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TECHNICAL REPORT

Livestock Waste Management and Biodigester-Based Resource Recovery in the Akaki Sub-Basin, Ethiopia

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Front cover photo: Cattle grazing (*photo:* Eryxson Fonseca/Unsplash)
Back cover photo: Heaps of livestock dung stored in nearby houses in peri-urban areas (*photo:* Zeleke Agide Dejen)

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Summary

Livestock waste management is an increasing concern in the Akaki sub-basin, which drains Addis Ababa, the capital of Ethiopia, and its surrounding areas. This study assessed livestock waste management practices and related challenges in the sub-basin and developed a business plan for a cooperative-based biodigester as a circular economy solution. A combination of quantitative and qualitative approaches was used. A representative household survey was conducted in Addis Ababa and Sheger City, both of which are drained by the Akaki sub-basin, and six focus group discussions were conducted to complement the household survey findings.

The results indicate that livestock waste management in the sub-basin remains largely unregulated and is generally characterized by limited adoption of improved waste management practices. This contributes to environmental pollution while also resulting in the loss of opportunities to recover valuable resources from livestock waste. The three most common livestock waste management practices are dumping, discharge into rivers, and traditional composting, with composting occurring mainly during the dry season. These practices are generally unsustainable and contribute to the inefficient management of livestock waste. Households in the sub-basin own approximately 12 dairy livestock per household on average, while farmers can broadly be categorizedas small-scale farmers, keeping 5–10 adult livestock, and large-scale farmers, keeping 10–20 adult livestock.

Biodigesters were identified as a feasible resource recovery option for the Akaki sub-basin, with the potential to convert livestock waste into biogas and organic fertiliser. Based on the assessment, three small- to medium-scale biodigester models were identified as potentially suitable under different conditions: private individual-farmer, cooperative-based, and independent youth-led models. Large-scale centralised biodigesters were also identified as a potential option for supporting integrated and sustainable livestock waste management in Addis Ababa and the surrounding areas.

Among the models assessed, farmers showed a strong preference for the cooperative-based approach. Accordingly, a detailed business plan was developed covering the proposed cooperative structure, feedstock and other resource requirements, expected outputs, and financial viability. The analysis resulted in a benefit-cost ratio (BCR) of 1.3 based on the direct financial benefits of the cooperative biodigester, indicating financial viability under the assumptions used. Beyond these direct financial returns, cooperative biodigesters also have the potential to generate wider environmental and socioeconomic benefits, including reduced pollution from livestock waste, improved public health, resource recovery, and employment opportunities. However, these additional benefits were not quantified in the present analysis. Overall, cooperative-based biodigesters offer a promising pathway for improving livestock waste management while advancing resource recovery and circular economy development in the Akaki sub-basin.

1 Background and Objectives

Livestock waste management is one of the fastest-growing challenges today, and a paradigm shift is needed from mere waste disposal to integrated resource recovery. Poor waste management can result in serious environmental risks, including pollution, nutrient leaching into watercourses and subsequent eutrophication, and the release of potent greenhouse gases. By contrast, livestock waste constitutes a substantial, underutilized reservoir of energy and nutrients (Jurgilevich et al. 2016). The development of modern waste management strategies increasingly focuses on technologies and practices capable of simultaneously mitigating these environmental hazards while recovering and valuing associated resources. The aim is to transform livestock waste into valuable products, including renewable energy and organic, nutrient-rich fertilizers, thereby closing agricultural nutrient loops, reducing reliance on synthetic inputs, and moving toward a more circular economy (Hussain et al. 2020). The benefits of resource recovery from livestock waste are multiple, encompassing direct and indirect economic, environmental, and health benefits (Laramee and Davis, 2013; Lima Silva et al. 2021).

The critical challenge of unmanaged livestock waste in the Akaki Sub-Basin, Ethiopia, driven by rising livestock numbers, represents a missed opportunity for a circular bioeconomy. Currently, this waste poses severe environmental and health risks, largely because waste management practices are unregulated (Abosse et al. 2025). However, this waste stream holds immense potential to be converted into valuable resources, such as clean energy and organic fertilizers, which could simultaneously mitigate pollution, reduce energy costs, and enhance agricultural productivity. The release of livestock waste into nearby rivers and water bodies contributes to serious environmental pollution (Ndambi et al. 2019). To realize this potential, the few existing resource recovery initiatives in the sub-basin must be scaled up through a coordinated and sustainable strategy involving affordable technology dissemination, financial incentives for farmers, capacity building, and supportive policies that create viable markets for recovered products. Although there are a number of resource recovery initiatives in the Akaki Sub-Basin, they have largely been based on donor-supported projects and face serious sustainability challenges. Most of the previously developed biodigesters have failed, mainly due to a lack of technical capacity and support following the completion of the projects that supported them (Surendra et al. 2014).

This study focuses on livestock waste management in the Akaki Sub-Basin within the context of a circular bioeconomy and resource recovery. The work builds upon a previous study that compiled global and Ethiopian case studies on resource recovery from livestock waste, including cases from the Akaki Sub-Basin. A review of the global cases identified three different business models based on resource recovery: (i) biogas and biofertilizers, (ii) soil nutrients, and (iii) feed for aquaculture. A workshop was organized in Addis Ababa based on the findings of the previous case study review, bringing together various stakeholders and livestock farmers. The business models identified from the global cases were discussed during the workshop, with the aim of developing an implementation pathway for resource recovery from livestock waste in the Akaki catchment. The main takeaway from the national workshop in Ethiopia was a preference for a biodigester-based model focused on energy and biofertilizer production. A cooperative-based model was preferred for implementation. Therefore, the current study builds on the previous study and consultation results to further assess and validate these findings. In addition, the study assesses existing livestock production and livestock waste management practices in the basin and provides an overview of a business plan for a cooperative-based biodigester model.

The objectives of the study are the following.

1. Characterize livestock and livestock waste management practices and related aspects in the Akaki Sub-Basin, Ethiopia
2. Analyze technical, socio-economic, and institutional factors affecting the adoption and success of biodigesters in the Akaki River Basin.
3. Assess the viability and scalability of biodigester-based business models through the development of a comprehensive business plan, including financing, market analysis, and risk evaluation.
4. Identify enabling conditions and investment interventions to promote sustainable, inclusive livestock waste management through community cooperatives.

2 Methodological Approaches

2.1 Description of the Study Area

The Akaki River, a tributary of the larger Awash River Basin, is the primary natural drainage system for the Ethiopian capital Addis Ababa and its surrounding areas. Its sub-basin encompasses the entire urban expanse of Addis Ababa and includes parts of the expanding new Sheger City, channeling stormwater from this rapidly growing metropolitan area. With a catchment area of approximately 1,300 km², the river ultimately flows into Lake Aba Samuel. This high degree of urbanization has fundamentally altered the sub-basin's natural hydrology and ecology. It is now a profoundly modified system, heavily impacted by human activity. These interventions include the proliferation of impervious surfaces such as roads and buildings, which increase surface runoff and reduce groundwater recharge. Furthermore, the river conveys a complex mixture of pollutants, receiving largely untreated waste from households, numerous livestock operations, and a concentration of light and heavy industries. This confluence of factors makes the Akaki sub-basin a typical example of an urban river ecosystem under environmental stress.

The Akaki River water is consequently highly polluted by multiple contaminants originating from various sources. The polluted river water is extensively used downstream by farmers in the outskirts of the city to grow vegetables, mainly for markets in Addis Ababa and its surrounding areas. This practice poses various health risks to local residents, with related cases reportedly increasing. Pollution from livestock waste represents a significant component of this pollution burden, given the increasing concentration of livestock in the sub-basin. The location map of the sub-basin is shown in Figure 1.

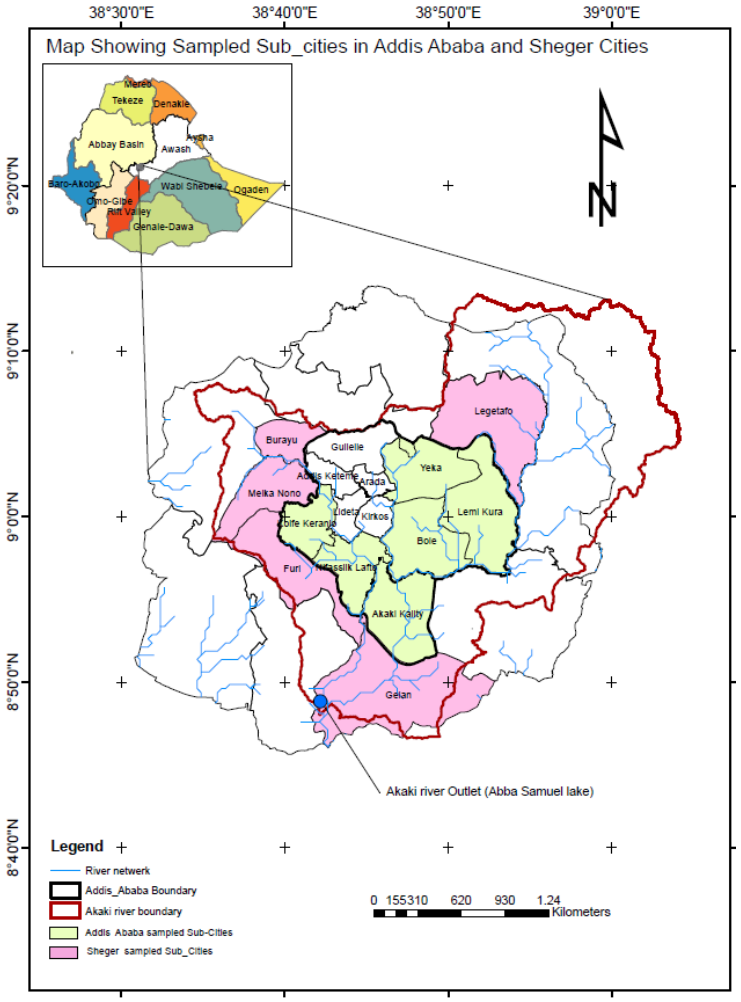


Figure 1. Location of Akkai sub-basin and sampling sub-cities.
Source: Author's creation.

2.2 Livestock and Related Data Collection Methods

Data for this study were collected using three complementary methods: site visits (reconnaissance), a household survey, and focus group discussions (FGDs) (Figure 3). The study team convened the reconnaissance visits during June 2025, which were followed by quantitative and qualitative data collections during July and August 2025. Prior to the initiation of the data collection, ethical approval from IWMI-IRB Committee was secured. To ensure ethical compliance and safeguard participants' rights, privacy, and confidentiality, the study team obtained informed consent during the primary data collection process. The following sub-sections elaborate on the details of the primary data collection process.

2.2.1. Site visits (reconnaissance)

Prior to the household survey and FGDs, field visits were conducted to selected livestock-owning households in collaboration with local livestock experts and the recruited enumerators. The site visits had four main objectives:

1. To identify the geographic locations of the target woredas[1] and the sampled households within them.
2. To obtain a general first-hand understanding of livestock waste disposal and management practices at the household level (Figure 2).
3. To engage with local livestock experts and incorporate their knowledge and insights on livestock waste management during the field visits.
4. To pilot-test the household survey questionnaire and identify any issues requiring clarification or modification before the main survey.



(a) Dumping



(b) Waste storage pit (Composting)



(c) Cow dung cake



(d) Pit with significant release to a nearby river



(e) Composting



(f) Direct application to crops

Figure 2. Pictures during site visit showing some of the current livestock waste management situations in the Akaki catchment

Source: Authors' photographs, taken during the site visit.

[1] **Woreda** is an administrative subdivision in Ethiopia, generally comparable to a district. The plural form is woredas. Woredas are further divided into smaller administrative units known as kebeles.

2.2.2. Household survey

The household survey collected quantitative information on household demographics, livestock ownership and numbers, livestock waste management practices, household energy needs and expenditures, household income and expenditure, and preferences for different waste management models, among other topics. The sampling approach described in Section 2.4 was used to obtain a representative sample of households across Addis Ababa and Sheger City.

2.2.3. Focus Group Discussion

FGDs were conducted to triangulate findings from the household survey, with particular emphasis on the challenges associated with poor livestock waste management and preferences for resource recovery models. Discussions also explored household perceptions of cooperative-based biodigester models, including their expected benefits, potential challenges, and the support services required for successful implementation. In total, six FGDs were conducted, three in Addis Ababa and three in Sheger City (see Section 2.4 for details).

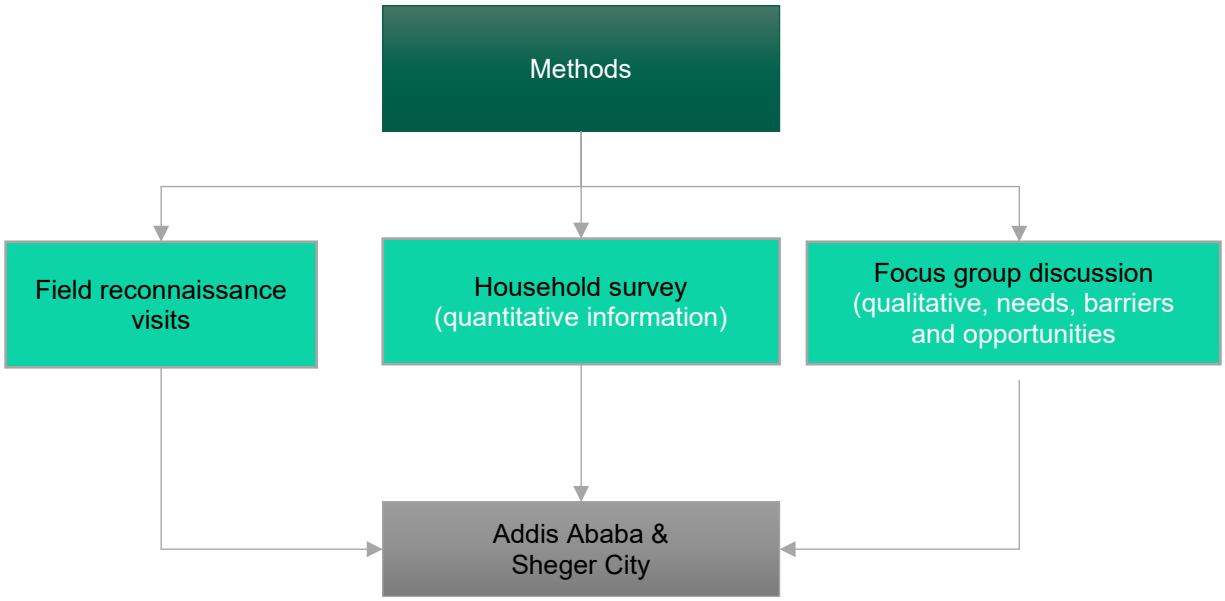


Figure 3. Data collection methods
Source: Author's creation.

2.3 Training of Enumerators

Three enumerators were recruited based on their prior experience in livestock production, livestock waste management, and biogas. All three participated in the site-visit reconnaissance to develop a clear understanding of on-the-ground livestock waste management conditions before the commencement of data collection. Following the field visits, the enumerators participated in a half-day training programme (Figure 4). Given their existing experience in livestock and livestock waste management, the training focused on three key objectives:

1. To ensure that enumerators had a clear understanding of all survey questions;
2. To ensure that all enumerators interpreted each question consistently and applied the same approach when recording different types of responses; and
3. To strengthen data quality by ensuring that enumerators were familiar with and able to administer the questionnaire accurately.



Figure 4. Training of enumerators
Source: Authors' photographs, taken during the site visit.

2.4 Study Sampling

2.4.1. Sampling approach for the household survey

A household survey of livestock-owning households was conducted across the Akaki catchment, with the sampling plan designed to provide coverage of the upstream, midstream, and downstream zones of the catchment, as well as urban and peri-urban areas. The household sample was distributed across the upstream, midstream, and downstream zones in proportion to the number of pre-identified eligible livestock-owning households in each zone, rather than allocating an equal number of households to each zone. The sampling approach comprised three main elements:

- **Livestock-ownership threshold:** households were eligible for inclusion if they owned more than five heads of cattle.
- **Stratification:** the study area was stratified by agro-ecological zone (high, middle, and low altitude) and by urban, peri-urban, and rural location within the catchment.
- **Household selection:** within the identified strata and woredas, eligible households were selected using lists compiled with the assistance of local livestock experts, with random selection applied to the available lists where feasible.

Districts for data collection were identified in both the Addis Ababa City Administration and the Sheger Ketema Administration in the Oromia region, which is treated as peri-urban in this study. In Addis Ababa, six sub-cities were selected, in consultation with the Administration's Farmers and Urban Agriculture Commission, from the city's eleven sub-cities. Three woredas were then identified within each selected sub-city in consultation with the respective local Farmers and Urban Agriculture Offices. Woreda selection considered livestock population and the extent of livestock waste management challenges. As the six selected sub-cities had broadly comparable numbers of livestock-owning households, sample sizes varied only modestly across them. Within each sub-city, the number of households sampled from each woreda was determined in proportion to its livestock population, based on data provided by woreda-level offices on households meeting the livestock-ownership criterion.

Within each woreda, household identification involved both reconnaissance and expert-assisted sampling. Enumerators first conducted short reconnaissance visits to one or two livestock-owning households per woreda, resulting in 30 households across the 18 woredas in Addis Ababa. These households were subsequently retained as part of the survey sample. Local livestock experts then provided lists of other eligible households, defined as those owning more than five head of cattle. The remaining households required to meet the woreda-level sample target were randomly selected from these available lists. Thus, random selection was applied to the households identified through the expert-assisted lists, while the initial reconnaissance households were included purposively.

A total of 170 household surveys were completed in Addis Ababa across the six selected sub-cities, representing approximately 57% of the original planned sample of 300 households. In Sheger City, five surrounding sub-cities were selected using a similar approach, based on the rationale of achieving coverage across the Akaki River Basin and areas with substantial livestock populations. A total of 133 household surveys were completed in Sheger City. The final combined sample therefore comprised 303 households, including 170 from Addis Ababa and 133 from Sheger City (Table 1). This final sample size of 303 households is used consistently throughout the remainder of the report, including Section 3.

Although slightly more than half of the Akaki River Basin's total area lies outside Addis Ababa, the planned sample was distributed as 57% for Addis Ababa and 43% for Sheger City. This distribution reflected four considerations: (i) Addis Ababa has a larger concentration of livestock-owning households meeting the livestock-ownership criterion (owning more than 5 heads of cattle) within a relatively smaller geographic area, whereas Sheger City has a lower household density but larger livestock holdings in some areas; (ii) livestock waste management challenges are comparatively pronounced in Addis Ababa, particularly in areas affected by river-corridor development and enforcement against waste discharge into waterways; (iii) Addis Ababa contains the main channels of the Akaki river system; and (iv) livestock waste management presents comparatively fewer challenges in parts of Sheger City, particularly rural areas where manure is commonly applied directly to agricultural land.

Table 1. Distribution of household surveys across selected locations in Addis Ababa and Sheger City

City	Sub-city	Household surveys collected
Addis Ababa	Bole	30
	Yeka	30
	Lemi Kura	20
	Akaki Kality	31
	Nefas Silk Lafto	30
	Kolfe Keranyo	29
Subtotal		**170**
Sheger City	Burayu	17
	Melka Nono	29
	Furi	21
	Gelan	30
	Legetafo	36
Subtotal		**133**
Total		**303**

Source: Author's creation.
Note: Numbers in parentheses indicate the identification codes of the selected woredas, where applicable. The final survey sample comprised 303 households: 170 in Addis Ababa and 133 in Sheger City.

Sampling limitations and potential bias

The sampling approach combined administrative consultation, reconnaissance visits, expert-assisted household identification, and random selection from available household lists. While random selection was used for households identified through the expert-assisted lists, the study did not have a complete, independently enumerated sampling frame of all eligible livestock-owning households across the Akaki catchment. In addition, the selection of sub-cities and woredas was based partly on administrative consultation, livestock population, and the extent of livestock waste management challenges rather than purely random selection. The households identified during the initial reconnaissance visits were also retained purposively in the sample. These features may introduce selection bias, as households that were known to local livestock experts or located in areas with more visible livestock and waste-management challenges may have been more likely to appear on the sampling lists. Consequently, while the survey provides broad coverage of the study area and incorporates random selection at the household level where sampling lists were available, the results should not be interpreted as a fully probability-based random sample of all livestock-owning households in the Akaki catchment.

2.4.2. Focus Group Discussions (FGDs)

Six FGDs, three in each city, were conducted in Addis Ababa and Sheger City as planned. Each FGD comprised 7–9 participants from different livestock-owning households, with particular emphasis on women's participation (Figure 5). To explore potential gender-related differences in perspectives, one female-only FGD was conducted in each city. Table 2 summarizes the FGDs conducted.

Table 2. Focus Group Discussions conducted

City	Urban/Rural	Sub-city	Target of FGD	No. of FGD
Addis Ababa	Urban	Akaki kality and Bole	Female	1
	Urban	Yeka and Lemi kura	Female – 3; Male - 5	1
	Urban	Nifas silk and Kolfe Keraneo	Female – 4; Male - 6	1
Sheger City	Peri-urban	Melka Nonno and Burayu	Female	1
	Peri-urban	Furi and Gelan	Female – 3; Male - 6	1
	Peri-urban	Legetafo	Female – 3; Male - 3	1
Total				**6**

Source: Author's creation



a. A picture from Akaki kality and Bole FGD



b. A picture from Melka Nonno and Burayu FGD



c. A picture from Furi and Gelan FGD



d. A picture from Legetafo FGD

Figure 5. Photographs of focus group discussions (FGDs).
Source: Authors' photographs, taken during the site visit.

2.5 Household Survey Data Collection Tool (Kobo Toolbox)

The household survey was administered using KoboToolbox, a digital data collection, management, and visualization platform that supports both online and offline data collection. The finalized household questionnaire was programmed using KoboToolbox's form builder and reviewed and pilot-tested during the site visits before the commencement of the main data collection.

2.6 Challenges Encountered During Data Collection

A few challenges were encountered during the site reconnaissance visits and household survey data collection:

Bureaucratic procedures in government offices: Sectoral government officers were generally cooperative in providing the necessary permissions and guidance for data collection. However, administrative procedures occasionally resulted in delays relative to the original fieldwork schedule.

Limited availability of local experts: Local livestock experts had competing professional responsibilities and were not always available according to the team's preferred schedule. Nevertheless, they remained supportive and worked with the team to arrange suitable times to assist with the fieldwork.

Initial reluctance among farmers: Some livestock-owning households were initially reluctant to participate in the survey, possibly due to misunderstandings about the study's objectives and concerns that the information provided could lead to government penalties for improper waste disposal or environmental pollution. The team addressed these concerns by clearly explaining the purpose of the study and assuring participants about the nature of the data collection, with support from local experts. This helped to substantially reduce reluctance and facilitated participation.

3 Results: Household Survey and Focus Group Discussion Findings

This section presents the findings from the household survey and focus group discussions conducted in Addis Ababa and Sheger City to assess the potential for livestock-waste-based biodigester systems. The analysis first establishes the demographic, livelihood, and livestock characteristics of surveyed households, followed by an assessment of livestock waste generation and current disposal practices. It then examines household awareness and experience with biodigester technology, preferred management arrangements, willingness to participate and contribute financially, household energy use, and gender-related considerations. Findings from the focus group discussions are used alongside the survey results to provide context on household motivations, perceived benefits and challenges, and the practical and institutional conditions that may influence adoption. Together, these findings provide the empirical basis for identifying the key requirements and design considerations for the biodigester business model presented in Section 4.

3.1 Household, Livelihood, and Livestock Profile

Sociodemographic characteristics

Based on the pooled dataset of all households considered in the survey in Addis Ababa and Sheger City, the average age of household heads was approximately 39 years, while the average household size was 5.4 members. The surveyed households were distributed across urban, semi-urban, and rural settings, with 53.0% located in the urban areas of Addis Ababa and 47.0% in the semi-urban and rural areas of Sheger City. Male-headed households accounted for 77.5% of the sample, while 22.5% were female-headed. Average total landholding was 0.42 ha, while households relied on a relatively limited range of income sources, indicating limited livelihood diversification. Approximately 71.3% of households reported a primary monthly income of ETB 20,000 (USD 125)[2] or more. Average monthly household expenditure was ETB 26,347 (USD 164.67), including ETB 2,407 (USD 15.04) for household energy (Table 3).

Access to formal financial and institutional support was relatively limited. Overall, 32.6% of households were members of a cooperative, while 27.5% reported access to credit. Cooperative membership and access to credit were more common among households in Addis Ababa than in Sheger City. These characteristics provide a baseline profile of the households considered in the subsequent analysis of livelihoods, livestock ownership, and biodigester management preferences.

Table 3. Household demographic and economic profile of respondents across the study areas

Variable	Addis Ababa (n = 170)	Sheger City (n = 133)
Age of household head (years)	40.75	36.34
Household size	5.9	4.7
Total land holding (ha)	0.42	0.49
Number of income sources	1.4	1.6
Primary income ≥ 20,000 ETB/month (%)	75.9	68.8
Monthly household expenditure	ETB 32,160.45 (USD 200.99)	ETB 25,676.50 (USD 160.48)
Monthly household energy expenditure	ETB 2,797.09 (USD 17.48)	ETB 2,548.98 (USD 15.93)

Source: Author's creation

The educational profile of household members surveyed in Addis Ababa and Sheger City (n = 1,632) was generally moderate to high. Secondary education accounted for the largest proportion (34.9%), followed by primary education (32.8%) and tertiary education (26.5%), while only 6.6% had no formal education. The overall education profile was broadly comparable between the two locations, although urban areas of Addis Ababa had higher proportions of household members with secondary and tertiary education than semi-urban and rural areas of Sheger City. Gender differences were also evident across education levels, with male household members generally having higher representation at the secondary and tertiary levels, while female members were more represented at the primary level and among those with no formal education. The gender difference was particularly evident at the tertiary level

[2] Exchange rate: USD 1 = ETB 160, based on the rate at the time of data collection.

in Addis Ababa, where the proportion among male household members was notably higher than among female members. The detailed education profile by location and gender is presented in Table 4.

Table 4. Education level of households by gender

Education category	Addis Ababa (n = 170)				Sheger City (n = 133)			
	Total no of household members	% of education level	% of male education level	% of Female education level	Total no of household members	% of education level	% of male educatio n level	% of Female educatio n level
No formal education	50	5	4.8	5.2	57	8.9	8.0	9.8
Primary level	325	32.4	29.8	35.6	210	32.7	29.8	35.9
Secondary level	375	37.4	36.9	38.0	194	34.2	31.8	28.4
Tertiary level	252	25.2	28.5	21.2	181	24.2	30.4	25.8

Source: Author's creation

Household income sources and livestock ownership

Beyond their demographic and educational characteristics, the surveyed households showed a strong dependence on livestock-based livelihoods. Livestock rearing was the dominant source of income, reported by 90.1% of households overall. This proportion was higher in Addis Ababa (92.9%) than in Sheger City (86.5%). Other primary income sources were reported by relatively few households, with crop farming accounting for 4.6%, trade for 3.0%, and employment for 2.3% of the overall sample (Table 5). This concentration of primary income in livestock rearing highlights the central role of livestock in household livelihoods and the limited diversification of income-generating activities.

Table 5. Main household income sources

Main income sources	Total sample (n = 303)		Addis Ababa (n = 170)		Sheger City (n = 133)	
	n	%	n	%	n	%
Crop Farming	14	4.62	5	2.95	9	6.77
livestock rearing	273	90.1	158	92.94	115	86.47
Employment	7	2.31	4	2.35	3	2.26
Trade	9	2.97	3	1.76	6	4.50

Source: Author's creation

Livestock ownership patterns further display the central role of livestock in household livelihoods. Cattle were the most consistently owned livestock, with households keeping an average of 12 head per household overall. Poultry were kept in substantially larger numbers, averaging 66.7 birds per household, although the very large standard deviation reflects considerable variation in flock size across households. Sheep and goats were present in relatively small numbers, while pig ownership was negligible, with no pigs reported among households in Sheger City (Table 6).

Table 6. Livestock owned per household

Livestock type	Addis Ababa (n = 170)	Sheger City (n = 133)
	Mean (Std. Dev.)	Mean (Std. Dev.)
Cattle	11.91 (9.40)	12.08 (6.89)
Sheep	0.48 (2.39)	0.47 (1.57)
Goats	0.28 (1.41)	0.08 (0.72)
Poultry	65.74 (439.54)	68.01 (629.97)
Pigs	0.06 (0.77)	0.00 (0.00)

Source: Author's creation

The strong dependence on livestock-based livelihoods was also reflected in the focus group discussions. Participants in both Addis Ababa and Sheger City consistently described livestock farming as a central component of household livelihoods, reinforcing the survey finding that approximately nine out of ten households depend on livestock rearing as their main source of income. At the same time, participants highlighted the vulnerability associated with this dependence. Limited diversification of income sources means that households can be particularly exposed to livestock-related shocks, including disease outbreaks, increases in feed costs, and fines associated with improper waste disposal. Such shocks were reported as having the potential to directly reduce household income and increase economic pressure.

3.2 Livestock Waste Generation and Current Disposal Practices

The importance of livestock to household livelihoods, as established in the previous section, is also reflected in the substantial amount of waste generated by these households. On average, households reported generating around 267 kg of solid manure and 266 L of liquid urine per day in Addis Ababa, compared with 241 kg and 234 L, respectively, in Sheger City (Table 7). Despite the noticeable variation in household-level waste generation, the per-animal estimates were relatively similar between the two locations, indicating that differences in total waste output are largely related to the scale of livestock holdings. This variation is important from a practical perspective because households with larger livestock holdings face substantially greater storage and disposal requirements. In addition, the estimates are based on household reporting and should therefore be interpreted as indicative rather than precise measurements of actual waste generation.

Table 7. Estimated livestock waste generation in Addis Ababa and Sheger City

Waste type	Addis Ababa (n = 170)	Sheger City (n = 133)
	Mean (Std. Dev.)	Mean (Std. Dev.)
Solid manure (kg/household/day)	266.79 (234.39)	240.73 (144.98)
Liquid urine (L/household/day)	266.19 (265.96)	233.75 (150.55)
Solid manure (kg/cattle/day)	22.62 (5.87)	20.94 (6.65)
Liquid urine (L/cattle/day)	22.55 (8.15)	20.20 (6.58)

Source: Author's creation

Disposal practices show considerable reliance on methods that offer limited opportunities for resource recovery. Dumping was widely reported in both locations, while direct release into rivers became substantially more common during the wet season. In Addis Ababa, for example, reported river discharge increased from 23.5% of households in the dry season to 67.1% in the wet season. Sheger City showed greater reliance on direct field application, reported by 42.1% of households in the dry season and 44.4% in the wet season, reflecting the greater presence of semi-urban and rural agricultural settings. In contrast, biogas use was almost absent in both locations, accounting for less than 2.5% of households in any season (Table 8).

Table 8. Livestock waste disposal practices by season and study area

Current Waste Disposal Practices	Addis Ababa (n = 170)		Sheger City (n = 133)	
	Dry season (% households)	Wet season (% households)	Dry season (% households)	Wet season (% households)
Composting	55.88	22.94	19.55	7.52
Biogas	2.35	1.76	0	0.75
Dumping	75.88	77.65	60.9	40.6
Selling	27.65	2.35	2.26	0
Cooking (dung)	36.47	1.76	14.29	2.26
Direct application	14.71	11.76	42.11	44.36
Release to river	23.53	67.06	15.04	45.11

Source: Author's creation.

The seasonal changes in disposal practices suggest that waste management is influenced by the availability and practicality of handling options rather than by waste generation alone. The marked increase in river discharge during the wet season, particularly in Addis Ababa, points to the difficulty of storing or otherwise managing liquid waste under wetter conditions. At the same time, the decline in composting, dung use for cooking, and manure sales during the wet season indicates reduced opportunities for recovering value from solid waste when drying and storage become more difficult. These patterns highlight a clear gap between the availability of livestock waste as a potential resource and the capacity of households to manage it through productive reuse.

The focus group discussions reinforced these findings. Participants in both study areas identified open dumping and discharge into nearby watercourses as common disposal practices. Solid manure was generally collected and dried where possible, with some households using it as cooking fuel or selling it, while liquid waste was more commonly discharged into nearby streams. Participants also noted that liquid waste disposal becomes more difficult during the rainy season. Although a small number of households had experience with biogas, limited technical knowledge and concerns about operation and maintenance were identified as barriers to wider adoption. The qualitative evidence therefore supports the survey finding that biogas remains largely absent despite the availability of livestock waste.

Taken together, the findings indicate that livestock waste represents both a management challenge and a potential resource for households whose livelihoods are strongly dependent on livestock. The relatively large quantities generated, limited land available for household-level handling, and widespread reliance on dumping or discharge create a clear need for more effective waste-management options. At the same time, the existing use of manure for fuel, sale, composting, and field application demonstrates that households already recognise some value in livestock waste. This provides a relevant basis for assessing whether improved systems for waste treatment and resource recovery, including biodigestion, can address current disposal constraints while generating additional household benefits. The extent to which this potential can be realised depends on households' familiarity with biodigestion and their experience with biogas and bio-fertilizer production. The next section therefore examines household awareness, previous exposure to the technology, and perceived demand for these products.

3.3 Awareness, Experience, and Demand for Biogas and Bio-Fertilizers

Awareness of bio-digesters was relatively widespread among the surveyed households, with 60.7% reporting that they were aware of the technology. Awareness was higher in Addis Ababa (70.0%) than in Sheger City (49.0%). However, practical exposure remained very limited. Only 6.3% of households had received training in biogas technology, including 9.0% in Addis Ababa and just 3.0% in Sheger City (Table 9). The findings therefore indicate a substantial gap between general awareness of the technology and access to practical knowledge or training.

Table 9. Household awareness of and training in biodigester technology

Variable	Addis Ababa (n = 170)		Sheger City (n = 133)	
	n	%	n	%
Aware of biodigester	119	70.0	65	49.0
Not aware of biodigester	51	30.0	68	51.0
Received training	15	9.0	4	3.0
No training received	155	91.0	129	97.0

Source: Author's creation.

The focus group discussions provide further context to these findings. A small number of long-term biogas users, including some with more than a decade of experience, described practical benefits such as access to cleaner cooking energy, reduced expenditure on conventional fuels, use of bio-fertilizer for crop production, and perceived improvements in household health. In contrast, non-adopters commonly identified limited access to technical training, the absence of nearby demonstration facilities, and weak institutional support as barriers to adoption. These observations are consistent with the survey results, which show that the vast majority of households had no formal training in biogas technology.

Participants also expressed interest in both biogas and bio-fertilizer, with bio-fertilizer viewed by several participants as having commercial potential in the context of increasing chemical fertilizer costs. However, participants emphasized that realizing this potential would require access to technical knowledge, appropriate financing, and reliable market linkages. Thus, interest in the technology appears to extend beyond energy production alone, with potential value also associated with the recovery and productive use of livestock waste.

The survey also captured broader awareness of resource recovery, with 76.7% of households reporting knowledge of practices such as biogas production and composting. This proportion was higher than the 60.7% reporting specific awareness of bio-digesters (Table 9). The difference suggests that familiarity with resource recovery does not necessarily translate into knowledge of particular technologies. Many households may therefore have some understanding of organic waste reuse while having limited knowledge of how a biodigester operates, how it should be managed, or what outputs it can generate. The FGD findings support this interpretation, particularly the emphasis placed by non-adopters on the need for practical training and opportunities to observe functioning systems.

Overall, the findings point to a distinction between awareness of the concept and readiness to use the technology. While a substantial proportion of households are already aware of bio-digesters and express interest in their potential benefits, very few have received formal training or gained direct experience with the technology. This gap is relevant to the design of the proposed business model, as effective uptake is likely to depend not only on awareness but also on practical knowledge, demonstration, financing, and access to markets for recovered products such as bio-fertilizer (Berhe et al.2017).

3.4 Preferred Biodigester Models and Willingness to Join a Cooperative

The limited practical experience with biodigestion also highlights the importance of how the technology would be introduced and managed at the household level. Since establishing a biodigester may require investment, technical support, and arrangements for the collection and use of livestock waste, the preferred management structure is an important consideration for its potential uptake. The following section therefore examines households' preferences for private, cooperative, or public management and their willingness to participate in a cooperative biodigester.

The preferred management model varied substantially between the two locations. Overall, cooperative management was the most commonly preferred option, selected by 49.5% of households, compared with 28.4% who preferred private management and 5.6% who preferred public management. However, the pattern differed markedly by location. In Sheger City, 69.9% of households preferred a cooperative model, whereas private management was preferred by only 14.3%. In Addis Ababa, private management was the most commonly preferred option (39.4%), followed by cooperative management (33.5%).

This difference may partly reflect the contrasting settlement contexts. In the predominantly urban setting of Addis Ababa, greater access to private services, infrastructure, and market-based options may make individually managed systems more familiar or feasible. In the more semi-urban and rural setting of Sheger City, cooperative arrangements may be more attractive because they allow households to pool financial resources, share infrastructure and technical support, and collectively manage the costs associated with waste collection and biodigester operation. These interpretations are consistent with concerns raised during the focus group discussions regarding the costs and practical requirements of establishing and maintaining shared systems. A further 16.5% of households were unable to identify a preferred management model, indicating some uncertainty about the most appropriate arrangement (Table 10).

Table 10. Preferred biodigester models

Variable	Addis Ababa (n = 170)		Sheger City (n = 133)	
	n	%	n	%
Private	67	39.4	19	14.3
Cooperative	57	33.5	93	69.9
Public	14	8.2	3	2.3
Don't know	32	18.9	18	13.5

Source: Author's creation.

Despite the substantial differences in preferred management structure, willingness to participate in a cooperative biodigester was relatively similar across the two locations. Overall, 60.0% of households expressed willingness to participate, while 24.0% were uncertain and 16.0% were unwilling. The proportion willing to participate was almost identical in Addis Ababa (59.0%) and Sheger City (61.0%). However, households in Addis Ababa were more likely to be uncertain about participation (29.0% compared with 18.0%), whereas unwillingness was higher in Sheger City (21.0% compared with 12.0%) (Table 11). Thus, the much stronger preference for cooperative management observed in Sheger City did not correspond to a substantially higher willingness to participate, highlighting a distinction between preference for a management arrangement and commitment to participation.

Table 11. Willingness to join a cooperative biodigester model

Variable	Addis Ababa (n = 170)		Sheger City (n = 133)	
	n	%	n	%
Yes	101	59.0	81	61.0
Maybe	49	29.0	24	18.0
No	20	12.0	28	21.0

Source: Author's creation.

The focus group discussions further highlighted several practical considerations that may influence the implementation of a cooperative biodigester. Participants identified opportunities to develop local technical skills and create employment, particularly for youth, but also raised concerns about the high initial and operating costs of shared systems. Other challenges included the distance between livestock holdings and a common biodigester, the cost and logistics of manure transportation, uneven commitment among cooperative members, flooding risks, and uncertainty surrounding land-use and policy arrangements. These concerns highlight that the feasibility of a cooperative model would depend not only on household interest, but also on the practical arrangements for site selection, waste collection, system management, and long-term participation.

These findings suggest that interest in a cooperative biodigester is accompanied by practical considerations regarding how such a system would be organized, financed, and managed. The relatively high proportion of households responding "maybe" or "no" to cooperative participation suggests that interest does not necessarily translate into commitment to join. Issues of financing, site accessibility, manure collection and transport, member responsibilities, and technical management would therefore need to be addressed when assessing the feasibility of a

cooperative-based model. The next section examines households' financing capacity, willingness to pay, and access to information and technical support, which are directly relevant to these considerations.

3.5 Financing Behaviour, Willingness to Pay, and Information Channels for Biodigester Adoption

The practical considerations identified above, particularly financing and access to technical support, are also reflected in households' reported access to credit, willingness to pay, and sources of agricultural and technical information. Among the 83.5% of households with stated willingness to adopt biodigester technology, only 27.5% reported access to formal credit (Table 12). Limited access to formal financing may therefore constrain households' ability to meet the upfront costs associated with biodigester installation and related infrastructure. This is consistent with the focus group discussions, in which participants identified flexible credit, subsidies, and instalment-based payment arrangements as important considerations for making the technology financially accessible.

Table 12. Household financing profile, willingness to pay, and information sources relevant to biodigester adoption

Variable	Households willing to adopt biodigesters (n = 253)
Currently a cooperative member – Yes (%)	32.63
Has access to formal credit – Yes (%)	27.54
Willing to pay up to 10,000 ETB (%)	40.25
Willing to pay up to 30,000 ETB (%)	37.29
Willing to pay up to 50,000 ETB (%)	16.95
Willing to pay up to 100,000 ETB (%)	3.39
Willingness to Pay greater than 100,000 ETB (%)	2.12
Main information source – Radio/TV (%)	40.68
Main information source – Extension officer (%)	32.63
Main information source – Neighbor (%)	17.37
Main information source – NGO (%)	12.29

Source: Author's creation

Households expressed a range of willingness to pay (WTP) as a contribution towards the establishment of a cooperative biodigester (Table 12). About 40.3% were willing to contribute up to ETB 10,000 (USD 63), while 37.3% were willing to contribute between ETB 10,001 and 30,000 (USD 63–188). A further 17.0% were willing to contribute ETB 30,001–50,000 (USD 188–313), 3.4% ETB 50,001–100,000 (USD 313–625), and 2.1% more than ETB 100,000 (USD 625). These responses show that households are willing to make a financial contribution to a cooperative biodigester, although the amount they are able or prepared to commit varies considerably. Most contributions are concentrated at the lower end, with nearly four in five households (77.5%) willing to contribute no more than ETB 30,000 (USD 188). This variation provides a basis for considering flexible payment structures and complementary financing options within the proposed business model.

To estimate the average contribution households are prepared to make, the share of households in each WTP band was multiplied by the midpoint of that band, and the weighted values were summed. A value of ETB 125,000 (USD 781) was assumed for the open-ended top band (above ETB 100,000). On this basis, the mean stated contribution is approximately ETB 19,400 (USD 121) per household. Because the survey recorded contribution bands rather than exact amounts, the estimate was bounded by applying the lower and upper limits of each band, giving a range of ETB 12,600–30,300 (USD 79–189) per household. The distribution is right-skewed: the 5.5% of households willing to contribute more than ETB 50,000 (USD 313) account for about 27% of the mean, and the estimated median contribution of approximately ETB 15,200 (USD 95) is well below the mean. Several caveats apply. The midpoint approach assumes that responses are evenly distributed within each band. The value for the open-ended top band is an assumption, although varying it between ETB 100,000 and 150,000 changes the mean only modestly (ETB 18,900–20,000). The estimates are also based on stated rather than revealed preferences and may therefore overstate actual payments, particularly where contributions are required upfront. In addition, they refer to households willing to adopt biodigesters, not all of whom indicated willingness to join a cooperative (Table 11). The mean should

therefore be interpreted as an upper indication of the average cash contribution that cooperative members could make.

Access to relevant information is another important consideration for potential adoption. Radio and television were the most commonly reported sources of agricultural and technical information (40.7%), followed by extension officers (32.6%), neighbors (17.4%), and NGOs (12.3%) (Table 12). The prominence of radio and television indicates the potential reach of mass-media channels for general awareness, while the substantial role of extension officers provides an existing channel for more practical and technical information. The focus group discussions similarly emphasized the need for training, ongoing technical guidance, and access to spare parts and maintenance support. Taken together, the findings suggest that information provision would need to combine broad awareness through accessible media with more practical, extension-based training and demonstration for households considering adoption.

Overall, the findings indicate that households show a clear willingness to engage with biodigester systems and contribute financially towards their establishment, although the level of contribution varies across households. Formal credit is currently available to only a proportion of households, highlighting the relevance of accessible financing arrangements alongside households' own contributions. At the same time, the range of information sources reported by households provides potential channels for building awareness and delivering technical guidance. Together, these findings provide important inputs for designing the financing structure, payment arrangements, and technical support mechanisms within the proposed biodigester business model.

3.6 Household Energy Use and Its Relevance to Biodigester Adoption

The financing and technical considerations discussed above are closely linked to the potential value that households may derive from biogas. Understanding current household energy use is therefore important for assessing where biogas could fit within existing energy practices and which fuels it could potentially replace.

Electricity accounted for the largest share of household energy use, representing 74.3% of total reported energy use on average (Table 13). Traditional fuels remained an important part of the energy mix, with firewood accounting for 9.3%, charcoal for 9.1%, and cow dung for 5.9%. In contrast, current use of biogas and LPG was very limited, accounting for 0.4% and 0.03%, respectively. The pattern was broadly similar across the two locations, although Addis Ababa households reported greater use of firewood (9.9%) and cow dung (8.8%), while Sheger City households reported higher shares of electricity (78.6%) and charcoal (10.3%).

Table 13. Household energy use mix

Energy Source	Percentage use in Addis Ababa (n = 170)	Percentage use in Sheger City (n = 133)
Firewood	9.94	8.39
Charcoal	8.22	10.26
LPG	0.06	0
Electricity	70.84	78.64
Biogas	0.65	0
Cow dung	8.77	2.14

Source: Author's creation

The focus group discussions provide further insight into the relevance of these energy-use patterns. Women participants in particular associated the use of firewood and dung for cooking with constraints such as smoke exposure and the time required for fuel collection. These experiences were identified as practical motivations for considering biogas, in addition to its potential economic and environmental benefits. The findings therefore suggest that the value of biogas for households may extend beyond replacing expenditure on conventional fuels to include potential reductions in exposure to smoke and the time required to obtain cooking fuel.

The current energy mix also provides an indication of the potential market for household-level biogas. Firewood, charcoal, and cow dung together account for approximately 24% of reported household energy use, while biogas currently represents only a very small share. These fuels therefore represent the most relevant categories for potential substitution by biogas. This is particularly relevant when considered alongside the average monthly

household energy expenditure of 2,407 ETB (USD 15.04) reported in Section 3.1. The existing expenditure on household energy, together with the continued use of traditional fuels, provides a basis for considering the potential economic value of biogas within the proposed business model.

Overall, the findings indicate that biogas would enter an existing household energy system in which electricity is dominant but traditional fuels continue to account for a meaningful share of energy use. The relatively limited current use of biogas also indicates that households have considerable scope to incorporate biogas into their existing energy practices. The differences in fuel composition between Addis Ababa and Sheger City should be considered when assessing potential demand and the scale of energy substitution that a biodigester could provide in each setting.

3.7 Gender Dimensions in Waste Management and Biodigester Adoption

The household energy findings also have a gender dimension, particularly because cooking fuel use, fuel collection, and day-to-day livestock care are closely linked to household responsibilities. The household survey indicates a modest gender difference in educational attainment at the tertiary level, with 30.0% of male household members having tertiary education compared with 22.7% of female members. The proportion reporting no formal education was slightly higher among women (7.1%) than men (6.0%) (Table 4).

The two women-only FGDs, conducted in Akaki Kality/Bole and Melka Nonno/Burayu, provided further insight into gender roles. Participants described women as having important responsibilities in decisions concerning cooking fuel, fuel collection, and day-to-day livestock care. They viewed biogas as having potential to reduce the time required for firewood collection and exposure to smoke associated with traditional cooking practices. Participants also identified opportunities for women to engage in income-generating activities and take on leadership roles within cooperative-based biodigester operations. They emphasized the importance of accessible finance, including soft loans or grants, technical training, and confidence-building support to enable women to participate more actively in cooperative governance.

The household profile provides further context for these findings. Among the 253 households with a stated preference for a biodigester management model, 77.5% were male-headed and 22.5% were female-headed. However, formal household headship does not necessarily reflect responsibility for specific household activities. The FGD findings suggest that women may play an important role in fuel and livestock-related decisions even in male-headed households. This distinction is relevant to the proposed business model, particularly in designing outreach, training, financing, and cooperative participation. Implementation and monitoring could therefore record the household members responsible for fuel and waste management alongside the formal household head. This would provide a clearer basis for assessing participation in training, leadership, and benefit-sharing, while helping ensure that the design of biodigester systems reflects the roles of those directly involved in their use and management.

3.8 Motivations, Challenges, Benefits, and Support Needs for Cooperative Participation

The open-ended survey responses and focus group discussions provide a consistent picture of why households are interested in cooperative biodigester systems, the concerns that may affect participation, and the types of support required for sustained operation. These findings bring together the earlier results on waste management, technology awareness, energy use, financing, and cooperative preferences and provide a direct basis for the business model developed in Section 4.

Environmental cleanliness, pollution reduction, and the potential to generate energy and income from livestock waste were among the most frequently cited motivations for cooperative participation. Households and FGD participants also identified training and financial support as factors that could encourage adoption. A smaller number preferred individual management or identified limited space as a consideration. The emphasis on environmental and livelihood benefits suggests that interest in biodigestion is linked not only to the technology itself but also to existing concerns around waste accumulation, pollution, energy use, and the productive use of livestock waste.

The main concerns centered on the practical and institutional requirements of collective management. Disagreements over profit distribution and decision-making, unequal participation among members, and the financial costs of establishing and operating a shared system were frequently mentioned in both the survey responses and FGDs. Participants also identified logistical challenges, particularly the distance between livestock holdings and a shared biodigester site and the associated cost and effort of manure collection and transport. Technical and safety concerns, including accidents and explosions, as well as flooding risks, were also raised in the FGDs. These findings

indicate that cooperative feasibility will depend not only on access to capital but also on clear governance arrangements, defined member responsibilities, suitable site selection, and workable systems for waste collection and transport.

Participants identified several potential benefits from cooperative bio-digesters, including additional income, reduced costs through resource and risk sharing, improved environmental conditions, and potential household health benefits. Opportunities to share skills, resources, and market access were also valued. The range of expected benefits indicates that households associate biodigestion with broader livelihood and environmental outcomes in addition to the production of biogas. This provides scope for outreach and engagement to communicate the technology in terms of waste recovery, energy, income opportunities, and environmental improvements rather than focusing only on its technical operation.

Reliable technical and institutional support emerged as another important requirement. Participants highlighted expert-led installation, structured training, ongoing supervision, and dependable access to spare parts and repair services. Financing support was also considered important, with flexible credit, subsidies, and instalment-based payment arrangements suggested through microfinance institutions or local authorities. Public-private partnerships and agricultural extension services were identified as potential mechanisms for strengthening technical and logistical support. The emphasis on continued supervision and maintenance indicates that service provision would need to extend beyond initial installation and continue throughout the operation of the system.

Taken together, the findings provide a coherent set of considerations for the biodigester business model. The proposed system would need to combine appropriate financing with clear cooperative governance, practical arrangements for manure collection and transport, and ongoing technical and maintenance support. Financing mechanisms should accommodate the variation in households' willingness to contribute, while cooperative rules should establish responsibilities for decision-making, revenue distribution, operation, and maintenance from the outset. Training and outreach should use the information channels already identified by households while providing practical opportunities to develop technical skills and understand the operation and benefits of biodigestion. The model should also recognize the roles of household members directly involved in fuel and livestock-waste management, including women, rather than relying solely on formal household headship.

Overall, the evidence indicates that the potential for a cooperative biodigester extends beyond the treatment of livestock waste or substitution of household cooking fuels. It encompasses waste management, energy generation, potential income and cost savings, resource recovery, environmental improvement, and opportunities for shared skills and services. At the same time, translating household interest into sustained participation will require the practical and institutional conditions identified by respondents to be addressed. These findings therefore provide the empirical basis for the investment structure, cooperative arrangements, technical services, financing mechanisms, and revenue streams developed in the business model in Section 4.

4 Biodigester Business Model and Planning

4.1 Alternative Models for Biodigester Development

The results presented in Section 3 provide the empirical basis for assessing the most appropriate management arrangements for biodigester development. The household survey and FGDs indicate that both individual and collective approaches have relevance, while the stakeholder consultation identified youth-led management as an additional option with potential for implementation in suitable settings. Based on these findings, three models were identified as having near-term potential in the Akaki sub-basin: private ownership, cooperative management, and an independent youth-led model. Their main characteristics, advantages, and implementation considerations are summarized in Figure 6.

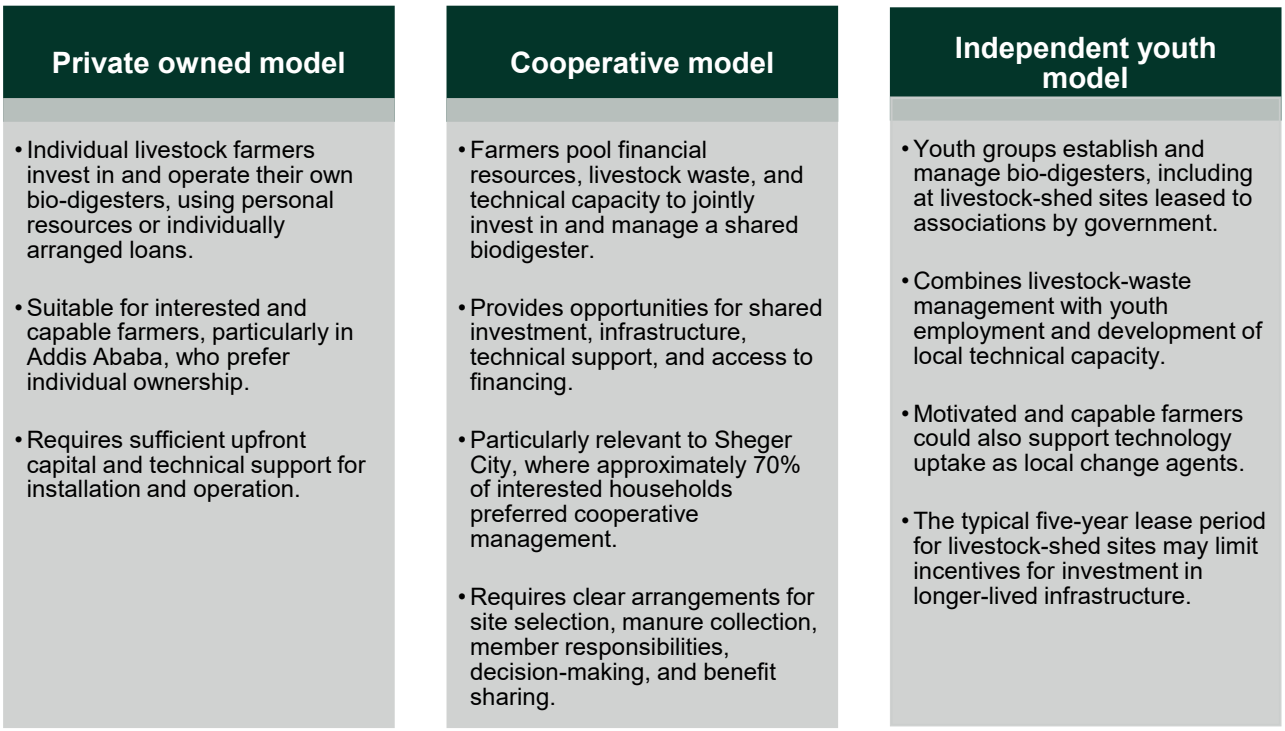


Figure 6. Biodigester business model options identified for the Akaki sub-basin
Source: Author's creation.

The three models provide different pathways for linking livestock waste management with energy and resource recovery, and their suitability is likely to vary according to the local institutional and operational context. The stakeholder consultation also identified a fourth, longer-term option involving large-scale bio-digesters of approximately 800 m^3 or more. Such systems could support the integrated management of livestock waste across a wider area while enabling recovery of both energy and organic fertilizer. However, their scale and investment requirements would necessitate detailed technical, economic, social, and environmental feasibility assessments. Stakeholders proposed that this option could be developed as a flagship initiative led by the Addis Ababa City Administration in collaboration with relevant government institutions and development partners.

For the near term, the three smaller-scale models provide practical options for testing different approaches to investment, ownership, and management within the Akaki sub-basin. The present report focuses on the cooperative model for detailed business planning. Its selection is supported by the household survey and FGD findings, as well as the stakeholder consultation, and provides an opportunity to examine how shared investment and management can be organized around livestock-waste collection, biogas production, and recovery of organic fertilizer. The following sections therefore develop the cooperative model in detail, covering its operational structure, governance arrangements, financial requirements, revenue streams, risks, and long-term sustainability.

4.2 Business Planning for Cooperative-Based Biodigester Model

4.2.1. Introduction

A cooperative-based biodigester model offers an opportunity to convert livestock waste into biogas and organic fertilizer while addressing growing waste-management challenges in the Akaki sub-basin. As a highly urbanized catchment, the sub-basin's watercourses receive pollution from multiple sources, including domestic, industrial, and livestock waste. The continued concentration of livestock production in and around the catchment has increased the volume of manure requiring appropriate management, while inadequate disposal practices contribute to the degradation of river systems. Recent restrictions on livestock waste disposal further strengthen the case for resource recovery and improved waste-management solutions.

Given the scale of livestock waste generation and the large number of livestock farmers in the sub-basin, a cooperative approach could provide a practical mechanism for pooling waste, investment, technical expertise, and operational responsibilities. The model is also aligned with Ethiopia's broader policy direction on climate-resilient development and sustainable energy, including the Climate-Resilient Green Economy Strategy and the National Sustainable Energy Development Strategy (FDRE, 2012; MoWE, 2024). This section therefore assesses the technical and financial feasibility of a cooperative biodigester system in which locally available livestock waste is used as feedstock for the production of biogas and organic fertilizer. Beyond these outputs, the model is designed to strengthen cooperative capacity in technical management, financial administration, and system operation, creating a foundation for potential replication and scaling in other sub-basins.

4.2.2. Advantages and drawbacks of cooperatives

Cooperative-based biodigesters offer a powerful model for waste management and resource recovery, but they may also have some key challenges. Table 14 highlights the breakdown of the advantages and disadvantages.

Table 14. Advantages and drawbacks of the cooperative model

Advantages	Drawbacks
Economic viability and shared costs: Pooling financial resources can reduce the individual investment burden and facilitate collective investment in the system.	Governance and benefit-sharing challenges: Differences in member contributions, responsibilities, and expectations may create disagreements over decision-making and benefit sharing.
Improved resource utilization: Pooling livestock waste can facilitate more efficient collection, treatment, and resource recovery.	Logistical complexity: Daily manure collection, transportation, storage, and feedstock management require effective coordination.
Improved access to affordable and reliable energy: Members and potentially surrounding communities can benefit from locally produced biogas.	High initial organizational effort: Establishing the cooperative, developing operating rules, and building trust among members require time and sustained engagement.
Production of organic fertilizer: Biodigester operation generates organic fertilizer that can provide an additional product and potentially reduce expenditure on chemical fertilizers.	Operational and maintenance requirements: Regular operation, monitoring, maintenance, and timely repair require appropriate technical capacity and support.
Strengthened social cohesion and collective action: Joint ownership and management can encourage cooperation and collective responsibility among members.	Unequal participation and benefit distribution: Differences in participation, waste contributions, or access to benefits may create tensions among members if not clearly managed.
Improved access to finance and support services: A formally organized cooperative may have greater capacity to access credit, technical assistance, training, and other institutional support.	Dependence on effective governance: Weak management, unclear responsibilities, or inadequate accountability could affect system performance and long-term sustainability.

Source: Author's creation

The balance between these advantages and drawbacks depends largely on the scale of the cooperative, the proximity of participating farms, the availability of feedstock, and the capacity of members to manage the system collectively. These considerations are particularly important when defining the size and composition of the cooperative. Based on the household and stakeholder findings presented earlier, the proposed model considers two broad categories of livestock farmers and develops a common medium-sized biodigester configuration that can be adapted to the number and scale of participating households.

4.2.3. Typical typology, inputs and outputs of the cooperative biodigester model

The proposed system is a standard underground fixed-dome biodigester with a cylindrical digester chamber. Anaerobic microorganisms decompose livestock manure in the absence of oxygen, producing biogas and digestate. The design therefore links the two principal functions of the cooperative model: management and treatment of livestock waste, and recovery of energy and organic fertilizer.

i. Size and typology of the cooperative model

Livestock farmers considered for the cooperative model in the Akaki sub-basin can broadly be classified into two groups: (i) small-scale farmers, typically keeping 5 to 10 adult dairy livestock, and (ii) larger or commercial farmers, typically keeping 10 to 20 livestock. Different numbers of households can be accommodated within each category according to the quantity of manure available, while maintaining a common medium-sized biodigester of approximately 80 m³ for the proposed model.

i.

Cooperative membership would be voluntary and would involve farmers located within relatively close proximity who are willing to collectively develop, operate, and benefit from the biodigester. Proximity is an important consideration because the feasibility of a shared system depends not only on the amount of manure available but also on the cost and practicality of transporting it to the digester. For the proposed model, participating farms are assumed to be located within a maximum distance of approximately 2 km from the digester site (Table 15).

Table 15. Livestock households typologies and proposed numbers in a cooperative

Cooperative Type	Typical number of households in a cooperative	Characteristics
Small-farmer cooperative	10-15	Medium-sized biodigester (e.g., 80 m³); relatively manageable waste-collection and logistics requirements; households within a maximum distance of 2 km. Average: 12 households.
Large/commercial-farmer cooperative	5-10	Same 80 m³ biodigester proposed for simplicity; larger volume of waste generated per household allows a smaller number of participating households. Farms within a maximum distance of 2 km. Average: 8 households.

Source: Author's creation

The two cooperative types differ primarily in the number of participating households and the amount of manure generated per household. The resulting feedstock availability and required daily input are presented below.

ii. Livestock waste quantity and inputs

The principal feedstock for the proposed biodigester is cattle manure collected from participating households. For modelling purposes, average daily manure availability is assumed to be approximately 130 kg per household for small farmers and 200 kg per household for larger or commercial farmers. Based on the average cooperative sizes presented above, this corresponds to approximately 1,560 kg and 1,600 kg of manure per day, respectively.

The collected manure would be mixed with water before entering the biodigester. A 1:1 manure-to-water mixing ratio is assumed for the proposed system. Based on the required daily feed volume and a manure density of approximately 1,000 kg/m³, approximately 1.33 m³ of fresh manure and 1.33 m³ of added water would produce about 2.67 m³ of slurry per day (Table 16).

Table 16. Waste quantity and inputs for a cooperative biodigester.

Parameter	*Small-farmer cooperative*	*Large/commercial-farmer cooperative*
Average no of households	12 (10-15)	8 (5-10)
Daily household animal waste, kg	130	200
Total daily solid manure, kg	1,560	1,600

Total daily liquid waste, liters	1,200	1,200
Biodigester size, m^3	80	80
Density of manure, kg/m^3	1,000	1,000
Hydraulic Retention Time (HRT), days	30	30
Daily slurry volume, m^3	2.67	2.67
Mix ratio manure: water	1:1	1:1
Daily fresh manure needed (half of slurry), m^3	1.33	1.33
Daily volume of required fresh manure, kg	1,330	1,330

Source: Author's creation

The estimated manure availability of approximately 1,560 kg/day for the small-farmer cooperative and 1,600 kg/day for the large/commercial-farmer cooperative is higher than the 1,330 kg/day required to operate the proposed 80 m³ biodigester at the assumed loading rate. This difference provides a practical margin to account for manure that may not be collected, seasonal fluctuations in manure availability, and day-to-day variations in feedstock supply. Accordingly, the business model assumes that approximately 80–85% of the available manure would be collected and delivered to the biodigester, providing a more realistic basis for continuous operation.

A reliable water supply would also be required to maintain the assumed 1:1 manure-to-water mixing ratio during slurry preparation. Since the participating farms are expected to be located within approximately 2 km of the biodigester, manure collection would need to be organized through a regular collection and transport system. Depending on the distance, road conditions, and volume of manure to be transported, the cooperative could use carts, small vehicles, or other suitable transport arrangements.

iii. Hydraulic Retention Time (HRT)

Hydraulic retention time (HRT) refers to the average period for which the feedstock slurry remains inside the digester and is available for anaerobic digestion. An HRT of 30 days is assumed for cattle manure under the conditions considered. With a daily slurry input of approximately 2.67 m³, a 30-day HRT corresponds to a working digester volume of approximately 80 m³.

The feedstock calculations indicate that approximately 1,330 kg of fresh manure is required daily under the assumed manure-to-water mixing ratio. This is below the estimated 1,600 kg of manure generated daily by the large/commercial cooperative. The model therefore assumes that approximately 80–85% of the available manure can be collected and supplied to the digester, allowing for collection losses and day-to-day variation in feedstock availability.

iv. Member contribution structure

The WTP estimates in Section 3.5 provide a basis for determining the share of the investment that cooperative members could realistically finance themselves. For an average cooperative of 12 households, the total upfront requirement of ETB 2,880,000 (USD 18,000) for the biodigester, land, and establishment costs corresponds to approximately ETB 240,000 (USD 1,500) per household if fully member-financed. This is more than twelve times the estimated mean stated contribution of ETB 19,400 (USD 121). At that level, a 12-member cooperative could mobilise approximately ETB 233,000 (USD 1,460), equivalent to about 8% of total upfront costs (range 5–13%) or 12% of the digester construction cost of ETB 1,920,000 (USD 12,000). Member contributions are therefore best positioned as an equity and commitment stake rather than the main source of capital, with the remaining 90–95% mobilised through grants, subsidies, development finance, or concessional credit (Section 4.1; Table 22). Because stated contributions vary widely and only 27.5% of households have access to formal credit, a uniform membership fee set at the mean would exceed the stated capacity of more than 40% of households. A tiered structure aligned with the WTP bands would therefore be more inclusive. Households would contribute according to their capacity, with the option of paying in instalments and substituting part of the cash contribution with in-kind inputs such as manure supply and labour for collection or operation. Cooperative bylaws should link benefit-sharing to these differing contributions, addressing the governance concerns raised in Section 3.8. Recurring costs are more manageable. Annual O&M costs of ETB 115,200 (USD 720), or approximately ETB 800 (USD 5) per household per month, are well within the projected annual revenue of approximately ETB 626,000 (USD 3,910) from surplus biogas and organic fertilizer sales (Tables 19–20). Once these markets are established, O&M could therefore be financed from

product revenues. During the start-up phase, a modest interim user fee set below the estimated household energy saving of ETB 600 (USD 3.75) per month could cover operating costs.

v. Outputs of the cooperative biodigester

The proposed cooperative biodigester converts collected livestock waste into biogas and digestate. Biogas provides an energy product for household and productive uses, while digestate can be used directly as liquid bio-slurry or further processed into solid organic fertilizer. The estimated daily quantities and processing pathways are presented in Figure 7, based on the assumed feedstock input, 80 m³ digester capacity, and associated technical parameters.

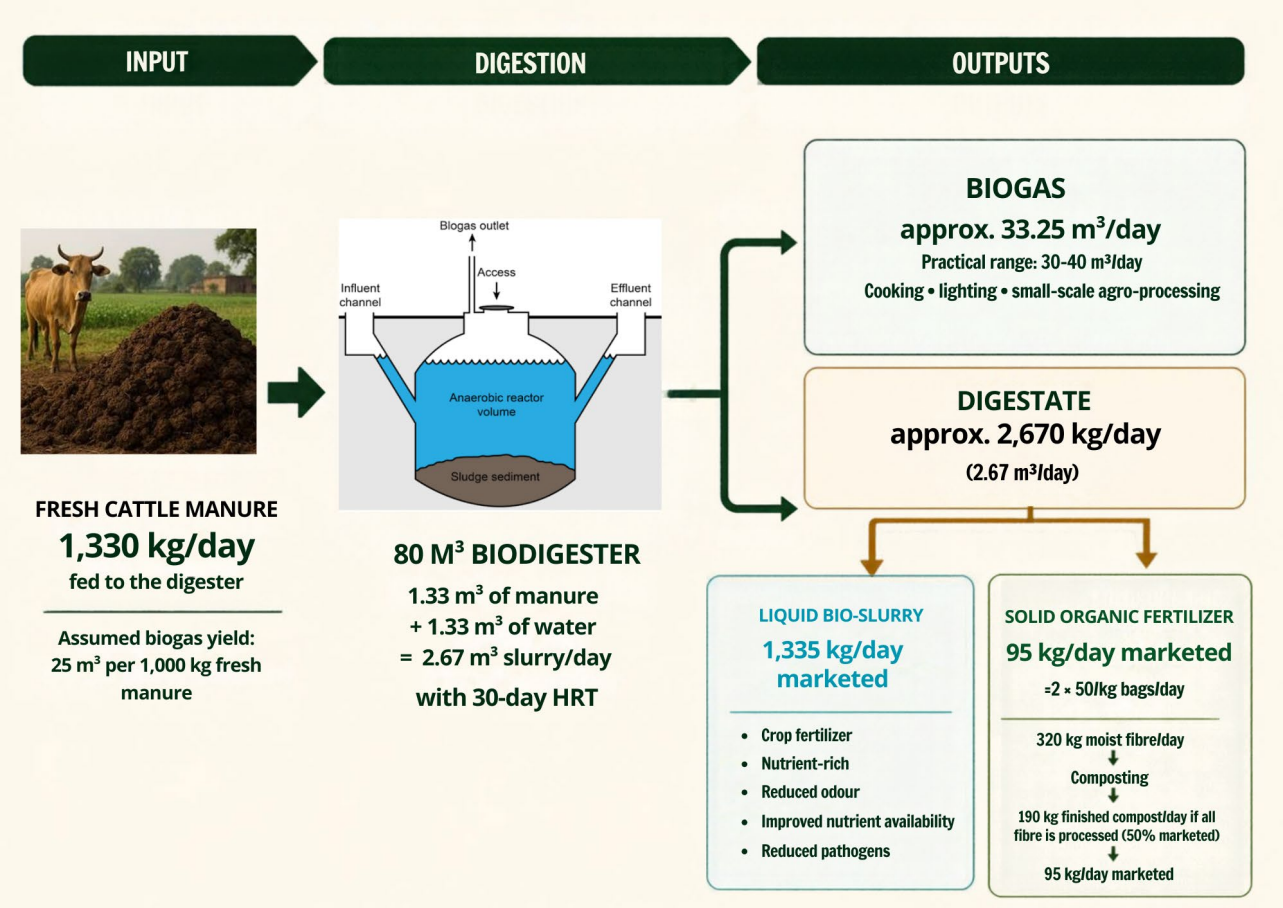


Figure 7. Estimated daily outputs and processing pathways of the proposed 80 m³ cooperative biodigester.
Source: Author's creation using Canva.

4.2.4. Components of the proposed cooperative biodigester

The biodigester is an integrated system comprising feedstock preparation, anaerobic digestion, gas collection, and digestate management. Manure and water are mixed in the inlet or mixing chamber before entering the underground digester through the inlet pipe. Within the sealed digester chamber, anaerobic digestion produces biogas, which accumulates in the fixed gas dome. As new slurry enters the system, digested slurry is displaced through the outlet into the compensation tank, where it can be collected for direct use or further processing as fertilizer. The main technical components required for the proposed system are presented in Table 17.

Table 17. Biodigester technical components

Component	Function	Key technical details & materials
1. Foundation	Base of the excavated pit. Provides a stable, level base to prevent structural settlement.	• Compacted soil, gravel, or a lean concrete slab. • Must be designed to withstand the weight of the structure and surrounding soil pressure.
2. Digester chamber	Main underground tank. Provides the sealed environment in which anaerobic digestion occurs.	• Shape: Spherical or cylindrical for structural strength. • Materials: Masonry, brick, or concrete. • Volume: Sized according to feedstock availability and hydraulic retention time (HRT), 80 m³ in this case.
3. Fixed gas dome	Integral roof of the digester chamber. Captures and stores biogas generated during digestion.	• Built as part of the main structure. • As slurry enters and exits the digester, the available gas space and gas pressure change accordingly.
4. Inlet pipe	Connects the inlet tank to the digester and channels the prepared feedstock into the digestion chamber.	• Typically made of PVC or HDPE pipe. • The entry point is positioned below the slurry level.
5. Inlet tank / mixing chamber	Above-ground chamber at the inlet. Allows manure and water to be mixed before feeding into the digester and facilitates controlled feeding.	• Simple brick or concrete tank. • Provides a small settlement area for heavy inert materials before the slurry enters the digester.
6. Outlet pipe	Connects the digester to the compensation tank and allows digested slurry (effluent) to exit as new feedstock enters the system.	• Its elevation helps determine the maximum slurry level inside the digester. • Positioned opposite the inlet pipe.
7. Compensation tank	Above-ground tank at the outlet. Collects displaced digested slurry for subsequent use or processing as fertilizer.	• Usually an open tank made of brick, concrete, or suitable plastic material. • Accommodates changes in slurry level and helps maintain the operating level of the digester.
8. Gas outlet pipe & valve	Located at the top of the gas dome. Transports biogas from the dome to the gas distribution system.	• Includes a main shut-off valve and a condensate drain/trap. • Connected to the main gas pipeline, typically using suitable PVC or HDPE piping.
9. Internal sealing layer	Applied to the internal surfaces of the digester and gas dome to create a gas-tight and liquid-tight system.	• Critical for preventing gas leakage and seepage. • May consist of multiple layers of fine cement plaster followed by a suitable gas-proof coating, such as bitumen-based or synthetic-resin-based materials.
10. Manhole / access port	Provides access for construction, inspection, maintenance, and periodic desludging.	• Extends to ground level where appropriate. • Sealed with a gas-tight, bolted lid during normal operation.
11. Slurry level indicator	Provides a simple visual indication of changes in the slurry level within the digester or outlet system.	• Can consist of a simple vertical pipe or other suitable level-indication mechanism. • Used to monitor slurry-level changes during operation and may provide an indication of operating conditions within the digester.

Source: Author's creation

4.2.5. Size and shape of the proposed biodigester

Based on the feedstock and HRT assumptions above, an 80 m³ fixed-dome biodigester is proposed for both cooperative typologies to provide a standardized basis for the business model. A cylindrical underground chamber is considered a practical configuration, with indicative dimensions of approximately 4.0 m in diameter and 6.4 m in height. Final dimensions and structural specifications should be determined through detailed engineering design and site-specific assessment. The fixed gas dome would be integrated into the digester structure and designed to accommodate the expected biogas production of approximately 30–40 m³ per day (Figure 8).

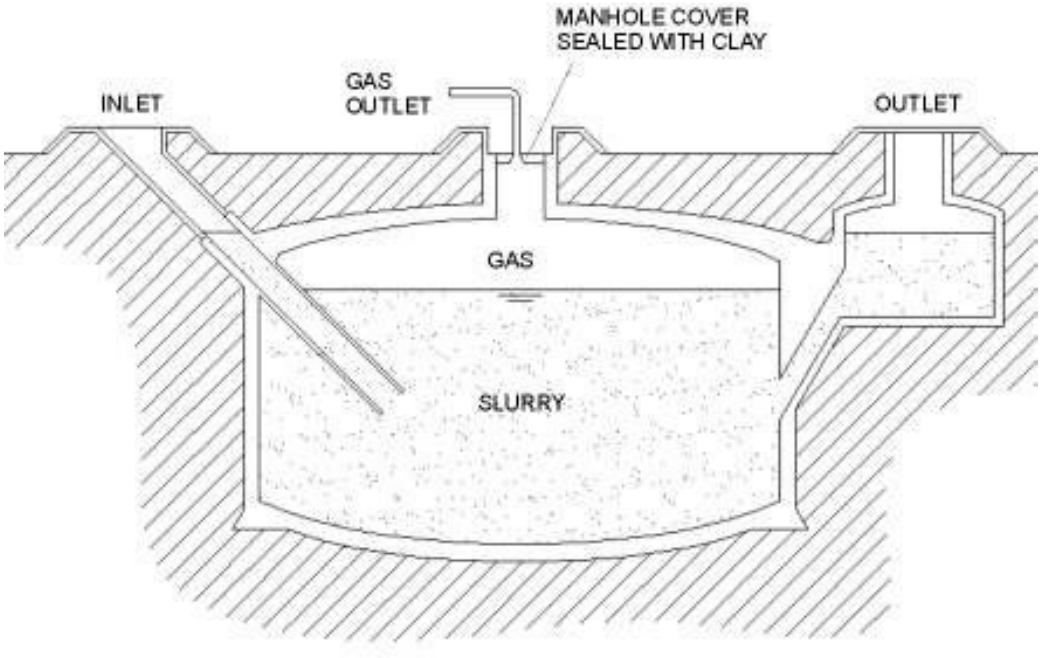


Figure 8. Typical fixed dome biodigester arrangement for the cooperatives
Source: Brennan and Butler 2007

4.2.6. Business model canvas for cooperative-based biodigester

The business model canvas is a strategic framework for describing how a business creates, delivers, and captures value. It consists of nine interlinked elements covering the key partners, activities, resources, value proposition, customer relationships, channels, customer segments, cost structure, and revenue streams (Figure 9). For the proposed cooperative biodigester, these elements translate the technical system described above into an operational and commercial model.

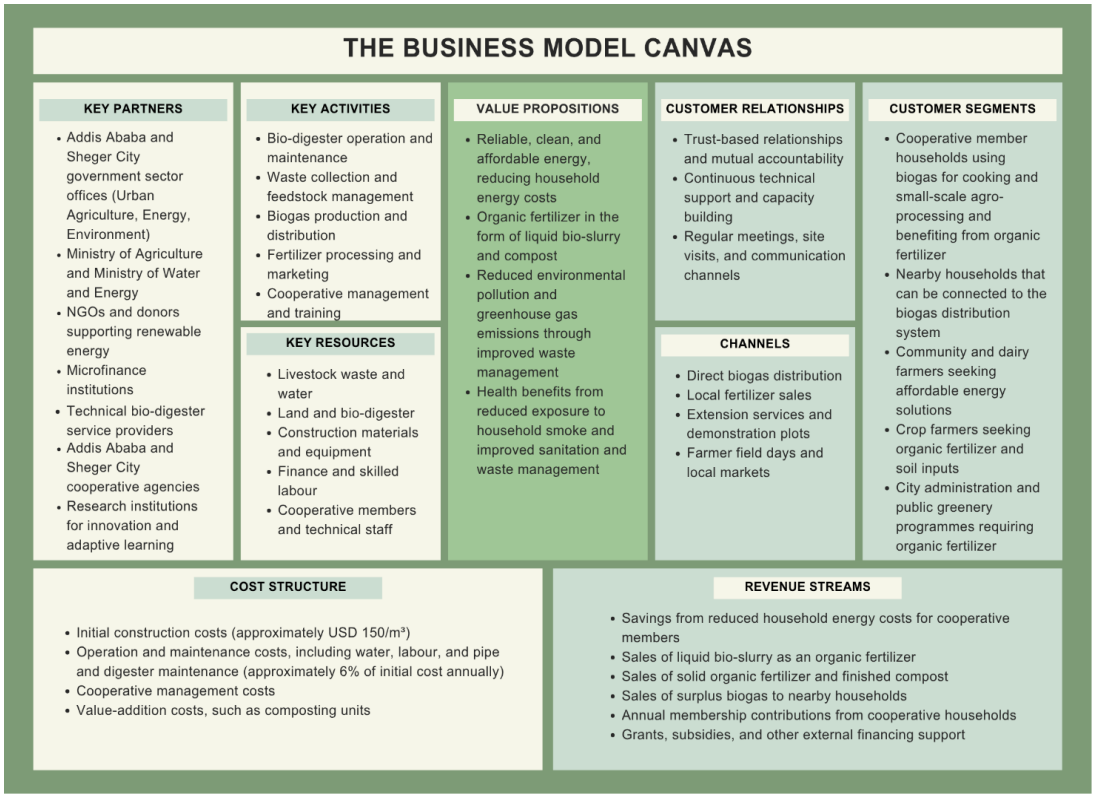


Figure 9. Business Model Canvas for the proposed cooperative biodigester
Source: Author's creation

4.2.7. Operation framework/governance

Implementing the cooperative biodigester would require clear ownership, defined responsibilities, transparent decision-making, and effective coordination among members and external support institutions. The cooperative-based model would be managed by newly formed cooperatives comprising approximately 8–15 livestock-owning households in the target area. Members would collectively own and manage the biodigester, with governance arrangements designed to promote accountability, transparency, and equitable participation.

The proposed governance structure would comprise three main bodies:

- **General assembly:** The highest decision-making body, responsible for major decisions concerning cooperative governance, membership, financial arrangements, benefit sharing, and overall management.
- ***Management committee*:** Elected members responsible for coordinating day-to-day operations, financial management, maintenance arrangements, and implementation of decisions made by the General Assembly.
- ***Technical staff*:** Trained cooperative members or employees responsible for feedstock collection, biodigester operation, routine monitoring, and basic maintenance.

The cooperative would also establish partnerships with local government agencies, NGOs, and technical service providers to provide training, technical backstopping, and other support. Systematic record-keeping would cover financial transactions, biogas distribution, fertilizer production and sales, and member contributions. Income distribution would follow the agreed cooperative bylaws.

Inclusive participation should be incorporated into the governance structure, including opportunities for women and youth to participate in decision-making, technical roles, and cooperative management. Long-term financial sustainability would depend on a combination of member contributions, service charges, product revenues, and reinvestment of a proportion of income into maintenance, upgrading, and future expansion.

4.2.8. Market options and strategy

The cooperative would operate in local markets for clean energy and organic fertilizer. Potential users of biogas include cooperative member households, nearby households that can be connected to the distribution system, and small enterprises requiring affordable energy for cooking or productive activities. Potential markets for organic fertilizer include local crop and vegetable farmers, private gardens, and public greenery programmes.

The cooperative can use different marketing strategies to sell the products, including:

- **Government partnerships:** Work with the Addis Ababa and Sheger City Urban Agriculture Bureaus and other relevant government offices to support market linkages, technical assistance, and access to institutional users.
- **Development partnerships:** Collaborate with NGOs, development partners, and donors to access technical assistance, financial support, market development opportunities, and wider distribution networks.
- **Clean-energy partnerships:** Establish linkages with renewable-energy and green-development programmes to promote biogas as a clean and affordable energy source and support the marketing of organic fertilizers for sustainable agriculture.
- **Demonstration and awareness:** Establish demonstration sites and organize regular community demonstrations and farmer field days to increase awareness, demonstrate the benefits of biogas and organic fertilizers, and build user confidence.
- **Local distribution and sales:** Market liquid bio-slurry and compost through local agricultural networks, markets, direct sales to farmers, and potential urban users, including private gardens and public greenery.
- **Product positioning:** Develop appropriate packaging, quality standards, and branding for bio-slurry and compost to position them as safe, reliable, and high-quality organic fertilizers and improve customer recognition and acceptance.

Market development should initially focus on nearby households, farmers, and institutions to minimize distribution costs and establish a stable customer base. As production capacity and market demand increase, the cooperative could gradually expand sales to additional households, agricultural producers, institutions, and urban users.

4.2.9. Financial viability of the cooperative biodigester

The financial viability of the proposed cooperative biodigester was assessed using a benefit-cost ratio (BCR). The assessment considers the initial investment required to establish the biodigester and associated infrastructure,

annual operation and maintenance (O&M) costs, and direct financial benefits from household energy savings and the sale of surplus biogas and organic fertilizer. Wider social and environmental benefits are discussed separately and are not monetized in the BCR analysis.

Financial assumptions

The analysis is based on the following assumptions (Table 18).

Table 18. Financial assumptions for the proposed cooperative biodigester

Parameter	*Assumption*
Biodigester capacity	80 m³
Expected biogas production	30–40 m³/day
Economic life	15 years
Initial biodigester cost	USD 150/m³
Annual O&M cost	6% of initial investment
Land and initial establishment costs	50% of initial investment
Discount rate	12%
Exchange rate	ETB 160/USD
Average cooperative size	12 households
Household biogas demand*	2 m³/household/day
Household energy saving	ETB 600/household/month
Surplus biogas price	USD 0.30/m³
Liquid bio-slurry price	USD 0.002/litre
Compost price	USD 0.05/kg
* Based on an assumption from Khandelwal and Gupta (2009) that with an average household size of 4-5 consumes 0.475 m^3 of biogas per hour and hence for 3-4 hours of biogas would result in a consumption of 2 m³/household/day**.**	

Source: Author's creation

Initial investment and operating costs

The estimated construction cost of the 80 m³ biodigester is approximately USD 150/m³, giving an initial investment of USD 12,000 (ETB 1,920,000) at the assumed exchange rate of ETB 160/USD. Annual O&M costs are estimated at 6% of the initial investment (Obileke et al. 2022), equivalent to ETB 115,200 (USD 720) per year. These include routine labour, water, maintenance of pipes and other system components, and minor repairs. An additional ETB 960,000 (USD 6,000) is allowed for land acquisition or preparation and initial cooperative establishment and administrative costs, equivalent to 50% of the initial investment.

Direct financial benefits

The cooperative can generate financial benefits through three main channels: household energy savings, surplus biogas sales, and organic fertilizer sales.

i. Household energy savings and surplus biogas

Household energy savings are based on the traditional fuels that biogas can replace. As shown in Section 3.6, firewood, charcoal, and cow dung account for approximately 24% of household energy use, and with average monthly household energy expenditure of ETB 2,407 (USD 15.04), this corresponds to approximately ETB 600 (USD3.75) per household per month. Electricity, which accounts for most household energy use, is assumed not to be substituted. For an average cooperative of 12 households, with estimated household demand of 2 m³ of biogas per day, total household demand is approximately 24 m³/day. At an average production level of 35 m³/day, approximately 11 m³/day would remain available for sale, equivalent to approximately 4,015 m³/year.

Table 19. Estimated annual financial benefits from the proposed cooperative biodigester

Benefit source	Basis	Annual value (ETB)
Household energy savings	ETB 600 × 12 households × 12 months	86,400
Surplus biogas sales	4,015 m³ × USD 0.30 × ETB 160	192,720
Subtotal		**279,120**

Source: Author's creation

The household energy savings are equivalent to approximately USD 540 per year, while surplus biogas sales generate approximately USD 1,204.50 per year. The combined annual value from household energy savings and surplus biogas sales is therefore 279,120 (USD 1,744.50) (Table 19).

ii. Organic fertilizer sales

The digestate generated by the biodigester provides an additional revenue stream. Approximately 50% of the daily digestate is assumed to be marketed as liquid bio-slurry, equivalent to approximately 1,335 litres/day. The remaining material can be processed into solid organic fertilizer, with approximately 95 kg/day assumed to be marketed as finished compost.

Table 20. Estimated annual financial value of organic fertilizer products from the proposed cooperative biodigester

Product	Estimated marketed quantity	Annual value (ETB)
Liquid bio-slurry	1,335 litre/day	155,928
Finished compost	95 kg/day	277,400
Subtotal		433,328

Source: Author's creation

The liquid bio-slurry is estimated to generate ETB 155,928 (USD 974.55) per year, while finished compost generates ETB 277,400 (USD 1,733.75) per year. The combined annual value of organic fertilizer sales is therefore ETB 433,328 (USD 2,708.30).

Combining energy savings, gas sales, and fertilizer commercialization, the estimated total annual direct financial benefit is ETB 712,448 (USD 4,452.80) (Table 20).

iii. Benefit-cost analysis

The BCR was calculated by comparing the present value of the quantified direct benefits with the present value of the total costs over the 15-year analysis period, using a discount rate of 12%.

Table 21. Summary of financial costs, benefits, and benefit-cost ratio of the proposed cooperative biodigester

Financial indicator	*Value*
Initial investment	ETB 1,920,000 (USD 12,000.00)
Land and initial establishment costs	ETB 960,000 (USD 6,000.00)
Annual O&M costs	ETB 115,200 (USD 720.00)
Present value of O&M costs	ETB 784,612 (USD 4,903.82)
Present value of total costs	ETB 3,664,612 (USD 22,903.82)
Annual direct financial benefits	ETB 712,448 (USD 4,452.80)
Present value of total benefits	≈ ETB 4,852,400 (≈ USD 30,327)
Benefit-cost ratio (BCR)	≈ 1.32

Source: Author's creation

Based on the assumed 12% discount rate and 15-year project life, the present value of total benefits is estimated at approximately ETB 4.85 million (USD 30,327), while the present value of total costs is approximately ETB 3.66 million (USD 22,904). The resulting benefit-cost ratio is 1.32 (Table 21). Under the assumptions used in the model, the estimated direct financial benefits exceed the corresponding discounted costs by about 32%. The result is sensitive to the assumed household energy savings: values of ETB 530–750 per household per month would give a BCR of about 1.31–1.36.(Table 21). Under the assumptions used in the model, the estimated direct financial benefits exceed the

corresponding discounted costs by 32%. However, the result should be interpreted as an indicative assessment rather than a definitive investment return. Actual financial performance will depend on construction costs, feedstock availability, biodigester efficiency, household energy demand, organic fertilizer prices and market absorption, transport costs, maintenance requirements, and the cooperative's ability to establish reliable commercial outlets for surplus products. A sensitivity analysis should therefore be undertaken during detailed feasibility assessment to examine how changes in capital costs, biogas yield, fertilizer pricing, feedstock availability, and operating costs affect long-term financial viability.

4.2.10. Risks and mitigation

Cooperative biodigesters have the potential to provide a financially viable and resource-efficient waste management and energy solution in the Akaki sub-basin. However, their long-term sustainability will depend on effective governance, reliable technical management, adequate financing, and a consistent supply of feedstock. Establishing a transparent, accountable, and legally sound cooperative structure is therefore critical to the success of the proposed model. Table 22 summarizes the main risks anticipated for the cooperative biodigester, drawing on the technical assessment as well as concerns raised by farmers during the household survey and FGDs (Section 3), together with the corresponding mitigation measures.

Table 22. Anticipated risks and mitigations

Risk Category	Description	Mitigation strategies
Technical	System breakdowns, inadequate or inconsistent feedstock supply, and fluctuations in biogas production.	• Engage qualified biodigester specialists for design and installation. • Provide technical training for operators. • Conduct regular inspection and preventive maintenance. • Maintain a dedicated fund for repairs and spare parts. • Establish a reliable feedstock collection and supply system.
Financial	High initial investment requirements, inadequate cash flow, and pressure from recurring operation and maintenance costs.	• Seek subsidies, grants, and development financing. • Introduce membership contributions or user fees. • Diversify revenues through biogas and fertilizer sales. • Develop partnerships with government agencies and NGOs. • Allocate revenues for O&M and future maintenance.
Social/Governance	Limited member commitment, unequal participation, leadership fatigue, and potential internal conflicts over responsibilities, costs, and benefits.	• Secure clear member commitments at establishment. • Develop clear legal bylaws and member responsibilities. • Ensure transparent governance and financial management. • Establish mechanisms for conflict resolution. • Rotate leadership roles and provide appropriate stipends.
External	Changes in government policies and regulations, fluctuations in energy and fertilizer prices, and changes in market conditions.	• Prioritize internal energy and fertilizer cost savings. • Monitor relevant policy and regulatory developments. • Maintain engagement with government and development partners.

	• Seek policy support for waste management and resource recovery. • Develop markets for biodigester outputs.

Source: Author's creation

5 Limitations of the Study

The findings should be interpreted considering several limitations. The household survey covered 170 households across the six selected sub-cities of Addis Ababa, representing approximately 57% of the planned sample of 300 households. While the survey provides useful insights into livestock waste management practices and farmers' perspectives, the smaller-than-planned sample may limit the extent to which the findings represent all livestock-owning households, particularly within individual sub-cities. The sampling approach was also not fully probability-based (Section 2.4.1), which may affect the generalizability of the findings and the interpretation of differences between locations. In addition, the data was self-reported, and the proposed biodigester business plan is based on modelling assumptions that have not yet been validated through on-site implementation. These limitations should be considered when interpreting the results and financial projections, while recognizing their value in informing planning, identifying opportunities, and guiding future pilot implementation and validation in the Akaki sub-basin.

6 Conclusions and Recommendations

The Akaki sub-basin encompasses the major urban centers of Addis Ababa and Sheger City, both of which have growing numbers of livestock-owning households. Livestock waste management is an increasing challenge across the catchment. Many livestock farms are located along riverbanks and watercourses, and a substantial proportion of livestock waste is ultimately discharged into rivers, contributing to water pollution and associated public health risks. In Sheger City, direct application of fresh manure to agricultural fields is also common, although disposal into rivers remains the dominant practice overall. Recent strengthening of municipal guidelines and penalties related to livestock waste disposal into rivers has increased the need for practical alternatives that support both waste management and resource recovery.

Three potential biodigester models were assessed for the sub-basin: cooperative-based, private individual-farmer, and independent youth-led models. The cooperative model was selected for detailed business planning because it allows investment and operating costs to be shared among members, facilitates collective management, and provides a mechanism for more equitable distribution of benefits. This is also consistent with farmers' stated preference for the cooperative approach (Section 3). An 80 m^3 biodigester is proposed for two cooperative configurations: small-scale farmers comprising approximately 10–15 households and large-scale commercial farmers comprising approximately 5–10 households. The proposed system is estimated to produce approximately 30–40 m^3 of biogas per day, which is expected to meet members' household energy requirements while providing scope for surplus biogas to be sold. Bio-slurry and compost would provide additional opportunities for resource recovery and revenue generation. The benefit-cost analysis resulted in a BCR of 1.3, indicating that the proposed cooperative biodigester model is financially viable under the assumptions used in the analysis.

Based on these findings, the following recommendations are proposed to advance sustainable livestock waste management and resource recovery in the Akaki sub-basin.

Large-scale biodigesters: In addition to the three near-term models assessed in this report, the Addis Ababa City Administration should consider developing well-planned large-scale biodigester facilities to support more comprehensive livestock waste management and resource recovery, particularly in areas with high concentrations of livestock production.

Support for individual farmers: A substantial proportion of livestock farmers in the sub-basin have expressed interest in investing in biodigesters using their own resources. Targeted technical and institutional support should be provided to these farmers to facilitate early adoption and piloting. Early adopters could also demonstrate the practical benefits of the technology and contribute to wider uptake among livestock producers.

Technical support and expert linkages: Although technical experts have been trained through various projects, stronger mechanisms are needed to connect these experts with farmers and groups seeking to establish biodigesters. The reported failure or non-functioning of some previously installed systems highlights the importance of appropriate design, installation, operation, and maintenance. Relevant local government offices should therefore

facilitate linkages between qualified technical experts and potential biodigester users and support access to technical services throughout the system's operational life.

Integration of biodigesters into livestock sheds: Government-developed livestock sheds, particularly those leased for dairy production, should incorporate appropriate livestock waste management facilities, including biodigesters where technically and economically feasible. Biodigesters should be considered during the design of new livestock sheds and, where feasible, integrated into existing facilities.

Strengthened stakeholder coordination: Effective livestock waste management requires coordinated action across the livestock, energy, agriculture, and environmental sectors. Urban Agriculture Offices, the Ministry of Agriculture, the Ministry of Water and Energy, the Environmental Protection Authority, NGOs, development partners, and technical experts should strengthen collaboration on planning, technical support, financing, regulation, and market development for recovered resources.

Research and innovation: Further research should support the development of sustainable livestock waste management and circular economy approaches. Priority areas include assessing the impacts of biodigester adoption, refining business models for different scales and user groups, improving biodigester technologies, and developing appropriate approaches for the collection, processing, quality assurance, and marketing of biodigester outputs.

Policy and institutional support: Livestock waste management in the Akaki sub-basin would benefit from clearer institutional responsibility and dedicated policy and strategic support. A government institution or designated authority should be given a clear mandate to coordinate livestock waste management, supported by appropriate strategies and guidelines for waste treatment, resource recovery, and the safe and effective marketing and use of recovered products.

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