Title: Bioenergy Analysis for 65 Factories of the Kenya Tea Development Agency Holdings Company Ltd (KTDA)

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Background

- Kenya Tea Development Agency Holdings Ltd. (KTDA) is Kenya’s largest tea producer.
- Fuelwood from third parties provides over 99% of the process heat required for drying tea at KTDA’s 67 tea factories.
- Fuelwood quality, supply security, sustainability **and price** are major concerns to KTDA’s management.
- Energy expenses are the second highest cost category after labor costs.

Goal and objectives

Goal:

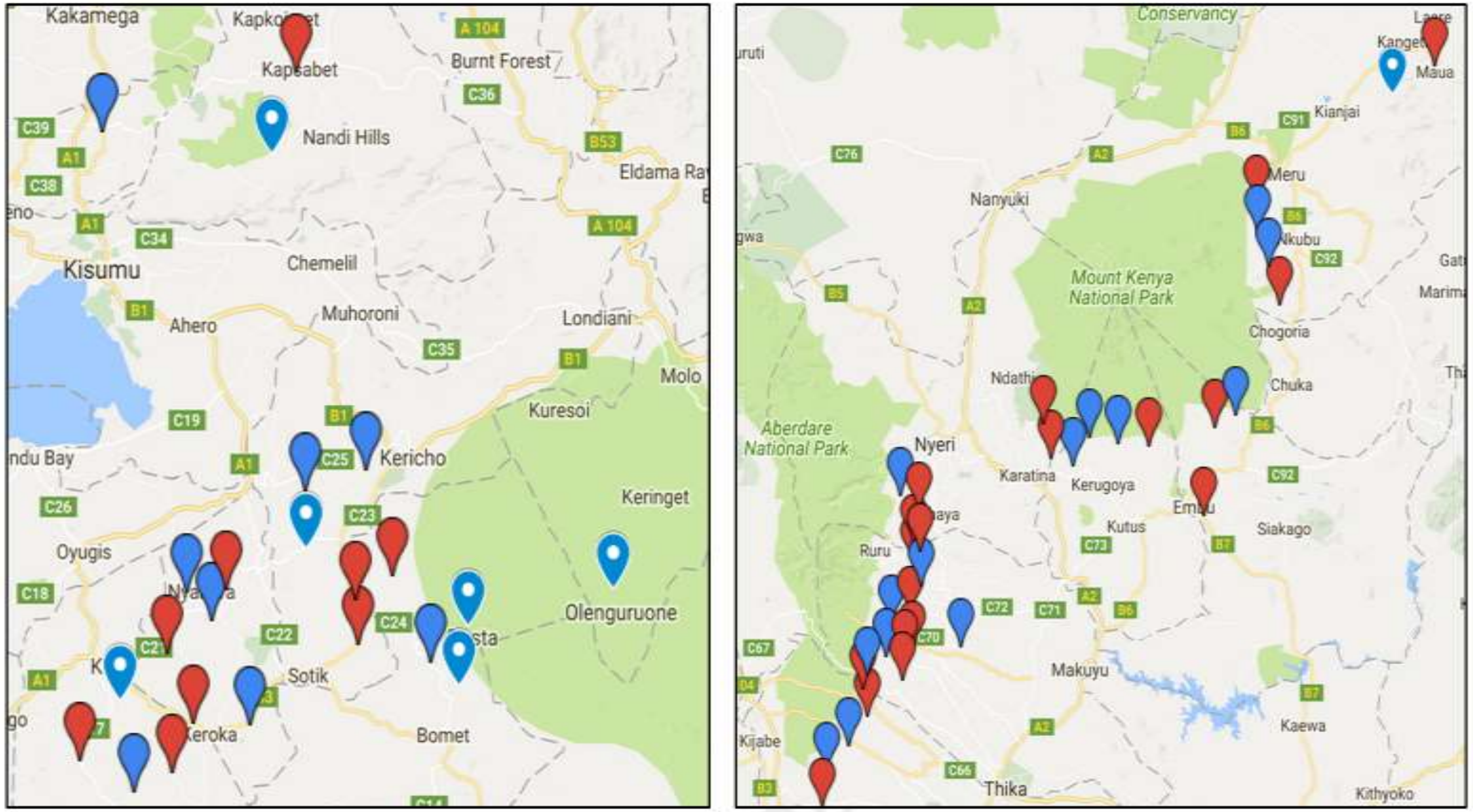
- Assist KTDA in identifying drivers of heat energy cost and specify performance and spread of 65 factories.

Research objectives:

- Review existing information
- Design an analytical framework covering:
  - fuelwood supply chains,
  - alternative biomass fuels supply chains,
  - onsite fuel logistics, and
  - boiler operations,
- Perform field surveys and Analyze results,
- Identify information gaps and suggest next steps.

This study does not replace the need for individual energy audits on a factory level.

Methodology: Factories Survey



2016 survey (blue) and 2020 survey (red)

Metrics for factories selection:

- Rep. across all seven KTDA regions,
- a range of factory sizes, and
- availability of mgmt to welcome the field team.

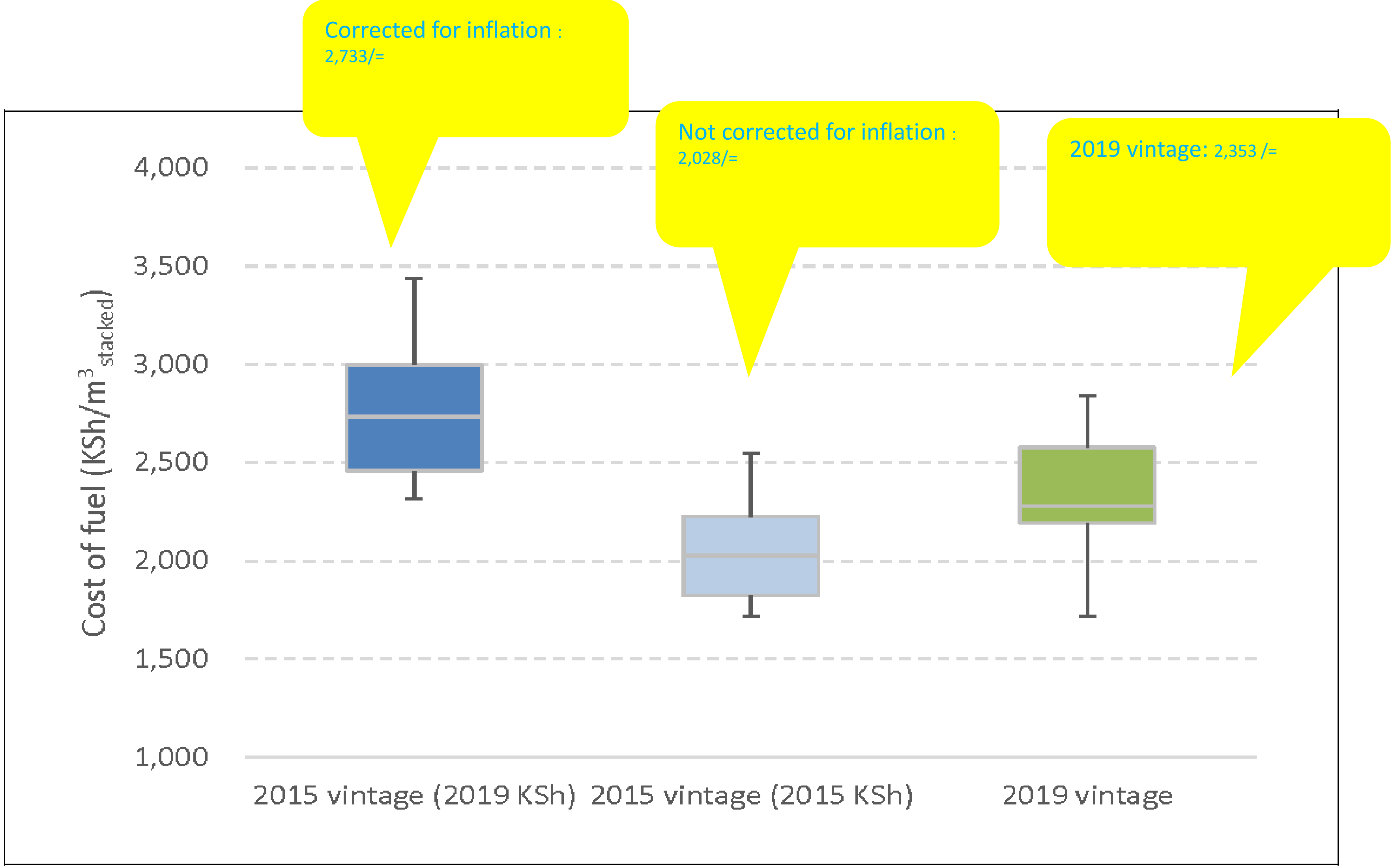
Variables analyzed

- Factory-level energy data
- Own fuelwood plantations
- Fuelwood storage and handling
- Fuelwood supply (up to 3 main suppliers)
- Current/Future alternative biomass use

Data Conversions and Analysis

- For the two separate cohorts of factories, we produced respective matrices consisting of information collected from all visited factories (Excel spreadsheets)
- The separate Excel spreadsheets were then appended to each other to allow KTDA-wide global analysis.
- Volumetric measurements for stacked fuelwood (m3 stacked) were converted to solid wood volume (m3 solid) using a factor of 1.4 (Francescato & Zuccoli, 2008).
- Calculated fuelwood energy content using the factory average moisture content of fuelwood at the gate and at the boiler mouth using 19 GJ/ton (Francescato & Zuccoli, 2008) for all wood species
- For energy content for alternative biomass fuels, we assumed 0.287 MWh per GJ.
- Financial data (e.g., wood price, plantation purchase costs, etc.) was normalized to 2019 KES to account for inflation.
- We analyzed the cases using classification and regression tree analysis (CART)

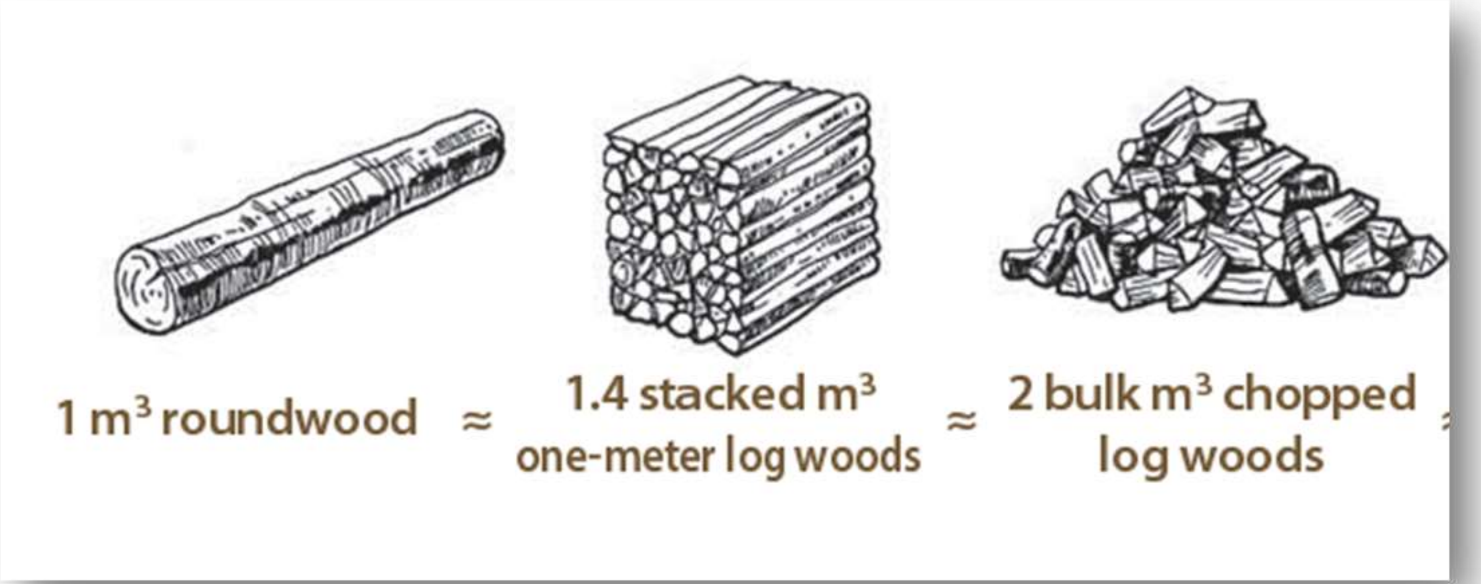
Fuelwood Cost Inflation: 2015 vs. 2019 data



When corrected for inflation, shows negligible increase in the cost of fuel between 2015 and 2019.

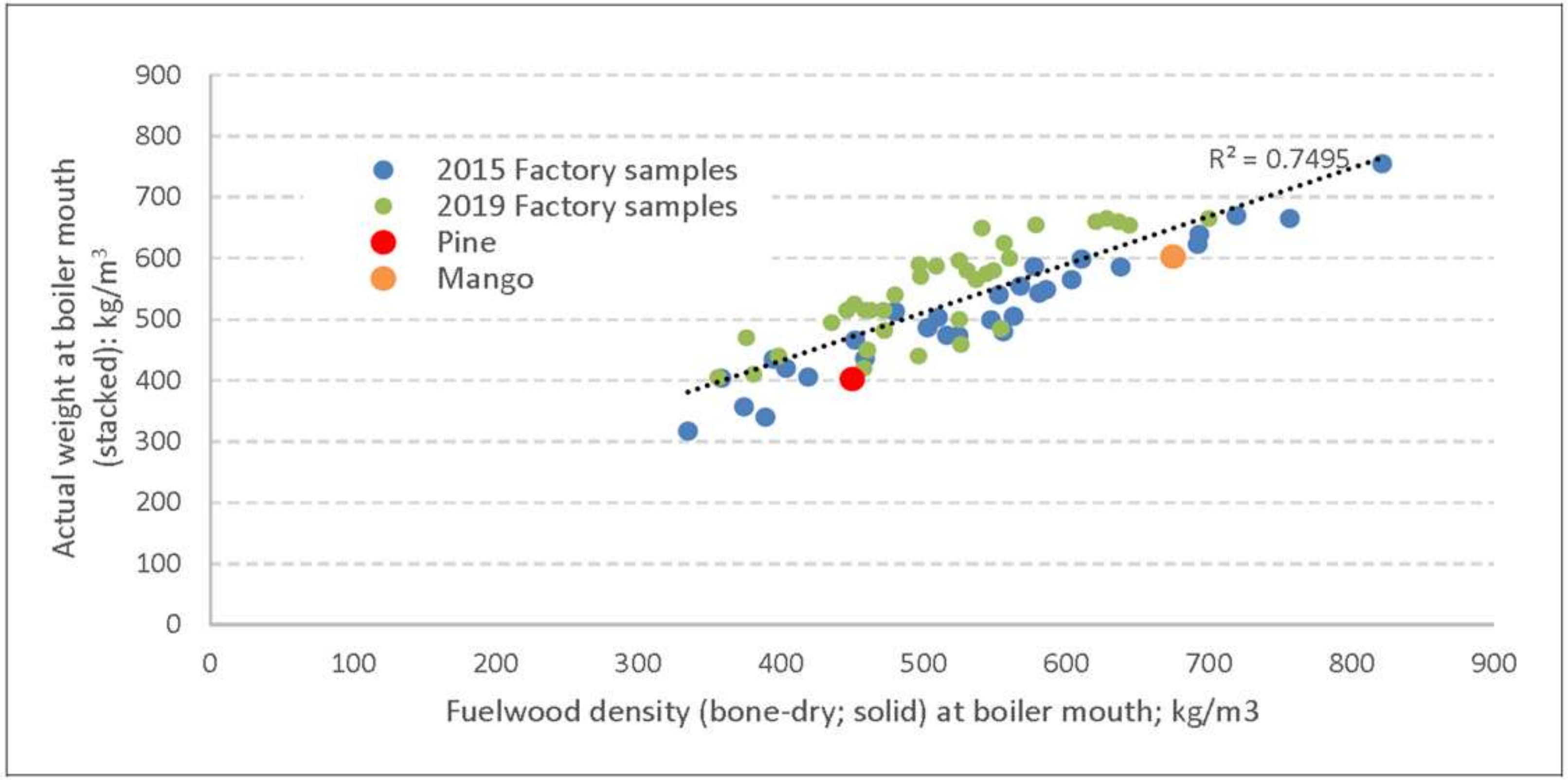
What is the Price for Fuelwood Energy?

- KTDA wants to pay for energy content (MWh), not wood ($m^3_{stacked}$)
- Good news: One tonne bone-dry wood has 19 Giga Joule
- Problem 1: We measure in volume ($m^3_{stacked}$), not weight (tonne)
- Problem 2: Species have different densities
- Problem 3: How much solid wood is in one $m^3_{stacked}$?



Results - Fuelwood Metrics

- Species mix cannot explain this range in recorded densities



- Wood density must be corrected for:
  - Moisture content, and
  - Stacking-to-solid conversion factor.
- Corrected wood density is a reliable predictor of wood energy content.
- Recommended new energy cost metric:
  - Fuelwood energy costs, expressed in KSh/MWh.
  - Normalize discrepancies in moisture content, stacking, etc

- Most likely error source :- conversion ratio of stacked to solid fuelwood volumes!

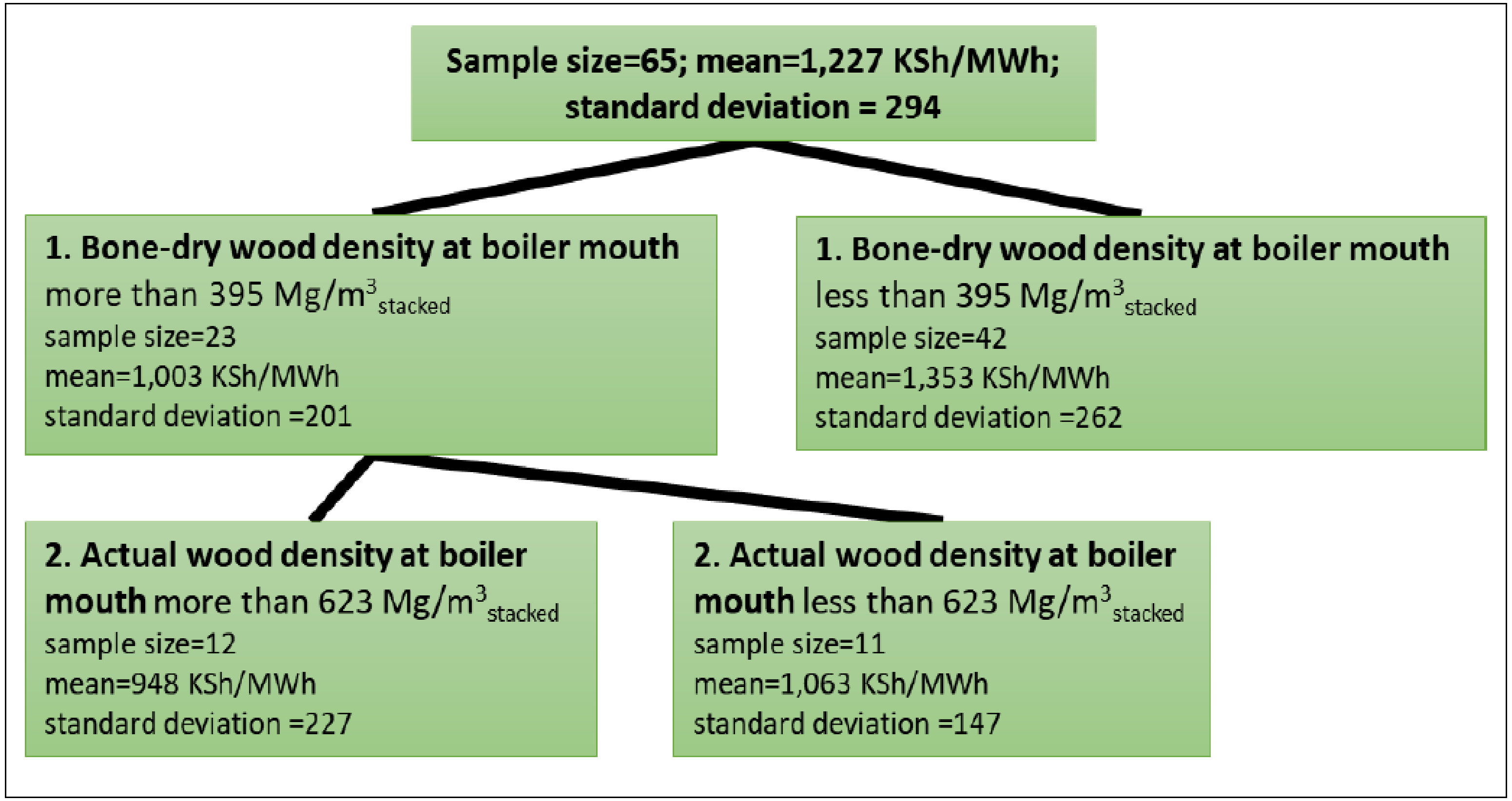
Wood Energy Cost Ranking

	Name	Energy cost at boiler mouth	Energy cost steam	Cost of fuel	Reported wood price	Average fuelwood transport distance	Fuelwood use efficiency Conven-tional[A]	Fuelwood use efficiency Specific[B]	Fuelwood density[C]
		KSh/MWh (LHV)	KSh/MWh (LHV)	KSh/m³	KSh/m3	km	kg/kg made tea	kg/kg made tea	kg/m3
90th pctl	Kionyo	872	1,056	2,418	1,745	30	1.9	2.8	757
	Kimunye	903	1,086	2,696	1,972	45	2.0	3.3	822
	Michimikuru	966	1,241	2,439	2,325	27	1.8	2.4	692
50th	Ragati	1,355	1,760	2,243	1,584	27	2.2	2.0	460
10th	29	2,007	N/A[D]	2,428	2,055	60	2.2	1.5	335
	1	2,092	2,622	2,999	2,426	20	1.8	1.4	404
	33	2,289	3,211	2,839	2,066	30	2.2	1.6	356

- Kionyo, Kimunye and Michimikuru factories had the lowest wood energy costs.
- Strong correspondence between fuelwood density rankings and fuelwood energy costs.

What Drives Heat Energy Cost?

Classification and Regression Tree (CART)



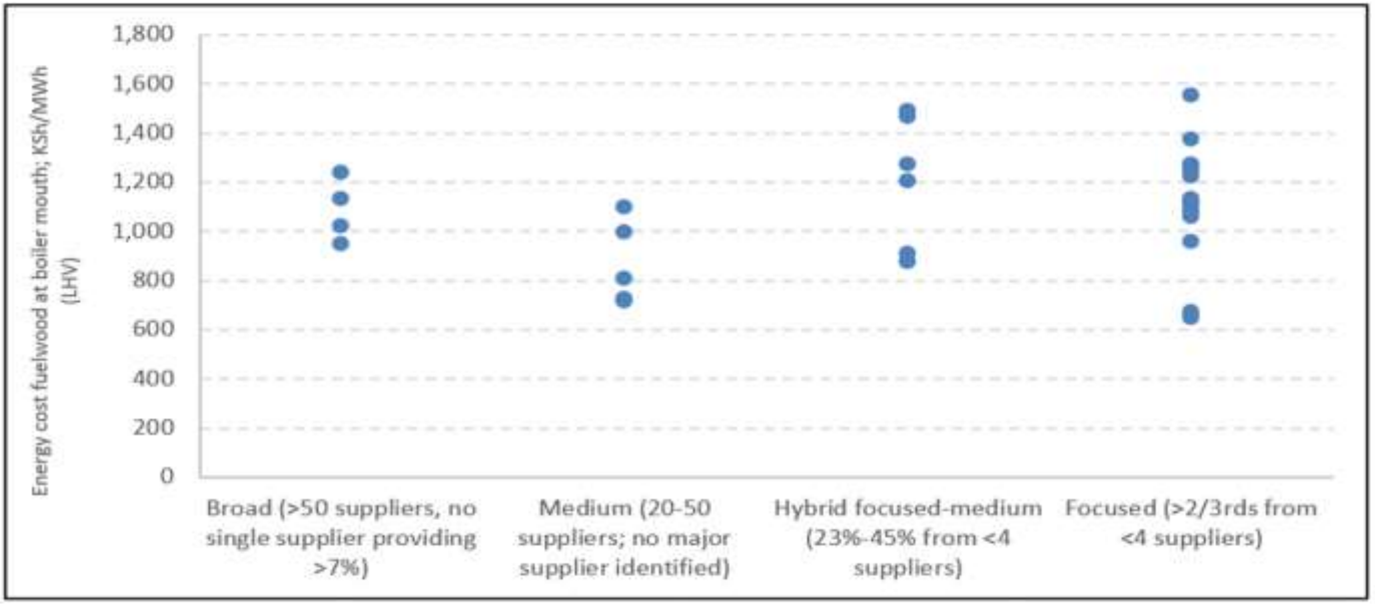
- A total of two splits resulted in a R^2 of 0.79 .
- Additional splits, i.e., adding more potentially predictive variables did not produce meaningful increases in R^2

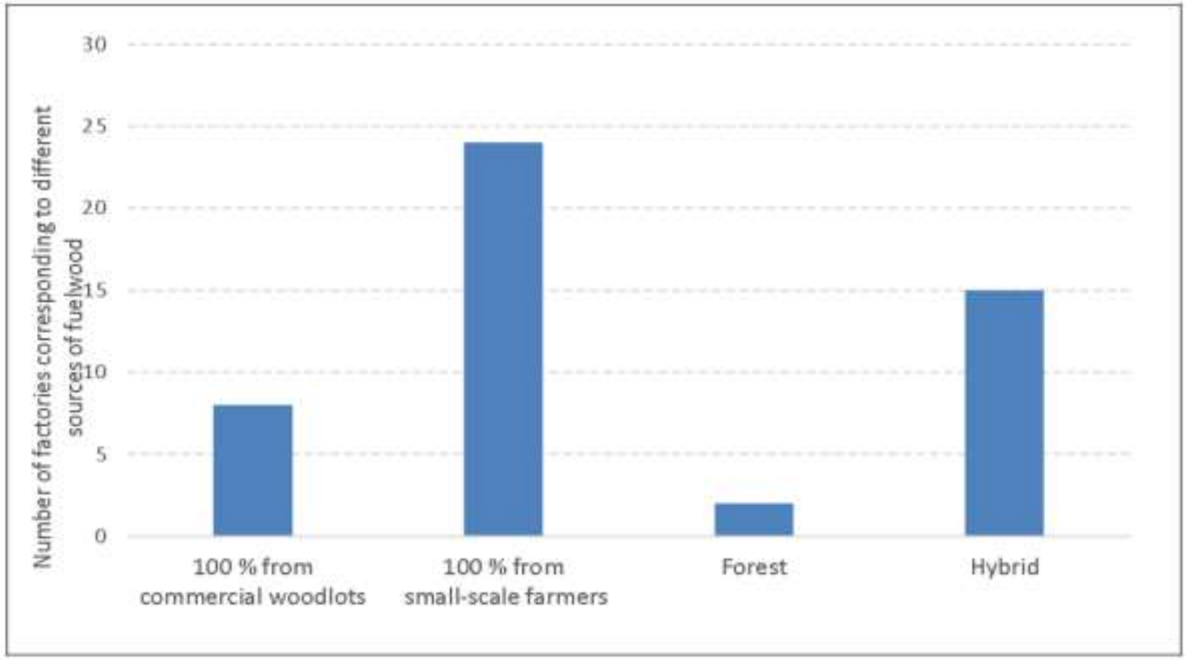
- The variables **do not** predict fuelwood energy costs:
  - Cost of Fuel;
  - Reported wood price;
  - Transport distance;
  - Storage time and capacity to store fuelwood stored under a roof;
  - Fuelwood moisture content at the gate or boiler;
  - Relative moisture content reduction during storage;
  - Total factory wood consumption;
  - Region; and
  - Fuelwood supply model.

Results – Fuelwood Supply Chain

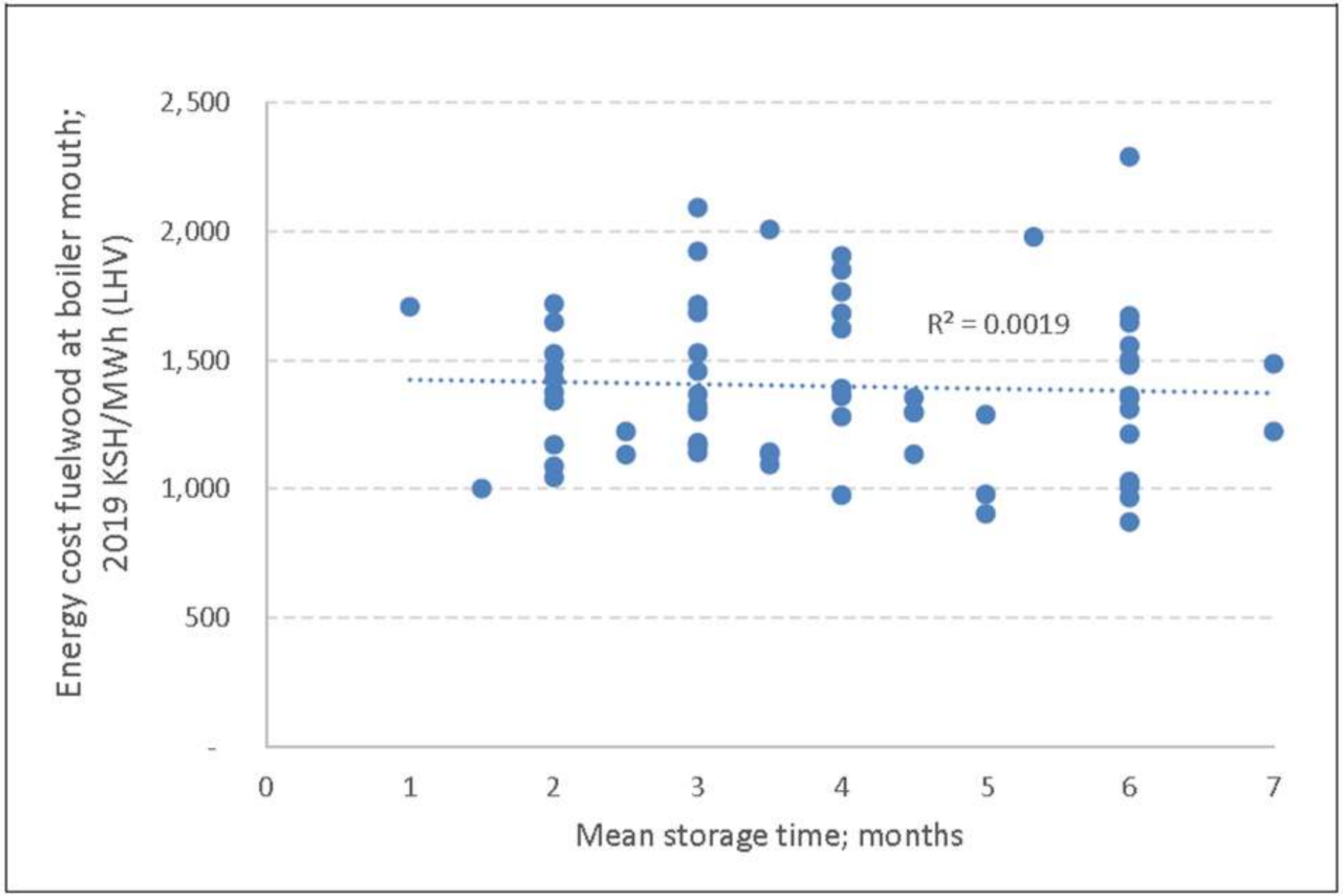
- 45 % of the 65 KTDA factories had a 'Broad' supplier model
- Supply models and KTDA regions did not explain differences in fuelwood energy costs.

- Half of the factories (49 %) sourced fuelwood from small-scale farmers.





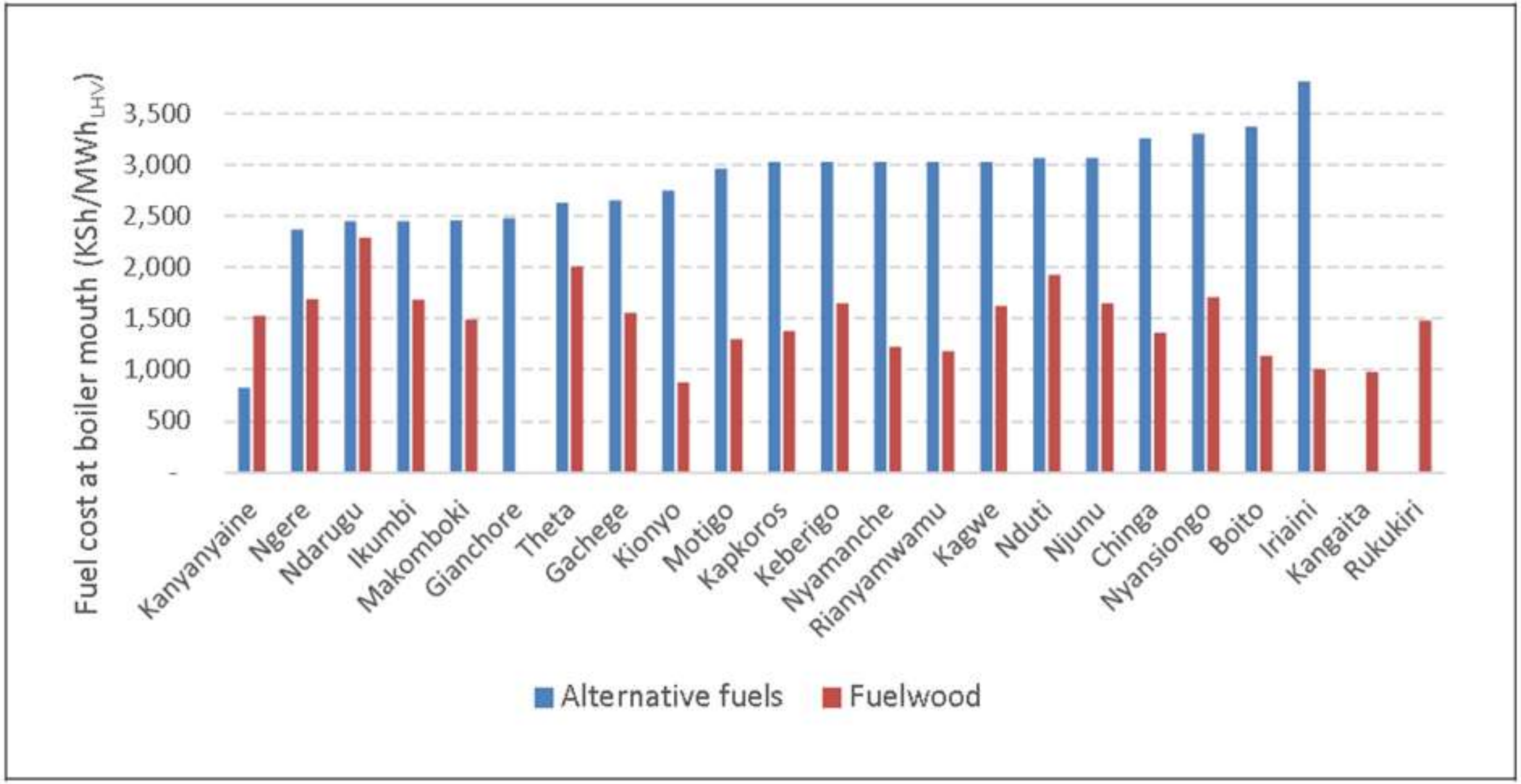
Results – On-site Logistics



- Onsite fuelwood logistics differed considerably between factories.
- Average fuelwood storage =4 months. Ranging 1-7 months.
- Average fuelwood shed capacity was 41 %, ranging 5% - 90% of annual wood demand.
- Factories achieved an average of 23 % in moisture reduction.
- Storage time had a muted impact on energy cost of fuelwood

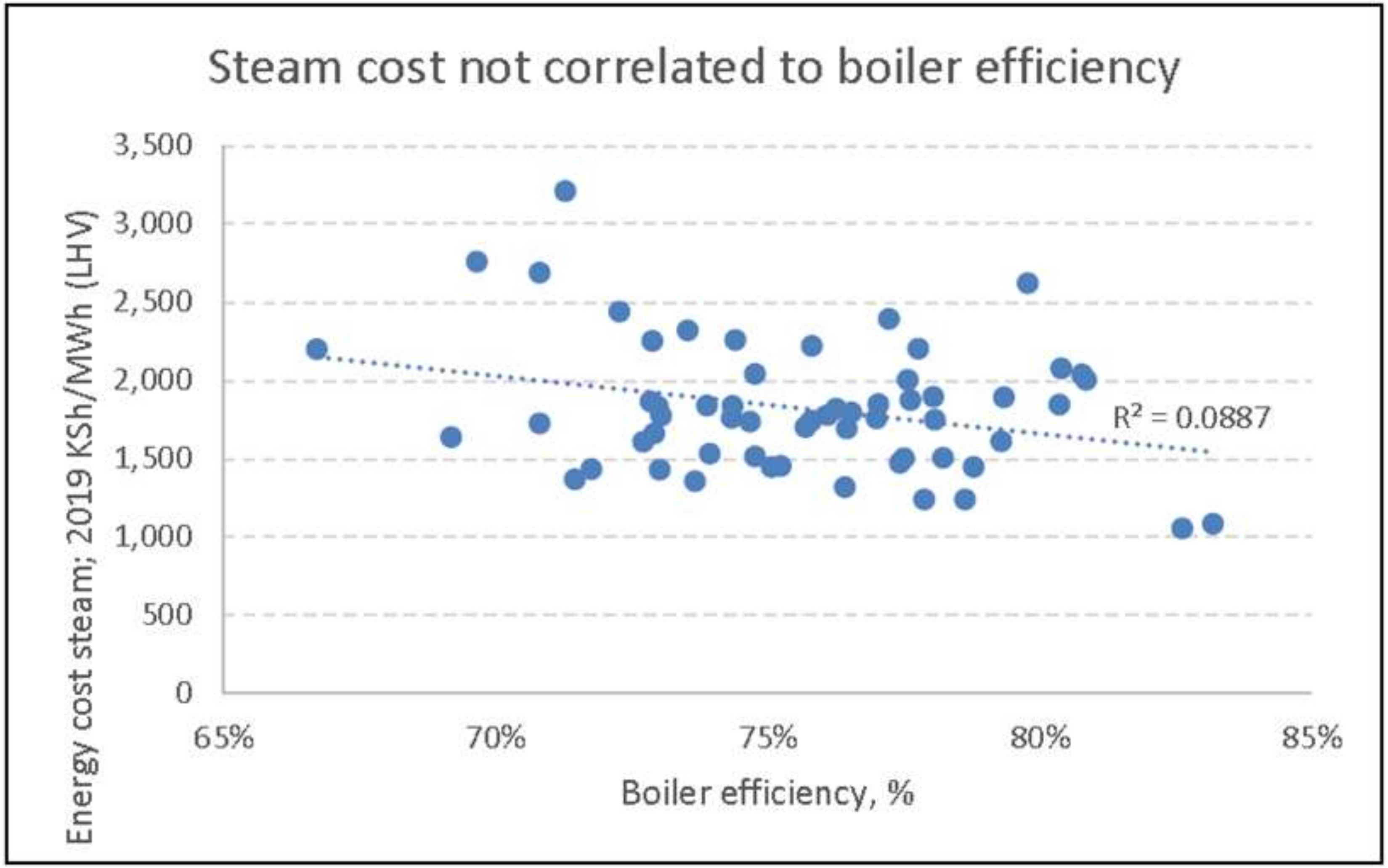
Results – Alternative Biomass Fuels (AF)

- Only four of the surveyed factories used alternative biomass **at substantial scales**.
- AF were transported over much **longer distances** and
- **More expensive** compared to fuelwood in terms of net heat content.
- Average fuel price of alternative biomass: **13 KSh/kg**



Results – Boiler Performance

- Overall boiler efficiencies averaged 87 %, ranging from 80 % (in Kapkatet) to 93 % (in Kimunye)
- Boilers performed fairly similarly – and well - across surveyed factories.
- Heat loss due to moisture in fuel had a muted impact on overall boiler efficiency.
- Differences in boiler performance across factories had a limited impact on steam production cost



Results – Fuelwood Plantations

- The most consistent and readily available data:
  - Total acreage purchased,
  - Acreage if established plantation, and
  - Distance
- By time of survey:
  - 19,300 acres were purchased,
  - 14,180 acres established,
  - Fuelwood plantations were established at an average of 79%.
- With price adjusted for inflation to 2019 KSh, Factories paid an average of 433,000 KSh/acre.

- Tree inventories were not available for any fuelwood plantation.
- Factories were not able to provide or substantiate growth estimates.
- Standardization of fuelwood plantation cost reporting should be adopted:
  - Fuelwood plantation costs reported as factory costs versus others break it out.
- Imenti and Mununga stood out in terms of data availability and performance.

Factory Rankings

- **Kimunye** and **Kionyo** excelled in several ranking categories and led the ranking in the most important metric – *fuelwood energy costs*.
- Along with **Imenti**, **Kimunye** and **Kionyo** performed best in *supply chain* metrics.
- **Makomboki** scored high in *onsite logistics* while **Nyansiongo** presented great a fuelwood storage design but fell short on drying fuelwood sufficiently.
- **Kimunye** excelled in *boiler efficiency* measures.
- **Makomboki** and **Gianchore** provide extensive experience in using *alternative biomass fuels*.
- **Imenti** and **Mununga** stood out in terms of both data availability and performance.

Suggested next steps

- **Create KTDA-wide exchange platform** and implement a permanent benchmarking procedure.
- **Introduce fuelwood energy cost** (KSh/MWh (LHV) at boiler mouth;
- Analyze further the use of fuelwood from native species in a few factories;
- **Facilitate a stand-alone, extended and onsite fuelwood plantation survey**;
- Boilers: Measure flue gas in regular intervals, install automated air controls and oxygen monitoring systems, and improve controls for boiler air fans;
- **Improve biomass receiving procedures**.
  - Provide biomass pricing lookup tables to KTDA factory managers & train staff in use of the lookup tables.
  - Encourage the use of weighbridges where installed (for green tea delivery) for fuelwood deliveries.
- **Consider annual fuelwood supply chain report**.
- **Follow up measurements and benchmarking…..** On periodical interval.
- **Continuation of energy audits**

Challenges Faced During the Project

- COVID-19 pandemic hindered data collection
- Challenges in mobilising participating KTDA factories
- Due to time constraints the study on feasibility of wood chips for use in KTDA was not undertaken

Areas for further study

- Based on energy cost, estimate cost of running on wood chips (rather than logs) fed in automated system of boilers.
- Estimating cost of alternative biomass fuel based on energy content, for purpose of recommending fair price of briquettes from different sources.
- Developing wood pricing chart or lookup tables for premium wood biomass, and whose bone-dry weight would be estimated at factory-gate.

THANKS