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ES-6085-2019 Standard Test for Energy Performance and Safety for Clean Cookstoves in Ethiopia

Summary report of Ethiopian standard test results for twenty-six solid biomass cookstoves

September 2024
Addis Ababa, Ethiopia

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Acronyms

CCT	Controlled Cooking Test
EnDev	Energising Development
ECA	Ethiopian Conformity Authority
ECCA	Ethiopian Clean Cooking Alliance
ES	Ethiopian Standard
ESA	Ethiopian Standards Authority
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
ICS	Improved Cookstove
IMS	Institutional Mirt Stove
IRS	Institutional Rocket Stove
ISO	International Organisation for Standardisation
KPT	Kitchen Performance Test
L	Litre
MoWE	Ministry of Water and Energy
PEA	Petroleum and Energy Authority
RETDPC	Rural Energy Technology Development and Promotion Centre

Executive Summary

Developing sustainable markets for energy-efficient, safe and quality cookstove technologies requires product testing and standardisation. Ethiopia has adopted national standards that are fully aligned with the international standards (ISO) for improved and clean cookstoves[1]. Standards help determine which stoves are most likely to achieve social, economic, and environmental benefits based on their performance in standard testing procedures. ISO standards also enable international comparisons of technologies.

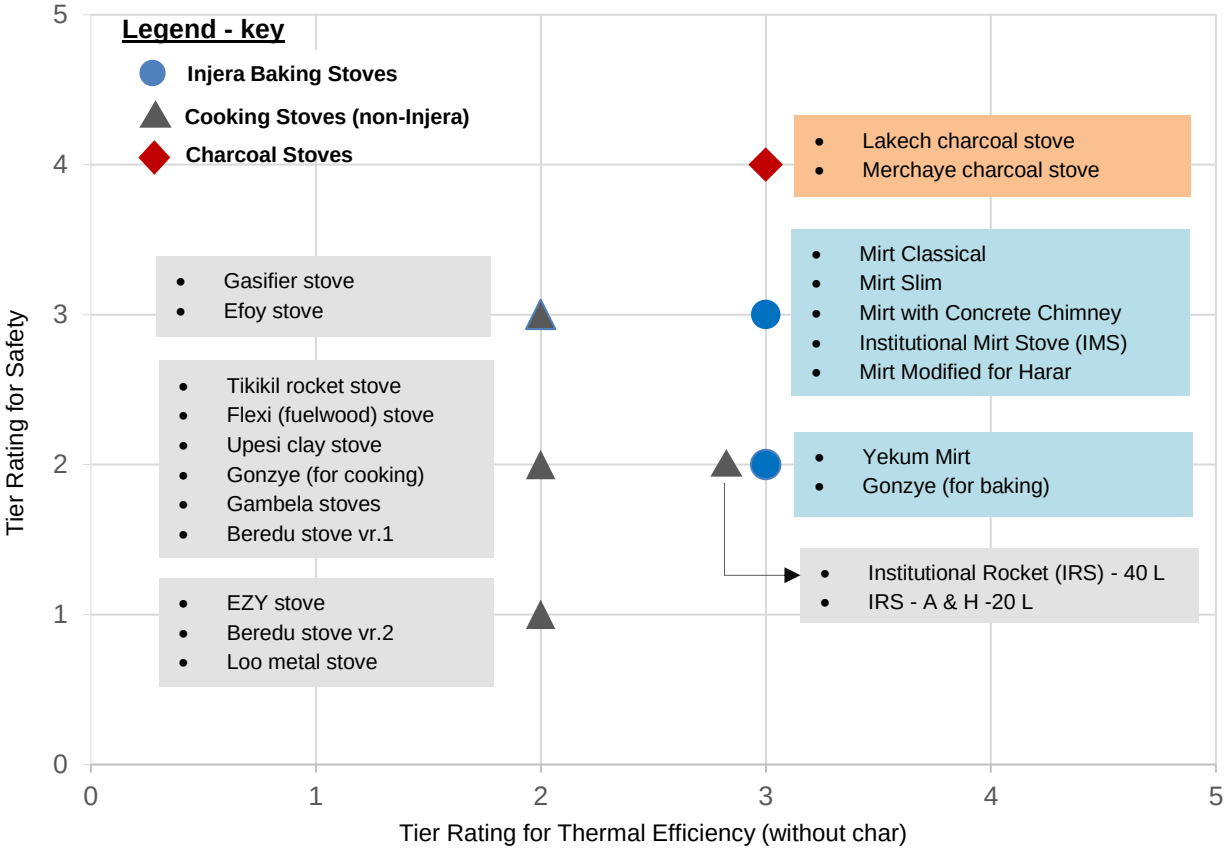
The objective of this study is to summarise the results of the Ethiopian Standard (ES) tests for thermal energy performance and safety for twenty-six solid biomass cookstoves in Ethiopia. Emissions and durability were not evaluated due to lack of necessary equipment. This study has been commissioned by the Energising Development (EnDev) Programme Ethiopia, implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, in collaboration with the Rural Energy Technology Development and Promotion Centre (RETDPC) of the Ministry of Water and Energy (MoWE), Government of Ethiopia.

Key Findings

The Ethiopian Standard test results indicate that the Ethiopian solid biomass cookstove portfolio offers cookstoves rated between Tier 2 and Tier 3 in terms of both thermal energy performance and safety. Most Injera baking stoves have achieved Tier 3 while most of the cooking stoves (non-Injera) have attained Tier 2 in both categories. The most widely promoted and marketed charcoal stoves nationally, Lakech and Merchaye stoves, have achieved a Tier 3 rating for thermal energy performance and a Tier 4 rating for safety.

The figure below provides a comprehensive mapping of ES test results combining the two dimensions (thermal energy efficiency and safety) for the tested solid biomass cookstoves in Ethiopia. Furthermore, Annex A provides a consolidated summary of ES test results for the tested solid biomass cookstoves in table form. It is important to note that this report only includes 26 selected stoves while there are more biomass stoves on the Ethiopian market that could not be included in the scope of this study due to various reasons. Annex B provides the thermal energy efficiency test results for one additional advanced biomass stove.

[1] The ES ISO standards are available on website of the Institute for Ethiopian Standards (https://ethiostandards.gov.et/).



Based on the study's findings, the following recommendations are provided to guide further action.

- **Complete ISO Standard Testing:** Conduct evaluations for the remaining two ISO metrics (emissions and durability) to fulfil all ISO test requirements. This is particularly important for emissions, as it is becoming the most demanding metric for project developers, donors, and development partners promoting clean cooking solutions. Moreover, it is recommended to include additional stoves in a future update of this report, in particular advanced biomass stoves, which may be at the market introduction stage.
- **Support Standardisation Efforts:** Use the Ethiopian Standard ISO test results to support efforts in enforcing the standard testing, certification, and labelling system for biomass cookstoves. This requires close coordination between relevant authorities – the Ministry of Water and Energy (MoWE), the Petroleum and Energy Authority (PEA), and the Ethiopian Standards Agency (ESA) – in cooperation with the Ethiopian Clean Cooking Alliance (ECCA) and GIZ. Labelling can help motivate consumers to purchase and use the best-performing stoves, achieve the greatest multifaceted impacts, and guide stove producers in providing quality products.
- **Compile Comprehensive Documentation:** As a complement to the Ethiopian Standard ISO test reports, compile complete documentation for the tested biomass cookstoves. This should include the Controlled Cooking Test (CCT) and Kitchen Performance Test (KPT) reports, as well as various complete manuals. This information is crucial for informing and leveraging project developers, impact donors, and relevant development partners in promoting cleaner cooking solutions.

1. Introduction

1.1 Background

Internationally recognised standards for household energy devices play an important role in developing sustainable markets by providing clear information on device performance as well as regulation and guidance for manufacturers to meet efficiency, environmental, safety, and quality standards. These standards instil consumer confidence by highlighting device reliability, fuel-saving potential, and emissions reduction. They also help identify which stoves are most likely to achieve social, economic, and environmental benefits based on their performance in standard testing. The results of these tests guide the promotion of stoves with the highest possible performance, taking into account household needs, costs, supply issues, and locations (WHO, 2022).

Since 2018, the International Organization for Standardization (ISO) has developed standards for improved cookstoves and clean cooking solutions, including protocols for testing stoves in both laboratory and field settings. The ISO standard laboratory protocols include detailed procedures for using water boiling tests to assess stove efficiency and emissions, as well as conducting safety and durability evaluations. Stove testing protocols in real-life settings assess social impacts such as time savings, gender impacts, and livelihood impacts.

Ethiopia has adopted two ISO standards at the national level:

1. Ethiopian Standard ISO 19867-1: 2018: Clean cookstoves and clean cooking solutions - Harmonized laboratory test protocols – Part 1: Standard test sequence for emissions and performance, safety, and durability (ESA, 2018).
2. Ethiopian Standard ISO 19869: 2021 – Clean cookstoves and clean cooking solutions - Field testing methods for cookstoves (ESA, 2021).[2]

Ethiopia's Cookstoves Landscape

More than 90% of the population in Ethiopia lacks access to clean cooking. In 2021, access to clean fuels and cooking technologies in Ethiopia reached only 7.5% (World Bank, 2024). The World Bank Group's Multi-Tier Framework (MTF) study report in 2018 revealed that 63.3% of households use three-stone open fires, 13.6% use self-built stoves, 18.2% use manufactured/produced biomass stoves, and 4.2% use clean stoves (World Bank/ESMAP, 2018).

One key observation relevant to this ISO test study is that 18.2% of households use manufactured/produced biomass stoves. Of these, 16.2% use charcoal stoves while 1.2% of households use firewood (and other biomass fuels burning) stoves[3]. This figure, though indicating a low penetration rate, implies the availability of predominately locally manufactured/produced improved cookstoves (ICS) technology in rural households. Several resources document that ICS offer economic, social, and environmental benefits (Jeuland and Pattanayak, 2012; Jeuland and Tan Soo, 2016). They also contribute to and serve as potential solutions in the transition towards cleaner cooking solutions.

[2] The ES ISO standards are available on website of the Institute for Ethiopian Standards (https://ethiostandards.gov.et/).

[3] The World Bank Multi-Tier report in 2018 was conducted based on the 2017 Ethiopian population estimate of 108.1 million, which translates to around 21 million households (with a household size of 5.81). Therefore:

- 16.2% of charcoal stove users translate to around 3.4 million households.
- 1.2% of firewood (other solid biomass fuels) stove users translate to around 252,000 households.

ISO standard test results are increasingly recognized as critical evidence for communicating the performance of nationally available cooking solutions at national and international level. Therefore, conducting and reporting ISO standard tests for improved biomass stoves in Ethiopia would strengthen ongoing national cookstove initiatives and enhance communication within the cooking energy sector, including among government bodies, the private sector, consumers, civil society organizations (CSOs), and development partners.

In this context, the Energising Development (EnDev) Programme Ethiopia, implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH in collaboration with the Rural Energy Technology Development and Promotion Centre (RETDPC) of the Ministry of Water and Energy (MoWE), has commissioned ES ISO standard tests for twenty-six major solid biomass cookstoves in Ethiopia. The tests were conducted at the RETDPC, the national body for testing of biomass stoves in Ethiopia.

The Energising Development Programme is a global partnership for providing energy access. EnDev Ethiopia is currently financed by four donor countries, Germany, the Netherlands, Norway, and Switzerland. EnDev focuses on providing access to affordable, reliable, sustainable, and modern energy to drive social, economic, and environmental change.

1.2 Objective of the study

The overall objective of the study is to conduct ES ISO standard tests for thermal energy performance and safety for major solid biomass cookstoves in Ethiopia. This report provides a summary of the test results.

The specific objectives of the study are:

- To provide comprehensive ES ISO standard test results for thermal performance and safety for the nationally available solid biomass cookstoves. This aims to inform government stakeholders, private sector, consumers, project developers, donors, and various development partners in the cooking energy sector (e.g., carbon finance projects).
- To contribute to the ongoing effort of developing and enforcing a standard and labelling framework. This framework will inform consumers in making decisions about cookstove products and help improve the quality of products available on the market.
- To contribute to preparing the national biomass cookstoves catalogue with comprehensive ISO test reports (thermal performance and safety). This catalogue will facilitate better communication and information sharing with international and national partners in the cooking energy sector.

1.3 Scope of the study

The ES ISO standard tests of 26 solid biomass stoves were conducted from 8 February to 28 May 2024 at the RETDPC, the national testing laboratory facility for biomass stoves in Ethiopia. It is important to note that this report only includes 26 selected stoves while there are more biomass stoves on the Ethiopian market that could not be included in the scope of this study due to various reasons. Annex B provides the test results for an additional advanced biomass stove. Other stoves may be included in future updates of this report. While the ES ISO standard requires evaluating four cookstove performance metrics – thermal efficiency, emissions, safety, and durability – this study primarily focuses on two of these metrics: thermal efficiency and safety. As a result, the scope does not include the evaluation of emissions and durability. Box 1 provides the rationale for the

exclusion of these two metrics at this time.

Box 1: Rationale for exclusion of emissions and durability metrics

In this study, the two ES ISO performance metrics for emissions and durability were not evaluated alongside the thermal performance and safety tests.

a) **Emissions test**: The emissions test was not conducted primarily because no emissions test equipment is available in Ethiopia. However, key informants from RETDPC, GIZ, and SNV highlighted that the emissions test equipment is under procurement and import from the Approvecho Research Centre (US), which is to be installed at the RETDPC's Lab Centre. This will allow conducting the emissions test to help update the ES ISO emissions test's documentation for solid biomass cookstoves.

b) **Durability test**: The durability test was not performed due to the absence of essential equipment in Ethiopia, such as the Lab Humidifier Chamber and Electric Furnace. These tools are crucial for assessing damage and deterioration of cookstove parts caused by high temperatures.

Overall, it is anticipated that emissions and durability tests will be conducted soon, likely by 2025, to complete the documentation for all four ES ISO performance metrics for solid biomass cookstoves.

A total of 26 solid biomass cookstove systems were tested, categorized as follows: a) seven Injera baking stoves, b) fourteen cooking stoves (non-Injera baking), c) five charcoal stoves. Table 1 lists the cookstoves tested and their respective categories.

Table 1: The cookstoves tested and their category

Sr. No.	Cookstove tested and their category
A)	**Injera baking stoves**
1	Mirt Classic
2	Mirt Slim
3	Mirt with Concrete Chimney
4	Yekum Mirt
5	Institutional Mirt Stove (IMS)
6	Mirt Modified for Harar
7	Gonzye for baking
B)	**Cooking stoves (Non-Injera baking)**
1	Tikikil rocket stove
2	Flexi multifuel stove (for fuelwood)
3	EZY stove
4	Efoy stove
5	Loo metal stove
6	Beredu stove vr.1
7	Beredu stove vr.2
8	Upesi stove
9	Gonzye for cooking
10	Gambela fuelwood stove
11	Gambela multifuel stove (for fuelwood)
12	Gasifier stove
13	Institutional Rocket Stove (IRS) – 40L

14	IRS (20L) – A & H
C)	**Charcoal stoves**
1	Lakech charcoal stove
2	Merchaye charcoal stove
3	Flexi multifuel stove (for charcoal)
4	Gambela multifuel stove (for charcoal)
5	Kulbich charcoal stove

With this introduction, the report is structured as follows. Section 2 provides the Ethiopian standard methodology (protocols) used for evaluating the thermal energy and safety of the cookstoves. This section also covers associated aspects such as statistical analysis, test quality and assurance issues, test equipment and their calibration to ensure accurate data collection. Section 3 presents and discusses the overall ES test results, including a concise mapping of the combined test results for thermal energy efficiency and safety. Finally, Section 4 provides the conclusion and recommendations based on the test findings.

2. Methodology

The methodology section includes the ES ISO protocols for evaluating thermal energy performance and safety, as well as associated aspects such as statistical analysis, test quality and assurance issues, and the calibration of test equipment to ensure accurate data collection.

The tests were conducted in compliance with the Ethiopian Standard protocol 19867-1:2019. The Ethiopian Standard has been prepared under the direction of the National Technical Committee for Clean Cookstove (TC 101) and published by the Ethiopian Standards Agency (ESA). It is important to note that the Ethiopian Standards is fully aligned with ISO 19867-1:2018 " *Clean cookstoves and clean cooking solutions — Harmonized laboratory test protocols - Part 1: Standard test sequence for emissions and performance, safety and durability*," published by the International Organization for Standardization (ISO). For the Ethiopian Standard, the term “International Standard (IS)” is replaced with “Ethiopian Standard (ES)” throughout the document. This approach is consistent with the global practice of adopting ISO standards for biomass cookstoves in various countries.

2.1 Standard protocol for thermal energy performance evaluation

The Ethiopian Standard ISO 19867-1:2018, “*Clean cookstoves and clean cooking solutions - Harmonized laboratory test protocols - Part 1: Standard test sequence for emissions and performance, safety, and durability*” was used for assessing the thermal energy performance of biomass cookstoves. Table 2 provides the ES ISO thermal energy national performance targets and tier rating.

Table 2: ES ISO thermal energy performance targets and tier rating

	Tier	Thermal efficiency (%)
Better Performance 	5	≥50
	4	≥40
	3	≥30
	2	≥20
	1	≥10
	0	<10

Three primary ISO standard procedures are used for evaluating the three categories of Ethiopian biomass cookstoves. The first and most significant ISO protocol is for assessing the energy performance of Injera baking stoves. These stoves are a crucial component of the Ethiopian cookstove portfolio, as Injera baking is an energy-intensive activity and represents the largest sector of primary energy consumption in Ethiopia. Due to the unique features and cooking customs associated with Injera baking stoves, a local context ISO test protocol was adopted. Box 2 below outlines the rationale for using 16 litres of water boiling to evaluate these Injera baking stoves.

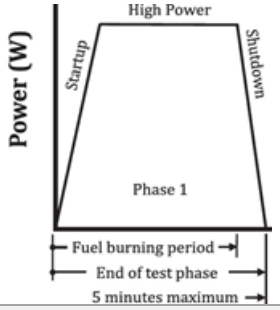
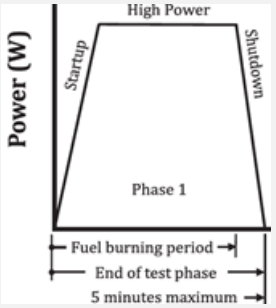
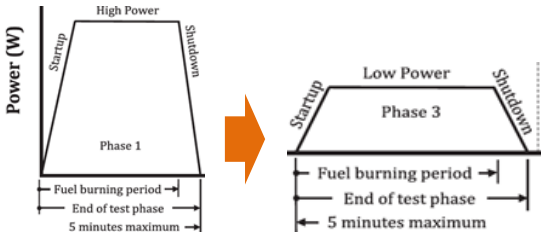
Box 2: Rationale for adopting 16 litres of water in ES ISO test thermal performance for Injera cookstoves

Injera is Ethiopia’s stable food, a traditional pancake-like bread made from ‘Teff’’, a grain commonly grown in Ethiopia. Injera baking cookstoves use a ceramic plate called ‘Mitad’, which is essential for the Injera baking process. Most Ethiopian households bake Injera 2-3 times a week, using average 16 litres of Injera dough per baking session, which typically yields 23-25 pieces of baked

Injera. The chosen 16 litres of water volume for testing reflects the actual volume used in a typical Ethiopian household. Due to the characteristic of the ceramic plate, which does not support boiling 16 litres of water, an aluminium pot with a diameter of 62 cm—proportional to the diameter of the baking cookstove—was used for the ES ISO test to evaluate energy performance. The large combustion chamber and associated large pot evaporation surfaces of these stoves are expected to result in high thermal efficiency. Additionally, Ethiopian households often use a significant portion of the leftover char from baking sessions for other cooking activities, such as making coffee or heating water. Therefore, the thermal efficiency metric, including char, provides a more accurate reflection of energy performance in the Ethiopian context.

Table 3 presents the three categories of cookstoves along with the associated ISO standard protocols used for evaluation, including Injera baking stoves, cooking stoves (non-Injera), and charcoal stoves.

Table 3: Categorisation of the cookstoves tested with employed standard test procedures

Sr. No.	Cookstoves Category	ISO Protocols used for evaluation	Cookstoves tested	Remarks
1	**Injera Baking Stoves**	• Continuous solid biomass fuels-fed stoves • Single level high-power phase test • 16 L water used • 60-minute boiling session 	1) Mirt Classical 2) Mirt Slim 3) Mirt with concrete chimney 4) Mirt modified for Harar 5) Institutional Mirt stove (IMS) 6) Yekum Mirt 7) Gonzye stove for baking	10 L was used for Mirt with modified for Harar (no. 4) to reflect the Harar region's common volume of dough.
2	**Cooking Stoves (non-Injera baking)**	• Continuous solid biomass fuels-fed stoves • Single level high-power phase test • 5 L water used • 60-minute boiling session 	1) Tikikil rocket stove 2) Flexi fuelwood stove 3) EZY stove 4) Efoy stove 5) Loo metal stove 6) Beredu stove vr.1 7) Beredu stove vr.2 8) Upesi clay stove 9) Gonzye for cooking 10) Gambela fuelwood 11) Gambela multifuel (for fuelwood) 12) Gasifier stove 13) Institutional Rocket stove (IRS) – 40L 14) IRS (20L) – A & H	Different water volumes were used for two types of IRS as they represent large cooking capacity. 40 L and 20 L were used for the two types of IRS cooking stoves.
3	**Charcoal Stoves**	• Batch-fed charcoal stoves • High-power and low-power phase tests • 2.5 L water used • 30-minute boiling session for each phase 	1) Lakech charcoal stove 2) Merchaye charcoal stove 3) Flexi multifuel stove (for charcoal) 4) Gambela multifuel stove (for charcoal) 5) Kulbich charcoal stove	ISO standard protocols have limited detailed guidance for charcoal stoves. Single high-power phase test (with 60 minutes) were used for stoves no.4 & 5.

2.2 Safety evaluation

The ES ISO 19867-1:2018 protocols for safety were employed for the safety evaluation. This standard provides detailed guidance on conducting each of the ten safety tests (ESA, 2018). Test scoring sheets and corresponding weighting factors were used to record and evaluate the specific safety test procedures. The ten safety test procedures are:

1) Sharp edges and points
2) Cookstove tipping
3) Containment of fuel
4) Obstructions near the cooking surface
5) Surface temperature
6) Heat transfer to the environment
7) Handle temperature
8) Chimney shielding
9) Flames surrounding cooking vessel
10) Flames existing fuel chamber.

The following materials and equipment were also used for assessing the ten-safety test procedures.

- Cloth, rag or loose clothing
- Stick chalk to sketch the stove, floor and/or wall
- Thermometer for measuring air temperature
- Infrared for measuring surface temperatures of the stove.

Tier rating for safety was conducted in accordance with ES ISO 19867-1:2018. Table 4 outlines the ES ISO safety performance targets and corresponding tier rating for solid biomass cookstoves.

Table 4: Ethiopian Standard ISO safety targets and tier rating

	Tier	Safety (Score)
Better Performance 	5	≥95
	4	≥86
	3	≥77
	2	≥68
	1	≥60
	0	<60

2.3 Statistical analysis of the test replicates

Guided by the ES ISO 19867-1: 2018 test protocol, at least five test replicates were performed on each sample stove tested. For all six required metrics, the mean value, standard deviation (SD), and 90% confidence interval[4] were analysed and presented. Further, the coefficient of variation (CoV) for each metric was analysed, determined, and presented to ensure and maintain an acceptable range of test results.[5]

[4] The confidence interval was calculated using the student's t-distribution at a confidence level of 90%.
[5] Preferably, the CoV should be below 25% based on good practices.

2.4 Test quality and assurance

For the two metrics – energy performance and safety – assessed for each tested cookstove, all procedures were followed in accordance with ES ISO 19867-1:2018 to adhere to the Ethiopian standard protocol. As a result, there were no deviations from the test protocol or implications due to operating conditions or measurement in the test results.

The calibration of test equipment at RETDPC's laboratory is conducted annually. The centre is currently the only national body performing stove test verification for various national cookstove carbon financing programs and projects. As part of key international carbon financing requirements, RETDPC ensures yearly equipment calibration and certification. Each piece of equipment at RETDPC is labelled with the following information: the equipment's serial number, calibration date, next calibration date, calibration certificate number, the name of the certifying body or agency, and the name of the calibrated expert.

2.5 Measurement methods

The measurement techniques (with corresponding equipment) for assessing thermal energy performance and safety[6] were conducted in accordance with ES ISO 19867-1:2018 protocol. Various key test equipment was used for specific tasks and activities related to the energy performance and safety evaluations. This testing equipment is calibrated annually at TECH-IN Ethiopia - Research and Development Institute, with calibration authorized by the Ethiopian Conformity Authority (ECA). The most recent equipment calibration was completed in June 2023. The following testing equipment was used for conducting the energy performance measurements (Figure 1).

- Thermometer (Testo brand with thermocouple, K type, made in Germany)
- Infrared thermometer (Fluke brand, made in the US)
- Digital scale (50 kg loading capacity, made in China)
- Moisture meter (Brennenstuhl Moisture Detector MD, made in Germany)

Figure 1: Test equipment: moisture meter, infrared, thermocouple, and digital scale

[6] Some of the equipment used for the thermal energy performance assessment (especially thermometer and infrared) was used for safety assessment as well, in particular for safety test evaluation no. 5, 6 and 7.

3. Test Results

3.1 Thermal energy performance

The ES ISO test results reveal a diverse range of results for the three broader categories of solid biomass cookstoves.

Injera baking stoves

- The energy performance of the seven Injera baking stoves indicates that their thermal energy efficiency, both without char and with char, ranges from 30% to 40% (with results between 31.2% to 36.7%). Thus, all Injera baking stoves are Tier 3 rated in terms of thermal efficiency. The highest thermal efficiency (without char) was measured at 36.3% for the Gonzye stove (for baking), while the lowest was at 31.2% for the Yekum Mirt.
- The high thermal efficiency of the Injera baking stoves is primarily attributed to the significant evaporation rate from the large surface area of the pot during the boiling of 16 litres of water. The cooking power measured for the Injera baking stoves ranges from a minimum of 2.50 kilowatt (kW) for the Mirt modified for Harar to a maximum of 4.78 kW for the Mirt with a concrete chimney.
- Regarding boiling point, all injera stoves reached the local boiling temperature before the end of 60-minute sessions. The maximum was recorded at 33 minutes for Institutional Mirt Stove (IMS), while minimum was recorded at 28 minutes for Mirt modified for Harar stove.

Cooking stoves (non-Injera)

- The energy performance of the cooking stoves reveals that their thermal energy efficiency, both with and without char, ranges from 20% to 30% (with results between 21.5% and 28.1%). This performance places most non-Injera cooking stoves at Tier 2 for thermal efficiency. The highest thermal efficiency (without char) was recorded for the Tikikil rocket stove at 28.1%, while the lowest was for the Upesi clay stove at 21.5%. The cooking power measured for these stoves ranges around 1 kW, specifically between 0.99 kW and 1.1 kW. Notably, the two large cooking stoves tested – the Institutional Rocket Stoves – achieved thermal efficiency above 30% (33.1% and 30.2%), qualifying them for a Tier 3 rating.
- Regarding boiling point, all cooking stoves (non-injera) reached the local boiling temperature before the end of 60-minute sessions. The maximum was recorded at 36 minutes for Flexi multifuel and EZY stoves, while minimum was measured at 27 minutes for Tikikil household rocket stove.

Charcoal stoves

- The most widely promoted and marketed charcoal stoves in Ethiopia, Lakech and Merchaye charcoal stoves have achieved thermal efficiencies of 33.2% and 30.9%, respectively. Both stoves are rated Tier 3 for thermal energy efficiency performance.

3.2 Safety

Safety assessment results indicate that most Injera baking stoves have achieved a Tier 3 rating, while most cooking stoves (non-Injera) have attained a Tier 2 rating.

Injera baking stoves

- Most Injera stoves (five out of seven), which are relatively heavier, fixed installed, and equipped with concrete-insulated combustion chambers have achieved a Tier 3 rating for safety. Only the Yekum Mirt and Gonzye stoves (for baking) have received a Tier 2 rating.

Cooking stoves (non-Injera)

- In terms of safety, the cooking stoves have achieved three different safety ratings. Most of the cooking stoves are rated Tier 2. However, two models – the Gasifier and Efoy stoves – have achieved Tier 3 ratings. In contrast, the entirely metal-made cooking stoves, such as the EZY stove, Loo metal stove, and Beredu stove vr.2 have received a Tier 1 rating for safety.

Charcoal stoves

- The widely and most marketed charcoal stoves nationally, Lakech and Merchaye charcoal stoves, have achieved a Tier 4 rating for safety.

Overall, Figure 2 provides a comprehensive mapping of ISO test results, combining the two dimensions of thermal energy efficiency and safety for the tested solid biomass cookstoves in Ethiopia.

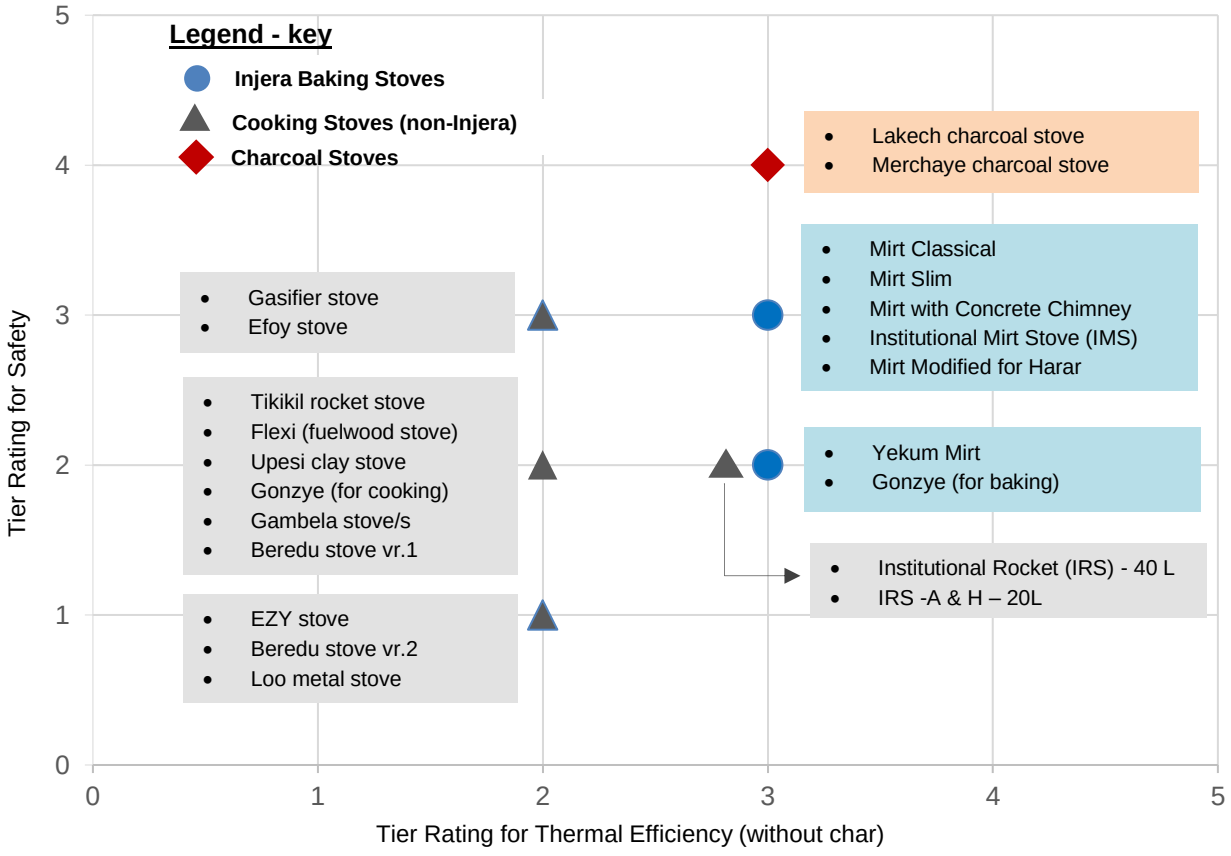


Figure 2: Mapping of ES ISO test results' tier rating in terms of thermal efficiency and safety

Additionally, the following three tables provide a summary of the results for the three categories of solid biomass cookstoves. Table 5 presents the summary test results for seven Injera baking stoves, while Table 6 and Table 7 provide summary test results for non-Injera cooking stoves and charcoal stoves, respectively.

Table 5 provides the summary of test results for the seven Injera baking stoves.

Table 5: Summary test results for Injera baking stoves

Sr. No.	Cookstove Name	Picture	Thermal Energy Performance		Safety (Score)
			Thermal efficiency (without char), %	Thermal efficiency (with char), %	
1	Mirt Classical		34.4 (Tier 3)	39.6 (Tier 3)	81 (Tier 3)
2	Mirt Slim		33.7 (Tier 3)	38.1 (Tier 3)	81 (Tier 3)
3	Mirt with Concrete Chimney		32.3 (Tier 3)	38.7 (Tier 3)	78.5 (Tier 3)
4	Mirt Yekum		31.2 (Tier 3)	36.5 (Tier 3)	76.5 (Tier 2)
5	Mirt Modified for Harar		31.7 (Tier 3)	38.8 (Tier 3)	81 (Tier 3)
6	Institutional Mirt Stove (IMS)		34.7 (Tier 3)	38.1 (Tier 3)	81 (Tier 3)
7	Gonzye stove (for baking)		36.3 (Tier 3)	39.6 (Tier 3)	76 (Tier 2)

Table 6 provides the summary of test results for the fourteen cooking stoves (non-Injera).

Table 6: Summary test results for cooking stoves (non-Injera)

Sr. No.	Cookstove name	Picture	Thermal Energy Performance		Safety (Score)
			Thermal efficiency (without char), %	Thermal efficiency (with char), %	
1	Tikikil rocket stove (for household)		28.1 (Tier 2)	29.5 (Tier 2)	73.5 (Tier 2)
2	Flexi multifuel stove (for fuelwood)		22.9 (Tier 2)	23.5 (Tier 2)	69.5 (Tier 2)
3	EZY stove		22.0 (Tier 2)	23.5 (Tier 2)	65 (Tier 1)
4	Efoy stove		24.1 (Tier 2)	27.4 (Tier 2)	81 (Tier 3)
5	Gonzye for Cooking		25.9 (Tier 2)	28.0 (Tier 2)	76 (Tier 2)
6	Gambela fuelwood stove		22.2 (Tier 2)	25.3 (Tier 2)	69 (Tier 2)
7	Gambela multifuel stove (for fuelwood)		21.5 (Tier 2)	24.3 (Tier 2)	70 (Tier 2)
8	Upesi clay stove		21.5 (Tier 2)	23.9 (Tier 2)	69 (Tier 2)

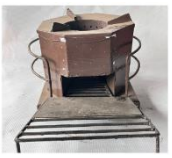
9	Loo metal stove		23.2 (Tier 2)	24.8 (Tier 2)	65 (Tier 1)
10	Beredu stove vr.2		23.5 (Tier 2)	24.2 (Tier 2)	65 (Tier 1)
11	Beredu stove vr.1		24.4 (Tier 2)	25.1 (Tier 2)	71 (Tier 2)
12	Gasifier stove		24.6 (Tier 2)	30.1 (Tier 3)	85 (Tier 3)
13	Institutional Rocket Stove (IRS) – 40 L		30.2 (Tier 3)	33.3 (Tier 3)	71 (Tier 2)
14	IRS (20L) – A & H		33.2 (Tier 3)	35.6 (Tier 3)	71.5 (Tier 2)

Table 7 provides the summary of the test results for the charcoal stoves.

Table 7: Summary test results for charcoal stoves

Sr. No.	Cookstove Name	Picture	Thermal Energy Performance		Safety (Score)
			Thermal efficiency (without char), %	Thermal efficiency (with char), %	
1	Lakech charcoal stove		33.2 (Tier 3)	N/A	86.5 (Tier 4)
2	Merchaye charcoal stove		30.9 (Tier 3)	N/A	86.5 (Tier 4)
3	Flexi multifuel stove (for charcoal)		24.6 (Tier 2)	N/A	92.5 (Tier 4)
4	Gambela multifuel stove (for charcoal)		27.7 (Tier 2)	N/A	90 (Tier 4)
5	Kulbich charcoal stove		20.2 (Tier 2)	N/A	86.5 (Tier 4)

4. Conclusion and Recommendations

The ES ISO test results indicate that the Ethiopian solid biomass cookstove portfolio included in this study offers cookstoves rated between Tier 2 and Tier 3 in terms of both thermal energy performance and safety. Most Injera baking stoves have achieved Tier 3 while most of the cooking stoves (non-Injera) have attained Tier 2 in both categories. The most widely promoted and marketed charcoal stoves nationally, Lakech and Merchaye stoves, have achieved a Tier 3 rating for thermal energy performance and a Tier 4 rating for safety.

Based on the preceding findings, the following recommendations are provided to guide further action.

- **Complete ISO Standard Testing:** Conduct evaluations for the remaining two ISO metrics (emissions and durability) to fulfil all ISO test requirements. This is particularly important for emissions, as it is becoming the most demanding metric for project developers, donors, and development partners promoting clean cooking solutions. Moreover, it is recommended to include additional stoves in a future update of this report, in particular advanced biomass stoves, which may be at the market introduction stage. Annex B provides the thermal efficiency test results for the Quayton pellet stove, which attained a Tier 3 rating.
- **Support Standardisation Efforts:** Use the Ethiopian Standard ISO test results to support efforts in enforcing the standard testing, certification, and labelling system for biomass cookstoves. This requires close coordination between relevant authorities – the Ministry of Water and Energy (MoWE), the Petroleum and Energy Authority (PEA), and the Ethiopian Standards Agency (ESA) – in cooperation with the ECCA and GIZ. Labelling can help motivate consumers to purchase and use the best-performing stoves, achieve the greatest multifaceted impacts, and guide stove producers in providing quality products.
- **Compile Comprehensive Documentation:** As a complement to the Ethiopian Standard ISO test reports, compile complete documentation for the tested biomass cookstoves. This should include the CCT and KPT reports, as well as various complete manuals. This information is crucial for informing and leveraging project developers, impact donors, and relevant development partners in promoting cleaner cooking solutions.

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Annex

Annex A: Consolidated summary table of ES ISO test results for 26 solid biomass cookstoves (non-exhaustive)

Table 8: Consolidated summary table of ES ISO test results for 26 solid biomass cookstoves (non-exhaustive)

Sr. No.	Cookstove Name	Thermal Energy Performance		Safety (Score)
		Thermal efficiency (without char), %	Thermal efficiency (with char), %	
A)	**Injera Baking Stoves**			
1	Mirt Classical	34.4 (Tier 3)	39.6 (Tier 3)	81 (Tier 3)
2	Mirt Slim	33.7 (Tier 3)	38.1 (Tier 3)	81 (Tier 3)
3	Mirt with Concrete Chimney	32.3 (Tier 3)	38.7 (Tier 3)	78.5 (Tier 3)
4	Yekum Mirt	31.2 (Tier 3)	36.5 (Tier 3)	76.5 (Tier 2)
5	Mirt Modified for Harar	31.7 (Tier 3)	38.8 (Tier 3)	81 (Tier 3)
6	Institutional Mirt Stove (IMS)	34.7 (Tier 3)	38.1 (Tier 3)	81 (Tier 3)
7	Gonzye stove for baking	36.3 (Tier 3)	39.6 (Tier 3)	76 (Tier 2)
B)	**Cooking Stoves (Non-Injera)**			
1	Tikikil rocket stove (for household)	28.1 (Tier 2)	29.5 (Tier 2)	73.5 (Tier 2)
2	Flexi multifuel stove (for fuelwood)	22.9 (Tier 2)	23.5 (Tier 2)	69.5 (Tier 2)
3	EZY stove	22.0 (Tier 2)	23.5 (Tier 2)	65 (Tier 1)
4	Efoy stove	24.1 (Tier 2)	27.4 (Tier 2)	81 (Tier 3)
5	Loo metal stove	23.2 (Tier 2)	24.8 (Tier 2)	65 (Tier 1)
6	Beredu stove vr.2	23.5 (Tier 2)	24.2 (Tier 2)	65 (Tier 1)
7	Beredu stove vr.1	24.4 (Tier 2)	25.1 (Tier 2)	71 (Tier 2)
8	Upesi stove	21.5 (Tier 2)	23.9 (Tier 2)	69 (Tier 2)
9	Gonzye stove for cooking	25.9 (Tier 2)	28.0 (Tier 2)	76 (Tier 2)
10	Gambela fuelwood stove	22.2 (Tier 2)	25.3 (Tier 2)	69 (Tier 2)
11	Gambela multifuel stove (for fuelwood)	21.5 (Tier 2)	24.3 (Tier 2)	70 (Tier 2)
12	Gasifier stove	24.6 (Tier 2)	30.1 (Tier 3)	85 (Tier 3)
13	Institutional Rocket Stove (IRS) - 40 L	30.2 (Tier 3)	33.3 (Tier 3)	71 (Tier 2)
14	IRS (20 L) - A & H	33.2 (Tier 3)	35.6 (Tier 3)	71.5 (Tier 2)
C)	**Charcoal Stoves**			
1	Lakech charcoal stove	33.2 (Tier 3)	N/A	86.5 (Tier 4)
2	Merchaye charcoal stove	30.9 (Tier 3)	N/A	86.5 (Tier 4)
3	Flexi multifuel stove (for charcoal)	24.6 (Tier 2)	N/A	92.5 (Tier 4)
4	Gambela multifuel stove (for charcoal)	27.7 (Tier 2)	N/A	90 (Tier 4)
5	Kulbich charcoal stove	20.2 (Tier 2)	N/A	86.5 (Tier 4)

Annex B: ES ISO test results for Quayton Pellet Stove

The Quayton household pellet stove was tested at RETDPC in accordance with ES 6085: 2019 for thermal energy efficiency only. As forced draft and batch pellet fuel-fed stove, the Quayton pellet stove was tested at high-power start phase for 60 minutes boiling sessions using 2.5 litres of water. For the test replicates on the samples, the thermal energy efficiency of the stove was measured at 37.7% - which implies a Tier 3 rating. The average cooking power of the stove was measured at 2.53 kW and the weighted fuel burning rate was determined at 9.0 g/min. Table 9 summarizes the test results.

Table 9: Test results for Quayton pellet stove

High power start phase (Variables determined)	**Unit**	**Average result**	**Picture**
Specific fuel consumption	g/liter	395	
Time to test	min	60	
Temp-corrected time to boil	min	61	
Burning rate	g/min	9	
Temp-corrected specific fuel consumption	g/liter	404	
Temp-corrected specific energy consumption	kJ/liter	7,070	
Boiling start time	min	17	
Thermal efficiency	**%**	**37.7**	
Firepower	watts	2,532	
Tier rating (thermal energy performance)	**3**		