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TNO 2022 P10362

Development of a waste stream-specific roadmap for the circular economy of Zimbabwe

Sub report Output 4

Date 6 April 2022

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Executive summary

In this activity technical, policy and market options and potential for circular handling of the prioritized waste stream, plastic waste, are analysed.

Technological pathways
There are several technological pathways of which 4 are discussed as relevant: (1) Composting, (2) Anaerobic digestion, (3) Solid fuel production (e.g. briquettes), and (4) Animal feed production (e.g. black soldier flies). Composting is an anaerobic process and depending on the time and effort you take for it, the quality can deviate largely. A specific type of composting is vermicomposting, in which earthworms are used to convert biomass to compost. Composting gives medium costs and medium revenues. The quality of compost can be increased by conducting a fertilization process on the compost to make organic fertilizer. The value of this product is much higher than of compost. Anaerobic digestion is a process in which bacteria breakdown organic waste and turn it into biogas. Both smaller and larger scale options are available. Often, small scale digestors use biogas directly via pipelines or it is stored for later use in unpressurized containers. Larger scale digestors generally turn to the upgrading of the biogas to natural gas. Another option is the conversion of biogas into electricity that can be used on the grid or a direct outlet such as a hospital. Anaerobic digestion has quite high costs, but the revenues are considerable. A third option is to convert low density biomass into high density and energy concentrated solid fuel outlets that can be used as a substitution of firewood for example. Often, these solid fuels are processed into briquettes. The costs for this are very low, while it is possible to receive some revenue. Option 4 is the conversion of the biomass into animal feed, generally by using insects or larvae. The larvae can be sold on the market and the residue can be further converted into compost, fertilizer or used in a biogas digester. The costs for this option are medium, the revenue is considerable. Combinations between the technological pathways is also possible and gives important valorization options. However, the countries still faces some challenges to handle organic waste in such a way, therefore designing a proper landfill with gas recovery is also important.

Policy landscape
Zimbabwe has good policies, strategic plans and pieces of legislation on waste management in general. However, the country does not have a circular economy policy, circular economy strategy or legislation. The existing policies hardly address a circular handling of organic waste, and are mainly focused on collection infrastructure or waste-to-energy solutions. There seems to be a mismatch between what the existing policies envision and the resources allocated to implementation. Additionally, most regulations seem to be focused on punishment of non-compliance and there is no mention of incentives to stimulate organic waste valorization as of yet.

Market and value chain analysis
Currently organic waste is almost always collected unseparated and ends up at (illegal) disposal sites. Preventing this waste to go to landfills and early separation give huge potential in valorization of organic household waste. Thus, better separation, collection and transport logistics are essential to scale the market for organic processing within Zimbabwe. A better understanding of the market and value chain is given for 2 out of the 4 technological pathways: composting and anaerobic digestion. The other 2 technologies are only sporadically used in the country and thus a market assessment of these is premature. For compost, the high cost of chemical fertilizer and a growing movement to prevent soil depletion is stimulating both organic fertilizer and compost. Additionally, high fuel, coal and electricity prices also increase the potential for biogas use. A challenge is that biodigesters are commonly used for human and animal manure and thus not on household organics. Meaning that innovation is needed to develop processes to make high quality biogas from organic household waste. Both technological pathways can be implemented in different scales: household level, community level and commercial level. Commercial level allows to benefit from economies of scale, however it also requires high volumes of waste and thus proper collection and separation. Although collection and separation is also key for

community level operations, the volumes do not have to be that high. Composting can quite easily be done at household level, it only requires a composting bin, some space and an outlet (e.g. a (communal) garden). A biodigester on household level is more difficult, since it requires to buy a quite expensive biodigester and equipment that resonates with biogas (e.g. cooking stoves) are needed. Two main challenges are foreseen; getting sufficient volumes in an economic manner; dealing with the low margins on products from household organics.

List of abbreviations

AD = Anaerobic digestion

BSF = Black soldier flies

CAPEX = Capital expenditure

CHP= Combined heat and power

CO_2 = Carbon dioxide

EIA = Environmental impact assessment

EMA = Environmental Management Agency

EPR = Extended producer responsibility

LCA = Life Cycle Assessment

LHV = lower heating value

OPEX = Operating expenditure

PPP = Public provide partnership

SI = Statutory Instrument

UOW = Urban organic waste

ZOPPA = Zimbabwe Organic Producers and Promoters Association

Contents

1 Introduction

This document is the deliverable of Activity 4 of the CTCN Technical Assistance study on circular economy in waste management in Zimbabwe. During this study, a baseline assessment for the current waste system was conducted, looking at plastics, paper, metal, glass, household organic waste and (small scale) agricultural waste. This was followed by a comparative analysis per waste stream on the potential to move towards higher levels of circularity. After a physical stakeholder consultation in Harare, October 2021 the choice was made to focus on organic waste for the remainder of the project. Following this specification, a more detailed analysis was conducted on the current status of the organic waste management system in Zimbabwe, looking at technology use, the policy and regulatory landscape and current markets and value chains on organic (waste) management. The results of this assessment are presented in the following chapters.

2 Technology pathways (activity 4.1)

2.1 Introduction

There are myriad technological pathways for the valorisation of solid urban organic waste (UOW). This section will provide a generic overview of several of the most important pathways that are relevant for the country of Zimbabwe. Technologically very immature or advanced pathways such as the chemical conversion of food waste into organic building blocks are not included in this assessment, as these are not deemed realistic to be implemented in the near future. Instead, this part focusses on four different pathways that could be a potential fit with the Zimbabwean context. These pathways are:

(1) Composting
(2) Anaerobic digestion
(3) Solid fuel production (e.g. briquettes)
(4) Animal feed production (e.g. black soldier flies)

For each of these pathways, a generic overview is given on the process, the different scales at which this can be implemented, and the key requirements to implementation.

2.2 Pathways

2.2.1 Composting

Composting is an **aerobic processing method** - this means that it requires the presence of air to decompose organic solid wastes. The results of the decomposition is a humus-like material known as compost. It can also generate liquid fertilizer[1].

Composting can be done on a very wide range of scales, ranging from very small composting bins at households for use in private gardens for example, to commercially operating composting plants that process the waste of a million households and more. The focus of this project is on composting from community to commercial level, and does not aim at household composting specifically.

Figure 1 provides a schematic overview of the process steps included in commercial scale composting. As with any technological pathway, the first step is the collection of the waste. In order to be able to process organic waste into compost, separation at source is quite critical to avoid the contamination of the waste with other streams such as plastics and metals. However, in Zimbabwe the separate collection of organic waste is currently largely inexistent, and thus something that has to be set up as a prerequisite for commercial composting.

1 Composting - water, environmental, pollutants, United States, history, types, soil, pesticide, industrial, sources, use, Process of Composting, Composting Techniques (pollutionissues.com)

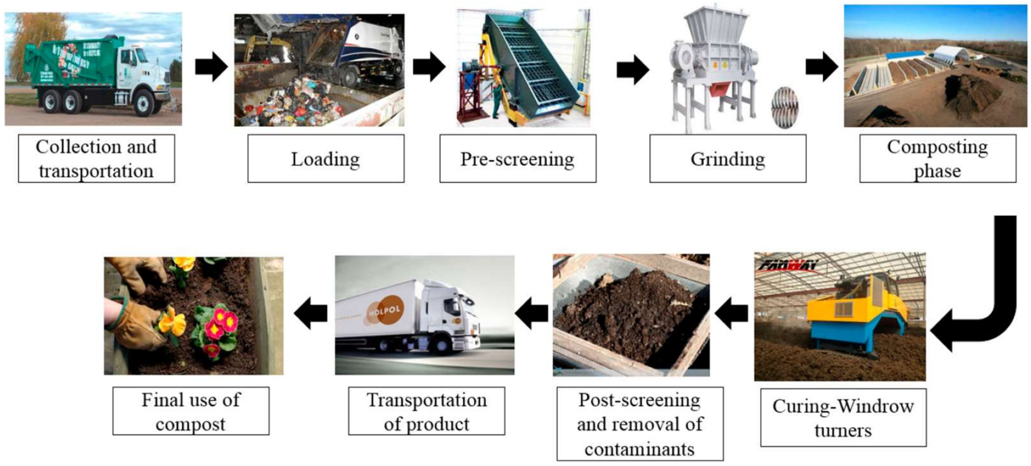

Figure 1. Commercial scale composting process[2]

Overall, composting requires the following processing steps after the waste has received the processing location:

1. Pre-screening and cleaning, reducing the amount of contamination of the waste by removing potential non-organics such as plastics or metal, or very slow decomposing components such as wood.
2. Grinding/ mixing, to allow for a fairly equal consistency of the waste, leading to equal processing times.
3. Composting. Often, composting facilities have multiple ‘chambers’ to store the compost of various timespans (Windrows, as in Figure 1). There are also different settings in which the compost is stored in a controlled drum (in-vessel composting) or in a static pile. Composting can take as less as three weeks to over a year, but generally commercial processes take three to six months[3].
4. Addition of air. If no air is added, the process becomes *anaerobic* and gases start to form, which is to be avoided in composting. In Windrow facilities, turners are used to turn and aerate the waste. In-vessel installations use mechanical mixing, statis aerated piles use for example tubes that blow in air, or add wood chips or other bulking materials that allow air to pass through.
5. Post-screening or sieving of the waste to remove any remaining contaminants.

At smaller scales, many of the steps that are presented in the figure as mechanical can be done manually. The pre-screening, turning and sieving are all steps that are often also done by manual labour. Sometimes, pre-screening is limited to only very large contaminants, and the compost is only cleaned properly at the post-treatment stage (see Figure 2).

Composting can be done at various quality levels. Higher quality compost generally demands more extensive pre and post treatment, more frequent turning, as well as longer durations[4].

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[2] Al-Rumaihi, A., McKay, G., Mackey, H. R., & Al-Ansari, T. (2020). Environmental impact assessment of food waste management using two composting techniques. *Sustainability*, *12*(4), 1595.

[3] Industrial Composting: What It Is and How It Works (urthpact.com) ; Renkow, M., Safley, C., & Chaffin, J. (1994). A cost analysis of municipal yard trimmings composting. *Compost Science & Utilization*, *2*(2), 22-34.

[4] Komilis, D., & Ham, R. K. (2000). Life cycle inventory and cost model for mixed municipal and yard waste composting. *North Carolina, USA*, 72.; Renkow, M., Safley, C., & Chaffin, J. (1994). A cost analysis of municipal yard trimmings composting. *Compost Science & Utilization*, *2*(2), 22-34.

The necessary quality can be determined based on the desired outlet. To be able to sell compost on the agricultural market for example, it is generally necessary to produce high quality compost.

Figure 2. Example of a small scale composting facility that does little pre-treatment (Malawi, 2021, own picture taken in Malawi)

2.2.2 Fertilizer

A second product that can be made from organic waste which starts with a similar process to compost production is fertilizer production. The difference between compost and fertilizer is very broadly put that compost feeds the soil while fertilizer feeds the plants. In terms of processing this means that after first composting, to produce fertilizer it is required to add additional organic nutrients as to boost the nutrient content. In addition, fertilizer production asks for additional drying and cooling and in some cases the import of additional nutrients. To have optimal quality, organic fertilizer must contain a percentage of moisture. If the fertilizer is too moist, then this reduces the quality and effectiveness of the fertilizer.

2.2.3 Vermicomposting

A specific type of composting is vermicomposting, which makes use of earthworms to convert the biomass into compost. Compared to traditional composting, vermicomposting accelerates the conversion process by two to five times and thereby greatly speeds up the conversion of wastes into valuable biofertilizer[5]. Vermicomposting does require a more narrow temperature range (25–40 °C) compared to composting, as well as a neutral pH and high humidity (70–90 percent) to sustain a large population of worms. This makes the process somewhat more complex that conventional composting and less applicable for industrial scales[6].

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5 Bhat, S. A., Singh, J., & Vig, A. P. (2018). Earthworms as organic waste managers and biofertilizer producers. *Waste and biomass valorisation*, *9*(7), 1073-1086.

6 Fornes, F., Mendoza-Hernández, D., García-de-la-Fuente, R., Abad, M., & Belda, R. M. (2012). Composting versus vermicomposting: a comparative study of organic matter evolution through straight and combined processes. *Bioresource technology*, *118*, 296-305.

2.2.4 Anaerobic digestion

Anaerobic digestion (AD) is a process through which bacteria break down organic matter into biogas. As the bacteria decompose the organic material, they release gases that can be harnessed as green gas or biogas. A by-product of biogas production can be fertilizer (from the digestate, which are the decomposed solids remaining in the digester) [7]. Food waste is a very suitable feedstock for anaerobic digestion as it generally gives a high yield compared to for example animal waste (which has already been 'preprocessed')[8].

As can been seen in Figure 3 (a very simplified overview of the biogas process), anaerobic digestion can be done with a broader range of organic waste streams than only UOW. Agriculture waste, manure, or sludge are all also suitable streams. Also for anaerobic digestion, pretreatment is generally the first step, to reduce the contamination with non-organics and to ensure the consistency of the feedstock is relatively equal for easier digestion. Then the input goes into the digestor, and depending on the temperature and type, the duration can differ. Approximate time periods range from 5-90 days, more commonly 10-30 days, depending on the makeup of the feedstock and type of anaerobic digester[9]. After this time biogas is produced. The methane content of biogas typically ranges from 45% to 75% by volume, with most of the remainder being CO_2. This variation means that the energy content of biogas can vary; the lower heating value (LHV) is between 16 megajoules per cubic meter (MJ/m^3) and 28 MJ/m^3 [10].

Biogas can be used directly as energy source for cooking, which requires it to be either compressed into containers, so it becomes transportable. Another option is to connect the digester directly to the consumption facility, such as a school or a mall. As the pressure of biogas is very low, transportation over long distances is not possible, so the outlet should be close by.

Smaller scale digestors generally produce biogas that is either used directly or compressed into containers. Larger scale installations generally turn to the upgrading into natural gas (a process that removes any CO_2 and other contaminants present in the biogas) to put this into the gas network, to subsequently distribute the gas to households (see Figure 3). Biomethane has an LHV of around 36 MJ/m^3. It is indistinguishable from natural gas and so can be used without the need for any changes in transmission and distribution infrastructure or end-user equipment, and is fully compatible for use in natural gas vehicles. To be able to implement this solution the presence of a gas grid is required[11].

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[7] Biogas, Green Gas, or Biomethane? Explained (selectra.com)
[8] International Energy Agency 2020 Outlook for biogas and biomethane: Prospects for organic growth
[9] Cogeneration | Inoplex
[10] International Energy Agency 2020 Outlook for biogas and biomethane: Prospects for organic growth
[11] International Energy Agency 2020 Outlook for biogas and biomethane: Prospects for organic growth

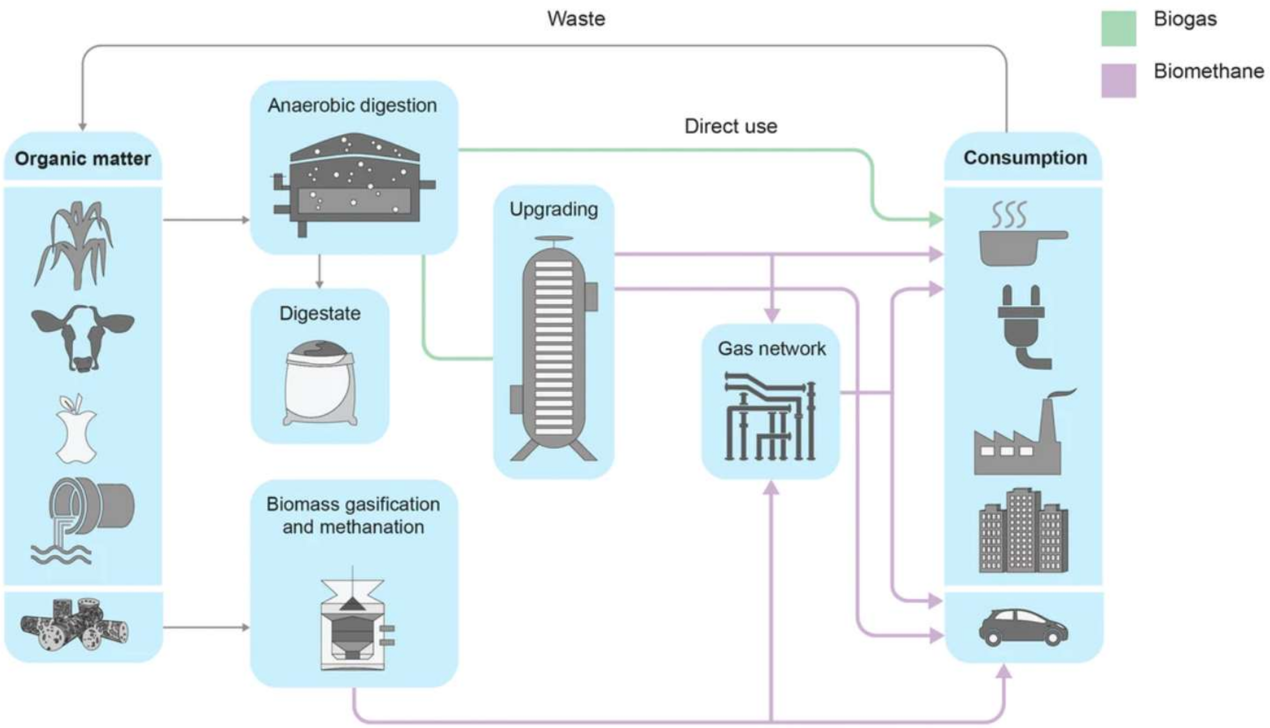
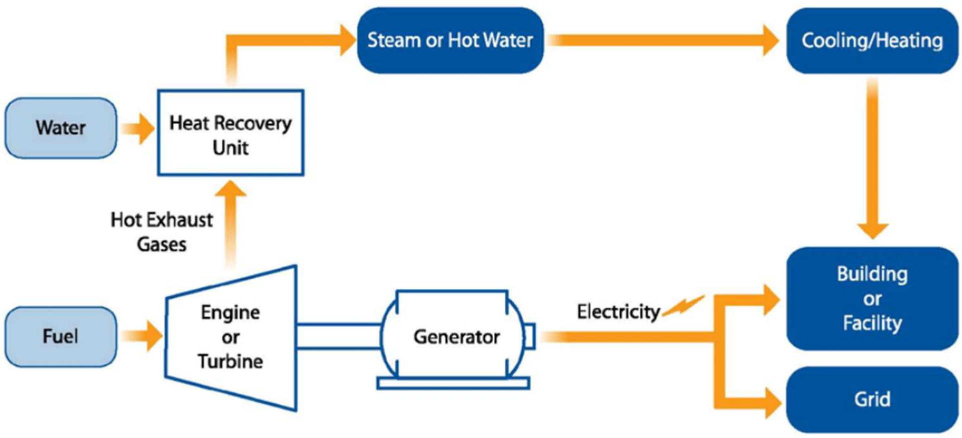


Figure 3. General process flow anaerobic digestion to biogas or biomethane (International Energy Agency, 2020)

2.2.5 Anaerobic digestion to electricity

A subsequent step that can be taken after the production of the biogas is the conversion of biogas into electricity by using a gas motor, generally a combined heat and power motor (abbreviated as CHP), which uses an engine that runs on a single fuel (see
Figure 4). It is possible to use biogas as this fuel. CHP systems burn biogas to turn generators which then produce electricity, and use heat recovery devices to capture the heat from the turbine. The electricity produced can then be connected to a direct outlet such as a mall or a hospital, or the electricity grid. This heat is usually converted into steam or hot water [12]. These kinds of biogas/ CHP installations are already possible at relatively small scales (<400 kgs of waste per day) (e.g. the Waste Transformers[13]).



[12] What Is CHP? | US EPA
[13] The Waste Transformers | Turning organic (food) waste into value on-site

Figure 4. Process flow of fuel (in this case biogas) to electricity using a gas motor (US EPA, 2021)

2.2.6 Compost and biogas combinations

Another option which is quite common is a combination of composting and AD (see Figure 5). This means the use of both a digestor as well as a dedicated composting facility in one. A part of the feedstock is provided to the digester, a part to the composting area. The digestate of the biogas production can subsequently be added to the composter to increase the compost generated.

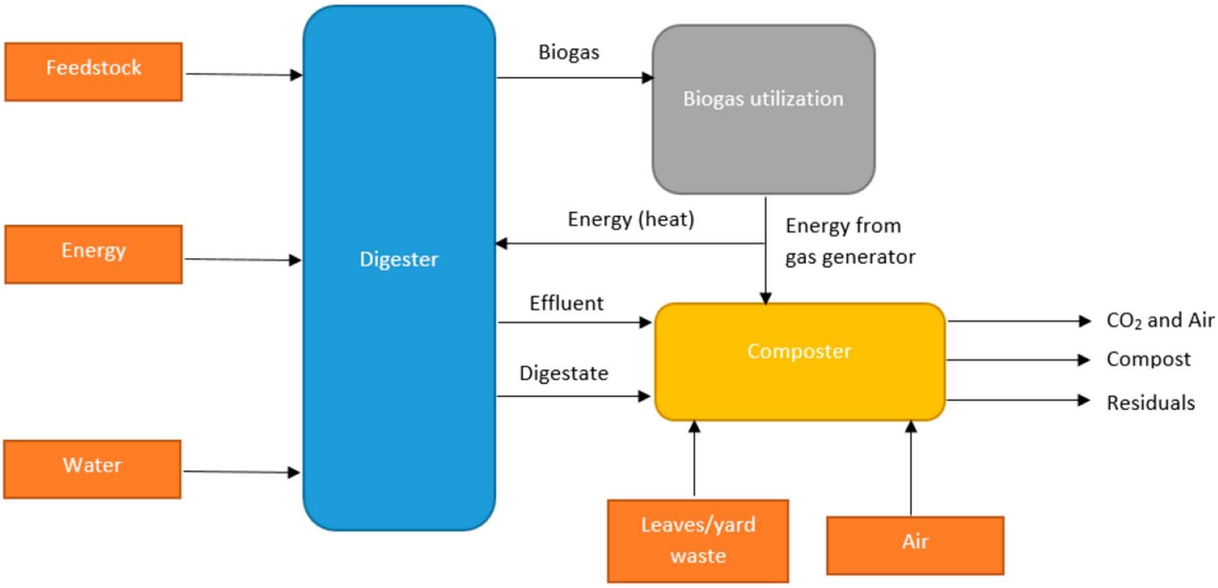


Figure 5. Integrated anaerobic digestion and composting (Al-Rumaihi, A., McKay, G., Mackey, H. R., & Al-Ansari, T. (2020). Environmental impact assessment of food waste management using two composting techniques. *Sustainability*, *12*(4), 1595.)

2.2.7 Solid fuel production

A third option is to convert low density biomass into high density and energy concentrated solid fuel outlets that can be used as a substitution of firewood for example[14]. Often, these solid fuels are processed into briquettes. The biomass briquetting process can be done in relatively rudimentary manners, and generally entails the following steps (see Figure 6):

After collection, the feedstock is either sun dried or dried using heat and smoke to remove any moisture. In some cases the input materials will have to be pre-treated to reduce the size, which can be done by hand or mechanically. Subsequently, the dried materials are 'carbonised' (slow burned) in a drum, which results in a char product that is the basis of the briquette. Lastly, the char is mixed with a filler (often sand like material) and a binder (frequently a starch water). The mixture can then be shaped, which can be done manually, or by using a press machine. Presses range from simple hand operated machines that cost $100 to large industrial plants that can produce thousands of kilograms of briquettes per hour[15].

[14] Briquetting - an overview | ScienceDirect Topics
[15] Living Earth (2013), Biomass Briquettes Infosheet

Figure 6. Manual briquetting process (Living Earth, 2013)

2.2.8 Animal feed production

The fourth pathway that is applicable to the valorisation of UOW in Zimbabwe is the conversion of the biomass into animal feed, generally by using insects or larvae. A route that is increasingly popular is the use of black soldier fly larvae. Figure 6 provides an overview as presented by the Swiss Federal Institute of Aquatic Science and Technology[16]:

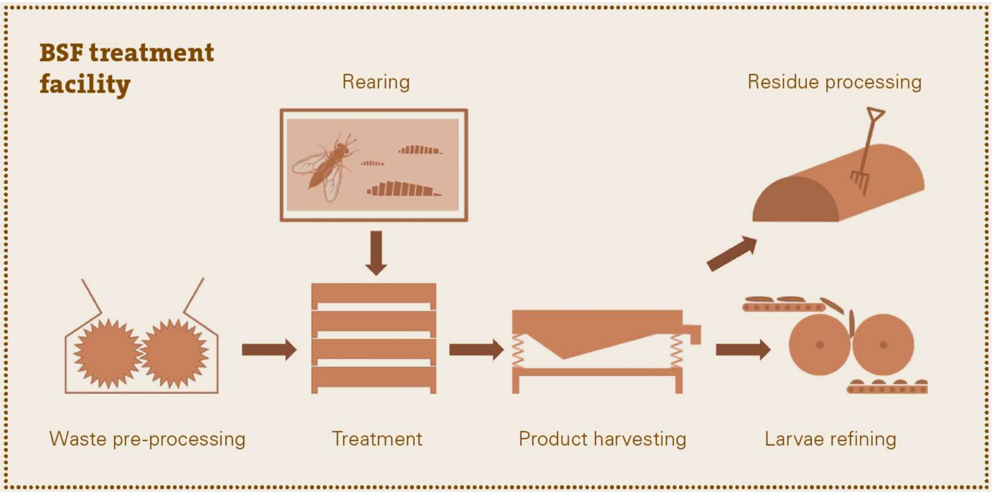


Figure 7. Black soldier fly larvae treatment process (Eawag, 2017)

The pretreatment steps of the biowaste are similar here as for many of the other pathways and require decontamination, grinding and sizing, and if necessary dewatering. After pre-treatment, the larvae are being put in the waste to feed and to grow into larger larvae, while processing the waste. Right before hatching, the larvae are removed and generally frozen or dried, and the larvae product can be further refined to meet market demand. The residue can be converted into compost or fertilizer or fed into a biogas digester.

[16] Eawag – Swiss Federal Institute of Science and Technology (2017), Black Soldier Fly Biowaste Processing, a Step-by-Step Guide

2.2.9 Combining pathways

The various technological pathways are now mainly presented as separate directions, with some suggestions for combinations given. However, it is of course possible to combine these pathways in various ways. In addition, it is very unlike that one pathway will be able to process all available UOW in Zimbabwe. Hence, it is valuable to pursue a combination of strategies within the country as a whole, critically looking at which geographical regions fit which (combination of) pathway(s) best.

2.2.10 'Base-pathway': Landfilling (with gas recovery)

The four pathways presented in the previous sections provide the key directions relevant to the valorisation of urban organic waste in Zimbabwe. However, due to the current challenges with collection and separation infrastructure as well as financial constraints, it will not be possible to convert a 100% of the biowaste of Zimbabwe into valuable outputs within a few years. To enable proper management of those parts of the waste streams that cannot yet be properly valorized, it is important to also design suitable and effective waste management solution in the form of an engineered landfill, which allows for the proper dumping of waste in a manner that avoids leakage of contaminants into the ground. In the ideal situation, landfills are designed in such a way that they include opportunities for gas capture, as landfills without gas capture release huge amounts of methane into air as organic material decomposes. Landfills with gas capture systems could harvest these gases to produce biogas or even conversion into electricity, as shown in the example in Figure 8[17].

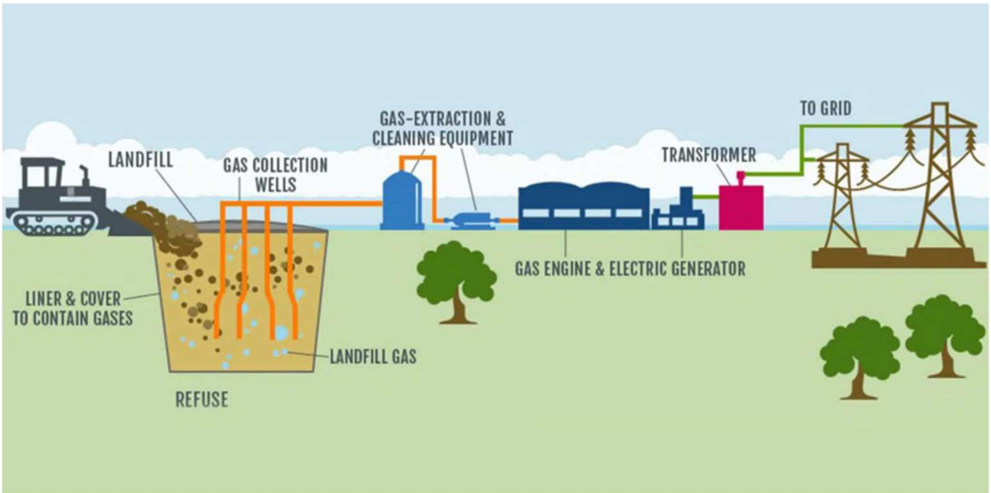


Figure 8. Landfill with gas capture and electricity conversion (KTS Engineering)

2.3 Application of pathways in the rest of the world

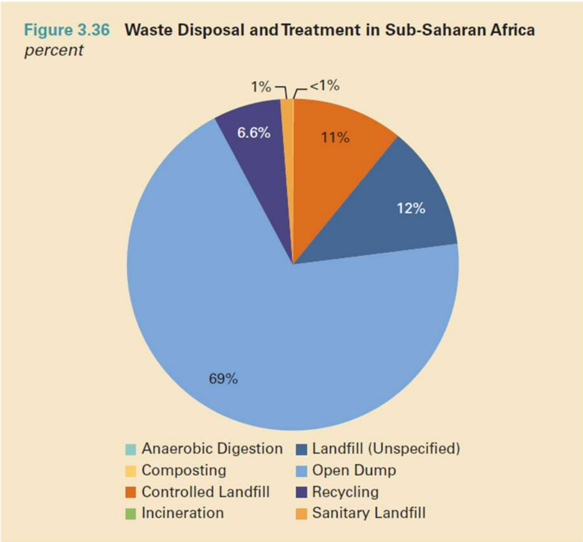
When looking to the application of conversion technologies in other places in the world, it shows that the two most common pathways outside of the global south are composting and AD. In Europe, composting comprises about 53% of the total solid organic waste valorised, while biogas processes about 47% (overall it can be seen that most countries have a preference for either one of the two, but total of the European countries balances out to an almost equal distribution)[18]. Yet the What a Waste Study of 2020[19] shows that when including Central Asia, composting comprises a much larger share

[17] Landfill gas | Biogas from garbage ▶ KTS Engineering® (kts-eng.com)

[18] Brusselaers, J., & Van Der Linden, A. (2020). Bio-waste in Europe—turning challenges into opportunities, European Environment Agency.

[19] Kaza, S., Yao, L., Bhada-Tata, P., & Van Woerden, F. (2018). *What a waste 2.0: a global snapshot of solid waste management to 2050.* World Bank Publications.

of the total waste processing than AD. For Sub-Saharan Africa, composting and AD comprises only a very small share of the total waste processed at all, which can be explained due to the low levels of infrastructure for separate collection of organic waste.



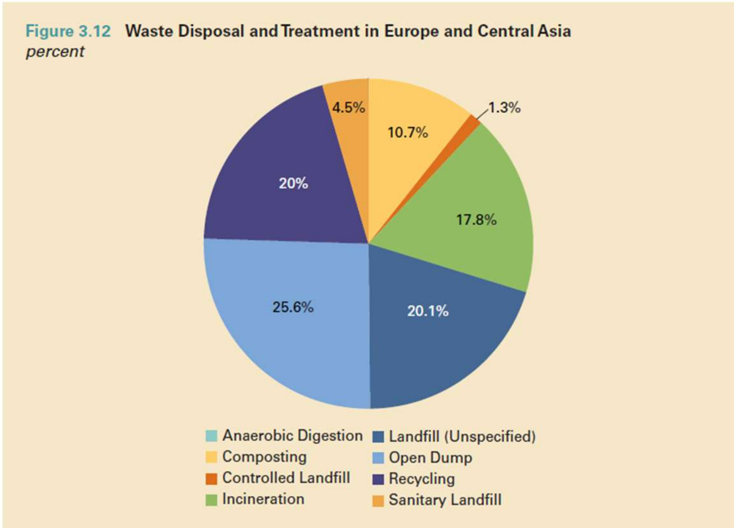


Figure 9. Figures from the What a Waste Study on total waste disposal and treatment in SSA and Europe and Central Asia (What a Waste 2020)

Briquetting and animal feed production are mainly found in the Global South. Briquetting is currently mainly done with agricultural and forestry waste, and not so much with UOW yet[20]. Black Soldier Flies particularly are a rapidly growing field in countries in the South, as these facilitate the right climate conditions for the cultivation of these larvae[21].

2.4 Application of pathways in Zimbabwe

When looking at the application of pathways in Zimbabwe it can be seen that UOW processing technologies are currently relatively immature, with little initiatives beyond the pilot scale. Most activities can be found on the production of biogas. Overview of activity per pathway:

Composting

Composting mainly takes place at farm level for subsistence fertilizer production. Moreover, there is some home composting in the higher income areas, as well as a few small scale pilots at for example Waste Transfer Stations, where the organic waste that is collected is separated and used for composting. Lastly, there is one entrepreneur working with vermicomposting, which also takes place at relatively small scales. There are only two commercially scaled composting facilities in the country, but these do not yet include UOW but mainly animal wastes.

In terms of technology development for composting equipment, the study showed there is only equipment production for earthworm vermicomposting (see box). In terms of equipment such as turners or grinders for larger scale composting, Zimbabwe remains dependent on imports as no domestic production was found.

[20] Global Biomass Briquette Market Forecast to 2027- COVID-19 Impact Size, Share: Ken Research

[21] Eawag – Swiss Federal Institute of Science and Technology (2017), Black Soldier Fly Biowaste Processing, a Step-by-Step Guide

Zimbabwe Earthworm Farms
Producer of biofertilizer using the earthworm technology (Vermicompost). They also produce Nutrich Refinded Compost, Nutrich Vermicompost, and Nutrich Foliar Vermi Biofertilizer. They use the JAIT composter. The cost of installing a JATI compost to produce vermicompost at the household level is US$250 and US$400 for JATI 4 compartments and JATI 6 compartments respectively. Zimbabwe Earthworm Farms also constructs community JATI composts as big as 50-100 m^2 at a cost of US$8000. Approximately 10-15 tons of compost fertilizer can be harvest from JATI compost per month.

Anaerobic digestion
Current technologies for UOW conversion into biogas exist mainly on household level biogas production (see the boxes for an example).

Bio-Energy Kits
Greentec Energy developed bio-energy kits for use by urban households generating small volumes of food wastes at a time. The kit can process household organic waste and can produce biogas for onsite use. The 1m^3 bioenergy kit costs approximately US$650.00. The cost can be reduced if a customer or owner sources some of the basic materials themselves e.g., sand, gravel and bricks.

Case Study: Zonful Energy (Pay as you Go Biogas)

Zonful Energy (Pay as you Go Biogas) is start-up to promote the use of biogas energy. 93% of Zimbabwe population use traditional biomass (firewood and charcoal) for cooking. These not only affect the environment (high rate of deforestation) but also smoke from the wood affects health and cause death. Women and young girls spend several hours collecting firewood thus depriving opportunity to do more productive activities and studying respectively.
Zimbabwe has potential for biogas production from rural farm waste and livestock waste. High capital needed for constructing digesters and lack of technical skills have been the limiting factor for scaling up biogas. Zonful Energy has found solution which eliminates the two limitations. We use Assembly biogas digesters and install for rural farmers and communities who pay back monthly through their mobile money until when they can fully own the digester.
The company connects with assembly biogas digester manufacturers and then help customers to find value of digesters.
The prefabricated digester needs cow dung from 2 livestock or 6 kgs of organic matter to produce biogas to cook 3 meals a day. The company has piloted with 500 households to date. The prefabricated digester comes with a single burner biogas stove and costs 700 USD over 36 months.
Source: William Ponela, Zonful Energy, December 2021.

Moreover, in Zimbabwe the Zimbabwe Domestic Biogas Programme ran from 2013 to 2015 and thereafter. The programme focused on household sized digesters of 6 cum to 20 cum in rural areas in Zimbabwe, and used mainly cow dung and some pig dung. The programme also conducted feasibility studies for municipal biogas plants for Bulawayo City Council at their sewage waste treatment plants. However, within these initiatives there was no focus on UOW. Up until this moment, there is no conversion of UOW through AD yet. In terms of technology development, there is domestic development of biogas equipment for household level digestion. Larger scale fixed domes are also developed domestically. There is currently no bottling of gas into containers (for sales/ easy transport).

Bariquetting
There are initiatives regarding briquetting that are using agricultural waste, all operating on small scales. No initiatives that process UOW into briquettes were discovered.

Animal protein
There are currently several Black Soldier Fly (BSF) entrepreneurs in Zimbabwe, for example in Kwekwe[22]. All initiatives are small scale.

2.5 Economic background

Although this study does not include a detailed economic assessments of the given pathways, it is possible and relevant to provide a generic comparison in terms of capital and operational expenditure per pathway, to get an idea of how these conversion routes compare. Of course, costs differ greatly depending on the scale on which the pathway is implemented. Overall, the investment and operational costs for briquettes and BSF can be relatively low. BSF can require quite some energy costs when the larvae are frozen, requiring freezers. Yet, in comparison to AD and in some cases composting, both are low capital solutions.

It is thus worthwhile to compare composting and AD particularly on medium to large scales. At small (household) or small to medium scales (commercial yet manual), composting is always far less financially demanding as all steps can be implemented manually and little labour and machinery is required. Also on larger scales, multiple studies indicate that generally the economics for composting is more positive compared to AD[23]. For AD, the necessary equipment makes the required capital costs always relatively high per unit of energy produced, see Figure 10 from the study of the International Energy Agency on Biogas and Biomethane (2020)[24]. Yet, it is relevant to note that the figure also shows that for AD there is quite some improvement to be achieved in terms of economy of scale, with capex and opex decreasing with increasing size of the digester.

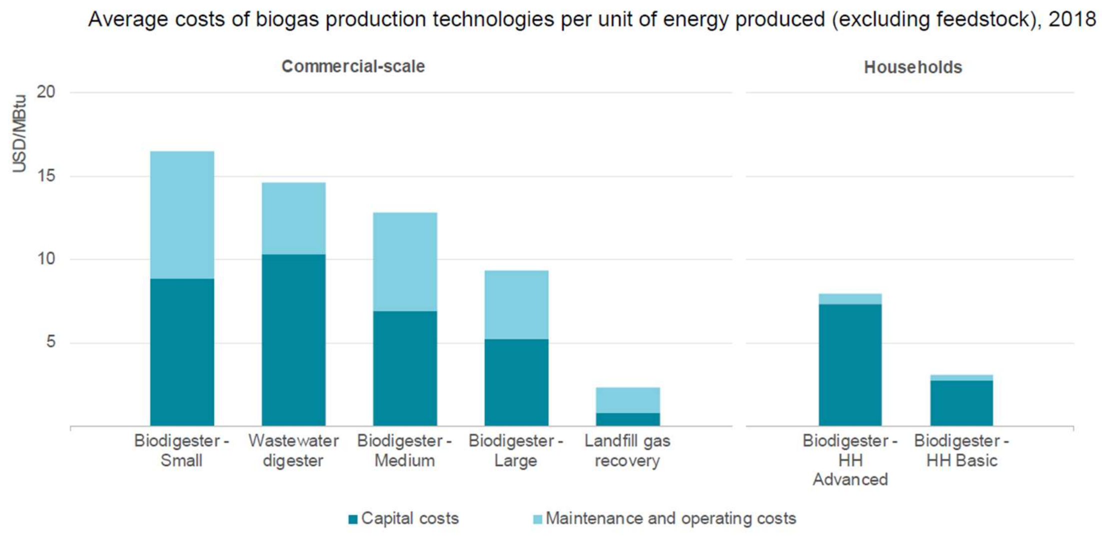


Figure 10. Average costs of biogas production technologies per unit of energy produced in 2018 (IEA, 2020)

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22 Zimbabwe: Maggots Help Rural Villagers Put Food On the Table - allAfrica.com

23 Zulkepli, N. E., Muis, Z. A., Mahmood, N. A. N., Hashim, H., & Ho, W. S. (2017). Cost benefit analysis of composting and anaerobic digestion in a community: a review. *Chemical Engineering Transactions*, *56*, 1777-1782.; Murphy, J. D., & Power, N. M. (2006). A technical, economic and environmental comparison of composting and anaerobic digestion of biodegradable municipal waste. *Journal of Environmental Science and Health Part A*, *41*(5), 865-879; internal TNO expert (consulted 11/2021)

24 International Energy Agency 2020 Outlook for biogas and biomethane: Prospects for organic growth

The costs of composting also largely depends on the type and scale of the facility and the quality of output that is pursued (high or low for composting), with the costs for mechanically operated facilities being related mainly to the building costs and the equipment and maintenance (a windrow turner can costs around 200k$)[25].

A comparative study of decentralized municipal composting and AD in Chile with conventional landfilling (Figure 11) shows the major difference in required capital investments for the instalment of an AD plant compared to a composting facility[26].

		Unit	Landfill [1]	Municipal Composting [4]	Municipal Anaerobic Digestion [5]
Costs	Operation	$/hh/y	0	14	312
	Transport	$/hh/y	256	256	256
	fees	$/hh/y	103	0	0
	Total costs	$/hh/y	359	270	568
Benefits	Compost	$/hh/y	0	36	0
	Vermicompost	$/hh/y	0	0	0
	Digestate	$/hh/y	0	0	7
	Biogas	$/hh/y	0	0	128
	Total benefits	$/hh/y	0	36	135
Profit		$/hh/y	–359	–234	–432
Capital Investment		$/hh	–	120	1.237

Figure 11. Cost and benefits in USD of current domestic solid organic waste management

Another key insights of this study, is the major contribution of **transport costs** to any valorisation option. These high costs provide an argument to work with Waste Transfer stations, to reduce the number of transport movements required from the various sources (households) to potential valorisation outlets.

In terms of product value potential, Lalander et al (2017)[27] have compared AD, composting and BSF product outputs, concluding that the highest revenue products are being produced with a combination of BSF with AD for the residue product, while composting yielded lowest revenues (26€/ton treated food waste) and BSF treatment + AD the highest total value of products (animal feed, vehicle gas and organic fertilizer; 215 €/ton treated food waste). Only AD led to a market price estimate of 137€/ton treated food waste. The exact market prices are of course dependent on local markets, but these outcomes do give an indication of the difference between the various pathways.

[25] Komilis, D., & Ham, R. K. (2000). Life cycle inventory and cost model for mixed municipal and yard waste composting. *North Carolina, USA*, 72.

[26] de Kraker, J., Kujawa-Roeleveld, K., J Villena, M., & Pabón-Pereira, C. (2019). Decentralized valorisation of residual flows as an alternative to the traditional urban waste management system: The case of peñalolén in santiago de chile. *Sustainability*, *11*(22), 6206.

[27] Lalander, C., Nordberg, Å., & Vinnerås, B. (2018). A comparison in product-value potential in four treatment strategies for food waste and faeces–assessing composting, fly larvae composting and anaerobic digestion. *GCB Bioenergy*, *10*(2), 84-91.

All in all, both composting as AD are generally dependent on quite substantial gate fees. AD mainly to cover for the capital and operational costs, in the case of composting mainly to add to the relatively low financial revenue. For AD, this gate fee is frequently insufficient. In many countries in Europe, the business case for biogas is only achieved by subsidies on green energy by national or EU level government[28].

As a very rough estimate, the economics for the various pathways can be summarized as follows. This does not take into account any possible combinations of pathways:

AD	**Composting**	**Solid fuel**	**Animal feed**
Capital intensive on all scales. On larger scale often need for subsidies. Gate fees required.	On small level it is relatively cheap, but can be expensive if implemented on larger scale because of equipment costs. Gate fees required to close the business case.	Not expensive at all. Particularly when done at small scale capital and operational costs are low.	Relatively little machinery involved and not expensive. Can demand some costs for freezers as well as electricity.

Pathway	CAPEX	OPEX	Revenue
Composting (manual)	$-$$	$	$-$$
Composting mechanical	$$-$$$	$$	$$
AD	$$-$$$$	$$-$$$$	$$-$$$$
Solid fuel production	$	$	$-$$
Animal feed production	$-$$	$-$$	$$$-$$$$

2.6 Impacts

2.6.1 A few words on circularity and UOW valorisation

The final purpose of this project is to design a roadmap for circularity in organic waste management. Therefore, it is worthwhile to briefly pause at the relation between UOW management and the circular economy. The circular economy is based on a set of key principles[29]:

- To design out and eliminate waste and pollution
- To keep resources, products and materials at their highest value possible by circulating them
- To regenerate nature

[28] Internal TNO expert (consulted 11/21); Brusselaers, J., & Van Der Linden, A. (2020). Bio-waste in Europe—turning challenges into opportunities, European Environment Agency.

[29] What is a circular economy? | Ellen MacArthur Foundation

From the perspective of UOW, such as food and garden wastes, it is possible to determine a hierarchy of which strategies are preferable from the perspective of the circular economy.
Figure 12 gives a visual representation of the various strategies for food waste management in particular[30].

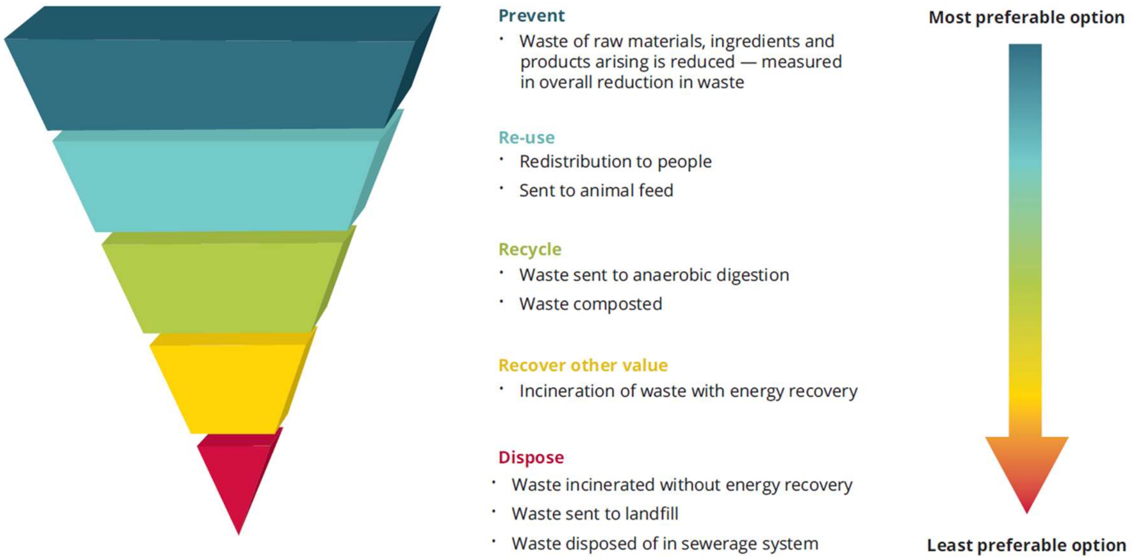

Figure 12. The hierarchy for food waste strategies, with the green arrow representing BSF, the blue arrow representing composting and AD, and the red arrow representing briquetting.

As the circular economy is about more than waste management but particularly also about the *prevention* of waste generation in the first place, the highest valued strategies are of course those aimed at food waste prevention (no overproduction for example, or less strict demands from retailers to farmers to reduce wastage of 'commercially unfit' foods), or the 'reuse' of food by redistribution to humans, or if that is not possible to animals. This can be done directly, or indirectly, for example in the case of BSF farming. If reuse is no longer possible, strategies should be deployed that harvest value from the waste at the highest level possible. This is where among others composting (waste to fertilizer) and AD come in (waste to gas or electricity). From the perspective of value retention it is only when these kinds of recycling strategies are not feasible, food waste should be incinerated – either directly, or in the form of char or briquettes. The last resort, only to be pursued when the other options are not feasible, or not feasible for the full 100% of the available volumes of waste, is to turn to incineration without energy recovery or the dumping of waste on the landfill. As described in the section above, landfill with gas recovery would be a more preferred option, as this allows for at least partial valorisation of the waste.

Hence, from the perspective of the circular economy Black Soldier Fly harvesting scores highest (turning the waste partially into animal feed, and partially recycling the residue into biogas or compost); followed by composting and AD; with solid fuel production scoring lowest on the ladder.

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[30] Caldeira, C., De Laurentiis, V., & Sala, S. (2019). Assessment of food waste prevention actions. *Development of an Evaluation Framework to Assess the Performance of Food Waste Prevention Actions.*; Food Recovery Hierarchy | US EPA; Waste prevention and management - Environment - European Commission (europa.eu)

2.6.2 Impact comparison pathways

In addition to the circularity assessment of the various pathways this section provides a rough impact comparison of the pathways based on the literature. The four pathways are compared on CO_2 impact, the broad environmental impact (LCA) and social impacts. Social impact is defined on an assessment on labor potential, potential for gender equality and working conditions.

In literature several LCA's can be found that research the environmental impact of different treatment technologies for organic waste. In Table 1 the results of the study by Morris, Matthews and Morawski (2013) are shown, who have done a literature review on LCA's determining a ranking of different organic waste treatment options. This study is used to give a comparative indication of the impact for 4 out of 5 technological pathways. Since the use of BSF is not mentioned in this study an additional study is consulted (Guo et al (2021)) To identify the global warming potential of the different technologies the following studies were used: Whiting and Azapagic (2014); Colón et al (2010); Ciceri et al (2021); Guo et al (2021) [31][32] [33] [34]. With the data from these articles Table 1 could be developed.

Table 1. Ranking of organic waste management methods[35]

Management method	Average ranking[a]							
	Human respiratory	Human toxicity	Human carcinogencitiy	Ecotoxicity	Acidification	Eutrophication	Ground level smog	Ozone depletion
Anaerobic digestion	1.0 (2)	2.2 (5)	1.5 (2)	1.3 (3)	1.0 (2)	3.0 (1)	1.0 (2)	NR
Aerobic composting	2.0 (5)	1.3 (7)	1.2 (5)	1.3 (6)	1.8 (6)	1.6 (5)	2.0 (2)	2.0 (1)
Mass burn WTE	2.7 (3)	2.0 (7)	2.4 (5)	2.3 (6)	2.2 (6)	2.3 (4)	1.7 (3)	NR
Home aerobic composting	NR	1.0 (1)	NR	1.0 (1)	1.5 (2)	1.5 (2)	1.0 (1)	1.0 (1)
LFGTE	2.0 (4)	2.3 (4)	1.8 (5)	2.0 (5)	1.8 (5)	2.0 (3)	1.5 (2)	NR
LF flare	3.5 (2)	2.5 (4)	2.5 (2)	3.5 (2)	3.5 (2)	3.5 (2)	NR	NR
Mass burn incineration	NR	NR	NR	3.0 (1)	3.0 (1)	2.0 (1)	3.0 (1)	NR
In-sink food waste disposer	NR	3.0 (1)	NR	3.0 (1)	2.0 (1)	3.0 (1)	NR	NR

NR = not ranked, because none of the reviewed LCAs provided quantitative rankings on the management method for the indicated environmental impact category.
[a] A higher ranking (e.g., 1.0 is the highest) means lower potential impact; number in parentheses is the number of studies that ranked that management method for the indicated environmental impact.

[31] Smetana, S., Schmitt, E., & Mathys, A. (2019). Sustainable use of Hermetia illucens insect biomass for feed and food: Attributional and consequential life cycle assessment. Resources, Conservation and Recycling, 144, 285–296. https://doi.org/10.1016/J.RESCONREC.2019.01.042

[32] Whiting, A., & Azapagic, A. (2014). Life cycle environmental impacts of generating electricity and heat from biogas produced by anaerobic digestion. Energy, 70, 181–193. https://doi.org/10.1016/J.ENERGY.2014.03.103

[33] Colón, J., Martínez-Blanco, J., Gabarrell, X., Artola, A., Sánchez, A., Rieradevall, J., & Font, X. (2010). Environmental assessment of home composting. Resources, Conservation and Recycling, 54(11), 893–904. https://doi.org/10.1016/J.RESCONREC.2010.01.008

[34] Ciceri, G., Hernandez Latorre, M., Kumar Mediboyina, M., Murphy Edited by Mar Edo, F., Hoffman, B., Johansson, I., & Roberts, D. (2021). Hydrothermal Carbonization (HTC): Valorisation of organic waste and sludges for hydrochar production of biofertilizers Title of publication Subtitle of publication.

[35] Morris, J., S. Matthews, H., & Morawski, C. (2013). Review and meta-analysis of 82 studies on end-of-life management methods for source separated organics. Waste Management, 33(3), 545–551. https://doi.org/10.1016/J.WASMAN.2012.08.004

Table 2. Environmental impact of the different technological pathways

Pathway	CO_2	Acidification	Eutrophication
Composting (manual)	##	# - ##	# - ##
Composting mechanical	## - ### *	##	# - ##
AD	###	#	###
Solid fuel production	##	##	## - ###
Animal feed production	#	N.D.	N.D.

In addition, the use of compost or compost to fertilizer as a substitute of chemical fertilizer also contributes greatly to the preservation of soil quality and the protection of food security, as crop yields can be similar but soil health can be expanded[36].

Table 3 gives an overview of the different pathways in terms of social impacts. Labour potential is based on the amount of manual activity involved in the pathway. The gender equality potential is based on the likeliness in the current context of woman participating in the activities. Scheinberg et al (2011) indicated that for composting there is a high potential for gender equality[37.] For the other pathways no clear sign for high or low potential is indicated, so therefore the potential is seen as average. The working conditions are based on human toxicity involved with the activities as identified in Table 1.

Table 3. Social impacts overview

Pathway	Labour potential	Potential for gender equality	Working conditions (toxicity)
Composting (manual)	XX	XXX	X
Composting mechanical	X	XXX	X-XX
AD	X	XX	XX
Solid fuel production	X	XX	XX
Animal feed production	XX	XX	N.D.

[36] Rosen, C. J., & Allan, D. L. (2007). Exploring the benefits of organic nutrient sources for crop production and soil quality. *HortTechnology*, *17*(4), 422-430; Ji, L., Wu, Z., You, Z., Yi, X., Ni, K., Guo, S., & Ruan, J. (2018). Effects of organic substitution for synthetic N fertilizer on soil bacterial diversity and community composition: A 10-year field trial in a tea plantation. *Agriculture, Ecosystems & Environment*, *268*, 124-132.; Hammad, H. M., Khaliq, A., Abbas, F., Farhad, W., Fahad, S., Aslam, M., ... & Bakhat, H. F. (2020). Comparative effects of organic and inorganic fertilizers on soil organic carbon and wheat productivity under arid region. *Communications in Soil Science and Plant Analysis*, *51*(10), 1406-1422.

[37] Scheinberg, A., Agathos, N., Gachugi, J. W., Kirai, P., Alumasa, V., Shah, B., Woods, M., & Waarts, Y. (2011). *Sustainable valorisation of organic urban wastes Insights from African case studies*. www.waste.nl

3 Policy landscape (activity 4.1)

3.1 Introduction

This chapter examines Zimbabwe's organic waste management policies, legislation, and regulations. This chapter investigates Zimbabwe waste management strategies, particularly organic waste, in the context of circular economy (CE) approach. As a result, the research examines the extent to which policies strive to encourage organic waste valorisation, as well as goods made from organic waste in the economy, with the goal of reducing or eliminating waste.

Zimbabwe is a democratic country, with democratic procedures and values influencing the formation of policy and legislation. The rule of law governs Zimbabwe, as it does most other countries. In terms of legislation, once the need for a new law or an amendment to an existing one has been identified and approved by cabinet, the relevant ministry prepares a proposal in consultation with the Attorney General's office, which then becomes a bill, which is debated and approved in the National Assembly, after which the public is consulted, and then signed by the President of the country as an Act of Parliament. The three sorts of national legislation are the Constitution, Acts of Parliament, and Statutory Instruments (SI). At the local government or municipal level, bylaws govern the jurisdiction.

3.2 Structure of waste management in Zimbabwe

According to Section 73 of Zimbabwe`s constitution, every person has a right to an environment that is not harmful to their health or well-being; and to have theat environment protected for the benefit of present and future generations, through reasonable legislative measures that prevent pollution and ecological degradation. The Environmental Management Act [Chapter 20:27] is fundamental in establishing structures that ensure a sustainable environment as envisioned in Zimbabwe’s constitution. The Act establishes the Environmental Management Agency (EMA) as the overall body to coordinate, regulate, and enforce environmental issues in the country. EMA has the mandate to promote public environmental education, awareness creation, and knowledge sharing to increase the capacity of communities to address environmental issues. These activities are also important to create values, attitudes, skills, and behaviour consistent with environmental management. The Urban Local Act [Chapter 29:15] designates the responsibility to manage municipal solid waste including organic waste to urban local authorities. This comprises collection, transportation, and disposal services in their areas of jurisdiction. It also presents opportunities to enforce partnerships with the private sector to develop sanitary facilities and infrastructure for effective solid waste management which will spur a circular economy in the organic waste stream. Table 4 lists policies, national strategies and legislations relevant to organic waste management in Zimbabwe. However, in terms of institutional arrangements, there is lack of institutional platform or structure to support the horizontal co-ordination of waste policies and activities across relevant sectors. Institutions are specific to certain ministries therefore cross linkages are essential. There is need for integrated approach that may involve Environmental Management Agency, Local Authorities, Private Sector, Households including farmers in the organic fertilizer waste stream. Additionally, not all policies are well enforced and there are opportunities to expand on the statutory instruments as well strengthen the already established ones to have harder penalties for offenders.

Table 4. Analysed policies, legislations, strategies and plans

POLICIES AND STRATEGIES
• National Agriculture Policy Framework (2018 – 2030) • National Development Strategy (2021 –2025) • National Renewable Energy Policy • Gender Policy (2015) • Vision 2030 • National Climate Policy • Zimbabwe Agriculture Investment Plan (ZAIP) 2013-2017 • National Health Strategy for Zimbabwe, 2016-2020 • Integrated Solid Waste Management Plan • Nationally Determined Contributions (NDCs) • National Climate Change Response Strategy (NCCRS) • National Biodiversity Strategy and Action Plan (NBSAP-2)
LEGISLATIONS
a. Constitution - Zimbabwe's Constitution of 2013
b. Acts of parliament • Environmental Management Act [Chapter 20:27] • Agricultural and Rural Development Authority Act • Urban Councils Act [Chapter 29:15]
c. Statutory Instruments • Environmental Management (Effluents and Solid Waste Disposal) Regulations, 2007 (SI 6 OF 2007) • Environmental Management (Atmospheric Pollution Control) Regulations, 2009 (SI 72 OF 2009)

3.3 Policies and strategies that enable circularity of organic waste in Zimbabwe

This section delves into the aspects of the laws and policies that address and enable

This section delves into the aspects of the policies and strategies that address and enable the transition from a linear economy to a circular economy with emphasis on organic waste in Zimbabwe. Table 5 presents the policies and legislation that are potentially relevant for a circular economy. The first column states the name of the policy/legislation, the second column gives a description of the content of the policy in relation to waste management or circular economy, and the third column provides a small analysis of the policy/legislation in relation to the level of circularity promotion for organic waste management.

Table 5. Analysis of policies and strategies in relation to circular management of organic waste

Policy/Strategy	Description	Analysis of the laws, policy in relation to circularity in managing organic waste
Vision 2030	Government is working towards building a new Zimbabwe, a country with a thriving and open economy, capable of creating opportunities for investors and employment. Vision 2030 is a strategic document that anticipates the transformation of Zimbabwe into a knowledge driven and industrialising Upper	The vision 2030 does not specifically flag out the waste sector. Nonetheless, valorising presents an opportunity for organic fertilizer industry, creating jobs and contributes to attainment of upper middle-income economy. Given that Zimbabwe is mainly an agrarian economy, anticipated industrial growth means increased demand of fertilizer, hence the vision is a key enabler for organic waste valorisation. As the economy and population grows more organic products will be consumed leading to more waste

Policy/Strategy	Description	Analysis of the laws, policy in relation to circularity in managing organic waste
	Middle-Income Economy by 2030.	generated which should be directed into circular pathways.
National Development Strategy 2021 –2025	The document seeks to share with the international community and domestic stakeholders, the key reform initiatives and commitments, on rebuilding and transforming Zimbabwe to become an Upper-Middle Income Economy by 2030. The strategy promotes new enterprise development, employment and job creation. Section 822 says that the government will promote implementation of pollution and waste management programs in order to improve ecosystems health.	The strategy does not specifically speak about circular economy in organic waste, but identifies the need to capacitate the local authorities and Environmental Management Agency for them to improve on management of environment and waste respectively. As part of the strategy it stresses implementation of pollution and waste management programs. Therefore, mainstreaming organic waste valorisation will align to NDS1. There is however need for concrete action- and implementation plans that promotes new enterprise development in the organic waste sector. There is also a need for strengthening the capacities of Environmental Management Agency and local authorities to fully execute their mandates.
National Agriculture Policy Framework (2018 – 2030)	To guide investments and subsector strategies to sustainably transform the agriculture sector.	The policy provides guidance and direction on how to promote and support the sustainable flow of investments that is needed to transform the agricultural sector. The aim of this transformation is to increase and sustain agricultural production, productivity and competitiveness. It's probable that the policy will need to be amended in order to stimulate the production of organic fertilizers and compost from organic and agricultural waste. Government programs such as Presidential Inputs scheme may need to consider exploring investing in use of organic fertilizer for crop production.
National Climate Policy	The policy calls for the reduction of greenhouse gas emissions. It also calls for mainstreaming of climate issues in all sectors of the economy including; energy, agriculture, industrial processes, waste, land use land cover and forestry. Promotes principles of sustainable development, prevention of pollution and ecological degradation and inclusive participation. The policy recognizes waste as one of the sectors drive of GHG emissions at 3.93%. Promote collection, archiving and maintenance of accessible database on quality, quantity and characterisation of waste. Promote fuel or energy generation from waste. The policy recommends establishing a 0.005% levy of net	The National Climate policy promotes circular economy in the waste sector in that it identifies waste reduction , reuse and recycling as part of government priority to reduce overall resource use and increase resource efficiency. It notes the need to valorise organic waste for renewable energy. However, the policy does not promote use of organic waste to produce compost or organic fertilizer. It is biased towards waste to energy production. Furthermore, it acknowledges that the current waste management system is focused on disposal which is linear model and failing therefore an opportunity to integrate circularity. The challenge presented in on how the resources generated from 0.005 % levy will be ringfenced for the purposes of addressing climate change issues as a result of waste generation. The policy does not promote use of organic waste to produce compost or organic fertilizer.

Policy/Strategy	Description	Analysis of the laws, policy in relation to circularity in managing organic waste
	profit for industries, including the organic waste sector, towards national green growth; as well as establishing and maintaining an inter-sectoral climate change think tank.	
National Climate Change Response Strategy (NCCRS)	Provides a framework for a comprehensive and strategic approach to climate change adaptation, mitigation, technology and finance. The Strategy aims to mainstream climate change adaptation and mitigation strategies in economic and social development at national and sectoral levels through multi-stakeholder engagement. The following strategies are proposed regarding the waste sector: a) Capacitate local authorities to deliver proper, effective and efficient waste management services in order. b) Reduce GHG emissions from waste management. c) Create an enabling framework to promote waste minimization through education and behavioural change of waste generators.	The strategy maintains and identifies technology transfer as well as infrastructure for accelerating sustainable development. It promotes circular economy in the waste sector, however more inclined towards waste to energy. It is silent on organic waste valorisation to produce organic compost. Successful implementation of the strategy is limited by the fact that local authorities are not yet fully capacitated to deliver efficient and effective waste management services. In addition, education and awareness raising should be strengthened to influence behaviour change of waste generators.
National Biodiversity Strategy and Action Plan (NBSAP-2)	The National Biodiversity Strategy and Action Plan is a cross-sectoral strategic document of Zimbabwe for the period 2015-2020. Its main objective is to utilize traditional knowledge, research, technology, innovations and best practices to protect the environment, conserve and sustainably use biodiversity and ecosystems to benefit present and future generations.	The plan recognises that insufficient solid waste management strategies are a cause of GHG emissions. It establishes the monitoring and enforcement of national quality standards for water, air and solid waste. The plan promotes increased recycling of waste and alternative uses for solid waste, such as biogas production. In addition the plan promotes increased consumer consciousness and demand for environmentally sustainable production and services. There is however need to extend the period of the plan as most actions are still to be implemented.
Zimbabwe Agriculture Investment Plan (ZAIP) 2013-2017	A plan to spur targeted investment in agriculture for sustainable development: • Recognizes the economic value of organic waste • Ensures that household hygiene, safe sanitation and waste management are priority components in addressing food and nutrition security	Although the plan does not mention circularity, it promoted some of the principles of circularity valorisation of organic waste. The period for the plan lapsed and the plan needs to be reviewed and extended

Policy/Strategy	Description	Analysis of the laws, policy in relation to circularity in managing organic waste
Zimbabwe National Industrial Development Policy, 2019-2023	This Policy is made on the backdrop of the country's economy suffering and de-industrialisation as a result of numerous challenges which have negatively impacted all productive sectors. The vision of the Policy is to achieve a technologically advanced, competitive and diversified industry by 2030.	Recognizes the need to establish a Clean Technology Centre, recycling of waste, waste disposal management; and resource (energy and water) efficient management programmes. However, the policy does not promote production of organic fertilizer from the waste. In addition, most of the provisions in the policy are still yet to be implemented. Support from industries has been derailed by economic and COVID 19 related challenges.
National Health Strategy for Zimbabwe, 2016-2020	This Policy envisions Zimbabwe to have the highest possible level of health quality of life for all its citizens. The 2016-2020 National Health Strategy builds on the 2009-2013 strategy and its extension in 2014-2015 by addressing existing gaps and, more importantly, seeks to sustain the gains achieved thus far through a comprehensive response to the burden of disease and strengthening of the health system to deliver quality health services to all Zimbabweans.	The strategy recognises behaviour change and communication to improve household hygiene, safe sanitation and waste. It promotes appropriate water treatment and waste management methods. Strengthen waste management systems to improve Environmental Hygiene through environmental awareness programmes. The strategy is relevant in that it promotes behaviour change at household. And behaviour change at household is key to attain waste separation at source. There is need of reviewing the successes and failures of the plan and if possible, extend the implementation period
Zimbabwe Long-term Low Greenhouse Gas Emission Development Strategy (2020-2050	Zimbabwe has pledged to reduce greenhouse gas emissions by 40%, from the current levels, by 2050 to avert catastrophic impacts of climate change. The strategy recognizes ineffective waste management as driver for GHG emissions. It promotes the development of low carbon waste initiatives and identifies generation of energy from waste. Additionally, it identifies key infrastructure needed for effective waste management: recycling facilities, waste transfer facilities, waste sorting and recycling facilities, waste compactors, bailing machines, forklifts, vehicles, shredders, among others.	The strategy is relevant in that it promotes principles of circular economy such as waste separation, recycling and use of waste transfer stations. However, the strategy was developed with strong inclination toward energy sector and does not emphasise production of organic fertilizer from organic waste, but rather waste to energy. As a result, the strategy lack support of the agriculture sector which is key in organic waste valorisation using composting and organic fertilizer pathway.
Revised National Determined Contributions (NDCs),	Zimbabwe's revised NDC target is a 40% per capita emissions reduction across all sectors of the economy below the projected business as usual scenario by	Relevant to the circular economy initiatives and promotes organic waste valorisation to produce compost. It also targets major cities, where most of the organic waste is generated. Most of the strategies in the INDCs are yet to be

Policy/Strategy	Description	Analysis of the laws, policy in relation to circularity in managing organic waste
	2030 (relative to the 2017 emission baseline). Waste is identified as a driver for GHG emissions. It identifies key strategies to reduce GHG emissions that include: improving market access for women and youth farmers in remote areas, minimizing waste, and reducing inequalities along agricultural value chains. Strategies to manage waste include: Increased composting and waste-to-energy processing in key areas i.e., Bulawayo, Harare, Gweru and Mutare metropolitan areas.	implemented and there is need for wider engagement and awareness raising.
Integrated Solid Waste Management Plan	It supports the establishment of Public-Private Partnerships and community participation through the adoption of separation of waste at source strategies. The plan is one of the few that proposes the use of incentives and subsidies that promote investment in solid waste recycling enterprises and facilities, which include the organic waste stream. For instance, the establishment of a Green Fund in which the banks, private sector, and development partners can contribute funds towards solid waste recycling and provide innovative funds and seed money for developing innovative waste (organic) recycling ideas.	The plan promotes principles of circular economy such as reduce, reuse, and recycling. It also promotes composting. Unfortunately, the plan was developed 7 years ago and according to stakeholder consultations less than 20% of strategies and actions in the plan were implemented. Key institutions that should have driven this plan were Local Authorities and Environmental Management Agency, which are limited by capacity related challenges to fully implement.

3.4 Laws and regulations that enable circularity of organic waste in Zimbabwe

This section delves into the aspects of the laws and regulations that address and enable the transition from a linear economy to a circular economy with emphasis on organic waste in Zimbabwe. Table 6 presents the laws and regulations that are potentially relevant for a circular economy. The first column states the name of the law/regulation, the second column gives a description of the content of the law in relation to waste management or circular economy, and the third column provides a small analysis of the policy/legislation in relation to the level of circularity promotion for organic waste management.

Table 6. Analysis of the laws and regulations in relation the circularity in managing organic waste

Law/Regulation	Description	Analysis of the law as an enabler for circularity in managing plastics as a waste stream
Zimbabwe's Constitution of 2013	The supreme law on land. According to Section 73, the constitution gives every person the right to an environment that is not harmful to their health or well-being. It also provides for the right to have the environment protected for the benefit of present and future generations, through reasonable legislative and other measures, including preventing pollution and promoting conservation.	Recognizes environmental rights and also include right to a clean and healthy environment. The constitution promotes sustainable economic and social development. Circularity in the organic waste will reduce environmental pollution and contributes to economic development of the country. However, during stakeholder consultation, it was established that majority of people know that there is a national constitution but lack full understanding of its contents. There is a need to raise awareness of the provisions of the constitutions to residents of Zimbabwe.
Environmental Management Act [Chapter 20:27]	An Act to provide for the sustainable management of natural resources and protection of the environment; the prevention of pollution and environmental degradation; the preparation of a National Environmental Plan and other plans for the management and protection of the environment; the establishment of an Environmental Management Agency (EMA) and an Environment Fund.	Mandated by EIA on projects touching on Waste treatment and disposal, energy plants, municipal solid waste: incineration, composting and recovery/recycling plants, landfill facilities. Also, the act mainstreams the development of Environmental Management Plans remedy environmental risks. The Act stipulates legal course of action and punishment for failure to comply such as fees, fines, and imprisonment consequences for defaulters but does not provide for any incentives to encourage investment in waste valorisation.
Environmental Management (Effluents and Solid Waste Disposal) Regulations, 2007 (SI 6 OF 2007)	SI 6 implement provisions of the EMA Act [20:27) relative to the control of the disposal of waste or effluent which may affect the quality of environment and the issue of licences for this purpose by the Environmental Management Agency.	The regulation covers the collection of waste as well as its management. It provides a platform for private companies and enterprises to collect waste and be involved in waste management, therefore it recognises waste as a business. The regulation also has requirements for local authorities to keep records of waste generated and managed according to each waste stream, which also supports a mechanism to avail data on organic waste generated for decision making process. It further requires waste collectors to separate waste at collection and

Law/Regulation	Description	Analysis of the law as an enabler for circularity in managing plastics as a waste stream
		management levels. However, it specifically makes an exception on households, which is a gap in separation at source. This gap in other waste streams is covered in further statutes like SI 98 of 2010 and SI 84 of 2012 which further elaborate on handling of plastic waste. For organic waste, there are no further statutes so this is a gap. The requirements for waste separation by collectors have never been enforced. Local authorities, the biggest waste collector does not separate waste on collection. The regulations prioritise recycling and sorting of waste, for all waste that are feasible. This a direct support to principles of circularity. It further gives responsibility to local authorities to clearly set aside locations and facilities for waste treatment and public collection sites, which makes it possible for waste transfer centres to be established. Agriculture waste is mentioned but not in terms of organic household waste.
Environmental Management (Atmospheric Pollution Control) Regulations, 2009 (SI 72 OF 2009)	The Regulation allows the provisions of [EMA Act20:27] to be subsequently brought into force, provide rules for the control of activities that may cause air pollution.	This regulation is relevant in preventing organic waste going to landfills or dump sites since organic waste contributes to air pollution when it decomposes. Organic waste is also not one of the waste types that is collected from landfills and dumpsites so when it accumulates, it causes generation of methane, a greenhouse gas. Preventing organic waste going to landfills is therefore atmospheric pollution control that can help supports management of organic waste in a sustainable manner. The relevant section is section 3(1)(g) which talks about any activity that causes the emission of a pollutant into the atmosphere. However, this SI was mainly applied to control of dust and gas emission from operation of machinery such as generators and vehicles that is why the current waste collection by local authorities to the landfill/ official dumpsites is considered normal practice.

Law/Regulation	Description	Analysis of the law as an enabler for circularity in managing plastics as a waste stream
Urban Councils Act [Chapter 29:15]	This Act guides the operations of local authorities. The Act, defines the roles of local authorities in terms of management of waste in their jurisdictions, including other duties. It is a detailed guide on the operations of a local authority so it is comprehensive.	Of note in relation to organic waste, the Act allows Local Authorities to collaborate with other stakeholders, including through joint committees or joint boards which enables PPPs in organic waste. Under the Act, Local Authorities can make, withdraw or amend by-laws in their jurisdiction which makes it possible for circularity projects to be context specific. They have clearly defined land which makes it possible for them to allocate land for various needs including for waste transfer centres and for businesses in organic waste valorisation. They can also authorise agriculture activities within their jurisdiction, so they can influence the use of organic fertiliser for urban agriculture.
The National Gender Policy (2013-2017)	This second National Gender Policy replaces the first National Gender Policy of 2004. The first National Gender Policy gave way to a range of initiatives meant to address gender inequalities. The ethos of Growth with Equity underpinned the 2004 NGP which was implemented under four thematic areas namely – (i) Women in Politics and Decision Making; (ii) Women and the Economy; (iii) Education and Training of Women; and (iv) Institutional Mechanisms for the Advancement of Women.	The National Gender Policy is the platform to argue for and rationalise the inclusion of women in circular economy of organic waste in Zimbabwe, especially under the second pillar of women and the economy and the third pillar on Education and training of women. The policy dictates interventions to ensure that women are included as entrepreneurs, employees and customers as well as points for the need for capacity development in the organic waste value chain including valorisation.
Zimbabwe Investment and Development Agency Act [Chapter 14:37]	An Act to provide for the promotion, entry, protection and facilitation of investment; to provide for the establishment of the Zimbabwe Investment and Development Agency.	The Agency facilitates investments in programmes in Zimbabwe and encourages investment by domestic and foreign investors. This Agency can therefore be useful when more circular economy projects are developed and requires funding more so focus on the use of organic waste to produce fertilizer or as a source of energy.

3.5 Synthesis of the policy assessment

Zimbabwe has good policies, strategic plans and pieces of legislation on waste management in general. However, the country does not have a circular economy policy, circular economy strategy or legislation. The major weakness has been lack of implementation of the available instruments. For example, there is a mismatch between most national strategies and plans explained in table 2 and the resources allocated to make execution easier (competing interests and limited budgets). The same applies to enforcement of legislation. For the country to achieve national strategies like Vision 2030 which envisions a robust and open economy capable of attracting investors and creating jobs, there is need for mobilisation of enough resources that will help drive the process. During stakeholder consultations, it was reported that enforcement of regulations, and efficient and effective functioning of key institutions such as EMA and Local Authorities is affected by capacity challenges.

In addition, results show that there is low levels of implementation of existing regulations. Enforcement of regulations on organic waste is a bit relaxed and this is mainly caused by capacity challenges. Some consulted stakeholders had the opinion that organic waste is less toxic to the environment than other waste stream hence low enforcement of regulations. The EPR scheme is currently voluntary and covers plastic waste stream only and needs to be extended to other waste streams. EPR has a potential to unlock the needed funding for organic waste valorisation.

The legislative landscape on waste management is clear on punitive procedures on non-compliance, and a focus on licenses, penalties, and jail time for violators with no mention of incentives. There is no provision for incentives such as taxes reduction and subsidies that promotes circularity in the waste sector in the available legislations. This shows that available legislations are more focused on environmental management of waste than business development in the waste sector. Where incentives and subsidies that promotes investment in solid waste enterprises and facilities are provided for, for example Integrated Solid Waste Management Plan 2014, resources mobilization for execution lacked. It supports incentives and the establishment of Public-Private Partnerships and community participation through the adoption of separation of waste at source strategies. For instance, the establishment of a Green Fund in which the banks, private sector, and development partners can contribute funds towards solid waste recycling and provide innovative funds and seed money for developing innovative waste (organic) recycling ideas. However, the plan also lacked specific mention of advancement of technology, more so on soil amendments from organic waste.

In terms of organic waste valorization, most policies and strategies in Table 2 and 3 are biased towards waste to energy. This may have been influenced by that most of them were developed in response to climate change challenges. There is lack of clear legislative support especially in the agriculture sector on composting of organic waste. There might be need to revise the National Agriculture Policy Framework (2018 – 2030) by incorporating organic waste valorization to stimulate and sustain the long-term investment flow in agriculture businesses.

Both public and private stakeholders bemoaned lack of updated national data. There is no national data base with waste data that can easily be accessed by stakeholders. Data that is available is housed by different institutions and in format convenient to the owners and is not easily available to other users. National Institutions like Zimbabwe Statistical Agency (ZimStats) also from time to time collect waste data for United Nations should be capacitated to have an updated national waste generation database and mechanism for sharing put in place. Other intuitions that should be considered are Environmental Management Agency and Local authorities.

Poor coordination on data also translate to low levels of coordination between sector players (including ministerial level) on the alignment of policies to enhance adoption of technology to promote use of organic waste for fertilizer and energy. Poor coordination leads to mistrust and lack of communication among stakeholders. During stakeholder consultations it was recommended that there is need of coordination and alignment of government policies and institutional arrangements to avoid pulling back by key players. For example, there should be linkages and integration of some components in the agriculture policies, environmental policies, climate policies and national investment policies.

All the policies, strategies and legislations analysed in Table 5 and Table 6 experience one common challenges that derail their effective implementation; and the challenge is funding. There is inadequate budgetary allocation extending to the development of organic valorisation infrastructure. Organic waste is voluminous and needs infrastructure support. However, there is inadequate budgetary allocation extending to the development of infrastructure. Opportunities should be created and explored for resources mobilisation for example through green climate fund, government budgetary allocation

4 Market and value chain analysis (activity 4.2)

The goal of the market and value chain analysis is to derive a detailed overview of the current situation for organic household waste. In addition to the data gathered during activity 2 and 3, interviews with market parties, a focal group discussion with public and private parties and a consultative stakeholder meeting were conducted. This has led to a thorough analysis of the current situation of the value chain and market for organic household waste which will be described in this section.

Organic household waste valorisation is just emerging. As of this moment, there are not many players involved in it yet. In urban areas, most organic household waste is mixed with other waste and ends up at open dumpsites, illegal dumpsites, landfills, or in the environment. While in rural areas most organic household waste is fed to livestock or used to fertilize the land, often without going through a complete fertilization or composting process.

There is huge potential in valorisation of organic household waste, since Zimbabwe has a large agricultural sector, with over 20% of the GDP coming directly from agricultural activities and approximately 50% of the Zimbabwean industries relying on agriculture products as raw materials. As described in section 2, there are roughly four routes for organic household waste valorisation: (1) Composting, (2) Anaerobic digestion, (3) Solid fuel production (e.g. briquettes), and (4)Animal feed production (e.g. black soldier flies). In this section, we will focus on the first two routes, since these are the most common in Zimbabwe. Routes three and four only happen sporadically and a market assessment of these routes is thus premature.

For compost, the high cost of chemical fertilizer and a growing movement for healthy eating is stimulating both organic fertilizer and compost. Additionally, high fuel, coal and electricity prices also increase the potential for biogas use. However, there are some barriers that should be overcome in order to implement the full potential of organic household waste valorisation. This section will provide a detailed overview the current situation, and its implications for a roadmap and pilot.

4.1 Organization of the current value chain

The value chain for organic household waste valorisation in urban areas consists roughly of five roles, as visualized in Figure 13. visualization of the organic household waste value chain in urban areas in Zimbabwe. The first role represents the sources from where households buy organics, e.g. markets, farms or retail (green). The second role represents the household itself which consumes organics and produces organic waste, of which some is reused within the household or community for e.g. feed for livestock (grey). The third role represents the collection mechanisms, which can either by public or private (including community based collectors). The waste that is collected can either by mixed or separated (yellow). The fourth role represents the disposal mechanisms used for organic household waste, which are either littering, illegal dumping or local authority controlled dumpsites and landfills (blue). The fifth and final role represents actors involved in waste valorisation, starting with inhouse or community processing and usage, aggregators, waste transfer stations or buy back centres, ending with recyclers and processors (orange).

In rural areas most organic household waste is used as feedstock for animals, composted or buried in rubbish pits.

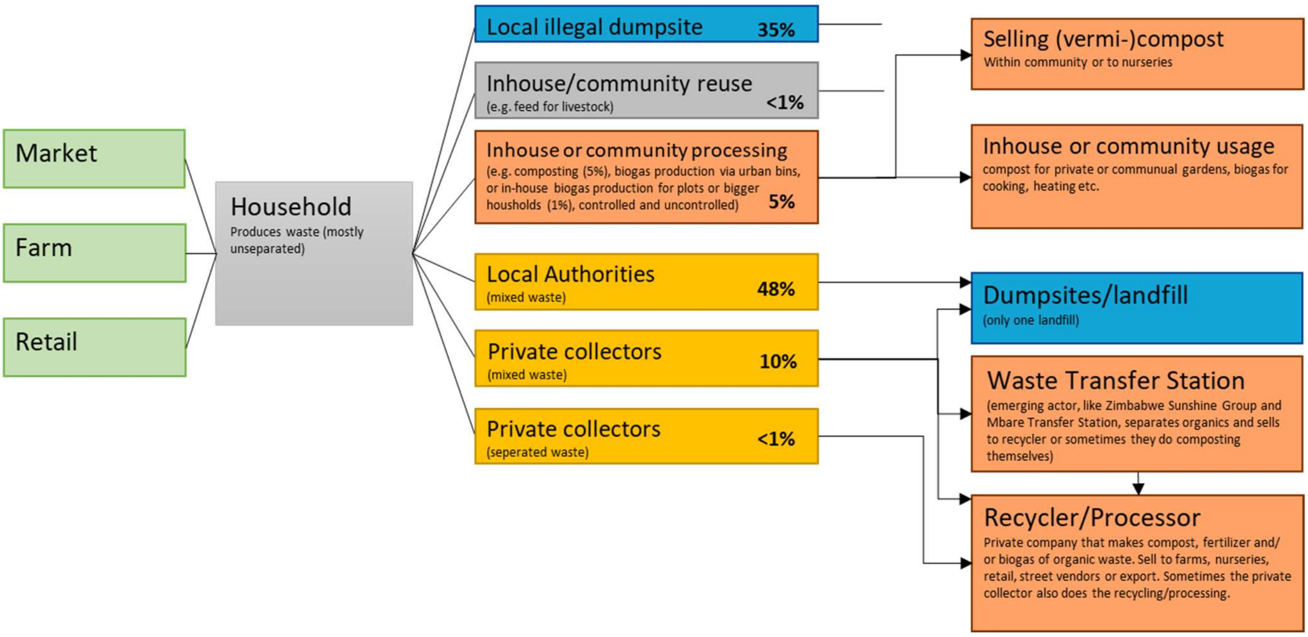

Figure 13. visualization of the organic household waste value chain in urban areas in Zimbabwe

The flow of materials and money within the organic household waste value chain is as follows:

- Households organics at the market, farms or retail (such as restaurants and shops).
- In the household organics are consumed and a part of it ends up as waste. Sometimes the organic waste is reused as food for livestock. The waste is largely mixed with other types of waste such as paper, plastics or glass and stored in bins or bags inside the house.
- These bags/bins are then either collected by public or private collectors (60%), end up at illegal dumpsites or littered (35%), or is used for inhouse or community processing such as compost or biogas production (5%). In the case of formal collection households usually pay a small monthly fee for mixed waste collection.
- In about 1% of the cases households do separate their organics and the organics are collected separately by a private collector who sells it to aggregators or the processing industry.
- The waste that is collected by public authorities is disposed in controlled dumpsites or the landfill, leaking methane and other greenhouse gasses.
- The waste that is collected by private authorities is either disposed in dumpsites (both legal and illegal) or sold to aggregators or the processing industry if the waste is already separated
- At the local authorities controlled dumpsites or the illegal dumpsites, formal and informal waste pickers collect certain waste types and sell this to aggregators or waste transfer stations, who then bulk this and sell to recyclers, processors or export it. However, organic waste is almost never picked by waste pickers.
- Some waste transfer stations separate incoming waste from private collectors and either sell to the processing industry or make compost themselves.
- Biogas which is made by inhouse, community or municipality digesters is mainly used in house for cooking, heating and lighting. Very little is compressed and sold due to the high prices of compression and transport
- Compost/fertilization which is made by inhouse or community composting facilities is used on private/communal gardens, sold to farms/nurseries or on the side of the road.

This system implies that currently the only options for organic household waste valorisation is via separated collection which only happens in about less than 1% of the households (such as Zimbabwe Sunshine Group who conduct mixed waste for a small number of customers who use their Bokashi bins), inhouse/community processing which happens with 5% of the households, or post-collection separation at waste transfer stations, of which it is unclear how much this happens.

When waste is disposed at disposal sites (illegal or legal) (which is over 85%), there is hardly any opportunity for valorisation anymore. Organics mix easily with other waste and are very difficult to separate. Additionally because of the smell and disease potential, waste pickers are not very interested in collecting such a high volume, low value product. Another downside is that organics also contaminate other waste at the disposal sites such as plastics and paper, making the usability of these waste streams lower and lower. Therefore separating organic waste should be a key focal point to not only increase organic waste valorisation but any type of waste valorisation

Thus, better separation, collection and transport logistics are essential to scale the market for organic processing within Zimbabwe.

Various pathways for separating and collecting waste are implemented in Zimbabwe or emerging in Africa. Table 7 and Table 8 summarize the existing and emerging pathways for separation and collection and the pros and cons of each pathway.

Table 7. Current practice (with asterisk) and emerging pathways for separation of household waste including pros and cons.

Proposed method	Requirements	Pros	Cons
Full household separation and separated collection	Frequent collection of various waste streams	Limited separation infrastructure needed after collection, easy to get sufficient volumes	Requires a big behavior change, various bins and thus space at households as well as a lot more trucks and frequent collection that might not be economically interesting due to low volumes
Only organic waste separation and separated collection*	Frequent collection of two different waste streams	No cross contamination of organics to other waste types, easier to separate waste	Requires a behavior change, one more bin at households and more trucks to do frequent collection
Waste picking at disposal sites*	(informal) waste workers	Situation as is now, no changes needed	Only small percentage of waste gets recycled
Manual separation at disposal sites	(informal) waste workers and a lot of space	No behaviour changes at households needed	Labour intensive, waste gets easily contaminated or buried
Manual separation at waste transfer stations*	(informal) waste workers, and a lot space	Transfer facility that links collection to processing industry, only true waste ends up at disposal site	Labour intensive

Proposed method	Requirements	Pros	Cons
Combination of manual and mechanical at disposal site or waste transfer station	(informal) waste workers, conveyor belt	More efficient that via solely waste workers	More expensive
Full mechanical separation	Specialized machinery and equipment	Efficient, not dependent on waste pickers	Does not create jobs for vulnerable groups, requires expert knowledge, high investment and O&M

Table 8. Current practice (with asterisk) and emerging pathways for collection of household waste including pros and cons.

Proposed method	Requirements	Pros	Cons
Kerbside system – trucks with open top*	Trucks, and high level of infrastructure, frequent collection to prevent illegal dumping	Limited behavior change needed from households. IT solutions can improve collection routes	Not possible in areas with narrow or bad roads, regular maintenance of trucks necessary,
Bring system – communal/block collection*	Trucks, and high willingness of communities, proper design to prevent smell	Less requirements on infrastructure and frequent collection	Large behavioural change necessary, regular maintenance of trucks necessary,
Informal sector IT-based collection	(informal) waste workers, IT infrastructure to connect households with waste to collection services	No high level of infrastructure needed, opportunities for job creation	Separation at households needed to earn profit, willingness from both waste collectors and households to go use app

4.2 Current market status

4.2.1 Actor overview

Even though valorisation of organic household waste is in its early stages, there are some organizations pioneering in this field. These organizations are mainly based in Harare. Their reach is still small, but it shows that early commercialization of valorisation pathways is possible. Table 9,

Table 10 and Table 11 provide a non-exhaustive overview, to give an idea on the actors currently operating in organic waste valorisation, their role and a description of their activities.

Table 9: Overview of selected organic waste actors and a detailed description of their activities

Name	Description
Zimbabwe Organic Producers and Promoters Association (ZOPPA)	Has 30,000 members in the country[38] who promote eating organic foods. They host events such as the Good Food Festival. ZOPPA Trust was established in 2008 as a national membership organisation, bringing together producers, promoters and processors for the development of the organic agriculture sector in Zimbabwe. Other associations that promote organic foods in Zimbabwe include Zimbabwe Smallholder Organic Farmers Forum (ZIMSOFF)[39]; Naturally Zimbabwean[40]; Traditional and Organic Food Forum; Participatory Ecological Land use Management Zimbabwe (PELUM-ZWE)[41]; Practical Action, Food and Agriculture Organisation.
Zimbabwe Earthworm Farms	Producer of biofertilizer using the earthworm technology (Vermicompost). They also produce Nutrich Refinded Compost, Nutrich Vermicompost, and Nutrich Foliar Vermi Biofertilizer. The cost of installing a JATI compost to produce vermicompost at the household level is US$250 and US$400 for JATI 4 compartments and JATI 6 compartments respectively. Zimbabwe Earthworm Farms also constructs community JATI composts as big as 50-100 m^2 at a cost of US$8000. Approximately 10-15 tons of compost fertilizer can be harvest from JATI compost per month.
Diana`s Huku-Mombe Compost	Produces compost from mixing cattle and chicken waste. They sale at US$7/bag and and offer free delivery in Harare for minimum order of 10bags. Their market is mainly in horticulture sector including in flower, lawn, and vegetable production. The source of the compost waste is the chickens and cattle from agriculture activities.
Org Fert	Producer of organically enriched blended fertilizers. They use high quality biodegradable organics, granulated and scientifically formulated and blended with chemical or inorganic fertilizer raw materials. The organic enriched fertilizers provide crops with adequate primary nutrients nitrogen (N), phosphorous (P) and potassium (K), secondary nutrients and micro nutrients such as boron (B), calcium (ca), magnesium (mg) and zinc
Nico Orgo	Production and supplying of organic fertilizer for maize, tobacco and vegetable enriched top dressing. After investing into dryer production capacity increased from 500metric tonnes to 6000metric tonnes per year. Their Organic fertilizer was 20% cheaper than chemical fertilizer and environmentally friendly

[38] https://zoppa.org.zw
[39] https://m.facebook.com/zimsoff
[40] https://naturallyzimbabwean.com
[41] https://pelumzimbabwe.wixsite.com

Table 10: Overview of biogas actors and a detailed description of their activities

Name	Description
Onyx Earth Biogas	A company that constructs and trades in biogas digesters of all sizes as well as appliances.
Zonful	A private company that is piloting 500 prefabricated digesters on a PAYG basis in rural parts of Zimbabwe. Each digester costs US$700 payable over 36 months.
SNV Netherlands Development Organisation	Technical advisor for the first Zimbabwe Domestic Biogas Programme in Zimbabwe (2013 – 15) and thereafter. The Zimbabwe Domestic Biogas Programme focused on household sized digesters of sizes 6cum to 20 cum digesters at household level in rural areas in Zimbabwe, that used mainly cow dung and some pig dung. The organization also conducted feasibility studies for municipal biogas plants for Bulawayo City Council at their sewage waste treatment plants. SNV was also a member of the Zimbabwe National Biogas Committee.
Ministry of Energy and Power Development (MoEPD)	Parent ministry that promotes all forms of biogas development in the country. Certified masons and quality controllers. Set policy for biogas targets in the National Renewable Energy Policy of Zimbabwe. Currently mobilises resources for the promotion and implementation of biogas programmes in the country and has dedicated staff who are assigned as quality controllers during the design, construction and implementation of biogas digesters of all types and sizes in Zimbabwe. Current chair of the National Biogas Committee in Zimbabwe.
Ministry of Agriculture	The co-chair of the Zimbabwe National Biogas Committee. Concerned with biogas as farm power and the slurry as organic fertilizer. Also discussed options of biogas to power farm implements such as tractors, and generators for water pumping. The partnership with Ministry of Energy and Power Development was borne from the fact that most of the feedstock for the Zimbabwe Domestic Biogas Programme (2013-15) was from livestock (cow dung, pig dung) from the agriculture sector, and that the biogas and slurry had market in the agriculture sector. The Ministry of also has certified quality controllers for the construction of biogas digesters.
Rural Electrification Agency (REA)	REA was also a member of the Zimbabwe National Biogas Committee. Where SNV and Hivos led the Zimbabwe Domestic Biogas Programme, REA ran a parallel programme where they focused on institutional sized digesters of sizes 20cum to 80 cum digesters at institutions such as schools, clinics, hospitals and vegetable markets, that used mainly human waste (sewage).
Hivos	Fund manager for the first Zimbabwe Domestic Biogas Programme in Zimbabwe (2013 – 15). Zimbabwe Energy Regulatory Authority (ZERA) – funded the development of biogas standards in Zimbabwe.
Standards Association of Zimbabwe (SAZ)	Standards development partner who produced two biogas standards for Zimbabwe.

Table 11: Overview of other actors active in organic waste management and a detailed description of their activities

Name	Description
Zimbabwe Sunshine Group	Operate a waste transfer station were waste is separated and sold to recyclers. Organic waste is collected separately from a small number of customers.
RESQ Energy	Interested in setting up Asher Incineration plants at municipal levels and selling the ash to brick paving making companies
Local Authorities	They are all involved in the collection and transportation of household waste to the landfills/ dumpsites. However, in recent years some of the have partnered private sector and or non-governmental organizations in organic waste valorisation. For example Mutare City Council partnered Care International in empowering communities of organic waste composting. Harare City Council partnered GIZ, Zim Sunshine group in organic waste valorisation. Harare City Council partnered several organidsations amnong them Zimbabwe Earthworms in development of organic fertlizer, GIZ in development of Integrated Solid Waste Management Plan and Oxfam in establishment of Biogas Incinerator. Recently Harare City partnered Geogenix BV to build waste to energy EPC power plant in Pomona the largest dumpsite in the capital city. Bulawayo City Council partnered Pragmalea for establishment of waste to energy plant.

The actor analysis shows that actor are already quite some private players active in organic household waste valorisation. Some are involved in biogas (Zonful Energy and Onyx Earth Biogas), while others are active in making organic or blended fertilizers (Zimbabwe Earthworm Farms, Diana Huku Mombe and Org Fert). One actor is involved in organic waste to ash for paving bricks manufacturers. These players all mainly use agricultural waste as feedstock, not organic household waste.

4.2.2 Current market status

Composting

There is huge market potential for compost and fertilizer made out of household organic waste since commercial farms purchase about 350.000 tons of chemical fertilizer per year and small holder farms about 100.000 tons, of which most is imported. The prices of chemical fertilizer vary depending quality and type, but usually range between 430-50$ for a 50kg bag. Most small scale and subsistence farmers cannot afford this, and have been using animal manure, crop straws and composts from their gardens as fertilization for many years. There is also organic compost on the market, with prices starting from 7-10$ per 50kg bag and blended fertilizers between 20-30$ per bag. Note that the organic and blended fertilizers currently available are made from agricultural waste, not household organics. Innovation is needed to develop processes to make high quality compost and fertilizers from organic household waste. Additionally, one would need to receive a steady stream of raw materials for composting (i.e. organic household waste) in an economic manner. Thus proper separation and collection routes for organics will be key.

Compost use has been mainly been produced at farm level for subsistence use. Uptake of compost for organic household waste valorisation has been low because of lack of knowledge and awareness on technology for value addition and access to technological equipment. Most of those who know about organic waste valorisation, only know the conventional way of manually digging pits, put organic matter and backfill the pits. Therefore there is limited awareness on proper composting process including choice of organic material, and temperature regulations has compromised the quality of compost fertilizer. Additionally, there is limited market knowledge of the nutrient composition of organic compost as compared to chemical fertilizer. As a result, there is lack of confidence in the performance of organic fertilizers as compared to chemical fertilizers in commercial agriculture. Chemical fertilizers are fully marketed on both radio stations and television, their nutrient composition and expected yields from their use is well known and as a result their demand is high.

There is no clear policy that supports the organic waste valorisation. Government through the Ministry of Agriculture is the major influence of adoption and demand of agriculture inputs such as seed and fertilizers. For example, in the Presidential Input Scheme program, farmers are supported with inputs such as seed and fertilizers. If organic fertilizer was part of the inputs in the scheme, the demand and awareness of the fertilizer was going to rise. There is lack of investment plan on and no distinct policy support on organic waste valorisation.

There general public perception on the effectiveness of organic compost is negative as compared to commercial fertilizers. However, with the increasing knowledge and awareness on health living, demand of organic foods has been on the rise during last few years. This resulted in formation of associations and forums such as Zimbabwe Organic Producers and Promoters Association (ZOPPA) and Zimbabwe include Zimbabwe Smallholder Organic Farmers Forum (ZIMSOFF) who are promoting consumption of organic foods. This emerging trend is promoting the use of organic fertilizers/ compost in vegetables and crop production.

There seems to be economic potential for organic compost and fertilizer, if the quality standards can be competitive to chemical fertilizer. The scale in which the compost is produced matters a lot. For **household level** compost one only requires a composting bin, space and an outlet such as their own garden, a communal garden or a collective aggregation and sales/purchasing mechanism so households do not need to worry about selling the small amounts of compost they produce. For **community level** compost a lot more is needed. Households need to separate organics and there needs to be a separated collection infrastructure available or households need to be incentivized to bring their organics to the community compost facility. Additionally there needs to be a clear outlet/market for the compost that is made and the quality of the compost needs to be acceptable to the market. The distribution of responsibilities and the ownership of the facility (including responsibility and costs of maintenance which is often neglected) needs to be very clear from the start. For **commercial level** compost one can make use of economies of scale, reducing the costs per produced unit and creating a potential profitable private business. A commercial scale compost facility however does require large volumes of organics. It thus requires a vast infrastructure for collection and separation of organics. Because one does not work with a dedicated community in this model, households need to be incentivized to separate via other mechanisms. Also quality guarantee is an important focus point to sell commercially.

Anaerobic digestion (biogas)

There is huge market potential for biogas production. The feedstock is free (compared to LPG) and after procurement only maintenance costs remain. The biogas can be used for various functions such as cooking, lighting, heating, cooling or as electricity production. On the African continent various sizes of digesters are already available and different types of business models are being applied to give people with insufficient financial means the opportunity to acquire digesters as well (pay-go, lease). Note that the biogas digesters currently available mainly function on human and animal waste, not household organics. Innovation is needed to develop processes to make high quality biogas from organic household waste. Additionally one would need to receive a steady stream of raw materials (i.e. organic household waste) in an economic manner.

The prices for a biogas digester differ greatly per scale. For a small prefabricated household digester one can expect to pay US$700-1000 in monthly payments over a period of 36 months. Such a digester requires 6kgs of waste per day. Larger digesters at municipality level would costs around US$60,000 including labour and materials for a 200m^3 digester, which makes enough gas for 200 households. Since biogas is a low pressure gas, it needs to be pressurized for efficient transport over longer distances. Pressurization is rather expensive, a booster pump costs roughly US$25k for 25cum/hour pumping capacity.

There seems to be economic potential for organic waste based biogas digesters, if quality standards can be competitive to those based on human and livestock waste. The scale in which the biogas is produced matters for the challenges that need to be overcome. For **household level** biogas production, the household needs to buy quite an expensive digester and invest in equipment that works on biogas, such as cooking equipment, lighting or cooling tools. It will most likely not be economically interesting to sell the gas, since the volumes will be low. Transport and pressurization of biogas is also to expensive for such small volumes. For **community level** biogas production households need to separate organics and there needs to be a separated collection infrastructure available or households need to be incentivized to bring their organics to the community biogas digester. Additionally there needs to be a clear outlet/market for the biogas that is made, which can either be the community itself which is then connected via pipelines or buys biogas in unpressurized tanks or the wholesale market which requires pressurization. The distribution of responsibilities and the ownership of the facility (including responsibility and costs of maintenance which is often neglected) needs to be very clear from the start. For **commercial level** biogas production one can make use of economies of scale, reducing the costs per produced unit and creating a potential profitable private business. A commercial scale biogas facility however does require large volumes of organics. It thus requires a vast infrastructure for collection and separation of organics. Because one does not work with a dedicated community in this model, households need to be incentivized to separate via other mechanisms. Also quality guarantee is an important focus point to sell commercially. Additionally the investment costs are quite high, the gas needs to be pressurized and one would need quality guarantees to sell on the wholesale market.

4.2.3 Challenges experienced by the processing sector

The interviews and learning visits to the processing sector highlighted some key challenges they experience that limits them from scaling their business and which they believe limits scaling of the organic processing industry in general.

The first challenge is **getting sufficient volumes in an economic manner**, the lack of separation at source, collection infrastructure, and post collection separation, results in large difficulties in getting sufficient volumes in an economic manner. The organic household material market is almost non-existent, with hardly any waste pickers collecting organic materials. Organic waste is only separated at sparse waste transfer stations or collected separately in about 1% of the households.

The second challenge has to do with **low margins on products from household organics.** For compost and fertilizers this is because of quality issues, lack of regulation and insufficient raw material supply. For biogas this is because the margins per unit of sale are low due to the high upfront costs and difficulty in economy of scale. Also biogas production requires a steady stream of raw materials and a vast transport network including expensive pressurization.

5 Summary of gaps identified

This section provides an overview of the key conclusions and gaps in the current landscape for plastics management, as well as the concluding advice on the relevance of the different pathways for Zimbabwe.

5.1 Key gaps within the technology landscape

In terms of technology development and application it can be concluded that the key gaps are not related to the lack of existing technologies – as for each of the pathways (compost, AD, solid fuel production and animal feed production) technologies are readily available. The main gap is the low implementation and spread of these technologies:

- There is currently no community level biogas production for solid organic waste
- There is currently no commercial scale biogas production
- There is no conversion of biogas into electricity
- There are currently only limited small or community scale composting or vermicomposting initiatives
- There is currently no commercial scale composting based on UOW (there are a few on commercial agricultural waste)
- There are only a few entrepreneurs working with Black Soldier Flies
- There is little domestic technology development for larger scale composting or biogas production. This means everything has to be imported and challenges arise when equipment breaks down.

5.2 Summary of the key gaps in the current policy landscape

In terms of policy landscape and implementation, there are multiple gaps regarding the way Circular Economy principles are addressed:

- Mismatch between what the policy envisions and allocation of resources to facilitate implementation (competing interests and limited budgets).
- The Environmental Management Act has adopted a punishment approach to non-compliance with no mention of incentives, but keen on fees, fines, and imprisonment consequences for defaulters.
- There is limited information and database on the quantities of waste. Data is a key enabler to decision making.
- Slow creation of local demand for organic waste with the specific attention in the policy documents.
- There is low focus on the potential of organic waste to organic fertilizer conversion in comparison to organic waste to energy.
- Inadequate budgetary allocation extending to the development of infrastructure.
- Low levels of coordination between sector players (including ministerial level) on the alignment of policies to enhance adoption of technology to promote use of organic waste for fertilizer and energy.
- Low levels of implementation of existing regulations; the EPR scheme from voluntary to mandatory stage to support the commitment from the private sector to curb packaging pollution.

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5.3 Gaps within current markets and value chains

In terms of current markets and value chains, the market and value chain assessment of organic household waste valorisation shows that the key gaps is getting sufficient volumes in an economic manner. Together with issues of quality and lack of regulations for fertilization and expensive upfront costs and issues with economy of scale for biogas, this leads to low margins made from organic household waste products. Which results in a vicious circle where collection infrastructure (e.g. separation, waste pickers, collection) does not scale due to low prices, and processing industry not getting sufficient volumes in an economic manner meaning they cannot pay collection infrastructure more for delivering organics.

5.4 Conclusions on the relevance of the technology pathways to Zimbabwe

Based on the assessment of the pathways, the study of the current policy framework and the development of current markets and value chains it is expected that within the next ten years, the most important pathways for Zimbabwe will be composting and biogas production on various scale, complemented with animal feed production. The production of solid fuel is not advised due to the high environmental impacts and the low benefits. Composting is expected to have the highest potential, as the technologies are readily available and investment costs are lower compared to biogas production. Moreover, there is huge market potential for compost and fertilizer made out of household organic waste since commercial farms purchase about 350.000 tons of chemical fertilizer per year and small holder farms about 100.000 tons, of which most is imported and which could potentially be substituted with organic compost and fertilizer. This can also contribute greatly to the improvement of soil quality, reducing the risks of depleting the soil and losing food production capacity. For lower income areas, home composting could be a solution, as this supports these communities with self-sustaining their food production. A full transition to home composting is not advised as commercial scale composting needs sufficient feedstock (albeit in earlier stages complementation with agricultural residues will probably be needed anyways, until collection and separation is fully developed). In addition to composting there is huge market potential for biogas production as well. It is expected home biogas production will expand, as market parties already take this up. It would be interesting to look into the potential for biogas production on community and commercial scales, as the currently existing systems run on human and animal waste, and not household organics. Animal feed production based on for example Black Soldier Flies could be an interesting third pathway to focus on, but which due to usually acceptable revenues compared to the investment costs will be taken up by the market and need less support from the side of government, compared to composting and AD.