Deutsches Biomasseforschungszentrum
gemeinnützige GmbH

DBFZ

DBFZ REPORT NR. 45

Status-Quo of organic waste collection, transport and treatment in East Africa and Ethiopia

Authors: Markus Lenhart, Marcel Pohl, Michael Nelles (DBFZ),
Jan Sprafke, Carina Zimmermann, Abdallah Nassour (RETech),
Ferew Bekele, Silvia Vanzetto (Cifa Onlus)

Supported by: german cooperation DEUTSCHE ZUSAMMENARBEIT; PREVENT Waste Alliance

in Collaboration with: German RETech Partnership Recycling & Waste Management Made in Germany; cifa FOR PEOPLE

IMPRINT

Publisher:
DBFZ Deutsches Biomasseforschungszentrum
gemeinnützige GmbH
Torgauer Straße 116
04347 Leipzig
Phone: +49 (0)341 2434-112
Fax: +49 (0)341 2434-133
info@dbfz.de

Funding:
DBFZ Deutsches Biomasseforschungszentrum gemeinnützige GmbH, Leipzig, an enterprise of the German Government with funding from the Federal Ministry of Food and Agriculture pursuant to a resolution by the German Bundestag.

With support from

Federal Ministry
of Food
and Agriculture

by decision of the
German Bundestag

General Management:
Prof. Dr. mont. Michael Nelles
(Scientific Managing Director)
Dr. Christoph Krukenkamp
(Administrative Managing Director)

DBFZ Report Nr. 45
Status-Quo of organic waste collection, transport and treatment in East Africa and Ethiopia
Leipzig: DBFZ, 2022
ISSN: 2197-4632 (Online)
ISBN: 978-3-946629-87-0
DOI: 10.48480/5qsb-t569

Authors:
Markus Lenhart, Marcel Pohl, Michael Nelles (DBFZ),
Jan Sprafke, Carina Zimmermann, Abdallah Nassour (RETech), Ferew Bekele, Silvia Vanzetto (Cifa Onlus)

Pictures:
If not indicated on the image: DBFZ, Stefanie Bader (Map),
Frontpage: Adobe Stock/Cifa Onlus (2nd row, right)

Date of Publication:
22/08/2022

DIRECTIONS

By train: Arrival Leipzig main station; streetcar line 3/3E (direction Taucha/Sommerfeld) to stop Bautzner Straße; cross the street, leave the parking lot on the right and use the main entrance of the DBFZ (house 1, Torgauer Str. 116). Please register at the reception

By car: on the A 14 motorway. Exit at Leipzig Nord-Ost; follow signs for Taucha; then follow signs for Leipzig; then follow signs for Zentrum, Innenstadt. Turn off left after the “bft” filling station (see “By train” for further directions).

By tram: line 3/3 E towards Taucha/Sommerfeld; Bautzner Strasse stop (see “By train” for further directions)

The German National Library lists these publications in the German National Bibliography; detailed bibliographic data are available on the Internet at the address www.dnb.de.

This publication was produced with the financial support of the PREVENT Waste Alliance, an initiative of the German Federal Ministry for Economic Cooperation and Development (BMZ). The contents of this publication are the sole responsibility of the authors and do not necessarily reflect the positions of all PREVENT Waste Alliance members or official policy positions of the governments involved.

PREVENT Waste Alliance Secretariat
GIZ GmbH
E-Mail: contact@prevent-waste.net
Website: www.prevent-waste.net/en

german
cooperation
DEUTSCHE ZUSAMMENARBEIT

PREVENT
Waste Alliance

Deutsches Biomasseforschungszentrum
gemeinnützige GmbH

Status-Quo of organic waste collection, transport and treatment in East Africa and Ethiopia

Markus Lenhart, Marcel Pohl, Peter Kornatz, Michael Nelles (DBFZ), Jan Sprafke, Carina Zimmermann, Abdallah Nassour (RETech), Ferew Bekele, Silvia Vanzetto (Cifa Onlus)

DBFZ Deutsches Biomasseforschungszentrum
gemeinnützige GmbH

Torgauer Straße 116
04347 Leipzig

Phone: +49 (0)341 2434-112
Fax: +49 (0)341 2434-133

www.dbfz.de
info@dbfz.de

german cooperation
DEUTSCHE ZUSAMMENARBEIT

PREVENT
Waste Alliance

Date: 04.07.22

Contact:

DBFZ Deutsches Biomasseforschungszentrum gemeinnützige GmbH
Torgauer Straße 116
04347 Leipzig
Phone: +49 (0)341 2434-112
E-Mail: info@dbfz.de
Internet: www.dbfz.de

M. Sc. Markus Lenhart
Phone: +49 (0)341 2434-382
E-Mail: markus.lenhart@dbfz.de

Dr.-Ing. Marcel Pohl
Phone: +49 (0)341 2434-471
E-Mail: marcel.pohl@dbfz.de

Dr. agr. Peter Kornatz
Phone: +49 (0)341 2434-716
E-Mail: marcel.pohl@dbfz.de

Prof. Dr. Michael Nelles
Phone: +49 (0)341 2434-112
E-Mail: michael.nelles@dbfz.de

German RETech Partnership e. V.
Kalckreuthstraße 4
10777 Berlin
Phone: +49 30 31582-563
Fax: +49 30 31582-400
E-Mail: info@retech-germany.net
Web: www.retech-germany.net

Dr.-Ing. Jan Sprafke
Phone: +49 3814034994
E-Mail: jan.sprafke@retech-germany.net

Carina Zimmermann
Phone: +49 176 19090940
E-Mail: carina.zimmermann@retech-germany.net

PD. Dr.-Ing. habil. Abdallah Nassour
Phone: +49 381 498-3403
E-Mail: abdallah.nassour@uni-rostock.de

CIFA Onlus
Torino, via Foscolo, 3 – 10126
Phone: +39 011 433 80 59

E-Mail: progetti@cifaong.it
Internet: www.cifaong.it

Silvia Vanzetto
Phone: +251 926942631
E-Mail: silviavanzetto@gmail.com

Ferew Bekele
Phone: +251 913929578
E-Mail: pcaddis.eth@cifaong.it

PREVENT Waste Alliance Secretariat
GIZ GmbH
E-Mail: contact@prevent-waste.net
Website: www.prevent-waste.net/en

Date of creation:	04.08.2022
Project number DBFZ:	P3210074
Projectnumber principal or grant authorities:	This publication was produced with the financial support of the PREVENT Waste Alliance, an initiative of the German Federal Ministry for Economic Cooperation and Development (BMZ). The contents of this publication are the sole responsibility of the authors (see above) and do not necessarily reflect the positions of all PREVENT Waste Alliance members or official policy positions of the governments involved.
Total amount of pages + Annex	102

Citate as following:

Lenhart, M.; Pohl, M.; Sprafke, J.; Zimmermann, C.; Bekele, F.; Vanzetto, S.; Nassour, A.; Nelles, M. (2022): Status-Quo of organic waste collection, transport and treatment in East Africa and Ethiopia. (DBFZ-Report, 45). Leipzig: DBFZ. 88 S. ISBN: 978-3-946629-87-0. DOI: 10.48480/5qsb-t569

German RETech Partnership
Recycling & Waste Management
Made in Germany

FOR PEOPLE

Table of content

List of abbreviations and symbols

Abbreviations	Explanation
AACA	Addis Ababa City Administration
ACCP	African Clean Cities Platform
ACSWMA	Addis Ababa City Solid Waste Management Agency
ABPP	The Africa Biogas Partnership Programme
CABI	Name of a Non-Profit Organization
CSA	Central Statistical Agency
EAC	Eastern African Country
EHPEA	Ethiopian Horticulture Producer Exporters Association
EPA	Environmental Protection Agency
ETB	Ethiopian Birr
ESA	Ethiopia Standard Agency
EWTI	Ethiopia Water Technology Institute
FDRE	Federal Democratic Republic of Ethiopia
GDP	Gross Domestic Product
GEF	Global Environment Fund
GNI	Gross National Index
HNI	High Income Country
HoAREC	Horn of Africa Regional Environmental Centre and Network
IAIP	Integrated Agro-Industrial Park
IGNIS	the Income Generation & Climate Protection
ISO	International Organization for Standardization
LIC	Lower-Income-Country
LMC	Lower-Medium-Income-Country
MoEFCC	Ministry of Environment, Forestry and Climate Change
MoH	Ministry of Health

MoUDH	Ministry of Urban Development and Housing
MoWIE	The Ministry of Water, Irrigation and Electricity
MSE	Micro Small Enterprise
MSW	Municipal Solid Waste
MSWM	Municipal Solid Waste Management
NAMA	Nationally Appropriate Mitigation Action
NCC	Nairobi City County
NDC´s	Nationally Determined Contributions
NBPE	National Biogas Program of Ethiopia
NBPE+	The Biogas Dissemination Scale-Up Program
RANAS	Risk Attitude Norm Ability Self-regulation
SBPDA	Beautification and Park Development Authority
SSA	Sub Saharan Africa
SWM	Solid Waste Management
UMC	Upper-Medium-Income-Country
UNDP	United Nation Development Program
UNEP	United Nation Environment Program
UNSD	United Nation Statistics Division
USD	United State Dollar
VPO	Vice President's Office
ZEMA	Zambia Environmental Management Agency

Preface

This publication was elaborated in the context of the pilot project "Guideline for organic waste treatment in East Africa" as part of a call for solutions by the PREVENT Waste Alliance. The aim of the project is to develop a legal, technical and economic guideline for dealing with organic waste as a basic strategy for politics, administration, research and the private sector for East African countries using the example of Ethiopia.

The guideline is supposed to be a profound basis to apprise decision-makers of a range of efficient and well-proven technical solutions in organic waste handling and give planners and builders a good starting point for future planning.

The purpose of this publication is to provide a general overview of the current state of organic waste management in East African countries, specifically using Ethiopia as an example, and thus represents the first part of the guideline. In a further step, technical solution will be developed on the basis of the knowledge compiled here and presented in a subsequent report.

1 Introduction

Poor management of solid waste is a universal issue which causes huge environmental, social, and financial costs to the global community. On the other hand, an integrated and holistic approach in the solid waste management system, which refers to both a better management of municipal waste as well as reducing waste generation, will substantially help to cope with the waste crisis affecting the world nowadays. Considering the waste as a potential resource will both contribute towards reduction of residual waste and will represent a concrete support to the circular economy development.

In regard to solid waste management, particular attention needs to be given to the emerging economies: countries that are shifting from low-income to middle- or high–income level will in fact experience an increment in per capita waste generation and an exacerbation of management difficulties due to the growth in prosperity and to the movement to urban centers. In this sense, waste generation and management constraints in Sub-Saharan Africa region are expected to increase at a higher rate than for any other region (Kaza et al. 2021). This study will focus on solid waste management in Eastern African countries, with a particular attention to organic waste fraction, including agricultural residues.

Waste management is one of the most important municipal employment services. To continue the various sub-sectors such as waste collection, transport, treatment and landfilling in combination with street cleaning, municipalities have to master great organisational and financial challenges and often overtax them (Pfaff-Simoneit 2012). In addition, the integration of the informal sector into existing and new structures under aspects of work safety and services of general interest is of great importance to civil society.

Dumping domestic and various other waste streams in irregular and open dumps in rural and urban areas together with uncontrolled incineration are common practices in East Africa. In particular, the proportion of non-native organic matter like recyclables and impurities in the waste pose a great danger for flora and fauna in the indirect and direct neighbourhood. To separate native organics from other waste streams, the establishment of adapted collection and treatment structures is expedient and indispensable.

The uncontrolled disposal of waste, especially organic waste, in public spaces is dangerous and often a source of contamination. Furthermore, waste is an attractor of pests and insects. In addition, high temperatures promote the development of pathogens that can lead to diseases of the gastrointestinal tract. Diseases such as hepatitis and cholera are also not uncommon in waste environments. Water can collect in impermeable waste components, where mosquitoes multiply and transmit diseases such as dengue fever, malaria, and yellow fever (ACCP 2019).

Improper organic waste treatment can promote the production of landfill leachate, which in the worst case can lead to groundwater and surface water contamination. Consequently, this in time has impacts on humans, animals, and plants in the surrounding area. In addition, uncontrolled methane and nitrous oxide emissions from open landfills promote the greenhouse effect and thus exacerbate the effects of global warming. In this respect, methane emissions are about 30 times as impactful as CO2 emissions. Methane emissions come exclusively from the organic fractions of the waste. Accordingly, adequate waste management of organic waste has a great influence on the reduction of greenhouse gases. There are also many other problems caused by mismanagement of organic waste, such as odour nuisance, the aesthetics of the residential environment and the danger to residents from flue gases from open incineration.

Illegally disposed waste and waste drifts are an infrastructural problem. For example, waste clogs drainage and irrigation channels contaminate groundwater and affects infrastructural traffic. The disorderly disposed waste also affects the aesthetics of a city and is an indirect sign of the efficiency of municipal administration (Pfaff-Simoneit 2012).

A special aspect in the development of waste management concepts is the temporal discrepancy between the purchase of a consumer good and its disposal in terms of the consumer's will to dispose of it. This problem is less important in the case of organic waste, but it does have an influence on the specific waste volume of residual waste and the proportion of impurities and other contaminants in the organic sub-fraction. With increasing prosperity, it can be assumed that the proportion of impurities and contaminants will increase and the total proportion of organic matter in residual waste will decrease.

This study is conducted as part of the project “Guideline for organic waste treatment in East Africa” which is carried out in the framework of a PREVENT Waste Alliance initiative. The Programme “Call for Solutions” was launched to foster innovative and scalable solutions to build a circular economy. This initiative acknowledges the fast-growing pace some of the most populated among the East African Countries are experiencing and aims at addressing the Municipal Solid Waste Management (MSWM) system in a way that possibility to recover sustainable energy and essential resources from organic waste is fully valorised.

The study will analyse the current status and the trends for waste generation and management in East Africa, focusing mainly on the organic fraction. Available technologies for organic waste processing and their applications in the specific context will be presented, also considering the relevant ongoing projects.

1.1 Project targets

The aim of the project "Guideline for organic waste treatment in East Africa" is to develop a legal, technical, and economic guideline for dealing with organic waste as a basic strategy for politics, administration, research and the private sector for East African countries using the example of Ethiopia.

In terms of content, the project pursues four main objectives in this regard:

- the evaluation of the status quo in the handling of organic waste,
- the establishment of a working group with a broad range of expertise and networking with local actors in Ethiopia,
- the proposal of suitable technical solutions,
- the transfer of knowledge to decision-makers and target groups by means of a guideline.

The crucial first step to support Ethiopia in building a circular economy is the provision and the dissemination of general information on locally adapted waste management solutions based on evaluated data. This way, local decision makers will be enabled to select appropriate solutions for their individual needs, which can even be transferred beyond the borders of Ethiopia to other East African countries with comparable local conditions.

In establishing the various treatment options, it is essential to develop concepts adapted for different development structures. The concepts will be developed for the following structures:

- Metropolises (very strongly urban)
- Semi-urban to urban areas
- Rural areas

The present study will serve as a baseline to national and international experts for developing the legal, technical, and economic guideline for dealing with organic waste.

1.2 Methodological approach

Being the study a general overview on the status quo of solid waste management, the specific analysis was not developed country by country; rather a comparison between countries in relation to organic waste treatment have been conducted. Ethiopia has been analyzed more in detail to have baseline data to design a strategy proposal on organic waste treatment.

Data on waste generation, waste composition, recycling rates and organic waste management have been obtained using secondary sources, as desk research.

In regards of basic data on waste generation, the study uses mainly the dataset of the "What a Waste 2.0" published in 2018, regardless if most recent updates were available for some of the considered countries, so to guarantee a sort of homogeneity in the data comparison. What a Waste 2.0 document is reporting data predominantly from 2011–17 although overall data span about two decades. Notes on data acquisition methodology of the What a Waste 2.0 can be found in its introduction chapter (Kaza et al. 2018, p. 9).

In regard to waste generation growth trends, the data and the projection for the East African countries have been extrapolated from the "What a Waste 2.0" and the most recent and updated publication "More Growth, Less Garbage", 2021 (Kaza et al. 2021) and utilizing population projection data (UNDESA 2019).

Regarding treatment technologies currently implemented in the Eastern Africa, as well as to relevant projects on organic waste management, major information has been gathered by research on the web and through information exchanges with experts of the area.

Data reported for Ethiopia's case studies (Addis Ababa, Hawassa and Gidole) have been collected through interviews conducted by the authors with the concerned stakeholders.

2 Fundamentals and definitions

2.1 Solid Waste, organic waste and technologies for the use of organic waste

This study analyzes the status quo of solid waste in East African countries to have a clear understanding about the potentialities of organic waste of the area.

Solid waste is intended to be the municipal solid waste that is the non-liquid waste from households, small business, industries, and institutions. Medical, hazardous, electronic, and construction and demolition wastes are not considered.

Organic waste is understood as biodegradable waste. According to the "Selecting Organic Waste Treatment Technologies" (SOWATT) manual (Zabaleta et al. 2020, p. 8) biodegradable waste is defined as any waste that can undergo anaerobic or aerobic decomposition, such as food, garden waste, agricultural waste, animal waste, paper and paperboard. To be noted that data on organic waste reported in chapter 3.3.1 are referring to a subset of organic waste, called biowaste. Biowaste comprises only biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises and comparable waste from food processing plants. *It does not include forestry or agricultural residues, manure, sewage sludge, or other biodegradable waste such as natural textiles, paper, or processed wood*. In figure 1 relations between biodegradable waste and biowaste and their potential sources are presented.

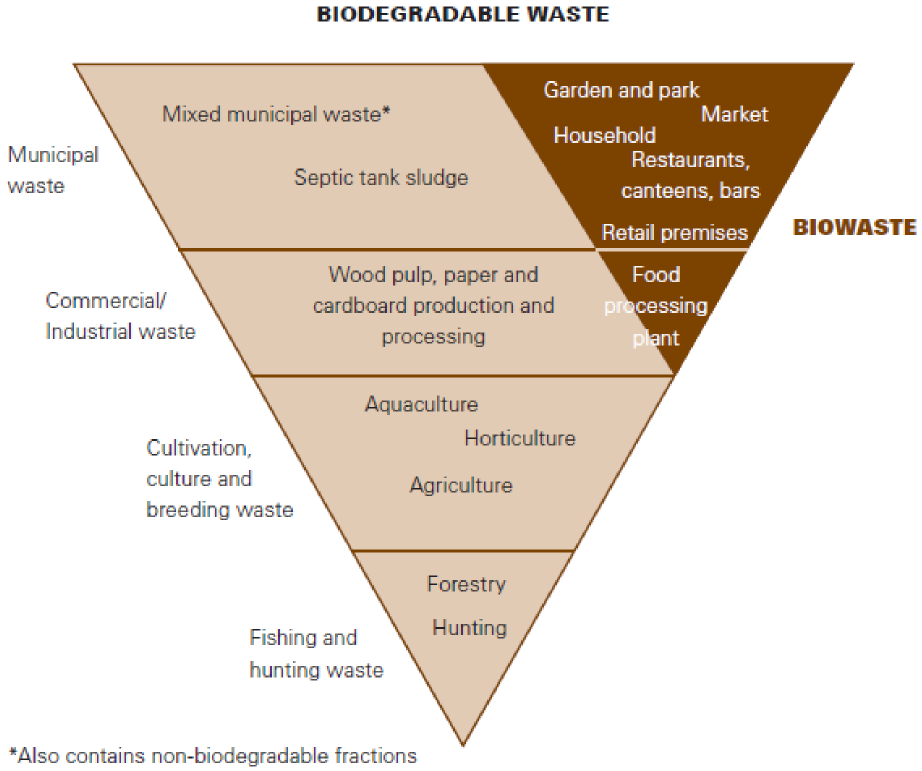


Figure 1: Potential sources of biodegradable waste and biowaste (Zabaleta et al. 2020, p. 8)

Data reported in the following chapters refers to the total waste generation, which represents the whole municipal solid waste regardless of how it is managed. Whenever residual waste is mentioned, it refers to the part of municipal solid waste that is ultimately disposed of, after other fractions are diverted for productive uses. Final disposal methods can include dumping, landfilling and incineration.

Organic waste products are the potential resources that can be obtained by proper treatment technologies, and that can be used as a resource in agriculture, in animal husbandry and for bio-energy production.

Impacts and potentialities of organic waste are the short- and long-term effects of the products of organic waste after its final disposal / end use treatment.

Negative impacts of improper organic waste management are the ones related to the organic waste natural degradation through biological activity (aerobically or anaerobically). In fact, if not properly handled, the organic degradation is very harmful to the environmental and public health, being cause of greenhouse gas emissions and global warming; cause of pollution of soil, water and air; and spread of disease vectors (Zabaleta et al. 2020, p. 9). Impact and consequences of an inappropriate management of organic waste are resumed in figure 2.

Element	Negative impact	Consequence
Soil	Contamination of soil through leachate	Deterioration of public and environmental health
	Devaluation of the fields	Economic costs
Water	Contamination of groundwater through leachate	Deterioration of public and environmental health
	Need for water treatment downstream	Economic costs
Air	Release of greenhouse gases (e.g.: methane)	Global warming
	Bad smell	Deterioration of comfort and public health
Other	Promoting/attracting disease carrying vectors (flies, rodents, etc.)	Deterioration of public health
	Visual pollution	Tourism

Figure 2: Potential impacts of untreated organic waste, table taken from SOWATT manual (Zabaleta et al. 2020, p. 9)

Organic waste treatment technologies have the potential to reduce the negative impact of improper organic waste management by controlling gaseous and liquid emissions while producing high quality products for soil improvement, energy consumption or animal husbandry via different processing pathways. Treatment technologies for source-segregated solid organic waste are grouped into four main categories: (1) direct use, (2) biological treatment, (3) physio - chemical treatment, and (4) thermochemical treatment. All possible pathways treatment technologies, their products and the products' end use are listed in figure 3 (Lohri et al. 2017).

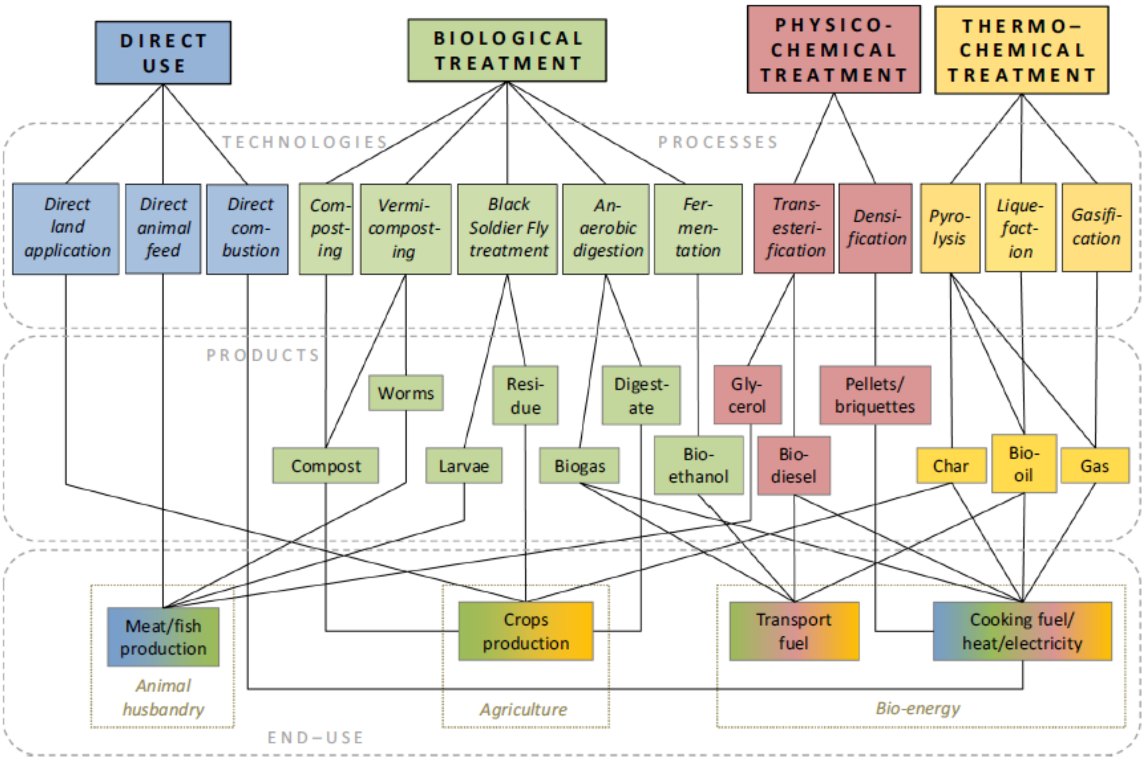


Figure 3: Overview of organic waste treatment technologies with the respective products generated from waste and their end use (Lohri et al. 2017)

2.2 Geographical Context

The study will focus on the status of organic waste management for the East African countries, as per UNSD Standard M49 - East Africa (Intermediate Region Code 014), as visualized in the following map:

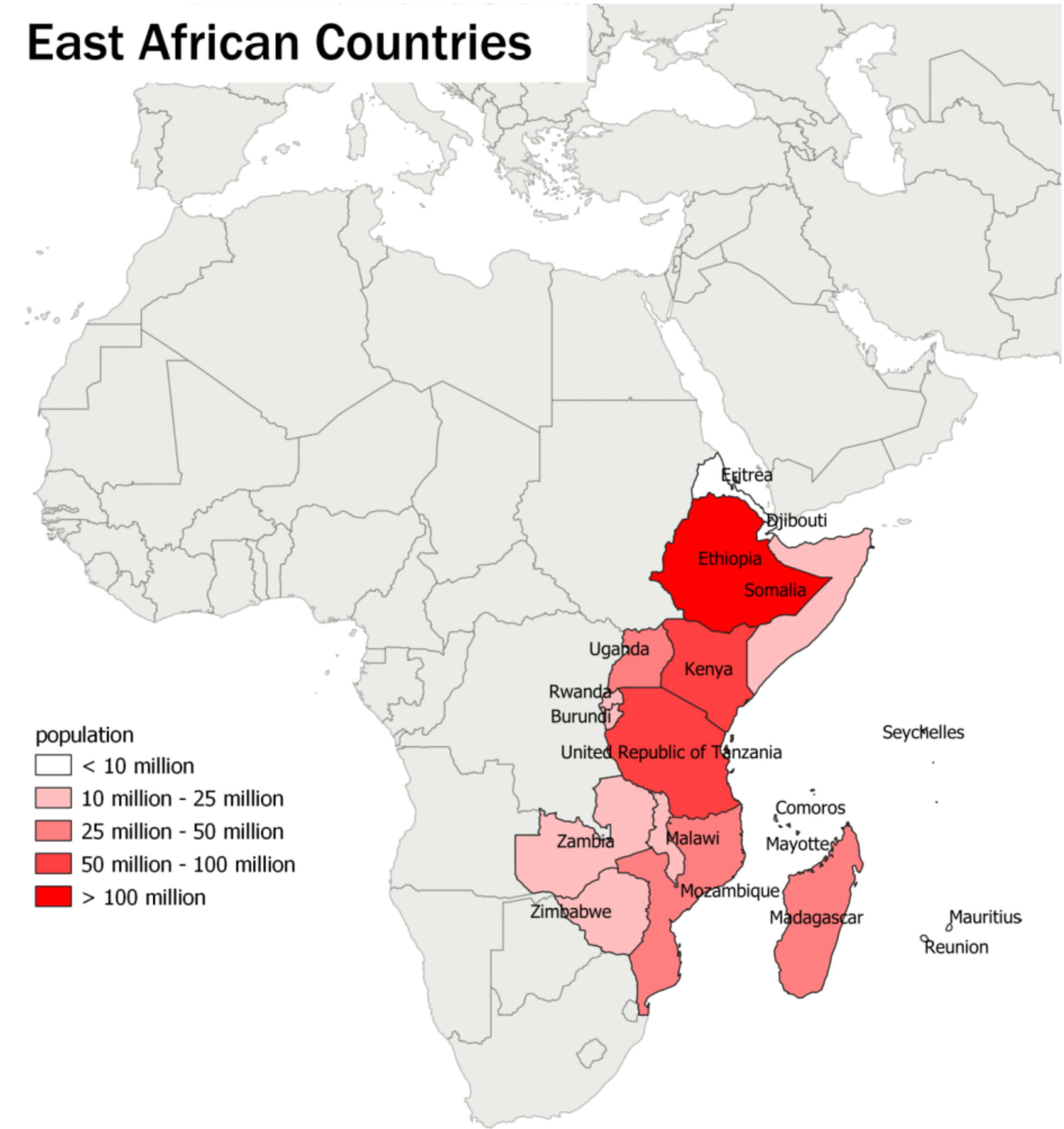


Figure 4: Map of EAC by population 2020 *data from: United Nations, Department of Economic and Social Affairs, Population Division (2019). Probabilistic Population Projections Rev. 1 (United Nations 2019)*

As per UNSD Standard M49, all the countries in Eastern Africa are classified as developing countries (UN Statistics Division 2021).

Table 1: List of Countries in Eastern Africa Region, Code 14, UNSD Standard (UN, n.d.)

Country or Area	M49 Code	ISO-alpha2 Code	ISO-alpha3 Code	Least Developed Countries (LDC)	Land Locked Developing Countries (LLDC)	Small Island Developing States (SIDS)	Developed / Developing Countries
British Indian Ocean Territory	86	IO	IOT				Developing
Burundi	108	BI	BDI	x	x		Developing
Comoros	174	KM	COM	x		x	Developing
Djibouti	262	DJ	DJI	x			Developing
Eritrea	232	ER	ERI	x			Developing
Ethiopia	231	ET	ETH	x	x		Developing
French Southern Territories	260	TF	ATF				Developing
Kenya	404	KE	KEN				Developing
Madagascar	450	MG	MDG	x			Developing
Malawi	454	MW	MWI	x	x		Developing
Mauritius	480	MU	MUS			x	Developing
Mayotte	175	YT	MYT				Developing
Mozambique	508	MZ	MOZ	x			Developing
Réunion	638	RE	REU				Developing
Rwanda	646	RW	RWA	x	x		Developing
Seychelles	690	SC	SYC			x	Developing
Somalia	706	SO	SOM	x			Developing
South Sudan	728	SS	SSD	x	x		Developing
Uganda	800	UG	UGA	x	x		Developing
United Republic of Tanzania	834	TZ	TZA	x			Developing
Zambia	894	ZM	ZMB	x	x		Developing
Zimbabwe	716	ZW	ZWE		x		Developing

There are instead some differences in the classification per income (see figure 5). In fact, while most of the Eastern African Countries are within low and lower-middle income status, the small islands with income derived from tourism sector are located in higher status: Mauritius is classified as an upper-middle income country and Seychelles as a high-income country.

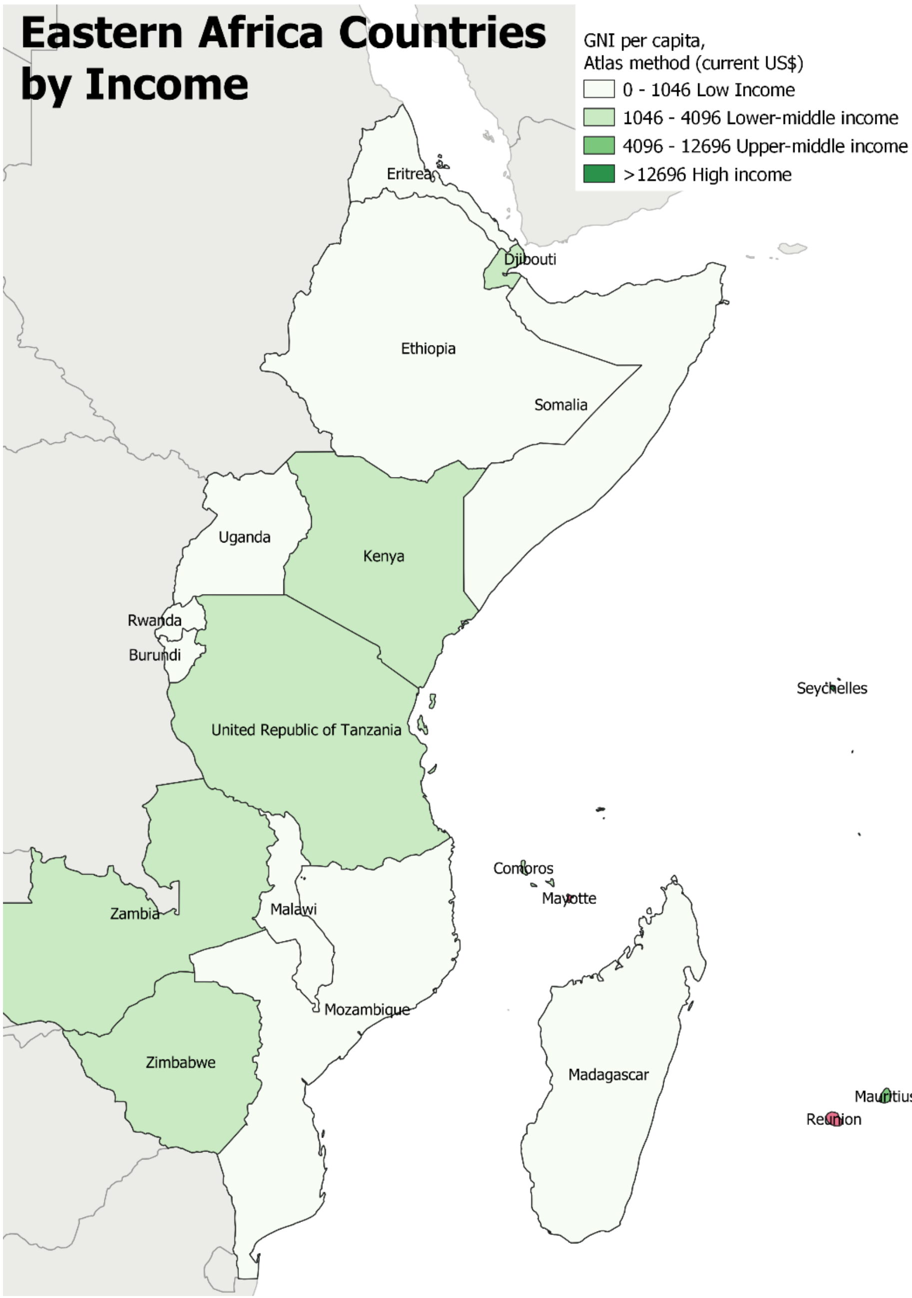


Figure 5: East African countries World Bank Classification by Income, Gross National Income per capita, June 2021

As per climate perspective, the Eastern Africa is characterized by a major dry climate with a huge diversity of climatic conditions. The different types of climates are equatorial (Congo Basin and Lake Victoria Basin), moist tropical (Central and Western Uganda and parts of Northern Uganda), dry tropical (several parts of East Africa mainly adjacent to the semi-arid region), semi-arid and arid (Northern Kenya, North-Eastern Uganda, semi desert in Southern, North -Eastern parts of Tanzania and central Tanzania), montane/alpine (mountain peaks of East Africa) and tropical monsoon (Coastal Regions). The diversity of climate zones is due to the complexity of the terrain and led to a variegate vegetation, biodiversity, and human occupations (Camberlin 2018, p. 1).

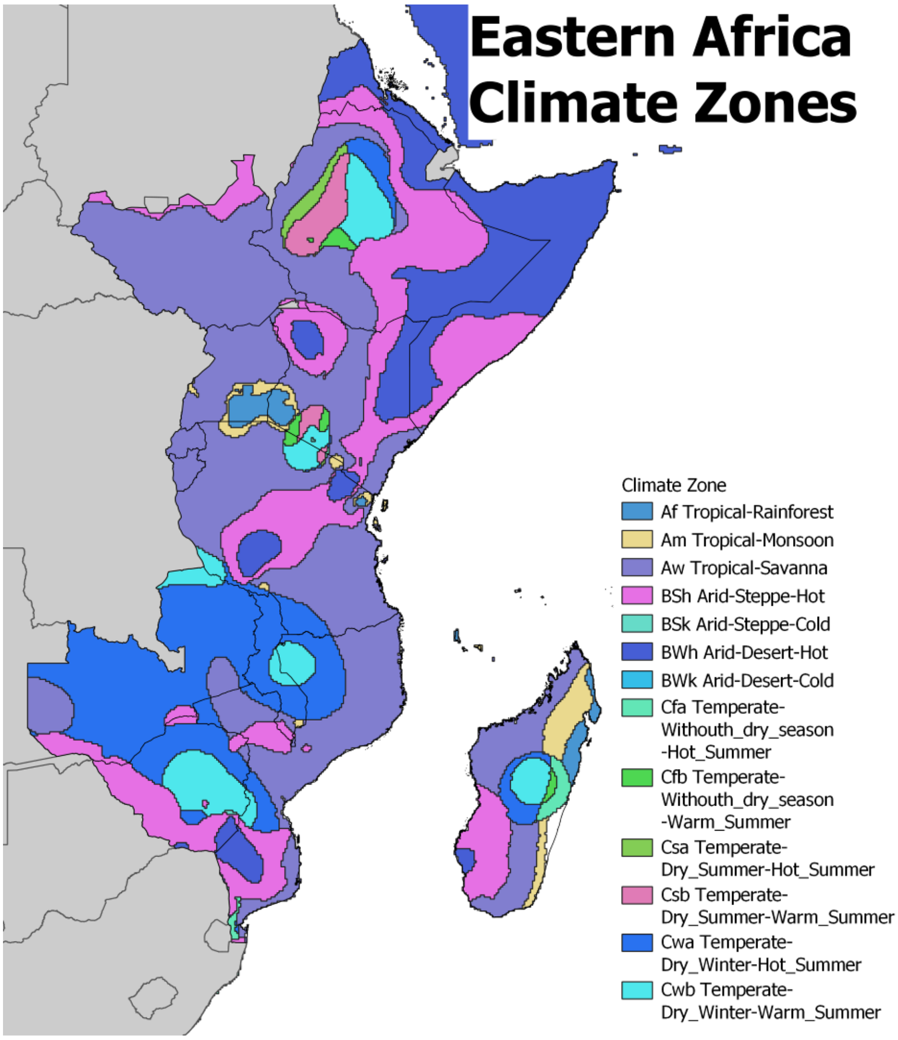


Figure 6: Climate zones in Eastern Africa according to Köppen-Geiger climate classification (Peel et al. 2007)

Vegetation is very varied. The map of potential natural vegetation of eastern Africa, prepared by a team of scientists from the World Agroforestry Centre (ICRAF) and the University of Copenhagen (UCPH), distinguishes 48 vegetation types, divided in four main vegetation groups: 16 forest types, 15 woodland and wooded grassland types, 5 bush-land and thicket types and 12 other types. The map of vegetation is available for consultation in the Biography (https://vegetationmap4africa.org/, 2022).

In regard to the status quo of organic waste, this study is affected by the limited numbers of publications and literature about the waste management specifically for Eastern African countries. Not all the listed countries have therefore been considered in the general data analysis. In particular, no data was found for British Indian Ocean Territory, French Southern Territories, Mayotte, Réunion while for Djibouti the analysis is limited by absence of data in What a Waste 2.0 dataset.

3 Results

3.1 Solid waste generation and composition in Eastern Africa

3.1.1 Solid waste generation

The total solid waste generated in Sub-Saharan Africa in 2016 was estimated to be 174 million metric tons a year, of which 52.6 million metric tons was from Eastern Africa countries. The average per capita waste generation in Sub-Saharan Africa in 2016 was calculated to be less than 0.5 kg/day/capita, which is much lower than the global average of 0.74 kg per day indicated in What a Waste 2.0 report (Kaza et al. 2018, p. 77). However, if we just consider the Eastern Africa countries, the average per capita waste generation increases by around 22 percent compared to the Sub-Saharan waste generation, with considerable spatial differences in the amount of waste generated (figure 7), which ranges from as low as less than 0.2 kg per day in Ethiopia to as high as 1.6 kg per day in the Seychelles or 1 kg per day for the Mauritius. High per capita waste generation rates reported for small-island States are quite common, often owing to high levels of tourism and better waste accounting (UNEP 2018, p. 24).

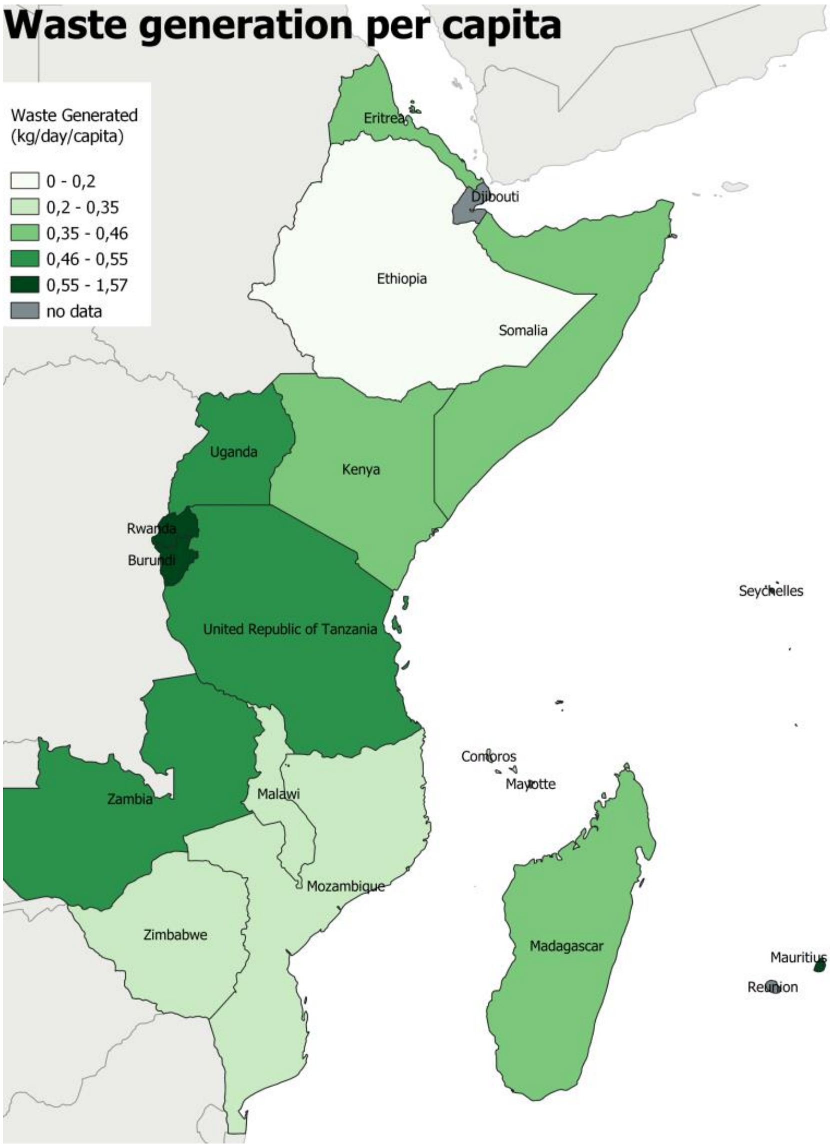


Figure 7: Spatial representation of waste generation per capita in Eastern Africa - data extrapolated from What a Waste 2.0 (Kaza et al. 2018, p. 78)

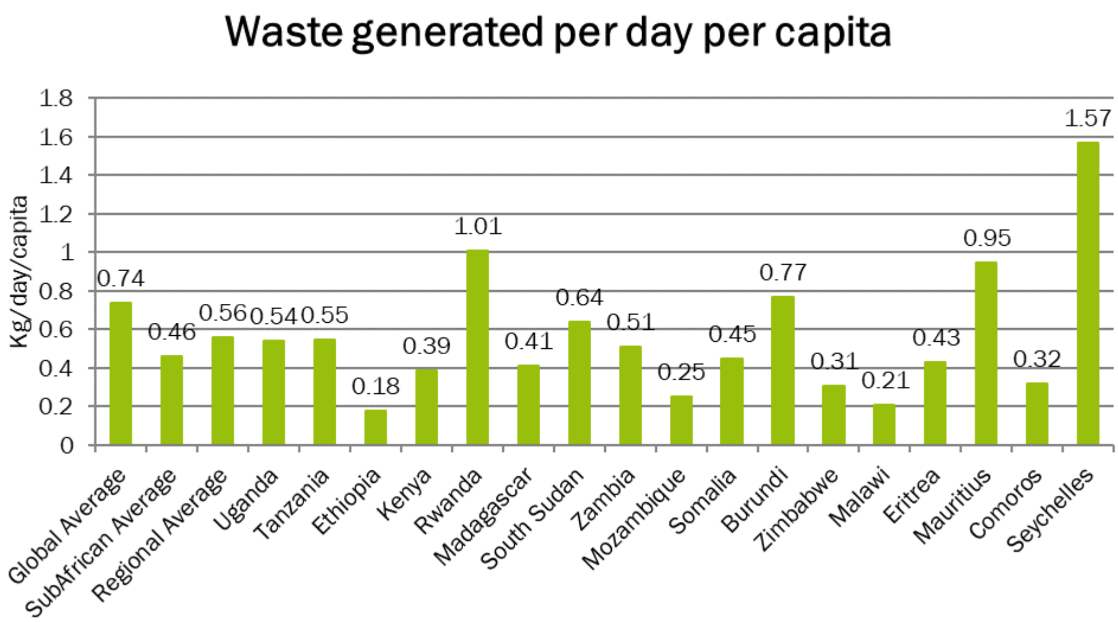


Figure 8: Waste generation per capita in East African countries - data extrapolated from What a Waste 2.0 (Kaza et al. 2018, p. 78)

On the other hand, the very low per capita waste generation in Ethiopia (one of the lowest in Sub-Saharan Africa and the lowest in East Africa) is also due to the high percentage of the population living in rural areas, which was reported to be 80 % in 2016; the reference year for the reported waste generation rate. This lowers the average per capita production rate, since rural population is considered to have a much lower waste generation rate than the urban one: in What a Waste 2.0 for example the rate of production of rural waste is reasonable around half the rate of municipal waste.

What a Waste 2.0 data are confirmed also by other studies. The average resident-specific waste generation in Ethiopia and other East African countries is reported to be extremely low compared to developed countries, below 0.5 kg/day/capita, with a waste density between 330 and 370 kg/m^3 (Birhanu 2015; Teshome 2021; Gelan 2021).

Looking at the data of total amount of waste produced per year, the situation is reversed: the small-island States produce little quantities of solid waste, while four of the 17 analyzed countries are producing more than 50 % of the waste generated in Eastern Africa (Figure 9), Ethiopia being the third major producer (Figure 10).

Waste Generation by Country

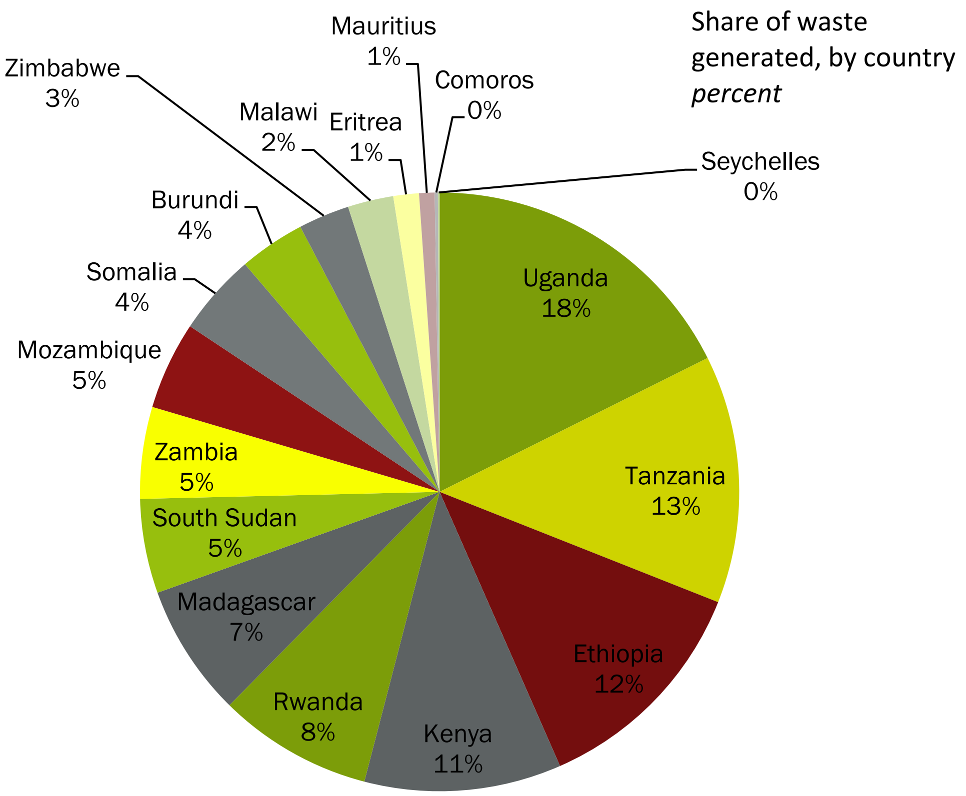


Figure 9: Share of waste generated by country - data elaborated from What a Waste 2.0 dataset (World Bank 2020)

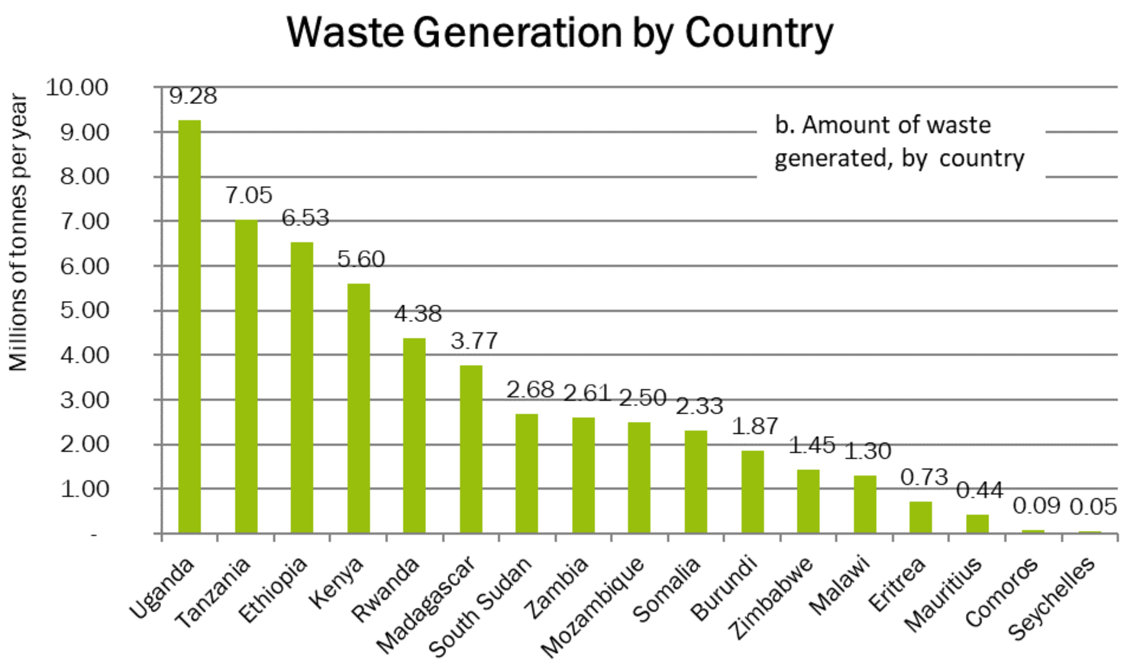


Figure 10: Amount of waste generated by country (tons per year) - data elaborated from What a Waste 2.0 dataset (World Bank 2020)

Kaza (Kaza et al. 2018) summarised that specific waste generation correlates with increasing GDP and that waste generation in developing and emerging countries is expected to triple by 2050. The ACCP (ACCP 2019) also forecasts a significant increase in waste generation due to the growing population.

3.1.2 Solid waste generation growth trend

Future of waste management is a big concern for Africa and in particular for sub-Saharan Africa because of the high expected increment of waste production in the region.

One of the greatest challenges in the economic development of low-income countries is the correlated development of specific waste volumes, which is often not considered in existing waste management structures, including in Ethiopia (Teshome 2021). Gelan (2021) found that in Addis Ababa, waste volumes are increasing but waste management efficiency is decreasing. The same problem exists in other developing countries around the world and is not unique to Africa. Most of the waste collected comes from households, which is characteristic of the region. While the average collection rate for sub-Saharan Africa is between 40 and 50 per cent, the residual waste recycling rate for the African continent is only four per cent (Teshome 2021; Gelan 2021; ACCP 2019).

According to the study “More growth, less garbage” published by World Bank in 2021, if no changes happen in the current management system, the waste generated globally is expected to grow from the 2.24 billion metric tons produced in 2020 to 3.88 billion in 2050 (increment of 73 %), while for sub-

Saharan Africa the amount will pass from the 193 million metric tons produced in 2020 to the 573 million metric tons predicted for 2050 (increment of 197 %) (Kaza et al. 2021, p. 3-8).

In the World Bank study, the waste generation projections was calculated considering two main influencing factors: the Gross Domestic Product (GDP) growth and the population growth. Urbanization rates, potential changes in country income classification and the impact of COVID pandemic could not be included for lack of reliable data and to simplify the analysis. Moreover, the analysis is carried out considering a "Business-As-Usual" waste generation model, with intent to help practitioners and policymakers better understand the potential impact of waste reduction decisions on waste projections. (Kaza et al. 2021, p. 5-6).

To estimate the trend of waste generation growth in East Africa, generation rate projections are taken from "More growth, less garbage" while population projections are from UN Population Projections, Medium Variant, 2019 Revision.

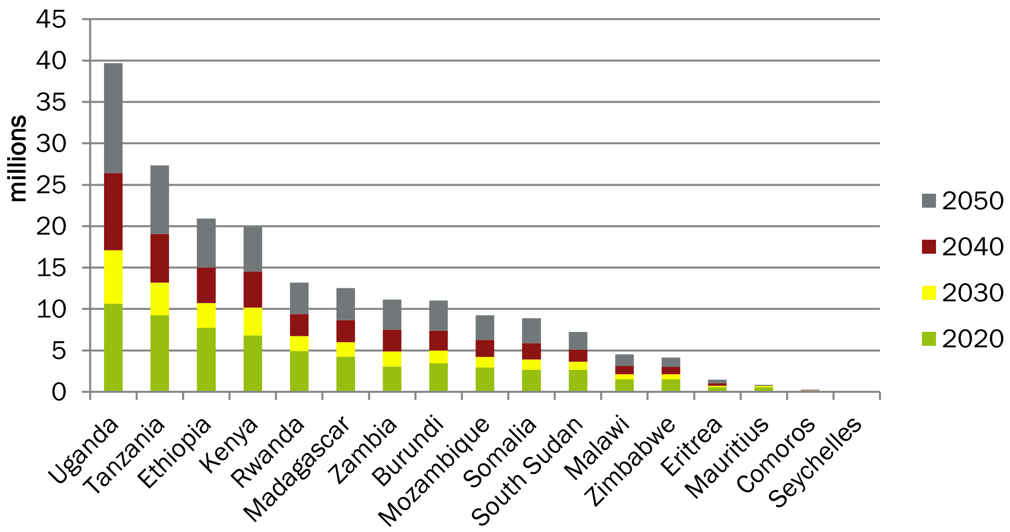


Figure 11: Waste generation growth projections for EAC in millions of tons (UNDESA 2019; Kaza et al. 2018)

In total, considering both the population growth and the variation on waste generated per day per capita, in 2050 total waste produced in Eastern Africa is expected to reach 192 million metric tons per year (an increment of three times from 2020).

The material and energy properties of waste will also change in the future. The main reason for this is the increasing share of consumer goods within the population due to the rising standard of living.

3.1.3 Solid Waste Composition

Waste composition is the categorization of types of materials in municipal solid waste (Kaza et al. 2018). Generally, the composition of waste varies according to the income level: with the increasing of income level, percentage of organic waste tends to decrease while quantity of plastic and paper waste increases.

In the case of Eastern Africa, very few data are available on composition of municipal solid waste which is generally extracted from major cities waste composition analysis.

In table 2 the types of materials (in percent) characterizing the solid waste of East African countries as per dataset of What a Waste 2.0 (World Bank 2020) are listed.

Table 2: waste composition characterization in percent

Country	organic waste	glass	metal	Paper/ cardboard	plastic	Rubber /leather	wood	Yard/ garden waste	other
Burundi	81	2.9	2.1	7.3	3.5	NA	NA	NA	3.2
Comoros	50	2	4	7	5	NA	NA	10	22
Eritrea	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ethiopia	87.6	0.8	1.2	3.8	2.3	NA	NA	NA	4.4
Kenya	57	3	1	11.3	18.7	NA	NA	NA	9
Madagascar	NA	NA	NA	NA	NA	NA	NA	NA	NA
Malawi	NA	NA	NA	NA	NA	NA	NA	NA	NA
Mauritius	64	2.8	NA	13	12.4	NA	NA	NA	8
Mozambique	60	NA	NA	25	NA	NA	NA	NA	15
Rwanda	NA	NA	NA	NA	NA	NA	NA	NA	NA
Seychelles	48.5	5.2	4.6	5.9	9.9	0.2	0.5	NA	25.8
Somalia	NA	NA	NA	NA	NA	NA	NA	NA	NA
South Sudan	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tanzania	NA	NA	NA	NA	NA	NA	NA	NA	NA
Uganda	74.5	0.8	0.6	6	7.6	NA	NA	NA	10.6
Zambia	NA	NA	NA	NA	NA	NA	NA	NA	NA
Zimbabwe	36	5	6	27	23	NA	NA	NA	3

A relatively recent study on waste composition in African countries has been compiled by the African Clean Cities Platform (ACCP 2019). The study collects the data of the 41 cities of 29 African countries that are participating in the program. These data have been integrated with the waste composition reported by UNEP in the “Africa Management Outlook” study (UNEP 2018) for 12 African cities. What a Waste 2.0 and ACCP 2019 use different methodological approaches, which is why the data generated can only be compared to a limited extent. A coarse comparison has been visualized in figure 12. East African cities waste composition was extrapolated and compared with waste composition percent reported by What a Waste 2.0 document for the 4 different class of level of income and with the Sub Saharan African average. Notable in the graph is the predominance of food waste in the waste composition. Bulawayo in Zimbabwe and Djibouti in Djibouti are reporting a percent of organic waste lower than the average in Sub Saharan countries (which is estimated to represent around 40 % of the waste); In regards of organic/food waste, Bulawayo in Zimbabwe and Djibouti in Djibouti and Lusaku in Zambia are reporting percentage comparable with the ones for the middle -income -countries, while all the others are far exceeding the percentage characterizing the low- income- countries. Moreover, the graph shows that the proportion of “others” is comparatively high in some cities, a fact that is explained by the inclusion of sand and fine particles from road cleaning (ACCP 2019p. 3-5).

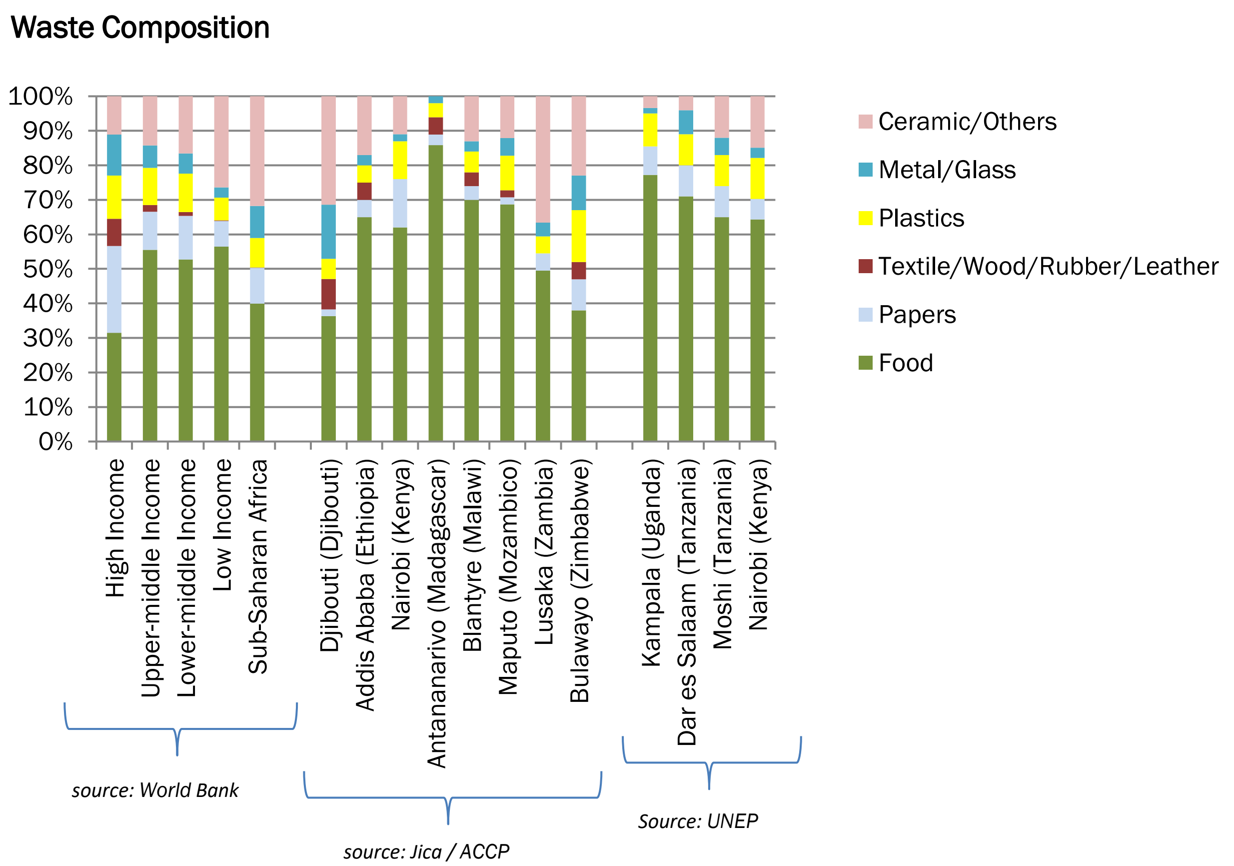


Figure 12: Waste composition in some capitals of Eastern Africa (ACCP 2019, p. 3-5) and (UNEP 2018, p. 27) and averages reported in What a Waste 2.0 (Kaza et al. 2018)

Waste composition has a remarkable influence on the efficiency of the treatment of the organic components and the quality of the desired final products. Based on a share of about 50 %, food and kitchen waste and other organic waste are the dominant fraction in residual waste. Compared to other countries, African residual waste has a high proportion of mineral components. These components result from unpaved roads, which are widespread (ACCP 2019). Due to the high proportion of native organic matter - compared to industrialised countries - the waste has higher water content. The high water content, together with sand and other minerals brought in by road cleaning, influences the material and energy properties and also has an impact on waste collection and treatment (ACCP 2019; Pfaff-Simoneit 2012). For example, the calorific value of the high calorific value sub-fraction of residual waste is reduced and, if necessary, thermal utilisation is very challenging. Separation of waste at the point of generation or at the point of disposal happens only partially and is still the exception (Birhanu 2015). In the context of continuous treatment systems, minerals can lead to abrasion and have a significant impact on economic efficiency.

3.2 Policies, Strategies and Legislation on SWM

The number of regional waste policy and strategies developed for Africa's solid waste management shows that this topic is considered a major challenge to be addressed and that there is a political commitment to improve the system. Just considering policies and strategies relevant to East Africa, it worth to mention:

- the First-Ten Year Implementation Plan of Agenda 2063 presented by African Union in 2013, which aspires to have "African cities recycling at least 50 per cent of the waste they generate by 2023" (NEPAD 2022).
- East African Community Development Strategy (2011) which outlines broad strategic goals for the region and includes the harmonization of policy interventions on the management of plastics and plastic waste and the establishment of an electronic waste (e-waste) management framework (UNEP 2018, p. 4).
- Ratification of the major waste related convention (table 3)

Table 3: Ratification status of waste related conventions as per October 2017 (UNEP 2018, p. 61)

Country	Minamata	Basel	Bamako	Stockholm	Rotterdam	Country	Minamata	Basel	Bamako	Stockholm	Rotterdam
Algeria	–	a	–	R	–	Liberia	S	a	–	a	a
Angola	S	a	–	a	S	Libya	S	a	R	a	a
Benin	R	a	R	R	R	Malawi	S	a	–	R	a
Botswana	a	a	–	a	a	Mali	R	a	R	R	R
Burkina Faso	a	a	–	R	R	Mauritania	R	a	–	R	A
Burundi	S	a	–	R	a	Morocco	S	a	–	R	a
Cameroon	S	a	R	R	R	Mozambique	S	a	a	R	a
Central African Republic	S	a	–	R	–	Namibia	a	a	–	a	R
Chad	R	a	–	R	R	Niger	R	a	R	R	a
DRC	–	a	a	a	R	Nigeria	S	R	–	R	a
Republic of the Congo	S	a	a	R	R	Rwanda	a	a	–	a	a
Cote d'Ivoire	S	a	R	R	R	Senegal	R	a	R	R	R
Djibouti	R	a	–	R	a	Sierra Leone	R	a	–	a	R
Egypt	–	a	–	R	–	Somalia	–	a	–	a	a
Equatorial Guinea	–	a	–	–	a	South Africa	S	a	–	R	a
Eritrea	–	a	–	a	a	South Sudan	–	a	a	R	a
Ethiopia	S	a	–	R	a	Swaziland	a	a	–	a	A
Gabon	A	a	–	R	a	Tanzania	S	a	R	R	R
Gambia	R	a	–	R	a	Togo	R	a	R	R	R
Ghana	R	a	–	R	R	Tunisia	S	a	R	R	R
Guinea	R	a	–	R	a	Uganda	S	a	a	a	A
Guinea–Bissau	S	a	–	R	R	Zambia	R	a	–	R	A
Kenya	S	a	–	R	R	Zimbabwe	S	a	a	R	A
Lesotho	a	a	–	R	a						

Abbreviations: A (acceptance), a (accession), R (ratification), S (signature)

3.2.1 Legal system on SWM for Eastern African countries

At national level, almost all the Eastern Africa countries have some policies to address the solid waste management (see table 4); this anyway is not guaranteeing that an efficient management system is actually applied. Factors that constrain the waste management system are indicated to be, among others, a weak legislation, lack of enforcement, low public awareness, negative attitudes, the poor state of services, corruption, political instability, and conflicts (Godfrey et al. 2020, p. 7).

Table 4: legal system and policy on SWM for Eastern Africa countries

Country	Legal system	Policy/Plan	Implementation system	Source
Burundi	NOT FOUND	NOT FOUND	NOT FOUND	
Djibouti	Code of Djibouti City Waste Management: basic principles and norms for solid waste.	Sanitation Policy in Djibouti City (2012-2019).	The Office de la Voirie de Djibouti (OVD) is in charge of managing solid waste in the city (street sweeping, collection, final disposal site operation, and road sign management). The Ministry of the Interior is in charge of SWM. The Ministry of Health is responsible for the management of bio-medical waste. Private sector: The private sector is not involved in SWM. Informal sector: The informal sector is involved in SWM through the collection of household waste in poor neighborhoods	(ACCP 2019)
Comoros	There is no basic law on SWM. A law on plastic waste has just been voted at the assembly	There is no policy on SWM but there are ministerial and municipal policies.	The Directorate General of the Environment is responsible for SWM. Other institutions involved in SWM include: The Environment Commission of the Islands. Town Halls (Municipalities): execute action plans.	(ACCP 2019)

			Private associations: recovery and recycling of solid waste. Informal sector: Informal sector participates in SWM but there is no policy for supporting the informal sector	
Eritrea	NOT FOUND	NOT FOUND	NOT FOUND	
Ethiopia	Solid Waste Management Proclamation No 513/2007. National Urban Solid Waste Management Standards. The related regulations are as follows: Environmental Protection Organs Establishment Proclamation No 295/2002. Environmental Pollution Control Proclamation No 300/2002. EIA Proclamation No 299/2002. Regulation on Prevention of Industrial Pollution No 159/2008. Standards for Industrial Pollution Control, 2013.	Urban Solid Waste Handling and Disposal Strategy, 2014. National Integrated Urban Sanitation and Hygiene Strategy, 2017. 2nd Growth and Transformation Plan (GTP-2 for 2016-2020). Environmental Policy of Ethiopia, 1997. Urban Development Policy, 1991. There is no privatization policy on waste management	Ministry of Urban Development and Housing (MoUDH): Main organization responsible for waste management. Ministry of Environment, Forest and Climate Change (MoEFCC): Responsible for overseeing the formulation and implementation of policies, strategies, laws and standards concerning the overall environment. Ministry of Health (MoH): Involved in waste management from a public health perspective. Ministry of Water, Irrigation and Electricity (MoWIE): Organisation responsible for formulation of policies, strategies and implementation of capacity building related to water resources development, urban water supply and sewerage. Ethiopia Standard Agency (ESA): Organization that sets and manages various standards. Ethiopia Water Technology Institute (EWTI): Established	(ACCP 2019)

			by JICA, mainly disseminates technologies related to excavation and management of wells, but also conducts waste management courses.	
Kenya	The related laws and regulations for SWM are as follows: Nairobi City County Solid Waste Management Act 2015: Provides for the management of solid waste in the County and for related matters	Integrated Solid Waste Management Plan (ISWMP)	Sector of Environment, Water, Energy and Natural Resources of the Nairobi City County (NCC): in charge of SWM in the city (street sweeping, collection, and final disposal site operation) and preparing the Integrated SWM Plan and SWM Act. Ministry of Environment and Forestry: in charge of coordination and giving policy direction for national environmental and forestry concerns. National Environmental Management Authority: in charge of national regulation and control of environmental concerns. Ministry of Health: responsible for management of medical waste.	(ACCP 2019)
Madagascar	Code of Water (Law 98-029 of January 1999). Urban Sanitation Management and Royalties (Law 95-035 of 1995). Charter of the Environment	There is no policy on SWM.	The Directorate of Sanitation, under the Ministry of Water, Energy and Hydrocarbons is responsible for SWM. Other institutions involved in SWM include the Ministry of Health and Ministry of Territorial Development.	(ACCP 2019)

Malawi	There is a framework law on SWM: Environment Management Act of 2017. There are three Regulations (2008): 1. Waste management and sanitation. 2. Chemicals and toxic substances. 3. Regulation on Ban of Thin Plastics. Local Government Act of 1998 assigns the municipalities to be responsible for SWM (this law is presently under review). The law is not implemented well due to lack of understanding among stakeholders, lack of specialised facilities, inadequate expertise, and lack of appropriate budget allocation.	The overall SWM strategy is outlined under the Waste Management Strategy of 2017-2022 (the policy development was supported by Basel Convention). The Waste Management Strategy identifies priority issues and parties for Malawi in SWM	At present, the Environmental Affairs Department of the Ministry of Natural Resources, Energy and Mining is in charge of SWM at the national level. The Department interacts with local government for conveying laws/regulations, providing instructions, and providing technical support. It monitors the status of SWM at municipalities and uses the information to provide local government with further instructions and to plan for the next year. At the local level, the local government/municipalities are responsible for SWM. However, sometimes environmental issues are low on the priority of Local Councils, thus actions tend to be slow. Other relevant authorities for SWM include the Ministry of Local Government and Ministry of Health. The informal sector as well as small-scale private operators is involved in collection of waste on the streets, transfer stations, and at disposal sites. Guidelines and licensing requirements for private	(ACCP 2019)

Mauritius	There is no national basic law on municipal solid waste. Local Government (Registration of Recycler and Exporter) Regulations 2013. Environment Protection (Banning of plastic bags) Regulations 2015. Environment Protection (Standards for hazardous wastes) Regulations 2001. Local Government (Dumping and Waste Carriers) Regulations 2003. Public Private Partnership Act (2004).	Solid Waste Management Strategy 2011–2015	The Solid Waste Management Division of the Ministry of Environment and Sustainable Development is responsible for solid waste management. Other organizations involved in solid waste management include: Ministry of Health and Quality of Life: responsible for medical waste Universities There is no policy for supporting the informal sector.	(ACCP 2019)
Mozambique	The related laws and regulations for SWM are as follows: Regulation on Urban Solid Waste Management of 2014. Regulation on Management of Hazardous Industrial Waste of 2014. Regulation on Plastic Bag Management of 2015. Technical Directive for the Implementation of Sanitary Landfill in Mozambique of 2010. Regulation on Management of Hazardous Industries Waste. Regulation on the Management of Biomedical Waste. Environmental Impact Assessment Law of 2015. No specific law on recycling. No law/regulation	National Strategy for Integrated Urban Solid Waste Management in Mozambique of 2013: clearly defines municipal waste and the responsibilities of the stakeholders but does not regulate the preparation of the national plan for municipal solid waste management (MSWM). Methodological Guide for the elaboration of municipal plans for the integrated management of urban solid waste	Ministry of Land, Environment and Rural Development (MITADER): Proposes policies, legislation and standards for the correct use of environmental components and control of environmental quality. Provides technical assistance to all levels of governance in waste management and the environment. Establishes standards, guidelines, and procedures for the preparation of environmental management plans for socio-economic development projects in the waste area. Promotes the elaboration and implementation of plans and programs	(ACCP 2019)

	specific to encouraging renewable energy. Law on Public-Private Partnership (PPP) of 2011		for the management of green spaces, waste, and liquid effluents. MITADER deals with urban/municipal waste and hazardous industrial waste. Ministry of Health: in charge of overseeing policies on medical waste. Proposes policies, legislation, and standards for the sanitary management of biomedical waste. There are informal activities in collection of recyclable materials on the streets and at disposal site	
Rwanda	NOT FOUND	NOT FOUND	NOT FOUND	
Seychelles	NOT FOUND	Seychelles National Waste Policy 2018-2023 was approved in December 2018	The Ministry of Environment, Energy and climate Change is responsible for the development and the implementation of all waste management policy, legal and regulatory frameworks. The Waste enforcement and Permit Division of the Environment Department is responsible for developing all policies regarding waste, waste collection, characterization, treatment and disposal.	(Ministry of Agriculture, Climate Change and Environment 2022)
Somalia	NOT FOUND	NOT FOUND	Solid waste management is the mandate of the respective municipalities under the Ministry of	(Ministry of Environment and Climate Change 2022)

			Environment and Climate Change	
South Sudan	There is a basic law on MSWM. The law defines municipal waste and the responsibilities of the stakeholders, and regulates the preparation of a national plan for municipal solid waste management. There is no specific law on recycling. There is a specific law/regulation to encourage renewable energy.	The overall development plan is outlined under the 2011-2013 South Sudan Development Plan (SSDP), entitled "Realizing Freedom, Equality, Justice, Peace and Prosperity for All." The overall environmental policy is outlined in the National Environment Policy. There is a long-term MSWM plan: Maintain public sanitation in cities by improving waste collection. Reduce environmental burdens by improving waste disposal. Reduce disposal amount by composting.	The National Ministry of Environment and Forestry is the lead agency for environmental management at the national level, responsible for guiding, directing, and coordinating stakeholders with its vision, "To ensure a clean and healthy environment for all the people of South Sudan". At the State level, the State Ministry of Health and Environment is the coordinating agency with regard to environmental management. States are governed by Local Government Councils (LGCs). Local Government's mandates are provided by the following laws and regulations: Interim Constitution of Southern Sudan of 2005. Transitional Constitution of the Republic of South Sudan. Local Government Act of 2009. Regulation and management of environment at the State/local level is under the jurisdiction of the local governments. The State and local governments' responsibilities include:	(ACCP 2019)

			Enforcement of environmental policy at the State level. Identifying training needs. Conducting environmental and social impact assessments. Implementing environmental education. The above-mentioned basic law on MSWM is not being enforced very well due to lack of understanding among the stakeholders. The Ministry of Environment and Forestry also monitors and evaluates the status of SWM in municipalities through reports and site visits	
Tanzania	There is no national basic law on SWM. Related laws and regulations are as follows: Environmental Management Act (EMA) 2004: Environmental and Social Impact Assessment (ESIA) is stipulated in the EMA. Local Government (Urban Authorities) Act of 1982 (revised in 2002). Public Health and Sewerage Act 2007: covers sanitation issues. Business Activities Registration Act 2007: SWM is a part of this Act.	The related policies are as follows: National Environmental Management Policy, 1997. National Solid Waste Management and Action Plan, 2010	President's Office - Regional Administration and Local Government: Promote rural and urban linkage, and ensure equity and equality in production and consumption of locally available resources and in accessing of social and economic services for a balanced growth. Vice President's Office (VPO) - Union and Environment: Oversee environmental management specifically on National SWM and Action Plan. Approve Strategic Environmental Assessment and ESIA. VPO - National	(ACCP 2019)

			Environment Management Council: conduct ESIA which includes addressing matters on solid waste. Ministry of Health, Community Development, Gender, Elders and Children: oversee Environmental Sanitation, which includes municipal and medical waste.	
Uganda	National Environmental Act, 2019	NOT FOUND	NOT FOUND	(National Environmental Management Authority, Uganda 24th February 2019)
Zambia	Solid Waste Regulation and Management Act, 2018: clearly defines municipal waste, responsibilities of the stakeholders, and regulates the preparation of a national MSWM plan. Environmental Management (Licensing) Regulations No. 112 of 2013. Environmental Impact Assessment No. 28 of 1997.	No specific law on recycling. No specific law/regulation to encourage renewable energy. No law/policy to support the informal sector.	Zambia Environmental Management Agency (ZEMA): In charge of environmental management, pollution prevention, pollution control, and waste management. Also responsible for issuing licences for various waste management activities such as generation, storage, transport, treatment and disposal to Local Authorities. Deals with both hazardous and non-hazardous waste. The Ministry of Local Government is in charge of policy-making on solid waste, commercial waste, and non-hazardous industrial waste. The Ministry of Sanitation and Environment is in charge of overseeing policies	(ACCP 2019)

			on hazardous and non-hazardous waste. The Ministry of Health is in charge of overseeing policies on medical/healthcare waste. There are informal activities in the collection of recyclable materials on the streets and at the disposal site.	
Zimbabwe	Waste Management By-law of 1979. Anti-Litter By-law of 2016.	Integrated Waste Management Plan: Consultant engagement in progress.	Other institutions involved in SWM include: Ministry of Environment Water and Climate: responsible for environmental regulations, including those relating to solid waste management through the Environmental Management Act. Ministry of Health and Child Care: Regulation of Environmental Health through the Public Health Act. Institute of Water and Sanitation Development: responsible for capacity building and skills transfer, as well as research and development.	(ACCP 2019)

Looking at the available legislation in the listed countries, there is a clear need to strengthen policies and laws regarding recycling and renewable energy. One of the major constraints for the development of a circular economy in relation to the SWM sector (and consequentially the recycling sector) is the poor financing, due to the fact that the waste sector is still perceived as a high-risk investment in Africa. In order to reduce the perceived sector risk, and to attract therefore private investors, there is the need of strengthening institutions and regulatory frameworks (Godfrey et al. 2020, p. 7).

3.2.2 A case study: History of Ethiopian Environmental and Waste Management Legislations

Ethiopia is one of the countries that does not follow the Common Law System, but the Civil Law System. That means that formal and substantive law is embodied in written law books and influenced by the "Corpus Iuris Civilis" of the Holy Roman Empire that is applied in most English-speaking countries and the European Union. It is primarily based on judicial rulings of the past, on so-called precedent cases.

Before the implementation of the Civil Law System in Ethiopia there exist legal directives as for example the "Fetha Negast" that can be translated as "The Law of the kings". After this legal code, in 1931 constitutions and legislations were adopted, which contained public announcements, regulations, decrees and ordinances. On 21 of August 1995 Ethiopia adopted a constitution that contains environmental laws as the most important applicable laws in the country and emphasizes the importance of environmental protection and necessity of an efficient environmental management. These legal regulations are an important precondition in economic, social and political terms (Hirpe and Yeom 2021).

The 1995 "Constitution of the Federal Republic of Ethiopia" establishes nine States that are separated on the Basis of language identity and settlement patterns. The States are now ten, with the recent recognition of Sidama Regional State, on June 2020. The Federal government and the State Authority have both legislative, executive and judicial powers. The Constitution can be divided into an urban level where city administrations exist and in rural areas that the administrative districts called "woredas" are responsible for the rural districts. These both administrations are mandated by state constitutions and are in charge of planning and executing projects for the residents and socio-economic programs.

"Kebeles", the village-level-authorities are located on the lowest level of the Ethiopian governance structure. The "Kebeles" oversee development in these communities and fulfils the duty to organize communal labour to support the execution of development activities, to collect income taxes from agricultural land and to support resolving problems. One of the biggest challenges for the "Woredas" and "Kebeles" is to deal with the inadequate funding for the provision of infrastructure and social services (Teko 2018).

Moreover, the constitution is the basis of all procedures and laws in the field of environmental management as well as for the protection of the environment. The constitution includes environmental rights as basic privileges for citizens. The right to sustainability is recognized, as well as the supposed direction to be taken in environmental policy that the country should follow. The Ethiopian environmental policy is an essentially document that has been adopted from the "Ethiopian Conservation Strategy". This environmental policy was adopted in April 1997 by the Council of Ministers together with the Prime Minister as the executive body in accordance with Article 74 (3) and Article 77 of the Ethiopian constitution as an all-encompassing development policy. This environmental policy was established with the objective of improving and promoting health and quality of life for the citizens and sustainable social and economic development as an overall policy goal (Hirpe and Yeom 2021).

In 2002 there were established two important proclamations regarding environment policies and solid waste management: No. 299/2002' and 'Environmental Pollution Control Proclamation No.300/2002. These proclamations encompass general attitudes to protect and preserve the nature at its resources in Ethiopia (Cheru 2016).

This expansion of the environmental legislation operationalized the objectives and the comprehensive framework for environmental management identified in Ethiopia's environmental policy. Despite this comprehensive legislative foundation, there is a consistent lack of institutional capacity for effective environmental management throughout Ethiopia and East Africa.

In general, the process of implementing regulations in the Federal Democratic Republic of Ethiopia (FDRE) is managed as follows: first a proclamation is passed by the president; according to the proclamation the council of minister issue regulations for effective implementation, and then the authorities issue the directives.

In 2007, Girma Wolde Giorgis, who was president from 2001-2013, set up the first law regarding solid waste, the Proclamation No. 513/2007 (Cheru 2016). The Proclamation is divided into five parts. The first part defines the terms in use and declares the title and objective. "The Objective of this Proclamation is to enhance at all levels capacities to prevent the possible adverse impacts while creating economically and socially beneficial assets out of solid waste." (Proclamation No. 513/2007) Moreover, the proclamation promotes community participation and coordinates the tasks and activities of various stakeholders and urban actors. The second Part is mainly about the responsibilities of urban administrators and the third part includes responsibilities of actors in handling different type of wastes. The following part is about guidelines for transporting solid waste and solid waste management and the last part of the proclamation describes penalties when these guidelines are violated (Cheru 2016). Article 5.1. states that Urban Administrators are intended to ensure that the lowest administrative levels and their respective local communities creates and implement their solid waste management plans. Furthermore, each region and urban administration should establish their own schedule, solid waste management plan and submit a report of implementation (Beyene 2015).

In 2011 the Medicinal Waste Management and Disposal Directive was adopted, a disposal that regulates medicinal waste and requires for the institutions to have all the facilities and practice standards prescribed under this Directive (Ministry of Agriculture 2020). Another important proclamation was adopted in 2018 with the Hazardous Waste Management and Disposal Control Proclamation No. 1090/2018 (see figure 13). The aim of this proclamation is to design a system for the disposal of hazardous waste and to establish a system for environmentally sound management. Furthermore, it prevents the human and animal health and protects the biodiversity.

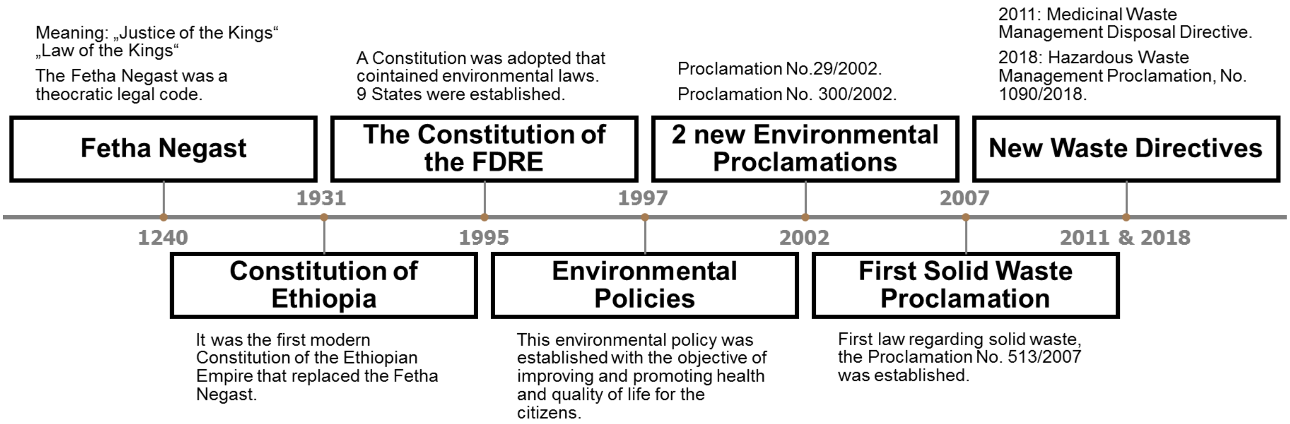


Figure 13: History of Ethiopian Environmental and Waste Management Legislations (© Carina Zimmermann)

3.2.3 Challenges in environmental policies in Ethiopia

As described in the previous chapter, the environmental law of the Federal Republic of Ethiopia acts as a "framework" for waste and environmental legislation. It has to be taken into account that the application of laws may overlap with individual areas of environmental policy. In this context, the question arises as to the superiority of the instruments of environmental policy with the laws enacted by the Parliament the “Schengo”. The environmental policy thus receives its legitimacy from the “Schengo” which significantly increases its legal status and legal certainty.

The prerequisite for environmental policy is to act as a framework for legislation. While laws may not exceed this framework, they are created by virtue of the legislative process in parliament, and not, like environmental policies, by decree of the Council of Ministers and the Prime Minister, and thus must be classified as higher-ranking law. As a result, if there is any overlap in the application of laws with the environmental policy, the law takes precedence. In this respect, the legal provisions take precedence over the provisions of environmental policy. The so-called legal framework, which sets out the environmental policy for the legislation, is, however, binding on the Parliament. Therefore, parliament has to ensure that all enacted laws do not contravene the norms of environmental policy. Once a law has been enacted and signed by the President of the Republic, that law shall be considered superior to the norms of environmental policy and shall take precedence over them (Hirpe and Yeom 2021).

Proper management of waste and biomass residues is strongly linked to climate change mitigation and adaptation policies. Ethiopia is a Party to the Paris Agreement and therefore adopted a plan to reduce its greenhouse gas emissions in order to reach the goals of the Paris Agreement.
Ethiopia presented its last Nationally Determined Contributions (NDCs) document in July 2021 (Federal Democratic Republic of Ethiopia 2021).

In the document, the updated climate change mitigation policy road map is illustrated as in figure 14.

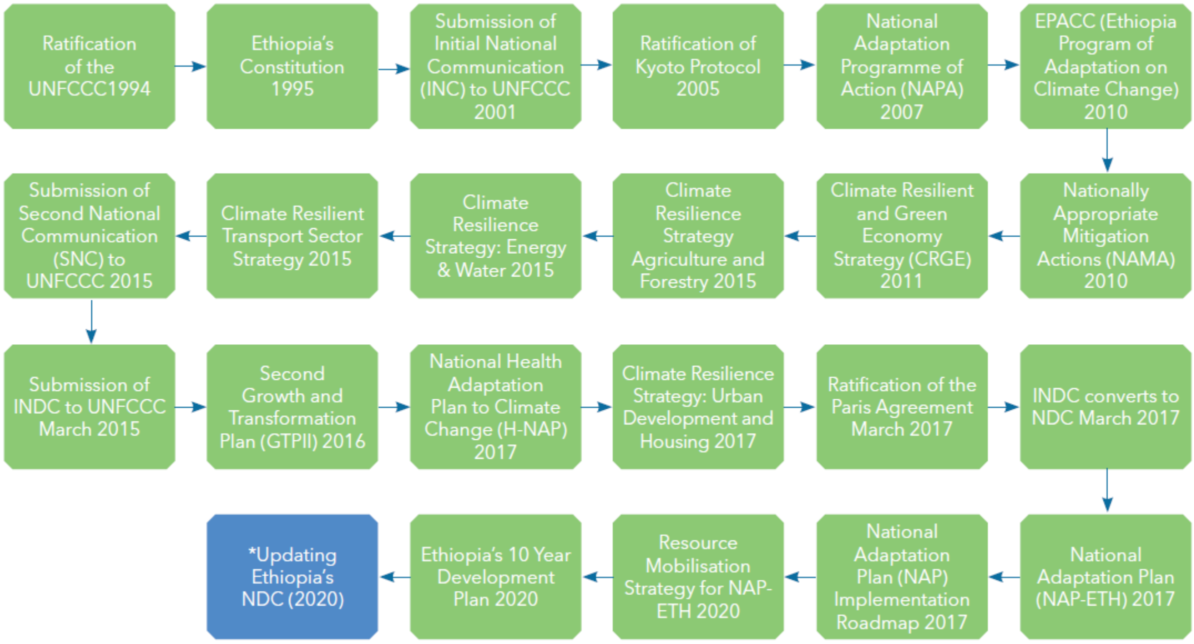


Figure 14: Ethiopia climate change roadmap as presented in NDC document (Federal Democratic Republic of Ethiopia 2021)

According to NDC document, the contribution of waste sector to total greenhouses emissions in a Business-as-Usual scenario is of 3 % in 2030, equals to 11.5 Mt CO_2 eq. This amount can be significantly reduced (-8.6 Mt CO_2 eq, a relative reduction of 74.7 %) adopting appropriate policies. The envisioned policies are reported in figure 15.

Policy intervention	Indicator (unit)	Lead institution/s (responsible)
Waste management ▪ Reducing emissions from reduced waste generation rate per capita ▪ Reducing emissions by aggressively diverting organic materials from landfills, i.e. waste separation and composting ▪ Reducing emissions from wastewater	Rate of waste generation (Ton/c) Share of organic material per ton of waste on landfills (%) Number of wastewater treatment plants constructed	Ministry of Urban Development and Construction Ministry of Water, Irrigation and Electricity (MoWIE)

Figure 15: policies intervention in waste sector as envisaged by NDC (Federal Democratic Republic of Ethiopia 2021)

The ratified policies that should guide the reduction of greenhouse emissions from waste and biomass residues are various, and among the ones listed in figure 15, should be mentioned (Grantham Research Institute on Climate Change and the Environment 2022):

- Climate-Resilient Green Economy (CRGE) Strategy:
- The Growth and Transformation Plan (GTP) II
- National Adaptation Plan Implementation Roadmap
- 10-year development plan

An important measure recommended in National Adaptation Plan Implementation Roadmap of 2017 is the increment of the use of organic fertilizers. One of the reasons for scarce use of compost in rural areas in fact, has been identified with the incentives given by government for the purchasing of the chemical fertilizers: chemical fertilizers in fact are easier to use than compost so that farmers easily are tempted to shift from traditional biological practices to chemical ones. On the other hand, agriculture extension workers, which are in charge to technically address the farmers in the cropland management, are not giving enough information on the benefit of using compost (Ndambi et al. 2019, p. 4-6). Practical actions to change this trend are very important.

Generally speaking, indications on waste treatment given in the mentioned policies are scarce and very general.

It has also to be underlined that even if legal and regulatory framework is well designed there are still several challenges to be overcome, such as:

- ambiguities as to whether SWM should be seen as state or municipal functions;
- challenges to streamline existing legal and regulatory frameworks; absence of mechanisms that would ensure inter-institutional collaboration;
- limited managerial and technical competencies in municipal SWM operations;
- lack of service delivery standards;
- absence of strong integration between urban planning and SWM operations
- indiscriminate disposal of waste by households,
- weak law enforcement by city administrations, and
- absence of monitoring and evaluation of private sector SWM operations.

Generally, weakness of solid waste management system in Ethiopia is attributable, at least in part, to inadequate supporting guidelines to laws and proclamations and to a weak enforcement of policies and regulations (Hirpe and Yeom 2021).

3.3 State of Organic Waste management in Eastern Africa

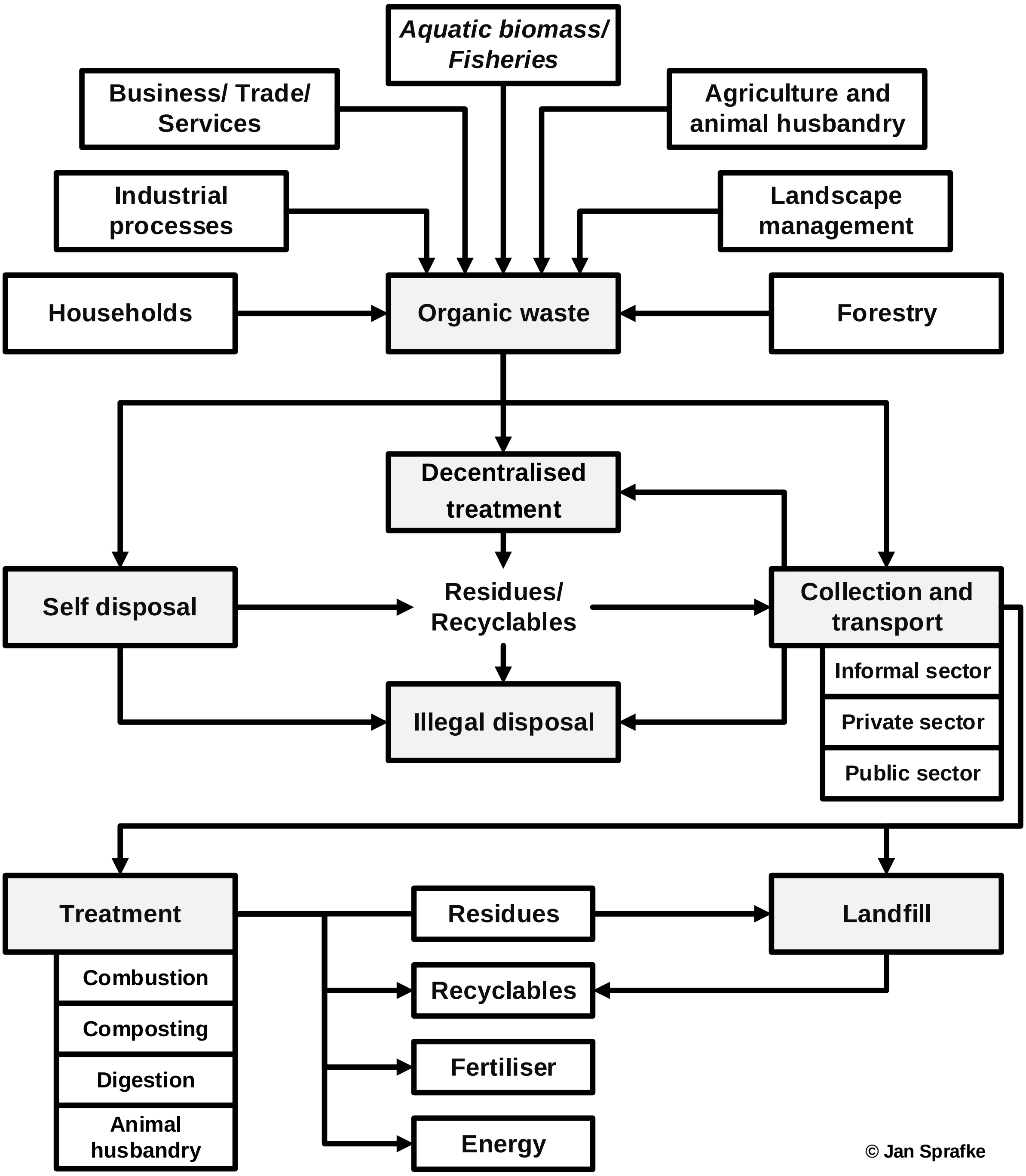


Figure 16: General schematization of segregated organic waste management as a starting point for future implementation in East African countries

A functioning waste management system is fundamentally based on four different strategies:

1. Material recovery and material recovery through recycling
2. Biological recovery of waste
3. Energy recovery from waste
4. Environmentally compatible treatment and disposal

To attain the state of a functioning waste management system, there are various stages and development steps to go through. The German RETech Partnership developed a Five Phase model to establish a waste management system (figure 17).

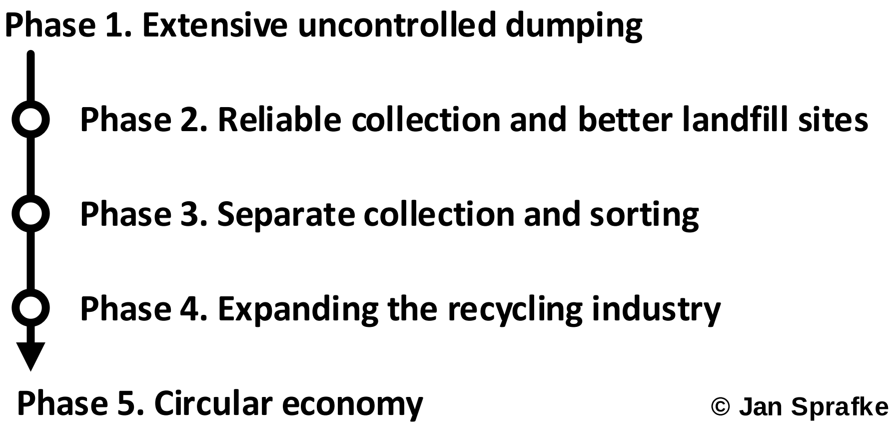


Figure 17: Five phase model by RETech (Jan Sprafke)

Between the five phases model of waste and the treatment of organic wastes there are many connecting points.

RETech's 5-phase model is intended to help various German waste management stakeholders as universities, waste management companies or plant constructors, who act worldwide. The model shall help in the discussion with local partners on site to assess all aspects and to formulate corresponding requirements and conditions so that a high-quality waste management system can grow.

The aim of the 5 stages of waste management is the transfer of adapted German knowledge and technology according to the individual needs of the target countries, states, cities or municipalities. The transitions of the five stages are seamlessly. More than one stage can be active at the same time. The political level is the basic requirement for the development of waste management. Laws and regulations, incentives, penalties and sanctions are needed to ensure that waste is disposed on proper landfills.

In phase 1 the dumping of waste takes place on wild dumps and regulated waste collection does not exist. Recyclable materials like plastics and metals are collected by the informal sector and are returned to be recycled through many stages. Unfortunately, in many countries people are living on landfill sites under inhuman conditions. Furthermore, basic principles of urban hygiene and environmental protection are neglected. In some countries waste is even often used for heating and cooking which has negative consequences for human health and the environment.

With regards to organic treatment many agricultural by-products and organic leftovers such as food and kitchen waste remain in local structures. Native organics are used for human and livestock use. Regional products are mainly traded locally and only in metropolitan areas and cities organic residues are discharged.

In phase 2 the introduction of a systematic, regulated and reliable collection system and the construction of orderly landfills constitute a further development of waste management. The economical transport of waste is facilitated by transfer stations at traffic-technical convenient hubs. Since the waste collection is the most expensive element of waste management, it is crucial that it is carried out efficiently and sustainably. At the same time, however, waste collection offers the greatest employment potential alongside sorting. It is crucial to identify the "right" collection system for a particular city or municipality and its circumstances. Even at this early stage, elements of a circular economy, for example in the form of separate collection of recyclables by manual sorting can be implemented. Composting of park and market waste in simple plants with the aid of mobile aggregates is the first stage of biological recycling.

In Ethiopia and East Africa, a phase 1 and 2 development status is most common. In urban areas, however, systems with a higher level of development can also be implemented.

Phases 3 to 5 represent the transition from waste disposal to a circular economy. In this process, the resource efficiency, more specifically the use of waste as a material and energy resource. In phase 3 the separation and collection in several containers form the basis for a high-quality sorting and for sophisticated recycling takes place. High-capacity waste collection vehicles with compacting equipment take over the waste collection. First optical separation aggregates allow the production of high-quality mono-fractions. The downstream secondary raw materials industry is developing since input quantities are increasingly secured. Furthermore, processes in the 3. phase are increasingly adapted to the materials.

Another feature of this phase is that jobs are created in significant amounts and waste management becomes a part of industrial policy. The sorting systems include mechanical separation stages, screening and classifying units and prepare the material for more efficient manual sorting. First trading structures for the recovered recyclables are created, for example for PET, paper and metals and these trading structures that meet industrial needs and generate revenues.

With the composting of separately collected organic waste and the sorting out of fractions with high calorific value for the production of refuse-derived fuels (RFDs) new products for various markets are increasingly developing.

In the fourth phase, modern sorting equipment is produced, which is used for the separation of plastic types and colour sorting. In composting and anaerobic digestion plants, biowaste is turned into compost and/or biogas.

Residual waste is recovered in waste incineration plants or incinerators or treated in mechanical-organic waste treatment plants. Organic waste treatment plants sort out recyclables, provide high calorific fractions for energy production, and degrade organic matter, which is largely responsible for emissions from landfills, especially landfill gas and leachate.

Thermal recycling plants and waste biomass cogeneration plants replace primary energy sources. This phase is very significant for climate protection: the measures lead to a significant reduction of climate-damaging emissions.

In the final stage, the priority is given to recycling or energy recovery; no more untreated municipal waste is deposited. The high recycling rates achieved lead to a functioning circular economy and only small residual quantities are landfilled without endangering the environment. The goal is waste prevention and lifecycle considerations of the production processes and our consumption decisions.

In addition to the 5 levels, which are more concerned with technical conditions and which are basically only available up to level 4 worldwide, it is important to consider other aspects of the target country or region so that the higher levels of waste management can be achieved. These areas are politics, market, financing and society.

As a rule, it is only possible to implement projects if the legal situation allows it. This means that large waste management centres are usually only created if the input is secured for at least the depreciation period. Politicians should create these framework conditions by means of a wide variety of individual measures, such as mandatory tendering and landfill bans for untreated waste.

Another factor that should not be underestimated is the society, because the development of waste management is a process that can take years or decades. Only if the society as a whole demands this development, politicians will take the necessary steps over the legislative periods. Furthermore, it is a prerequisite that there is an environmental awareness in society, because otherwise waste management will not develop further.

The third factor that should be considered is the market. It should be noted that export and import restrictions, customs barriers and bureaucratic hurdles often make logistics more difficult. Therefore, there should be a customer structure in the target country/region. The provision of high-quality secondary raw materials usually also leads to the development of industrial customers who, in adapted manufacturing processes, make the circular economy possible in the first place.

The last factor that should be considered is the financing. Since high-quality waste treatment and environmentally sound disposal of residual materials always involve higher costs, the funds must be provided by society and politics. The financing could be provided in form of waste fees, lost grants, low-interest loans, incentives or depreciation. Without these financial opportunities and support from the banking sector, again, higher levels of waste management are not achievable.

As shown in the next chapters, Eastern African countries are laying between phase 1 and 2; high interest and some efforts are there to improve the situation and fully adopt the further phases too.

3.3.1 Generation

Sources of generation for organic waste (intended as bio-waste) considered in this chapter are households, restaurants, caterers, open markets and retail premises, garden and parks (leaves, grass, brush), and food processing plants.

Since no sufficient data have been found on status of organic waste production quantities for the East Africa, this study will rely on the percentage of waste characterization calculated within What a Waste 2.0 document and reported in Table 2 of this study. In case the data was not available (NA) for a particular country, a proxy which is the value reported in Table 5 for correspondent level of income, was used.

Table 5: Waste Composition (percent) by Income Level (Kaza et al. 2018, p. 30)

Level of Income	Food/ Green	Paper/ cardboard	Wood/ Rubber/ Leather	Plastic	Metal/ Glass	Other
High Income	31.5	25.2	7.9	12.5	11.9	11.1
Upper-middle Income	53.6	10.7	1.9	10.4	6.2	13.8
Lower-middle Income	52.8	12.6	1.1	11.2	5.8	16.6
Low Income	56.4	7.4	0.2	6.6	2.9	26.4

The calculation of total amount of organic waste available per year is therefore based on the percentage of food and green waste and on the projected quantities of total waste produced per year. Results are resumed in Table 6.

Table 6: 2020 and 2030 organic waste quantity estimations

Country	Income level	2020 estimated TOTAL waste generation (ton/year)	2030 estimated TOTAL waste generation (ton/year)	% organic waste	2020 estimated ORGANIC waste production (ton/year)	2030 estimated ORGANIC waste production (ton/year)
Burundi	LIC	3,425,452	4,987,072	81 %	2,774,616	4,039,528
Comoros	LMC	90,070	133,543	50 %	45,035	66,771
Eritrea	LIC	570,527	748,690	56.4 %	321,777	422,261
Ethiopia	LIC	7,741,935	10,713,196	87.6 %	6,781,935	9,384,759
Kenya	LMC	6,787,815	10,173,003	57 %	3,869,055	5,798,612
Madagascar	LIC	4,247,560	5,997,239	56.4 %	2,395,624	3,382,443
Malawi	LIC	1,502,969	2,142,799	56.4 %	847,674	1,208,538
Mauritius	UMC	581,589	717,079	64 %	372,217	458,931
Mozambique	LIC	2,923,360	4,227,881	60 %	1,754,016	2,536,728
Rwanda	LIC	4,894,203	6,732,909	56.4 %	2,760,330	3,797,361
Seychelles	HIC	57,067	63,222	48.5 %	27,678	30,663
Somalia	LIC	2,675,723	3,915,707	56.4 %	1,509,108	2,208,459
South Sudan	LIC	2,680,226	3,636,961	56.4 %	1,511,648	2,051,246
Uganda	LIC	9,240,940	13,179,616	56.4 %	5,211,890	7,433,304
Tanzania	LMC	10,634,099	17,091,307	52.8 %	5,614,804	9,024,210
Zambia	LMC	3,034,758	4,869,943	52.8 %	1,602,352	2,571,330

Zimbabwe	LMC	1,491,355	2,141,304	36 %	536,888	770,870
tot		**62,579,647**	**91,471,469**	**61 %**	**37,936,646**	**55,186,013**

We can estimate that amount of organic waste available in 2030 in Eastern Africa will be around 55 million metric tons.

Figure 18 shows the foreseen distribution of organic waste among the East African countries.

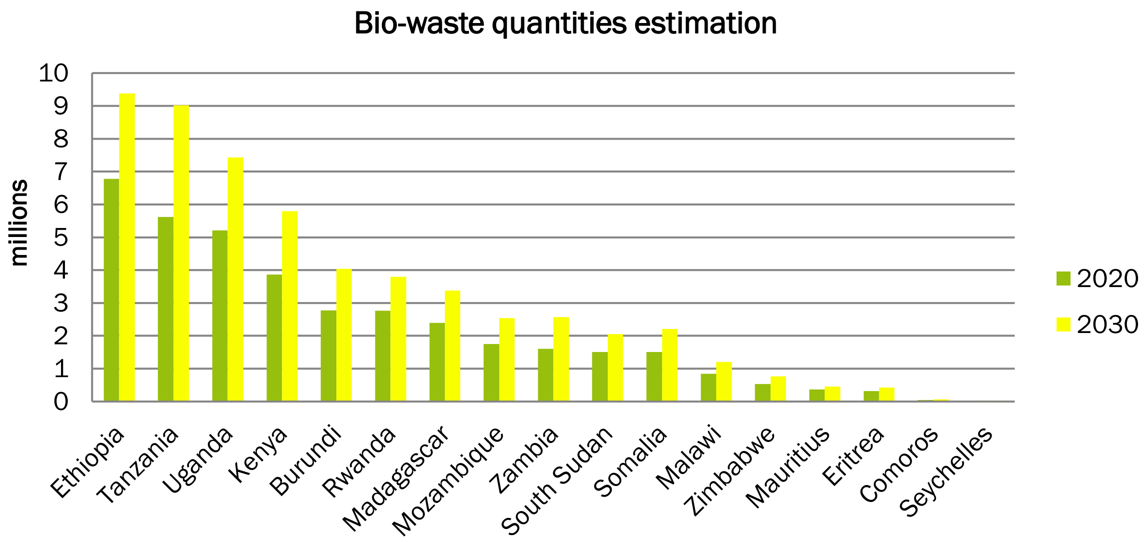


Figure 18: Organic waste quantity distribution among Eastern Africa countries

3.3.2 Other sources of organic waste production in East Africa

Data presented up to now are referring to bio-waste, the fraction of organic waste coming mainly from municipal waste and some specific industrial food waste (see figure 1). Other biomasses such as forestry, agricultural and aquatic residues, or manure were not considered.

Nevertheless, agriculture, forestry and aquatic residues are produced in very high quantities in agro-pastoral economies such the ones characterizing the Eastern African countries.

Land use map (figure 19) gives an idea on the magnitude of agricultural production and fodder production as well as the potential quantity of generated residues in East Africa.

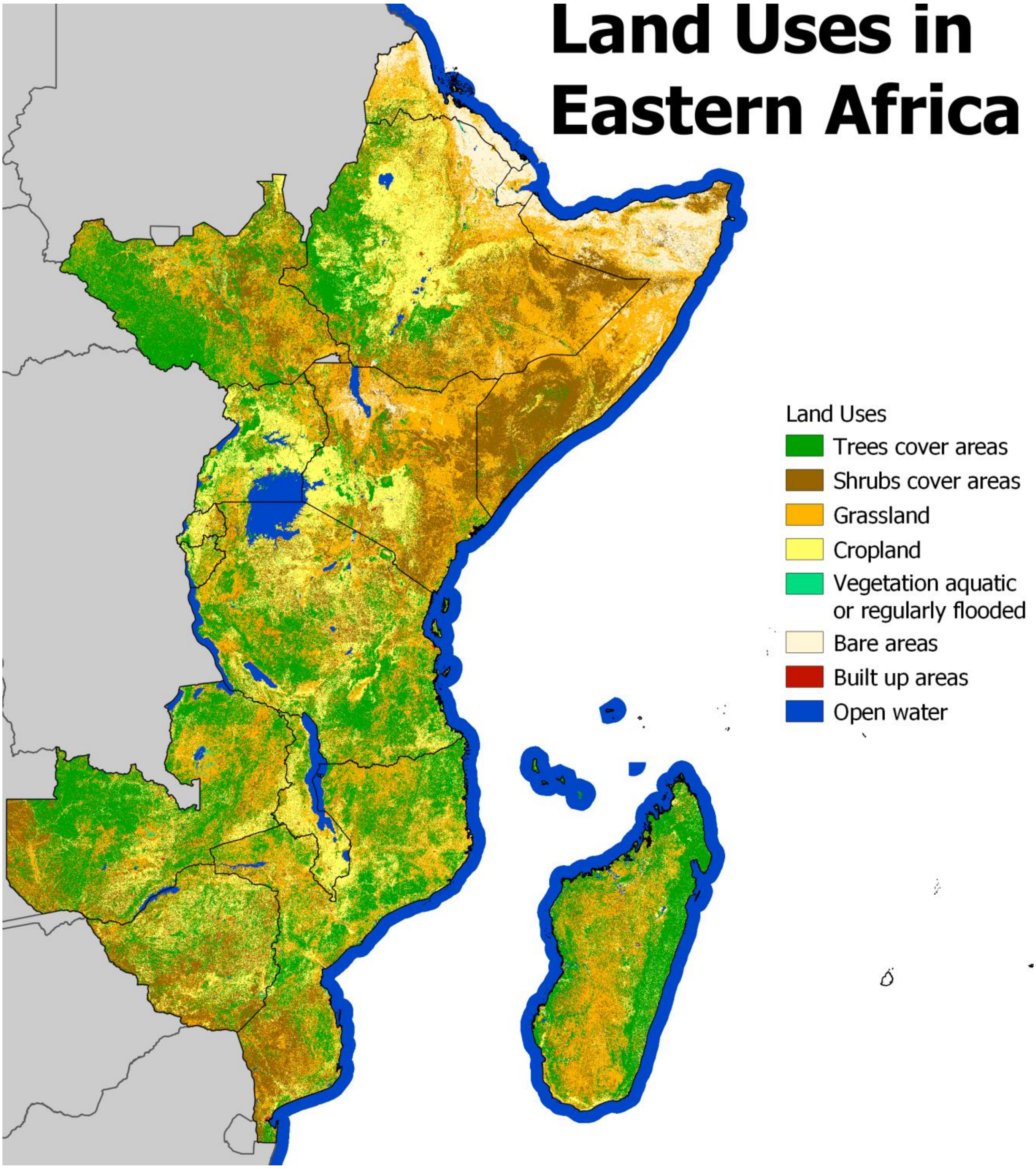


Figure 19: Land Cover 20m map of Africa 2016 (ESA climate change initiative 2016)

Data on major products exported by Eastern African countries are also an indication of the potential quantity of biomass residues produced in these countries. As shown in table 7, the top product in export for 7 over 17 East African countries are implying a production of biomass residues.

Table 8 shows that for Eastern African countries, exports of products that are potentially having biodegradable residues are representing almost the 30 % of the total export value.

Table 7: Principal export per East African country (OEC 2019)

	Country	Section	Product	Trade Value ($)
1	Mauritius	Foodstuffs	Processed Fish	270,761,411
2	Malawi	Foodstuffs	Raw Tobacco	583,558,565
3	Comoros	Vegetable Products	Cloves	24,954,308
4	Ethiopia	Vegetable Products	Coffee	837,354,167
5	Kenya	Vegetable Products	Tea	1,129,765,395
6	Madagascar	Vegetable Products	Vanilla	651,033,009
7	Djibouti	Animal Products	Other Animals	33,418,955
8	Zambia	Metals	Raw Copper	5,373,974,654
9	Mozambique	Mineral Products	Coal Briquettes	1,365,750,846
10	South Sudan	Mineral Products	Crude Petroleum	1,618,513,462
11	Seychelles	Mineral Products	Refined Petroleum	261,551,589
12	Burundi	Precious Metals	Gold	137,309,952
13	Rwanda	Precious Metals	Gold	444,053,253
14	Somalia	Precious Metals	Gold	173,862,500
15	Tanzania	Precious Metals	Gold	1,387,434,439
16	Uganda	Precious Metals	Gold	1,714,239,856
17	Zimbabwe	Precious Metals	Gold	1,717,127,750

Table 8: Trade value of biomass products in 2019 (OEC 2019)

	Total Export Value ($)	Vegetable Product ($)	% of tot	Animal Product ($)	% of tot	Food stuff ($)	% of tot
Burundi	282,507,142	91,407,721	32 %	166,413	0 %	8,549,855	3 %
Comoros	76,869,768	33,168,222	43 %	358,358	0 %	6,882	0 %
Djibouti	133,707,184	25,524,771	19 %	63,307,378	47 %	115,063	0 %
Ethiopia	3,110,547,485	1,747,311,595	56 %	84,588,995	3 %	27,332,152	1 %
Kenya	6,254,911,515	2,622,630,078	42 %	137,204,162	2 %	521,929,020	8 %
Madagascar	3,199,196,408	899,172,646	28 %	116,173,108	4 %	133,673,959	4 %
Mozambique	5,660,761,077	445,415,101	8 %	71,179,490	1 %	448,906,566	8 %
Mauritius	2,531,714,172	48,421,325	2 %	179,752,946	7 %	534,942,582	21 %
Malawi	1,048,766,118	228,470,469	22 %	1,346,599	0 %	690,316,446	66 %

Rwanda	1,349,178,684	258,045,534	19 %	17,143,790	1 %	117,155,906	9 %
Somalia	419,599,547	86,155,099	21 %	134,863,515	32 %	764,739	0 %
South Sudan	1,710,514,484	31,533,055	2 %	406,618	0 %	300,816	0 %
Seychelles	968,888,785	6,816,843	1 %	224,663,539	23 %	260,108,761	27 %
Tanzania	4,282,038,859	1,009,787,326	24 %	190,248,074	4 %	411,436,231	10 %
Uganda	3,008,670,224	578,414,164	19 %	304,960,648	10 %	155,494,255	5 %
Zambia	10,070,073,940	103,251,637	1 %	56,499,829	1 %	461,924,915	5 %
Zimbabwe	4,052,790,281	158,861,848	4 %	24,348,308	1 %	738,980,518	18 %
tot East Africa	48,160,735,673	8,374,387,434	17 %	1,607,211,770	3 %	4,511,938,666	9 %

Agricultural waste is not felt as a threat for environment and for public health or even as a nuisance since it is traditionally disposed through direct use (direct animal feeding, direct application to fields or direct combustion). Nevertheless, it is important to consider that agriculture and livestock production practices are rapidly changing in East Africa and the amount and type of residues generated could became a problem in the near future. Furthermore, direct use is not an efficient way to treat these types of residues that rather could be valorized as energy supply; for rural areas, this end-use is particularly recommended to contrast the overexploitation of wood biomass and to give a solution to the lack of connection to the electric grid.

The study “Biomass Potential in Africa” reviewed all the studies analyzing the energy potential of waste and residues in Africa and range of results show only moderate variation lying between 2 100 PJ/yr and 5 200 PJ/yr with the mean value calculated as 2 900 PJ/yr (Stecher et al. 2013, p. 24). In figure 20 the potential of residues and waste is visualized by time period, geographical areas and study; the figure shows clearly how biomass potential in sub-Saharan Africa is going to grow with time.

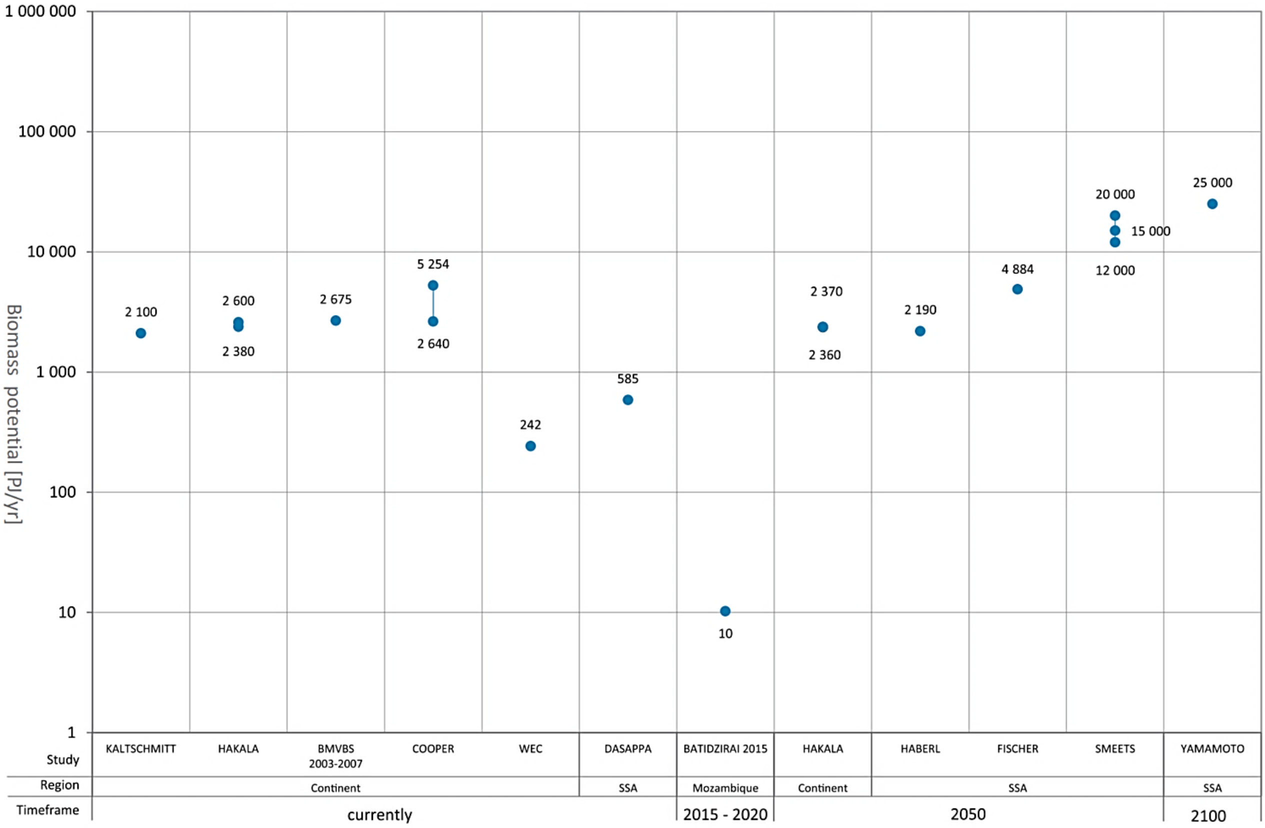


Figure 20: Residues and waste potential as dependent on time-period, African region and study (Stecher, Brosowski, & Thrän, 2013, p. 30)

The same study also reports the contribution to energy potential of different waste/residues categories, as per table 9. Crop residues are the most analyzed category and they represent the higher contribute for energy potential in the waste/residues categories, animal residues are less studied but the few studies reported show an average high potential of energy production.

Table 9: Residue and waste biomass potential energy data for Africa (PJ/yr.) (Stecher et al. 2013, 25)

Study	Crop residues	Animal residues	Municipal waste	Industrial wood waste	Logging residues	Bagasse	Coconut shells	Oil palm
KALT-SCHMITT	900	1 200	-	-	-	-	-	-
HAKALA	2 380-2 600 (current) 2 360-2 370 (2050)	-	-	-	-	-	-	-
BMVBS	1 161	28	353	4	822	208	11	88
COOPER	1 089-3 588	1 450	-	-	-	86-201	15	-
WEC		-	-	-	-	242	-	-
DASAPPA	135	-	-	356	94	-	0.001	0.007
DUKU	0.07	-	-	-	-	-	-	-
BATIDZIRAI				2	1	8	-	-
HABERL	2 190	-	-	-	-	-	-	-
FISCHER	4 884	-	-	-	-	-	-	-
SMEETS	12 000-20 000	-	-	0	0	-	-	-
YAMAMOTO	42 % (10 500)	not specified	-	not specified	not specified	-	-	-

A study conducted in 2018 on available biomass residues and their bio-energy production potential, focusing just on Ethiopia, calculated a total bio-energy production potential of 750 PJ/yr. Within the total potential, forest residues could contribute with 350 PJ/yr, (almost 46.6 %), crop residues have a potential of bio-energy at 250 PJ/yr (34 %) and livestock manure of 140 PJ/yr (19 %), the remaining 3.8 PJ/yr potential (0.4 %) being the share from MSW from major cities in the country (Gabisaa & Gheewalaa, 2018).

As per regard of bio-energy potential of biomass from agricultural residues, the share from maize residue was highest at about 45 % followed by coffee husk (20 %) and sorghum (14 %), which indicates that they are the most suitable for energy production.

Table 10: bio-energy potential from crop residues (Gabisa and Gheewala 2018)

Crop	Type	Production amount (ton)	Share of waste production amount (%)	Potential bioenergy (PJ/yr)	Share of potential bio-energy (%)
Maize	Stalk, cob, husk	7200	29	252	45
Sorghum	Straw	4300	17	75	14
Wheat	Straw	4230	17	39	7
Cane	Bagasse, top&leaves	2820	11	23	4
Sweet Potatoes	Peels	2700	11	14	3
Barley	Straw	2000	8	19	3
Millet	Stalk	915	4	16	3
Coffee	Husk	420	2	110	20
Rice	Straw, husk	132	1	3.5	1
Soybeans	Straw, pods	72	0	3.8	1

As per regards of quantity of residues generated, maize, sorghum and wheat waste are the crops with the higher contribution.

According to a study on sugarcane landraces of Ethiopia, in 2018 sugarcane plantations had area coverage of 98,986 hectares and production of 400,000 tons of sugar and 25,388 m^3 of ethanol per year. The study also mentions an expansion plan foreseeing new sugar factories have ethanol and cogeneration facilities in order to boost the annual sugar production to 3.9-4.17 million tons, the ethanol production to 181 million liters and to have the factories contributing 709 Mega Watt electric power to the national grid (Gashaw et al. 2018).

While practices for reutilization of sugar, bio-products seem already well implemented, proper treatment of coffee residues is particularly important to be implemented, so as to minimize the environmental impacts of its processing waste (Woldesenbet et al. 2014).

Ethiopia is the major exporter of coffee among all the African countries (see figure 21). Just to have an idea of the order of magnitude, the amount of coffee exported in 2019/2020 from Ethiopia was 271,111 metric tons (International Trade Administration); Ethiopian coffee production varies from around 370,000 tons to 470,000 tons in the last decade (Degaga 2020, p. 9).

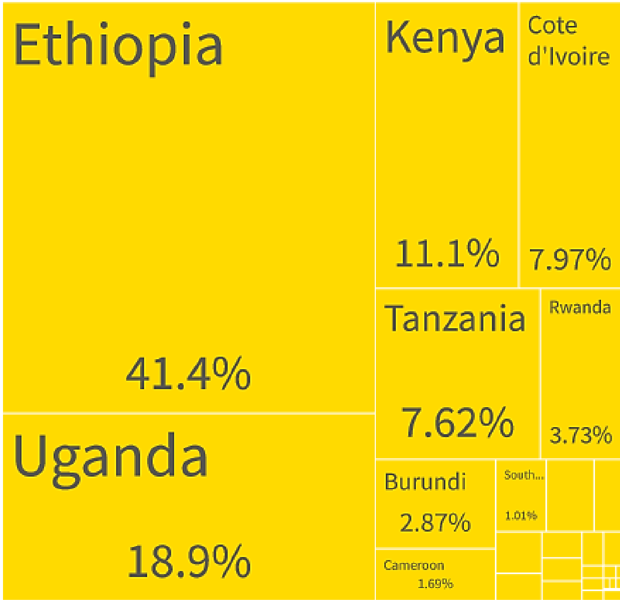


Figure 21: value of coffee export in 2019 among African countries (OEC 2019)

Given the huge amount of bio-product generated by the coffee process sector, and the high potential environmental problems caused by coffee processeing residues (Woldesenbet et al. 2014), there is great interest of converting coffee bio-products from a threat to a resource, as evidenced by the numerous studies on this topic available in the literature.

According to a study on Biogas Potential of Coffee Processing Waste in Ethiopia, coffee by-products exhibit promising bio-methane potential, comparable to common agro-industrial residues and some energy crops. The study estimated that anaerobic fermentation of coffee processing by-products generated by the Ethiopian coffee sector has a significant potential to generate methane as high as 68×10^6 m^3 per year, which can produce 238,000 MWh_{el} (0.85 PJ/yr) of electricity and 272,586 MWh_{th} (0.98 PJ/yr) thermal energy (Chala et al. 2018, p. 12).

Water Hyacinth is another important biomass to be considered for treatment, because of the problems this invasive aquatic plant is creating in East Africa. As per CABI's invasive species compendium description (CABI 2022), water hyacinth (*Eichhornia crassipes*), a native of South America, is a major freshwater weed in most of the frost-free regions of the world and is generally regarded as the most troublesome aquatic plant. It has been widely planted as a water ornamental around the world because of its striking flowers. Wherever it has encountered suitable environmental conditions it has spread with phenomenal rapidity to form vast monotypic stands in lakes, rivers and rice paddy fields.

Figure 22: Water Hyacinth invasion - Lake Victoria (Kenya) and Koka Reservoir (Ethiopia) (Maps Data: Google, Placemarks Africa ©2022 Maxar Technologies)

The plant is largely distributed in almost all eastern African countries (table 11), directly and indirectly affecting fish, crop and livestock productions, electric power generation, irrigation, waterway transportation, tourism, and human health. Even if eradication is almost impossible to obtain, several controlling mechanisms are available which include biological, physical (mechanical and manual removal), and chemical control (Dechassa and Abate 2020). When physically removed, the plant can be used as mulch, for making compost, fuel bricks, paper or board, for generating methane biogas, and for removing nutrients and toxic chemicals from water (Gaurav et al. 2020). Nevertheless, it should be underlined that mechanical and manual removal is most of the time ineffective, labor intensive work and in some areas, there is serious safety and health risks associated (snakes, hippos, crocodile, malaria and bilharzia) (Dechassa and Abate 2020, p. 43).

Table 11: Water hyacinth distribution in East Africa (adapted from CABI 2022).

Country	Distribution	Origin	Invasive
Burundi	Present	Introduced	Invasive
Ethiopia	Present, Localized	Introduced	Invasive
Kenya	Present, Widespread	Introduced	Invasive
Madagascar	Present, Widespread	Introduced	Invasive
Malawi	Present, Widespread	Introduced	Invasive
Mauritius	Present	Introduced	Invasive
Mozambique	Present, Localized	Introduced	
Réunion	Present	Introduced	Invasive
Rwanda	Present, Widespread	Introduced	Invasive
Seychelles	Present	Introduced	

Tanzania	Present, Widespread	Introduced	Invasive
-Zanzibar Island	Present, Localized	Introduced	

A further important biomass to take into consideration both because of its potential impact on the environment and public health as well as for its bio-energy production potential is the livestock product. In East Africa, the livestock subsector plays an important role in livelihoods, food security, nutrition, and economies across the region through local, regional, continental and global trade (FAO and IGAD 2019).

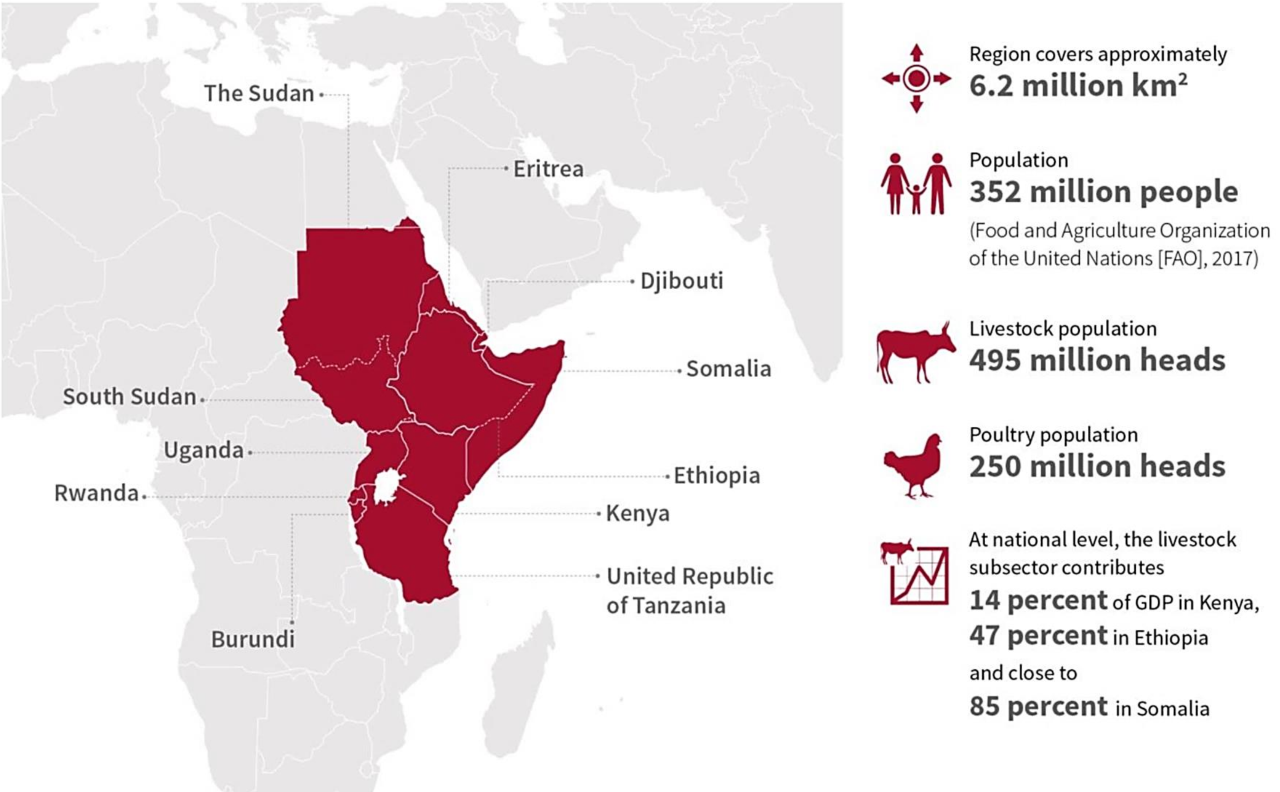


Figure 23: Livestock sector in East Africa (FAO and IGAD 2019, p. 1)

Livestock constitutes the main source of meat and milk for domestic markets, and it is also source of live animal and meat exports to the Middle East and North Africa for international markets. Most livestock are kept under extensive production systems. Pastoralists and agro-pastoralists are particularly dominant in the arid and semi-arid lands of Djibouti, Ethiopia, Kenya, Somalia, South Sudan, the Sudan and Uganda (FAO and IGAD 2019). Livestock breeding is conducted mainly in a traditional way while the commercial sector is very small so that it plays a lesser role in the residues production sector. In the pastoral system, the livestock grazes on common sites by moving to different pastures. This makes the collection efficiency of residues low (Gabisa and Gheewala 2018).

Manure is a great asset and if well-managed, could serve as an organic fertilizer and soil amendment that could restore degraded soils. In sub-Saharan Africa, manure management techniques are various and each of them presents advantages and disadvantages (table 12), but it has to be noted that at the farm level, manure management is poor, often due to insufficient labor, lack of capital for investment, and a lack of knowledge: this mismanagement causes nutrient losses by rain and sun (Ndambi et al. 2019).

Table 12: Summary of advantages and disadvantages of major manure management options in SSA (Ndambi et al. 2019, p. 9)

Manure treatment	Brief description	Advantages	Disadvantages
Fresh application (solid and liquid manure)	Direct application of either solid or liquid fresh manure to pastures or crops	• Fresh manure, like any other form of organic manure improves the structure of the soil which allows better aeration of the soil, improves drainage, and reduces erosion. • Manure nutrients become slowly available as plant food and can have effects on crops for several years. • Good crops can be obtained with reduced need for extra chemical inputs.	• Minerals from manure may not be immediately available to plants; mainly for ruminant manure. • There can be a mismatch in time between nutrient release and plant uptake; • Risks associated with transmission of zoonotic diseases if crops are consume; • Seeds of weed can be transferred to the field trough fresh manure.
Drying	When manure is left in heaps on natural earth for a long periods till it dries up. Manure is also actively molded and dried for fuel in some countries like Ethiopia	• Drying makes manure less bulky and easier to transport. • Dried manure contains organic matter that provides similar advantages of using organic fertilizer as in fresh manure.	• During drying, nitrogen is lost from manure through volatilization of NH3. • Also, if dried manure is not protected from rain, rewetting events can lead to GHG emissions. These N losses will also result in a poorer quality fertilizer. • Nitrogen and organic matter are lost when manure is used as fuel
Composting	Composting is an active process of preparing organic fertilizer. Manure is usually combined with plant material and left to undergo aerobic decomposition.	• It provides the same advantages of organic fertilizers to the soil as manure and in addition: • It is less expensive compared to other soil amendments. • It is less bulky and easier to transport than fresh manure • Composting makes it easier for plants to take up the nutrients in the soil. • Composting exposes manure to high temperatures that reduce pests, diseases, and destroy weed seeds in fresh manure. • Large amounts of vegetation, such as crop remains, garden weeds, kitchen, and household wastes, hedge cuttings, garbage, etc., can be put to use. • Compost is odorless as compared to manure	• Compost preparation is time consuming. • Most of the nitrogen from manure is lost during composting. • High nitrous oxide emissions • Water is required for compost making and it is a difficult option during the dry periods or in areas where water is scarce. • Composting requires large amounts of high carbon material (usually straw or crop residues) which might not be available at some times of the year
Anaerobic Digestion (with use of bio-slurry as fertilizer)	This is the conversion of manure by anaerobic bacteria into biogas and digestate. The digestate which is also called bio-slurry is a mixture of digested dung and water having a dry matter content of ~7%.	• Provides energy and fertilizer value is maintained or even enhanced. • It provides the same advantages of organic fertilizers to the soil as manure and in addition: • Reduce labor especially of women and girls who spend many hours searching for fuel wood. • Reduce cost on purchase of synthetic fertilizers, which will be (partly) replaced by the bio slurry • Lower risk of infection due to the hygenization during digestion Affordable lighting in rural (for learning and doing house chores in the evenings) • Reduce risk of respiratory diseases linked to the use of fuel wood, dung cakes, and charcoal. • Reduced greenhouse gas emissions as the produced CH_4 is captured and used for cooking. • Bio-slurry is odorless as compared to manure	• This requires a very high initial investment, often not affordable to smallholder farmers, except though subsidies. • It requires continuous availability of water. • Requires frequent feeding of manure • Liquid digestate is more difficult to manage than dried manure due to high water content

Source: The table is based on data from Inckel et al. (2005), NBPE (2007), Bruun et al. (2014), Warnars and Oppendoort (2014) and Vu et al. (2015) authors' experiences.

The three most common ways of treating manure in sub-Saharan Africa include drying (active and inactive), solid storage, sometimes with active composting, and anaerobic digestion. Different practices are adopted according to the farmer production scale (compare table 13 for the Ethiopian case). In case of use of biodigesters, an in-depth analysis conducted for Ethiopia showed that the large farms with biodigesters discharged most of the digestate into waterways while the smaller farms dried it to obtain dung cakes used for cooking (Ndambi et al. 2019).

Table 13: Description of manure management in Ethiopia using proportions of farms carrying out various practices (Ndambi et al. 2019, p. 7)

		Ethiopia		
		Large	Mid	Small
	Number of farmers interviewed	11	7	5
1	Fraction of farms using bedding material and which is removed while mixed with animal excretions	9%	0%	0%
2	Fraction of farms using anaerobic digestion	27%	14%	0%
3	Fraction of digestate (bio-slurry) used for on-farm crop fertilization?	25%	0%	0%
4	Fraction of digestate used for off-farm crop fertilization (sold or given away)	0%	0%	0%
5	Fraction of farms discharging the digestate	75%	0%	0%
6	Fraction of farms storing urine (separate from dung and for a longer period)	18%	14%	0%
7	Fraction of urine storages with waterproof floor and walls	50%	0%	0%
8	Fraction of urine storages with roof/cover	50%	0%	0%
9	Fraction of stored urine used for on-farm crop fertilization	0%	0%	0%
10	Fraction of farms storing liquid manure (slurry, a mixture of urine and dung)	0%	0%	0%
11	Fraction of liquid manure storages with waterproof floor and walls	0%	0%	0%
12	Fraction of liquid manure storages with roof/cover	0%	0%	0%
13	Fraction of stored liquid manure used for on-farm crop fertilization	0%	0%	0%
14	Fraction of farms storing solid manure	91%	100%	100%
15	Fraction of solid manure storages with waterproof floor?	0%	0%	0%
16	Fraction of solid manure storages with roof/cover	0%	0%	0%
17	Fraction of stored solid manure used for on-farm crop fertilization	25%	40%	30%
18	Fraction of stored solid manure used for off-farm crop fertilization	0%	0%	0%
19	Fraction of stored solid manure used for fuel	75%	60%	70%
20	Fraction of farms which improved their manure management (storage, treatment, application) in the past 5 years?	27%	29%	40%

Other important agricultural residues to be taken into consideration are the ones related to the agro-processing industry, a sector which is rapidly expanding in East Africa, as described in the following chapter. In Ethiopia, the Environmental Pollution Control Proclamation No. 300/2002 incorporates the polluter-pays principle (Vibhute 2008, p. 94); this is true also for most of the East African countries. Polluter pays principle foresees that the agro-industries are responsible for collection and treatment of the generated waste; the level of enforcement of this principle is anyway difficult to evaluate.

3.3.3 Collection and transport

In Sub Saharan Africa overall waste collection rates are about 44 %, although the rate is much higher in urban areas with over 50 % than in rural areas, where waste collection services are minimal (9 %) (Kaza et al. 2018, p. 79).

The collection of waste is often non-existent or sporadic, especially in economically underdeveloped regions (Teshome 2021). As an example, for Ethiopia's largest city, Addis Ababa, the collection rate is

70 % (Kaza et al. 2018). With a population of around 3.350.000, this corresponds to a daily uncollected amount of waste of around 500 t.

This situation led to a general dissatisfaction on collection municipal services. Places with scattered and illegally disposed waste are frequently found. This is one of the reasons why the population is very critical of municipal waste management. Collection service by collection vehicles and by the informal sector is often irregular. A common problem with waste collection is that often the vehicle fleet is too small, vehicles are unsuitable or existing vehicles cannot be used because they are used for other activities outside the waste sector (Teshome 2021). Another problem is that collection vehicles are often antiquated, insufficiently maintained, drivers are poorly trained or transport is inefficient. Municipally and privately owned collection vehicles are often used for other activities such as transporting materials and are not available for waste transport (Teshome 2021).

Kaza (2018) listed that in sub-Saharan Africa, waste collection often takes place in 2 stages. In the first stage, household waste is collected, often by the informal sector, using small un-motorised transport vehicles (carts, handcarts, etc.) and transferred to a collection point. Afterwards, this waste is transported to the landfill by larger vehicles. The average distance between the point of origin and the landfill is between 10 and 40 km. Often, waste is also deposited at so-called temporary landfills. These landfills are often undeveloped land in the urban area (Gelan 2021).

For households where waste is not collected or collected only sporadically, the only treatment option is illegal disposal, waste incineration or self-responsible transport to the nearest landfill or collection point.

In Eastern African countries, we can roughly categorize type of waste collection and transport depending on the socio-economic area we are considering; in fact, practices applied for rural or peri-urban areas are quite different from the ones adopted in urban areas.

In rural and peri-urban areas, with high self-sufficient livelihoods such as harvesting crops and raising livestock, reduction of waste at source, and specifically organic waste, through self-disposal is common practice: in these cases, food and organic wastes are directly utilized for animal feeding or composted. Open burning is also a common way for households' waste reduction (ACCP 2019). Therefore, there does not seem to be an urgent demand among rural communities for collection and transport of household produced organic waste.

In any case, it should be considered that fields' productivity is significantly increasing and that agriculture practices are rapidly changing in Eastern African economies (Dorosh and Minten 2020). In Ethiopia for example, the agricultural sector is employing 80 % of the total population, contributing 39 % to GDP, and generating 90 % of its foreign currency from exports. Currently, agricultural exports consist mainly of unprocessed raw materials. To boost trade and exports of agriculture production, the Ethiopian government is supporting a huge investment in agro processing industrial parks, aiming at making Ethiopia a top manufacturing hub on the continent. 17 agro-industrial growth corridors (AIGC) are planned for development, with coverage in all nine regional states, and four Integrated Agro-Industrial Parks (IAIP) are currently under construction (UNIDO and PcP Ethiopia 2018). Agro-industrial processes involve livestock, sesame, cereals, coffee, sugar plantations, pulses, fruits, and vegetables, and this will lead to an important production of residues. For this reason, activities revolve also the production of agri-inputs (for example, bioenergy, compost, renewable energy), and agri-infrastructure (for example, energy management, mechanization and transport, storage facilities) (Dorosh and Minten 2020, p. 404).

Considering that agro-industrial parks are located in rural areas (figure 24), nearby middle-sized towns where waste collection and transport coverage service is almost absent, a strict monitoring of an actual implementation of efficient re-utilization of bio-product is very important.

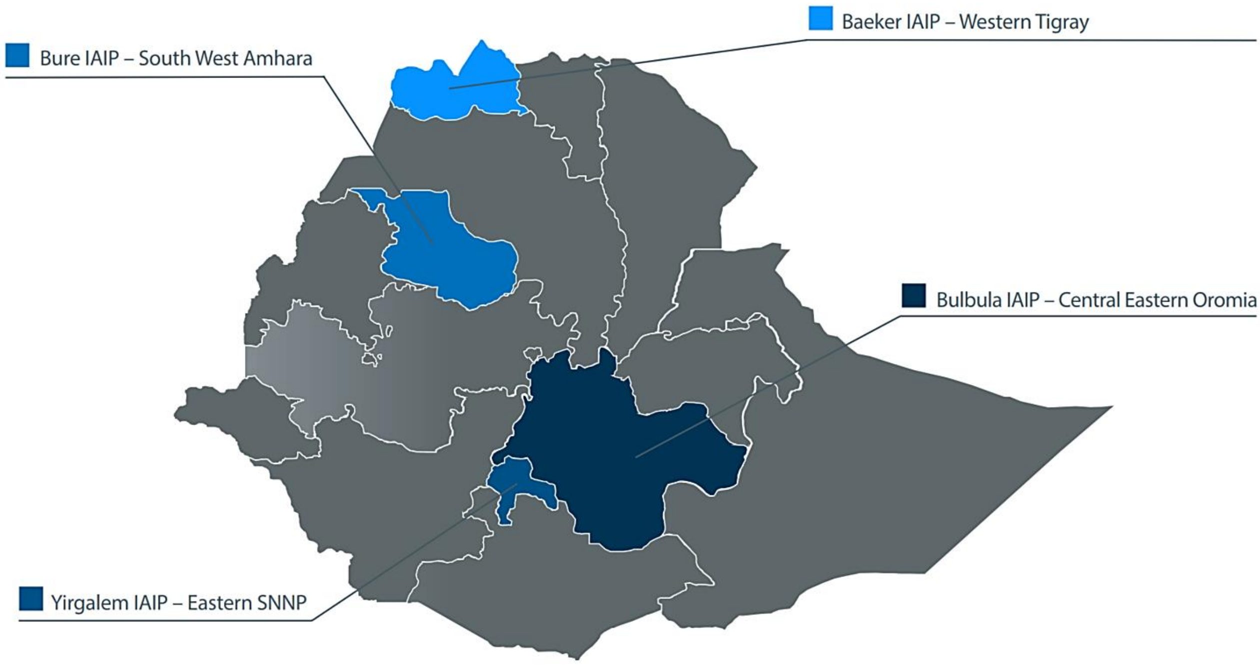


Figure 24: location of the IAIPs under construction (UNIDO and PcP Ethiopia 2018, p. 2)

Similar situation is found for the floriculture industry. According to Ethiopian Horticulture Producer Exporters Association (EHPEA) currently the flower, fruit, vegetable, and herb farms occupy 10,897.21 hectares of land. There are 72 flowers farms in Ethiopia (EHPEA 2022) and no clear understanding on how the produced residues are treated. EHPEA is working in biomass management (composting) and in adopting technologies (bio-energy) to improve green water management practices and efficiency but no data could be found on the progress of this initiative.

Figure 25: greenhouses of the floriculture industry in Bati (Ethiopia) on the shore of Lake Ziway. (Maps Data: Google, Placemarks Africa ©2022 Maxar Technologies)

At now, there is no a national standard either for floriculture or other industries to guide the waste disposal system. The residues from floriculture industry are particularly dangerous because of the use of fertilizers produced specifically for flower farm purposes and which can affect the soil and surrounding environment adversely (Kifle 2021). In order to regularize the sector, Ethiopian Standard Agency is preparing national standard for controlling and limiting harmful wastes from the horticulture industry.

In urban areas, reduction at source is not applied, mainly because of lack of space; nevertheless, open burning is still a common practice. Segregation at source is not institutionalized, even if waste pickers from informal sector are often collecting recyclables house to house. An attempt to institute city-wide segregation of waste at source, reported to be the first in East Africa, has been done in Kigali, Rwanda. Unfortunately, the initial attempt ended in failure (Kabera et al. 2019, p. 68).

The recovery of recyclable components such as paper, cardboard, plastics, metals, textiles and leather is common and involves a wide variety of groups of people. The collection of recyclables is not carried out under aspects of maximum collection of recyclables but under economic aspects, which lead to the fact that not all sub-fractions are collected in residual waste and, depending on the market situation and price, material flows also remain in residual waste. This approach to the collection and sorting of recyclables also influences the quality of a substitute fuel sub-fraction and the economic operation of a waste incineration plant in a relevant way.

In addition to municipal employees, the informal/private sector is often involved in sorting, whose working conditions are often dangerous and inhumane. Despite the partial collection of recyclables, there are still large amounts of recyclables in the residual waste.

Even if collection rates are high in urban areas, the impact of an improper collection and transport of solid waste is very huge due to the particular socio-economic living conditions. In the absence of a regular solid waste collection service, waste is dumped in open spaces, on access roads and along watercourses. Dumps are invaded by waste pickers and animals which scatter the wastes and the organic component of wastes serve as breeding grounds for disease vectors, primarily flies and rats. Leachate from decomposing garbage percolates into soil and nearby water sources, and the resultant contamination of food, water and soil can have serious environmental consequences (Coffey and Coad 2010, p. 18).

Un-Habitat identified the main causes of the improperness of waste collection system typical of developing countries in an inadequate resource mobilization, an over-reliance on imported equipment, inappropriate methods of finance, a use of inappropriate technology, and the inequity in the service provision (Coffey and Coad 2010, p. 18-20).

All these problems are typical also for East Africa collection system in urban areas as confirmed in Africa Solid Waste Management, 2019 Data Book compiled by the African Clean City Platform. According to the study, one cause of low collection rates and irregular collection service is the general lack of collection and transport equipment. With regard to individual equipment conditions, waste in developing countries contains more organic waste than waste in developed countries, which translates into higher water content. Due to the heavy specific gravity, the types of waste compactor vehicles typically used in developed countries are unable to function effectively in developing countries. Frequently upwards of half of the equipment on hand in a city is non-operational because of maintenance difficulties. These difficulties include a lack of technical capacity, complicated mechanisms within the equipment, and a lack of the time or budget needed to import parts" (ACCP 2019).

Door to door service is the most common collection system in East Africa cities. To overcome access difficulties, often the secondary transport is arranged by carts, wheelbarrows or small vehicles. The waste collected is then temporary accumulated in transfer stations. The improper management and design of waste transfer stations is a further problem of the collection/transport system in East Africa cities. Waste transfer stations are designed to give flexibility to the primary collection, increasing its efficiency and reducing related costs. Nevertheless, for East African cities, transfer points are most of the times simply unprotected open spaces or open containers: when pick up is delayed they can become a serious nuisance for the city, causing odors, compromising the neighborhood's aesthetic and above all seriously affecting environment and public health.

3.3.4 Treatment and final disposal

The simplest way of treating organic waste is composting. There are many challenges in composting the organic fraction of residual waste. Since waste mixtures are often composted, the compost quality is low. Additionally, the demand from users in agriculture, landscaping and forestry is equally low, since commonly the utilisation of industrial fertilizer is preferred and the application of compost seems to be too complex in comparison. The problem of insufficient compost quality is also well known in Germany and solution strategies are very complex and costly. Conditioning the compost involves additional costs and is often not done in developing countries.

Thermal waste treatment is an alternative to composting. Due to the high water and inert contents as well as the absence of the valuable fractions removed in advance, the energetic use of high calorific waste components is more complicated. Pfaff-Simoneit (2012) pointed out that, especially in developing countries, the waste qualities do not guarantee self-sufficient incineration and the use of supporting fuels is necessary, which does not generate any economic added value. The technology used is often inadequate and the measurement and laboratory structures are often insufficient or non-existent. In Addis Ababa a 50 MW waste-to-energy plant was inaugurated in 2018 on 19 hectares of land at the country's largest landfill site, which has serious operational problems (Gelan 2021; Teshome 2021). The reasons for the project's problems are manifold; for one, the calorific value of the waste was too low and the waste collection and separation too inefficient.

The third type of organic waste treatment is the fermentation of waste. This type of treatment is particularly suitable for unmixed organic waste with low proportions of contaminants and recyclables.

Especially waste from industry, agriculture, trade and commerce is suitable for energy recovery under certain conditions. In principle, household waste is also suitable for digestion, but it contains a high proportion of impurities, which makes it even more difficult to use fermentation residues as fertiliser. For this reason, separate collection or sorting of organic waste in combination with composting is the preferred option for organic waste. There are several advantages to this alternative:

1. Higher calorific value in the residual waste
2. Involvement of the informal sector in collection and pre-sorting
3. Substitution of conventional fertilisers
4. Conservation of resources through decentralised value chains
5. Reduced transport costs
6. Improved suitability for subsequent processing
7. Enhanced quality of treatment output

Despite the available options, data for Sub-Saharan Africa region shows that 69 percent of waste (urban and rural generated) is openly dumped, and often burned. Only 24 percent of waste is disposed of in some form of a landfill (controlled dumping or sanitary landfill) and about 7 percent of waste is recycled or recovered (Kaza et al. 2018, p. 81-82).

Controlled and uncontrolled dumping is the cheapest and easiest way to dispose waste but it is cause of severe environmental and public health hazards. The waste in open dumps is left untreated, uncovered, and unfenced, attracting waste pickers looking for recyclables and animals looking for feeding; there is no groundwater protection or leachate and gas recovery. Moreover, methane accumulations within dumpsites structural weaknesses cause disastrous waste landslides, as the one happened in 2017 in Addis Ababa Koshe dumpsite, where 115 people were killed.

Recycling is commonly done by waste recycling businesses, supported by a large, and active, informal sector that includes itinerant buyers and waste pickers. This implies that recycling sector is mainly focusing on financially profitable business chain, such us plastic, metal, glass and paper recycling, while organic waste is often neglected.

Organic waste treatment plants at large scale is very expensive both in capital costs and in O&M costs and often, in developing countries, they are heavily subsided by international agencies. In developing context, small scale plants are much more efficient and sustainable but generally they have no the capacity to cover treatment of an adequate quantity of organic waste.

Data on final disposal of solid waste and existence of organic waste treatment plants are very difficult to gather. Table 14 resumes the information found with concerned source. Just studies or reports published after 2010 have been considered.

Table 14: types of final disposal and treatment facilities for SW available in some Eastern Africa cities

Country	City	Final disposal	Organic waste treatment	Other recycling practice	source
Burundi	Bujumbura	Open dump	no	informal	(Manirakiza et al. 2020)
Djibouti	Djibouti	Sanitary landfill	no	no	(ACCP 2019)
Comoros	Moroni	Open dump	composting at small scale by private	informal	(Ali et al. 2018)
Eritrea		NA	NA	NA	
Ethiopia	Addis Ababa	Open dump	composting at small scale by private	Waste-to-Energy plant, private recyclers	(ACCP 2019)
Kenya	Kiambu	Open dump	no	private	(ACCP 2019)
	Nairobi	Open dump	Black Soldier	private	(ACCP 2019; Couder and Kibuthu 2020)
Madagascar	Antananarivo	Controlled	Composting	MRF	(ACCP 2019)
Malawi	Blantyre	Controlled	composting (0.5 tons/day)	no	(ACCP 2019)
Mauritius		Sanitary landfill	no	various private recyclers	(Ministry of Environment, Solid Waste Management and Climate Change 2022)
Mozambique	Maputo	Sanitary landfill	composting (10 tons/3month)	MRF	(ACCP, 2019)
	Gurue	Open dump	no	no	(ACCP, 2019)
	Inhambane	Controlled	buried at landfill	informal	(ACCP, 2019)
	Kelimane	Open dump	composting (300kg/day)	No	(ACCP, 2019)
Rwanda	Kigali	Open dump	no	no	(Kabera, Wilson, & Nishimwe, 2019)
Seychelles		Controlled	composting at small scale by private.	various private recyclers	(Ministry of Agriculture, Climate Change and Environment 2022)
Somalia	Mogadisu	Open dump	no	no	(Ministry of Environment And Climate Change 2022)
South Sudan	Juba	Controlled	no	informal	(ACCP 2019)
Tanzania	Zanzibar	Open dump	SME, small scale	plastic bottles	(Hydroplan 2018)

Uganda	Kampala	Sanitary landfill	Informal	informal/private	(Oyoo et al. 2014)
Zambia	Lusaka	Sanitary landfill	no	various private recyclers	(ACCP, 2019)
Zimbabwe	Harare	Controlled	no	no	(ACCP, 2019)
	Bulawayo	Sanitary landfill	no	no	(ACCP, 2019)

Even if there is a trend in African countries to upgrade their end-of-life disposal infrastructure, from open-dumping to controlled dumping, controlled landfilling and finally sanitary engineered landfilling, open dumping is still the predominant disposal option for 70 per cent of waste in sub-Saharan Africa. The landfills often have no or insufficient base and surface sealing as well as systems for leachate and landfill gas collection and processing (ACCP 2019). Even when sanitary landfill is adopted as final disposal, it is quite common to find that it is not operated as per design specifications mainly because of budget limitations and the lack of skilled manpower (UNEP 2018, p. 37).

3.4 A case study: organic waste management in Ethiopia

In Ethiopia the waste management is based on numerous laws, regulations and ordinances. Moreover, Waste collection and disposal in Addis Ababa follows formal and informal approaches. Therefore, different stakeholders are involved in the waste management, such as public institutions, the formal and informal sector, the private sector, governmental organisations and NGOs. Different ministries are responsible for waste management in Ethiopia. One is the Ministry of Urban Development and Housing (MoUDH), as well as the Ministry of Environment, Forestry and Climate Change (MoEFCC) and the Ministry of Health (MoH). The MoUDH advises local governments on the design of waste management concepts and reviews them on an ongoing basis (ACCP 2019).

On the national level the Environmental Protection Authority (EPA) has the major responsibility for the implementation of environmental laws and solid waste management. In 1997 the EPA in cooperation with the Ministry of Finance and Economic Development Cooperation published an environmental policy in Ethiopia (Bjerkli 2013).

Ethiopia has therefore several policies and legal frameworks and has ratified a few international waste management conventions that support the enforcement of the MSWM system in the country. Nevertheless, lack of policy and legal framework enforcement, lack of supporting guidelines, lack of skilled human resources, infrastructure constraints, and the low public awareness highly put the implementation of SWM practices at risk (Hirpe and Yeom 2021). As a result, practices of municipal SWM in Ethiopia are different in each city and region. In the following chapters, a brief analysis and case study of organic waste management in three different contexts of Ethiopia is presented.

3.4.1 The case of Addis Ababa

Addis Ababa, the capital city of Ethiopia, is a megacity in rapid development that counts 3,774,000 inhabitants, according to projection from the data collected by CSA (Central Statistical Agency) in 2007, but whose actual population is realistically near to five million people.

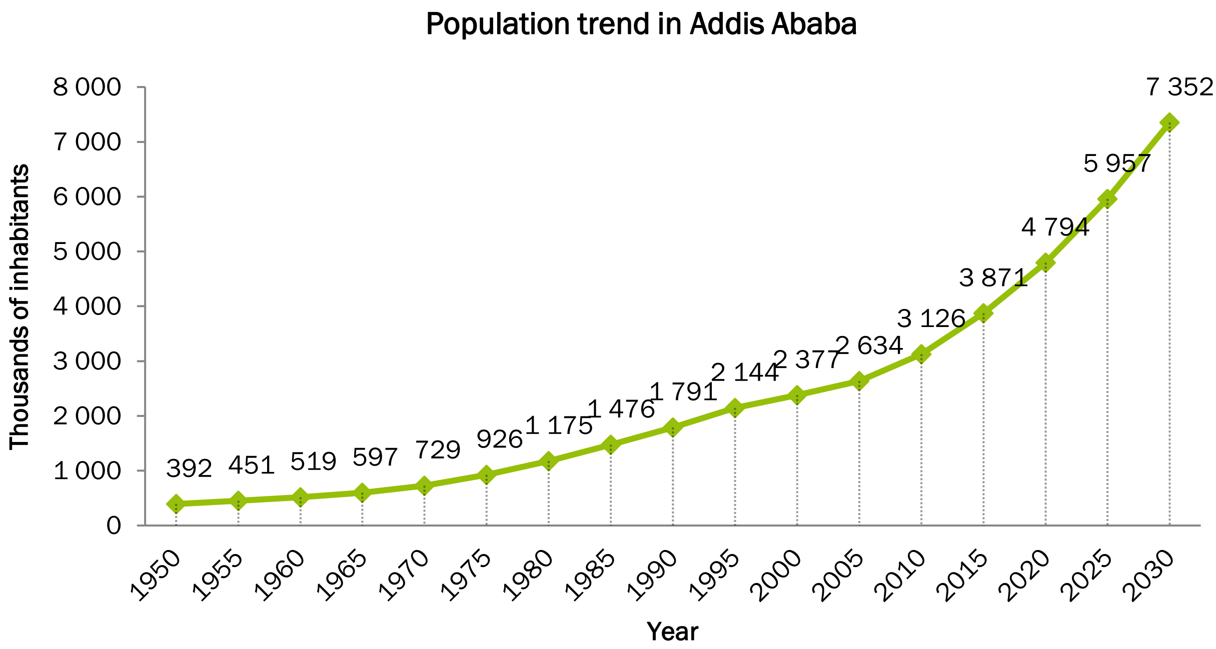


Figure 26: population growth trend for Addis Ababa city (UNDESA 2019, custom data acquired via website)

Management of solid waste in the city was structured in relatively recent time and was, and is still, subjected to various changes that aim at adapting the system to the needs and capabilities of the specific context.

After the Ethiopian central government takeover, the municipal health department, which was under the Department of Environment and Health, was the first organisation responsible for waste management. Unfortunately, proper waste management could not be achieved because the municipal health department already had many tasks and responsibilities and was overwhelmed with the tasks. In 2003, this problem was solved when the Federal Democratic Republic of Ethiopia (FDRE) implemented new structural reforms and transferred responsibilities to secondary units. Therefore, in Addis Ababa, the institution that was in charge of the waste management was the Addis Ababa City Sanification, Beautification and Park Development Authority (SBPDA) and also waste management departments have been founded in smaller administrative units. The main challenge for the SBPDA was the organization and administration of the waste management in sub-cities and the regulation of policies regarding to solid waste. The sub-cities were in charge of the collection and transportation of the waste in their area, meanwhile the “Kebeles” were responsible for the primary collection and daily waste operations (Cheru 2016).

Since January 2010 till now, responsibility of solid waste management is assigned to Addis Ababa City Solid Waste Management Agency (AACSWMA). The organizational chart representing the management structure of solid waste in Addis Ababa is well represented in the Addis Ababa Solid Waste Data document, published by the Solid Waste Management Agency in September 2019 (AACSWMA 2019) and reproduced in figure 27.

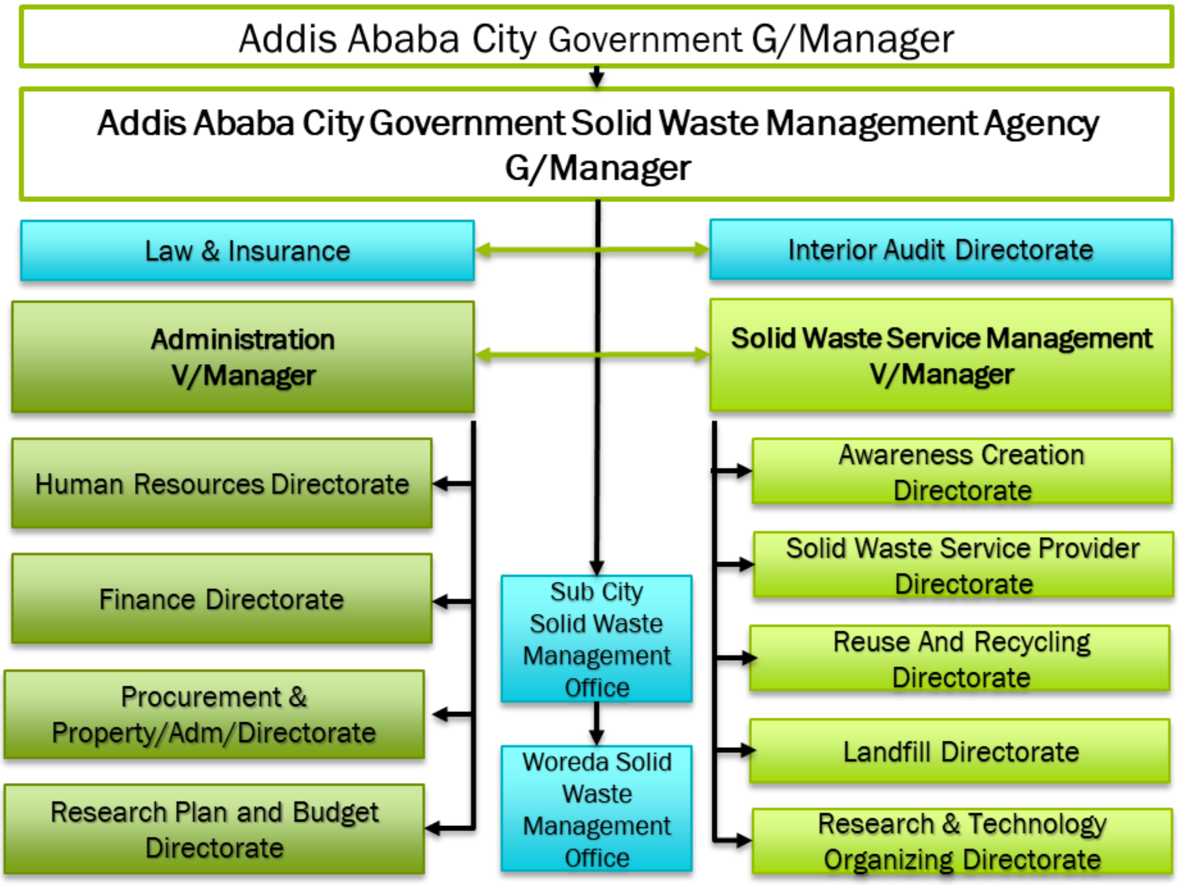
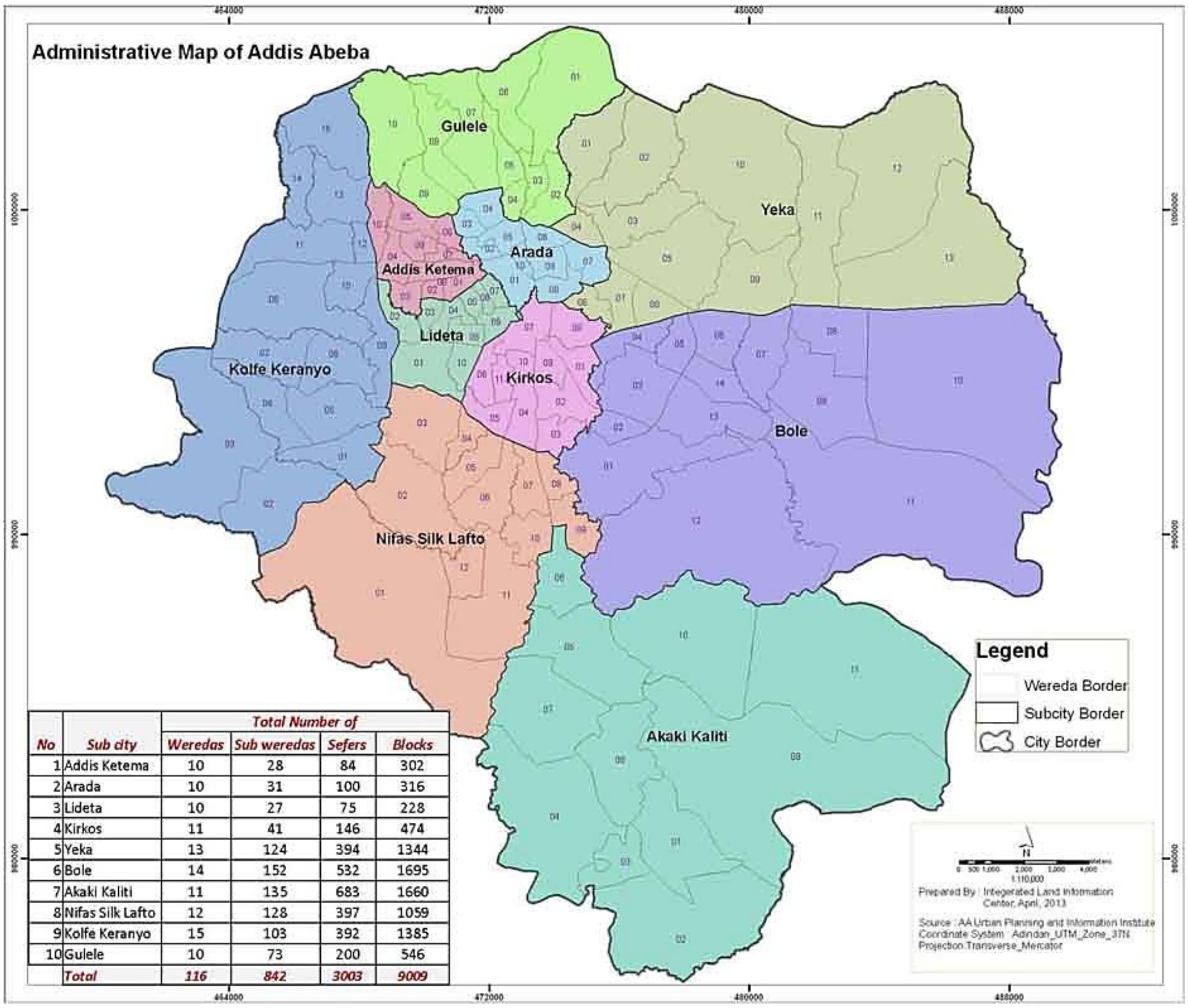


Figure 27: AACSWMA organizational chart (based on AACSWMA 2019)

Since 2004, as per its development plan, Addis Ababa started encouraging private companies and Micro and Small Enterprise (MSE) Unions to participate in SWM. As a result, in 2017, there were 6 private companies and 521 MSEs with more than 10,000 operators collecting from households, institutions and commercial areas (Mohammed and Elias 2017). In 2018, the MSEs involved in the collection of municipal solid waste were grouped into cooperatives, called collectors' associations; each of the newly formed collectors' associations was appointed to provide collection service exclusively to one or two Woredas, depending on their geographical extension. Woredas are the districts into which Addis Ababa is administratively divided (see figure 28, FANABC 2020) and consequently number of Woredas increased. Each association of collectors takes care of the door-to-door collection of waste for families residing in the area of competence, and usually manages to provide service to each family unit twice a week. The associations are under the supervision of the Woreda Solid Waste Management office.



No	Sub city	Total Number of Weredas	Sub weredas	Sefers	Blocks
1	Addis Ketema	10	28	84	302
2	Arada	10	31	100	316
3	Lideta	10	27	75	228
4	Kirkos	11	41	146	474
5	Yeka	13	124	394	1344
6	Bole	14	152	532	1695
7	Akaki Kaliti	11	135	683	1660
8	Nifas Silk Lafto	12	128	397	1059
9	Kolfe Keranyo	15	103	392	1385
10	Gulele	10	73	200	546
	Total	*116*	*842*	*3003*	*9009*

Figure 28: Administrative Map of Addis Ababa up to 2019 - since 2020 the City was restructured into 11 sub-cities, an updated map is still pending (Addis Ababa Planning and Information Institute 2013)

In Addis Ababa, waste is collected through a multi-stage system. The structure is based on the administrative districts of the city. The Addis Ababa Solid Waste Management Agency organises the entire waste collection and promotes the integration of the private sector, which is in charge of collecting waste from institutions, into existing administrative structures. Currently, 119 municipal collection vehicles and 161 private vehicles of 53 private companies are engaged in waste transport to the city-owned Reppi landfill (Gelan 2021).

Due to the high number of independently operating companies in the waste sector, coordinated waste collection and treatment is very challenging. The districts' solid waste management offices are responsible for collecting the waste from temporary collection sites and transporting it to the landfill in their area. This leads to the fact that there are different types of waste collection. Household waste is mainly collected by 87 waste collectors' associations, with an uprising trend. The associations are structured as a cooperative. as previously mentioned. Members of these associations collect waste manually from 600 to 1050 households and transport it to passable roads where the waste is loaded by transport vehicles and driven to the landfill (Gelan 2021). Manual collection of waste is often necessary because residential areas in developing countries are densely built-up and roads and paths are unpaved and not passable with heavy equipment. This also results in a high manpower requirement of 7 to 14 persons per 1000 t per year (Pfaff-Simoneit 2012).

A useful option for the collection of waste, for pre-treatment, or waste separation, are so-called collection points. Each of the Solid Waste Collectors association utilizes several collection points to daily store their waste collected from the close by neighbourhood. The waste is brought to the collection points by means of small-scale transport vehicles. The municipality is then in charge to take care of the transport to the landfill by compactor trucks. These trucks are scheduled to pass each collection point at least once or twice per day per, but the schedule is often not respected due to scarcity of trucks and the high frequency of stops. Due to the insufficient supply of the collection points, special attention must be paid to hygienic conditions, as these collection points are often located in the immediate vicinity of buildings. This situation is actually a big nuisance to the neighbour and often cause of disagreement and conflicts between collectors and community.

Figure 29: general waste accumulated in a temporary site of Addis Ababa (Cifa Onlus 2021)

In addition, the collection stations are also utilized as an initial pre-sorting of waste, which enable the simultaneous collection of recyclables and also is creating additional income for the cooperative members. The members of the cooperative are remunerated on the basis of the quantity of solid waste delivered to landfill (currently they receive 0.71 ETB - equal to 1.4 cent USD – per kilogram of waste delivered). Solid Waste Management Agency deposits the due amount of money monthly in the cooperative bank account and the members divide equally the income after deducting the running costs. The amount of money a single collector manages to gain monthly is generally not sufficient and income has to be increased through re-selling of recyclable materials (Tiruneh 2021).

Figure 30: temporary collection station in Addis Ababa utilized also for waste sorting (Cifa Onlus 2021)

As described, the compensation system adopted by AACSWMA for waste collection is based on quantity of waste delivered to the landfill; the quantity is measured by weight at the entrance of the landfill itself. In this way the cooperatives are incentivized to collect as much waste as possible; the approach is thought to ensure that most of the waste will be transported to its final destination and to reduce illegal dumping practices. On the other hand, this system discourages practices aimed at reducing the amount of waste entering in landfill such as recycling practices. This is particularly true for that fraction of waste characterized by substantial weight and low market potential, such as the organic fraction. As a result, while business chains for recyclables as plastics, metals or paper/cardboard are well developed thanks to the joint involvement of private sector, associations of collectors, and informal sector, there is no interest in finding an alternative route to organic waste to the one ending up in the landfill, with obvious consequences.

Figure 31: a collection site for PET plastic in Addis Ababa (Cifa Onlus 2021)

According to the study "Methane Gas Emission and its Management Practices from Solid Waste Stream, Case Study: Addis Ababa and its Surrounding Oromia Special Zone Towns", a total of 4,848,147 tCO_{2e} methane was emitted in 2012-2017, with a positive correlation with the increment of solid waste disposal in the study area. The study indicates as cause of the huge amount of emission a low level of 3Rs strategy implementation in Solid Waste sector that restricts resource recovery and contributes for GHG emission in the study area (Ali and Tarekegn 2018, p. 5).

To overcome this problem, the municipality of Addis Ababa decided to promote the creation of compost producers' MSEs and to link them with the cooperatives in charge of urban greenery as a first market outlet. In 2022, there were 76 compost MSEs active (more or less one per Woreda), involving around 772 members. At the moment of their creation, the compost producers' associations were provided with small land (300 m^2 in average) and with basic business and technical training (Vanzetto 2021). Municipality further promoted this business guaranteeing a monetary incentive for each kg of compost sold to Urban Greenery cooperatives.

Figure 32: compost produced by MSEs of Addis Ababa (Cifa Onlus 2021)

For the treatment of organic waste from households, the concept of decentralised composting has proven to be effective. The small plant capacities require less complex plant technology and involve workers from informal sectors, but this must be accompanied by a good connection with the potential buyers; this also implies guaranteeing a good quality final product.

Since 2020, organic waste from largest Addis Ababa's markets has been collected and subjected to aerobic treatment carried out by the 76 cooperatives appositely created in small plants as described before. Due to the high diversity of the aerobic treatment, and the low quality of organic waste at source which is often contaminated with impurities, it can be assumed that a consistent quality of the compost products cannot be guaranteed and the compost products are only comparable with certified products to a limited extent. Furthermore, almost none of the composting sites of the associations are provided with a shelter (roof and/or slab); this is mainly due to the land ownership problems currently underway in Addis Ababa which make it almost impossible to obtain the required construction permits. The market for the compost produced through this initiative is unlikely to be profitable enough to guarantee decent income for the members of the cooperatives (10 on average per cooperative). If cooperatives will not be further supported in enhancing quality of final product and in diversifying market outlet, the sustainability of this action is doubtful.

The compost producers are gathering organic waste almost exclusively from vegetable markets and hotels and restaurant. In this way they manage to have a relatively not too much contaminated organic waste fraction and they avoid entering into competition with the solid waste collectors who are giving service to households. Market and restaurants are anyway contributing for a small percentage to the waste generated in the city (figure 33, markets and restaurants are part of the "Commercial and other institutions" category) and it is unlike those the compost producers' cooperatives will have a significant impact in solid waste management in the city.

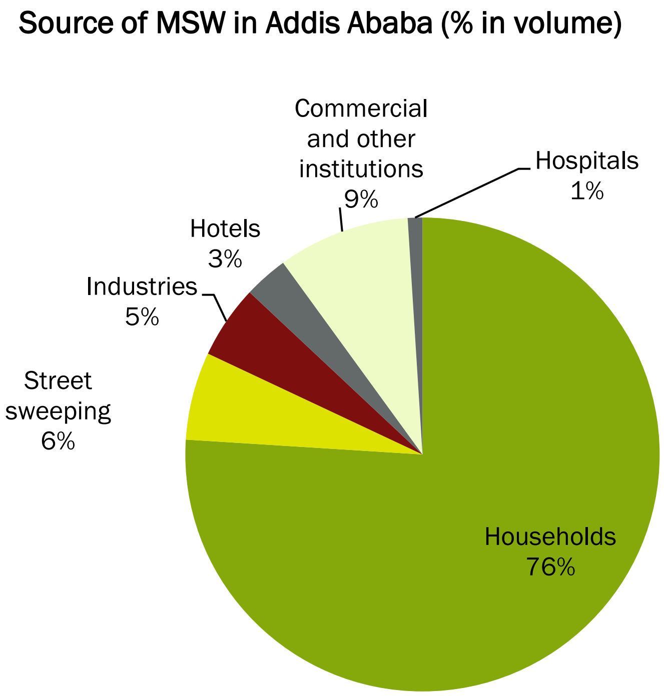


Figure 33: sources of municipal solid waste collected in Addis Ababa (AACSWMA 2019)

In 2021, according to the projections done in the study "Municipal Solid Waste Generation Rate and Characterization Study report" the amount of waste generated by institutions was 253 tons per day (GES 2020, p. 54), of which 68 % is organic waste (food and garden waste). This means that organic waste produced by institution per day is around 172 tons per day.

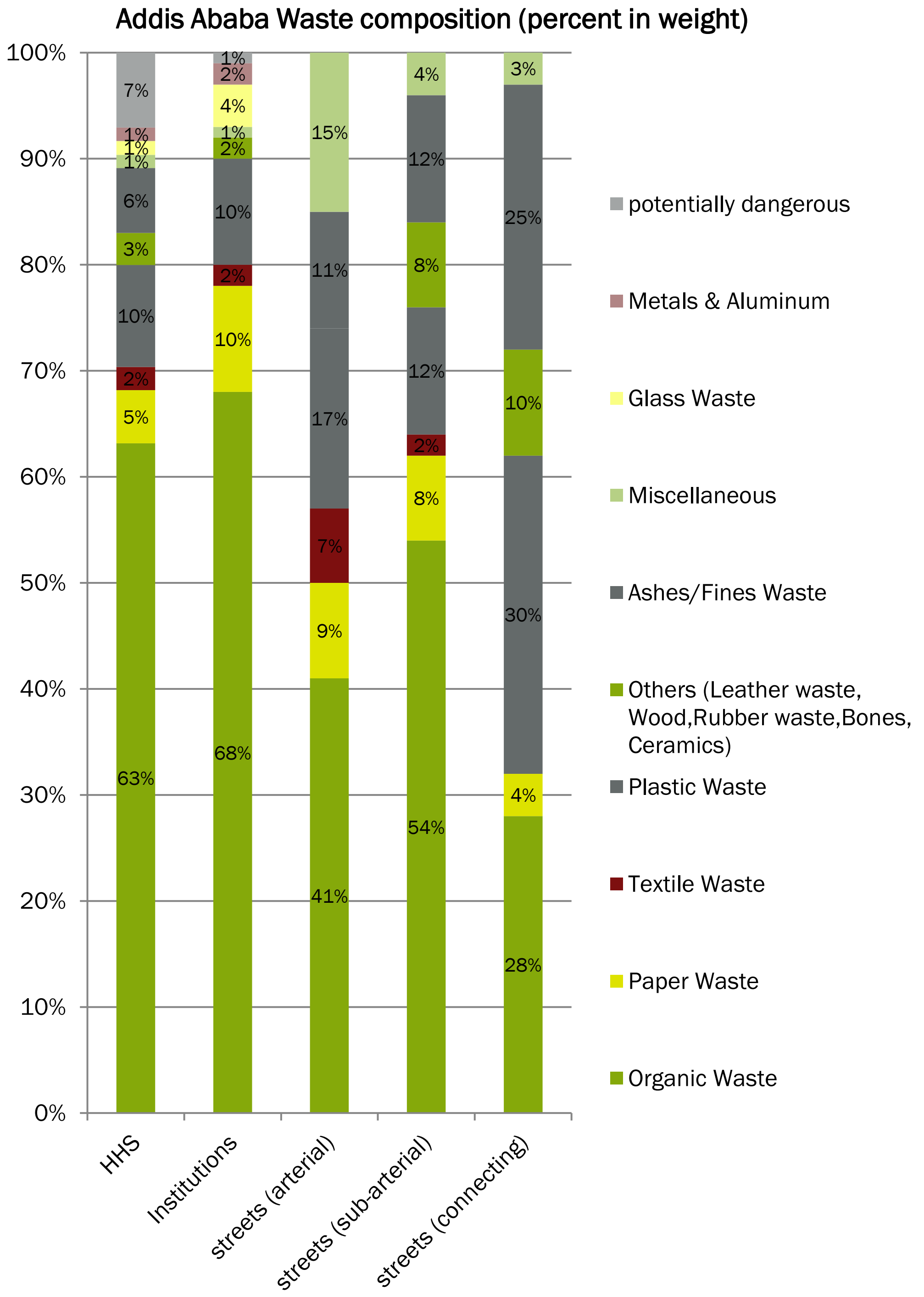


Figure 34: composition of waste in Addis Ababa according to source (GES 2020)

The food waste estimated to be generated by households in 2021 was 1271 tons per day (GES 2020, p. 52), almost ten times the amount produced by the institutions. In order to avoid this fraction to be wasted in the landfill, households' organic waste should be treated directly by the associations of collectors. As already mentioned, this is unlike to happen because of the almost insignificant increment of net income if compared to the direct selling of the waste to landfill (0.71 etb/kg the amount gained). Considering that waste sorting at source is not practiced by citizens of Addis Ababa, the workload and costs for producing a rather low -quality compost do not attract solid waste collectors to get involved in this activity.

Segregation at households' level is actually foreseen by Ethiopian Solid Waste Management proclamation in Article 11.1 (households are responsible for the segregation of waste) but there is practically no measure to enforce the law (Teshome 2021). According to a survey conducted in 2021 through RANAS methodology in order to support behavior change interventions on organic waste separation, one of the observed problems for the citizens who would like to separate organic waste from the rest is the lack of space where to locate the segregation bins (Gamma and Kramer 2021). Lack of a legal system applying incentive and penalty mechanism is also a reason for not practicing sorting at source.

At the current state of things, decreasing quantities of impurity in the organic waste fraction depends on the rate of collection of other more valuable recyclables. In Addis Ababa recyclables are collected at source by private/informal sector (called korales), sorted in the temporary collection points by the collectors' associations, or picked at landfill by informal scavengers.

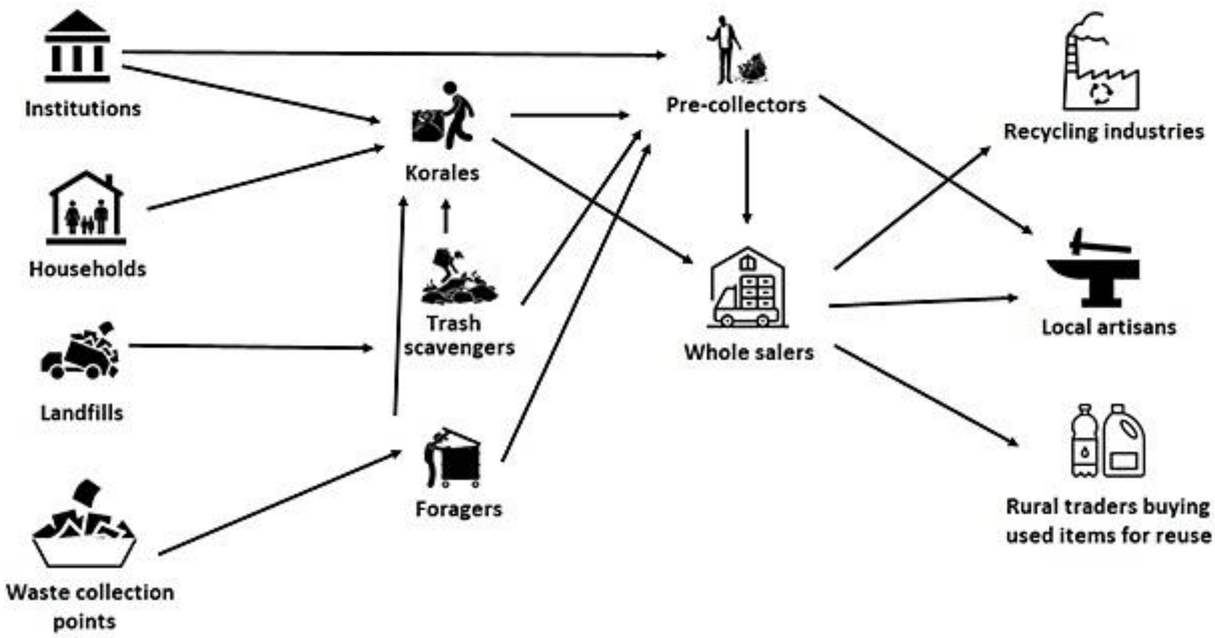


Figure 35: network among actors involved in recyclables chain (UNDP 2020c)

Even if informal sector plays a big role in recovering valuable resource from waste, their contribution is hardly recognized and efforts in regularize and enhance the system are still unsatisfactory. Working conditions in the informal sector are very critical. Unhygienic conditions and child work are still widespread and the potential for risk from disease is extremely high. Workers in the informal sector often come from minority groups and are not given the opportunity to find employment in the formal sector. Nevertheless, the informal sector is more active and efficient than the formal sector (Pfaff-Simoneit 2012). Private companies are heavily involved in Ethiopian waste management and compete with the informal sector. As in industrializing and developing countries, local governments often lack financial and technical resources and skilled labour to provide efficient basic services for the urban population. Most informal waste management actors in Addis Ababa are particularly involved in the collection, recycling and reprocessing of plastics, metals and paper (Hirpe and Yeom 2021). Bjerkli (2013) noted that:

> *"The informal recycling system in Addis Ababa is similar to other informal recycling systems found in urban areas in developing countries. It consists of different actors who are involved in activities related to the*

> *collection, trade, reuse, and recycling of waste. The system is highly organized and consists of eight levels and nine different groups of actors: households, foragers, scavengers, Qorqoro alleh, pre-collectors, wholesalers, middlemen, small-scale craftsmen, and local industries*." (Bjerkli 2013)

Important actors in informal waste management are in particular the buyers of scrap metal (corales), the street boys who resell recyclable raw materials from the garbage containers to the corales, the garbage collectors at the landfill site and some of the municipal workers. The corales mainly collect items such as cans, bottles, glass (jars) perfume and nail polish containers, paper, rubber shoes, scrap metals, old clothes (Hirpe and Yeom 2021). The Addis Ababa administration integrated the informal sector into the formal sector: informal workers were registered and given licences. In this way, they could operate as private enterprises and were also exempted from taxes (Alemu and Adesina 2017). According to Bjerkli (2013) the informality (informal sector) in the economy can be seen as a process where changes can be noticed related to the politics and the state. From the pre-selections in 2010 the informal actors in Addis Ababa such as street vendors and shoe shiners were forced by the government to register and pay taxes to the "kebeles" when they want to continue with their activities.

Until the early 2000s, Ethiopian waste management had operated for more than three decades without clear policy guidance or well-defined standards and regulations. The collection of residual materials has always been fundamentally unregulated, inadequate and inefficient. The growing health and environmental threats posed by the Repi landfill were the result of inefficient land use and irresponsible handling of hazardous waste. Although the existence of informal actors in waste management was well known at various levels and sectors of the city administration, their significant contribution to waste reduction, reuse, and recycling was neither noted nor officially recognized by the city government (Hirpe and Yeom 2021).

With the ten- year plan, AACSWMA wants to create a new compost site for organic waste treatment and to support the action with initiatives aimed at improving the collection service: in the immediate future we will probably see substantial changes in the solid waste management of the city.

3.4.2 The case of Hawassa

Hawassa is a rapidly growing city of about 400,000 inhabitants which are expected to double by 2030.

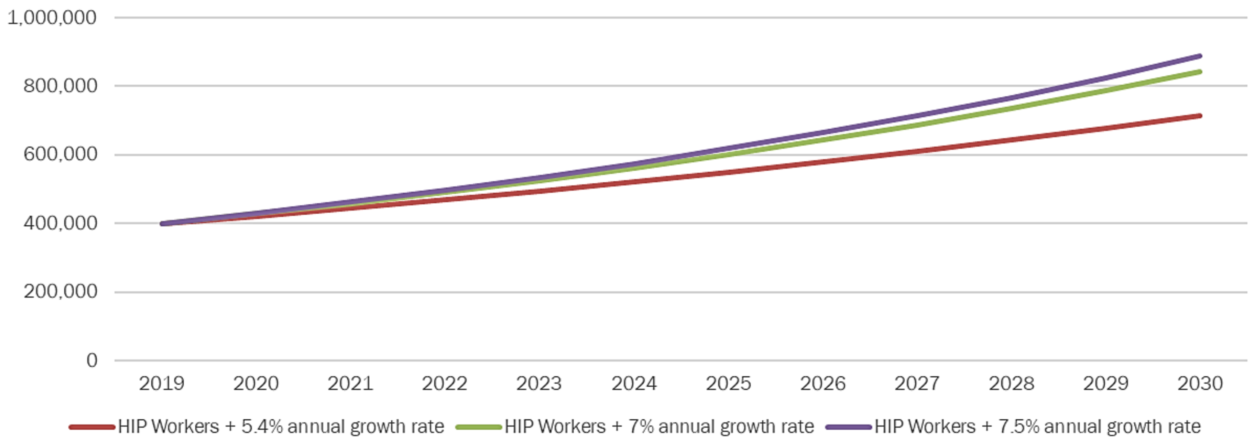


Figure 36: Population Projections for Hawassa City (2019-2030) with HIP workers Included (Hawassa City Administration and UNHABITAT 2020)

The city is located about 300 km South of Addis Ababa, in the newly formed Sidama Regional State, a region characterized by the high agricultural productivity and particularly famous for the production of coffee. Hawassa rises on the homonymous lake, which attracts local and international tourists, hosts an important University center and a quite recently constructed industrial park (HIP, Hawassa Industrial Park). This makes the city an important trade and touristic center which attracts around 200,000 visitors every year.

The solid waste management of the city is quite problematic. SWM in Hawassa is facing several challenges at every stage: no sorting of waste at the source, SW collection and transportation is operated using limited means (donkey carts) and the existing dumpsite is totally inadequate both in capacity point of view both for the environmental treat it represents (Hawassa City Administration and UNHABITAT 2020).

There are 6 associations which are taking care of collection and transport of waste up to dumpsites. The associations have assigned an area where to give service and they are paid directly by the waste producers. In Hawassa in fact there is no a tax system to cover the costs for waste collection services, therefore the system is based on the private agreement among client and service provider. This system favours the involvement of the informal sector in waste collection: the current situation is in fact that the informal sector deals with the door-to-door collection from private individuals while the associations of collectors have contracts with large producers such as hotels, restaurants or condominiums. Private citizens in fact, usually call waste collectors as per need, without following a fixed schedule; at early hours of the days, the informal collectors wander around the city with their donkey carts and collect waste from who is in need to get rid of it; the waste producers pay according to the quantity of waste to be disposed of, usually by volume. On the other hand, waste producers that need a regular service, such as restaurant, hotels or condominiums usually get into a regular contract with the collector's association with a fixed schedule for collection and monthly payment. Associations of collectors usually have a motorized mean to collect waste, are reliable in their schedule and can provide a formal receipt for the service.

Both associations and informal sectors try to increase the income generated from collection selling the valuable found in the solid waste to the recyclers working in the city or to middlemen who are re-selling the recyclables in Addis Ababa.

Therefore, it is quite common that the associations of collectors, to which the Municipality have assigned a temporary collection site, are also engaged in the production of compost. The compost produced is then sold to the Municipality for Urban Green or used for the production of seedlings when the associations have engaged in this activity as an additional alternative income.

The municipal SW generation in Hawassa city (household + business) is estimated to be 206 t/day and at least 51 % of the generated waste is organic. This means that the city generates at least 105 t/day of organic waste (RWA 2020).

Hawassa was chosen for the implementation of the NAMA project, a UNDP / GES program designed to boost compost production from municipal solid waste (see also 3.5.7). The keys for the selection of Hawassa were the full an inadequate structured landfill, the cities need of compost for the urban greenery, the city is well-known for its beautiful gardens, as well as the need of compost of the farmers working in the peri-urban areas, whose income is mainly base on agricultural production. The city has been provided with a shade of around 2500 m^2, located in the dump site, and with a mechanical turner and a shredder to facilitate the operation for compost production (UNDP 2020c).

Figure 37: Hawassa dumpsite; the shade for compost is located on the left of the dumpsite (Maps Data: Google, CNES / Airbus ©2022 Maxar Technologies)

Two associations of collectors, named Hawassa Wubet and Lewit Be Sira and one compost producer association, Green Irry, have been involved in the producing compost from MSW; all of them have an extensive experience in compost production. As part of the NAMA activities, the associations received training on compost production; after which each of them was assigned a part of the shade where to store the organic waste. Waste is arriving at the shade unsorted and the associations are taking care of separating organic waste from impurities. This process is conducted manually. The organic waste is left to mature in heaps for three months. Once per week, the organic material is mixed with the mechanical turner, which is property of Municipality and assigned to the three associations for free use. The compost is ready for market in around three months, and then the product is sold to Municipality or to private buyers. The associations produced about 162 m^3 of compost in the last production cycle of three months.

Hawassa Wubet is one of the three associations of collectors involved in the production of compost. Mr Henok Dangote, the chairperson of the association, is working in the waste sector for more than 15 years. He started as informal collector with a donkey and a cart; while the business was growing he decided to involve in the recyclables business chain, in particular with PET plastics and compost production. He is producing compost since 2016. Before receiving training from the NAMA project, he was practicing trench composting, producing around 20 quintals of compost every three months. The compost was then sold to Municipality for around 280 etb per quintal.

After having the possibility to use the machineries and the shade in the dumpsite, he started to produce heap compost. For the firstround production, the association involved 22 workers for organic waste sorting.

Figure 38: mixing and shredding operations supervised by Mr Henok (Dangote 2021)

The association managed to produce 72 m^3 of compost of a relatively high quality. Certificate of quality is mandatory to participate to Municipality bids; Hawassa Wubet sent a sample of the produced compost to Hawassa University. The high percentage of impurities is clearly visible in the composting heap (see figure 38) which is jeopardizing the final quality of the product. From the 72 m^3 of compost ready in December 2021, the association sold around 18 m^3 to a coffee producer. Mr Henok is complaining about scarce access to market and he doubts he will manage to sell the whole quantity of compost produced. He believes that the main reason is the lack of awareness of the farmers about the benefits of using compost in their cultivations and a general adaptation to chemical fertilizers. This consideration is also confirmed by the study “Manure Management Practices and Policies in Sub-Saharan Africa” (Ndambi et al. 2019, p. 4-6). The Municipality is no more purchasing compost from Hawassa Wubet association since it enters a sole contract with another of the three compost producer associations. At the moment, Hawassa Wubet association has 4 windrows of organic waste under maturation for compost production;nevertheless, Mr Henok declared that is not so sure he will continue to produce compost if he will not manage to sell the one produced up to now (Vanzetto 01/2022).

The main problem for associations of Hawassa in the production of compost are the quality of the product and the market access. Attempts to involve associations or private sectors in the production of compost when the supply chain is not well developed are risky because they can create false expectations which, if not met, could lead the entrepreneur not to try this type of business once again.

3.4.3 The case of Gidole

Direshe Special Woreda District is located in SNNPRs Regional State, around 500 km South of Addis Ababa. It counts around 140,000 inhabitants, with a population density of 95.98. The main town is called Gidole which is about 60 km far from the city of Arba Minch, an important center for agricultural trade. The town counts about 13,000 inhabitants.

The livelihood in Direshe district is mainly based on rural economy; also, in the two small towns present in the territory, Gidole and Mande, urban gardening is a common practice. The community is mainly practicing agroforestry with animal integration bred by traditional practices. Agriculture products are sold mainly to the local market and to the big markets happening in Southern Omo, Gamo Gofa, Konso, and in the southwest of Oromiya; some of the products reach also the big city of Arba Minch. There is no any agro-industry nearby but the government has plans to develop the agriculture sector enhancing food processing in the long run.

In regards to energy sources, most of the population is using biomass (wood) for their needs. Just the urban centers and some villages are reached by the electric national grid.

Waste management is not still a felt issue within the community and no data are available about waste generation or composition. At a glance, it can be estimated that more than 80 % of the generated waste is organic, followed by plastic and a really small percentage of paper.

There is no formal collection and transport system organized by local authorities, not even in urban area. In the rural area people simply throw their waste in the open area, while in Gidole town there is a common area where people dump waste, which was inappropriately located nearby a river. The most common way to get rid of waste anyway is open burning.

Valuable things destined to no longer be used, such as broken hard plastic containers or used garments, are recovered by recycler collectors, traditionally called “korale”. This is actually happening just in Gidole town and only in some neighbouring districts. As per regard to food waste, in town is not re-utilized, but is usually thrown away mixed up with the other waste. In rural areas instead, it is utilized to feed the animals or buried in the soil to improve its properties. Agriculture waste and dung is also utilized in rural area to improve soil fertility. For those farmers who are not living nearby their own farmland, dungs are burnt or washed away by rain.

Gardula Development Association is a local organization that is working for more than 20 years in Gidole district. One of the projects under implementation is promoting agroforestry and permaculture practices for the sustainable development of the area. The project aims at reaching 7000 farmers trained on sustainable farming practices and growing 70,000 fruit trees using permaculture and agroforestry principles. Therefore, there is an important component that promotes the use of compost and teaches about modern methodologies of production. The project started in 2020 involving 18 Farm Training Centers. In addition to the training, garden tools, seeds and some structural maintenances of the Training Centers have been provided by the project. Currently, training centers are preparing compost to demonstrate to farmers the advantage of using organic fertilizer. The lessons learned shows, that in this area farmers are applying new knowledge only after seeing the benefits and advantages from a concrete application. The compost that will be produced by farmers is intended to be applied to their own farmland.

Figure 39: heap composting in an agriculture training center in Gidole (Dagne 2021)

As a matter of fact, farmers know traditionally the potential of organic waste and still utilize agricultural waste to improve soil quality. Therefore, they are very proud to see that traditional practices are recognized by modern technologies. Nevertheless, in the last 30 years, a policy aimed at boosting agriculture production in a short time promoted massively the use of industrial input also for small-scale farmers. This confused farmers who are now mostly adapted to conventional farming; project implementers are seeing that is not easy to convince farmers to go back to traditional farming practices. There are also additional reasons that prevent farmers from producing compost: smell generated during a mismanaged process, fear for impacts on health, and the intensive labor process required. It's anyway reassuring to see that farmers actually recognized that the use of chemical fertilizers is not sustainable.

Figure 40: demonstration on how to apply compost for horticulture (Dagne 2021)

The project, still ongoing, is highlighting that farmers are not very motivated in compost production for farmland use, as a massive amount of compost is needed to cover the extent of their land: as per indication of Federal Environmental Protection Authority per 1 hectare of land is needed from 100 to 150 sacks of compost to produce a comparable impact with the one obtained utilizing around 30-40 kg industrial fertilizer. Moreover, production of compost requires intensive work and a lot of time. Compost production is much easier to be promoted for farmers or city dwellers that intend to adopt in urban backyards and gardens, on a smaller scale.

3.5 Projects on organic waste treatment in Eastern Africa

Considering the amount of organic waste produced in East Africa, and the high percentage ending up in open dumps with the consequent environmental, health and safety impacts, there is a high interest of municipalities and communities in diverting this component of waste to safer and potentially income generating treatment technologies.

Available technologies for organic waste treatment are various (see figure 2, figure 3) but the most utilized in low- and middle-income settings (apart from improper practices such as direct land application, densification, direct combustion) are composting (windrow and in-vessel) and anaerobic digestion.

During the compilation of this study, a database on organic waste treatment application in Africa could not be found; such database will allow a sharing and a transfer of knowledge to practitioners that could be very useful in view of improving waste management in low- and middle-income settings (Lohri et al. 2017, p. 117).

An attempt follows to list the various initiatives implemented or underway in East Africa on the treatment of organic waste: the list is not to be considered exhaustive as it is based on internet research and indications from experts in the sector: It should also be noted that the objectives, methodologies and results achieved which are reported for each of the listed initiatives are taken from the projects' website and are not verified in the field. The list is intended as a first reference for further and in-depth investigations.

3.5.1 Africa: the African Circular Economy Network

A significant network for the waste management is the African Circular Economy Network. (ACEN), that counts as recognized Expert Network for the Circular Economy in different African countries. ACEN representatives are located in Algeria, Angola, Benin, Botswana, Burkina Faso, Cameroon, Cote d'Ivoire, Democratic Republic of Congo, Egypt, Ethiopia, Ghana, Guinea Conakry, Kenia, La Reunion Island, Madagascar, Mauritius, Morocco, Namibia, Niger, Nigeria, Rwanda, Senegal, Somalia, South Africa, Sudan, Tanzania, Togo, Tunisia, Uganda, Zambia and Zimbabwe. ACEN was founded in July 2016, with the purpose of building

> "*a restorative African economy that generates well-being and prosperity inclusive of all its people through new forms of economic production and consumption which maintain and regenerate its environmental resources*." (ACEN 2022)

The African Network tries to achieve their goals through research, networking, training & awareness, knowledge sharing, networking & events, and with case studies reports.

3.5.2 Horn of Africa: Sustainable Energy, Carbon and Urban Resilience

The Horn of Africa Regional Environmental Centre and Network (HoAREC) was founded under the Addis Ababa University. The mission of this NGO is:

> "*to contribute to sustainable development, promote better environmental governance and management in the Horn of Africa while enhancing the development of environmental support sectors such as the promotion of renewable energy and the stimulation of new value chains for sustainable products and services*" (HoAREC 2022)

Some important goals of HoAREC are to integrate the local and cultures and traditions of the region in environmental protection schemes and to establish a sustainable financing for the Network and the Centre. In particular, the program "Sustainable Energy, Carbon and Urban Resilience" aims to unite academia and practitioners to promote environmental conservation and natural resource management across the Horn of Africa (HoAREC 2022).

3.5.3 Ethiopia, Kenya, Mozambique, Rwanda, Tanzania, Uganda and Zambia: Assessing the prospects and requirements for bioenergy -development in seven demand sectors in Sub-Saharan Africa

Phase 1 of the BSEAA (2016-2017) consisted of scoping research that investigated the realities of bioenergy technology in some target countries across SSA, with a specific focus on commercial and industrial applications (i.e. productive use). The scoping phase also included a broad investigation of the challenges and opportunities affecting the adoption and roll out of bioenergy technology across SSA narrowing down to 10 target countries: Ethiopia, Ghana, Kenya, Mozambique, Nigeria, Rwanda, South Africa, Tanzania, Uganda, Zambia. This research will lead to an improved understanding of the commercial, economic and institutional requirements and opportunities for scaling up generation and application of bioenergy for various uses in low-income countries in sub-Saharan Africa.

The research focus on general biomass as feedstock of bioenergy; the team has developed a range of research reports, tools, policy briefings and databases to guide developers, investors and policy makers which can be useful to address organic waste treatment too (NIRAS 2021).

3.5.4 Ethiopia, Kenya, Tanzania, Uganda: Africa Biogas Partnership Program (ABPP)

The Africa Biogas Partnership Program (ABPP) is a partnership between Hivos and SNV in supporting national program on domestic biogas in five African countries. The program aimed at constructing 100,000 biogas plants in Ethiopia, Kenya, Tanzania, Uganda, and Burkina Faso providing about half a million people access to a sustainable source of energy by the year 2017.

The overall objective of the ABPP was to contribute to the achievement of the Millennium Development Goals through sustained construction of domestic biogas plants as a local, sustainable energy source. This was intended to be fulfilled through development of a commercially viable and market-oriented biogas sector. Until its project end in 2019 the ABPP has constructed over 18,500 biogas plants overall (ABPP 2019).

3.5.5 Ethiopia: IGNIS multilateral foundation

IGNIS-the Income Generation & Climate Protection by Valorising Municipal Solid Wastes in a Sustainable Way in Emerging Mega-Cities of tomorrow is a multilateral institution, funded by the German Federal Ministry of Education and Research. This multilateral foundation was founded in 2008 and ended in 2013, and implemented two pilot projects in Addis Ababa and the main tasks was to create jobs that would have positive effects on greenhouse gases and other emissions. The projects included among others the composting of organic waste, occupational safety improvement of waste collector and paper recycling (IZES 2017).

3.5.6 Ethiopia: Biogas Dissemination Scale-Up Programme (NBPE+)

The Biogas Dissemination Scale-Up Program (NBPE+) is a public-private partnership at federal, regional and district level funded by the European Union and the Government of Ethiopia. SNV manages this program and also provides technical assistance in the implementation. The Ministry of Water, Irrigation and Electricity (MoWIE) executes the program on behalf of the Government of Ethiopia.

The Program was launched in May 2017 with an implementation period of over five years. The Biogas Dissemination Scale-Up Program builds on the achievements of the National Biogas Program of Ethiopia (NBPE) which has been implemented since 2009 in four regions funded by the governments of the Netherlands and Ethiopia. NBPE is part the Africa Biogas Partnership Program (see 3.5.4), with Hivos as fund manager and SNV providing technical assistance. By the end of 2016 NBPE had supported the installation of over 15,000 bio-digesters in Ethiopia. Within NBPE+, further 36,000 bio-digester are planned to be constructed (SNV 2022).

3.5.7 Ethiopia: URBAN NAMA COMPOST: Creating opportunities for municipalities to produce and operational solid waste management transformation

Urban NAMA COMPOST project is designed to promote greater use of Integrated Solid Waste Management (ISWM) and Urban Green Infrastructure (UGI) approaches in Ethiopian cities/towns to assist the Government of Ethiopia in achieving its objectives of its Growth and Transformation Plan (GTP II) (UNDP Ethiopia 2022).

The project, funded by UNDP, is implemented in Ethiopia and among other activities foreseen the construction of large-scale windrow composting plants in 6 Ethiopian cities (Adama, Bahir Dar, Bishoftu, Dire Dawa, Hawassa and Mekelle). Six composting sheds were constructed and equipped with essential facilities which improved both the quantity and quality of compost production. The compost production capacity of the cities reached more than 45,000 tons per year per city. The compost produced is expected to be utilized for Urban Green. Project started in January 2017 and closed on March 2022 (UNDP Ethiopia 2022)

3.5.8 Ethiopia: A programmatic approach to beautifying Sheger through sustainable urbanisation and urban resilience

The Prime Minister of Ethiopia has launched a flagship initiative titled ‘Beautifying Sheger Project’ which aims at renewing the Addis Ababa City and making it green as well as clean. This intervention will work on greening the riverside; installing proper sewerage and drainage infrastructure as alternatives to liquid waste disposal; and finding alternative livelihoods for people whose lives are dependent on the rivers. The program will support the Addis Ababa City Administration (AACA) to implement the Sheger Project using a holistic approach of nesting integrated watershed management within the broader ambit of sustainable urban land use planning. The overall objective is “to support the implementation of the Sheger Project through human and institutional capacity building and an integrated urban planning and watershed management approach”. This will be achieved through four components: (1) institutional strengthening of the AACA; (2) enabling framework for integrated watershed management; (3) livelihood programs for sustainable riversides development; and (4) knowledge management and monitoring and evaluation.

In particular, within component 3, the program will capitalize on the results of the Beautifying Sheger Transition Project that UNDP is planning to implement in 2 pilot sites that are currently being identified. The pilots will consist of cleaning selected parts of the river and managing waste while providing short term livelihoods to communities especially the youth and women. Business models will be developed for waste transformation into compost and recycled products, and generation of biogas, among others (UNDP 2020a).

3.5.9 Ethiopia: 100 % environment and community: waste recovery and communities awareness raising for the protection of Kebena river in Addis Ababa

The project is financed by the Italian Agency for Development Cooperation within the initiative “Riverside development project in Addis Ababa”. It is currently implemented by the CSO CIFA Onlus in the period from March 2020 up to June 2022. The main scope is to contribute to the improvement of environmental, living and health conditions of residents in Woredas 02 and 03, Yeka Subcity, Addis Ababa, through awareness raising and the creation of collection and recycling chains for plastic, paper and organic waste. In particular in regard to organic waste recycling, the project will work in strict collaboration with two compost producer associations, recently created by Addis Ababa City Municipality to guarantee the supply of compost needed for the urban greenery projects and in particular for the Beautifying Sheger Project. The associations will be linked with organic waste producers to guarantee a constant flow of feedstock and trained in order to enhance the quality of the compost produced. A study on compost marketability will be conducted and the compost producer associations will be linked with potential buyers. The purchase of compost is anyway guaranteed by the municipality that is subsidizing the compost (4 etb/kg will be added to the compost’ selling price). The whole component regarding compost will be supervised by the cooperative “Erica”, which has an extensive experience in projects on organic waste management in developing countries.

Parallel to this project, the Italian Agency for Development Cooperation will soon finance a pilot study on waste status in Addis Ababa which also include Solid Waste Management Agency staff training and a feasibility study on organic waste treatment in Addis Ababa.

Information was collected during an interview with Eng. Elena Lovat, Programme Coordinator for WASH, Environment, and Energy at Italian Agency for Development Cooperation in Addis Ababa Office.

3.5.10 Ethiopia: Development of the collection and recycling system of PET plastic waste in Hawassa, Ethiopia (100 % Plastic)

The project, funded by the Italian Agency for Development Cooperation, was implemented by CIFA Onlus in Hawassa city from 2017 to 2020. Despite the title, the project included a component of organic waste management and in particular a pilot on solid waste segregation at source and compost production; this component was implemented in collaboration with Hawassa University and Turin Municipality Urban Solid Waste Management department. Final output was a Guidance document for the integrated waste management cycle in the city of Hawassa that contains a chapter on guidelines for composting of organic waste in Hawassa City (Cifa 2022).

3.5.11 Ethiopia - Improved Sanitation Value Chain in Arba Minch

The project is financed by the African Development Bank for the period January 2016 to March 2021. The overall project objective is to facilitate the strengthening of the sanitation service chain and contribute to the increase of the population with improved access to sanitation in Arba Minch.

The project foresaw to reach, among others, the following outputs: production of compost from bio-solids (human excreta and solid waste); compost quality assured for reuse purposes; demand for compost for reuse increased (AFDB 2021a).

3.5.12 Ethiopia: Agro-Forestry in Rural Ethiopia

The project is implemented by the Gardula Development Association, a local NGO based in Gidole district. The project is aimed to train 7000 farmers on permaculture and Agroforestry practice which involves solid waste management mainly compost preparation and utilization to develop resilient capacity of small-scale farming community and contribute to reducing organic waste load to the environment both in rural and urban areas. The project is funded by BMZ and is expected to last from Dec 1, 2020 to Dec 31st 2023 (GDPA 2022).

3.5.13 Ethiopia: GAIA Clean Energy

Gaia Clean Energy is an Ethiopian Civic Society Organization established in 2005. Gaia seeks to revolutionize the Ethiopian household energy economy by introducing and promoting clean, safe and affordable cooking and lighting technologies.

Of particular interest a project implemented in Addis Ababa city with introduction of a technology to produce ethanol in micro scale: the Addis Ababa Ethanol Micro Distillery (EMD) project was launched after establishing partnership with Project Gaia Inc (PGI), Stockholm Environmental Institute (SEI) and The World Bank for the end use of Former Women Fuelwood Carriers Association (FWFCA). The project targets to install 1000 lit/day ethanol producing distillery plant at Akaki Kality sub city of Addis Ababa to supply ethanol and distribute ethanol fueled cooking stoves to 1000 low- and middle-income households at the outskirts of Addis Ababa by establishing a community owned and run EMD.

The Organization also arranges the production of char-briquette from feedstock (seasonal grasses) (Gaia Clean Energy 2015).

3.5.14 (Project Gaia 2018) Ethiopia: Healthy Fire PLC

Healthy Fire is a social enterprise that provides households in Addis Ababa with access to highly efficient fan-forced gasifier stoves. The business model is “improved cookstoves + pellets + charcoal buy-back”, wherein the Company sells stoves and pellets, and buys-back the charcoal the stoves generate by giving the customer equal the mass of the charcoal that they return in new pellet fuel. Then the Company converts the charcoal into fertilizer, water, and air filters. Fuel pellets are produced from biodegradable waste (e.g., spent coffee grounds, coffee husks, sawdust, wood chips, khat stems) (Anega Energies Manufacutirng 2022).

3.5.15 Uganda: NAMA on Integrated Waste Management and Biogas in Uganda

This project, funded by UNDP, aims to provide environmental benefits and reduce greenhouse gas emissions from improper an inadequate management and treatment of wastewater and organic waste in towns, municipalities and agro-processing industries in Uganda. The project combines demonstration and investment in integrated waste management and biogas plants in agro-processing industries and municipalities (including biogas-based, on-grid electricity generation) with institutional strengthening, capacity building for improved waste management, and an improved regulatory framework.

The project started in September 2018 and will end in August 2023 (UNDP 2017).

3.5.16 Malawi: Waste for Wealth Project: Promoting a Zero Waste Environment

The project, funded by UNDP, was implemented in 2012 in the city of Lilongwe (UNDP 2018).

The project's main objective was to form an effective pro-poor PPP in waste management, create employment, improve the urban environment, generate data and information for planning and decision-making purposes, build the capacity of waste stakeholders, reduce costs associated with municipal solid waste management at community level and support a conducive regulatory environment for sustainable solid waste management.

Among the activities the project foresaw support to production of compost from organic waste, trough provision of trainings, compost site creation and enhancement of compost market (UNDP 2018).

3.5.17 Zambia: Waste Management and Youth

The project, funded by UNDP, started in March 2020 and will be finalized in December 2021. Overall goal of this project is to improve waste management and recycling practices in urban and peri-urban settings in Lusaka and Ndola while creating opportunities and employment for women and youth led enterprises. It is led by the vision that waste collection and recycling sectors expand income-earning opportunities that are decent and sustainable, especially for youth and women in the poorest areas.

It is not specified if the project will take care of organic waste (UNDP 2020b).

3.5.18 Kenya: Construction of an Integrated Sustainable Waste Management Facility in Kajiado County

The KISWAM is a resource recovery facility in which organic matter is used to generate biogas and electricity, and valuable resources recovered through recycling and re-use of waste. Ensuring that the project is socially acceptable, environmentally friendly and economically viable were key considerations in the selection of technologies for the waste-to-energy facility. The recommended technology is a combination of bio-dryer and bio-reactor units, a more flexible and affordable solution than other options considered. The robust, labour- intensive technology is expected to create 200 new jobs. The project was planned to start in 2020 with the support of Italian Agency for Development Cooperation (UN Habitat 2019).

3.5.19 Kenya - Kabira Waste-To-Energy - SEFA Project

The proposed Project is a 12 MW, grid connected municipal Waste-To-Energy plant to be located in Kabira, a suburb of Kenya's capital Nairobi. The WTE project aims to convert three forms of biomass; municipal solid waste (MSW), crop residues and livestock waste to biogas/fuel ethanol and generate electricity. The Kabira site (tip/landfill site) currently receives approximately 1,000 tons/day of MSW from Nairobi County. The sponsors have received approvals from and entered into a contract with Nairobi County Council (municipal authority) to develop, construct and operate (Build Own and Operate) the WTE facility. The approval provides the sponsors with rights/access to MSW and supply agreements with contracted MSW collection companies approved/authorised by the county. The plant will be connected to the national transmission grid which is located within 0.4 kms from the project site (AFDB 2021b).

3.5.20 Kenya: Sanergy compost production

City Fresh waste management services provided by Sanergy, a Kenyan company with over 8 years of experience in professional waste management and reuse, work with municipalities and private sector companies to clean up cities. A fully certified processing plant (Black Soldier Fly treatment) in the Athi River EPZA in Machakos County is able to safely treat over 70,000 tonnes of organic waste annually, and it processes waste into useful agricultural inputs (organic fertilizer and animal feed) and it manufactures low-cost, high-energy environmental-friendly briquettes - EverMoto - from the organic waste collected, offering industries a high-calorie briquette ready for burning in any industrial biomass boiler (Kibuthu 2021).

3.5.21 Madagascar, Malawi, Mozambique and the Union of Comoros: 'Building Urban Climate Resilience in South Eastern Africa,'

A first multi-country project of UN-Habitat funded by the Adaptation Fund. The four-year USD 14 million project will strengthen urban resilience, promote disaster risk reduction and increase climate change adaptation in Madagascar, Malawi, Mozambique and the Union of Comoros. Priority actions for the project will cut across regional, national and city levels and include preparation and implementation of sub-projects, development of tools and guideline for training delivery and inter-country sharing of experiences and lessons learnt. One of the sub-projects will concern Solid Waste Management (UN Habitat 2022).

3.5.22 Madagascar: Collection and recovery of FAKOFIA waste

The activity consists of collecting and recovering all household waste from the urban municipality of Fianarantsoa. The CTVD (Waste Sorting and Valorization Center) is a place equipped with standards for sorting and essentially transforming the collection into Ecocert certified compost for organic use.

Organic waste, representing 75 % of waste, is stored, and subjected to a precise composting process.

The resource obtained is organic compost, marketed under the name Soavokatsa and meeting the needs of farmers for the improvement of their soils (RAHERINAINA 2020).

3.5.23 Madagascar: Support for household waste management in Fianarantsoa (2012-2016)

The specific objectives of the project are: create the pre-collection service and strengthen the collection, sorting and disposal service for household waste and design, set up and finance recovery channels for collected waste.

The recovery of household waste resulting from waste sorting (around 85 % of waste consists of biodegradable organic matter) is carried out in the form of compost offered to local farmers. The recovery of plastic waste (about 6 % of the mass collected) is put on hold given the new legislation prohibiting the use of plastic film in households (ISF 2016).

4 Conclusions and recommendations

Organic waste is currently an environmental and public health issue for East Africa. The current generated quantities are estimated to be around 41 million of metric tons, with an ascending growth trend of 199 % in the next 30 years if a business-as-usual approach is maintained. These quantities are currently very poorly managed: the solid waste management system in East Africa is characterized by a low rate of collection, inadequate transport system and unsafe final disposal. If the system does not improve substantially in the near future, the ability to cope with the problem is at serious risk.

On the other hand, the current situation can be seen as an opportunity to organize a waste management system based on the consideration that organic waste is a resource that can be converted into valuable products, such us biogas, compost or solid fuel.

Currently, a relevant percentage of organic waste is open dumped in Eastern African countries. Few attempts to address the organic waste into a business chain have been recorded.

Small scale solutions seem to be more successful than large scale plants, which are very expensive, need constant and quality provision of organic feedstock and are most of the time difficult to manage. On the other hand, in urban context, small scale plants are hardly satisfying treatment needs for the huge quantities of organic waste generated by big cities. Considering the fast growing of megacities in Eastern Africa, it is vital to propose viable and effective solutions to this problem.

In rural areas, the need of an efficient organic waste management seems to be less urgent because of the capacity of rural community to reduce the amount of residual waste through self-disposal practices. Nevertheless, the problem should not be neglected: socio-economic transformation, rapid urbanization and consequent fast development of medium size rural town, installment of new agro-processing industries, could led to a huge problem of waste management if not properly followed. Furthermore, it should be remembered that rural communities depend mainly on carbon-based energy sources (wood and locally produced charcoal) which are inefficient and cause dangerous environmental and health impacts. In rural areas, the conversion of organic waste into energy must therefore be pursued not only to ensure a safe treatment technology for organic waste, but also to reduce the excessive exploitation of natural resources and minimize environmental pollution caused by fossil fuels.

At now the largest scale attempt to solve the problem of organic waste treatment seems to be the one conducted in Ethiopia, within the NAMA COMPOST project: 6 cities were provided with composting shelters; each of the composting site have an estimated production capacity of more than 45,000 tons per year, which correspond to the treatment of around 150,000 tons of organic waste per year. The financial and social sustainability of this approach is questionable and has still to be verified, being the project still ongoing.

Again, in Ethiopia, precisely in Addis Ababa, a small-scale approach for compost production is being piloted. The Municipality is attempting to create occupation through the creation of small associations (around 20 members each) in charge to produce compost collecting organic waste from neighborhood. The compost produced is then sold to the association in charge of the urban green and the Municipality further subsidizes the selling. The initiative is still very young and it is not clear which percentage of the organic waste produced in Addis Ababa will be actually treated and how the compost cooperative will be linked with waste producers.

In Addis Ababa we could also find some private companies and local CSO attempting to develop a business along the value chain of organic waste: it will be interesting to further study these examples in order to evaluate the viability of the practice.

In summary, there is still a high demand for adequate treatment, logistics and regulatory solutions related to organic residues in East African countries. Besides the aforementioned problems of inadequate waste management, there are also opportunities to convert considerable amounts of biomass into energy or material utilisation. A successful shift towards a circular economy requires cooperation between stakeholders from science, the private sector, regional administration and national politics. In particular, knowledge transfer about existing technological and regulatory opportunities to decision-makers should be promoted. In addition, procedural assistance can support local business enterprises in optimising existing structures.

List of figures

List of tables

Publication bibliography

AACSWMA (2019): Addis Ababa Solid Waste Data. Addis Ababa Solid Waste Management Agency.

ABPP (2019): Africa Biogas Partnership Programme. Edited by ABPP, SNV. Available online at https://www.africabiogas.org/, updated on 2019, checked on 8/3/2022.

ACCP (2019): Afrrica Solid Waste Management Data Book. Edited by Afican Clean Cities Platform. UNHABITAT.

ACEN (2022): Welcome to The African Circular Economy Network. African Circular Economy Network. Available online at https://www.acen.africa/, checked on 8/3/2022.

AFDB (2021a): Ethiopia - Improved Sanitation Value Chain in ArbaMinch - IPR March 2021. Edited by African Development Bank Group. Available online at https://www.afdb.org/en/documents/ethiopia-improved-sanitation-value-chain-arbaminch-ipr-march-2021, checked on 8/3/2022.

AFDB (2021b): Kenya - Kabira Waste-To-Energy - SEFA Project Summary Note. Edited by African Development Bank Group. Available online at https://www.afdb.org/en/documents/kenya-kabira-waste-energy-sefa-project-summary-note, updated on 3/1/2021, checked on 8/3/2022.

Alemu, Abebe Ejigu; Adesina, Jimi O. (2017): In Search of Rural Entrepreneurship: Non-farm Household Enterprises (NFEs) as Instruments of Rural Transformation in Ethiopia. In *African Develompent Review* No. 2 (Vol. 29), pp. 259–271, checked on 8/3/2022.

Ali, Ali Issihaka; Karouach, Fadoua; Lahboubi, Nabila; Bakraoui, Mohammed; El Bari, Hassan (2018): Perception and Behavior Analysis of Comorians Citizens on the Solid Household Waste Problems. In *ESJ* 14 (26), p. 297. DOI: 10.19044/esj.2018.v14n26p297.

Ali, Idriss Husen; Tarekegn, Mekonnen Maschal (2018): Methane Gas Emission and its Management Practices from Solid Waste Stream, Case Study. Addis Ababa and its Surrounding Oromia Special Zone Towns. In *Environ Pollut Climate Change* 02 (03). DOI: 10.4172/2573-458X.1000160.

Anega Energies Manufacutirng (2022): HealthyFire. Let's work towards clean & healthy cooking in Ethiopia together. Available online at https://anegaenergiesmanufacturing.org/, checked on 8/3/2022.

Beyene, Zellalem Tadesse (2015): Green Supply Chain Management Practices in Ethiopian Tannery Industry: An Empirical Study. In *International Research Journal of Engineering and Technoloy (IRJET)* 07 (Volume 02), pp. 587–598. Available online at https://www.irjet.net/archives/V2/i7/IRJET-V2I789.pdf, checked on 8/3/2022.

Birhanu, Yohanis (2015): Assessment of Solid Waste Management Practices and the Role of Public Participation in Jigjiga Town, Somali Regional State, Ethiopia. In *IJEPP* 3 (5), p. 153. DOI: 10.11648/j.ijepp.20150305.16.

Bjerkli, Camilla Louise (2013): Governance on the Ground. A Study of Solid Waste Management in Addis Ababa, Ethiopia. In *Int J Urban Reg Res* 37 (4), pp. 1273–1287. DOI: 10.1111/j.1468-2427.2013.01214.x.

CABI (2022): Invasive Species Compendium. Eichhornia crassipes (water hyacinth). Available online at https://www.cabi.org/isc/datasheet/20544, updated on 11/19/2019, checked on 8/3/2022.

Camberlin, Pierre (2018): Climate of Eastern Africa. In Von Storch et al H. (Ed.): Oxford Research Encyclopedia of Climate Science: Oxford University Press. Available online at https://hal.archives-ouvertes.fr/hal-02456899.

Chala, Bilhate; Oechsner, Hans; Latif, Sajid; Müller, Joachim (2018): Biogas Potential of Coffee Processing Waste in Ethiopia. In *Sustainability* 10 (8), p. 2678. DOI: 10.3390/su10082678.

Cheru, Meaza (2016): Solid Waste Management in Addis Ababa. A new approach to improving the waste management system. Thesis. Helsinki Metropolia University of Applied Science, Helsinki, Finland. Available online at https://www.theseus.fi/bitstream/handle/10024/121490/Cheru_Meaza.pdf?sequence=1&isAllowed=y, checked on 8/3/2022.

Cifa (2022): 100% Plastic. Collection and recycling of plastic waste in Hawassa, Ethiopia. CIFA ONLUS. Available online at https://www.cifaong.it/a/en/environment/100-percent-plastic/cleaning-plastic-island-hawassa.

Coffey, Manus; Coad, Adrian (2010): Collection of municipal solid waste in developing countries. Nairobi Kenya: UN-HABITAT.

Couder, Louise; Kibuthu, Sheila (2020): Unlocking the circular economy potential to tackle the sanitation challenge. In *Field Actions Science Reports* (Special Issue 22). Available online at https://journals.openedition.org/factsreports/6361, checked on 8/3/2022.

Dechassa, Nagassa; Abate, Belay (2020): Current Status of Water Hyacinth (Eichhornia crassipes) in Ethiopia. Achievements, Challenges and Prospects: A Review. In *JEES. DOI:* 10.7176/JEES/10-12-03.

Degaga, Jima (2020): Review on Coffee Production and Marketing in Ethiopia. In *JMCR. DOI:* 10.7176/JMCR/67-02.

Dorosh, Paul Anthony; Minten, Bart (Eds.) (2020): Ethiopia's agri-food system. Past trends, present challenges, and future scenarios. Washington D.C.: International Food Policy Research Institute.

EHPEA (2022): Sectoral Information. Edited by Ethiopian Horticulture Producer Exporters Association. Available online at https://ehpea.org/sectoral-information/, checked on 8/3/2022.

ESA climate change initiative (2016): CCI LAND COVER - S2 PROTOTYPE LAND COVER 20M MAP OF AFRICA 2016. Available online at https://2016africalandcover20m.esrin.esa.int/.

FANABC (2020): Addis Ababa To Be Restructured In To 11 Sub Cities. In *Fana Boradcasting Corporate*, 10/20/2020. Available online at https://www.fanabc.com/english/addis-ababa-to-be-restructured-in-to-11-sub-cities/, checked on 8/3/2022.

FAO; IGAD (Eds.) (2019): East Africa Animal Feed Action Plan.

Federal Democratic Republic of Ethiopia (2021): Updated Nationally Determined Contribution. Edited by Federal Democratic Republic of Ethiopia. UNFCCC. Available online at https://unfccc.int/sites/default/files/NDC/2022-06/Ethiopia%27s%20updated%20NDC%20JULY%202021%20Submission_.pdf, checked on 8/3/2022.

Gabisa, E. W.; Gheewala, S. H. (2018): Potential of bio-energy production in Ethiopia based on available biomass residues. In *Biomass and bioenergy* 111, pp. 77–87. DOI: 10.1016/j.biombioe.2018.02.009.

Gaia Clean Energy (2015): Introduction of a technology to produce ethanol in micro scale. Available online at https://gaiaethiopia.org/, updated on 2015, checked on 8/3/2022.

Gamma, A.; Kramer, S. (2021): Behaviour change interventions for littering, organic waste separation and latrine use in Addis Ababa Ethiopia. Edited by AICS.

Gashaw, Esayas Tena; Mekbib, Firew; Ayana, Amsalu (2018): Sugarcane Landraces of Ethiopia. Germplasm Collection and Analysis of Regional Diversity and Distribution. In *Advances in Agriculture* 2018 (6), pp. 1–18. DOI: 10.1155/2018/7920724.

Gaurav, Gajendra Kumar; Mehmood, Tariq; Cheng, Liu; Klemeš, Jiří Jaromír; Shrivastava, Devesh Kumar (2020): Water hyacinth as a biomass. A review. In *Journal of Cleaner Production* 277, p. 122214. DOI: 10.1016/j.jclepro.2020.122214.

GDPA (2022): Agroforestry in Rural Ethiopia. Edited by Gardula Development Association. Gidola, Ethiopia. Available online at https://www.facebook.com/pages/category/Non-Governmental-Organization--NGO-/Gardula-Peoples-Development-Association-102039528331678/, checked on 8/3/2022.

Gelan, Eshetu (2021): Municipal Solid Waste Management Practices for Achieving Green Architecture Concepts in Addis Ababa, Ethiopia. In *Technologies* 9 (3), p. 48. DOI: 10.3390/technologies9030048.

GES (2020): Municipal Solid Waste Generation Rate and Characterization Study report. Edited by AACSWMA. Addis Ababa.

Godfrey, Linda; Ahmed, Mohamed Tawfic; Gebremedhin, Kidane Giday; Katima, Jamidu H. Y.; Oelofse, Suzan; Osibanjo, Oladele et al. (2020): Solid Waste Management in Africa. Governance Failure or Development Opportunity? In *Regional Development in Africa. DOI:* 10.5772/intechopen.86974.

Grantham Research Institute on Climate Change and the Environment (2022): Climate Change Laws of the World. LAS. Available online at https://climate-laws.org/legislation_and_policies?from_geography_page=Ethiopia&geography%5B%5D=58&type%5B%5D=executive, checked on 6/21/2022.

Hawassa City Administration; UNHABITAT (2020): The Structure Plan of Hawassa 2020-2030. Edited by UK AID.

Hirpe, Lemesa; Yeom, Chunho (2021): Municipal Solid Waste Management Policies, Practices, and Challenges in Ethiopia. A Systematic Review. In *Sustainability* 13 (20), pp. 1–16. DOI: 10.3390/su132011241.

HoAREC (2022): Our Vision and Mission. Edited by Horn of Africa Regional Environment Centre and Network. Available online at https://hoarec.org/about-us/vision-mission/, checked on 8/3/2022.

Hydroplan (2018): ZUSP - CS for Development of Solid Waste Management Strategy for the Zanzibar Archipelago. Edited by IDA.

IZES (2017): IGNIS - Income Generation & Climate Protection by Valorising Municipal Solid Wastes in a Sustainable Way in Emerging Megacities of Tomorrow, Addis Ababa, Ethiopia. Institut für ZukunftsEnergie- und Stoffstromsysteme. Available online at https://www.izes.de/en/projekte/ignis-income-generation-climate-protection-valorising-municipal-solid-wastes-sustainable, checked on 8/3/2022.

Kabera, Telesphore; Wilson, David C.; Nishimwe, Honorine (2019): Benchmarking performance of solid waste management and recycling systems in East Africa. Comparing Kigali Rwanda with other major cities. In *Waste management & research : the journal of the International Solid Wastes and Public Cleansing Association, ISWA* 37 (1_suppl), pp. 58–72. DOI: 10.1177/0734242X18819752.

Kaza, Silpa; Shrikanth, Siddarth; Chaudhary, Sarur (2021): More Growth, Less Garbage. Edited by World Bank Group. Washington, DC (Urban development series). Available online at https://openknowledge.worldbank.org/handle/10986/35998.

Kaza, Silpa; Yao, Lisa; Bhada-Tata, Perinaz; van Woerden, Frank (2018): What a waste 2.0. A global snapshot of solid waste management to 2050. Washington DC: World Bank Group (Urban development series).

Kibuthu, Sheila (2021): Driving sustainability in cities through integrated waste management solutions. Sanergy. Available online at https://www.sanergy.com/2021/06/30/driving-sustainability-in-cities-through-integrated-waste-management-solutions/, updated on 6/30/2021, checked on 8/3/2022.

Kifle, Ilyas (2021): Floriculture waste management standard to be introduced. Edited by Addis Zeybe. Available online at https://addiszeybe.com/floriculture-waste-management-standard-to-be-introduced, updated on 12/15/2021, checked on 8/3/2022.

Lohri, Christian Riuji; Diener, Stefan; Zabaleta, Imanol; Mertenat, Adeline; Zurbrügg, Christian (2017): Treatment technologies for urban solid biowaste to create value products. A review with focus on low- and middle-income settings. In *Rev Environ Sci Biotechnol* 16 (1), pp. 81–130. DOI: 10.1007/s11157-017-9422-5.

Manirakiza, Norbert; Théophile, Ndikumana; Jung, Celine Gisele (2020): Municipal Solid Waste Sorting in Burundi, Inventory and Perspectives: Case of Bujumbura City. In *International Journal of Innovative Science and Research Technology* 2 (Volume 5), pp. 1148–1155.

Ministry of Agriculture (2020): Environmental and Social Management Framework (ESMF). Edited by The Federal Democratic Republic of Ethiopia. Ministry of Agriculture, Sustainable Land Management Program (SLMP). Addis Ababa.

Ministry of Agriculture, Climate Change and Environment (2022): Waste Management. Edited by Rebunlic of Seychelles. Available online at http://www.meecc.gov.sc/index.php/what-we-do/waste-management/#:~:text=The%20Seychelles%20National%20Waste%20Policy,quality%20of%20life%20in%20Seychelles, updated on 2022, checked on 8/3/2022.

Ministry of Environment And Climate Change (2022): Structure of MOERD. Edited by Republic of Somalia. Somalia. Available online at https://moecc.govsomaliland.org/article/structure, updated on 2022, checked on 8/3/2022.

Mohammed, Ali; Elias, Eyasu (2017): Domestic waste management and its environmental impacts in Addis Ababa City. In *African Journal of Environmental and Waste Management* 3 (Vol. 4), pp. 206–216.

National Environmental Management Authority, Uganda (24th February 2019): THE NATIONAL ENVIRONMENT ACT 2019. UGA-2019-L-111164. In *The Uganda Gazette* Volume CXII (Vol. 10). Available online at http://www.ilo.org/dyn/natlex/docs/ELECTRONIC/111164/138460/F-1865473437/UGD111164.pdf, checked on 8/3/2022.

Ndambi, Oghaiki Asaah; Pelster, David Everett; Owino, Jesse Omondi; Buisonjé, Fridtjof de; Vellinga, Theun (2019): Manure Management Practices and Policies in Sub-Saharan Africa. Implications on Manure Quality as a Fertilizer. In *Front. Sustain. Food Syst.* 3. DOI: 10.3389/fsufs.2019.00029.

NEPAD (2022): Second Continental Report on the Implementation of Agenda 2063. Edited by African Union Comission and African Union Development Agency. AUC & AUDA-NEPAD. Johannesburg, South Africa. Available online at https://au.int/sites/default/files/documents/41480-doc-2nd_Continental_Progress_Report_on_Agenda_2063_English.pdf, checked on 8/3/2022.

NIRAS (2021): Assessing the prospects and requirements for bioenergy -development in seven demand sectors in Sub-Saharan Africa. Available online at https://www.niras.com/projects/bioenergy-for-sustainable-local-energy-services-and-energy-access-in-africa-bseaa-2/, updated on 9/8/2021, checked on 8/3/2022.

OEC (2019): The Economic Complexity Observatory: An Analytical Tool for Understanding the Dynamics of Economic Development. With assistance of A. J.G. Simoes, C. A. Hidalgo. Observatory of Economic Complexity. Available online at https://oec.world/, checked on 8/3/2022.

Oyoo, Richard; Leemans, Rik; Mol, Arthur P. J. (2014): Comparison of environmental performance for different waste management scenarios in East Africa. The case of Kampala City, Uganda. In *Habitat International* 44, pp. 349–357. DOI: 10.1016/j.habitatint.2014.07.012.

Peel, M. C.; Finlayson, B. L.; McMahon, T. A. (2007): Updated world map of the Köppen-Geiger climate classification. In *Hydrol. Earth Syst. Sci.* 11 (5), pp. 1633–1644. DOI: 10.5194/hess-11-1633-2007.

Pfaff-Simoneit, Wolfgang (2012): Entwicklung eines sektoralen Ansatzes zum Aufbau von nachhaltigen Abfallwirtschaftssystemen in Entwicklungsländern vor dem Hintergrund von Klimawandel und Ressourcenverknappung. Dissertation. Universität Rostock, Rostock. Agrar- und Umweltwissenschaftliche Fakultät. Available online at https://rosdok.uni-rostock.de/file/rosdok_derivate_0000005003/Dissertation_Pfaff-Simoneit_2013.pdf, checked on 8/3/2022.

RAHERINAINA, ELMY (2020): ETUDE DES CHIFFONIERS DE LA VILLE DE FIANARANTSOA. [S.l.]: EDITIONS UNIVERSITAIRES E.

RWA (2020): Source-to-Lake Analysis of Plastic Waste Management in Lake Hawassa Basin. Edited by Resource and Waste Advisory Group.

SNV (2022): Biogas Dissemination Scale-Up Programme (NBPE+). SNV Netherlands Development Organisation. Available online at https://snv.org/project/biogas-dissemination-scale-programme-nbpe, checked on 8/3/2022.

Stecher, K.; Brosowski, A.; Thrän, D. (2013): Biomass Potentials in Africa. Edited by IRENA. Deutsches Biomasseforschungszentrum gGmbH (DBFZ).

Teko, Edmund (2018): Ethiopia Policy Environment Paper. With assistance of Santhosh Kodukala. Edited by Wuppertal Institut. Urban Pathways. Berlin. Available online at http://www.urban-pathways.org/uploads/4/8/9/5/48950199/up_new_layout_ca_ethiopia-small.pdf, checked on 8/3/2022.

Teshome, Fiseha Bekele (2021): Municipal solid waste management in Ethiopia; the gaps and ways for improvement. In *Journal of Material Cycles and Waste Management* 23 (1), pp. 18–31. DOI: 10.1007/s10163-020-01118-y.

Tiruneh, Kalkidan Yifru (2021): Impacts of industrial parks on their employees environmental quality of life. A case of Bole Lemi I Industrial Park and Eastern Industry Zone. Available online at http://essay.utwente.nl/88992/.

UN Habitat (2019): Using Rubbish to Generate Electricity and Employment in Kajido County. Available online at https://unhabitat.org/using-rubbish-to-generate-electricity-and-employment-in-kajiado-county, checked on 8/3/2022.

UN Habitat (2022): UN Habitat helps South Eastern African Countries build urban resilience. Zomba City, Malawi. Available online at https://unhabitat.org/un-habitat-helps-south-eastern-african-countries-build-urban-resilience, updated on 3/29/2022, checked on 8/3/2022.

UN Statistics Division (2021): Standard country or area codes for statistical use (M49). Edited by UN Statistics Division. Available online at https://unstats.un.org/unsd/methodology/m49/overview/, checked on 6/12/2021.

UNDESA (2019): World Population Prospects 2019. Edited by United Nations, Department of Economic and Social Affairs, Population Division. Available online at https://population.un.org/wpp/, checked on 6/12/2021.

UNDP (2017): Nama on Integrated Waste Management and Biogas in Uganda. Available online at https://info.undp.org/docs/pdc/Documents/UGA/Approved%20Project%20Initiation%20Document%20for%20NAMA%20Biogas%20Project.pdf.

UNDP (2018): Waste for Wealth Project: Promoting a Zero Waste Environment. Available online at https://erc.undp.org/evaluation/evaluations/detail/5822, checked on 8/3/2022.

UNDP (2020a): A programmatic approach to beautifying Sheger through sustainable urbanisation and urban resilience. Edited by UNDP, Office of the Mayor of Addis Ababa.

UNDP (2020b): Waste Management and Youth. Available online at https://info.undp.org/docs/pdc/Documents/ZMB/AWP%202020%20Waste%20Management%20and%20Youth%20Project%20FINAL%20(002).doc, checked on 8/3/2022.

UNDP (2020c): Minalesh Tera: How Addis Ababa's informal recycling and reusing market supports formal waste management. Available online at https://www.undp.org/ethiopia/blog/minalesh-tera-how-addis-ababa%E2%80%99s-informal-recycling-and-reusing-market-supports-formal-waste-management, updated on 7/30/2020, checked on 8/3/2022.

UNDP Ethiopia (2022): URBAN NAMA COMPOST. United Nations Development Programme Ethiopia. Available online at https://www.undp.org/ethiopia/projects/urban-nama-compost, checked on 8/3/2022.

UNEP (2018): Africa Waste Management Outlook. Nairobi, Kenya.

UNIDO; PcP Ethiopia (2018): Integrated Agro-Industrial Parks (IAIPs) in Ethiopia. Edited by UNIDO. United Nations Industrial Development Organization. Available online at https://www.unido.org/sites/default/files/files/2018-08/Integrated-Agro-Industrial-Parks-in-Ethiopia-booklet.pdf, checked on 6/12/2021.

Vanzetto, Silvia (2021): Solid Waste Management in Addis Ababa. Interview with AACSWMA. Addis Ababa.

Vanzetto, Silvia (01/2022): NAMA project Hawassa. Interview with Henok Dangote. Hawassa.

Vibhute, Khushal (2008): Environmental Policy and Law of Ethiopia: A Policy Perspective. Available online at https://journals.co.za/doi/pdf/10.10520/AJA00220914_51.

Woldesenbet, Asrat Gebremariam; Woldeyes, Belay; Chandravanshi, Bhagwan Singh (2014): Characteristics of Wet Coffee Processing Waste and Its Environmental Impact in Ethiopia. In *International Journal of Research in Engineering and Science* 4 (Volume 2), pp. 1–5.

World Bank (2020): What a Waste Global Database. Available online at https://datacatalog.worldbank.org/search/dataset/0039597, updated on 6/20/2021, checked on 7/26/2022.

Zabaleta, I.; Mertenat, A.; Scholten, L.; Zurbrügg, C. (2020): Selecting Organic Waste Treatment Technologies. SOWATT. Dübendorf, Switzerland. Available online at https://www.eawag.ch/fileadmin/Domain1/Abteilungen/sandec/schwerpunkte/swm/SOWATT/sowatt.pdf, checked on 7/26/2022.

PUBLICATIONS

Previously published reports:

DBFZ Report Nr. 44 Monitoring erneuerbarer Energien im Verkehr
DBFZ Report Nr. 43 Beitrag zur Optimierung des Pelletierverhaltens von Gärresten und Landschaftspflegeheu sowie deren Mischungen
DBFZ Report Nr. 42 Rahmenbedingungen für einen optimierten Betrieb von kleinen biomassebasierten BHKW
DBFZ Report Nr. 41 National Resource Monitoring for Biogenic Residues, By-products and Wastes – Development of a Systematic Data Collection, Management and Assessment for Germany
DBFZ Report Nr. 40 Basics of Anaerobic Digestion - Biochemical Conversion and Process Modelling
DBFZ Report Nr. 39 Optimierte Regelungsstrategien für Pellet-Solar-Kombiheizanlagen zur Steigerung der Systemeffizienz bei gleichzeitiger Minimierung der Energiekosten
DBFZ Report Nr. 38 Hydrothermal processing of biogenic residues in Germany - A technology assessment considering development paths by 2030
DBFZ Report Nr. 37 Economic assessment of biogas plants as a flexibility option in future electricity systems
DBFZ Report Nr. 36 BioplanW: Systemlösungen Bioenergie im Wärmesektor im Kontext zukünftiger Entwicklungen
DBFZ Report Nr. 35 Leitfaden zur Substrat- und Effzienzbewertung an Biogasanlagen
DBFZ Report Nr. 34 Entwicklung einer Methode zur Verwendung der Daten des Schornsteinfegerhandwerks für die energiewirtschaftliche Berichterstattung - Dissertationsschrift
DBFZ Report No. 33 Recommendations for reliable methane emission rate quantification at biogas plants
DBFZ Report Nr. 32 Wärmenutzung von Biogasanlagen
DBFZ Report Nr. 31 Die Niedertemperatursynthese von Methan in Thermoöl-temperierten Plattenreaktoren – Dissertationsschrift –
DBFZ Report Nr. 30 Anlagenbestand Biogas und Biomethan – Biogaserzeugung und -nutzung in Deutschland
DBFZ Report Nr. 29 Effiziente Bioenergie für Regionen - Ergebnisse der technisch-ökonomischen Begleitforschung zur Fördermaßname Bioenergie-Regionen 2012-2015
DBFZ Report Nr. 28 Potenziale zur Steigerung der Leistungsfähigkeit von Biogasanlagen - Energetische Effizienz von Repoweringmaßnahmen
DBFZ Report Nr. 27 Neuartiger emissionsarmer Kaminofen (DBU-NEKO)
DBFZ Report Nr. 26 Bewertung technischer und wirtschaftlicher Entwickoungspotenziale künftiger und bestehender Biomasse-zu-Methan-Konversionsprozesse - Dissertationsschrift
DBFZ Report Nr. 25 Nachrüstlösung zum katalytischen Abbau von gasförmigen organischen Emissionen aus Kaminöfen
DBFZ Report Nr. 24 Biomasse zur Wärmeerzeugung– Methoden zur Quantifizierung des Brennstoffeinsatzes
DBFZ Report Nr. 23 Technisch-ökonomische Begleitforschung des Bundeswettbewerbes „Bioenergie-Regionen“
DBFZ Report Nr. 22 Die Biokraftstoffproduktion in Deutschland – Stand der Technik und Optimierungsansätze
DBFZ Report Nr. 21 Entwicklung der Förderung der Stromerzeugung aus Biomasse im Rahmen des EEG
DBFZ Report Nr. 20 KlimaCH4 – Klimaeffekte von Biomethan
DBFZ Report Nr. 19 Hy-NOW – Evaluierung der Verfahren und Technologien für die Bereitstellung von Wasserstoff auf Basis von Biomasse
DBFZ Report Nr. 18 Kleintechnische Biomassevergasung – Option für eine nachhaltige und dezentrale Energieversorgung
DBFZ Report Nr. 17 Grünlandenergie Havelland – Entwicklung von übertragbaren Konzepten zur naturverträglichen energetischen Nutzung von Gras und Schilf am Beispiel der Region Havelland
DBFZ Report Nr. 16 Algae biorefinery – material and energy use of algae
DBFZ Report Nr. 15 Politics and Economics of Ethanol and Biodiesel Production and Consumption in Brazil
DBFZ Report Nr. 14 Holzpelletbereitstellung für Kleinfeuerungsanlagen
DBFZ Report Nr. 13 Basisinformationen für eine nachhaltige Nutzung von landwirtschaftlichen Reststoffen zur Bioenergiebereitstellung
DBFZ Report Nr. 12 Monitoring zur Wirkung des Eneuerbare-Energien-Gesetz (EEG) auf die Entwicklung der Stromerzeugung aus Biomasse
DBFZ Report Nr. 11 Monitoring Biokraftstoffsektor
DBFZ Report Nr. 10 Ermittlung des Verbrauchs biogener Festbrennstoffe im Sektor Gewerbe, Handel, Dienstleistungen (GHD-Sektor) – Endbericht
DBFZ Report Nr. 9 Analyse und Bewertung ausgewählter zukünftiger Biokraftstoffoptionen auf der Basis fester Biomasse
DBFZ Report Nr. 8 – Kompakt – Sammelband
DBFZ Report Nr. 7 Final Report – Global and Regional Spatial Distribution of Biomass Potentials – Status quo and options for specication –
DBFZ Report Nr. 6 Katalytisch unterstützte Minderung von Emissionen aus Biomasse-Kleinfeuerungsanlagen
DBFZ Report Nr. 5 Optimierung und Bewertung von Anlagen zur Erzeugung von Methan, Strom und Wärme aus biogenen Festbrennstoffen
DBFZ Report Nr. 4 Identifzierung strategischer Hemmnisse und Entwicklung von Lösungsansätzen zur Reduzierung der Nutzungskonkurrenzen beim weiteren Ausbau der Biomassenutzung
DBFZ Report Nr. 3 Feinstaubminderung im Betrieb von Scheitholzkaminöfen unter Berücksichtigung der toxikologischen Relevanz
DBFZ Report Nr. 2 Methodische Vorgehensweise zur Standortidentifikation und Planung der Biomassebereitstellung für Konversionsanlagen am Beispiel von Bio-SNG-Produktionsanlagen
DBFZ Report Nr. 1 Bewertung und Minderung von Feinstaubemissionen aus häuslichen Holzfeuerungsanlagen

Further information and free downloads:
https://www.dbfz.de/en/press-media-library/publication-series/dbfz-reports

DBFZ Deutsches Biomasseforschungszentrum
gemeinnützige GmbH
Torgauer Straße 116
04347 Leipzig
Phone: +49 (0)341 2434-112
E-Mail: info@dbfz.de

www.dbfz.de