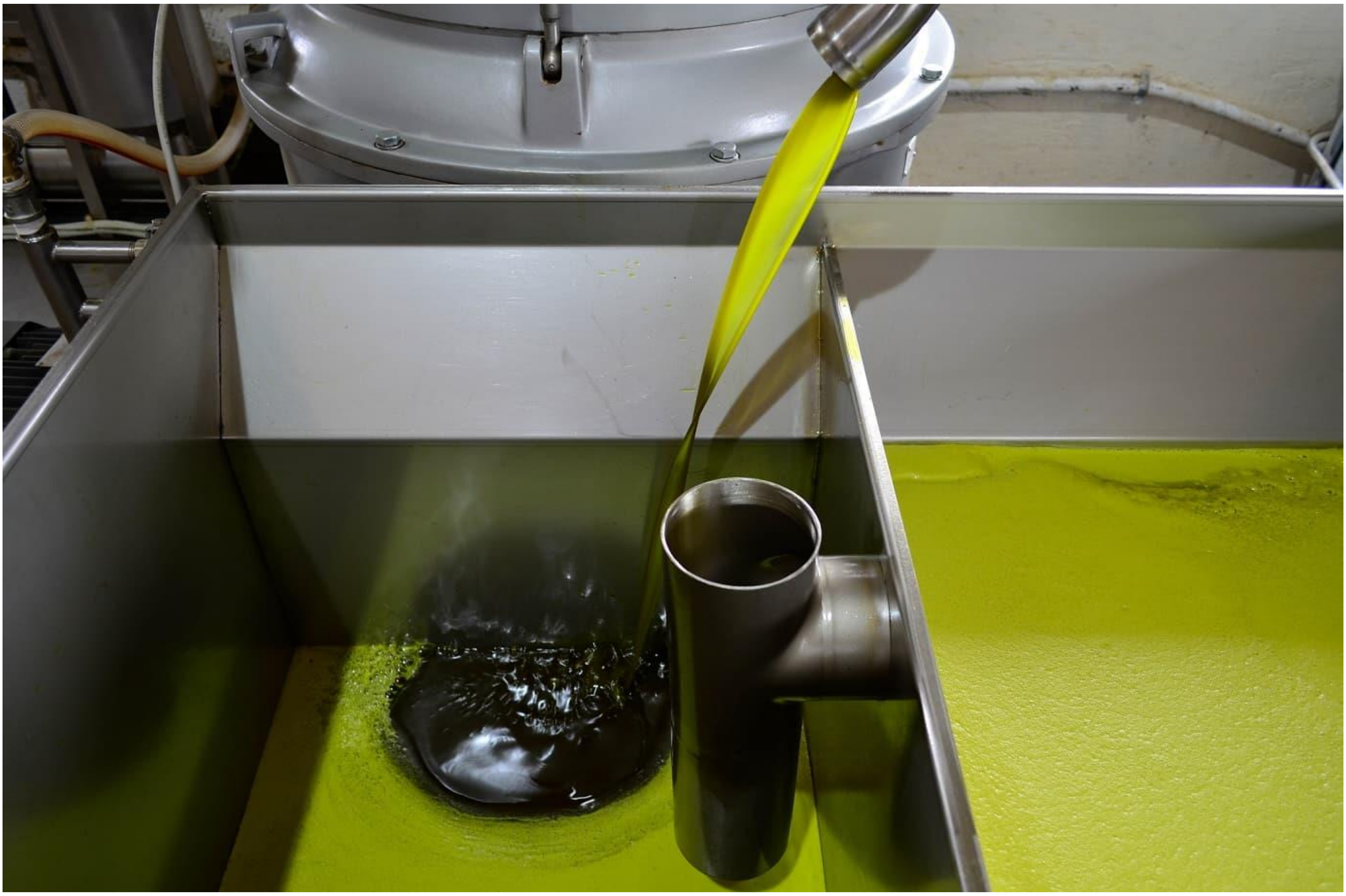

Guideline

May 2023

Waste Management Guideline for Yirga Alem Industrial Park and others

german cooperation
DEUTSCHE ZUSAMMENARBEIT

Funding programme develoPPP
Where business meets development.

Implemented by giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

In cooperation with TRADIN Organic
Global Organic Ingredients

Imprint

Published by the
Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

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As at
May 2023

Printed by
Name
Addis Ababa, Ethiopia

Design
Frédéric Koehl
Cully, Switzerland

Photo credits/sources
Cover page: Tradin Agriculture B.V.
All other pages: As indicated in the document

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On behalf of the
German Federal Ministry for Economic Cooperation and Development (BMZ)

Table of Contents

List of Annexes

List of Figures

List of Tables

List of Abbreviations

AAIT	Addis Ababa Institute of Technology
CHP	Combined heat and power system
BSF	Black soldier fly
DBFZ	Deutsches Biomasseforschungszentrum
DS	Dry solid
DSC	Dry solid content
EIC	Ethiopian Investment Commission
EPA	Environmental Protection Authority
FDRE	Federal Republic of Ethiopia
IAIP	Integrated Agro-Industrial Park
IPDC	Industrial Park Development Cooperation
kWh	Kilowatt hour
kWheq	Kilowatt hour equivalent (for forms of energy that are not electricity to compare with electricity)
MoI	Ministry of Industry of Ethiopia
MWh	Megawatt hour
NPV	Net present value
O&M	Operations and maintenance
SRVC	Strengthening Rural Value Chains in Ethiopia
STA-DPP	Building an avocado and Sesame Value Chain in Ethiopia (develoPPP)
TS	Total solids
TSS	Total suspended solids
TVS	Total volatile solids
WWTP	Wastewater Treatment Plant

Currency Rate

In this document the following currency rate was considered for the Sunvado case study:

1 EUR is equivalent to about 60 ETB

0 EXECUTIVE SUMMARY

0.1 Introduction

The agro-processing results in **huge amounts of organic waste**, with great variability in quantity and quality, for example, avocado-oil processing, consisting of the kernel, skin and avocado pulp (hereafter referred to as pomace). Much of this waste is generated in industrial parks across the country. The obligation to cope with the waste from factories in Integrated Agro-Industrial Parks (IAIP) is with the **Industrial Park Development Cooperation (IPDC)** and not with the tenant industries hosted by the IPDC.

Given the complexity and **challenge for IPDC to manage this unpredictable variety of waste**, IAIP are therefore faced with challenges that are often difficult to manage this waste.

This issue has emerged and been addressed in the context of two projects between 2018 and 2023 by the **Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)**. As a federally owned enterprise, GIZ supports the German Government in achieving its objectives in the field of international cooperation for sustainable development. With the develoPPP-programme, the German Federal Ministry for Economic Cooperation and Development (BMZ) promotes private-sector activities where entrepreneurial opportunities and development policy potential meet. Within this funding programme, GIZ together with a Dutch company called Tradin Organic Agriculture B.V set up a project named **Building an Avocado and Sesame Value Chain in Ethiopia (STA-DPP)** with the common objective to increase local value addition of the organic sesame and avocado sector in Ethiopia. Waste Management was a core component of the STA-DPP, under its "*work package 4: set up the value chain for waste use*".

Therefore STA-DPP contracted the international consulting firm ECOPSIS S.A. to develop the present waste management guideline (hereafter referred to as **Guideline**) for the Yirga Alem Industrial Park, on how to cope with the waste streams in a sustainable and environmentally friendly way. The **Guideline** was established by conducting and **using a case study** of organic waste from avocado oil produced by the company **Sunvado**, a local subsidiary of Tradin Organic B.V., based at the **Yirga Alem IAIP**. The results of research activities implemented in 2023 by the **Addis Ababa Institute of Technology (AAIT)** on avocado waste, financed by the project **Strengthening Rural Value Chains in Ethiopia (SRVC)**, were also used in the development of this Guideline. In partnership with the Ministry of Agriculture, the SRVC projects supports private sector-led agricultural development in Ethiopia. The project works with all actors along the avocado, onion and soybean value chains in the Amhara, Oromia and Sidama regions. SRVC project objectives include generating employment and better incomes, improving agricultural productivity and resilience, and improving access to agricultural inputs, services and markets.

The **overall aim** is to find **sustainable ways of managing the waste from agro-processing of the IAIP** on the example of avocado oil processing. The above and other ideas were developed to find new ways not only to treat waste, but also to close the loop and **recycle** it in the value chain or **recover** it in other ways. The waste management guideline was designed for the IPDC and their tenants and in a way that can be used for all agro-industrial parks in Ethiopia.

0.2 Framework Conditions of the Waste Management

At the time of this Guideline preparation, following documents defined the framework conditions of the waste management in Ethiopia.

- Environmental Policy of Ethiopia, 1997
- Solid Waste Management Proclamation No 513/2007
- Environmental Protection Organs Establishment Proclamation No 295/2002
- EIA Proclamation No 299/2002
- Regulation on Prevention of Industrial Pollution No 159/2008
- National Urban Solid Waste Management Strategy, 2017
- Environmental Pollution Control Proclamation No 300/2002
- Standards for Industrial Pollution Control, 2013

The most relevant stakeholders were identified, listed, and analysed. The analysis is shown in Annex 2 Stakeholder Mapping and Analysis. The categories of stakeholders considered is as follows:

- National stakeholders
- Decentralized stakeholders
- Development Partners

As with waste management policy, strategy and regulation, this list of stakeholders is subject to change as government organization may evolve in the future. If so, it may be necessary to update this Guideline.

0.3 Guideline

0.3.1 Key principles

Three principles are fundamental to the application of the Guideline:

1. **Waste hierarchy** (see figure below)
2. Waste as an opportunity and part of the business strategy (savings, risk mitigation, etc.)
3. **Get the required expertise** (for technical aspects and marketing aspects)

Figure 0-1 : Waste hierarchy

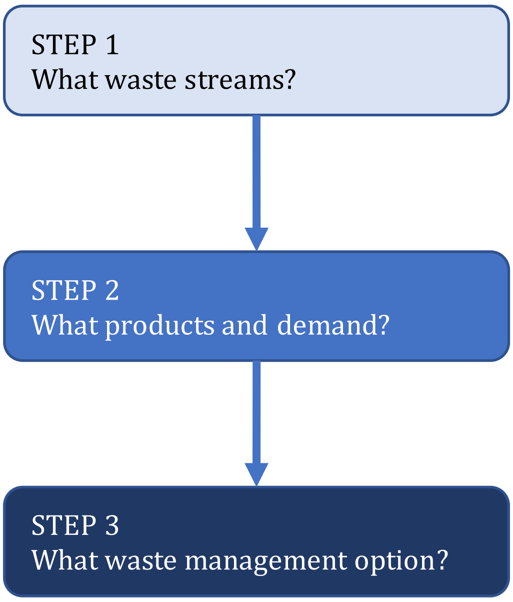
0.3.2 Demand-driven Stepwise Approach

To determine the most appropriate management option, it is important **not to start by choosing a treatment technology**.

Instead, it is recommended to **first identify the products for which the demand is the highest (quantity, value)** and then find the best management options. However, it is of course necessary to have knowledge of the feasibility of waste management options to exclude products that would clearly not be feasible to produce.

The approach adopted for this guideline therefore consists of the following three steps, with characterisation of the waste streams as the starting point.

Figure 0-2 : Demand-driven Stepwise Approach of the Guideline



0.4 Sunvado Case Study

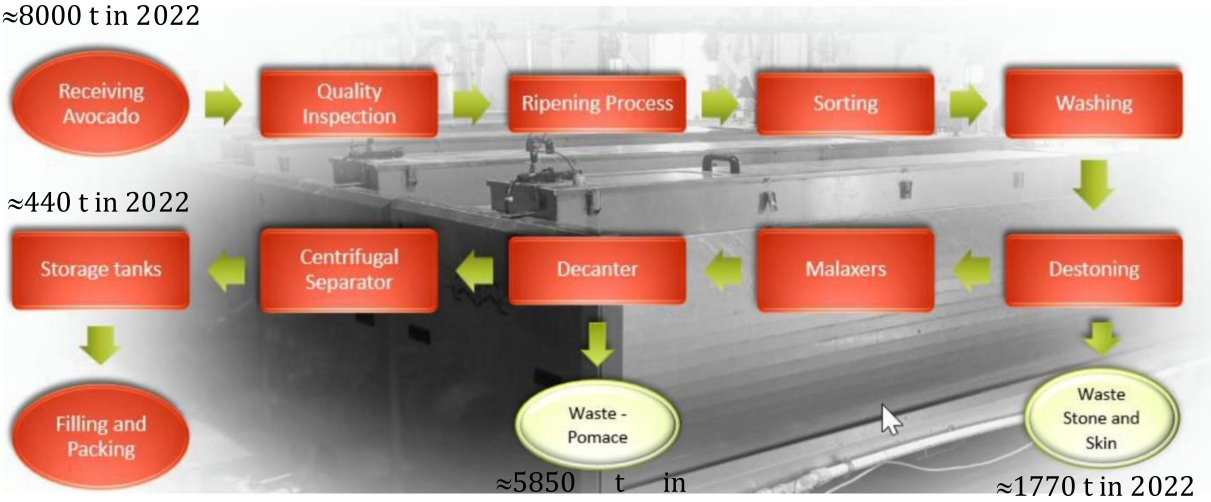
This Guideline is accompanied by the case study of the avocado oil factory of Sunvado located at the Yirgalem Integrated Agro-Industrial Park (Yirgalem IAIP). This case study was used to develop the Guideline.

0.4.1 Step 1 – What Waste Streams?

There are two types of waste produced by the oil production process:

- the **pomace** flowing out of the decanter that separates the oil from the rest of the input material; it is a thick liquid with a dry solid content (DSC) of between about 15 and 20%.
- the avocado **stones (or seeds)** and the **skins (or peels)** are extracted together and transported on trucks via a conveyor belt, before being evacuated off site.

Figure 0-3 : Sunvado case study – Process flow chart



Source: Sunvado

0.4.2 Step 2 – What Products and Demand

Five options were considered in the case study:

- Option 1 – Dewatered Waste as Soil Amendment
- Option 2 – Compost as Soil Amendment
- Option 3 – Animal Feed after Waste Drying
- Option 4 – Animal Feed from BSF
- Option 5 – Biogas Energy from Anaerobic Digestion

Table 0-1 : Sunvado case study – Demand for the most relevant Products (about 60 ETB per EUR)

Product type	Potential demand from	Products	Demand
Energy	Sunvado (for own process, e.g., water boiler of 190 kW)	Heat	190 kWh x 24h / efficiency pellet stove @maximum 0,03 EUR/kWh
		Biogas	190 kWh x 24h / efficiency gas stove @maximum 0,03 EUR/kWh
		Heat / Cooling	190 kWh x 24h / efficiency CHP @maximum 0,03 EUR/kWh
	Sunvado (for own process) Public electricity operator	Electricity	190 kWh x 24h / efficiency CHP @maximum 0,03 EUR/kWh Surplus sale at 5 to 6 EUR cent per kWh
Soil amendment (nutrient)	Nurseries Famers	Dewatered waste	Value: - 2 EUR/ton (incl. transport cost) Quantities > need of avocado suppliers
		Compost	Value: 8 EUR/ton (incl. transport cost) higher values could be achieved but only with extensive and costly marketing measures Quantities > need of avocado suppliers
Animal feed (nutrient)	Animal feed producers, farmers	Dried pomace	Value: 250 EUR/ton (incl. transport). Values up to 350 EUR/t are also mentioned but would first need to be confirmed. Quantities are not a limiting factor according to SUNVADO

Product type	Potential demand from	Products	Demand
		BSF larvae	Value: unknown in Ethiopia (market assessment is needed, in particular in case of export). At least as much as for animal feed (≥ 250 EUR/t (incl. transport)) Rwanda: one factory @ 650 EUR/t of dried larvae; Indonesia market assessment 300 to 600 EUR/t of dried larvae. Both cases: for the domestic market. Quantities are not a limiting factor according to SUNVADO

0.4.3 Step 3 – What most adequate Waste Management Option?

Given the available information, assuming that the quality of the dry pomace allows to agree on a selling price of at least 250 EUR/t, as co-substrate for animal feed production, the **Option 4 (Animal feed from dried waste) is recommended**. It requires to dry the pomace via a solar drying facility.

It could be challenged by **the Option 5 (Animal feed from BSF)**, but this option requires research on the best waste to optimize the protein conversion rate and a market assessment (domestic and export markets), even though current available figures give an advantage to Option 4. **Starting with option 4 does not necessarily preclude moving on to option 5 or implementing both options in parallel.**

Thus, also considering the production plan and its timing, it is recommended to **gradually increase the drying capacity** and start with the implementation of a first solar drying capacity stage. Dewatering containers should be assessed as they offer the possibility of improving solar drying through preliminary dewatering.

If animal feed is to be produced, the **seeds and peels must be managed separately**. It is recommended to explore the research opportunity suggested by the Deutsches Biomasseforschungszentrum (DBFZ) to produce biochar as an alternative to the solution of recycling in agriculture (a soil amendment). DBFZ is a German research centre, that develops various concepts for the economically viable, ecologically harmless and socially acceptable energetic use of biomass and from 2021 to 2026 implements a project on soil improvement in Ethiopia through the energetic and material use of agricultural residues (ETH-Soil).

1 INTRODUCTION

1.1 Background Information

1.1.1 Origin of this Guideline

The Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (**GIZ**) is a federally owned enterprise that supports the German Government in achieving its objectives in the field of international cooperation for sustainable development. In line with the development objectives and high interest of the Ethiopian government in industrial development, economic development including local value addition, GIZ established a project concept in collaboration with a private company, Tradin Organic, to develop the sesame and avocado value chain in Sidama, Amhara and the Oromia Region in Ethiopia.

Tradin Organic is a Dutch company founded in the 1980s in the Netherlands which soon became a pioneer of the organic food trade in the emerging European market. Today, Tradin supplies the international food industry with globally sourced certified organic raw materials, directly sourcing more than 150 products from more than 60 origins.

GIZ together with Tradin Organic set up a project named **Building an Avocado and Sesame Value Chain in Ethiopia (STA-DPP)** with the common objective to increase local value addition of the organic sesame and avocado sector in Ethiopia. The cooperation between GIZ and Tradin Organic Agriculture B.V was launched on 1st June 2018 for a total of 5 years.

Waste Management was a core component of the STA-DPP, under its "*work package 4: set up the value chain for waste use*". With the anticipated increase in production inside the industrial park over the project period, the project aimed to find innovative solutions to valorise growing amounts of waste beyond established initiatives. To maximize the benefits of the avocado and sesame value chains in addition to other agro-processing products within the **industrial parks** for the local economy, the project targeted to develop and test value proposals for new product development from the organic waste generated through agro-processing, with application in food, cosmetic, medicine processing industries on the one hand, and valorisation of waste streams including crop/fruit residues on the other hand.

Strengthening Rural Value Chains in Ethiopia (SRVC) is a project commissioned by the German Federal Ministry for Economic Cooperation and Development (BMZ) and implemented by GIZ withing the project term 2021 to 2024. The SRVC project support value chain development along the avocado, onion and soybean value chains in the Amhara, Oromia and Sidama regions. SRVC project objectives include generating employment and better incomes, improving agricultural productivity and resilience, and improving access to agricultural inputs, services and markets. This includes supporting climate change adaptation and promoting circular economy approaches to recycle the often-valuable bio-waste from agricultural production and processing. To this end, the project financed research at the **Addis Ababa University Institute of Technology (AAIT)** that investigated different options to recycle the unused parts of the avocado from avocado oil processing.

Yirga Alem Integrated Agro-Industrial Park, located in Sidama Regional State, is the third integrated agro-industrial park being developed within the framework of the Programme for Country Partnership for Ethiopia, which is a flagship programme of the United Nations Industrial Development Organization (UNIDO). It was inaugurated in March 2019 with sound infrastructure on electricity and water supply, road infrastructure and child-care facility. In 2022, there were two companies engaged in avocado-oil production and one company producing industrial flavoured milk products.

1.1.2 The Problem

The agro-processing results in **huge amounts of organic waste**, for example, avocado-oil processing, consisting of the kernel, skin and avocado pulp (hereafter referred to as pomace). The obligation to cope with the waste from factories in Integrated Agro-Industrial Parks (IAIP) is with the **Industrial Park Development Cooperation (IPDC)** and not with the tenant industries hosted by the IPDC.

The IPDC therefore has to **deal with a wide range of different types of waste. The quantity and quality of these wastes is hardly predictable** since the establishment or not of industries in the IAIPs depends on opportunities and market conditions. Also, production depends on consumer demand, which is itself frequently dependent on the global market (in any case in the case of exports) as well of the seasonal varying availability of raw materials. Parks are therefore faced with challenges to manage this waste.

1.1.3 The Objective

STA-DPP aimed to develop the present waste management guideline (hereafter referred to as **Guideline**) for the Yirga Alem Integrated Agro-Industrial Park, on how to cope with the waste streams in a sustainable and environmentally friendly way. The **Guideline** was established by conducting and **using a case study** of organic waste from avocado oil produced by the company **Sunvado based at the Yirga Alem IAIP**. After an international tendering process, the project contracted the Switzerland-based consulting firm **ECOPSIS S.A.** to conduct a case study on revalorisation of the organic wastes generated from the processing of avocado oil and to develop this Guideline, to make findings and acquired knowledge available to relevant stakeholders in Ethiopia. The results of research activities financed by SRVC and implemented in 2023 by the Addis Ababa Institute of Technology (AAiT) on avocado waste were also used in the development of this Guideline.

The **overall aim** is to find **sustainable ways of managing the waste from agro-processing of the IAIPs** on the example of avocado oil processing. The above and other ideas will be developed to find new ways not only to treat waste, but also to close the loop and **recycle** it in the value chain or **recover** it in other ways.

After conducting a first stakeholder consultation in June 2022, a period of research and data collection and a final field visit and presentation of main findings, this Guideline was completed in April 2023. Thus, the Guideline is based on the results of the case study and state of knowledge in 2023 and may be supplemented and adapted in the future.

1.1.4 Targeted Guideline Users

The waste management guideline is designed for the IPDC and their tenants in a way that can be used for all agro-industrial parks in Ethiopia.

Given the complexity and challenge for IPDC to manage this unpredictable variety of waste, but also given the recycling and recovery objectives, this Guideline is primarily addressed to each tenant that will have to first best manage their waste produced at their factory.

However, this should not prevent IPDC and their individual tenants or even groups of tenants, to formally agree for a more centralized management.

The scope of the guideline does not include this organisational aspect of waste management and does not impose responsibilities in the management of waste.

1.2 Contribution to the Sustainable Development Goals

The application of the Guideline contributes primarily to achieve the **SDG 12** to "**Ensure sustainable consumption and production patterns**", for the targets:

- 12.4 By 2020, achieve the **environmentally sound management of chemicals and all wastes throughout their life cycle,** in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment.
- 12.5 By 2030, substantially reduce waste generation through prevention, reduction, recycling, and reuse.

Since the boundary between solid waste and liquid waste is not always clear in particular for industries, where a wide range of waste can be generated, the application of the Guideline also contributes to achieve the **SDG 6** to "**Ensure access to water and sanitation for all" for the targets**" for the following target:

- 6.3 By 2030, improve water quality by reducing pollution, eliminating dumping, and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater, and substantially increasing recycling and safe reuse globally.

Depending on the case, it may also contribute to the achievement of the goals of other SDGs, e.g. if the outcome is the construction of an anaerobic digestion facility then this contributes to SDG 13 "Take urgent action to combat climate change and its effects" to reduce and improve the indicator "Total greenhouse gas emissions per year".

2 FRAMEWORK CONDITIONS OF WASTE MANAGEMENT

2.1 Overview of Main Policy, Strategy and Regulations

The **1995 Constitution of the Federal Democratic Republic of Ethiopia** (FDRE) is the source of key principles and cornerstone of all policies, including environmental policies. In article 44 of the Federal Democratic Republic of Ethiopia (FDRE), it asserts “All people have the right to live in a healthy and clean environment”. In addition, article 92 of FDRE constitution states that “The role of government to ensure all Ethiopians live in a clean and healthy environment”.

The **Environmental Policy of Ethiopia was adopted in 1997**. The overall policy goal is to improve and enhance the health and quality of life of all Ethiopians and to promote sustainable social and economic development through the sound management and use of natural, human-made and cultural resources and the environment as a whole so as to meet the needs of the present generation without compromising the ability of future generations to meet their own needs.

At the national level, the Environmental Protection Agency of Ethiopia is responsible for ensuring that environmental laws and regulations are adhered to policy objectives.

Table 2-1 : Environmental policies and regulations related to waste management in Ethiopia

Document	Relevant content
Environmental Policy of Ethiopia, 1997	The policy’s stated goal is to “improve and enhance the health and quality of life of all Ethiopians and to promote sustainable social and economic development through the sound management and use of natural, human-made and cultural resources and the environment as a whole…” This is done through several sectoral policies as well as some cross-sectoral policies. One sectoral policy specifically addresses waste management through: " The Key Guiding Principles are: […] d. The use of non-renewable resources shall be minimized and where possible their availability extended (e.g., through **recycling**); e. Appropriate and **affordable technologies** which use renewable and non-renewable resources efficiently shall be adopted, adapted, developed, and disseminated;” “3.8. Control of Hazardous Materials and Pollution from Industrial Waste The Policies are: […] m. To promote **waste minimization** processes, including the **efficient recycling** of materials wherever possible;”
Solid Waste Management Proclamation No 513/2007	Article 2 (6) “Solid Waste” means anything that is neither liquid not gas nor is discarded as unwanted. Article 2 (7): “Solid Waste Management” means the collection, transportation, storage, recycling or disposal of solid waste, or the subsequent use of a disposal site that is no longer operational. Article 4 (2): Any person shall obtain a permit from the concerned body of an urban administration prior to his engagement in the collection, transportation, use or disposal of solid waste.
Environmental Protection Organs Establishment Proclamation No 295/2002	Article 2 (1): "Authority" means the Environmental Protection Authority re-established under Article 3 of this proclamation. Article 2 (2): "Competent Agency" means any federal or regional government organ entrusted by law with a responsibility related to the subject specified in the provisions where the term is used. Article 2 (4) " Environmental Protection Organs" means the Authority; the Council/the Sectoral and Regional environmental units. and agencies mentioned under Article 111- and 15 of this Proclamation.

Document	Relevant content
	Article 2 (8 &9): ''Region" means any of those parts of Ethiopia specified as Regions under Article 47(1) of the Constitution of the Federal Democratic Republic of Ethiopia and for the purpose of this Proclamation, includes the Addis Ababa and Dire Dawa Administrations; "Regional Environmental Agency" means any regional government organ entrusted, by that Region, with a responsibility for the protection or regulation of the environment and natural resource.
EIA Proclamation No 299/2002	Article 6(1): no person shall commence any new development activity under any category listed in any directive issued pursuant to this Proclamation ('project') which requires an environmental impact assessment (further specified in art. 5) without an authorization of the Environmental Protection Authority. The Authority or the relevant regional environmental agency may decide that the possible impact of the project is significant and therefore that no EIA shall be carried out (art. 3).
Regulation on Prevention of Industrial Pollution No 159/2008	Article 2 (5) defines industry "existing factory" means a factory that is under operation or a project to which an application to obtain a license to establish a factory has been submitted before or on the date of entry into force of this regulation. Article 2 (6) also defines "pollution" means any condition which is hazardous or potentially hazardous to human health, safety or welfare or to living things created by altering any physical, radioactive, thermal chemical, biological or other property of any part of the environment in contravention of any condition, limitation or restriction made under this Regulation, the relevant environmental standard or under any other relevant law. Article 4 (1) of the regulation indicates: a factory subject to this regulation shall prevent or, if that is not possible, shall minimize the generation of every pollutant to an amount not exceeding the limit set by the relevant environmental standard and dispose of it in an environmental sound manner. Article 4(5) of article 4 also states that: Even if a factory is not subject to the provisions of this regulation, the competent environmental organ may require it to take appropriate measures in order to eliminate any risk that might emanate from its operation.
National Urban Solid Waste Management Strategy, 2017	The Integrated Urban Sanitation and Hygiene Strategy (IUSHS) makes it clear that sanitation and hygiene improvement in urban areas must go beyond the approaches that have served rural sanitation well. Promotion of hygiene awareness, behaviour change, and household investment in toilets are necessary, but must be integrated with a robust chain of services to support improved household sanitation, with effective systems to collect and deliver liquid and solid wastes for safe management, disposal, and possible re-use. Liquid waste service delivery, including safe disposal of human excreta, liquid waste generated by human activities (domestic, industrial, and commercial waste), institutional waste, and safe management of drainage. Solid waste service delivery, including solid waste generated by human activities (domestic, industrial, commercial, and institutional) and safe management of drainage. Promotional and behaviour change including correct hygiene practices, use and management of latrines, uptake of and payment for services, eradication of open defecation, menstrual hygiene management, solid waste management (reduce, reuse, recycle), and other interventions.
Environmental Pollution Control Proclamation No 300/2002	Article 3 (3): Any person engaged in any field of activity which is likely which is to cause pollution or any other environmental hazard shall, when the Authority or the relevant regional environmental agency so decides, install a sound technology that avoids or reduces, to the required minimum, the generation of waste and, when feasible, apply methods for the recycling of waste. Article 3 (4): Any person who causes any pollution shall be required to clean up or pay the cost of cleaning up the polluted environment in such a manner and within such a period as shall be determined by the Authority or by the relevant regional environmental agency.
Standards for Industrial Pollution Control, 2013	The purpose of introducing the standards is to prevent significant industrial pollution by indicating standards which must be observed and by indicating pollution limits beyond which the environment would not tolerate. The limit values specified are for emission to the atmosphere, emission to water and noise.

2.2 Stakeholders Identification and Analysis

The most relevant stakeholders at the time of this Guideline preparation were identified, listed, and analysed. The analysis is shown in Annex 2 Stakeholder Mapping and Analysis). The summary list is shown below. This list may evolve as the organization of public administrations evolves in the future.

Main national stakeholders:

- Ethiopian Investment Commission (EIC)
- Ministry of Industry (MoI)
- Industrial Parks Development Corporation (IPDC)
- Food and Drugs Authority
- Conformity Assessment Agency

Decentralized stakeholders:

- Public authorities and agencies:
    - Decentralized entities of national stakeholders
    - Regional Administration, municipalities
    - Environment Protection Authority (EPA)
    - Agricultural Transformation Agency (ATA)
    - Sidama Regional Trade and Industry Bureau
- Universities or research institutes
- Technical and Vocational Education and Training (TVET)
- Cooperative Unions and Farmers

Development Partners

3 GUIDELINE

3.1 Key Principles

3.1.1 Waste Hierarchy

The principle of the waste hierarchy illustrated by the Figure 3-1 is the foundation of the Guideline with the following key principles:

1. Off-site waste disposal should be an option of last resort and should only involve small quantities of waste: zero waste should be the target.
2. **Prevention**: waste production shall always be minimized as far as possible.
3. **Re-use trough recycling or recovery after preparation** (i.e., treatment), with a priority given to recycling. Recovery is a reuse outside the production cycle.

Figure 3-1 : Waste hierarchy

The waste hierarchy is an approach used worldwide and that was not developed specifically for this Guideline. The founding principles are often already included in country and stakeholder policies and strategies.

Defining the waste hierarchy requires to define the end-of-waste criteria, which allows to distinguish between a "*waste*" and a "*product*." The end-of-waste criteria are often either of form of treatment (requirement on the means used) or requirements on the characteristics of the waste / product.

3.1.2 Waste as an Opportunity and part of the Business Strategy

A sound waste management following the principles of the waste hierarchy implicitly involves economic opportunities:

- Providing savings to businesses, especially in resource extraction and use, by waste prevention actions, recovery and/or recycling activities.
- Increasing business opportunities.
- Reduced business risks with an increased recycling (less dependencies from external resources and increase share of the value chain).

The principle set here is to improve the *economic sustainability* of the company via waste prevention and re-use, which is the primary condition for the *sustainability* of a sound waste management.

Waste management should not be ignored or neglected and pushed aside. It should be an integral part of the business plan and strategy and be considered as an opportunity.

In addition, there are implicit health and environmental benefits involved, which are at least as follows:

- Reducing impacts on human health and environment
- Reducing greenhouse gas emissions
- Encouraging resource efficiency, reducing the demand for primary raw materials and the threat of their depletion.

3.1.3 Get the required Expertise

Given the wide variety of wastes, waste management options and products, but also the opportunities that waste management represents, it is recommended to call on and invest in the needed expertise for:

- **Marketing aspects** to identify products with the strongest market demand because in-house marketing capacities may not be familiar with these products.
- **Technical aspects** to identify and evaluate the most appropriate waste management options and products, as the range of options is often wide and changing rapidly due to the dynamics of the sector.

This should be considered as an investment to seek value for money, which can be recovered through the waste management savings / revenues.

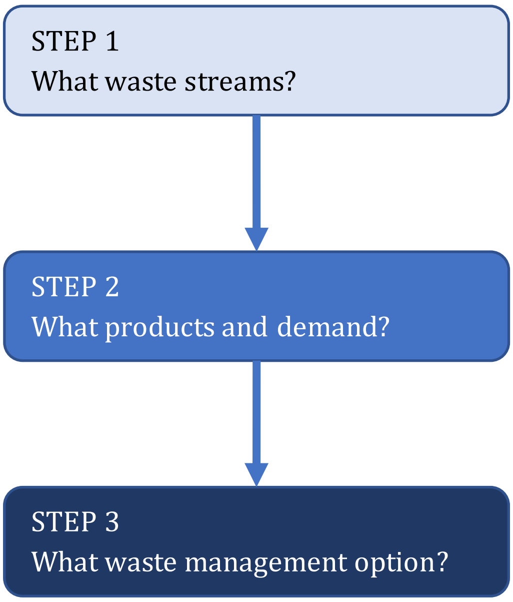
3.2 Demand-driven Stepwise Approach

To determine the most appropriate management option, it is important not to start by choosing a treatment technology.

It is recommended to first identify the products for which the demand is the highest (quantity, value) and then find the best management options. However, it is of course necessary to have knowledge of the feasibility of waste management options to exclude products that would clearly not be feasible to produce.

The approach adopted for this guideline therefore consists of the following three steps. Characterisation of the waste streams is of course the starting point.

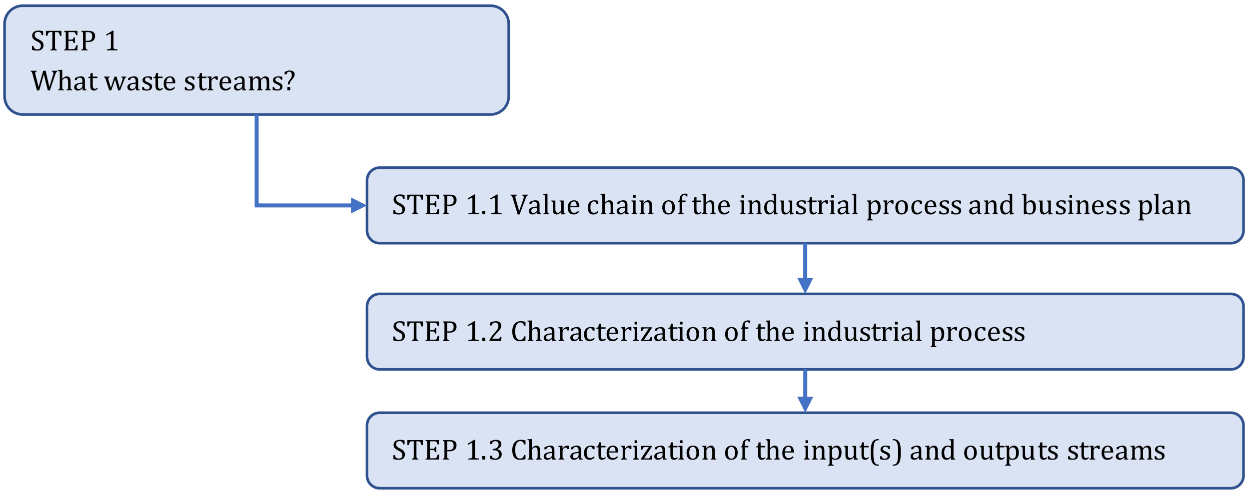
Figure 3-2 : Demand-driven Stepwise Approach of the Guideline



3.3 Step 1 – What waste streams?

The following figure summarises the different steps included in step 1:

Figure 3-3 : Steps of to identify and characterize the waste streams (Step 1)



3.3.1 Step 1.1 - Value Chain of the Industrial Process and Business Plan

The value chain analysis will inform about the business plan, in particular the resources, partners/suppliers, and distribution channels, which may represent opportunities for the waste management:

- Resources: internal demand for valorisation (e.g., energy from waste).
- Partners/suppliers: suppliers of avocado may become clients for organization.
- Distribution channels: existing distribution channel used for the industrial product can be used to distribute the co-product recovered for the waste.

Sunvado case:

The waste can be recycled in agriculture and be part of a deal with farmers for the sourcing of avocado.

The value chain should include information about localizations and transportation requirements.

The design horizon of the business plan should apply to the waste management plan. The waste management option should be reconsidered each time the business plan is updated.

3.3.2 Step 1.2 - Industrial Process

3.3.2.1 Process Flow Chart

The starting point is the establishment of a comprehensive **process flow chart**, which includes:

- The different process steps and machines.
- The input material and resources.
- The output product.
- The waste generated.

It should focus on the main wastes that are produced without going into irrelevant details like for example in charts according to ISO 15519.

3.3.2.2 Factory Location and Layout arrangement

The flow chart should be accompanied by a plant location map and a layout drawing, which shows the elements of the flow chart within the factory compound, in and outside the factory building, with a scale and distances. It should ideally also include service lines for:

- Drinking water
- Process water
- Wastewater
- Electricity
- Gas
- Etc.

The aim is to facilitate understanding of the flowchart and to provide the information necessary to identify feasible waste management infrastructure works and constraints in Step 3.

3.3.3 Step 1.3 - Input(s) and Output(s) Streams

3.3.3.1 Scope of the Assessment

The streams of the inputs and outputs consists of the **quantity** and **quality** as well as their **variations over time**. This assessment must be conducted for the existing situation and the future situation (at design horizon). Data can originate from literature or on field investigations, but they should be representative enough for the subsequent steps.

The inputs are of two natures:

- Product(s) to be processed by the factory.
- Resources needed for the process: water, electricity, gas, chemicals, etc.

Regarding the latter, the resources of interest are those that can be replaced by resources from recycling or waste recovery.

The outputs are of two natures:

- Output product(s): The quality of the output products of the industrial process (e.g., avocado oil) is usually not relevant to identify the best waste management option. Quantities can be assessed to establish and verify material balances throughout the manufacturing process.
- Waste: characterizing the waste streams is the priority.

3.3.3.2 Quantifies and their Temporal Variations

The quantities of the **outputs are proportional to the quantities of the inputs**. The quantities of the inputs **depend on the production plan of the factory** and may fluctuate according to several parameters.

The **seasonal variations** depend on the:

- Seasonal availability of fresh products.
- Price fluctuations of the products to be sourced.
- Possibility to store the products before processing.
- Etc.

Depending on the process requirements there can be **daily and weekly variations**:

- How many working shifts per day? How many working hours per day? With a constant production?
- How many working days per week?

It is important to identify the peak quantities of production as well as the minimum and average since this will influence the selection of the most appropriate waste management option.

3.3.3.3 Quality and their Temporal Variations

Usually, the quality does not vary much over time. In this case, the quality can be assessed with grab samples. However, this assumption must be verified on a case-by-case basis.

Should there be variations over time, adequate sampling methods have been used. This is usually a time proportional or a flow proportional sampling, over the variation duration. For example, if variations can occur over a 24-hour period, the sampling will last 24 hours, with one sample per hour. The samples can later be mixed at the lab as desired to obtain a representative sample to be analysed (time proportional or a flow proportional sampling).

If the quality of the inputs and waste produced by the factory are already well known and do not depend much on the specific factory process and inputs, then the quality assessment may rely solely on literature data or may rely on literature data confirmed by only a few analyses results. For other cases, it is recommended to plan representative sampling an analysis program.

The standards applicable for sampling and analysis may evolve over time. Therefore, the Guideline does not intent to prescribe standards. The methods used should meet the standards applicable at the time of the sampling and analysis.

However, a particular attention should be paid to unstable samples, which need to be cooled until analysis to prevent uncontrolled process that would affect the original characteristics of the sample.

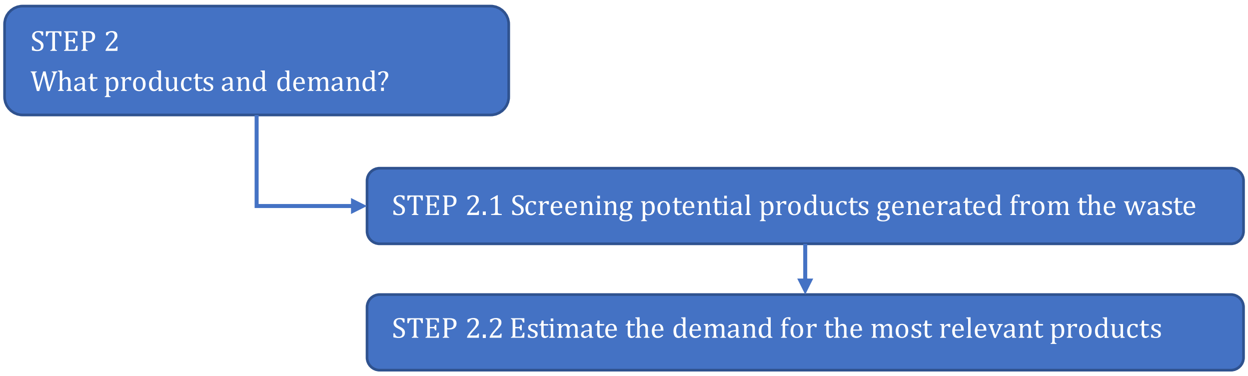
The parameters to be analysed depend on the type of industrial process and the type of waste. A priori, the parameters to be analysed include at least:

- Solids (TS, TSS, TVS, TDS)
- Fat and oil
- Nutrients for soil application
- Nutrients for animal feed

3.4 Step 2 – What Products and Demand?

The following figure summarises the different steps included in step 2:

Figure 3-4 : Steps to identify and characterize the products from waste and the demand (Step 2)



3.4.1 Step 2.1 – Screening Potential Products

Potential products that can be generated from the waste must be screened and the most relevant ones must be selected.

This step involves to also review the most relevant waste processes. Only waste processes that are feasible in the context and at industrial scale should be considered. Waste processes that are not yet mature can be piloted on a small scale if the potential is worth waiting for results and investing in a pilot.

> Sunvado case:
>
> Demand for cosmetic and pharmaceutical products extracted from avocado waste was increasing, but the extraction process was out of reach in the context and too risky. Sunvado has therefore decided to exclude this product.

Ideally, a market analysis should be conducted to assess the potential products and the demand for them, as well as the related waste processes.

The results of that screening can be summarized in a tabular form like the following table, which also show the typical products that can be generated from agro-waste.

Table 3-1 : Screening of potential product and technologies

Product type	Products	Waste process	Potential demand from
Nutrient	Dewatered waste or dewatered digestate	Direct dewatering Digestate via anaerobic digestion followed at least by dewatering	Land farmers (individual, cooperatives, firms)
	Composted wasted	Vermicomposting or composting or co-composting	
	Dried waste (>90% DSC)	Drying Dewatering and drying	Animal feed producers, animal farmers

Product type	Products	Waste process	Potential demand from
	Black soldier flies (protein)	Black soldier flies rearing	Animal feed producers, animal farmers
Energy	Heat	Waste transformation to pellets or briquettes used in a stove	Internal industrial process
	Biogas	Anaerobic digestion and direct use with gas stove	
	Electricity, hot/cold fluid, steam	Biogas via anaerobic digestion and conversion to heat via combine heat and power unit (CHP), but complex technology	
Etc.	Etc.	Etc.	Etc.

3.4.2 Step 2.2 – Estimate the Demand for the most Relevant Products

As mentioned in the previous section, ideally a market analysis should be conducted to assess the demand for the selected product.

The demand assessment should determine:

- The quantities demanded including their variations over time.
- If the waste cannot be recycled by the waste producer itself and must be sold:
    - The prices related to these quantities.
    - The potential buyers.

The variations over time are important to be considered and compared with the waste production variations because it can involve the need for storage cost or even make the option unfeasible if the products cannot be stored.

The prices are of course a key factor to be considered for the comparison and selection of the best waste management option in Step 3.

The types of potential buyers will inform about the risks and the costs for the waste producer and is an element that will contribute to the business plan development. Usually, dealing with

- a single and large buyer, which tends to have a monopolistic market share increases the risk of pressure on the prices.
- a large number of smaller buyers reduces the risk but increases the management costs.

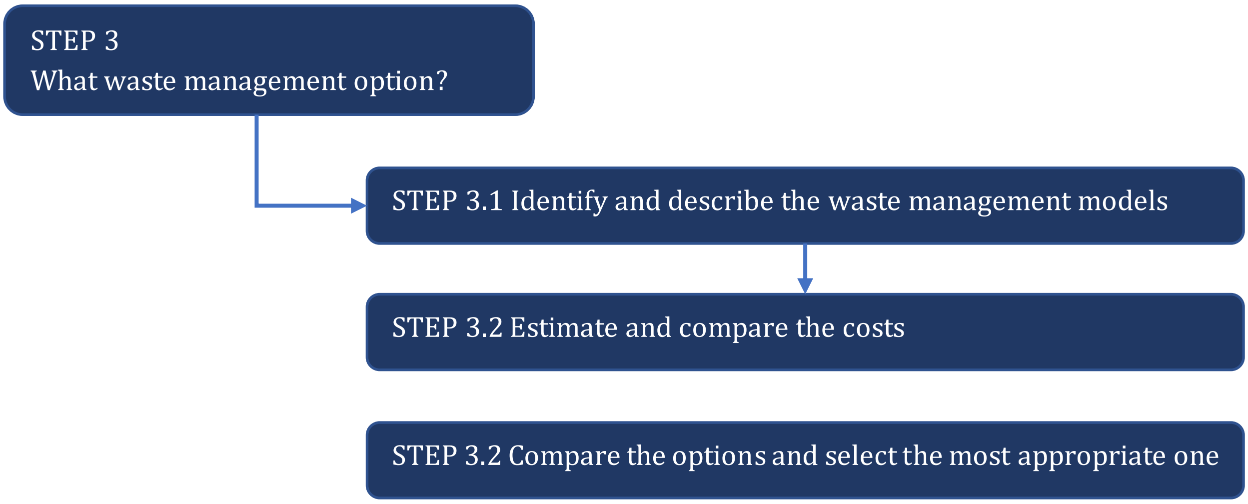
The market assessment shall also ideally provide information about the **dynamic of the demand**., i.e., provide forecasts.

Based on this assessment of the demand the final list of products and waste processes can be established and be compared in Step 3.

3.5 Step 3 – What most adequate Waste Management Option?

The following figure summarises the different steps included in step 3:

Figure 3-5 : Steps to compare and select most adequate waste management option (Steps 3)



3.5.1 Step 3.1 – Identify and describe the Waste Management Models

Each selected option should be clearly described by illustrating the waste management value chain with a diagram, including the actors involved and the waste processes.

It is recommended to use diagrams to facilitate reading and understanding.

> Sunvado case:
>
> Avocado oil production is a new industry with limited experience in waste management, so research had to be conducted with public assistance to refine the selection of adequate options.

3.5.2 Step 3.2 – Estimate and compare the Costs

3.5.2.1 Estimate the Costs

The capital investment as well as the operation and maintenance must be estimated. They must be sufficiently accurate to estimate allow the comparison of options.

3.5.2.2 Compare the Costs

If the options are financially easy to compare, then it is not necessary to calculate and compare the Net Present Value (NPV) of the options. Only costs varying form one option to another can be considered for the comparison.

NPV calculations consider the time value of money and therefore allow to compare options with difference expenditure schedules (typically high initial investment and low operations and maintenance (O&M) expenditures versus low initial investment and high O&M expenditures).

A more detailed financial analysis can be conducted after the selection of the most appropriate waste management options, together with a more detailed design of the selected option.

3.5.3 Step 3.3 – Compare the Options and select the most appropriate One

The comparisons and selection of the most appropriate options should base on following criteria:

- The financial criteria.
- The non-financial criteria.

Non-financial criteria are related to the business plan and strategy, which involve other factors than only those of the waste management. For example, this can be the extension of the scope of services and share in the value chain.

Multi-criteria analysis can be used, but not necessarily. If applied too strictly, it can distort the results. If used, it should be used to structure comparisons by assessing criteria qualitatively (without numerical assessment and weightings).

Given the dynamics of the circular economy sector, it is important that the chosen option can if necessary be implemented gradually and leave the door open for further improvements.

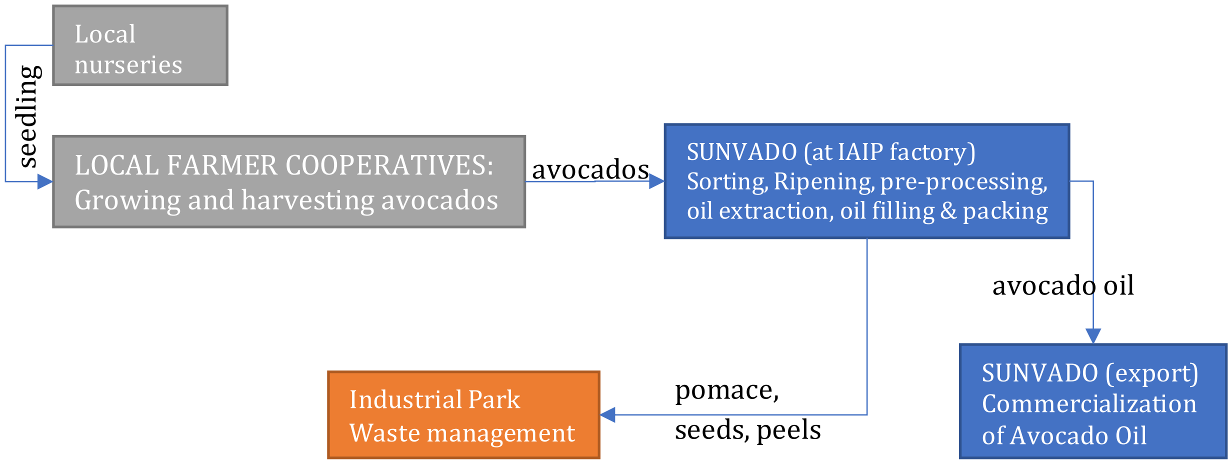
4 SUNVADO CASE STUDY

4.1 Step 1 – What waste streams?

4.1.1 Step 1.1 - Value Chain of the Industrial Process and Business Plan

In 2022, the supply and value chain can be summarised as follows.

Figure 4-1 : Sunvado case study – Supply and value chain



The information below were provided by Sunvado:

"In 2022, Sunvado does not have its own farm but buy the avocado fruits from farmers through their representative cooperatives, currently working with close to 80,000 farmers in Sidama regional state.

Sunvado provides to the farmers agronomical expertise based on organic farming by assigning extension workers permanently. The extension workers work closely with each farmer on providing trainings, follow up and helping them on farm operation like post harvesting, harvesting etc.

A well-organized sourcing team of Sunvado manages daily avocado purchase and supply to the processing facility as per the required quality standard."

Despite the framework agreement between Sunvado and its fresh avocado suppliers and Sunvado's efforts, the supply of avocado fruits is problematic because of the competition on the fruits' sourcing. This results in problems in sourcing sufficient quantities with the **minimum required quality**: avocados are often not ripe enough to be efficiently processed.

This sourcing issue is the major risk in the business model of Sunvado. In addition to the mitigation measures Sunvado has already implemented, expanding its operations into avocado production would reduce this threat.

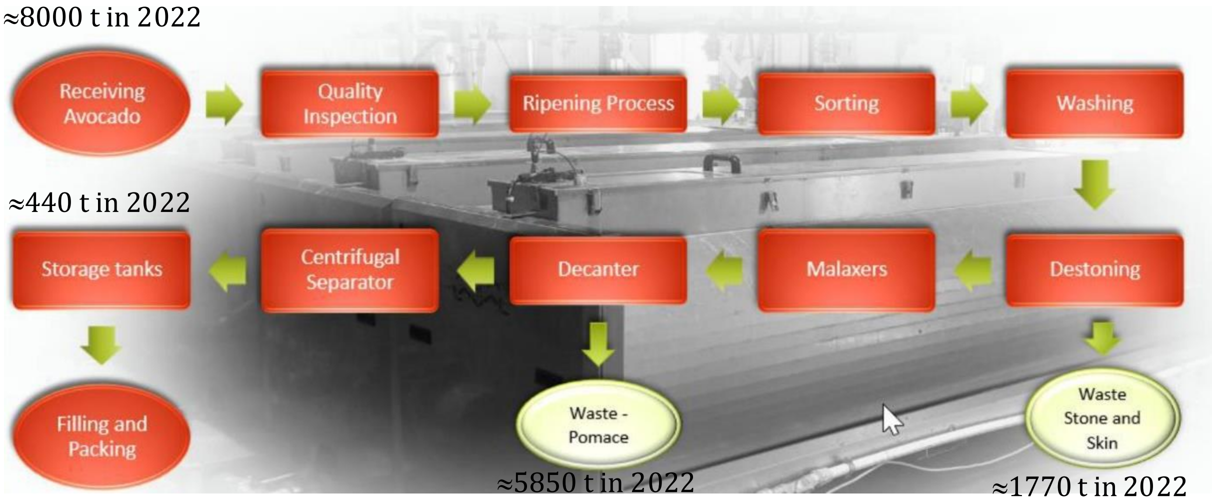
The avocado oil is exported, which increases the risks and constraints but increases the income because the value is higher than on the domestic market.

4.1.2 Step 1.2 - Industrial Process

4.1.2.1 Process Flow Chart

The following figure shows the process flow provided by Sunvado, including the estimates of the production plan in 2022.

Figure 4-2 : Sunvado case study – Process flow chart



Source: Sunvado

There are two types of waste produced by the oil production process. As illustrated by the following pictures:

- <u>on the left</u>, the **pomace** flowing out of the decanter that separates the oil from the rest of the input material; it is a thick liquid with a dry solid content (DSC) of between about 15 and 20%.
- <u>on the right</u>, the avocado **stones (or seeds)** and the **skins (or peels)** are extracted together and transported on trucks via a conveyor belt, before being evacuated off site.

Figure 4-3 : Sunvado case study – Pictures of the waste produced by the oil production process

Source: Sunvado

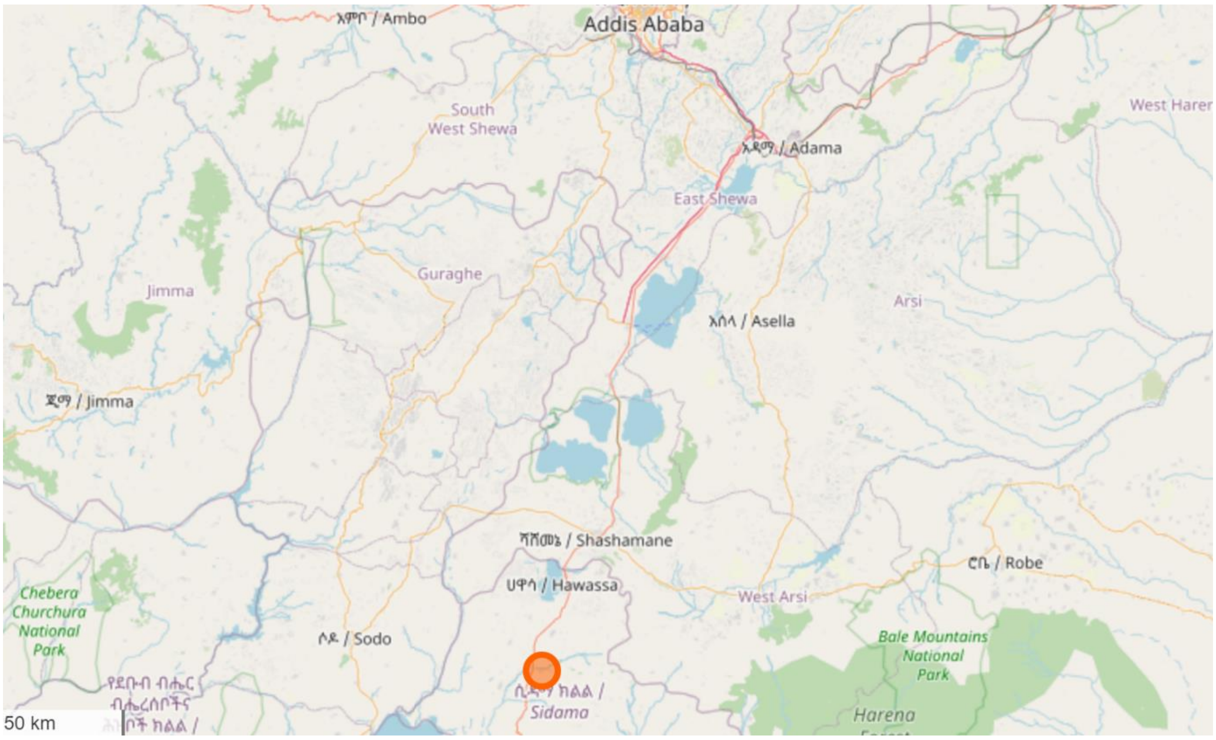
The decanter could be replaced with a tricanter, which would produce a thicker pomace (20 to 25% DSC). This opportunity has not been planned concretely and therefore has not been considered. The installation of such equipment would alleviate dewatering and drying efforts. It may be best to wait until more experience with this type of equipment for oil separation and dewatering and this type of avocado process is available. This change represents a form of risk and can also have a significant impact on oil production and may require new optimization efforts and costs.

4.1.2.2 Factory Location and Layout arrangement

The factory is in the Yirga Alem industrial park which is about 50km south to Hawassa and 320 south to Addis Ababa. As shown on the satellite map (Figure 4-5, December 2022), the industrial park was hardly occupied in 2022.

The layout plan provided by Sunvado shows that there is little space available inside the existing building, but a free space outside the building of approximately 2 500 m^2, where only a shed exists. There could be space for a second production line in the building in parallel to the existing single line.

Figure 4-4 : Sunvado case study – Location in Ethiopia of the Yirgalem industrial park

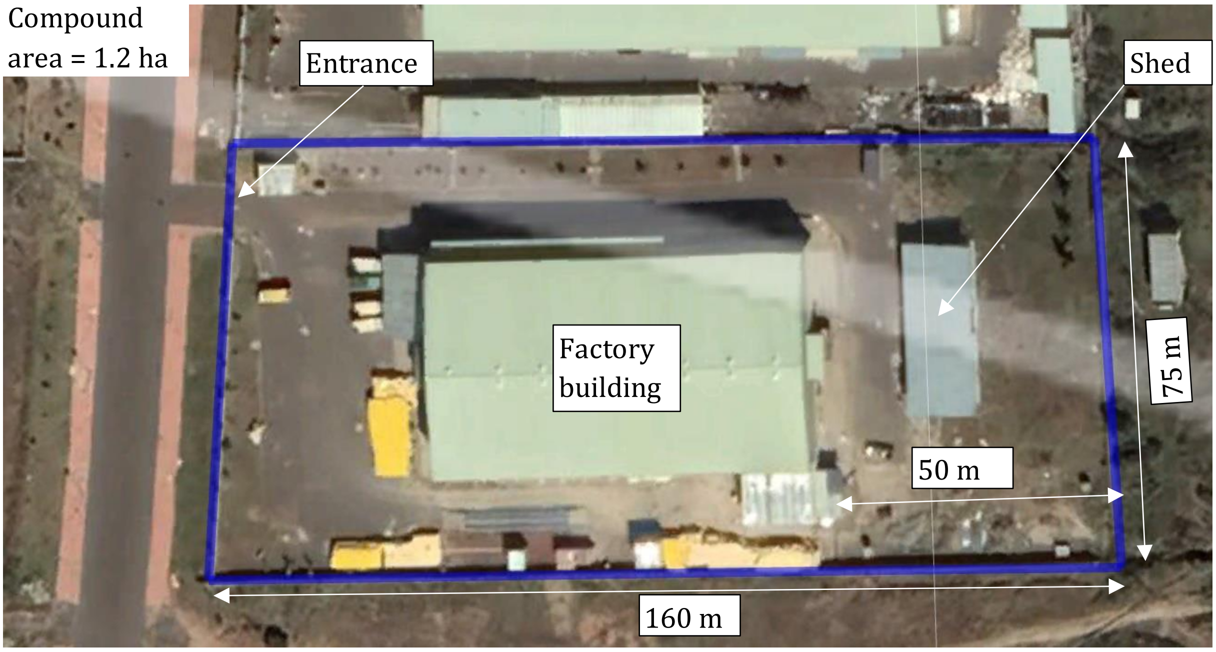


Source: *©Openstreetmap contributors*

Figure 4-5 : Sunvado case study – Layout map of the Yirgalem industrial park

Source:©Google Earth, ©Maxar Technologies

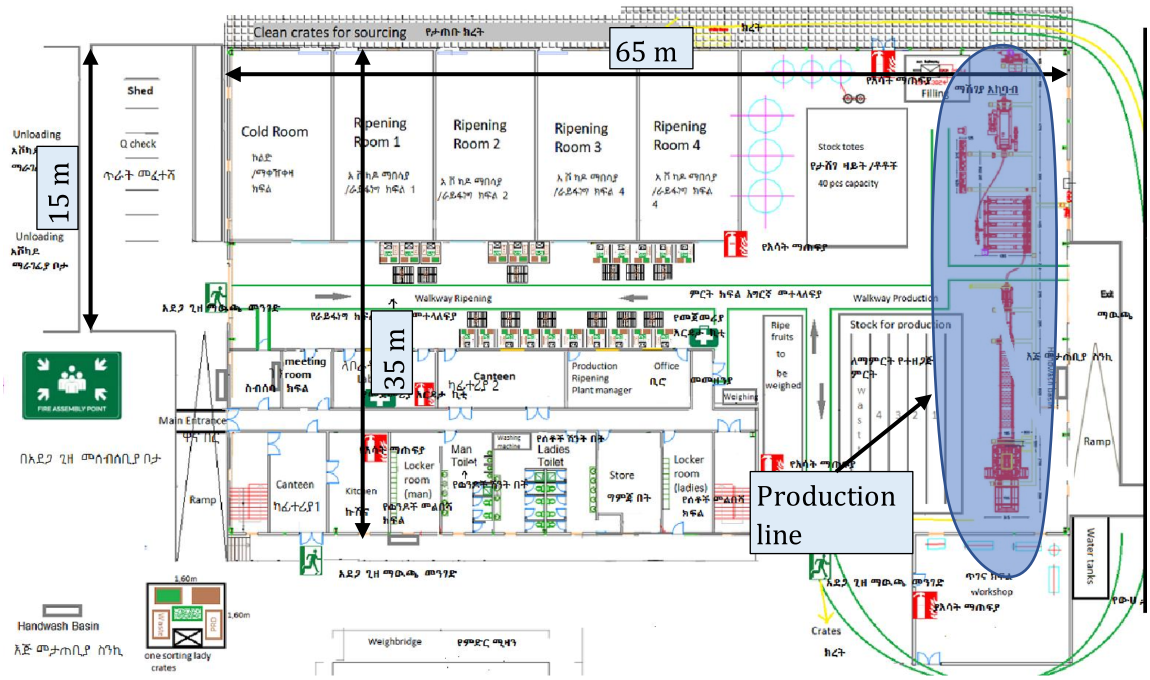
Figure 4-6 : Sunvado case study – Layout view of the factory and compound



Source: *©Google Earth, ©Maxar Technologies*

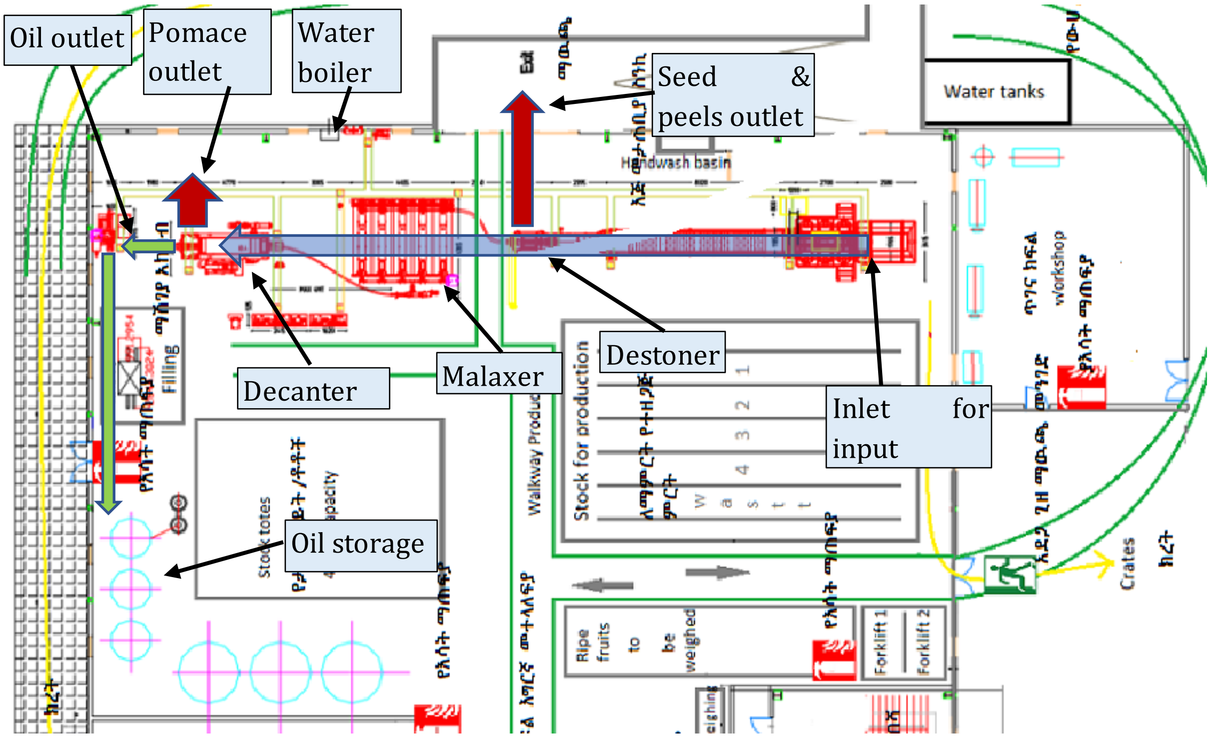
The compound is fenced with a wall. The space in the backyard (on the right of the above orthophoto) is not very occupied except a shed area and represent a free space of about 3,000 m². According to Sunvado, additional space can be provided by the IAIP on demand.

Figure 4-7 : Sunvado case study – Layout view of the factory building



Source: *Sunvado*

Figure 4-8 : Sunvado case study – Layout view of the production line



Source: *Sunvado*

4.1.3 Step 1.3 - Input(s) and Output(s) Streams

4.1.3.1 Quantities and their Temporal Variations

The waste production rates are proportional to the input processed. The rates are presented in the below table:

Table 4-1 : Sunvado case study – Waste production rates

Material	Share of the weight
Raw fruits	100%
Pomace	72%
Seeds and peels	23%
Oil	5%

Source: *Sunvado*

The production plan for 2022 and the related waste generation are presented below:

Table 4-2 : Sunvado case study – Monthly production plan in 2022

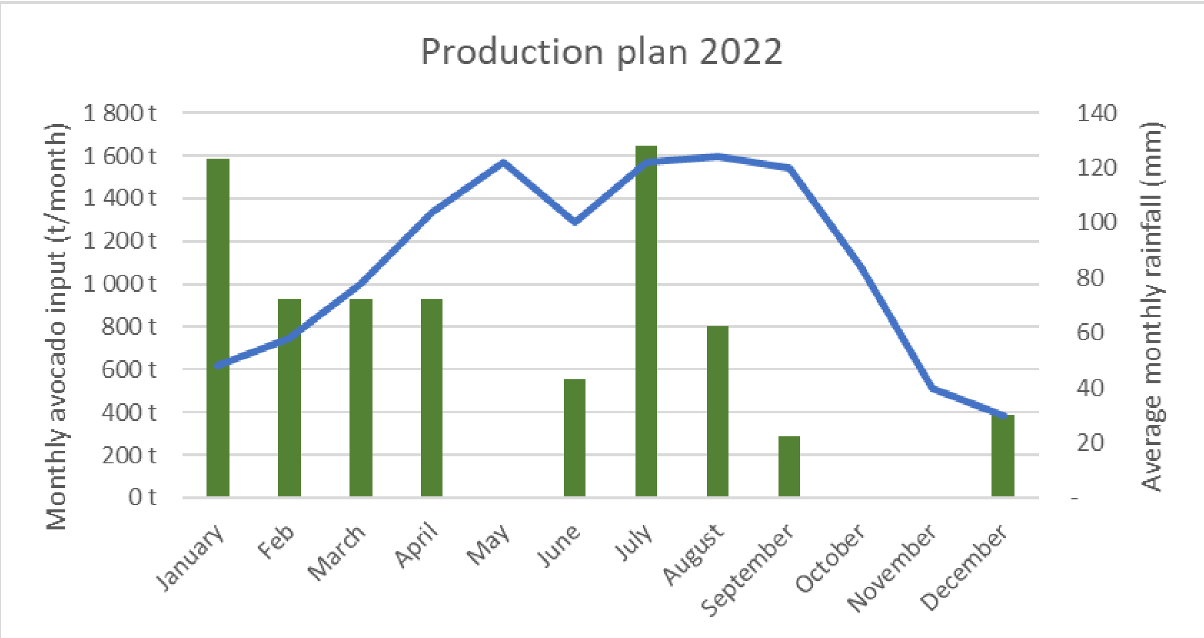
Month	Avocado input	Seed + skin output (average 23% of the input raw material)	Pomace output (Decanter waste) (average 72% of the input raw material)	Oil output (average 5% of the input raw material)
January	1 586 t	365 t	1 142 t	79 t

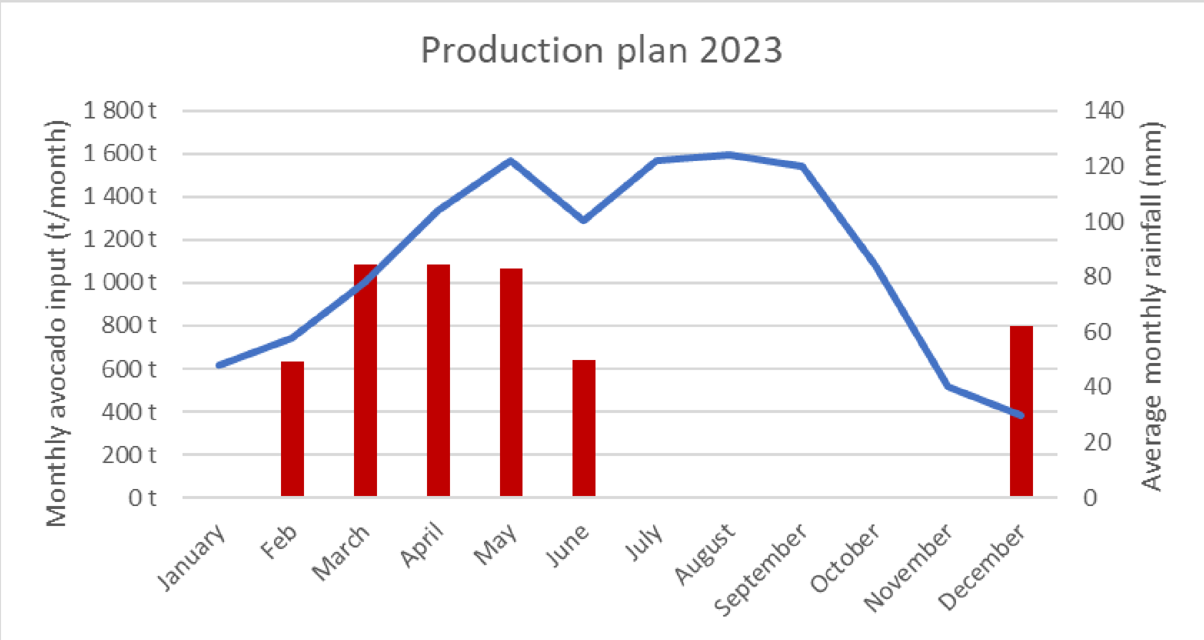
Month	Avocado input	Seed + skin output (average 23% of the input raw material)	Pomace output (Decanter waste) (average 72% of the input raw material)	Oil output (average 5% of the input raw material)
Feb	931 t	214 t	670 t	47 t
March	931 t	214 t	670 t	47 t
April	931 t	214 t	670 t	47 t
May	0 t	0 t	0 t	0 t
June	558 t	128 t	403 t	28 t
July	1 647 t	379 t	1 186 t	82 t
August	806 t	185 t	581 t	40 t
September	284 t	65 t	205 t	14 t
October	0 t	0 t	0 t	0 t
November	0 t	0 t	0 t	0 t
December	388 t	89 t	280 t	19 t
Total	**8 062 t**	**1 853 t**	**5 806 t**	**403 t**

Source: *Sunvado*

The monthly production plans for 2022 and 2023 are compared with the average monthly rainfall in Hawassa. The main rainy season is between May and September and can coincide with a period of avocado oil production and therefore waste, while the production that begins in December usually takes place during a few dry months.

Figure 4-9 : Sunvado case study – Production plan in 2022/2023 and rainfall in Hawassa





Sources: *Sunvado and http://ethiomet.gov.et/climates/climate_of_city/2466/Hawassa (rainfall)*

The current production capacity indicated by Sunvado is shown in the following table. As mentioned in section §4.1.1, the production plans of 2022 and 2023 are lower than the production capacity due to the avocado sourcing problems.

All peak capacities assume uninterrupted production. In reality, this cannot happen because the machines need to be overhauled periodically. This has been neglected for this case study.

Table 4-3 : Sunvado case study – Peak production capacity in 2022

Period	Avocado input	Pomace	Seeds and peels	Pomace, seeds and peels
Hourly peak	4 t/h	2.9 t/h	0.9 t/h	3.8 t/h
Daily peak	96 t/d	69 t/d	22 t/d	91 t/d
Weekly peak	672 t/week	485 t/week	155 t/week	640 t/week
Monthly peak	2 880 t/month	2 070 t/month	660 t/month	2 730 t/month
Annual peak	34 560 t/year	24 880 t/year	7 950 t/year	32 830 t/year

Sources: *Sunvado*

4.1.3.2 Quality and their Temporal Variations

It is assumed that there is no temporal variation of the waste quality. The information on the waste quality is presented below:

Table 4-4 : Sunvado case study – Production plan in 2022

Parameter	Pomace	Seeds and peels	Mix (pomace, seeds and peels)*
Dry solid content	17 to 22%	35 to 45%	20 to 23%

Parameter	Pomace	Seeds and peels	Mix (pomace, seeds and peels)*
Total volatile solids	77%	n.a.	n.a.
Fat content	0 to 5%	n.a.	n.a.

* as produced by the factory (as production rates of Table 4-1)

4.2 Step 2 – What possible products and demand?

4.2.1 Step 2.1 – Screening Potential Products

This review of possible products and the related waste processes is summarized in the following table. Product options were part of a research study conducted by the Addis Ababa Institute of Technology (AAIT).

The black soldier fly (BSF) option was not pursued within the AAIT research because another research program was planned to apply BSF to avocado waste from the Yirga Alem IAIP, but it ended up starting later than planned and not involving this waste.

Table 4-5 : Sunvado case study – Screening of potential products

Product type	Potential demand from	Products	Waste processing technologies	Comment
Energy	Sunvado (for own process, e.g. water boiler of 190 kW)	Heat	Pellets or briquettes used in a stove	The value for energy is currently low because of the current low electricity cost in Ethiopia (0,02 USD/kWh). But a 2014 World Bank study recommended a tariff increase of up to about USD 0.14/kWh to meet the future needs[1]. A full-scale biogas plant treating avocado pomace is in operation in Kenya since 2019. Another one was under construction in Mexico. This option was researched but only as potential long-term option.
		Biogas	Anaerobic digestion and direct use with gas stove	
		Heat / Cooling	Biogas via anaerobic digestion and conversion to heat via CHP unit	
	Sunvado (for own process) Public electricity operator (surplus power)	Electricity	Biogas via anaerobic digestion and conversion to electricity via CHP unit	
Soil amendment (nutrient)	Nurseries Famers	Dewatered waste	Dewater the waste (sand drying bed)	Probably a low value product, but easy to produce.
		Compost	Vermicompost or compost or co-compost	

1 https://addisfortune.net/articles/increase-in-electricity-tariffs-required-to-realise-power-generating-projects

Product type	Potential demand from	Products	Waste processing technologies	Comment
Animal feed (nutrient)	Animal feed producers, farmers	Animal feed	**Solar drying** to about 90% DSC	Quality compliance to be confirmed[2]
			Black soldier flies larvae production and waste residue management	Larvae = protein Waste residue management as for raw pomace or dewatered pomace. This option was not researched because research capacities were not yet ready in 2022.
Active component	Cosmetics and nutraceutics companies	Several (antioxidants, etc.)	Extractions with solvents; can be combined with complex drying technologies (vacuum drying, spray drying, freeze drying).	High added value needed to cover high extraction costs; <u>real</u> demand to be assessed. Several new technologies are continuously developed, but full-scale viability is usually not yet proven. This option was finally not followed.
Starch	Food thickener Pulp for paper Fabrics Disposable cutlery	Starch	Usually, wet extraction methods to extract the starch	Former agreement with an industrial partner was cancelled by this partner because starch of avocado seed is not white but brown. This option was finally not followed.

4.2.2 Step 2.2 – Estimate the Demand for the most Relevant Products

The estimated demand figures according to the available information is summarized in the below table. Information is limited and would need additional investigations. However, it can be implemented in a second step to refine the outcome of the waste management option selection.

Furthermore, it does not consider the impact of activities that could increase the demand for value (e.g., marketing actions to demonstrate the nutritional value and impact of soil amendment or animal feed from the avocado factory waste).

Table 4-6 : Sunvado case study – Demand for the most relevant Products (about 60 ETB per EUR)

Product type	Potential demand from	Products	Demand
Energy	Sunvado (for own process, e.g., water boiler of 190 kW)	Heat	190 kWh x 24h / efficiency pellet stove @maximum 0,03 EUR/kWh
		Biogas	190 kWh x 24h / efficiency gas stove @maximum 0,03 EUR/kWh
		Heat / Cooling	190 kWh x 24h / efficiency CHP @maximum 0,03 EUR/kWh
	Sunvado (for own process)	Electricity	190 kWh x 24h / efficiency CHP @maximum 0,03 EUR/kWh Surplus sale at 5 to 6 EUR cent per kWh

[2] At the time of writing, the quality of the waste is being verified by Sunvado's prospective buyer through extensive laboratory analysis in Europe. The results are not yet available.
In addition, a PhD research is to be completed by 2024 in the University of Hawassa regarding the toxicity of dried pomace waste for animals. Research papers will already be published in 2023. The initial results of the research are positive and give confidence in the feasibility of using dried pomace as ingredient for animal feed.

Product type	Potential demand from	Products	Demand
	Public electricity operator		
Soil amendment (nutrient)	Nurseries Famers	Dewatered waste	Value: - 2 EUR/ton (incl. transport cost) Quantities > need of avocado suppliers
		Compost	Value: 8 EUR/ton (incl. transport cost) higher values could be achieved but only with extensive and costly marketing measures. Quantities > need of avocado suppliers
Animal feed (nutrient)	Animal feed producers, farmers	Dried pomace	Value: 250 EUR/ton (incl. transport). Values up to 350 EUR/t are also mentioned but would first need to be confirmed. Quantities are not a limiting factor according to SUNVADO
		BSF larvae	Value: unknown in Ethiopia (market assessment is needed, in particular in case of export). At least as much same as for animal feed (≥ 250 EUR/t (incl. transport) Rwanda: one factory @ 650 EUR/t of dried larvae; Indonesia market assessment 300 to 600 EUR EUR/t of dried larvae. Both cases: for the domestic market. Quantities are not a limiting factor according to SUNVADO

4.3 Step 3 – What is the most adequate Waste Management Option?

4.3.1 Step 3.1 – Identify and describe the Waste Management Models

4.3.1.1 Option 1 – Dewatered Waste as Soil Amendment

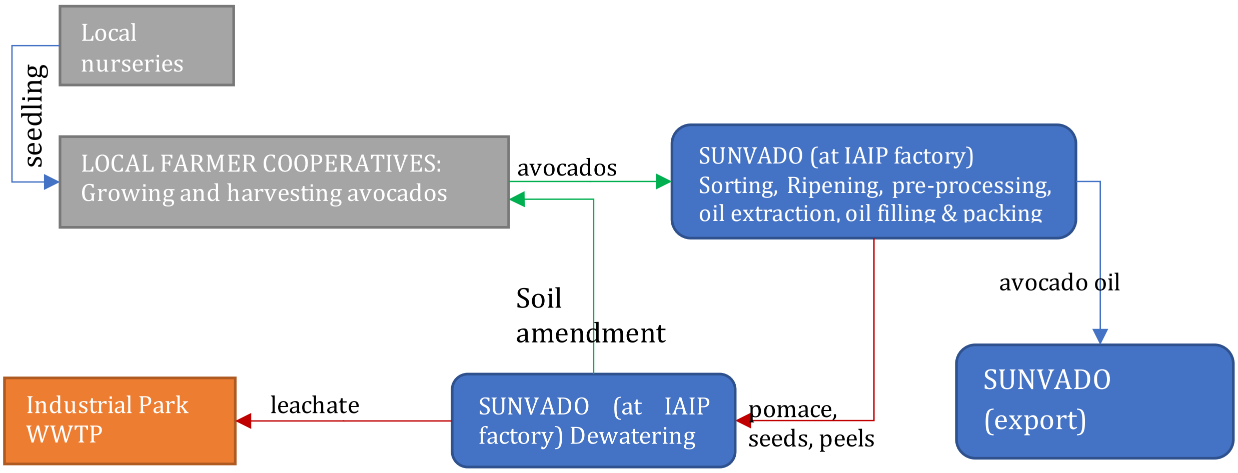
a) General Description

The first and easiest option is to produce a soil amendment via simple waste dewatering, which can be sold to the farmer or cooperatives of farmers supplying the avocados. These elements can be considered in negotiations on the purchase prices of avocado as part of a more comprehensive agreement.

Alternatively:

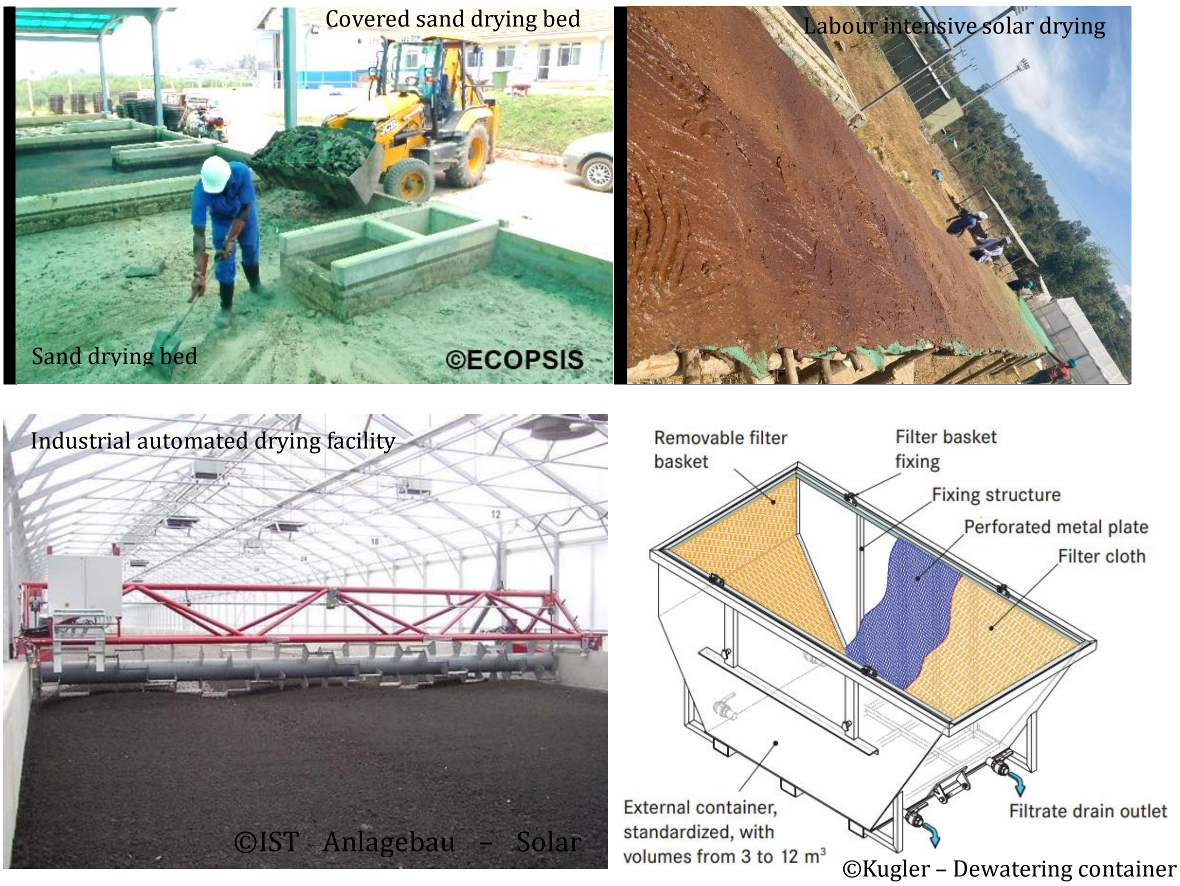
- If Sunvado were to produce avocados themselves, they could use this product to reduce their costs of purchasing soil amendment or fertiliser.
- The dewatered waste can be sold to other potential clients, which offer a better price, including transport, if they are for example close to the park.

Figure 4-10 : Sunvado case study – Option 1 – Soil amendment after waste dewatering



The basic dewatering options are either sand drying beds or solar drying as assessed during the research by AAIT. Alternatively, it would be possible to consider dewatering skip container equipped with an inner geotextile (e.g. [Roll-Off Dewatering Containers| KUGLER GmbH (kugler-gmbh.de)]) but this was not tested by AAIT and Sunvado. These three dewatering processes can be considered as technology variants of this Option 1.

Figure 4-11 : Sunvado case study – Option 1 – Dewatering processes



b) Sand Drying Beds

According to the research results of AAIT, the approximate dewatering time is about 10 days. This would mean that approximately 4,000 m^2 of sand drying bed is required, assuming that the 36 cycles per year do not result in slow clogging of the bed. These pilot test results are not yet available at the time of writing. Considering a more conservative approach, with a lower annual loading rate per bed area, the area needed could reach up to about 22,000 m^2. It must be mentioned that 4,000 m^2 would be almost sufficient for the production in 2022 or 2023.

As shown by the Figure 4-11, the sludge removal require labour. Machine should not be used to prevent compacting and damaging the drying beds and their underground drainage system.

c) Solar Drying

Solar drying is a priori used to dry waste, but it can also be used to dewater it. For this case study two types of solar drying facilities are considered (see Figure 4-11 for illustrations):

1. Industrial automated solar drying facility.
2. Labour intensive solar drying facility.

For the peak production of the factory, two industrial automated drying halls of each about 12m width and a length of about 100m would be needed. It should be noted that with a single drying hall, it would be possible to dewater more than double the production of 2022 or 2023, or to dewater these production amounts but over 30% DSC.

Following the positive results of the solar drying research, SUNVADO took the initiative to test a solar drying facility on a slightly larger scale, also based on the dewatering container principle. The facility is intended to be low-cost and labour intensive: spreading. The labour must spread, turn, and remove the waste from the nets which are about 1m above the ground. According to SUNVADO, it needs about 1 week to dewater (up to 30% DSC), and the surface area needed for dewatering the peak production capacity (about 90 $t_{raw\ waste}$/d) is about 400 m^2. It is a hybrid combining the principle of solar drying with the principle of a dewatering container.

d) Dewatering Container

Assuming this process would be suitable for the avocado waste and the dewatering would occur within 1 to 5 days, this could be a compact process, with for the peak production capacity a surface area of about 400 m^2/d of dewatering duration. E.g., should the dewatering from 20% to 30%:

- need only 1 day, then the surface area needed would be 400 m^2
- need 2 days, then the surface area needed would be 800 m^2
- need 5 days, then the surface area needed would be 2,000 m^2

The longer it takes to dewater, the more containers will be needed, and the higher will be the investment costs. The stickiness observed during the AAIT research on the avocado waste during dewatering, which is probably due to the remaining fat content, may constrain the dewatering, unlike a solar drying system, where the sludge is regularly turned by a machine.

Dewatering containers, like sand drying beds, can be combined with a solar drying facility to enhance the drying performance (Option 2).

e) Dewatering under a covered Area

A roof can protect the dewatering system from the rain and the “re-watering” of the waste, thus slowing down the process and reducing the dewatering capacity.

Nevertheless, considering the related investment needs, it is not recommended to invest in a roof immediately, especially as production in 2022 and 2023 was still limited due to sourcing problems. This should be seen as an optimisation potential to be implemented only if necessary.

f) Dewatering under a Greenhouse

The AAIT research tested the situation of a dewatering within a greenhouse, but the results available are limited. However, it shows a slight acceleration of the dewatering the first 2 or 3 days compared to the same sample that was outside. The test should be replicated to confirm and refine the results. The investment would probably only be worth if the surface area need for the dewatering remains low and if it can be built with low-cost local construction methods.

Regarding the solar drying system, as with the installation of a roof, it may be possible to install the solar drying system without a greenhouse in the first instance.

g) Leachate Management

Except for the solar drying, where the liquid part is evaporating, leachate is generated and must be treated. The leachate can be discharge into the sewer network of the industrial park to undergo the needed treatment. The data on characteristics and quantities were not yet available at the time of writing this Guideline. However, considering the reduction in water content, in 2022 and 2023 it was a maximum of 12 m^3 per day (a part of this volume is also evaporating and not only draining by gravity through the filter) at the day peak, which is low on the scale of the IAIP.

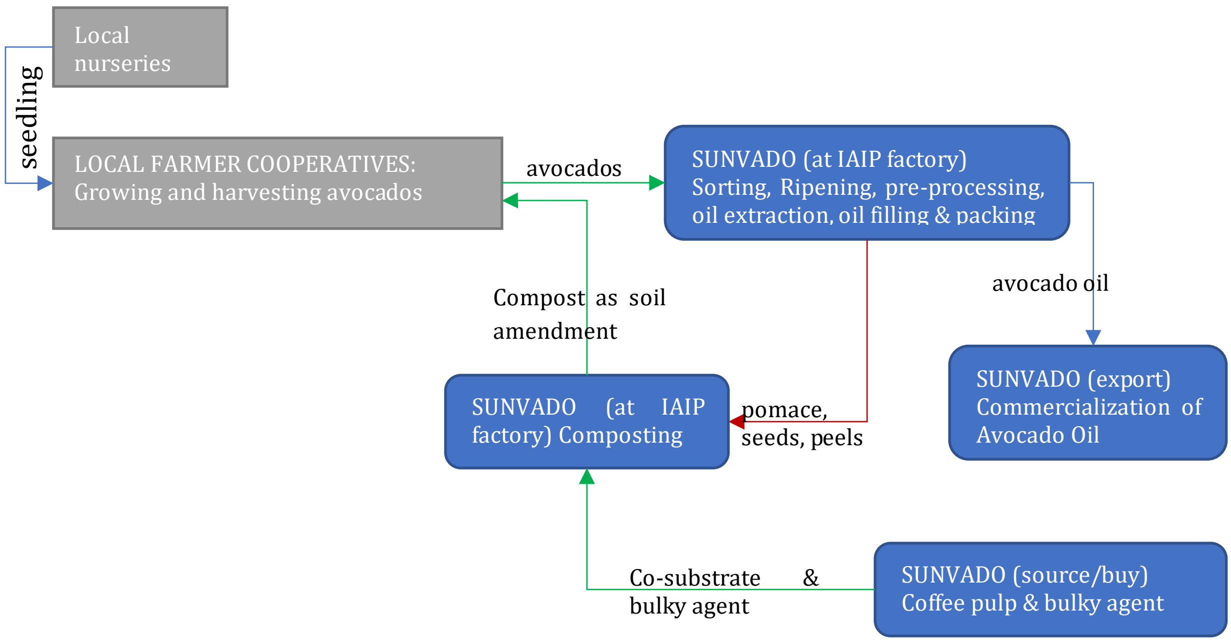
The planned WWTP of the IAIP is mentioned with a capacity of 200 m^3/d (figures on the maximum pollution load allowed are not available). Alternatively, an onsite biodigestion treatment facility could have been built in the Sunvado compound to treat the leachate and to produce biogas, but the production cost would be higher (> 14 USD cent per kWheq) than the electricity cost via the electricity grid (in 2022, 3 EUR cent per kWh).

4.3.1.2 Option 2 – Compost as Soil Amendment

a) General Description

An alternative waste process to produce soil amendment could be to co-compost or vermicompost the waste of the avocado oil factory. It can either be a composting or a vermicomposting.

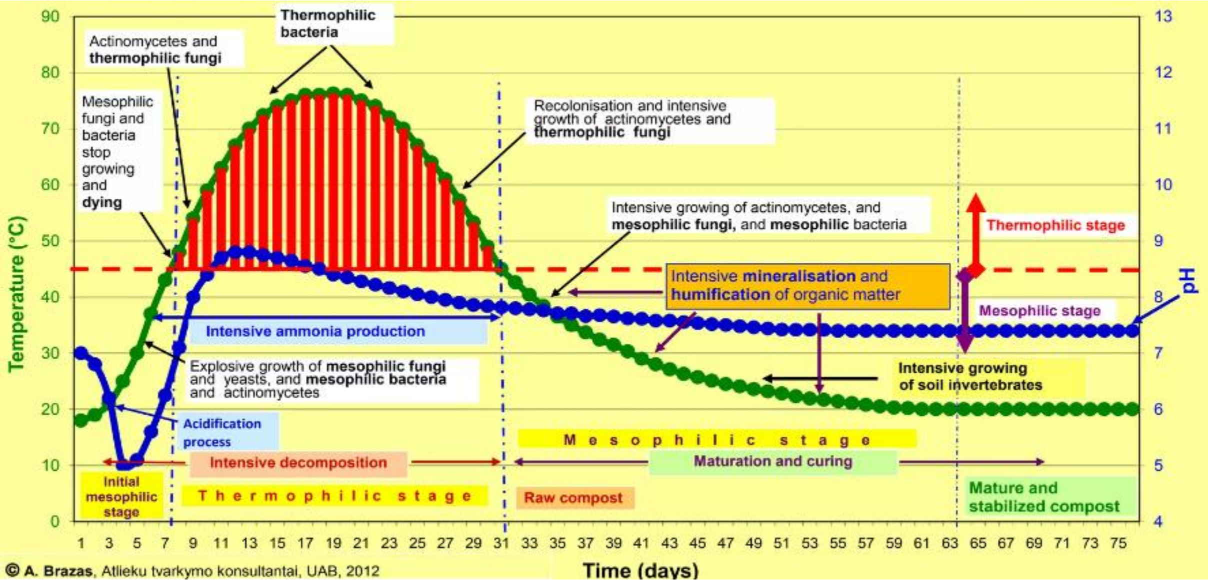
Figure 4-12 : Sunvado case study – Option 2 – Soil amendment from composting



b) Composting Variant

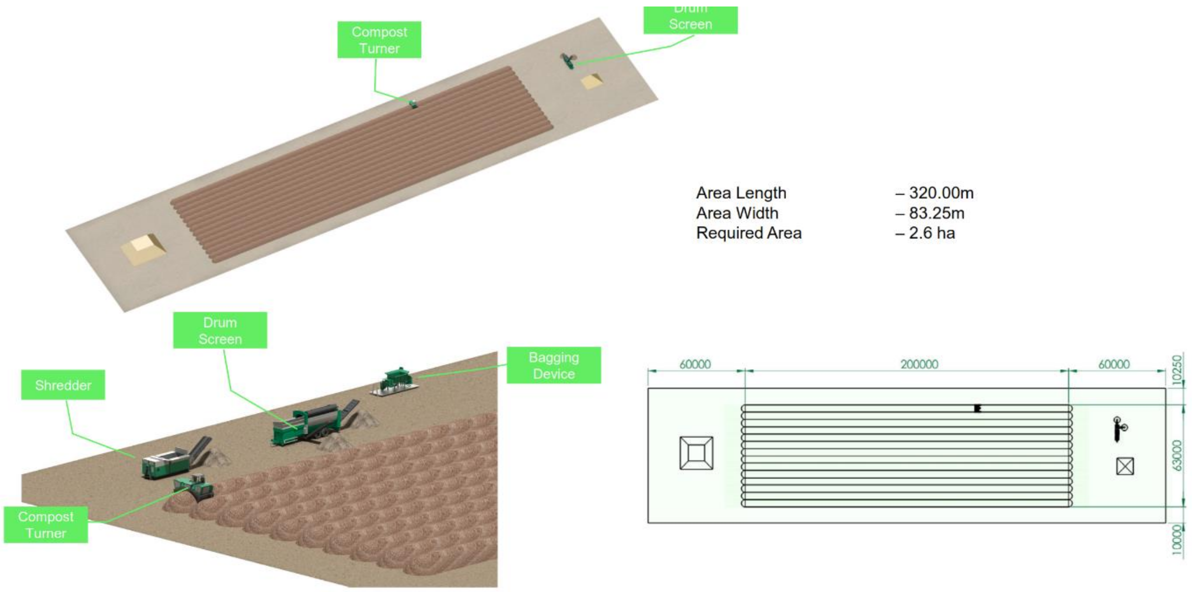
The composting process presented by the Figure 4-13 involves a sequence of composting process stages (1-mesophilic, 2-thermophilic, 3-maturation), with a temperature increase above 45°C (up to 70-80°C) for 2 to 3 weeks. It is usually a process that does not last longer than 1.5 to 2 months.

Figure 4-13 : Sunvado case study – Option 2 – Targeted stages of composting process of composting



For the peak production capacity of the Sunvado factory, the space required would be about 2.6 hectares. It consists mainly of the compost windrows which need to be regularly turned by a turning machine.

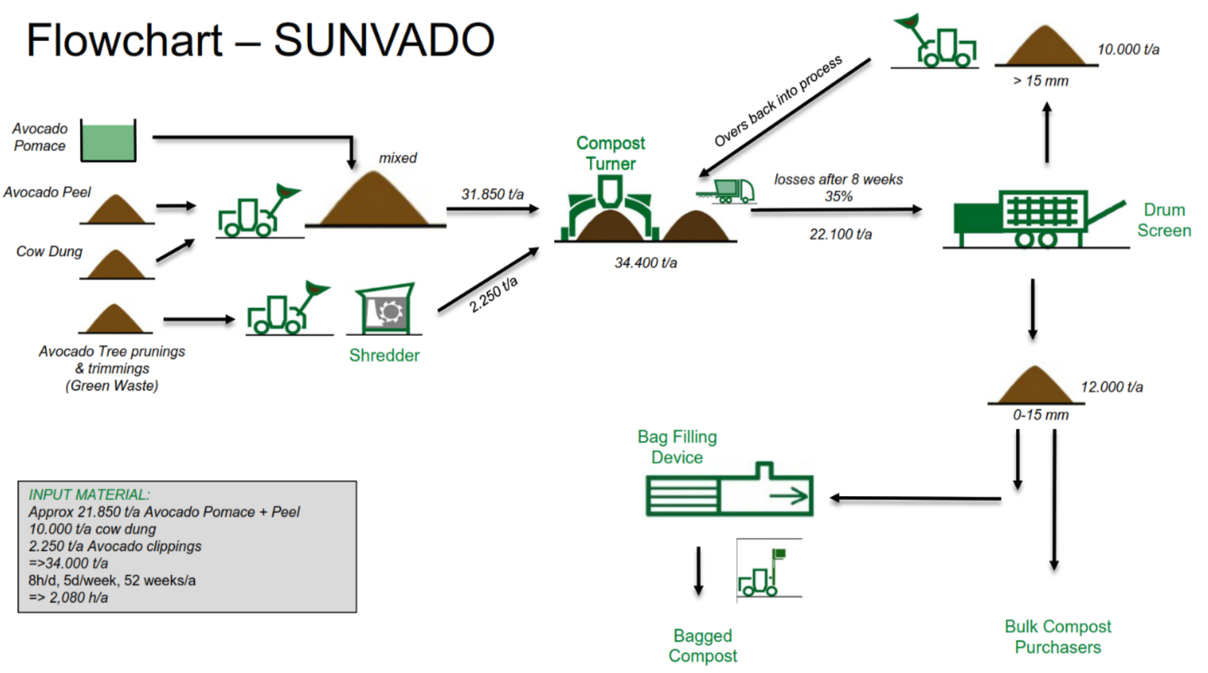
Figure 4-14 : Sunvado case study – Option 2 – Layout view of a composting site



Source: *KOMPTECH*

The following chart is a tentative process flow chart submitted by a composting equipment supplier. It illustrates the main processing steps.

Figure 4-15 : Sunvado case study – Option 2 – Composting process flow chart

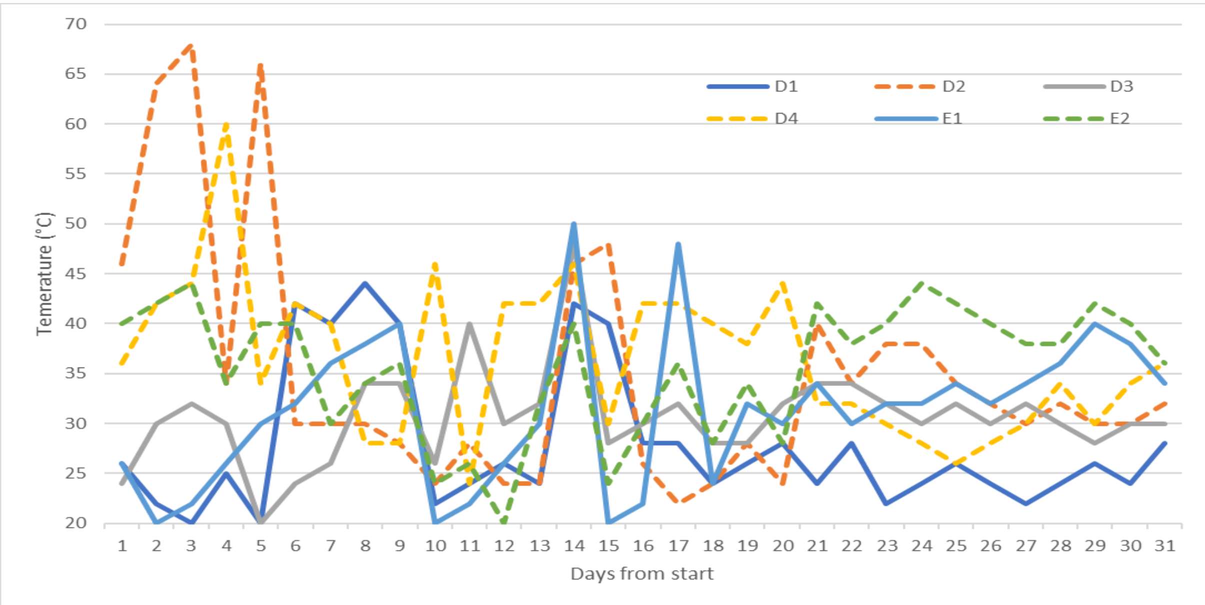


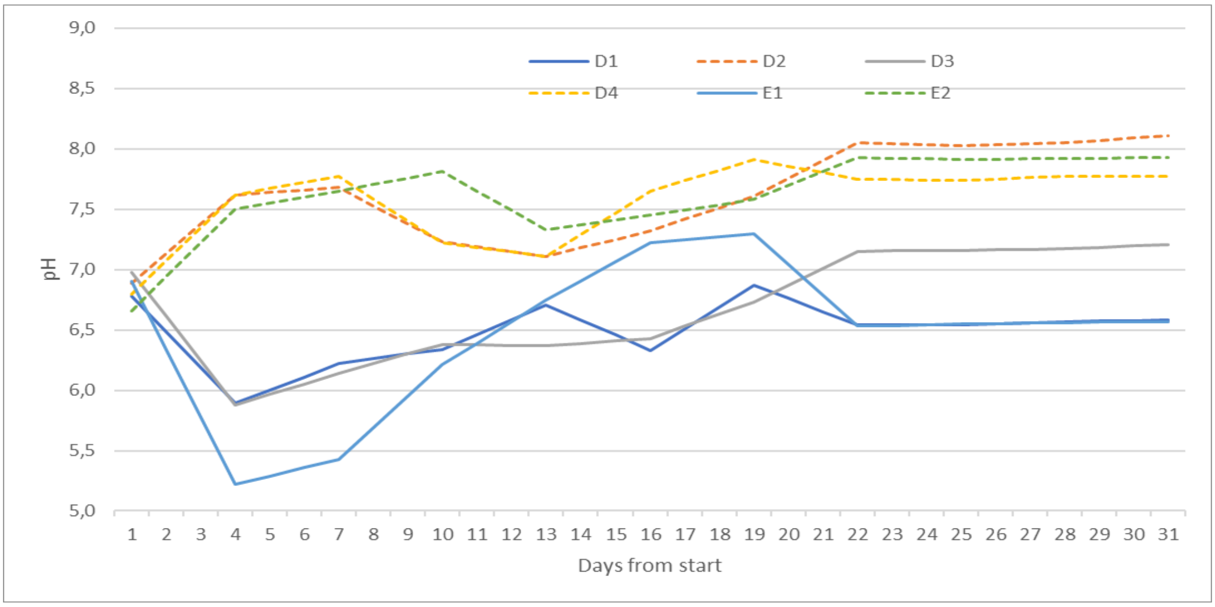
Source: *KOMPTECH*

c) <u>Preliminary composting research result</u>

The AAIT research on co-composting and vermicomposting were only partly available at the time of writing this Guideline. However, the available results already show that composting did not undergo the targeted thermophilic composting step, as shown in the graphs below. Thermophilic temperatures are hardly reached for a brief period and only for a couple of trials (D2, D4, E2).

Figure 4-16 : Sunvado case study Option 2 – Composting – Temperatures and pH from AAIT research





Source: AAIT's raw data

The best visual impression after 1 month was for the trials, with **co-substrates** (coffee pulp) in addition to the Sunvado waste and with **bulky agents** (reeds). Neither is available for free to Sunvado. Their purchase would probably be too costly for farmers/cooperatives to be willing to finance through the sale price of this co-compost.

d) <u>Vermicomposting Variant</u>

The composting process presented by the Figure 4-13 involves a sequence of composting process stages (1-mesophilic, 2-thermophilic, 3-maturation), with a temperature increase above 45°C (up to 70-80°C) for 2 to 3 weeks. It is usually a process that does not last longer 1.5 to 2 months.

Vermicomposting (trials E1 and E2) takes normally longer than composting (trials (D1 to D4), with between 2.5 to 3.5 months. The longer composting time means that even more space is needed than for composting: about 50% more space, thus about 4.0 hectares would be needed for vermicomposting.

4.3.1.3 Option 3 – Animal Feed after Waste Drying

a) <u>General Description</u>

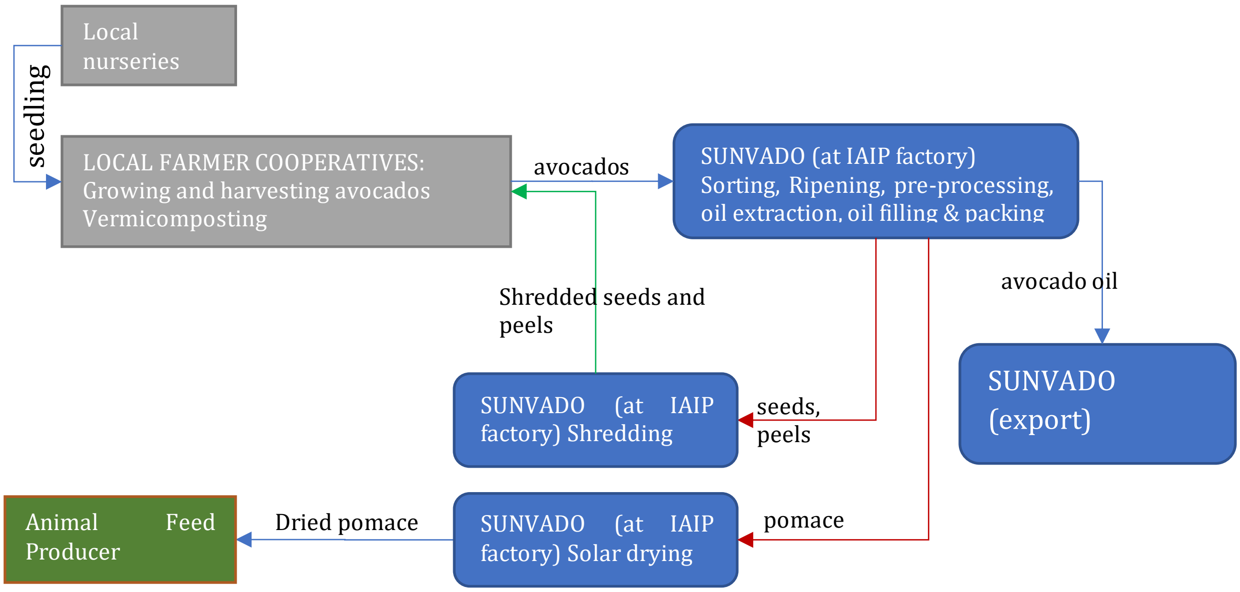
The demand for substrate to produce animal feed is important in Ethiopia because of the large livestock in Ethiopia and the constraints on sourcing substrate for animal feed and animal feed import. The main requirement for animal feed is for the dry solid content, which much reach above about 90% to prevent the development of fungi and pathogens.

According to negotiations between Sunvado and an animal feed producer, the latter will not accept the dried seeds and peels because of the toxins they contain. If ingested in large doses by certain animals, they might be harmful. Therefore, that options foresee only the **solar drying** of the pomace.

Furthermore, the same potential buyer (animal feed producer) of Sunvado's converted pomace waste requires additional analysis to measure the *persin* content to make sure the content is not too high, and the dried pomace is an adequate ingredient to prepare animal. At the time of the writing of this Guideline, the results were not yet available. Negotiations and the supporting laboratory analysis were still ongoing (contents of ash, proteins, carbohydrates, fibres, etc.) and their results will define the price agreed between Sunvado and its potential buyer.

If the input into the solar drying is too liquid, it may be needed to recirculate the dried output and mix it with the liquid input to reach 30% DSC at the entrance of the solar drying facility. It is rather recommended to dewater the waste input into the solar drying up to 30% with a preliminary dewatering system.

Figure 4-17 : Sunvado case study – Option 3 – Animal feed after waste drying



a) Management of Seeds and Peels

The basic solution is to return the shredded seeds and peels to farmers/cooperatives, which can vermicompost them (vermicomposting was introduced with the support of GiZ at farmer scale).

A potential alternative for the processing of the seeds and peels is to pyrolyze them to produce a biochar, which can be sold as soil amendment. Pyrolysis at large industrial is a complex and expensive technology, which is not suitable in this context. The German biomass research institute DBFZ intends to start in 2023 a research programme targeting the development of small scale low-cost and low-tech pyrolizer for farmers. This could be an opportunity for the DBFZ to test larger pyrolizer, which would be located and operated by Sunvado, or to test small scale pyrolizers for the famers, which would buy the shredded seeds and peels. This commercialization of the Biochar to farmers can be part of a broader commercial deal with farmers supplying avocado fruits to Sunvado for the oil production.

4.3.1.4 Option 4 – Animal Feed from BSF

This option considers the black soldier flies (BSF) larvae as another protein product, which can be sold to animal feed producers or even directly to farmers.

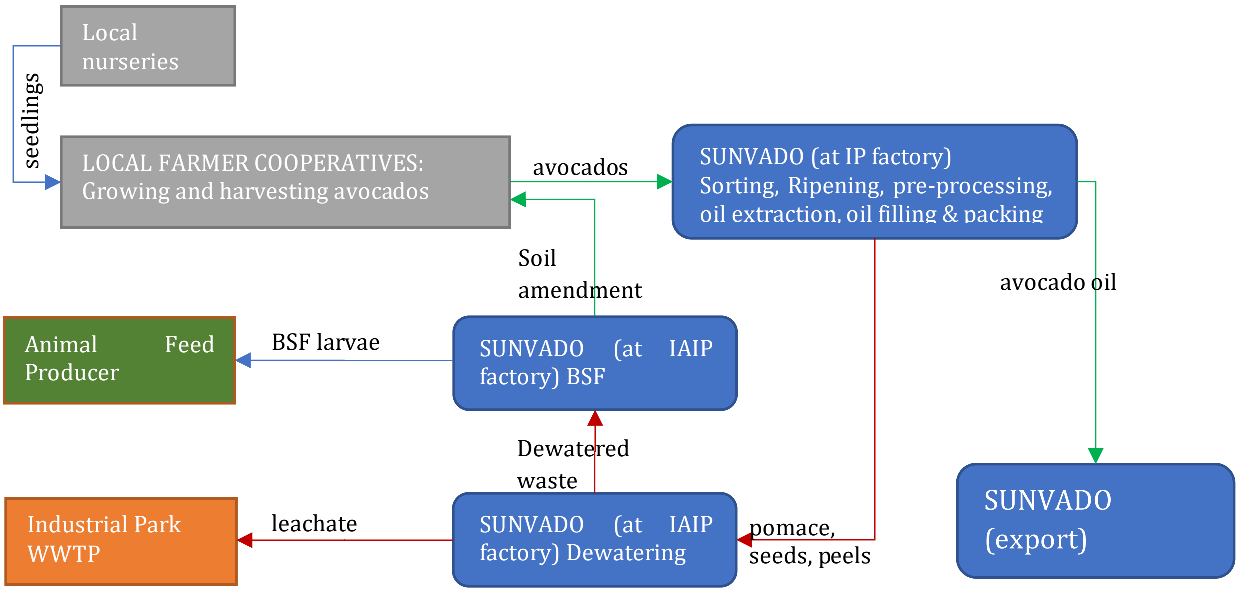
It requires prior dehydration, which makes this Option 4 look like an extension of Option 1 by allowing a new product to be generated. It requires a preliminary dewatering since waste with higher water content like the pomace, cannot be efficiently converted by BSF. The DSC should rather be like a humus or compost (between 30 and 50% DSC).

It is a waste conversion process carried out by insects. The converted product is the larvae, which has high protein content and is usually dried to ease its commercialization. However, the BSF waste process generates residual waste (say about 40% of the input waste), which can be valued as soil amendment like the dewatered factory waste.

The number of BSF waste processing plants is growing, in particular small-scale plants, but there is no experience for the conversion from avocado waste. This would require research, which could not be conducted in parallel of the preparation of this Guideline. Therefore, the analysis of this option is based on several assumptions.

For example, considering the usual space requirement for small scales plants, the space need for the Sunvado peak production capacity is estimated between 1.5 and 2.0 hectares of covered and protected area. This is usually within a building, which can involve large capital expenditures.

Figure 4-18 : Sunvado case study – Option 4 – Animal feed from BSF



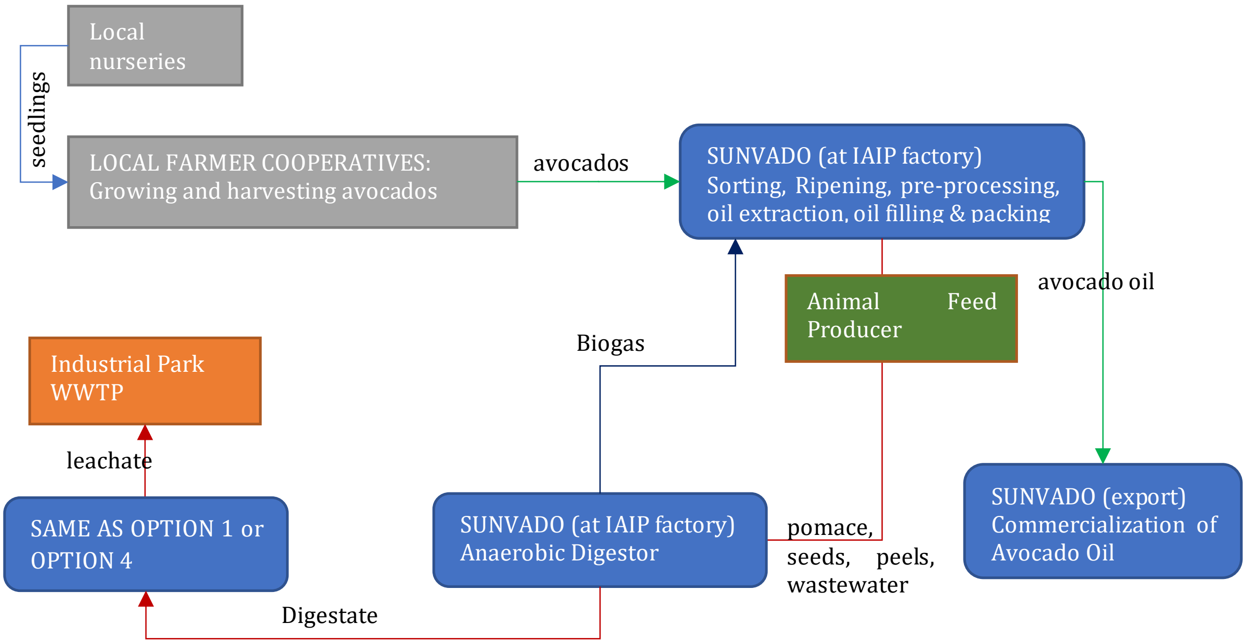
4.3.1.5 Option 5 – Biogas Energy from Anaerobic Digestion

As mentioned in section §4.2.2, this option would have been attractive if the price of electricity in Ethiopia had been higher. Biogas energy is too expensive compared to the cost of electricity from the grid, to be profitable with the current electricity tariff grid. Electricity production costs from biogas facilities for agro-industries typically range between about EUR 100 and 200 / MWh. The feed-in tariff, which is currently about EUR 50 to 60 / MWh in Ethiopia should be at least as high as the production cost to provide the enabling financing environment for the construction of such biogas facilities. The biogas solution would need significant subsidies to make it economically sustainable, with for example an adequate subsidised feed-in tariff for electricity generated from biogas.

The digestate is the residual waste form the anaerobic digestion. It needs to undergo further treatment and cannot be discharge into the sewer network.

This Option 5 is actually an extension of Option 1 or Option 4, because it follows the same value chain and process, but with an additional digestor before the dewatering step. They would allow to generate soil amendment or animal feed (via BSF).

Figure 4-19 : Sunvado case study – Option 5 – Biogas Energy from Anaerobic Digestion



4.3.2 Step 3.2 – Estimate and compare the Costs and Revenues

Only cost of the relevant waste management options and for which enough information is available are presented hereafter.

The cost estimate does not include costs that are repeated for each option (for example a bagging system or basic labour).

4.3.2.1 Option 1 - Cost and Revenues of Dewatering Processes

The table below presents the approximate cost and features of dewatering systems for an increase from 20% to 30% DSC.

Table 4-7 : Sunvado case study – Option 1 – Dewatered Sludge as Soil Amendment

Item	Solar drying facility - Automated	Solar drying facility – Labour intensive	Sand drying bed	Dewatering container
Investment cost	240 000 €	60 000 €	220 000 €	210 000 €
Investment cost with Greenhouse or roof	250 000 €	80 000 €	260 000 €	218 000 €
Number of halls	1	1	n.a.	n.a.
Surface area (m^2)	1 130	2 100	4 000	800
Capacity (t_{waste}/year)	17 900		5 460	32 800
Capacity to be confirmed (t_{waste}/year)	31 000	32 800	32 800	n.a.
Comment	Enough capacity for the existing production 2022, 2023	Specific capacity to be confirmed (for all seasons of a year)	Enough capacity for the existing production 2022, 2023	Enough capacity for the existing peak production capacity

Item	Solar drying facility - Automated	Solar drying facility – Labour intensive	Sand drying bed	Dewatering container
	Capacity for peak production to be confirmed (research results to be confirmed). If not confirmed, the facility size and cost will almost double.	Dewatering cycle is 1 week. Labour costs represent about 31 000 EUR per year. The net present value is about 380 000 EUR.	Capacity for peak production to be confirmed because of clogging risk.	But cost proportional to cycle duration that is still to be defined (here 2 d; between 1 to 5 d?)

* The assumptions made for the calculations of the net present values were: 20 years lifetime, 3% discount rate and 0% price increase. However, salary increase will most probably occur.

The "labour intensive solar drying" has a low capital investment, but high labour cost. The dewatering containers can provide a simple and low-cost alternative if the testing shows short dewatering cycles.

The sale of dewatered waste to farmers as organic fertilizer or co-product to their composting / vermicomposting does not generate revenues but is rather estimated to be approximately null, because the revenues only cover the transportation costs to the farmers (see Table 4-6). No revenue from the valorisation can co-finance the waste management costs.

4.3.2.2 Option 2 - Cost and Revenues of Composting

The table below presents the approximate cost and features of a composting facility.

Table 4-8 : Sunvado case study – Option 2 – Soil Amendment from composting

Item	Composting – Low end equipment	Composting – High end equipment
Investment cost	150 000 €	900 000 €
Surface area (m²) for composting	26 000	26 000
Surface area (m²) for vermicomposting	40 000	40 000
Capacity (t_{waste}/year)	32 800	32 800
Capacity (t_{waste}/year)	32 800	32 800
Comment	Enough capacity for the peak capacity production. Performance, lifetime, and maintenance cost are worse than for high end equipment.	Enough capacity for the peak capacity production.

The cost is the same for the production of 2022-2023 (up to 7 700 t per year) or for the peak capacity of the factory, because they consist of machines that are the same. The cost comprises a compost turner, a drum screen, a tractor + water spreader, spare parts, transport, and import.

The low-end compost equipment is of worse quality and durability than the equipment costed for dewatering and solar drying, and cannot be compared, but it is presented here for information. As this is a highly mechanized equipment, on which the capacity to process waste depends (if it breaks down, there is no treatment capacity left), it is not recommended to opt for low-end equipment.

The cost of sourcing co-substrate could not be precisely estimated, but the transport cost alone would cost between 5 and 10 EUR per ton. By realizing that co-substrates are used for recovery, it is likely that producers of these wastes will end up selling them to Sunvado at a rate close to, for example, a poor-quality organic fertiliser (EUR 5 to EUR 10 per ton). This would be a cost of about 10 to 20 EUR per ton, thus an average of EUR 15 per ton of co-substrate. Assuming the co-substrate share of 1/3 in the compost mix and a mass reduction of 50%, the cost of co-substrate sourcing is estimated at EUR 10 per ton of compost.

The sale of compost to farmers as organic fertilizer or co-product to their composting / vermicomposting generate a revenue of about EUR 5 to 10 per ton, which hardly even cover the cost of co-substrate sourcing. No revenue from the valorisation can co-finance the important waste composting equipment and costs.

4.3.2.3 Option 3 - Cost and Revenues of Drying Processes

The table below presents the approximate cost and features of solar drying systems for an increase from 30% to 90% DSC. The efforts and costs needed to dry the waste up to 90% are much higher than those need to dewater it up to 30% DSC.

Table 4-9 : Sunvado case study – Option 3 – Animal Feed after Waste Drying

Item	Solar drying facility - Automated #1	Solar drying facility - Automated #2	Solar drying facility – Labour intensive #1	Solar drying facility - Labour intensive #2
Investment cost	710 000 €	1 190 000 €	55 000 €	90 000 €
Investment cost with Greenhouse or roof	750 000 €	1 250 000 €	75 000 €	125 000 €
Number of halls	3	5	n.a.	n.a.
Surface area (m^2)	3 250	5 700	1 900	3 200
Capacity (t_{waste}/year)	8 100	14 300		
Capacity to be confirmed (t_{waste}/year)	14 000	25 000	14 000	25 000
Comment	Enough capacity for the existing production 2022, 2023 IF research is confirmed	Enough capacity for the peak capacity production IF research is confirmed	Enough capacity for the existing production 2022, 2023 IF research is confirmed. Additional labour costs of 28 000 EUR/year (about 50 workers). The net present value* represents 430 000 EUR.	Enough capacity for the peak capacity production IF research is confirmed. Additional labour costs of 48 000 EUR/year (about 100 workers). The net present value* represents 720 000 EUR.

* The assumptions made for the calculations of the net present value of the labour costs of the were: 20 years lifetime, 3% discount rate and 0% price increase. However, salary increase will most probably occur.

As for the dewatering, using labour intensive solar drying needs a low initial investment but it requires high annual labour cost. Given the uncertainties on the lifetime of the initial investment, the cost difference between the labour intensive solar drying facility and the automated solar drying facility is not necessarily important. More accurate data would be needed to make an NPV calculation to compare both solutions. However, based on preliminary assumptions, the NPV of the labour intensive solar drying facility remains lower except if the lifecycle and the salary increase area important.

The sale of dried waste to animal feed producers can generate potential revenues of about 1 380 000 EUR per year if the plant runs at peak capacity the entire year. This potential revenue can finance the investments in the needed waste management infrastructures.

The potential revenues for different production scenarios are presented below:

Table 4-10 : Sunvado case study – Option 3 – Animal Feed after Waste Drying - Potential revenues

Item	Peak production capacity	Production in 2022	Production in 2023
Raw waste quantity (t/year), pomace only	24 900	5 805	3 826
Raw waste DSC	20%	20%	20%
Raw waste DS quantity (t_{DS}/year)	4 980	1 161	765
Dried waste DSC	90%	90%	90%
Dried waste quantity, rounded (t/year)	5 530	1 290	850
Potential revenue (rounded)	1 380 000 EUR	320 000 EUR	210 000 EUR

4.3.2.4 *Option 4 - Cost and Revenues of a BSF Plant*

As research could not be conducted for the BSF in parallel with the establishment of this Guideline, and experiences in Ethiopia are still scarce, the available data does not reflect the situation in Ethiopia for this market.

The conversion rates to BSF larvae (the protein to be sold) depends very much on the characteristics of the inputs, and it may be needed to source co-substrates to improve the conversion rate. Literature gives sometimes a value of 45 kg of dry larvae produced from a dewater waste at say 30% DSC.

In the case of Sunvado, assuming peak production capacity is used, the annual production would be about 22 000 t waste with 30% DSC. Without taking into account the co-substrate, this would represent a potential quantity of almost 1 000 tons of dry larvae per year, thus a potential revenue between EUR 300 000 and EUR 600 000 per year.

The potential revenues for different production scenarios are presented below:

Table 4-11 : Sunvado case study – Option 4 – Animal Feed from BSF

Item	Peak production capacity	Peak production capacity	Production in 2022	Production in 2022
Raw waste quantity (t/year)	32 800	32 800	7 659	7 659
Raw waste DSC	20%	20%	20%	20%

Item	Peak production capacity	Peak production capacity	Production in 2022	Production in 2022
Raw waste DS quantity (tDS/year)	6 560	6 560	1 532	1 532
Dewatered waste DSC	30%	30%	30%	30%
Dried waste quantity, rounded (t/year)	21 870	21 870	5 110	5 110
Assumed dry larvae output	984	984	230	230
Assumed dry larvae price	300 EUR/t	650 EUR/t	300 EUR/t	650 EUR/t
Potential revenue (rounded)	300 000 EUR	640 000 EUR	70 000 EUR	150 000 EUR

Operation and maintenance depend on the scale of the factory and the mechanization of the process. It can be at least EUR 200 000 per year at full scale capacity. In addition, there are the costs associated with the construction or renting of the BSF plant.

A more precise market assessment and research tests would be needed to refine the cost and the revenues, and thus the feasibility of the business model.

4.3.2.5 Option 5 - Cost and Revenues of a Biogas Plant

As the results of the research could not be made available early enough, quotations and proposals for biogas installations were not available at the time of writing this Guideline.

Biogas production capacity is often related to the quantities of TS or TVS. For agricultural waste, the values are between 200 and 400 Nm^3_{CH4}/t_{TVS}. To be on the safe side a value of 200 Nm^3_{CH4}/t_{TVS} is considered.

The following table summarizes the potential revenues and cost. The revenues assume a feed-in tariff of 60 EUR per MWh. However, the production cost will be at least around 100 EUR per MWh, in particular if Sunvado starts with a smaller facility before extending it, to limit the investment risks. This means that this option cannot be financed.

Table 4-12 : Sunvado case study – Option 5 – Biogas Energy from Anaerobic Digestion

Item	Peak production capacity	Production in 2022
Raw waste quantity (t/year)	32 800	7 659
Raw waste DSC	20%	20%
TVS rate	75%	75%
Raw waste TVS quantity (t_{TVS}/year)	4 920	1 149
CH4 production rate (Nm^3/t_{TVS})	200	200
CH4 production (Nm^3/year)	984 000	229 767
Equivalent energy kWheq/CH_4	11	11
Equivalent energy (MWheq/year)	10 824	2 527
Equivalent energy (kWheq/d)	29 655	6 924

Item	Peak production capacity	Production in 2022
Equivalent energy (kWheq/h)	1 236	289
CHP efficiency	65%	65%
Electricity produced (MWh/year)	7 000	1 600
CHP efficiency	65%	65%
Electricity produced (MWh/year)	7 000	1 600
Electricity sale tariff (EUR/MWh)	60 €	60 €
Electricity revenue per year	420 000 €	96 000 €

4.3.3 Step 3.3 – Compare the Options and select the most appropriate One

4.3.3.1 Excluded Options

As mentioned earlier, the economic sustainability of **Option 5 – Biogas Energy from Anaerobic Digestion** is not yet given because it is not competitive with the electricity form the grid.

In the case of **Option 2 – Compost as Soil Amendment**, the research results for composting showed the need to source and buy a co-substrate and a bulky agent. The market research did not show that this additional cost can be covered by additional revenues. The market prices are already given by existing compost products, whose prices are low.

Given the uncertainty on the sustainability of the permeability of the sand drying beds as well as their higher operation constraints, this does not seem to be the most appropriate option for dewatering.

4.3.3.2 Recommended Waste Management Option

Given the available information, assuming that the quality of the dry pomace allows to agree on a selling price of at least 250 EUR/t, as co-substrate for animal feed production, the **Option 4 (Animal feed from dried waste) is recommended**. It requires to dry the pomace via a solar drying facility.

It could be challenged by **the Option 5 (Animal feed from BSF)**, but this option requires research on the best waste to optimize the protein conversion rate and a market assessment (domestic and export markets), even though current available figures give an advantage to Option 4. **Starting with option 4 does not necessarily preclude moving on to option 5 or implementing both options in parallel.**

Thus, also considering the production plan and its timing, it is recommended to **gradually increase the drying capacity** and start with the implementation of a first solar drying capacity stage.

It is recommended to invest in a labour-intensive solar installation, as initiated by SUNVADO, because:

- it allows for a lower initial investment than with an automatic solar dying facility, and therefore limits the investment risks.

- allows for a more flexible increase in capacity as the need for increased drying capacity arises.
- allows for greater flexibility if solar drying is to be combined with a preliminary container dewatering.

However, it is recommended to **invest in upgrading the existing solar drying facility** to improve its operation and reduce costs:

- The receiving nets/sieves could be built into plates with edges to collect the liquid part cleanly.
- The plates can be mobile and used to tip the dried products into a bin outside the greenhouse and clean it before re-use.
- The plates could be stacked in solid racks.

Should the solar drying facility be upscaled, such upgrades and operation improvement are mandatory.

Dewatering containers should be tested as they offer the possibility of improving solar drying through preliminary dewatering. This could reduce the issue and need to collect the liquid part of the pomace in the solar drying facility. The duration of a dewatering cycle will inform about the number of skip container needed and the related investment costs. If well designed, the skip containers can be operated with a forklift (already available at the factory).

To increase the revenue from valorisation as animal feed, Sunvado may eventually consider producing the animal feed itself. However, information on the potential added value, and the regulatory constraints of such an expansion of Sunvado's activities, would be needed for Sunvado to take such a decision.

As mentioned in section §4.3.1.3, if animal feed is to be produced, the **seeds and peels must be managed separately**. It is recommended to explore the research opportunity suggested by the German biomass research institute DBFZ to produce biochar. The basic solution would be to return the shredded seeds and peels to farmers/cooperatives, which can vermicompost them or pyrolyze them. Like for Option 1 (Soil amendment from dewatered waste), Sunvado cannot expect revenues but rather to get rid of waste at low (or no) cost, while giving the farmers the opportunity to valorise it in a decentralised way.

Annex 1

Bibliography

No.	Year	Author	Title	Category	Type
[01]	2022	Sunvado	Factory layout arrangement	Sunvado case	Drawing
[02]	2022	Sunvado	Process diagram	Sunvado case	Figure
[03]	NA	GiZ Consultant	Activities and ideas on avocado waste management	Sunvado case	Note
[04]	2019	Sante Consulting Group	Global Avocado Oil Industry Report	Sunvado case	Note
[05]	NA	GiZ	Overview of Yirga Alem Industrial Park	Sunvado case	Note
[06]	NA	Sunvado	Pomace lab test results	Sunvado case	Note
[07]	2022	Sunvado	Several information replying to ECOPSIS' requests	Sunvado case	Note
[08]	2020	SNNP	ESIA for the proposed Yirgi Alem and Dilla Staple Crops Processing Zone (SCPZ)	Sunvado case	Report
[09]	2018	Kahsay Gebretensae	Biodiversity Impact Assessment Report for the proposed Yirga-Alem integrated Agro-Industrial Park (IAIP) and Dilla Rural Transformation Centre (RTC)	Sunvado case	Report
[10]	2010	Rosenblat et al	Polyhydroxylated fatty alcohols derived from avocado suppress inflammatory response and provide non-sunscreen protection against UV-induced damage in skin cells	Active components	Research publication
[11]	2019	Bhuyan et al	The Odyssey of BioActive components in Avocado (Persea americana) and their Health Benefits	Active components	Research publication
[12]	2019	Avramescu et al	Recovery of Natural Antioxidants from Agro-Industrial Side Streams through Advanced Extraction Techniques	Active components	Research publication
[13]	2019	Trujillo-Mayol et al	Improvement of the polyphenol extraction from avocado peel by assisted ultrasound and microwaves	Active components	Research publication
[14]	2019	Shiferaw	Extraction of Oil and Phenolic Retanning Agent from Avocado Seed	Active components	Research publication
[15]	2019	Tan Vo et al	Process Optimization for Extraction of Polyphenols from Avocado Seeds (Persea americana Mill.) Using Response Surface Methodology	Active components	Research publication
[16]	2020	Permal et al	Optimising the Spray Drying of Avocado Wastewater and Use of the Powder as a Food Preservative for Preventing Lipid Peroxidation	Active components	Research publication
[17]	2020	Alissa et al	Developing New Health Material: The Utilization of Spray Drying Technology on Avocado (Persea Americana Mill.) Seed Powder	Active components	Research publication
[18]	2019	Olivado	Olivado launches massive sustainability project in Africa	Anaerobic digestion	Blog

No.	Year	Author	Title	Category	Type
[19]	2014	SANDEC	Anaerobic Digestion of Biowaste in Developing Countries - Practical Information and Case Studies	Anaerobic digestion	Book
[20]	2015	CDM Smith	Anaerobic Digestion & Biogas	Anaerobic digestion	Book
[21]	2013	Katharina Panse	Feasibility and Profitability Analysis of the IGNIS Anaerobic Digestion Plant in Addis Ababa	Anaerobic digestion	Master thesis
[22]	2015	Jolly	Comparison of Biogas Usage Options - CHP, Turbines or Gas	Anaerobic digestion	Report
[23]	2019	Kenasa et al	Optimization of Biogas Production from Avocado Fruit Peel Wastes Codigestion with Animal Manure Collected from Juice Vending House in Gimbi Town, Ethiopia	Anaerobic digestion	Research publication
[24]	2018	Poirier et al	Inhibition of anaerobic digestion by phenol and ammonia: Effect on degradation performances and microbial dynamics	Anaerobic digestion	Research publication
[25]	2015	Deressa et al	Production of Biogas from Fruit and Vegetable Wastes Mixed with Different Wastes	Anaerobic digestion	Research publication
[26]	2008	SANDEC	Marketing Compost - A Guide for Compost Producers in Low and Middle-Income Countries	Composting	Book
[27]	2012	Azeb Legesse	Urban Agricultural Households' Willingness to Pay for Compost: The Case of Addis Ababa	Composting	Master thesis
[28]	2011	Lena Mecklenburg	General Assessment of a Small-Scale Composting Pilot Project in Addis Ababa, Ethiopia	Composting	Research publication
[29]	2019	SANDEC	Pyrolisis of Biowaste in Low- and Middle-Income Settings - A Step-by-Step Manual	Pyrolisis	Book
[30]	2012	Matthias Gersdorf	Drum - pyrolysation of rose waste (biomass) on a flower farm in Debre Zeyit	Pyrolisis	Master thesis
[31]	2022	Cheikhyoussef	Avocado (Persea Americana) Wastes: Chemical Composition, Biological Activities and Industrial Applications	Recycling and upcycling options	Research publication
[32]	2021	Mora-Sandí et al	Agro-Industrial Avocado (Persea americana) Waste Biorefinery	Recycling and upcycling options	Research publication
[33]	2020	García-Vargas et al	Avocado-Derived Biomass as a Source of Bioenergy and Bioproducts	Recycling and upcycling options	Research publication
[34]	2020	Jimenez et al	Pulp, Leaf, Peel and Seed of Avocado Fruit: A Review of BioActive components and Healthy Benefits	Recycling and upcycling options	Research publication
[35]	2021	Del Castillo-Llamosas et al	Hydrothermal treatment of avocado peel waste for the simultaneous recovery of oligosaccharides and antioxidant phenolics	Recycling and upcycling options	Research publication

No.	Year	Author	Title	Category	Type
[36]	2019	Woolf et al	Avocado oil	Recycling and upcycling options	Research publication
[37]	2019	Vintial et al	Residueal Biomass from Food Processing Industry in Camerron as Feedstock for 2nd Generation Biofuels	Recycling and upcycling options	Research publication
[38]	2020	SANDEC	Selecting Organic Waste Treatment Technologies (SOWATT)	Recycling and upcycling options	Book
[39]	2007	SANDEC	Manual of On-Farm Vermicomposting and Vermiculture	Vermicomposting	Book
[40]	2020	Maurya et al	Agro-waste for vermicomposting	Vermicomposting	Research publication
[41]	2009	Garg et al	Vermicomposting of Agro-Industrial Processing Waste	Vermicomposting	Research publication

Annex 2

Stakeholder Mapping and Analysis

Stakeholder Mapping and Analysis

Stakeholder	Potential role with respect to the *Guideline*?	Influence towards *Guideline*?	Attitude towards *Guideline*?	Analysis
Ethiopian Investment Commission (EIC)	• Will/can facilitate Waste Management compliance uptake by the investors. • Creating enabling environment for investment as well as implementation of the Waste Management Guideline • Sensitize investors on the sustainable production requirements & usefulness of the Guideline. • Promotion of the Guideline	High	Positive	Can contribute to the dissemination of the guidelines in the form of policies and promotion including its implementation.
Ministry of Industry (MoI)	• Facilitating conducive policy and regulatory environment for the implementation of the Waste Management guideline • Serve as the gateway to provide different training or capacity development to implement the Guideline. • Create awareness among processing industries about the Waste Management Guideline • Could serve as regulatory body to enforce the use of the guideline amongst processing industries. • Improve relationship with other stakeholders	High	Positive	Can contribute to the dissemination of the guidelines in the form of policies and promotion including its implementation.
Sidama Industrial Parks Development Corporation	• Pilot/suitable IAIP to contextualize the guideline with agro-industrial parks and best suited to show case its importance for future national regulatory frameworks. • Design internal systems and guidelines to regulate tenants. • Build internal capacity to implement the Guideline. • Resource (technical and financial) mobilization to the implementation of the guideline	High	Positive	Can contribute to the dissemination of the guidelines in the form of policies and promotion including its implementation.
Sidama Regional Investment Commission	• Will/can facilitate Waste Management compliance uptake by the investors. • Creating enabling environment for investment as well as implementation of the Waste Management Guideline • Sensitize investors on the sustainable production requirements & usefulness of the Guideline	Medium	Positive	Same as for EIC but at regional level.

Stakeholder	Potential role with respect to the *Guideline*?	Influence towards *Guideline*?	Attitude towards *Guideline*?	Analysis
Sidama Regional Administration	• Facilitates and influences for the maximum production in the value chain, provision of land, infrastructures and utilities. • Awareness creation on by products	Low	Neutral	May need to keep being informed
Yirgalem town Municipality administration and nearby woredas	• Provides land and utility. • Responsible for the cleanliness of the town • Controlling and monitoring the environmental impact of projects to avoid negative impacts. • Handle grievances on environmental pollution	Low	Neutral	May need to keep being informed
Yirgalem town EPA	• Monitoring safety and environmental audit • Training to the community and the tenants on environmental protection • Undertakes EIA	High	Positive	Can contribute to the dissemination of the guidelines in a constraining manner: regulation enforcement for environmental aspects.
Ministry of Agriculture (Regional)	• Enhance the value chain. • Increasing productivity • Capacity to farmers and processors • Balancing input and output	High	Positive	Can contribute to the guidelines in a constraining manner: regulation enforcement for environmental aspects.
Agricultural Transformation Agency (ATA)	• Enhancing the value chain • Commodity study /assessment for improvement • Research and development • Capacity building to farmers and processors • Creates market linkages	High	Positive	Can contribute to support industries with research activities
Sidama Regional Trade and Industry Bureau	• Providing aftercare service to the companies, checking if they are complying with the environmental standard coordinating with EPA. • Provide technical support	High	Positive	Can contribute to the dissemination of the guidelines by accompanying the industrial companies.
Hawassa University	• Support on research and development throughout the value chain • Capacity building	High	Positive	Can contribute to support industries with research activities

Stakeholder	Potential role with respect to the *Guideline*?	Influence towards *Guideline*?	Attitude towards *Guideline*?	Analysis
Technical and Vocational Education and Training (TVET)	• Improved seed • Supply chain	Medium	Positive	Can contribute to support industries with research activities and the later scaling up (capacity building)
Hawassa Industrial Park	• Sharing learning experience • Coordinates stakeholders • Resources mobilization	Medium	Neutral	Learnings from waste management setup at the scale of an IAIP may be relevant
Cooperative Unions and Farmers	• They coordinate and organize farmers. • Legalize unions. • Capacity building • Market linkages • Provide improved input to processors	Low	Neutral	Avocado value chain actors
Development Partners	• Capacity building of the government agency tasked for the development and management of the park. • Provide technical and financial support	Medium	Neutral	May provide support for scaling-up
Food and Drugs Authority	• Ensure the safety and quality of food production. • Issuing certificate of competency (COC) • Auditing safety, inspection and laboratory testing • Issuance Certificate of disposal, to protect relabelling disposed food to the market again, and facilitate tax exemptions by the customs Commission. • Food safety team, Yirgalem together- they recommend the development of new standards based on the type of the products.	Low	Neutral	May only become relevant if Active components extracted from waste will be upcycled in the food industry in Ethiopia
Conformity Assessment Agency	• Issues standard conformity certificate (inspecting ingredients compliance and allow companies to use labels to their products	Low	Neutral	May only become relevant if Active components extracted from waste will be upcycled in the food industry in Ethiopia