fat is the most valuable product produced during rendering followed by protein meal, blood meal and bone meal.

Rendering has been carried out for many centuries, primarily for soap and candle making. The earliest rendering was done in a kettle over an open fire.

Figure 35: Historical rendering process (Mavitec, 2017)

This method caused nuisance odours and this has led to the perception that rendering is the dirtiest of biowaste treatment methods. It must be noted that the changes in technology in rendering have made significant headway in ensuring that nuisance odours are managed. The modern day “dry” rendering processes such as micro-rendering have improved energy use in the process, a better protein yield, faster processing, and fewer obnoxious odours (Mavitec, 2017).

Figure 36: Micro rendering plant outside of an abattoir (WRT, 2017)

Benefits of using rendering

- Proven track record
- High potential organic waste reduction
- Large amount of continually available feedstock
- Feedstock flexibility – can use multiple types of feedstock including infectious animal waste
- High value fats and proteins for livestock / pet rations
- Multiple product uses for rendered fats – tallow, candles, grease, biodiesel, soap
- After rendering, the materials are much more resistant to spoiling
- Can use high moisture content feedstock without pre-treatment
- Relatively cheap fuel source
- Inexpensive technology
- Improved emissions control due to higher temperatures
- Toxic elements and pathogens in the feedstock are completely destroyed

Challenges associated with rendering

- Potential malodours if not correctly managed
- May require mechanical pre-treatment such crushing and grinding
- Poor public-perception and understanding of the technology
- Meat and bone meal from ruminants may not in turn be used in ruminant feed as a prevention for Bovine Spongiform Encephalopathy (BSE), however they can be used for non-ruminant feed. Separation and management are therefore essential

- Nutrient enriched by-product can be used as soil enhancer but the off-set market is inconsistent therefore it must be used as a wetting agent for composting or dried as a fertiliser.

Potential environmental impact

- Incorrect storage of raw material (feedstock) could lead to leachates entering surface or groundwater sources
- Incorrect storage of raw material (feedstock) could lead to nuisance odours and attract pests
- Reduction in methane and CO_2 emissions and nuisance odours due to the diversion from landfill
- Reduction in used landfill airspace
- Reduces the use of fossil fuels for energy
- Carbon neutral for emission of greenhouse gases

6.5.10 Torrefaction

Torrefaction is a similar process to pyrolysis in that the biomass is treated thermo-chemically in the absence of oxygen. However, torrefaction is typically carried out over longer times and at a lower reaction temperature (200-400°C), similar to roasting. During the torrefaction process a combustible gas is released, which is utilised to provide heat to the process.

The main product of torrefaction is a solid with similar characteristics to coal and is sometimes known as bio-coal. (Haigh & Görgens, TORR: Torrefaction (TORR-1)/ Torrefaction and Pelleting (TORR-2), 2014). The bio-coal is considered to have better fuel characteristics than the original biomass material.

Torrefied biomass is fragile, has a low density and a tendency to produce reactive dust. As a result it is generally considered necessary to grind and pellet the biomass in order transport it.

Figure 37: Torrefaction of biomass (Indiamart, 2017)

Benefits of using torrefaction[34]

- High potential organic waste reduction
- Large amount of continually available feedstock
- Feedstock flexibility – can use multiple types of woody feedstock
- Improves the physical properties of the biomass as a more efficient fuel
- Makes biomass hydrophobic
- Longer storage life of the bio-coal due to it being hydrophobic[35]
- Smoke producing compounds removed
- Relatively cheap fuel source
- Carbon neutral with respect to greenhouse gas emissions
- Reduces reliance on fossil fuels
- Creation of biochar for use as an organic soil enhancer
- Improved emissions control due to higher temperatures
- High energy efficiency
- Toxic elements and pathogens in the feedstock are completely destroyed

Challenges associated with torrefaction[36]

- Expensive technology
- No commercial torrefaction plant in operation yet
- Torrefaction does not reduce corrosive deposits on boiler tubes
- Torrefaction on its own does not seem viable, it must be combined with pelleting
- May require mechanical pre-treatment such as chipping
- Poor public-perception and understanding of the technology

Potential environmental impact

- Incorrect storage of raw material (feedstock) could lead to leachates entering surface or groundwater sources
- Incorrect storage of raw material (feedstock) could lead to nuisance odours and attract pests
- Reduction in methane and CO_2 emissions due to the diversion from landfill
- Reduction in emissions due to high heat and temperatures
- All emissions are captured and used
- Reduction in used landfill airspace
- Reduces the use of fossil fuels for energy
- Carbon neutral for emission of greenhouse gases

---

[34] (Haigh & Görgens, TORR: Torrefaction (TORR-1)/ Torrefaction and Pelleting (TORR-2), 2014) (Dutta & Leon)
[35] tending to repel or fail to mix with water or absorb moisture
[36] (Haigh & Görgens, TORR: Torrefaction (TORR-1)/ Torrefaction and Pelleting (TORR-2), 2014), (Dutta & Leon)

7 ENVIRONMENTAL IMPACTS

Biological treatment of organic waste affects the environment in several ways. The type and magnitude of the effects strongly depend on the specific waste system and technology. The actual quantification of potential environmental effects from biological treatment requires knowledge about mass and energy flows, emissions to air, water, soil and groundwater as well as effects from upstream and downstream processes (Boldrin, Neidel, Damgaard, Bhander, Møller, & Christensen, 2011). The overriding positive impact of beneficiating organic waste is its removal from landfill and dumping to land which in turn is associated with greenhouse gas emissions, soil as well as ground water pollution.

The section below identifies impacts associated with various organic feedstocks and treatment options from Europe, South Africa and Australia. As is shown, the impacts are similar for each thus emphasizing the applicability of a Norms & Standards document to ensure sustainable management. Typically the impacts that have been identified relate to air quality, water quality, soil quality and aesthetics.

In 2004 COWI collated and documented the various treatment methods and environmental impacts associated with biodegradable waste. The treatment options considered include landfilling, incineration, composting and anaerobic digestion. Since the majority of the treatment options considered in this report fall into the same groupings as that of the COWI report, the impacts shown in the tables below, along with those identified in the sections above have been used to guide the mitigation / management requirements formulated as part of this process.

The COWI report also considered the impacts associated with the transportation of the feedstock from source to the treatment centres. It is recommended that the Norms & Standards include management actions as part of the requirement for responsibility of waste from source.

A final table has been developed using the information below to provide an assessment of expected impacts per technology.

Table 12: Environmental impacts related to the collection and transport of organic feedstock (COWI, 2004)

	Emissions	**Potential impacts**	
		Environmental impacts	**Health impacts**
Transportation (collection)	**AIR** *Exhaust gases from trucks* CO, CO2, nitrogen oxides Soot particulates VOCs *From tear and wear and spills* VOCs Dust Rubber and metals Odour Litter	Impairment of ambient air quality (locally) Local contamination of road sides and gardens Aesthetic impact (litter)	Potential for exposure to – exhaust gases from trucks – pathogens in biowaste Nuisance caused by odour
	WATER *Leaching and runoff from road surfaces* Oil/diesel surfactants etc. from cleaning of trucks	Potential for contamination of groundwater or surface water	Marginal exposure to contaminated groundwater used as water supply Marginal exposure to contaminated surface waters used for recreation, fishing etc.
	SOIL Emissions to soil only via air	Local contamination of soil and vegetation	Marginal, but especially children could be exposed

Table 13: Emissions and related impacts from various waste treatment options (COWI, 2004)

Treatment Method	**Emissions**	**Potential Impacts**	
		Environmental Impacts	**Health Effects**
Landfilling	**AIR** Dust Odour Landfill gases (CO_2, CH_4, NH_3 and trace compounds) Microorganisms Exhaust gases from trucks Litter	Contribution to global warming, in particular from emissions of methane (CH_4) (possible to mitigate by collection and combustion to CO_2) Potential for local eutrophication (NH_3, NO_x) and to some extent acidification (acidic gases)	Inhalatory exposure to potentially harmful pollutants and pathogens (causing infectious diseases + minor sickness such as diarrhoea) Nuisance caused by odour and dust
	WATER Leachate (containing salts, acids, organic matter and low levels of contaminants) to	Contamination of ground and surface water impairing water quality	Exposure to contaminated groundwater used for supply of drinking water

	groundwater, surface water and sewer		
	SOIL No emissions outside landfill area except via air	Eutrophication of natural oligotrophic ("low nutrient") ecosystems disamenity due to windborne litter	
Incineration	**AIR** Emissions of SO_2, NO_x, HCl, CO, CO_2, VOCs Minor emissions of heavy metals, dioxins and other persistent organic compounds Some dust and odour may arise from the handling of waste prior to incineration	Potential for soil acidification (NO_x ; SO_2) and eutrophication (NO_X) To a lesser degree increase in soil levels of metals, dioxins etc. Contribution to global warming (CO_2)	Inhalatory exposure to potentially harmful chemical substances of which some are associated with serious long term effects e.g. cancer
	WATER *From gas cleaning scrubber water and surface runoffs:* Low levels of heavy metals, salts and various organic pollutants	Small contribution to contamination of surface water	No significant effects likely
	SOIL *From ash, slag and gas cleaning residuals:* Salts and relatively low levels of heavy metals, dioxins and other persistent pollutants *From deposition of pollutants emitted to air:* Inorganic acids Minor amounts of heavy metals, dioxins etc.	Possible leaching of inorganic ions and some metals to groundwater Minor contamination of vegetation and soil with heavy metals and persistent organics	Minor exposure to soil and crops contaminated with metals, dioxins etc
Composting	**AIR** Dust Odour Microorganisms CO_2 Methane (CH_4)	No significant effects likely Limited contribution to global warming (CO_2 and methane, the latter especially from windrow composting)	Potential for exposure to pathogens causing infectious diseases or minor sickness (diarrhoea) Nuisance caused by odour and dust
	WATER *Runoff/leachate from open composting plants and storage facilities:*	Small contribution to contamination of surface water and groundwater	No significant effects likely

	Inorganic salts Dissolvable organic matter Small amounts of heavy metals and other pollutants		
	SOIL *Compost:* Trace contaminants in compost feedstocks (including metals and organic compounds)	Potential for some increase in metals and other contaminants in crops when compost is used on soils Increased soil fertility and improved soil structure Some reduction in use of artificial fertilizers	Minor exposure to contaminants in compost when handling the product Uptake of small amounts of contaminants by crops produced on compost amended land
Anaerobic Digestion	**AIR** Odour CO_2, NO_x, SO_x and minor amounts of methane and VOCs CH_4 Fugitive emissions	Some contribution to global warming (CO_2) No other significant environmental effects from emissions to air are likely	No significant health effects likely Nuisance caused by odour
	WATER No significant emissions to surface or ground water	No significant effects likely	No significant effects likely
	SOIL *Liquid and solid digestate:* Trace contaminants in feedstocks, e.g. heavy metals and various organic compounds	Potential for some increase in metals and other contaminants in crops and other plants when digestate is used on soils Increased soil fertility Reduction in use of artificial fertilisers	Uptake of small amounts of contaminants by crops produced on fertilised land

The table below (Department of Environmental Affairs, 2013) identified typical impacts associated with composting only, but these are applicable to most treatment facilities for organic feedstock. These are included to show the comparison with the EU documented impacts.

Table 14: Typical impacts and potential mitigation measures for a composting operation (Department of Environmental Affairs, 2013)

Impact	**Source**	**Potential Mitigation Measures**
Air Quality		
Unpleasant Odours	Anaerobic decomposition	Increase aeration of compost piles Decrease moisture content of over-saturated piles Prevent waterlogging Minimise storage of unprocessed feedstock

		Install odour control equipment
Gas Emissions	Aerobic decomposition (Carbon Dioxide)	Not Applicable
	Anaerobic decomposition (Methane; hydrogen sulphide, organic sulphides and/or volatile fatty acids)	Increase aeration of compost piles Decrease moisture content of over-saturated piles Prevent waterlogging Minimise storage of unprocessed feedstock
Ammonia and amines	High nitrogen feedstocks	Correct the C:N ratio Reduce the use of high quality nitrogen feedstocks
Exhaust emissions	Exhaust emissions from vehicles	Attach emission filters on equipment
Dust	Vehicle movement, exposed soils and during storage, shredding, mixing, and screening of compost	Cover dusty materials Applying a light water spray over dry materials Revegetate exposed soils Paving of all operating, storage, unloading and loading areas Shredding on non-windy days Windbreaks around facility and piles Suction sweeping of areas
Bio-aerosols	These organisms can enter the ambient air during the movement and agitation of materials	Paving of all operating, storage, unloading and loading areas Applying a light water spray over dry materials Windbreaks around facility/piles Suction sweeping of areas
Water Quality		
Surface Water	Leachate generation from the processing of compost	Keep contaminated stormwater and leachate separate from clean stormwater Minimising, containing and re-using contaminated stormwater and leachate so there is no discharge of contaminated wastewater from the premises Avoid run-off from feedstock or compost material
	Sediments and suspended solids	Revegetate exposed soils Reduce runoff volume and velocity Avoid run-off from feedstock, compost material, exposed soil Good housekeeping
Ground Water	Leachates from the processing of compost	Store feedstock and compost on bunded and hard foundation, where practical to

		minimise groundwater intrusion
Soil Quality		
Soil contamination	Leachate allowed to infiltrate through the ground	Reduce leachate infiltration Store feedstock and compost on bunded and hard foundation, where practical to minimise groundwater intrusion
Noise		
Ambient Noise	Vehicles	Install and maintain silencers on vehicles and equipment Where possible, noisy equipment should be housed within a building or similar structure Provide noise attenuation screens such as earth berms or trees Restrict operating hours Maintain designated buffer distances
	Machinery	
Waste		
Litter	Transportation of general waste	Good house keeping Educate staff Litter trap Windbreaks such as trees
	Employee disregard	
	Windblown general waste	
General	General facility operations (offices, eating areas, workers etc.)	Recycle Disposal at a registered general landfill site
Hazardous	Hydrocarbon spills from equipment and machinery	Disposal at a registered hazardous landfill site
	Animal waste from feedstock	
Aesthetics		
Unpleasant aesthetics	General visual presence of facility	Vegetation screening Good house keeping Landscaping
Pests		
Fauna	Rodents, flies, and birds	Remove residual waste promptly Cover compost piles Good housekeeping
Flora (Alien invasive infestation)	Transport of invasive plants, their seeds or propagules to the facility, from the facility itself or from the final compost product	Monitor feedstock and final product Good house keeping
Fire		

Uncontrolled Fires	Anaerobic decomposition produces methane as by-product. Methane is highly flammable	Keep fire extinguisher in close proximity Prevent anaerobic decomposition[37] Keep area free of open flames or sparks
	Dry stockpiles of feed stock or compost	Keep fire extinguisher in close proximity Keep area free of open flames or sparks

The table below has been sourced from the Environmental Guidelines: Composting and Related Organics Processing Facilities (Department of Environment and Conservation (NSW), 2004). The categories referred to are according to Table 2 shown earlier in the report.

Table 15: Typical impacts associated with compost and related organics processing facilities

Impact	**Source**	**Potential Mitigation Measures**
Air Quality		
Unpleasant Odours	*Compost:* Moisture levels greater than 60% in the compost pile, eliminating adequate free airspace Initial carbon to nitrogen ratio (C:N) below 25:1, promoting ammonia volatilisation Compost pile pH greater than 7.5, promoting hydrogen sulfide and mercaptan generation compost pile oxygen concentration below 16%, promoting volatile organic formation	Increase aeration of compost piles Decrease moisture content of over-saturated piles Prevent waterlogging Minimise storage of unprocessed feedstock Install odour control equipment Enclosed storage and processing facilities should be used, particularly for the processing of Category 2 and Category 3 organics There should be immediate attention to potential odorous organic loads, such as rapidly biodegradable organics should be covered, and the quantity of such material exposed to the atmosphere should be kept to a minimum; rapidly biodegradable organics include grass clippings, food and animal organics and organic sludges Rapidly biodegradable organics of food and animal origin should be stored in moisture- and vermin-proof bins that are designed and constructed to resist the action of organic acids and facilitate washing; these bins should be located on a concrete- or bitumen sealed and bunded washdown apron that is: —connected to the leachate collection system —protected to prevent the infiltration of rain into the leachate collection system The quantity of cured organics stored at the facility should not be greater than 18 months' worth of production
	Related processes: Mixing and aeration creating high peak odour emissions Storing of rapidly biodegradable organics for more than 24 hours Emissions of SO2, NOx, HCl, CO, CO2, VOCs	

[37] For composting only

		The quantity of Category 1 organics awaiting processing should not exceed 10% of the currently utilised facility processing capacity (tonnes/year). The quantity of Category 2 and Category 3 organics awaiting processing should not exceed one day's production, unless it is stored in a manner that prevents the release of odours. The quantity of organics received for processing each year should be based on either current trends, where available, or on production plans for the forthcoming year The storage times of organic feedstock should be controlled to avoid emissions of offensive odours. Flaring of biogas from anaerobic process alternatively capturing of biogas for recovery
Particulate matter	Dust	Construct sealed or gravel roads from the public roadway to the gatehouse or organics reception section of the composting and related organics processing facility Spray water to suppress matter that has been deposited on unsealed roads; additional suppression methods may be required in areas with fine soils and in dry or windy condition Regularly turn composting windrows and ensure that they have a suitable moisture content
	Airborne pathogens	Do not allow organics that are being processed, or products such as composts, soil conditioners and mulches, to lose too much moisture; for example, keep the moisture content at 25% (m/m) or more Have adequate environmental management techniques at the facility to manage particulate matter (such as PM_{10}, deposited matter and suspended particulates) Avoid uncontrolled emissions of biogas in aerobic processes by keeping the organics being processed adequately aerated
	<u>*Greenhouse impact:*</u> Emission of methane to the atmosphere Emission of CO_2 trucks and machinery Oxygen poor landfill sites produce significant amounts of methane	Capture of biogas / landfill gas for recovery Aerobic treatment with proper moisture content management reduces methane generation
Water Quality		

Surface water and Leachate	Incorrect blending of organics leading to excessive leachate in compost Leachate becoming acidic under anaerobic conditions Leachate becoming alkaline under aerobic conditions Incorrect stockpiling of organics Uncovered / unprotected stockpiles causing sediment run off	Leachate can be minimised by mixing Category 2 organics into windrows containing a large proportion of actively composting Category 1 organics (typically at a ratio of 25:1 Category 1: Category 2 (w/w) or greater. Regular turning of windrows can also help minimise the quantity of leachate draining from the windrows. The receipt and use of unsuitable organics may lead to product quality problems in the case of contaminated organics or to processing problems in the case of the wrong types of organics The working surfaces, including the incoming organics, final product, process residuals and contaminated material storage areas, the active composting pad (for windrow composting) and access roads, must: • be bunded and graded sufficiently to prevent both run-on and run-off of surface water • be designed and constructed from an inert low-permeability material such as compacted clay, modified soil, asphalt or concrete over a compacted base able to support, without sustained damage, the load of material on it and the load of any machinery used in the composting facility • be able to support all structures, machinery and vehicles as applicable and allow access to any utilised part of the processing site, irrespective of the weather conditions; vehicles may include: —transport vehicles used for the delivery of organics and the transport of finished products —mobile equipment used in all phases of all the processes operated on the site —fire-fighting vehicles and equipment.
Fire		
Uncontrolled fires	Poorly managed composting processes leading to explosion or spontaneous combustion Uncontrolled biogas emissions Cigarettes and sparks from welding not controlled Unauthorised access	Clear signs should tell the public that flammable liquids are not permitted on the site. This should be reinforced by advice to customers at the gatehouse and inspection of loads at the organic reception area Approved quantities of combustible contaminants that have been separated from the organics received for processing and are destined for recycling (such as tyres and plastic bottles) should be stockpiled in small piles or in windrows
		All fuels or flammable solvents for operational use should be stored in an

		appropriately ventilated and secure store All flammable liquids should be stored within a bund that can hold 110% of the volume of the flammable liquids stored there, so that any release of raw or burning fuel cannot cause a fire in the combustible organics present on the site or affect the stormwater.
Amenity (Aesthetics)		
Pests	Invasive noxious weeds Vermin and birds	Setting up a plan to manage any declared noxious weeds Cover rapidly biodegradable organics, keeping the quantity exposed to a minimum Store rapidly biodegradable organics (see Glossary) of food and animal origin in moisture and vermin-proof bins that are designed and constructed to resist the action of organic acids and to facilitate washing Locate the bins on a concrete- or bitumen-sealed and bunded washdown apron that is: —connected to the leachate collection system —protected to stop rain getting into the leachate collection system. Take steps to ensure that surfaces are adequately drained to prevent ponds of water forming on the site Episodic outbreaks of pests or vermin at composting and related organics processing facility sites should be controlled by established deterrence and eradication measures.
Litter	Litter delivered as part of the organic waste Windblown litter Employee negligence Litter sticking to wheels of site vehicles	The occupier should introduce procedures that prevent the unnecessary proliferation of litter; they should also consider the use of litter fences, and be responsible for ensuring that all wind-blown litter that leaves the site is retrieved Clear all fences and gates of litter, preferably on a daily basis or as required Exit signs need to advise transport operators and private vehicle drivers that they can be fined for any litter on public roads resulting from improper transport of wastes or organics All litter that leaves the site should be retrieved on a daily basis The site occupier should provide a wheel washing or wheel cleaning facility for use by all vehicles before exiting the facility

Noise	Noise from equipment or traffic	Acceptable noise attenuation measures include siting noise-sensitive land uses away from the development, erecting acoustical barriers, treating equipment acoustically and limiting hours of operation. Particular attention should be paid to the design of items such as speed humps and vibration grids to prevent noise generation.

Table 16 below uses the impacts identified in the tables above, along with specific impacts identified for each technology to provide a matrix as to the potential environmental impacts that could be expected for each technology. Transport and storage impacts occur across the board along with possible air and water impacts for operation and use of the product materials. It must be noted that all of these can easily be mitigated to prevent impacts from taking place by implementing effective management mechanisms. These are provided in Section 8 below.

Table 16: Potential impacts per technology

Technology	Transport			Storage			Operation					Residue / Product		
	Air	Water	Weeds	Air	Water	Fauna	Air		Water		Noise	Air	Water	Soil
	Air emissions	Leaching & runoff from road surfaces	Alien invasive species	Nuisance odours	Leaching to groundwater, surface water and sewer	Pests (rodents, flies & birds)	Air emissions	Nuisance odour	Leaching to groundwater, surface water and sewer	Sediments and suspended solids	Machinery & vehicles	Nuisance odour	Leaching to groundwater, surface water and sewer	Soil contamination / nitrification
Mechanical														
Briquette	x*	x*	x*		x					x	x			
Centrifuge	x	x		x	x	x		x	x			x	x	x
Chipping	x*	x*	x*		x				x		x			
Pelleting	x*	x*	x*		x				x		x			
Sonification	x*	x*	x*	x	x		x^o	x	x	x			x	x
Chemical														
Chemical hydrolysis	x	x		x	x	x			x				x	
Chemical oxidation	x	x		x	x	x	x			x			x	
Transesterifi-cation	x	x		x	x	x			x				x	
Saponification	x	x		x	x	x		x	x				x	
Anaerobic														
Anaerobic digestion	x*	x	x	x	x	x	x^o					x	x	x
Aerobic														

Technology	Transport			Storage			Operation					Residue / Product		
	Air	Water	Weeds	Air	Water	Fauna	Air		Water		Noise	Air	Water	Soil
	Air emissions	Leaching & runoff from road surfaces	Alien invasive species	Nuisance odours	Leaching to groundwater, surface water and sewer	Pests (rodents, flies & birds)	Air emissions	Nuisance odour	Leaching to groundwater, surface water and sewer	Sediments and suspended solids	Machinery & vehicles	Nuisance odour	Leaching to groundwater, surface water and sewer	Soil contamination / nitrification
Aerobic digestion				x	x			x	x	x		x	x	x
Black soldier fly larvae	x*	x*	x*	x	x			x	x	x		x		
Composting	x*	x*	x*	x	x	x		x	x	x		x		
Vermicomposting	x*	x*	x*	x	x	x		x	x	x		x		
Thermal														
Aqueous phase reforming	x	x		x	x	x	x^{o}		x	x			x	
Combustion	x	x		x	x	x	x	x					x	x
Drying	x	x		x	x		x	x						
Gasification	x	x		x	x	x	x^{o}							
Hydrothermal carbonisation (HTC)	x	x		x	x	x	x^{o}		x	x			x	x
Hydrothermal liquefaction (HTL)	x	x		x	x	x	x^{o}		x				x	
Pressure heating / SCWG	x*	x*		x	x	x	x^{o}						x	
Pyrolysis	x	x		x	x	x	x^{o}						x	
Rendering	x	x		x	x	x		x	x			x		
Torrefaction	x	x		x	x	x	x^{o}						x	

x*- transport can be significantly mitigated by use of mobile or on-site technology
x^{o} – all gas emissions are captured for re-use

The above table demonstrates the potential impacts associated with each of the technologies across their lifecycles. These can all be mitigated by implementing correct management mechanisms and siting of the facilities.

7.1 AIR QUALITY IMPACTS

The majority of the technologies that have air quality impacts and which will subsequently fall into the NEM:AQA ambit, are the thermal treatments. However, it must be pointed out that most of these aim to capture the gases released from the organic material for use as biofuels. Only combustion and drying technologies may potentially require mitigation to minimise the emissions.

In 2012 DEA proposed the development of a National Air Quality Indicator (NAQI) (Department of Environmental Affairs, 2012) The aim of the NAQI is to monitor national progress in air quality management, provide measurable indicators to inform authorities and members of the public and assist in the determination of the efficacy of interventions. The NAQI is based on 5 major air pollutants – PM_{10}, $PM_{2.5}$, NO_2 , SO_2 and O_3.

Using the NAQI and the 2009 National Ambient Air Quality Standards it is possible to provide a limit consideration for the technologies that may impact on air quality, in particular combustion and drying technologies.

AQ Level	Levels of Health Concern	Band	NO_2 (μg/m³)		SO_2 (μg/m³)		O_3 (μg/m³)		PM_{10} (μg/m³)		$PM_{2.5}$ (μg/m³)	
Low	Good	1	0-66	0	0-115	0	0-26	0	0-40	0	0-22	0
		2	67-133	67	116-231	116	27-53	27	41-80	41	23-43	22
		3	133-200	133	232-350	232	54-80	54	81-120	81	44-65	44
Moderate	Moderate	4	201-267	201	351-400	351	81-107	81	121-130	121	66-75	66
		5	268-334	268	401-450	401	108-134	108	131-140	131	76-85	76
High	Unhealthy	6	335-400	335	451-500	451	135-160	135	141-150	141	86-95	86
		7	401-467	401	501-550	501	161-187	161	151-160	151	96-105	96
Very High	Very Unhealthy	8	468-534	468	551-600	551	188-213	188	161-170	161	106-115	106
		9	535-601	535	601-650	601	214-240	214	171-180	171	116-125	116
Hazardous	Hazardous	10	>602	602	>651	651	>241	241	>181	181	>126	126

Figure 38: Banding of the SA AQI (Department of Environmental Affairs, 2012)

In terms of the generation of greenhouse gases, Stafford et al (2017) identified how biofuels perform in terms of global effect (greenhouse gas emissions) and local emissions (air pollutants) compared to fossil fuel counterparts of petrol, diesel, and natural gas. The focus of the report was on bioenergy, but it is interesting to note the level at which biogas and subsequently, the anaerobic digesters, is located on the emission spectrum.

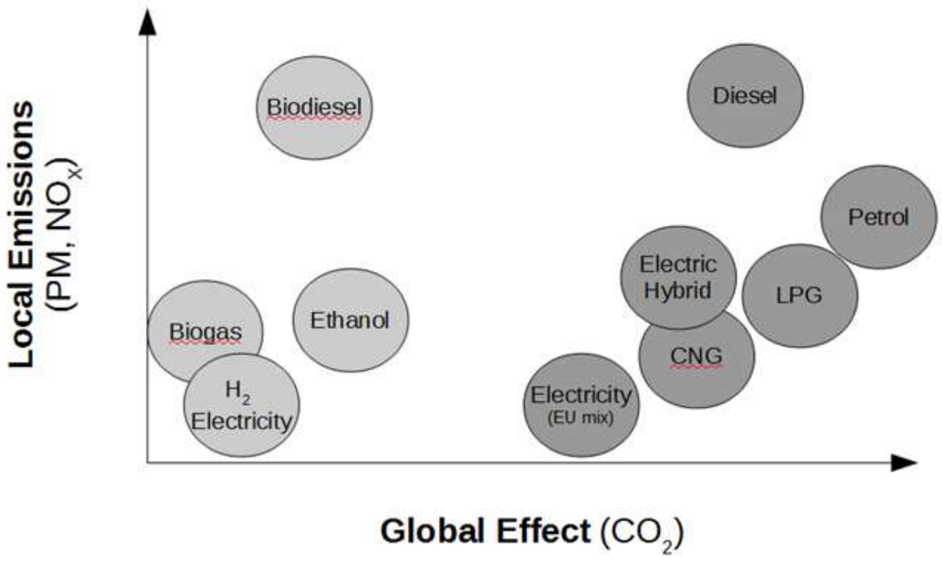


Figure 39: Diagrammatic representation of the performance of biofuels compared to petroleum fuels in terms of global effect (greenhouse gas emissions) and local emissions (air pollutants) (Stafford, Lotter, von Maltitz, & Brent, 2017)

It must be highlighted that both Stafford et al (2017) and Schubert et al (2008) emphasize the potential negative impacts associated with crops being grown for bioenergy and support the use of biomass waste as a better alternative. Thus from a greenhouse gas (GHG) emissions approach, the removal of organic waste from landfill immediately reduces the GHG impacts and any of the technologies that convert organic waste to biofuels reduce emissions further.

If any of the technologies exceeds the thresholds provided in the National Greenhouse Gas Emission Reporting Regulations dated 3 April 2017 in terms of the NEM:AQA, it is required to register with the Department in the format provided. The full regulation is included in Appendix 1.

7.2 ODOUR AND DUST IMPACTS

Organic feedstock has a high potential to create nuisance odours. Since odours can be very subjective and very difficult to trace, it is important for any facility to ensure correct site management which will minimise most odour potentials. Odour problems associated with composting and related organics processing facilities can be traced to problems with one or more of the following four processes: process control; containment of odorous areas; odour control technology; and siting (Giggey , Pinnette, & Dwinal, 1995). In most cases this happens under anaerobic conditions when methane is produced.

Compound	Description of smell	Detection limit for a particular odour panel
Sulfur compounds		
Dimethyl disulfide	Rotten cabbage	0.1 µg/m^3
Dimethyl sulfide	Rotten cabbage	2.5 µg/m^3
Carbon disulfide	Rotten pumpkin	24 µg/m^3
Hydrogen sulfide	Rotten egg	0.7 µg/m^3
Methane thiol	Pungent sulfur	0.04 µg/m^3
Nitrogen compounds		
Ammonia gas	Medicinal	27 µg/m^3
Trimethyl amine	Fishy	0.11 µg/m^3
Volatile fatty acids		
Acetic acid	Sour (vinegar)	1019 µg/m^3
Propionic acid	Rancid	28 µg/m^3
Butyric acid	Putrid	0.3 µg/m^3

Figure 40: Odour compounds (Department of Environment and Conservation (NSW), 2004)

Currently there are no South African thresholds identified for odour monitoring. It is recommended that in the event that odour issues are identified and no improvements occur by implementing management actions, an odour assessment should be undertaken by an air quality specialist.

Dust generated due to organic feedstock storage and potentially in the product storage must be correctly managed. This could include covering the material, keeping materials dam, managing access and speed control on roads that could cause dust. The Dustfall standard in the National Dust Control Regulations must be complied with where dust is a problem impact.

Restriction Areas	Dustfall rate (D) (mg/m^2/day, 30-days average)	Permitted frequency of exceeding dust fall rate
Residential area	D < 600	Two within a year, not sequential months.
Non-residential area	600 < D < 1200	Two within a year, not sequential months.

Figure 41: Acceptable dust fall rates (Department of Environmental Affairs, 2013)

A full copy of the regulation is include as Appendix 2 of this report.

7.3 WATER QUALITY IMPACTS

Potential water quality impacts could occur during transportation of materials, storage of feedstock and storage of product material. Leachates from composting and related organics-processing facilities have the potential to pollute groundwater and surface water bodies. They can be high in nutrients; this makes them favourable host media for bacteria and other microorganisms and gives them a high biological oxygen demand (BOD). Leachates can be acidic when generated under anaerobic conditions. (Department of Environment and Conservation (NSW), 2004)

These potentially include:

- Leachate of hydrocarbons from vehicles. This could be mitigated by
  - Processing on site i.e. transporting product which means less trips;
  - Ensuring vehicles and machinery are correctly maintained thereby avoiding spills / drips;
  - Using alternative transport such as rail.
- Leachate from feedstock storage. This can be mitigated by
  - Increasing dry matter content of the feedstock to facilitate absorption i.e. underlying and mixing with straw;
  - Storage areas must be surfaced with a low permeable layer which could be clay, cement, plastic or any other proven material;
  - Covered storage areas will prevent leaching, however this is dependent on location of the facility and space constraints;
  - Storage areas must have sufficient drainage and run off collection sumps / ponds.
- Leachate from product storage. This can be mitigated by
  - Increasing dry matter content of the feedstock to facilitate absorption i.e. underlying and mixing with straw;
  - Storage areas must be surfaced with a low permeable layer which could be clay, cement, plastic or any other proven material;
  - Covered storage areas will prevent leaching, however this is dependent on location of the facility and space constraints;
  - Storage areas must have sufficient drainage and run off collection sumps / ponds.

The irrigation or use of biodegradable industrial wastewater must comply with the standards as determined in the Revision of General Authorisations in terms of Section 39 of the National Water Act dated September 2013.

A full copy of the regulation is included as Appendix 3.

Table 17 : Wastewater limit values applicable to the irrigation of any land or property up to 2000m3 (Department of Water & Sanitation, 2013)

Variables	**Limits**
pH	not less than 5,5 or more than 9,5 pH units
Electrical Conductivity	does not exceed 70 milliSiemens above intake to a maximum of 150 milliSiemens per metre (mS/m)
Suspended Solids	does not exceed 25 mg/l
Chloride as Free Chlorine	does not exceed 0,25 mg/l
Fluoride	does not exceed 1 mg/l
Soap, Oil and Grease	does not exceed 2,5 mg/l
Chemical Oxygen Demand	does not exceed 75 mg/l
Faecal coliforms	do not exceed 1000 per 100 ml
Ammonia (ionised and un-ionised) as Nitrogen	does not exceed 3mg/l
Nitrate/Nitrite as Nitrogen	does not exceed 15 mg/l
Ortho-Phosphate as phosphorous	does not exceed 10 mg/l

Table 18: Wastewater limit values applicable to the irrigation of any land or property up to 500m^3 (Department of Water & Sanitation, 2013)

Variables	Limits
pH	not less than 6 or more than 9 pH units
Electrical conductivity	not exceed 200 milliSiemens per metre (mS/m);
Chemical Oxygen Demand (COD)	does not exceed 5000 mg/l after removal of algae;
Faecal coliforms	do not exceed 100 000 per 100 ml
Sodium Adsorption Ratio (SAR)	does not exceed 5 for biodegradable industrial wastewater

Table 19: Wastewater limit values applicable to the irrigation of any land or property up to 50m^3 (Department of Water & Sanitation, 2013)

Variables	Limits
pH	not less than 6 or more than 9 pH units
Electrical conductivity	not exceed 200 milliSiemens per metre (mS/m);
Chemical Oxygen Demand (COD)	does not exceed 5000 mg/l after removal of algae;
Faecal coliforms	do not exceed 100 000 per 100 ml
Sodium Adsorption Ratio (SAR)	does not exceed 5 for biodegradable industrial wastewater

7.4 SOIL QUALITY IMPACTS

The potential for soil quality impacts is associated with the water quality impacts with regard to leachate and irrigation of wastewater as well as with the application of product material to land in the form of organic fertiliser. The management required for water quality will lead to the minimisation of impacts on the soil and thus is not addressed here.

In terms of the application to land as an organic fertiliser, over application can lead to an increase in nutrients in the soil. It is thus important that the end user should have some knowledge or experience in utilising the product but the seller should also ensure that the product does not lead to soil quality impacts. As such the limits provided by the DAFF for organic fertilisers as contained in the Regulations Regarding Fertilisers dated 23 March 2007 in terms of the Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act, 1947 must be complied with. These regulations are included as Appendix 4.

7.5 POSITIVE ENVIRONMENTAL IMPACTS

Whilst there is a tendency to focus on potential negative environmental impacts in a typically risk adverse environment, the positive impacts associated with the correct management of organic waste cannot be underestimated. With the correct management standards put in place, the obvious benefits are immense. For each of the technologies considered in this document, the products generated unlock downstream environmental and economic benefits.

Positive impacts include:

- Removal of organic waste from landfill thus ensuring sustainable landfill airspace;
- Reduction of CO_2 and methane emissions from organic waste in landfills;
- Capturing of useful gases thus lessening further greenhouse gas emissions;
- Reduction in nuisance odours at landfill sites;
- Reduction in the spread of pathogens and harmful bacteria from organic waste as well as reducing the presence of pests at landfill sites which is harmful to human health;
- Utilising organic waste products such as compost, biochar and bio-coal to improve soil condition leading to more effective food security, water use and land management ;
- Combustion of bio-coal and mechanically and thermal treated woody biomass produces less smoke and less ash;
- Reduces the impacts of deforestation on virgin woody biomass material;
- Most technologies are able to reduce or completely destroy weed seeds from alien invasive materials;
- Utilising high energy organic waste products as efficient and renewable alternatives to fossil fuels, leading to lower greenhouse gas emissions and a carbon neutral energy environment;
- Utilising organic waste to produce high protein livestock / pet feeds, lessening the impacts on stressed wild fisheries;
- Reduction in the fuel loads associated with woody biomass residue;
- Processing of organic waste can improve water consumption practises and reduce water pollution;
- Improves soil quality, structure and potential when used as organic fertiliser;
- Nutrient recycling.

7.6 ECONOMIC IMPACTS

The disposal of organic material (as part of general waste) to landfill in 2011 ranged between R100 – 150 / ton (Department of Science & Technology, 2014). These costs are considered to be artificially low and in 2013 the DEA commenced with regulations aimed at correcting these price distortions. Many believe that the low cost of landfills has led to the crisis around shrinking landfill airspace and the lack of innovation in the waste management sector.

According to the DST Waste Roadmap, moving waste up the hierarchy towards reuse, recycling and recovery contributes to the principles of a 'green economy' in a number of ways:

- Re-introduction of resources back into the economy
- Contribution to economic growth and job creation, and
- Reducing social and environmental costs

Waste prevention is required to ensure resource efficiency, but resource scarcity and increasing resource demands require that secondary resources, locked up in waste streams, be recovered and reused. By unlocking the barriers to the re-use of organic feedstock, the DST calculated that over R7.3 billion per year could be generated with 100% recovery. (Department of Science & Technology, 2014).

	Value (Rand/year)			
Stream	Scenario 1 (Baseline)	Scenario 2	Scenario 3 (DST Goal)	Scenario 4 (100%)
Municipal waste (non-recyclable portion)	0	740 547 527	1 481 095 054	2 962 190 108
Organic component of municipal waste	199 624 053	299 436 079	399 248 106	570 354 437
Biomass waste from industry	0	2 046 933 732	4 093 867 465	6 823 112 441
Construction and demolition waste	66 157 613	136 450 038	206 742 463	413 484 925
Paper	735 995 662	809 595 449	1 032 976 649	1 291 220 811
Plastic	734 824 361	1 677 846 536	2 449 411 002	4 082 351 670
Glass	150 499 090	204 584 780	282 185 904	470 309 840
Metals	5 668 103 740	6 022 360 735	6 376 617 729	7 085 130 810
Tyres	3 620 455	38 015 658	72 410 862	90 513 577
WEEE	6 884 000	19 453 250	32 022 500	64 045 000
Slag	469 959 700	587 449 625	704 939 550	939 919 400
Ash	6 867 312	14 299 656	21 732 000	108 660 000
Waste oils	146 666 667	193 333 333	240 000 000	333 333 333
Total	**8 189 202 652**	**12 790 306 399**	**17 393 249 283**	**25 234 626 353**

Figure 42: Value of selected wastes (Department of Science & Technology, 2014)

Scenario 1: Baseline (2011) waste quantities and recycling rates, as per the National Waste Information Baseline (DEA 2012); reflecting the tonnages of materials that were being recycled as at 2011.

Scenario 2: Short-term scenario (2017) based on targets in Industry Waste Management Plans (IndWMP) and targeted recycling rates for 2017. Where a short-term target was not available for a particular waste stream, a middle point between Scenario 1 and Scenario 3 was adopted.

Scenario 3: A medium-term scenario (2022), based on the goal of the DST's Waste Research, Development and Innovation (RDI) Roadmap (DST, 2012), to reduce industrial waste5 by 20% and domestic waste6 by 60% by 2022, from the 2011 baseline. This goal of reducing waste to landfill was translated to recycling/recovery targets for the individual waste streams.

Scenario 4: A hypothetical long-term scenario of 100% recycling/recovery, reflecting the tonnages that could be recovered if all waste was diverted from landfill

There is clearly significant economic potential in recovering waste from landfill, with the additional potential of producing high value materials from the feedstock such as keratin from chicken feathers which sells at ±R2000 per gram.

8 MITIGATION AND MANAGEMENT

The mitigations and management of the impacts identified in the section above can be applied very generically and as such are suitable for Norms & Standards. The most important mitigation which must be applied is the correct site location identification for any of the identified technologies. The exclusionary sites as identified in Section 4 of this document must be complied with as a first measure. These have been captured in the draft Norms & Standards document included in Appendix 5 of this report.

Table 20: Management requirements per technology type

Technology	Transport	Storage & Handling	Pre-treatment	Operation	Residue / Product
Mechanical					
Briquette Centrifuge Chipping Pelleting Sonification	-Mobile plants minimise transportation impacts -All vehicles must be regularly maintained and roadworthy -Ensure emissions filters are fitted on vehicles and machinery -Potentially use rail for transport if possible -Cover dusty materials during transit	-Storage must comply with the Waste Storage N&S -Storage on impermeable surfaces (concrete, clay or heavy duty plastic) with run off collection areas -Minimising, containing and re-using contaminated stormwater and leachate so there is no discharge of contaminated wastewater from the premises -No long term storage i.e. feedstock must be used within 90 days - The quantity of Category 2 and Category 3 organics awaiting processing should not exceed one day's production, unless it is stored in a manner that prevents the release of odours -Good housekeeping on site to prevent pests and malodours -Correct management of stock piles to prevent fires	-Pre- treatment must take place on impermeable surfaces (concrete, clay or heavy duty plastic) with run off collection areas. -Good housekeeping on site to prevent pests and malodours -Install and maintain silencers on vehicles and equipment -Provide noise attenuation screens such as earth berms or trees -Restrict operating hours -Maintain designated buffer distances where applicable -Provide fire safety protocol	-Ensure aeration of material to prevent methane generation, unless specifically required -Prevent waterlogging -Treatment must take place on impermeable surfaces (concrete, clay or heavy duty plastic) with run off collection areas - Minimising, containing and re-using wastewater so there is no discharge of contaminated wastewater from the premises -Good housekeeping on site to prevent pests and malodours -Install and maintain silencers on vehicles and equipment -Where possible, noisy equipment should be housed within a building or	-Prevent waterlogging of finished product -Cover dusty materials -Product must be stored on an impermeable surface -Increase dry matter content to minimise leachate.

Technology	Transport	Storage & Handling	Pre-treatment	Operation	Residue / Product
		-Avoid shredding on windy days -Ensure good record keeping for type and volume of feedstock entering the premises -Increase dry matter content to minimise leachate.		similar structure -Provide noise attenuation screens such as earth berms or trees -Restrict operating hours -Maintain designated buffer distances where applicable -Provide fire safety protocol	
Chemical					
Chemical hydrolysis Chemical oxidation Transesterification Saponification	-Mobile plants minimise transportation impacts -All vehicles must be regularly maintained and roadworthy -Ensure emissions filters are fitted on vehicles and machinery -Potentially use rail for transport if possible -Cover dusty materials during transit	-Storage must comply with the Waste Storage N&S -Storage on impermeable surfaces (concrete, clay or heavy duty plastic) with run off collection areas -Minimising, containing and re-using contaminated stormwater and leachate so there is no discharge of contaminated wastewater from the premises -No long term storage i.e. feedstock must be used within 90 days - The quantity of Category 2	-Pre- treatment must take place on impermeable surfaces (concrete, clay or heavy duty plastic) with run off collection areas. -Good housekeeping on site to prevent pests and malodours -Install and maintain silencers on vehicles and equipment -Provide noise attenuation screens such as earth berms or trees	-Storage of chemicals must be done in terms of the Hazardous Substances Act -Treatment must take place on impermeable surfaces (concrete, clay or heavy duty plastic) with run off collection areas - Minimising, containing and re-using wastewater so there is no discharge of contaminated wastewater from the premises -Good housekeeping on site to prevent pests and	-Prevent waterlogging of soil with digestate -Avoid over fertilising soils -Compliance with DWS & DAFF guidelines for use of organic fertilisers to soil -Storage of biofuels must not lead to leachates polluting soils or waterways -Product must be stored on an impermeable surface -Increase dry matter content to minimise leachate.

Technology	Transport	Storage & Handling	Pre-treatment	Operation	Residue / Product
		and Category 3 organics awaiting processing should not exceed one day's production, unless it is stored in a manner that prevents the release of odours -Good housekeeping on site to prevent pests and malodours -Correct management of stock piles to prevent fires -Avoid shredding on windy days -Ensure good record keeping for type and volume of feedstock entering the premises	-Restrict operating hours -Maintain designated buffer distances where applicable -Provide fire safety protocol	malodours -Install and maintain silencers on vehicles and equipment -Where possible, noisy equipment should be housed within a building or similar structure -Provide noise attenuation screens such as earth berms or trees -Restrict operating hours -Maintain designated buffer distances where applicable -Provide fire safety protocol	
Anaerobic					
Anaerobic digestion	-Mobile plants minimise transportation impacts -All vehicles must be regularly maintained and roadworthy -Ensure emissions filters are fitted on vehicles and machinery -Potentially use rail for	-Storage must comply with the Waste Storage N&S -Storage on impermeable surfaces (concrete, clay or heavy duty plastic) with run off collection areas -Minimising, containing and re-using contaminated stormwater and leachate so	-Pre- treatment must take place on impermeable surfaces (concrete, clay or heavy duty plastic) with run off collection areas. -Good housekeeping on site to prevent pests and malodours	-Treatment must take place on impermeable surfaces (concrete, clay or heavy duty plastic) with run off collection areas - Minimising, containing and re-using wastewater so there is no discharge of contaminated wastewater	-Prevent waterlogging of soil with digestate -Avoid over fertilising soils -Compliance with DWS & DAFF guidelines for use of organic fertilisers to soil -Product must be stored on

Technology	Transport	Storage & Handling	Pre-treatment	Operation	Residue / Product
	transport if possible -Cover dusty materials during transit	there is no discharge of contaminated wastewater from the premises -No long term storage i.e. feedstock must be used within 90 days - The quantity of Category 2 and Category 3 organics awaiting processing should not exceed one day's production, unless it is stored in a manner that prevents the release of odours -Good housekeeping on site to prevent pests and malodours -Correct management of stock piles to prevent fires -Ensure good record keeping for type and volume of feedstock entering the premises -Increase dry matter content to minimise leachate.	-Install and maintain silencers on vehicles and equipment -Provide noise attenuation screens such as earth berms or trees -Restrict operating hours -Maintain designated buffer distances where applicable -Provide fire safety protocol	from the premises -Good housekeeping on site to prevent pests and malodours -Install and maintain silencers on vehicles and equipment -Where possible, noisy equipment should be housed within a building or similar structure -Provide noise attenuation screens such as earth berms or trees -Restrict operating hours -Maintain designated buffer distances where applicable -Provide fire safety protocol	an impermeable surface -Increase dry matter content to minimise leachate.
Aerobic					

Technology	Transport	Storage & Handling	Pre-treatment	Operation	Residue / Product
Aerobic digestion Black soldier fly larvae Composting Vermicomposting	-Mobile plants minimise transportation impacts -All vehicles must be regularly maintained and roadworthy -Ensure emissions filters are fitted on vehicles and machinery -Potentially use rail for transport if possible -Cover dusty materials during transit	-Storage must comply with the Waste Storage N&S -Storage on impermeable surfaces (concrete, clay or heavy duty plastic) with run off collection areas -Minimising, containing and re-using contaminated stormwater and leachate so there is no discharge of contaminated wastewater from the premises -No long term storage i.e. feedstock must be used within 90 days - The quantity of Category 2 and Category 3 organics awaiting processing should not exceed one day's production, unless it is stored in a manner that prevents the release of odours -Good housekeeping on site to prevent pests and malodours -Correct management of stock piles to prevent fires -Avoid shredding on windy days -Ensure good record keeping for type and volume of	-Pre- treatment must take place on impermeable surfaces (concrete, clay or heavy duty plastic) with run off collection areas. -Good housekeeping on site to prevent pests and malodours -Install and maintain silencers on vehicles and equipment -Provide noise attenuation screens such as earth berms or trees -Restrict operating hours -Maintain designated buffer distances where applicable -Provide fire safety protocol	-Ensure aeration of material to avoid methane generation -Prevent waterlogging -Treatment must take place on impermeable surfaces (concrete, clay or heavy duty plastic) with run off collection areas - Minimising, containing and re-using wastewater so there is no discharge of contaminated wastewater from the premises -Good housekeeping on site to prevent pests and malodours -Install and maintain silencers on vehicles and equipment -Where possible, noisy equipment should be housed within a building or similar structure -Provide noise attenuation screens such as earth berms or trees -Restrict operating hours	-Prevent waterlogging of soil with digestate -Avoid over fertilising soils -Compliance with DWS & DAFF guidelines for use of organic fertilisers to soil -Compliance with DAFF guidelines for feed protein in livestock -Product must be stored on an impermeable surface -Increase dry matter content to minimise leachate.

Technology	Transport	Storage & Handling	Pre-treatment	Operation	Residue / Product
		feedstock entering the premises -Increase dry matter content to minimise leachate.		-Maintain designated buffer distances where applicable	
Thermal					
Aqueous phase reforming Combustion Drying Gasification Hydrothermal carbonisation (HTC) Hydrothermal liquefaction (HTL) Pressure heating	-Mobile plants minimise transportation impacts -All vehicles must be regularly maintained and roadworthy -Ensure emissions filters are fitted on vehicles and machinery -Potentially use rail for transport if possible -Cover dusty materials during transit	-Storage must comply with the Waste Storage N&S -Storage on impermeable surfaces (concrete, clay or heavy duty plastic) with run off collection areas - Minimising, containing and re-using contaminated stormwater and leachate so there is no discharge of contaminated wastewater from the premises -No long term storage i.e. feedstock must be used within 90 days - The quantity of Category 2 and Category 3 organics awaiting processing should not exceed one day's production, unless it is stored in a manner that prevents the release of odours -Good housekeeping on site to prevent pests and	-Pre- treatment must take place on impermeable surfaces (concrete, clay or heavy duty plastic) with run off collection areas. -Good housekeeping on site to prevent pests and malodours -Install and maintain silencers on vehicles and equipment -Provide noise attenuation screens such as earth berms or trees -Restrict operating hours -Maintain designated buffer distances where applicable -Provide fire safety protocol	-Ensure that air scrubbers are utilised for technologies where gas capture cannot take place (combustion & drying) -Treatment must take place on impermeable surfaces (concrete, clay or heavy duty plastic) with run off collection areas - Minimising, containing and re-using wastewater so there is no discharge of contaminated wastewater from the premises -Good housekeeping on site to prevent pests and malodours -Install and maintain silencers on vehicles and equipment -Where possible, noisy equipment should be housed within a building or	-Prevent waterlogging of soil with digestate -Avoid over fertilising soils -Compliance with DWS & DAFF guidelines for use of organic fertilisers to soil -Storage of biofuels must not lead to leachates polluting soils or waterways -Product must be stored on an impermeable surface

Technology	Transport	Storage & Handling	Pre-treatment	Operation	Residue / Product
Pyrolysis Rendering Torrefaction		malodours -Correct management of stock piles to prevent fires -Avoid shredding on windy days -Ensure good record keeping for type and volume of feedstock entering the premises		similar structure -Provide noise attenuation screens such as earth berms or trees -Restrict operating hours -Maintain designated buffer distances where applicable -Provide fire safety protocol	

The application of these management requirements will mitigate the potential environmental impacts associated with the various technologies. Any organic waste containing pathogens, viruses and bacterial that are harmful (i.e. infectious material), will require specialised treatment to ensure total destruction and are not covered as part of these norms & standards. Specific technologies (most notably chemical and thermal) that have shown proven abilities to destroy pathogens, viruses and harmful bacteria might be used on case specific instances, but this must be agreed to by the various competent authorities with the necessary precautions being put in place. For example DEA&DP and DAFF agreeing on the use a facility / technology (composting with sterilisation) for the destruction of avian flu in chickens recently in the Western Cape. See section 10 below for more information.

9 BIOENERGY

Several of the technologies that have been identified in this document produce an end product that provides an energy alternative to the use of fossil fuels. These include biogas, bio-coal, biofuel and biodiesel. The benefits of moving away from reliance of fossil derived fuels has been gaining steady momentum and is undisputed in ecological circles.

According to the DEA State of Environment 2012, the prognosis for future greenhouse gas emissions from South Africa is that they are going to increase significantly in the next five years or so as the Kusile and Medupi power stations are commissioned, and with the possibility of a third large scale coal-fired power plant within the next 15 years. At the same time, continued growth in traffic volumes will also contribute to greenhouse gas increase as will a new refinery, especially if such a refinery is based on coal-to-liquid technology. South Africa will thus continue to be a globally significant emitter of greenhouse gases, especially if viewed per capita.

Energy sources derived from biogenic wastes and residues are more conducive to climate change mitigation than farmed energy crops and should therefore be prioritised for use in bioenergy production (Schubert, et al., 2009). This provides a second very strong motivation for the use of organic wastes to energy after that of removing the material from landfill sites.

Box 7.2-1

Bioenergy: Definitions

Biomass is diverse – both in its origins and in its options for conversion and technical application. Biomass, bioenergy and their possible uses are defined below.

BIOMASS

Biomass stores solar energy. In photosynthesis, CO_2 and water are converted with the aid of solar radiation into organic matter. Some of the energy thus absorbed is released again when biomass is burnt and thus becomes available for use. Biomass consists primarily of the elements carbon (C), oxygen (O) and hydrogen (H) and may be described by the empirical formula $C_nH_mO_p$. More generally, according to Kaltschmitt and Hartmann (2003) the term 'biomass' encompasses all material of organic origin:

– all living phytomass and zoomass (plants and animals),
– the residues that are formed from these (e.g. animal excrements),
– dead (but not yet fossilized) phytomass and zoomass,
– in the wider sense all (waste) substances that have been formed through a technical conversion process and/or through the use of biogenic resources for production processes (e.g. black liquor, cellulose and pulp, residues from animal carcass disposal and from the waste management industry, etc.).

Biomass is classified into primary and secondary products. Primary products are formed directly through photosynthesis, and thus include all plant biomass (energy crops and vegetable by-products from farming and forestry operations). Secondary products arise indirectly through the transformation of primary products, i.e. they are created by the decomposition or conversion of organic matter in heterotrophic organisms (e.g. animals or bacteria). These include all zoomass, its excrements and sewage sludge.

Biomass is either produced deliberately by cultivating farmed feedstocks or arises as organic residue in other production processes. Farmed feedstocks include energy crops (e.g. cereals, *Miscanthus* grasses, harvested timber), while organic residues include harvest residues (e.g. straw, logging residues) and organic wastes and by-products (e.g. slurry, household organic wastes, animal fats, green cuttings: Kaltschmitt and Hartmann, 2003; FNR, 2005).

BIOENERGY

Bioenergy is the final or useful energy that can be released and made available from biomass.

BIOFUELS

The term biofuels refers to fuels in liquid or gaseous form of biogenic origin that are used primarily as transport fuels but also have application in electricity and heat generation, e.g. in small-scale combined heat and power (CHP) units. A distinction is made between 1st-generation and 2nd-generation biofuels. The 1st generation includes vegetable oil, biodiesel and bioethanol, obtained through established physical and chemical (pressing, extraction, esterification) or biochemical (alcoholic fermentation) processes. The 2nd generation includes synthetic biofuels such as BtL (biomass-to-liquid, Fischer-Tropsch diesel), biomethane (or bio-SNG, synthetic natural gas) and biohydrogen, produced using thermochemical processes (gasification, pyrolysis). Almost without exception these technologies remain at present at the laboratory or demonstration stage. Biomethane produced by fermentation can also be included in the 2nd generation. The division of biofuels into the 1st and 2nd generations is not very strict and is based on different parameters depending on the literature consulted, such as whether parts of the plant (1st generation) or the entire above-ground plant (2nd generation) is used, or even whether or not the fuels in question are already established in the marketplace. WBGU therefore designates liquid and gaseous fuels as 2nd generation in the case of biomethane or where the fuels have been obtained by thermochemical processes.

BIOGAS

Biogas is a gas mixture of approx. two-thirds methane (CH_4) and approx. one-third carbon dioxide (CO_2). It also contains small quantities of hydrogen, hydrogen sulphide, ammonia and other trace gases. Biogas is formed by the anaerobic fermentation of organic matter. The component of the gas with a usable energy content is the methane (FNR, 2006a).

BIOMETHANE

The gases with no usable energy content such as CO_2 and other noxious components (e.g. hydrogen sulphide) can be removed from biogas, resulting in a fuel of the quality of natural gas. Known as biomethane, this can be fed into the existing natural-gas network and used in all final energy sectors (electricity, heat, shaftpower – for electrical, thermal and mechanical energy). Through the gasification of solid and liquid biomass it is also possible to produce a raw gas that, after cleaning (clean gas) and conditioning (synthesis gas), is converted, via methane synthesis, into biomethane (bio-SNG; bio-synthetic natural gas) (IE, 2007a).

Figure 43: What is Bioenergy? (Schubert, et al., 2009)

The technology sections earlier in this report touched on what materials produce what type of energy products. The figure below provides a summary.

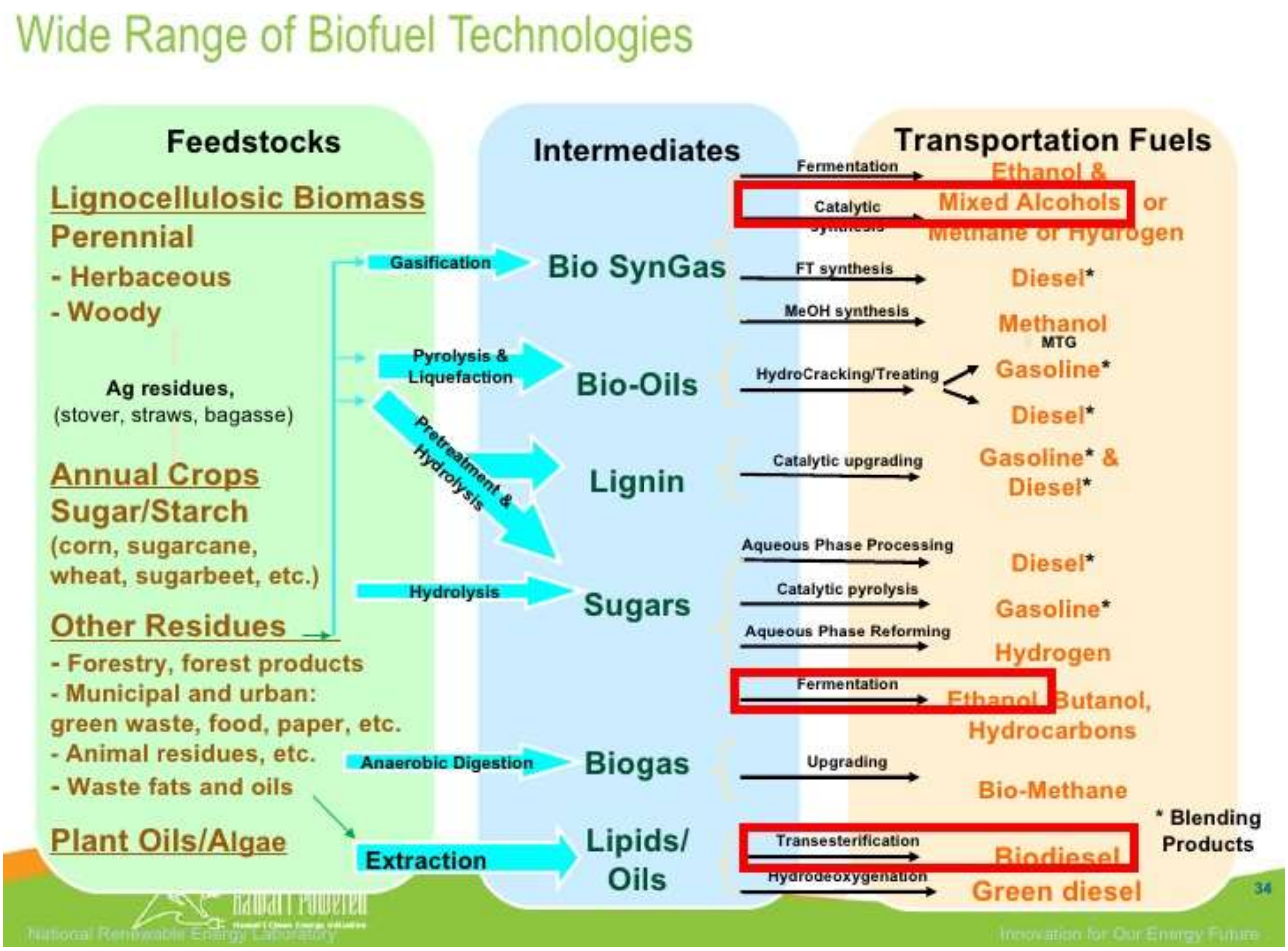


Figure 44: Biofuel technologies (Norton, 2009)

The adoption of norms and standards for the waste management portion of these processes and technologies, will significantly unlock the potential to produce bioenergy in South Africa whilst addressing the high impact of waste generation and disposal. Thus the technologies should be seen primarily as waste management actions with renewable energy benefits.

10 USE OF PRODUCT MATERIAL

The products generated by the various treatments generally consist of the following:

- Organic fertilisers (solid and liquid);
- Bio-char;
- Bio-coal;
- Natural gases;
- Biofuel, biocrude and biodiesel;
- Heat;
- Ash;
- CO_2 and H_2O;
- Protein.

Depending on the type of technologies applied, some potentially harmful constituents may remain or even potentially bio-accumulate thus potentially contaminating the product. The European Union Animal By-Product Regulations (1774/2002) (Anon, 2002) limits the disposal routes to incineration (either on or off-farm), rendering, high temperature/pressure alkaline hydrolysis, disposal at maggot farms or through licensed waste collectors (European Commission, 2002) for potentially harmful pathogens, whilst the complete breakdown of metals at high thermal treatments has been proven in technologies such as gasification.

In order to ensure that contamination of land is prevented, it will be necessary for products to undergo testing and comply with the relevant guidelines for soil and water pollution prevention.

10.1 PRION AND PATHOGEN DEACTIVATION

The DAFF on previous occasion have raised their concern regarding the safety of some residues, notably from compost and anaerobic digestion especially related to pathogenic endurance. The Red Meat Abattoir Association (RMAA) has raised the issue of the need for applied research on compost / digestate using abattoir waste to address prions. The term "prion" is derived from proteinaceous infectious particle and refers to the pathogen that causes transmissible spongiform encephalopathies (TSEs). The two most notable TSEs being Bovine spongiform encephalopathy (BSE or mad cow disease) seen in cattle and livestock and Creutzfeldt-Jakob disease (CJD) seen in humans (Robertson, 2017).

Since prions are proteinaceous, they can be destroyed by means of denaturation. Effective prion decontamination relies upon protein hydrolysis or reduction or destruction of protein tertiary structure. Examples include sodium hypochlorite, sodium hydroxide, and strongly acidic detergents such as LpH. 134 °C for 18 minutes in a pressurized steam autoclave has been found to be somewhat effective in deactivating the agent of disease. Thus thermal and chemical treatments are effective means of destroying the pathogen (Robertson, 2017).

The RMAA commissioned a literature review of pathogen survival of various under various conditions. In previous years, rendering was the default mechanism for treating abattoir waste but with the discovery of the BSE prion, the economic value of rendering was severely compromised and alternate treatment methods were considered (Franke-Whittle, 2011).

Pathogen	Inactivation by					
	Pasteurisation (70 °C)	Anaerobic digestion at 37 °C	Anaerobic digestion at 55°C	Pre-pasteurisation and Anaerobic digestion at 37 °C	Composting	Alkaline hydrolysis
Escherichia coli	++	+	+	(++)	+	(++)
Salmonella	++	+	++	(++)	++	(++)
Clostridium	-	-	-	(-)	-	(++)
Brucella abortus	++	NI	(++)	(++)	NI	(++)
Bacillus antracis	-	-	-	(-)	-	(++)
Mycobacterium bovis	++	(+)	(++)	(++)	++	++
Erysipelothrix rhusiopathiae	++	+	++	(++)	++	(++)
BSE prion	-	-	-	(-)	-	++
Aphto virus	(++)	NI	(+)	(++)	C	(++)
Rabies virus	++	NI	(++)	(++)	(++)	(++)
African Swine Fever Virus	++	NI	(++)	(++)	++	(++)
Phlebo virus	(++)	NI	NI	(++)	(++)	-
Cysticercus bovis	(++)	++	++	(++)	(++)	(++)

++ total inactivation
+ inactivation
- survival
(++) no information on process, but predicted inactivation of pathogen
(-) no information found, but predicted survival of pathogen
NI no information found
C contradictory information

Figure 45: Summary of inactivation of different pathogens by different treatments (Franke-Whittle, 2011)

In a 2002 outbreak of Avian Influenza (AI) in Virginia in the US, complaints regarding possible contamination of groundwater sources led to the investigation of alternative means of treating the carcasses and litter. These included on-site burial, burial in sanitary landfills, controlled slaughter, incineration with air curtain destructors, and in-house and Ag-Bag composting. Of these, in-house composting provided the highest level of disease containment by confining the virus to the poultry house. It also provided higher levels of environmental protection than other disposal methods. (Flory & Peer, 2010). Composting as a carcass disposal method has at least two benefits: (1) it produces a useful end product and (2) any virus present in the feed or litter can be deactivated by mixing this material into the compost windrows.

The June 2017 AI outbreak in the Western Cape is being treated in similar fashion. This prevents further spread of the virus by composting on site and avoiding transport to Vissershok. Furthermore it provides some economic recovery in that the composted product, once confirmed as uncontaminated, can be sold or used to land as an organic fertiliser.

10.2 COMMERICAL PRODUCTS CONTAINING SLUDGE

Regardless of the type of technology applied, any products generated from sewage sludge, will be required to comply with DAFF and DWS guidelines for application to land in the form of organic fertilisers or where the product is re-used as ash in construction materials. It must be noted that these guidelines will also be applied to any commercially generated organic fertiliser, regardless of whether sewage sludge is included or not.

	Fertilizer products	Commercial products: Construction
Applicable Act Governing Practice	Fertilizer, Farm Feed, Agricultural Remedies and Stock Remedies Act (Act 36 of 1974) Hazardous Substances Act (Act No 15 of 1973) National Health Act (Act 61 of 2003)	Hazardous Substances Act (Act No 15 of 1973) National Health Act (Act 61 of 2003)
Authorisation Required	Registration as a fertilizer with Department of Agriculture	None specified
Lead Authority	Department of Agriculture	Department of Health
Regulatory Instrument	Certificate of registration Applicable health and pollution control regulations, provincial and local bylaws	Applicable health and pollution control regulations, provincial and local bylaws
Regulatory Guidelines	Sludge Guidelines (Volume 5) and/or Minimum Requirements (latest applicable versions)	

Figure 46: Regulatory requirements for the commercial use of sludge (Department of Water Affairs , 2008)

From the above, it can be concluded that the deactivation, denaturing or destruction of potentially harmful substances is best done at high temperatures or at thermophilic (45 and 55°C) temperatures for an hour or more. Facilities that treat such materials must ensure that these protocols are implemented as part of their Standard Operating Procedures (SOP).

11 CONCLUSION

"*There is no such thing as organic waste, only wasted organics*" (Vermi~BIOLOGICALS).

South Africa has a risk averse approach to environmental management, which has resulted in impressive legislative mechanisms aimed at preventing environmental degradadation. Unfortunately, this can lead to onerous and expensive processes which should perhaps rather be addressed simply using proven actions. Legislative review and policy formulation processes will not result in significant action unless the various actors take responsibility to implement the recommended actions (Loubser, Govender, & Royal, 2012). Enforcement alone is not sustainable mechanism to bring about ecological ownership.

Environmental management by its very nature cuts across various disciplines, and as such requires an interdisciplinary approach to ensure effective results. This approach will also reduce unintended duplication of efforts by various role-players. A strong focus on co-operative governance, policy alignment, especially where multiple SEMA's are involved and streamlined service delivery is therefore required to give effect to change and successful implementation. This then is the basis on which the Norms and Standards is founded. The legislative direction is provided by it being a legally binding environment, the standards are developed with the industries making it co-operative and complying with the standards requires a degree of self-regulation from industries thus ensuring a sense of ownership in sustaining the environment.

It has been a challenge during this document to avoid using the term "waste" for the organic material that has been discussed. In terms of the definition provided by NEM:WA, yes, it could be seen to be a waste, yet at the same time, although perhaps not necessarily wanted by the generator for whatever reason, the value in organic material both environmentally and economically makes it clearly a resource or feedstock for another process.

Globally, organic waste has been recognised as a quick win or low hanging fruit in the battle to reduce unnecessary use of landfill airspace and many technologies available for its re-use are positively old fashioned. So, it most certainly has not always been considered a waste product. The example of rendering animal products to produce soaps and oils from man's early days to digging agricultural residues back into the earth to improve soil quality is a clear indication that organics used well are very much wanted and not wasted.

Organic feedstock then, can be utilised in its entirety to produce valuable and environmentally beneficial products whilst ensuring sustainability of landfill airspace, reduction in the emission of greenhouse gases and energy recovery from non-fossil fuel sources. With modern technologies such as HTC, HTL, APR, organic feedstocks can be reduced to the basic ethanols and used to power technologically advanced machinery or low technological processes like composting can be used to combat modern viruses.

The potential negative environmental impacts associated with organic feedstock technologies can all be managed to significantly minimise to acceptable levels or eliminate risks completely. The positive environmental impacts realised simply by removing this feedstock from landfill and then beneficiating are significant on many levels.

Unlocking the waste economy has been identified at a presidential level (Operation Phakisa) to have the potential to vastly improve the lives of South Africans environmentally, socially and economically. Making opportunities available for the re-use and recovery of organic feedstock will improve community health, develop SMME's, create alternative energy security, foster improved agricultural practises and reduce greenhouse gas emissions. The application of these Norms & Standards will encourage opportunities for facilities to be developed which may have been deterred under the normal licensing processes, especially NEM:AQA.

This report has been developed in order to comply with regulation 9 of the NEM:WA Waste Classification and Management Regulations of 2013 of which the end product is the Norms & Standards for the treatment of organic waste included as Appendix 5 of this report. This Motivation Report has clearly shown that the management of these technologies to make use of a feedstock rather than a problematic waste, can be undertaken without unacceptable risk to the environment or to human health. The management required for the technologies can be implemented and conducted consistently and repeatedly in a controlled manner thus meeting the requirements for a system of standards.

This report will be made available to key stakeholders, including authorities, industry and members of the public in order to ensure transparency in the process and consistency in identifying issues and impacts. This will also enable the potential users and enforcers of the norms and standards to confirm if the requirements that will be expected to be implemented are applicable and will ensure sustainable management of organic feedstocks.

12 BIBLIOGRAPHY

(2017). Retrieved September 4, 2017, from Iowa State University Office of Biotechnology: www.biotech.iastate.edu/wp_single/wp-content/.../TransesterificationofOilTBG.doc

(2017). Retrieved September 5, 2017, from University of Notre Dame: https://ace.nd.edu/

Abnisa, F., & Daud, W. (2014, November). A review on co-pyrolysis of biomass: An optional technique to obtain a high-grade pyrolysis oil. *Energy Conversion and Management, 87*, 71 - 85.

Agbelie, I., Bawakyillenuo, S., & Lemaire, X. (2015, May 18). *Waste-to-energy: African cities can transform their energy landscapes*. Retrieved July 20, 2017, from UrbanAfrica.net: https://www.urbanafrica.net/urban-voices/waste-to-energy-african-cities-can-transform-their-energy-landscapes/

Ahmed, M. M., Nasri, S. N., & Hamza, U. D. (2012, February). Biomass as a renewable source of chemicals for industrial applications. *International Journal of Engineering Science and Technology (IJEST), 4*(2), 721 - 730.

All Power Labs. (2017). *Gasfiication Explained*. Retrieved September 7, 2017, from All Power Labs: http://www.allpowerlabs.com/gasification-explained

Amos, W. A. (1998). *Report on Biomass Drying Technology.* National Renewable Energy Laboratory, US Department of Energy, Colorada, USA.

Arthurson, V. (2009). Closing the Global Energy and Nutrient Cycles through Application of Biogas Residue to Agricultural Land – Potential Benefits and Drawbacks. *Energies*(2), 226 - 242.

Bareja, B. G. (2011, July). *Earthworms Have Many Uses, But They Also Have Disadvantages*. Retrieved September 5, 2017, from Cropsreview.com: http://www.cropsreview.com/earthworms.html

Basso, D., Castello, D., Baratieri, M., & Fiori, L. (2013). Hydrothermal carbonization of waste biomass: Progress Report and Prospects. *21st European Biomass Conference and Exhibition.* Copenhagen, Denmark.

Bello, I. A., Ismail, M. N., & Kabbashi, N. A. (2016, May 14). Solid Waste Management in Africa: A Review. *International Journal of Waste Resources, 6*(2).

Binder, J. P., & Raines, R. T. (2010, March 9). Fermentable sugars by chemical hydrolysis of biomass. *PNAS, 107*(10), 4516 - 4521.

Blanchard, R., Richardson, D., O'Farrell, P., & Von Maltitz, G. (2011). Biofuels and biodiversity in South Africa. *South African Journal of Science, 107 (5/6)*, Art. #186.

Boldrin, A., Neidel, T., Damgaard, A., Bhander, G., Møller, J., & Christensen, T. (2011). Modelling of environmental impacts from biological treatment of organic municipal waste in EASEWASTE. *Waste Management, 31*(4), 619 - 630.

Briens , C., Piskorz , J., & Franco, B. (2008). "Biomass valorization for fuel and chemicals production" A review. *International Journal of Chemical Reactor Engineering, 6*.

clivusmultrum Incorpporated. (2010). *How the Clivus Multrum Works*. Retrieved September 5, 2017, from clivusmultrum Incorpporated: http://www.clivusmultrum.com/science-technology.php

Coronado, I., Stekrova, M., Reinikainen, M., Simell, P., Lefferts, L., & Lehtonen, J. (2016, July). A review of catalytic aqueous-phase reforming of oxygenated hydrocarbons derived from biorefinery water fractions. *International Journal of Hydrogen Energy, 41*(26), 11003 - 11032.

Council of the European Union. (1999, July 16). Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste. *Official Journal of the European Communities*.

COWI. (2004). *Preliminary Impact Assessment for an Initiative on the Biological Treatment of Biodegradable Waste.* COWI.

Department for Environment, Food and Rural Affairs (DEFRA). (2004). Review of Environmental Health Effects of Waste Management: Municipal Solid Waste and Similar Wastes. London, United Kingdom: Queen's Printer and Controller of HMSO 2004.

Department of Environment and Conservation (NSW). (2004). *Composting and Related Oganics Processing Facilities.* Waste Management Section. Sydney: Department of Environment and Conservation (NSW).

Department of Environmental Affairs . (n.d.). *SAWIC Licensing*. Retrieved July 11, 2017, from South African Waste Information Centre (SAWIC): http://sawic.environment.gov.za/?menu=88

Department of Environmental Affairs (DEA). (2014). *Draft Norms & Standards for Organic Waste Composting.* Pretoria, South Africa: Government Gazette 37300.

Department of Environmental Affairs. (1998). National Environmental Management Act 107 of 1998. Pretoria, Republic of South Africa: Goverment Gazette 31884.

Department of Environmental Affairs. (2004). National Environmental Management: Air Quality Act 39 of 2004. Pretoria, Republic of South Africa: Government Gazette 27318.

Department of Environmental Affairs. (2008). National Environmental Management: Waste Act 59 of 2008. Pretoria, Republic of South Africa: Government Gazette 32000.

Department of Environmental Affairs. (2012). Chapter 5: Air Quality. In DEA, *2012 SOUTH AFRICA ENVIRONMENT OUTLOOK.* Pretoria, South Africa.

Department of Environmental Affairs. (2012). *National Waste Information Baseline Report.* Pretoria, South Africa: Department of Environmental Affairs.

Department of Environmental Affairs. (2012). Proposed Air Quality Index for South Africa: A simplified tool for reporting air quality to thegeneral public. *National Air Quality Governance Lekgotla.* Rustenburg, South Africa.

Department of Environmental Affairs. (2013). *National Dust Control Regulations GN 827.* Pretoria, South Africa: Department of Environmental Affairs.

Department of Environmental Affairs. (2013). *The National Organic Waste Composting Strategy.* Pretoria, South Africa: Department of Environmental Affairs.

Department of Environmental Affairs. (2014). National Environmental Management: Waste Amendment Act 26 of 2014. Pretoria, Republic of South Africa: Government Gazette 37714.

Department of Science & Technology (DST). (2014). *A National Waste RDI Roadmap for South Africa. Trends in waste management.* Department of Science & Technology (DST). Pretoria: Department of Science & Technology (DST).

Department of Science & Technology. (2014). *National Waste Research & Development (R&D) and Innovation Roadmap for South Africa: Phase 2 Waste RDI Roadmap. The economic benefits of moving up the waste management hierarchy in South Africa: The value of resources lost through landfilling.* Pretoria, South Africa: Department of Science & Technology.

Department of Water & Sanitation. (2013). *Revision of General Authorisations in terms of Section 39 of the National Water Act, 1998 GN665.* Pretoria, South Africa: Department of Water & Sanitation.

Department of Water Affairs . (2008). *Guidelines for the Utilisation and Disposal of Wastewater Sludge: Volume 5 – Requirements for thermal sludge management.* Guideline Series, Water Research Commission, Department of Water Affairs , Pretoria, South Africa.

Department of Water Affairs. (1998). National Water Act 36 of 1998. Pretoria, Republic of South Africa: Government Gazette 19182.

Diener, S., Nandayure, M., Studt, S., Gutiérrez, F. R., Zurbrügg, C., & Tockner, K. (2011). Biological Treatment of Municipal Organic Waste using Black Soldier Fly Larvae. *Waste Biomass Valor*(2), 357–363.

Diener, S., Zurbrügg, C., Gutiérrez, F. R., Nguyen, D. H., Morel, A., Koottatep, T., et al. (2011). Black Soldier Fly Larvae for Organic Waste Treatment – Prospects and Constraints. In M. Alamgir, Q. H. Bari, I. M. Rafizul, S. M. Islam, G. Sarkar, & M. K. Howlader (Ed.), *2nd International Conference on Solid Waste Management in the Developing Countries.* Khulna, Bangladesh.

DST. (2014). *A National Waste R&D and Innovation Roadmap for South Africa: Phase 2 Waste RDI Roadmap. The economic benefits of moving up the waste management hierarchy in South Africa: The value of resources lost through landfilling.* Department of Science & Technology (DST). Pretoria, South Africa: Department of Science & Technology (DST).

Dutta, A., & Leon, M. A. (n.d.). Pros and Cons of Torrefaction. University of Guelph.

Ebshish, A., Yaakob, Z., Taufiq-Yap, Y. H., Bshish, A., & Tasirin, S. M. (2012). Review of hydrogen production via glycerol reforming. *Journal of Power and Energy, 226*(8), 1060 -1075.

ecoideaz. (2016). *Vermicomposting – Producing Manure with Earthworms*. Retrieved September 5, 2017, from ecoideaz: http://www.ecoideaz.com/expert-corner/vermicomposting-composting-with-earthworms

Eunomia Research & Consulting. (2002). *Economic Analysis of Options for Managing Biodegradable Municipal Waste - Final Report to the European Commission.* Final Report, European Union, Bristol, United Kingdom.

Eunomia Research And Consulting. (2002). *Appendices to Final Report: Economic Analysis of Options for Managing Biodegradable Municipal Waste.*

European Commission. (2002). *REGULATION (EC) No 1774/2002 of THE EUROPEAN PARLIAMENT AND OF THE Council laying down health rules concerning animal by-products not intended for human consumption.* Brussels, Belgium: European Commssion.

Eurostat. (2013). *Waste indicators on generation and landfilling measuring sustainable development 2004-2010*. Retrieved July 19, 2017, from eurostat - Statistics Explained: http://ec.europa.eu/eurostat/statistics-explained/index.php/Archive:Waste_indicators_on_generation_and_landfilling_-_monitoring_sustainable_development

Eurostat. (2017). *Municipal Waste Statistics*. Retrieved July 19, 2017, from eurostat - Statistics Explained: http://ec.europa.eu/eurostat/statistics-explained/index.php/Municipal_waste_statistics

Federal Ministry of Agriculture, F. E. (22 - 23 November 2001). Applying Compost Benefits and Needs. Brussels: European Commission.

Flory, G. A., & Peer, R. W. (2010). Verifi cation of Poultry Carcass Composting Research through Application during Actual Avian Influenza Outbreaks. *Institute for Laboratory Animal Research (ILAR) Journal, 51*(2), 149 - 157.

Franke-Whittle, I. (2011). *Pathogen survival in the products obtained after anaerobic digestion, alkaline hydrolysis (low pressure – as used in the RSA) and composting.* RMAA, Pretoria, South Africa.

Gemco Energy. (2017). *A SUMMARY OF BIOMASS PELLET PLANT FAQ – PART 1*. Retrieved August 29, 2014, from Gemco Energy: http://www.biomass-energy.org/blog/biomass-pellet-plant-faq-part-1.html

Giggey , M. D., Pinnette, J. R., & Dwinal, C. A. (1995, February). Odour control factors in compost site selection. *Biocycle*, 74 - 79.

GreenCape. (2014). *Market Intelligent Report: Waste Economy.* Cape Town, South Africa: GreenCape.

GreenCape. (2016). *Waste Economy: Market Intelligence Report 2016.* Cape Town: GreenCape.

Habjanec , D. (2014, January 19). *Hydrothermal liquefaction facts*. Retrieved September 7, 2017, from Interesting Energy Facts: http://interestingenergyfacts.blogspot.co.za/2014/01/hydrothermal-liquefaction-facts.html

Haigh, K., & Görgens, J. (2014). APR: Aqueous Phase Reforming. In W. Hugo (Ed.), *Bioenergy Atlas.* Pretoria, South Africa: Department of Sciene & Technology.

Haigh, K., & Görgens, J. (2014). Syn-Prd: Syngas Production from Lignocellulose. In W. Hugo (Ed.), *Bioenergy Atlas.* Pretoria, South Africa: Department of Sciience & Technology.

Haigh, K., & Görgens, J. (2014). TORR: Torrefaction (TORR-1)/ Torrefaction and Pelleting (TORR-2). In W. Hugo (Ed.), *Bioenergy Atlas.* Pretoria, South Africa: Department of Science & Technology.

Haigh, K., & Görgens, J. (2014). TRANS--1: Transesterfication of Waste Oil to Biodiesel. In W. Hugo (Ed.), *Bioenergy Atlas.* Pretoria, South Africa: Department of Science & Technology.

Helmenstine, A. (2015, November 30). *How saponification makes soap*. Retrieved September 5, 2017, from ThougtCo.: https://www.thoughtco.com/how-saponification-makes-soap-606153

Helmenstine, A. (2017, May 12). *Saponification Definition and Reaction*. Retrieved September 5, 2017, from ThoughtCo.: https://www.thoughtco.com/definition-of-saponification-605959

Huang, J. (2014, August 6). *How To Make Briquettes From Daily Wastes*. Retrieved May 8, 2017, from Renewable Energy World: http://www.renewableenergyworld.com/ugc/articles/2014/08/how-to-make-briquettes-from-daily-wastes.html

Hugo, W. (Ed.). (2016). Bioenergy Atlas for South Africa - Synopsis Report. Pretoria, South Africa: Department of Science & Technology.

Indiamart. (2017). *Torrefaction of biomass*. Retrieved September 8, 2017, from Indiamart: https://www.indiamart.com/proddetail/torre-faction-of-biomass-6808160948.html

James , H. C., & Fabien, I. D. (2008). *Introduction to chemical from biomass.* United Kingdom: John Wiley & Sons.

Kigozi, R., Aboyade, A., & Muzenda, E. (2014). Biogas Production Using the Organic Fraction of Municipal Solid Waste as Feedstock. *Int'l Journal of Research in Chemical, Metallurgical and Civil Engg. (IJRCMCE), 1*(1), 107 - 114.

Kigozi, R., Aboyade, A., & Muzenda, E. (2014). Biogas Production Using the Organic Fraction of Municipal Solid Waste as Municipal Solid Waste as Feedstock. *International Journal of Research in Chemical, Metallurgical and Civil Engineering, 1*(1).

Kopinke, F.-D. (2016, March 17). *Hydrothermal Carbonization HTC*. Retrieved from Helmholtz Centre for Environmental Research (UFZ): https://www.ufz.de/index.php?en=37433

Lachos-Perez , D., Juliana , P. M., Torres-Mayanga , P., Forster-Carneiro, T., & Meireles, M. (2015). Supercritical Water Gasification of Biomass for Hydrogen Production: Variable of the Process. *Food and Public Health, 5*(3), 92 - 101.

Lalander, C. H., Fidjeland, J., Diener, S., Eriksson, S., & Vinnerås, B. (2015). High waste-to-biomass conversion and efficient Salmonella spp.reduction using black soldier fly for waste recycling. *Agronomy for Sustaintainable Development, 35*, 261 - 271.

Levis, J., Barlaz, M., Themelis, N., & Ulloa, P. (2010). Assessment of the state of food waste treatment in the United States and Canada. *Waste Management*.

Li, H., Chen, Q., Zhang, X., Finney, K. N., Sharif, V. N., & Swithenbank, J. (2011). *Evaluation of a Biomass Drying Process using waste heat from process industriess: A case study.* Sheffield University, Department of Chemical and Biological Engineering. Sheffield, United Kingdom: Sheffield University.

Li, T., Xu, J., Wu, H., Wang, G., Dai, S., Fan, J., et al. (2016, September). A Saponification Method for Chlorophyll Removal from Microalgae Biomass as Oil Feedstock. (P. Long, Ed.) *Marine Drugs, 14*(9).

Loubser, J., Govender, S., & Royal, M. (2012). Chapter 15: Options for Action. In DEA, *2nd South Africa Environment Outlook. A report on the state of the environment.* Pretoria, South Africa: Department of Environmental Affairs.

Lucian, M., & Fiori, L. (2017, February 13). Hydrothermal Carbonization of Waste Biomass: Process Design,Modeling, Energy Efficiency and Cost Analysis. *energies, 10*, p. 211.

Ma, R., Xu, Y., & Zhang, X. (2014). Catalytic Oxidation of Biorefinery Lignin to Value-added Chemicals to Support Sustainable Biofuel Production. *ChemSusChem Reviews, 7*, 1 - 29.

Mason, T. J. (2008, May). The effects of sonication on bacteria. *The Journal of the Acoustical Society of America, 123*(5).

Mavitec. (2017). *Archives: Processing Methods*. Retrieved September 8, 2017, from Mavitec: http://mavitecrendering.com/rendering-process/

Minh, D. (2013, September 5). *Thailand eyes Biomass*. Retrieved September 7, 2017, from Broadgate Financial: http://www.broadgatefinancial.com/blog/thailand-eyes-biomass/

Mosia, R., Laugesen, C., Pillay, A., & Tsikata, M. (2012). Chapter 13: Waste Management. In DEA, *2nd South Africa Environment Outlook. A report on the state of the environment.* Pretoria, South Africa: Department of Environmental Affairs (DEA).

MRA Consulting. (2016, April 20). *State of Waste 2016 – current and future Australian trends*. Retrieved July 19, 2017, from The Tipping Point: https://blog.mraconsulting.com.au/2016/04/20/state-of-waste-2016-current-and-future-australian-trends/

Muvhiiwa, R., Hildebrandt, D., Chimwani, N., Ngubevana, L., & Matambo, T. (2017). The impact and challenges of sustainable biogas implementation: moving towards a bio-based economy. *Energy, Sustainability and Society, 7*(20).

myclimate. (2017). *Composting avoids methane emissions*. Retrieved September 5, 2017, from myclimate: http://www.myclimate.org/carbon-offset-projects/projekt/indonesia-waste-management-7117/

New Energy and Fuel. (2009, June 26). *Virent is the Bio Fuel Producer to Beat*. Retrieved September 7, 2017, from New Energy and Fuel: http://newenergyandfuel.com/http:/newenergyandfuel/com/2009/06/26/virent-is-the-bio-fuel-producer-to-beat/

Nexus Energy. (2017). *Lauber L-ENZ (dryer for bulk solids)*. Retrieved September 7, 2017, from Nexus Energy: http://nexusenergyuk.com/process-drying

Norton, P. (2009). *Hawaii Clean Energy Initiative and NREL: Implementing Energy Efficiency and Renewable Energy.* University of Hawaii, Manoa, Hawaii.

O'Beirne, S., Johnson, B., Retief, F., & Oranje, M. (2012). Chapter 14: Environmental Outlook. In DEA, *2nd South Africa Environment Outlook. A report on the state of the environment.* Pretoria, South Africa: Department of Environmental Affairs.

Oliveira, L. S., Oliveira, D. S., Bezerra, B. S., Pereira, B. S., & Gomes Battistelle, R. A. (2017). Environmental analysis of organic waste treatment focusing on composting scenarios. *Journal of Cleaner Production*(155), 229 - 237.

Overend, R. P. (1999). Direct Combustion of Biomass. In *Renewable Energy Sources Charged With Energy from the Sun and Originated from Earth-Moon Interaction Volume 1.* Encyclopedia of Life Support Systems (EOLSS).

Oxford University Press. (2017). *Oxford English Dictionary Online*. Retrieved June 7, 2017, from Oxford English Dictionary Online: https://en.oxforddictionaries.com

Pronk, M., de Kreuk, M. K., de Bruin, B., Kamminga, P., Kleerebezem, R., & van Loosdrecht, M. C. (2015). Full scale performance of the aerobic granular sludge process for sewage treatment. *Water Research, 84*, 207 - 217.

R3 Water. (2013). *Hydrothermal Carbonisation - HTC.* Technology Fact Sheet, Germany.

Robertson, S. (2017). *What is a Prion?* Retrieved September 11, 2017, from News Medical Life Sciences: https://www.news-medical.net/health/What-is-a-Prion.aspx

Saifuddin, N., Samiuddin, A., & Kumaran, P. (2015). A Review on Processing Technology for Biodiesel Production. *Trends in Applied Research, 10*, 1 - 37.

Schubert, R., Schellnhuber, H., Buchmann, N., Epiney, A., Grießhammer, R., Kulessa, M., et al. (2009). *Future Bioenergy and Land Use.* London, United Kingdom: Earthscan.

Sonotronic. (2017). *Sonication of Biosolids* . Retrieved August 29, 2017, from Sonotronic : http://www.sonotronic.de/technologies/ultrasonic/sonication-of-bio-solids?set_language=en

Stafford, W. H., Lotter, G. A., von Maltitz, G., & Brent, A. C. (2017). *Biofuels technology development in Southern Africa.* Development Southern Africa.

Stuart, P. (Undated). *The Advantages and Disadvantages of Anaerobic Digestion as a Renewable Energy Source.* Loughborough University, Loughborough, United Kingdom.

Tatsis, E. C., & O'Connor, S. E. (2016, December). New developments in engineering plant metabolicpathways. *Current Opinion in Biotechnology, 42*, 126 - 132.

Toor, S. S., Rosendah, L., & Rudolf, A. (2011). Hydrothermal liquefaction of biomass: A review of subcritical water technologies. *Energy, 36*, 2328 - 2342.

United Nations. (2009). *Africa Review Report on Waste Management.* United Nations , Economic Commission for Africa. Addis Ababa, Ethiopia: United Nations.

United States Department of Agriculture. (2017, April 14). *Biomass Pyrolysis Research*. Retrieved September 7, 2017, from Agricultural Reserach Service: https://www.ars.usda.gov/northeast-area/wyndmoor-pa/eastern-regional-research-center/docs/biomass-pyrolysis-research-1/what-is-pyrolysis/

US Department of Energy. (n.d.). *Advantages of Gasification*. Retrieved September 7, 2017, from National Energy Technology Laboratory: https://netl.doe.gov/research/coal/energy-systems/gasification/gasifipedia/advantage-of-gasification

US Department of Energy. (n.d.). *Gasification Background*. Retrieved September 7, 2017, from National Energy Technology Laboratory: https://netl.doe.gov/research/coal/energy-systems/gasification/gasifipedia/challenges

US Environmental Protection Agency. (2000). *Decentralized Systems Technology Fact Sheet: Aerobic Treatment.* Office of Water. Washington D.C., USA: USEPA.

US Environmental Protection Agency. (2014). *Municipal Solid Waste Landfills - Economic Impact Analysis for the Proposed New Subpart to the New Source Performance Standards.* US EPA Office of Air and Radiation. North Carolina, USA: US Environmental Protection Agency.

US Environmental Protection Agency. (2016). *Wastes - Non-Hazardous Waste - Municipal Solid Waste*. Retrieved July 19, 2017, from US Environmental Protection Agency: https://archive.epa.gov/epawaste/nonhaz/municipal/web/html/

Uys, G. (2016, June 23). Benefits of vermiculture. *Farmers Weekly*.

Van Deuren, J., Lloyd, T., Chhetry, S., Liou, R., & Peck, J. (2002). *4.4 Chemical Oxidation*. (U.S. Army Environmental Center) Retrieved August 29, 2017, from FRTR Remediation Technologies Screening Matrix and Reference Guide, Version 4.0: https://frtr.gov/matrix2/section4/4_4.html

Vermiculture. (2009). Retrieved September 5, 2017, from Full Cycle: http://www.fullcycle.co.za/index.php/Information/more-information.html

Wiese-Fales, J. (2011, July 20). *Under pressure and in hot water: biomass to gas*. Retrieved September 7, 2017, from College of Engineering - University of Missouri: http://engineering.missouri.edu/2011/07/under-pressure-and-in-hot-water-biomass-to-gas/

WPP Energy Corp. (2010). *Biomass Gasification*. Retrieved September 7, 2017, from WPP Energy Corp: http://wppenergy.com/biomass-gasification.html

WRT. (2017). *Welcome to Waste Resolution Technologies*. Retrieved September 8, 2017, from WRT: http://waste-resolution-technologies.co.za/

13 GLOSSARY OF TERMS[38]

Acceptable Risk Level	The concentration of a substance that will have a minimal effect on the environment
Activities	When used in Chapter 5 of the National Environmental Management Act (NEMA, Act 107 of 1998 as amended), means policies, programmes, processes, plans and projects identified in terms of section 24(2)(a) and (b).
Aerobic treatment	Treatment process requiring free oxygen.
Agro-processing	Agro-processing is a subset of manufacturing that processes raw materials and intermediate products derived from the agricultural sector. Agro-processing thus means beneficially transforming products that originate from agriculture, forestry and fisheries (FAO 1997).
Anaerobic treatment	Treatment process requiring an absence of free oxygen.
Analysis	An investigation to ascertain the constituents of a waste
Aquifer	Water-bearing strata of fractured or permeable rock, sand or gravel. When capable of sustaining community water or other needs, such strata may be considered to represent strategic water resources, requiring protection from pollution
Attenuation	In this context, attenuation is the process of reducing leachate concentration by means of natural physical, chemical and biochemical processes such as dilution, oxidation and cell synthesis. Natural systems have an attenuation capacity which may render small volumes of contaminants (leachate) insignificant. However, when this capacity is exceeded, pollution results
Audit	A site inspection at which the condition of the site on that day is appraised in terms of a number of predetermined criteria
Audit Team	Those who attend the audit or site inspection and assist in compiling the audit report
Bio-Accumulation	The combined intake of pollutants from food and water by organisms.
Biodegradable	A substance or object capable of being decomposed by bacteria or other living organisms and thereby avoiding pollution.
Biogas	Biogas is a gas produced by the anaerobic decomposition of organic

[38] Any definitions not already contained in gazetted legislation have been obtained from the Oxford English Dictionary.

	material by various micro-organisms. It is primarily composed of methane and carbon dioxide. Depending on the substrate that has been decomposed traces of other compounds may be found in the gas. These compounds include, but are not limited to, hydrogen sulphide (H2S), ammonia (NH3), siloxanes and water vapour.
BPEO	"Best Practicable Environmental Option." The outcome of a systematic consultative procedure that emphasises the protection of the environment. It establishes, for a given set of objectives, the option that provides the most benefit or least damage to the environment as a whole at acceptable cost
Buffer Zones	Buffer zones in this case refer to separations between the boundaries of registered landfill sites and residential developments. They may vary between 500m and 1000m in width, depending on the classification of the landfill. No residential development may take place within a proclaimed buffer zone. At the discretion of the local authority and the state department, however, developments such as industrial developments may be permitted.
Business Waste	Waste that emanates from premises that are used wholly or mainly for commercial, retail, wholesale, entertainment or government administration purposes.
Carcinogens	A substance or agent producing or inciting cancer. These substances can be grouped as: Group A - Clinically and epidemiologically proven in humans, Group B - Proven without doubt in laboratory animals, Group C - limited evidence in animals, Group D - Inadequate and doubtful data.
Category 1 feedstock	Category 1 feedstock are organics that have the lowest environmental impact but have the potential to generate offensive odours. These include garden and landscaping organics, untreated timber (sawdust, shavings, timber offcuts, crates, pallets, wood packaging), natural fibrous organics (sugar bagasse, peat, straw, seed husks etc.) and processed fibrous organics (paper, cardboard, paper-processing sludge, non-synthetic textiles).
Category 2 feedstock	Category 2 feedstock are organics that have a greater environmental impact that Category 1 and have the potential to attract vermin and vectors. These include natural or processed vegetable organics (vegetables, fruit and seeds and processing sludges and wastes, winery, brewery and distillery wastes, food organics excluding those in Category 3) and biosolids and manures (sewage biosolids, animal manure and mixtures of manure and biodegradable animal bedding organics.
Category 3 feedstock	Category 3 feedstock are organics that may generate harmful leachate,

	which could contaminate surface water, groundwater and soil if not correctly managed. These include meat, fish and fatty foods (carcasses, parts of carcasses, blood, bone, fish, fatty processing or food), fatty and oily sludges and organics of animal and vegetable origin (dewatered grease trap, fatty and oily sludges of animal and vegetable origin) and mixed residual waste containing putrescible organics (putrescible organics including household domestic waste, commerce and industry waste sent to municipal sites).
Cattle Unit	The number of non-bovine species considered equivalent to one bovine animal
Chronic Toxicity	The effects of prolonged exposure of organisms or of man to a chemical substance
Class A Landfill	Landfill site for the disposal of Type 1 Waste with Hazardous Ratings 1 – 4 and includes asbestos waste, expired, spoilt or usable hazardous products, PCBs or PCB containing waste >50ppm, general waste excluding domestic waste, which contains hazardous waste or hazardous chemicals and mixed, hazardous chemical wastes from analytical laboratories and laboratories from academic institutions in containers less than 100 litres.
Class B Landfill	Landfill site for the disposal of Type 2 Waste which includes domestic waste, business waste not containing hazardous waste or hazardous chemicals, non-infectious animal carcasses and garden waste.
Class C Landfill	Landfill site for the disposal of Type 3 Waste which includes post-consumer packaging and waste tyres.
Class D Landfill	Landfill site for the disposal of Type 4 Waste which includes building and demolition waste not containing hazardous waste or hazardous chemicals and excavated earth material not containing hazardous waste or hazardous chemicals.
Closure	The act of terminating the operation of a facility. Closure is preceded by rehabilitation and followed by post closure monitoring
Community	The people living in the vicinity of a proposed, planned or developed activity
Compaction	The process whereby the volume of waste is reduced, using a purpose built compactor or other suitable machine
Competent Authority	An authority mandated to make a decision related to a specific legislation.
Composite Liner	An assembled structure of geosynthetic materials and low permeability

	earth materials (clay or bentonite), placed beneath a landfill to form a barrier against the migration of leachate into the underlying soils and ground water
Compost	Stabilised, homogenous, fully decomposed substance of animal or plant origin to which no plant nutrients have been added and that is free of substances or elements that could be harmful to man, animal, plant or the environment.
Compostable organic material	Carbon-based material of animal or plant origin that naturally enhances fertility of soil through a natural degradation process but excludes human made organic chemicals. This excludes infectious, poisonous, health-care and hazardous organic wastes.
Composting	Controlled biological process in which organic materials are broken down by micro-organisms in the presence of oxygen.
Concept Permit	Any landfill permit issued before the promulgation of the Environmental Conservation Act, 1989 (Act 73 of 1989).
Contaminate	The addition of foreign matter to a natural system. This does not necessarily result in pollution, unless the attenuation capacity of the natural systems is exceeded
Contaminated organic material	Organic feedstock that contains significant levels of toxic chemical compounds and metal compounds; physical contaminants such as plastic and glass or pathogenic contaminants that will affect the quality of the processed product. These materials must be separated from the general organic feedstock and treated separately
Corrosive	Solids or liquids that can, in their original state, severely damage living tissue. Corrosivity can be measured by determining the degree to which a standard coupon of steel dissolves
Cover	The material used to cover waste. Cover Material is usually soil, but may comprise builders' rubble, ash or other suitable materials
Cradle - to – grave	A policy of controlling any Waste from its inception to its ultimate disposal
Danger Group	For transport purposes, hazardous substances that are listed in SABS Code 0228 are placed in a Danger Group
Delisting	The reclassification of a hazardous waste for disposal on a lower class of landfill. This would only be allowed by the Department, based on proof of low mobility or concentration, or proof of successful treatment to render it less hazardous

Destruction	To neutralise or get rid of a waste by incineration or other physical or chemical means
Detection Monitoring	This is routine water monitoring carried out bi-annually, using a limited number of indicators parameters, with a view to indicating pollution from the landfill
Dispersion	The movement of a substance from a landfill into the surrounding environmental
Digestate	The liquid and or solid product remaining after the anaerobic digestion of a biodegradable feedstock.
Domestic waste	Primarily household waste and garden refuse
Dose	The amount of a substance in g/ha that is to be landfilled
Duty of care	This requires that anyone who generates, transports, treats or disposes of waste must ensure that there is no unauthorised transfer or escape of waste from their control, and must retain documentation describing both the waste and any related transactions. The person retains responsibility for the waste generated or handled
Ecotoxicity	The potential to harm animals, plants, ecosystems or environmental processes
Effluent	Liquid outflow from domestic, commercial, industrial or agricultural process operation
Engineered Cell	A cell that is designed and engineered to contain hazardous waste. It is underlain by a liner to prevent the waste or the leachate from the waste coming into contact with the environment
Environment	The natural environment, consisting of air, water, land and all forms of life. The social, political, cultural, economic and working context and other factors that determine people's place in and influence on the environment and the natural and constructed spatial surroundings.
Environmental Authorisation	When used in Chapter 5 of NEMA, means the authorisation by a competent authority of a listed activity or specified activity in terms of this Act, and includes a similar authorisation contemplated in a specific environmental management Act (SEMA).
Environmental Impact Assessment (EIA)	An investigation to determine the potential detrimental or beneficial impact on the surrounding communities, fauna flora, water, soil, and air, arising from the development or presence of a landfill
Estimated Environmental	The Estimated Environmental Concentration represents the

Concentration (EEC)	concentration of a substance in the aquatic environment when introduced under worst case scenario conditions. It is used to indicate possible risk, by comparison with the minimum concentration estimated to adversely affect aquatic organisms or to produce unacceptable concentration in biota, water or sediment
Exposure	The amount of hazardous substances available to man or living matter.
Fatal Flaw	A factor or situation which prevents the development of an environmentally acceptable waste disposal facility, except at prohibitive cost
Feasible	Acceptable, capable of being used or implemented successfully, without unacceptably damaging the environment
Feedstock	Raw material required to supply or fuel a machine or industrial process. For the purpose of this document, feedstock includes any organic materials included in a specific treatment that is biodegradable or fermentable. This includes waste or non-waste organic material.
Fertiliser	Any substance which is intended or offered to be used for improving or maintaining the growth of plants or the productivity of the soil.
Fertilizer group	The category under which a particular fertilizer falls. Fertilizers are categorised as follows: **Group 1** which is a fertilizer containing a total equal or greater than 100 g/kg of N, P or K or any combination thereof; or **Group 2** which is a fertilizer containing a total of less than 100 g/kg of N, P or K or any combination thereof or any other recognised plant nutrient(s) in acceptable amounts as indicated in Tables 1 -9 and 13 -15; **Group 3** which is a fertilizer containing natural or synthetic substance(s) or organism(s) that improve(s) or maintain(s) the physical, chemical or biological condition (fertility) of the soil; and "soil Improver" has the same meaning.
Flocculation	The intentional grouping of very small particles or colloids in a suspension in water or other liquids, the purpose being to increase the settlement rate of the solids.
Garden Waste	Organic biodegradable waste material generated from the likes of a typical garden.
General Waste	Waste that does not pose an immediate hazard or threat to health or the environment, and includes domestic waste, building and demolition waste, business waste, inert waste or any waste classified as non-hazardous in terms of regulations made under section 69 of NEM:WA.

Generator	A Waste Generator is any person whose actions, production processes or activities, including waste management activities, results in the generation of waste.
Geosynthetic Clay Liner (GCL)	A manufactured composite barrier system comprising f layers of clay material and geosynthetic materials to form a single sheet for use as a liner.
Ground Water	Water occupying pores in the soil and cavities and spaces in rocks in the saturated zone of the profile. This water may rise from a deep, magmatic sources or be due to the infiltration of rainfall (recharge).
Guideline	While not requirements, guidelines are recommended actions which represent good practice. They are not enforceable, but may form the basis for site specific permit conditions in which case they become mandatory
Handling	Functions associated with the movement of waste, including storage, treatment and ultimate disposal, by means of manual systems or automated systems.
Hazard Rating	A system for classifying and ranking wastes according to how great a hazard they present to human health and the environment.
Hazardous waste	Any waste that contains organic or inorganic elements or compounds that may, owing to the inherent physical, chemical or toxicological characteristics of that waste, have a detrimental impact on health and the environment and includes hazardous substances, materials or objects within business waste, residue deposits and residue stockpiles for any wastes identified in Schedule 3 of NEM:WA Amended Act 26 of 2014.
Hazardous Waste Landfill	A containment landfill, designed specifically for the disposal or co-disposal of hazardous waste
Health Care Waste	Waste emanating primarily from human and veterinary hospitals, clinics and surgeries. Also from chemists and Sanitary Services. They may comprise, inter alia, sharps (used hypodermic needles and scalpel blades), malignant tissue, body parts, soiled bandages and liner, and spent or outdated medicines or drugs. They have the ability to affect other living organics, and are considered hazardous
Healthcare risk waste	Infectious waste emanating primarily from hospitals, clinics, surgeries, chemists and sanitary services
IMDG-RSA Code=SABS Code 0228	A code in which over 4000 hazardous substances are listed and assigned a danger group for transport purposes. The Code forms the basis of the present system for classifying Hazardous Waste and is

	being upgraded for waste disposal purposes. In future hazardous substances will be assigned a hazardous rating for waste disposal in the SABS Code 0228
Immobilisation	Immobilisation (or chemical stabilization) is a process in which the waste is converted to a more chemically stable or more insoluble or more immobile form
Industrial Groups	Industrial groups or activities, which are likely to produce a Hazardous Waste
Industrial waste	Hazardous and non-hazardous waste in either a dry or liquid form from industrial and commercial generators
Infectious Substances	Micro-organisms including those which have been genetically modified, pathogens, cells, cell cultures and human endoparasites which have the potential to provoke infection, allergy or toxic effects.
Infectious Waste	Any waste which is generated during the diagnosis, treatment or immunization of humans or animals; in the research pertaining to this; in the manufacturing or testing of biological agents - including blood, blood products and contaminated blood products, cultures, pathological wastes, sharps, human and animal anatomical wastes and isolation wastes that contain or may contain infectious substances.
Integrated Environmental Management (IEM)	A management approach designed to ensure that the environment consequences of development proposals are understood and adequately considered in the planning process
Interested and Affected Parties (IAPs)	Any persons who will be affected in some way by the development of a facility. They may be represented by adjacent residents or farmers, a residential community, the public at large, interest groups, NGOs or local, provincial and national government forums
ISO 14001	Specifies requirements for an environmental management system, to enable an organization to formulate a policy and objectives taking into account legislative requirements and information about significant environmental impacts
ISO 17025	Specifies the general requirements for the competence to carry out tests and/or calibrations, including sampling
ISO 9001	Specifies requirements for a quality management system where an organisation needs to demonstrate its ability to consistently provide product that meets customer and applicable regulatory requirements, and aims to enhance customer satisfaction through the effective application of the system, including processes for continual improvement

	of the system and the assurance of conformity to customer and applicable regulatory requirements
Lagoon	A lined dam constructed to contain liquid waste or effluent.
Lairages	Kraals in which animals are received and penned at an abattoir prior to slaughter.
Landfill gas	A combination of gases that form as a result of the anaerobic decomposition of organic waste in a landfill site.
Landfill site	The area permitted for waste disposal on which landfill cells and other structures required for the safe disposal of waste are constructed
Leachate	An aqueous solution arising when water percolates through decomposing waste and as a result of the biodegradation of the waste. It contains final and intermediate products of decomposition, various solutes and waste residues
Leachate Management	The collection and drainage of leachate to a point where it can be extracted for treatment
Liner	A layer of impermeable material placed beneath a landfill, lagoon or any waste storage site and designed to direct leachate to a collection drain or sump, or to contain leachate
Local authorities	Municipalities, district councils and government institutions who have a mandate to administer laws and by-laws pertaining to specific areas.
Manifest System	A system for documenting and controlling the fate of a Hazardous Waste from cradle-to-grave
MCCSSO	A standard system of soil profiling, which describes the soil in terms of Moisture, Colour, Consistency, Structure, Soil type and Origin
Minimum Requirements	A standard by means of which environmentally acceptable waste disposal practices can be distinguished from environmentally unacceptable waste disposal practices
Minister	The Minister responsible for environmental matters in South Africa.
Monitoring	Continuous or non-continuous measurement of a concentration or other parameters for purpose of assessment or control of environmental quality or exposure and the interpretation of such measurements. The process of checking for changes in status or trends over time. This may be achieved by compiling successive audits or analyses results
MRF	Materials Recovery Facility
MSDS	Materials Safety Data Sheet. It will give you the chemical name and then

	a description how toxic the waste is to humans and to aquatic life. It will give a short description about the physical and chemical properties, what will happen if you come in contact, inhale or ingest the chemical. How to treat it during a fire. How to handle and to store the chemical. What protection to wear. It will tell you how stable and reactive the chemical is and how to transport the chemical.
Neutralisation	To render harmless or less hazardous by the addition of acid or alkali to bring the PH in the region of 7
Norms & Standards	When used in Chapter 5 of NEMA, means any norm or standard contemplated in section 24(10). Norms & Standards are a system of managing activities that require prior authorisation but can be developed for activities where the impacts and mitigation measures are known. Standards are clear, measurable, inflexible rules which provide performance criteria for proactive environmental management. The administrative focus of standards is on monitoring and compliance which is based on the upfront knowledge of impacts and the measurement of specific performance criteria. Compliance with standards should guarantee the absence of significant impacts associated with a development or activity.
Offal	The organs of a slaughtered animal, usually divided into "red offal" (liver, lungs, heart, diaphragm, tongues, tails, spleen, pancreas, brains, testes, clean fat, damasked heads) and "rough offal" (heads (cattle and sheep), stomachs, intestines, hooves (cattle and sheep), caul (amniotic membrane enclosing a fetus) fat; rough offal requires more intensive cleaning.
Offensive odour	Any smell which is considered to be malodorous or a nuisance to a reasonable person.
Organic fertiliser	Fertiliser manufactured from substances of animal or plant origin, or a mixture of such substances, and that is free of any substances that can be harmful to man, animal, plant or the environment containing at least 40g / kg prescribed nutrients.
Organics	Both processed and unprocessed compostable organic waste.
Organic waste	Waste of biological origin which can be broken down, in a reasonable amount of time, into its base compounds by micro-organisms and other living things and/or by other forms of treatment.
Permit Holder	The person who, having obtained a Permit to operate a waste disposal site, in terms of Section 20 (1) of the Environmental Conservation Act, is legally responsible for the site, both during and after closure.

Phreatic Surface	A surface defined by the level at which the ground water will come to rest in a series of boreholes drilled in an area. The surface indicates the level at which the pressure in the ground water is atmospheric
PPE	Personal Protective Equipment. This is any devise or item that is issued to an individual to protect them from a physical, chemical, biological and mechanical hazard
Precautionary Principle	Where a risk is unknown; the assumption of the worst case situation and making provision for such a situation.
Pre-treatment	Pre-Treatment means a form of treatment that takes place prior to the utilisation of the technologies identified that may be required to minimise the risk associated with pathogens, bacteria or prions that could be hazardous to the environment and human health. This can include sterilisation, pasteurisation, UV treatment or any similar process required for a specific period of time.
Putrescible organic waste	Putrescible organic waste means organic matter capable of being decomposed by microorganisms and of such a character and proportion as to cause obnoxious odours and to be capable of attracting or providing food for birds or animals. Often associated with the organic fracture of municipal solid waste.
Recycle	A process where waste is reclaimed for further use, which process involves the separation of waste from a waste stream for further use and the processing of that separated material as a product or raw material
Reduction	Involves various possible measures to reduce the amount of waste generated, e.g. manufacturing process optimisation, or raw material reduction of substitution.
Re-use	To utilise articles from the waste stream again for a similar or different purpose without changing the form or properties of the articles.
Renewable Energy	Energy obtained from a source that is not depleted when used and can be naturally regenerated over a short time scale such as wind, solar, geothermal, tidal energy and biomass, but will also include energy from the decomposition of organic material.
Residue	A substance that is left over after a waste has been treated or destroyed
Risk Assessment	The identification of possible impacts of a waste facility on the environment so that they can be addressed in the design
Sanitary Landfilling	A method of disposing of waste on land without causing nuisances or hazards to public health or safety. Sanitary landfilling uses the principles

	of engineering to confine the waste to the smallest practical area, to reduce it to the smallest practical volume, and to cover it with a layer of earth at the conclusion of each day's operations or at such less frequent intervals as may be acceptable
Solidification	Solidification or cementation is a process in which the waste is converted to an insoluble rock-like material by mixing with suitable materials.
Standard	A measure by which the accuracy of quality of others or degree of excellence is judged, or a model for imitation
Sterilise	Make something free from bacteria or other living micro-organisms
Surface Water	Water (usually rainfall) which flows across the ground surface towards and in man-made and natural drainage features such as drains, rivers, streams, lakes and ponds
Toxic	Poisonous and harmful to health and the environment.
Transporter	Any person who conveys or transfers waste between the waste generator and the waste management facility or between waste management facilities.
Treatment	Any method, technique or process that is designed to change the physical, biological or chemical character or composition of a waste, or remove, separate, concentrate or recover a hazardous or toxic component of a waste; or destroy or reduce the toxicity of a waste.
Waste	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 ruse of for the purpose of production; - That must be treated or disposed of; or - That is identified as a waste by the Minister by notice in the Gazette and includes waste generated by the mining, medical or other sector; but – - A by product is not considered waste; and - Any portion of waste, once re-used, recycled and recovered ceases to be waste.
Waste Disposal	The burial, deposit, discharge, abandoning, dumping, placing or release of any waste into, or onto, any land.
Waste Disposal Facility	Any site or premise used for the accumulation of waste with the purpose of disposing of that waste at that site or on that premise.

Waste Load Allocation	This term refers to volumes of hazardous waste permitted on certain landfills. Such allocations are calculated taking both the nature of the waste and the specific site characteristics into account
Waste Management Activity	Any activity listed in terms of NEM:WA and includes the importation and exportation of waste, the generation of waste, the accumulation and storage of waste, the collecting and handling of waste, the reduction, re-use, recycling and recovery of waste, the trading in waste the transportation of waste, the transfer of waste and the disposal of waste.
Waste Treatment Facility	Any site that is used to accumulate waste for the purpose of storage, recovery, treatment, reprocessing, recycling or sorting of that waste.
Woody plants	Plants that contain lignin that cross-links cellulose, hemicellulose, and pectin components to provide structural support. Plants are considered as having characteristics of wood or are woody when the lignin content is greater than 20%. This includes trees and shrubs as well as some herbaceous plants and bamboo.

TYPES OF FEEDSTOCK

Agriculture:	
Manure	Animal dung or slurry.
Mortalities	Used in relation to agricultural livestock, this refers to animals that have died on site due to natural causes and excludes mortalities due to infectious diseases as identified by DAFF that requires hazardous treatment / intervention. These are specifically animals that have died before intentional slaughter.
Biomass: Lignocellulose (woody)	
Agricultural crop residue	Woody plant material remaining after harvesting, including bark, stalks, roots, leaves, etc.
Invasive plant species	Woody plant species identified as invasive species in terms of the NEM:BA and requiring management actions to remove / destroy. In many instances the material may not remain in situ to prevent ongoing spread and must be removed.
Plantation residue	Branches, bark, stumps and any part of the tree discarded after harvesting has taken place.
Sawmill residue	This includes sawdust, woodchip, bark, planer shavings, and pole shavings that accumulate at milling sites.

Biomass: Low Lignocellulose (non woody)	
Agricultural crop residue	Residue from low lignocellulose crops such as maize, sweet sorghum, groundnuts, soybeans and sunflowers.
Invasive plant species	Non-woody plant species identified as invasive species in terms of the NEM:BA and requiring management actions to remove / destroy. In many instances the material may not remain in situ to prevent ongoing spread and must be removed.
Sugar bagasse	Bagasse is the fibrous matter that remains after sugarcane or sorghum stalks are crushed to extract their juice. It is dry pulpy residue left after the extraction of juice from sugar cane. Bagasse is used as a biofuel and in the manufacture of pulp and building materials.
Processing:	
Abattoir Waste	Abattoir waste can be defined as waste or waste water from an abattoir which could consist of the pollutants such as animal faeces, blood, fat, animal trimmings, paunch content and urine.
Food Oils	Food oils used for human consumption are generally plant oils and extracts and animal fats and oils. Vegetable oils include extracts from olives, palm, soybean, rapeseed / canola, sunflower seed, peanuts, coconuts and avocado to name a few, whilst animal oils include fish oil (omega 3 oil), lard and lanolin. As waste products these are characterised by high salinity, low pH values, high contents in phenol derivates and organic matter and nutrients.
Organic Fraction of Municipal Solid Waste (MSW)	Biodegradable organic waste produced by residential, commercial and industrial activities and disposed of at municipal landfill sites. In 2011, South Africa generated 59 million tons of municipal waste of which 13% was classified as organic waste.
Restaurant Waste	Can be food left overs such as fish, beef cooked or fresh, chicken cooked or fresh, potato fried fresh, vegetable, beans, cake and bread as an mixer or single waste
Food processing	Residues from the processing of agricultural and food products and includes whey, fruit and vegetable pulp, dairy products, wine and beer manufacturing.
Sewage:	
Sludge	Sewage sludge refers to the residual, semi-solid material that is removed and produced as a by-product during the treatment of sewage. There are two basic forms of sewage sludge - raw or primary sludge and secondary sludge, also known as activated sludge or waste activated sludge in the case of the

	activated sludge process. Sewage sludge is usually treated by one or several of the following treatment steps: lime stabilization, thickening, dewatering, drying, anaerobic digestion or composting.

DEFINITIONS OF TECHNOLOGIES

Mechanical:	
Briquetting	A briquette (or briquet) is a compressed block of coal dust or other combustible biomass material such as charcoal, sawdust, wood chips, peat, or paper used for fuel and kindling to start a fire. Biomass briquettes are a biofuel substitute to coal and charcoal.
Centrifuge	A centrifuge is a device, which employs a high rotational speed to separate components of different densities. This becomes relevant in the majority of industrial jobs where solids, liquids and gases are merged into a single mixture and the separation of these different phases is necessary. A decanter centrifuge separates solid materials from liquids in slurry and therefore plays an important role in wastewater treatment, chemical, oil and food processing industries. There are several factors that affect the performance of a decanter centrifuge and some design heuristics to be followed which are dependent upon given applications.
Chipping	Chipping is the process of reducing woody waste to smaller pieces mechanically in order to speed up decomposition of the material. Once chipped, the woody material can be used as mulch, for composting, as a fuel source or even compressed for a slower burning fuel source.
Pelleting	Compressing of organic matter to create a dense, low moisture fuel source. Pellets can be made from industrial waste and co-products, food waste, agricultural residues, energy crops, and virgin lumber.
Sonification	Sonication is the act of applying sound energy to agitate particles in a sample, for various purposes. It can aid mixing and particle dispersal as well as perform cell lysis. The process can generate heat which can result in further thermal processing.
Chemical:	
Chemical hydrolysis	Hydrolysis is a type of decomposition reaction where one reactant is water. Typically, water is used to break chemical bonds in the other reactant.

	Sometimes this addition causes both substance and water molecule to split into two parts. In such reactions, one fragment of the target molecule (or parent molecule) gains a hydrogen ion.
Chemical oxidation	Chemical oxidation is a process involving the transfer of electrons from an oxidising reagent to the chemical species being oxidised. Oxidation chemically converts hazardous contaminants to non-hazardous or less toxic compounds that are more stable, less mobile, and/or inert. The oxidizing agents most commonly used are ozone, hydrogen peroxide, hypochlorites, chlorine, and chlorine dioxide. In water and wastewater engineering, chemical oxidation serves the purpose of converting putrescible pollutant substances to innocuous or stabilised products.
Transesterification	Animal and plant fats and oils are composed of triglycerides, which are esters formed by the reactions of three free fatty acids and the trihydric alcohol, glycerol. In the transesterification process, the alcohol (commonly, methanol) is added to the free fatty acids together with a base that deprotonates the alcohol so that it reacts to form fatty acid methyl ester- the main component of biodiesel.
Saponification	Soaps are sodium or potassium salts of long chain fatty acids. When triglycerides in fat/oil react with aqueous NaOH or KOH, they are converted into soap and glycerol. This is called alkaline hydrolysis of esters. Since this reaction leads to the formation of soap, it is called the Saponification process.
Anaerobic:	
Anaerobic digestion	Anaerobic fermentation is a process that causes the breakdown of organic compounds without the presence of oxygen. This process reduces nitrogen to organic acids and ammonia. Carbon from organic compounds is released mainly as methane gas (CH4). A small portion of carbon may be respired as CO_2. The decomposition technique occurring here is used in composting. The decomposition occurs as four stages namely: hydrolysis, acidogenesis, acetogenesis, and methanogenesis.
Aerobic:	
Aerobic digestion	Aerobic digestion is a process typically used in sewage treatment designed to reduce the volume of sewage sludge and make it suitable for subsequent use. The technology can also be applied to other organic wastes; such as food, cardboard and horticultural waste. It is a microbial process occurring in the presence of oxygen. Microbes rapidly consume organic matter and convert it into carbon dioxide, water and a range of lower molecular weight organic compounds. It is an important part of the process in composting and,

	when carried out optimally can generate sufficient heat to aid in destruction of pathogens (harmful bacteria and pathogens).
Black fly larvae	Valorisation of municipal organic waste through larval feeding activity of the black soldier fly, *Hermetia illucens* provides waste reduction and stabilisation while providing a product in form of the last larval stage, the so-called prepupae, which offers a valuable additive in animal feed.
Composting	A controlled biological process in which organic materials are broken down by micro-organisms in the presence of oxygen.
Vermicomposting	Vermicompost (or vermi-compost) is the product of the composting process using various species of worms, usually red wigglers, white worms, and other earthworms, to create a heterogeneous mixture of decomposing vegetable or food waste, bedding materials, and vermicast. This process of producing vermicompost is called vermicomposting.
Thermal:	
Aqueous phase reforming	The reaction of biomass-derived oxygenated compounds (e.g. glycerol) in aqueous solution at low temperature in the presence of a platinum catalyst to produce hydrogen and light alkanes. Aqueous oxygenated hydrocarbons are reformed at low temperatures (200–250 °C) and high pressures (1.5–5 MPa).
Combustion	Combustion is a thermal process that produces heat and light energy from fire. Combustion occurs at high temperatures (generally above 1200˚C) when a fuel is oxidised and for complete combustion sufficient aeration is needed to provide an excess of oxygen. For example, when wood burns, oxygen in the air joins with carbon in wood and the carbon is oxidised to carbon-dioxide, leaving only minerals in the ash.
Drying	Application of heat to evaporate water from biosolids. Either direct or indirect heating methods are used. In the most common case, a gas stream, e.g., air, applies the heat by convection and carries away the vapor as humidity. Other possibilities are vacuum drying, where heat is supplied by conduction or radiation (or microwaves), while the vapor thus produced is removed by the vacuum system. Another indirect technique is drum drying (used, for instance, for manufacturing potato flakes), where a heated surface is used to provide the energy, and aspirators draw the vapor outside the room. In contrast, the mechanical extraction of the solvent, e.g., water, by centrifugation, is not considered "drying" but rather "draining".
Gasification	Gasification is a thermal process that converts fuel into energy rich gases; such as carbon monoxide, hydrogen (synthesis gas or syngas). This is achieved by reacting the material at moderate temperatures (>700 °C), with a limited and controlled amount of oxygen and/or steam.

	The syngas can be burned to produce electricity or further processed to manufacture chemicals, fertilizers, liquid fuels, substitute natural gas (SNG), or hydrogen.
Hydrothermal Carbonization (HTC)	HTC is a thermochemical process for the conversion of organic compounds to structured carbons. It can be used to reduce the water content from the digestate / fertilizer and convert the solid fraction into "green coal" or brown coal formation (coalification). Typical hydrothermal carbonization conditions are 180oC and 1 MPa of pressure.
Hydrothermal Liquefaction (HTL)	Hydrothermal liquefaction of biomass is the thermochemical conversion of biomass into liquid fuels by processing in a hot, pressurized water environment for sufficient time to break down the solid biopolymeric structure to mainly liquid components. Typical hydrothermal processing conditions are 125˚C–374˚C of temperature and operating pressures from 4 to 22 MPa of pressure.
Pressure heating	Mechanism using heat and pressure to improve char and lighter gases in biomass.
Pyrolysis	Pyrolysis is a thermal process that decomposes of organic material at in the absence of oxygen at temperatures of 300-600oC. It involves the simultaneous change of chemical composition and physical phase, and is derived from the Greek word for "fire separating". Pyrolysis is also known as thermal cracking, cracking, thermolysis, depolymerization, etc.
Rendering	Rendering is a thermal process that converts waste animal tissue into stable, value-added materials. The rendering process simultaneously dries the material and separates the fat from the bone and protein. A rendering process yields a fat commodity (yellow grease, choice white grease, bleachable fancy tallow, etc.) and a protein meal (meat and bone meal, poultry byproduct meal, etc.). Rendering plants often also handle other materials, such as slaughterhouse blood, feathers and hair, but do so using processes distinct from true rendering
Torrefaction	Torrefaction is a thermal process to convert biomass into a more coal-like material through light roast at 200-300˚C, giving it better fuel characteristics than the original biomass. Torrefied biomass is more brittle, making grinding easier and less energy intensive.