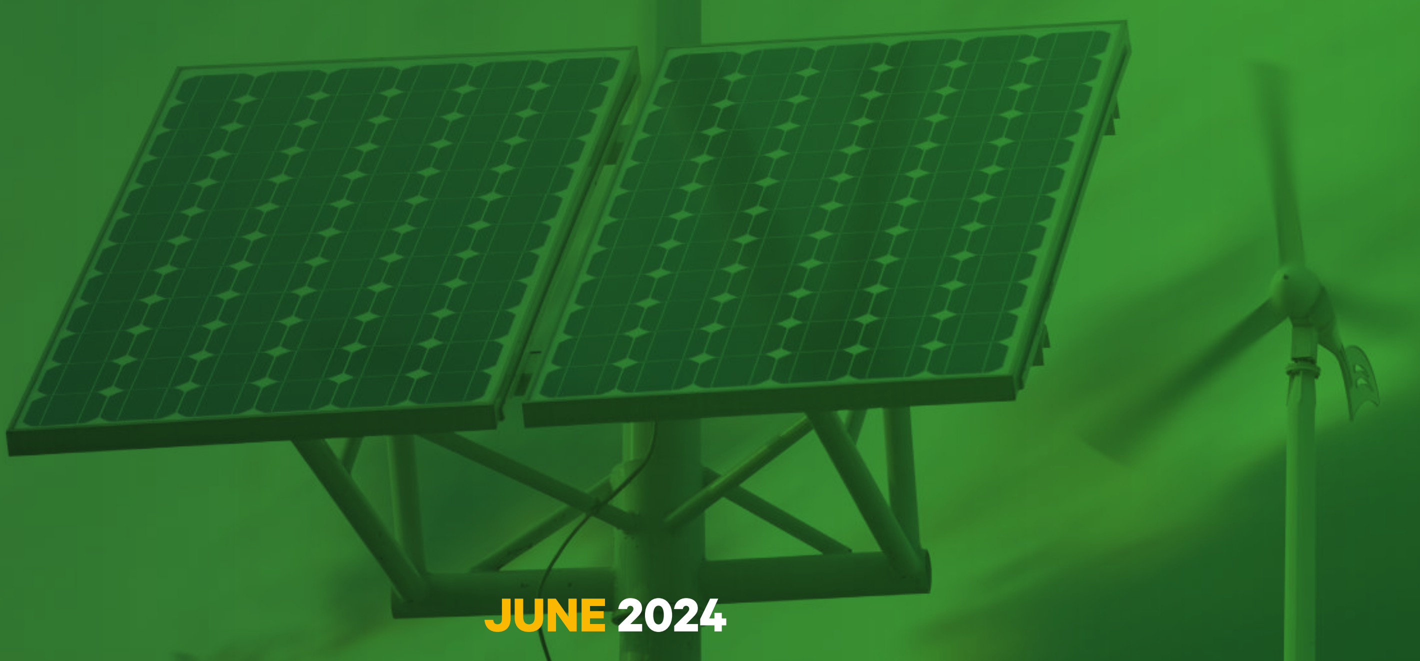
Energy & Petroleum Regulatory Authority

Quality Energy Quality Life

ENERGY PERFORMANCE BENCHMARKING STUDY FOR DESIGNATED ENERGY CONSUMING FACILITIES

FINAL REPORT



JUNE 2024

Director General's Foreword

The mitigation of global climate change is one of the greatest challenges of our time and actions to reduce greenhouse gas emissions in energy end-use sectors are necessary.

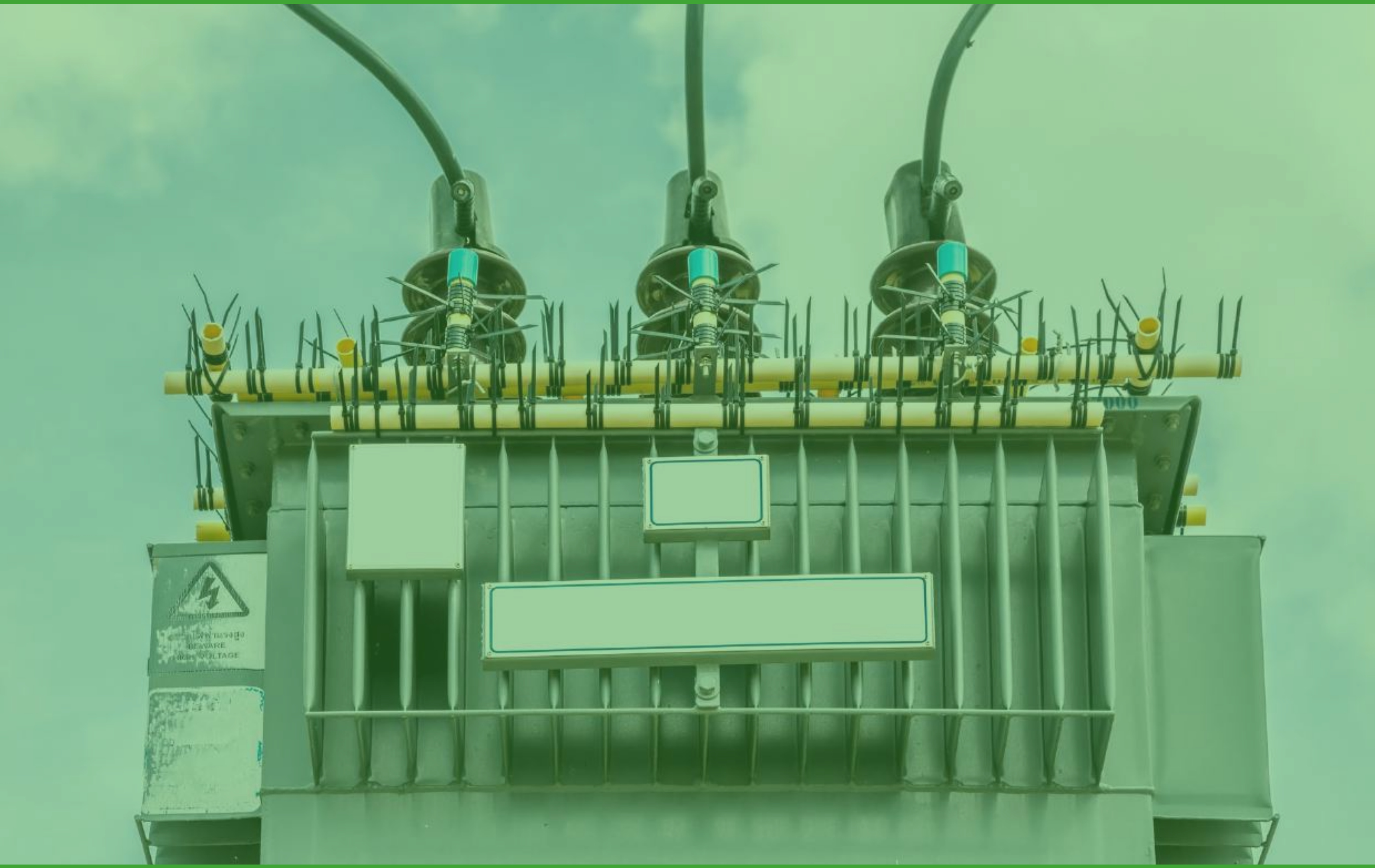
Energy efficiency is considered the "first fuel" in clean energy transitions, as it provides some of the quickest and most cost-effective emission mitigation options while lowering the overall cost of production. Energy efficiency involves adopting innovative technologies and practices to reduce energy consumption.

The Energy Act 2019 mandates EPRA to develop and implement national energy efficiency and conservation programmes. The Authority executes this mandate through various regulations and initiatives on energy management. One such initiative is the development of energy benchmarks for various sectors of the economy as outlined in the Act. Energy benchmarking is a process of evaluating energy performance of an individual facility or sector against a reference facility or sector. Energy benchmarking based on the performance of industry leaders or best practices is particularly useful for identifying energy inefficiencies in the production processes and estimating the potential for energy savings.

This study was undertaken to develop energy benchmarks for seven sectors in Kenya namely: Cement, Sugar, Tea, Dairy, Flower farms, Fast Moving Consumer Goods and Hotels. The adoption of these energy benchmarks will go a long way in improving energy efficiency in the designated facilities in these sectors while reducing greenhouse gas emissions. The Authority shall progressively develop energy benchmarks for other sectors.

Daniel Kiptoo Bargoria, MBS, OGW

Director General



This study was jointly carried out by:

Rencon Associates and the following officers from the Energy and Petroleum Regulatory Authority

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ABBREVIATIONS AND ACRONYMS

ADO	Automotive Diesel Oil
BRC	Biomass Research Center, UK
CHP	Combined Heat and Power
CIP	Cleaning-in-Place
DEG	Diesel Engine Generator
DoE NREL	Department of Energy, National Renewable Energy Laboratory, USA
EER	Energy Efficiency Ratio
EI	Energy Intensity
EPA	Environmental Protection Agency, Unite States of America
EPI	Energy Performance Index
EPRA	Energy and Petroleum Regulatory Authority
EUI	Energy Use Index /Enegy Intensity
FMCG	Fast-Moving Consumer Goods
GDP	Gross Domestic Produce
GJ	Giga Joule
HFO	Heavy Fuel Oil
HHV	Higher Heating Value
IDO	Industrial Diesel Oil
IPP	Independent Power Producer
KAM	Kenya Association of Manufcturers
KDB	Kenya Dairy Board
Kg	kilogram
KPLC	Kenya Power and Lighting Company
KSh	Kenyan shilling
KTDA	Kenya Tea Development Agency
kW	kilowatt
kWh	Kilowatthour
L/l	Litre
LPG	Liquefied Petroleum gas
LRA	Linear Regression Analysis
MJ	Mega Joule
MoE	Ministry of Energy, Kenya
MW	Megawatt
OI	Outsourcing Intensity
PAT	Profit After Tax
Rencon	Rencon Associates Ltd
RMI	Raw Material Intensity
SI	Software Intensity
ToR	Terms of Reference
UNIDO	United Nations Industrial Development Organisation
V	Volts
W	Watts
TDI	Technology Development Intensity

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EXECUTIVE SUMMARY

The overall objective of the study was to develop energy performance benchmarking models for each of the seven industries and determine the energy efficiency ratio cut-off points from the models.

The Energy Act 2019 mandates EPRA to develop and implement national energy efficiency and conservation programmes.

To implement this mandate, the Act has specified several initiatives that the Authority should undertake. One such initiative is the establishment of minimum energy performance benchmarking metrics that will enable the Authority and stakeholders to identify best practices that would enhance energy performance. Specifically, the Act mandates EPRA to set specific energy consumption benchmarks and enforce compliance. EPRA conducted a study to establish energy performance benchmarks for Cement, Tea, Hotel, Dairy, Fast Moving Consumer Goods (FMCG), Flower farming and Sugar industrial sectors. The work was undertaken by Rencon Associates Ltd.

The specific objectives of the study were:

i. To identify and discuss various existing energy performance benchmarking models and standards in the industry, and related incentivization schemes

ii. To determine, normalized to all energy consumption independent variables, product-based energy utilization indices from a statistically representative sample of the categories identified in the stated sectors

iii. To recommend the minimum required energy use index for each category of the facilities studied

iv. To develop, test, and validate a dynamic mathematical benchmarking models for each of the sectors

v. To develop a benchmarking model software complete with a user guide

The assignment adopted a mix of qualitative and quantitative approaches. The qualitative approach was used to analyze the various benchmarking models used in other countries and organizations. It involved reviewing of available literature on energy performance benchmarking to gain insight into the various energy benchmarking models. This review was essential to the study approach. Quantitative approach involved analysis of the energy performance data from the selected industries, for development of the model.

The study population was drawn from the designated facilities. In 2013, EPRA designated facilities which should comply with the Energy (Energy Management) Regulations 2012, via a gazette notice. This designation requires that facilities that use more than 180,000 kwh of energy (thermal and electrical), should comply with the Regulations. The study targeted 443 facilities, drawn from the seven sectors. A census approach was used for three of the sectors, that is sugar, dairy and cement, due to their small population. Out of the 437 facilities, only 53 were from these three sectors. For the four sectors, stratified random sampling was adopted, and a sample size of 211 was used. A sample size of 256 facilities was studied. The study also analysed benchmarking tools from four countries, that is the USA, Canada, India and Japan and two organizations, that is the European Union (EU) and United Nations Industrial Development Organisation (UNIDO). Document analysis was used to collect qualitative data on different benchmarking models from the countries and organizations. Structured questionnaires were used to collect data from the sampled facilities. The questionnaires had checklist questions, which targeted to collect data on energy consumption and production for two years. The checklist questions were customized for each sector. For example, production data for flower farms was in form of the harvested sticks while cement production was in tons.

Studies of energy benchmarks in the USA revealed that the modelling and enforcement is implemented by the Environmental Protection Agency (EPA). It uses the Energy Star. The energy star model is empirically derived from data gathered from industry, and is sector specific. It uses the energy efficiency ratio (EER). Production and consumption data is used to develop a sector wise linear regression model. This model is then used to develop the desired energy use index (EUI) for each facility, using the recorded production data. The actual EUI is then determined, using the production and energy consumption from each facility. EER is then computed by getting the ratio of the desired EUI over the actual EUI. The computed EERs for each facility are then plotted on an ogive. The cutoff EER is determined on the ogive and facilities are required to comply with it. Incentives differ from state to state. However, tax credits and rebates are common in most states.

Canada uses a model similar to USA and the government offers rebates. The Canada Green Building council offers technical support, training, and free guideline to enhance energy benchmarks. India, like Canada, has also adopted the Energy Star model of USA. The country has however introduced more variables in the model, to cater for factors such as labour intensity, repair intensity, technology development intensity, plant and machinery intensity and profit after tax intensity. This approach is different from the Canadian and USA ones, which only focus on energy use intensity.

European Union (EU) countries, Japan and United Nations Industrial Development Organisation (UNIDO) also use empirical based energy benchmarking model. The model uses production and energy consumption data, and other attributes that have significant influence on energy consumption. Such attributes include temperature, relative humidity and precipitation. Benchmarks are defined per sector. As opposed to the EER used by the USA, Canada and India, EU focuses on energy intensity as the benchmark. In the EU, they deploy fiscal and non-fiscal based incentives. Japan uses a command and control approach, with no fiscal based incentives. UNIDO uses this tool to develop technical assistance for various facilities across the world.

The review of the benchmarking models from various countries and organizations reveals prevalence of use of product-based energy performance benchmarking tools. This is as opposed to process based models. Product based models use energy consumption, production and other variables, at a factory scale. Process based tools focus on particular performance of equipment or processes in a factory. These tools are more "faithful" but complicated, compared to product based ones. A good model should balance between "faithfulness" and simplicity. This consultancy chose to use the product based benchmarking tool, to achieve the balance between simplicity and "faithfulness".

Table 0.1 presents a summary of energy use indices for the studied facilities.

Table 1.0: Production and Energy Consumption

Sector	Total Annual Production per Facility	Electrical Energy Intensity	Thermal Energy Intensity
Tea	4122.38 tons of black tea	570.29 kWh/Ton	29.91 GJ/Ton
Dairy	40.71 million Litres	40.71 million Litres	1.77 GJ/Kilolitre
Cement		42.27 kWh/ton(clinker only)	0.037 GJ/ton (clinker only)
		92.86 kWh/ton (integrated plant)	2.76 GJ/ton (integrated plant)
FMCG	76010 tons	87.17 kWh/ton	1.87 GJ/ton
Hotels	25,355 bednights	61.94 kWh/bednight	89.15 MJ/bednight
Flowers	38.2 million stems	1.15 kWh/1000 Stems to 127.1 kWh/1000 Stems	N/A

The Cement industry has different processes, each done by different facilities, to come up with the final product. Allocation of production per facility could therefore lead to double accounting and this was not provided in Table 1. To validate these results, the total EUI (thermal and electrical) was compared to published works in other countries. The comparison is presented in Figure 0-1.

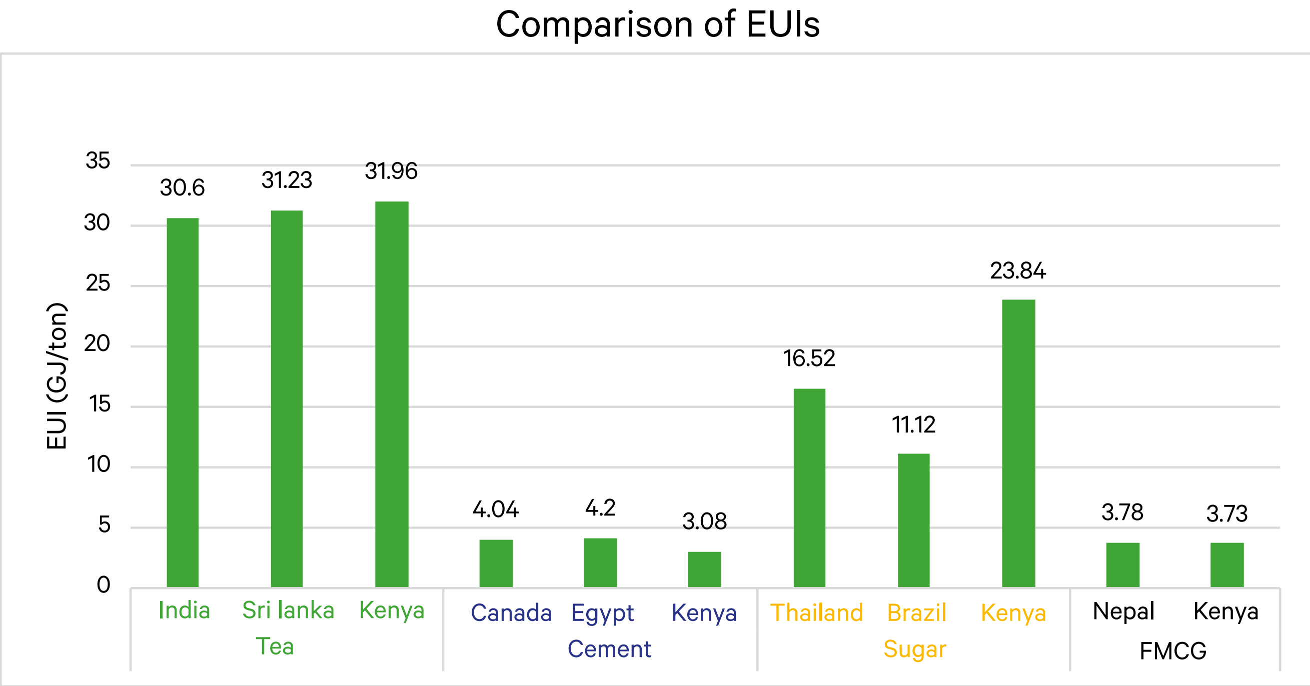


Figure 0-1: Comparison of total EUI in select countries for various sectors

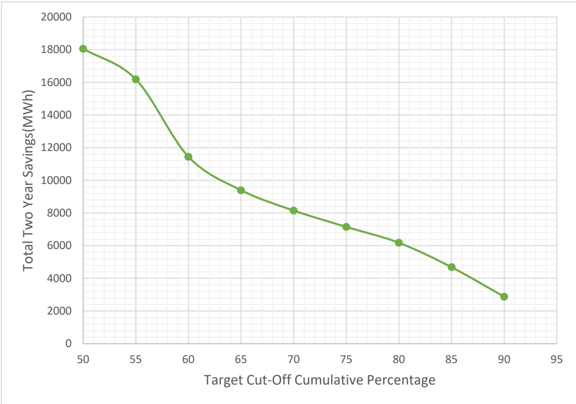
In the flower and hotel sectors, the study could not find any relevant sector benchmarks for comparison because of different approaches by different countries.

The production and energy consumption data for the 24 months was used to develop regression models for each sector. Table 0.2 presents the adjusted regression models for benchmark setting.

Table 2.0: Adjusted Energy Benchmarking Regression Models

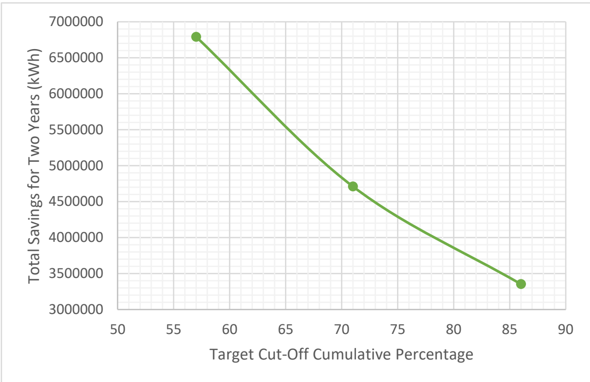
Sector	Energy Input	Model Governing Equation	Coefficient of Determination
Sugar	Electrical Energy	y = 0.3479x + 3698.4	0.7982
	Thermal Energy	y = 3.4024x + 9443.5	0.7749
Dairy	Electrical Energy	y = 0.0542x + 745.47	0.4966
Tea	Electrical Energy	y=0.5159x+1385.3	0.8755
	Thermal Energy	y=0.0027x+23371	0.7226
Cement (Clinker Firing)	Electrical Energy	y = 0.0773x + 89.417	0.9856
Cement (Grinding)	Electrical Energy	y = 0.0323x + 195.97	0.7869
Hotel	Electrical Energy	y= 0.0217 *bed nights + 47.34 * temperature difference + 565.82	0.8765
	Thermal Energy (Boiler Diesel)	y = 0.6697x + 15589	0.4776
	Thermal Energy (LPG)	y = 0.9001x + 20242	0.6764
Flowers	Electrical Energy	y = 0.0176x + 536633	0.6592
FMCG	Electrical Energy	y = 0.0764x - 104429	0.9609

Even after adjustment, some models still had coefficient of determination less than 0.7. Such models may not statistically represent the population. EERs were nonetheless developed for all the sectors and presented using ogives. From the ogives, simulation of possible energy savings, against performance cut-off benchmarks, was done and the results presented in graphs as follows:



Tea

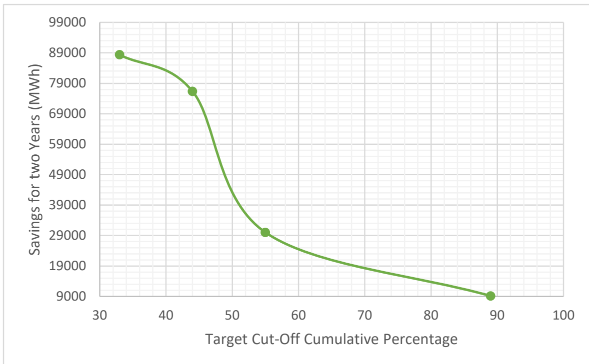
Tea



FMCG

Clinker Firing

Clinker Grinding

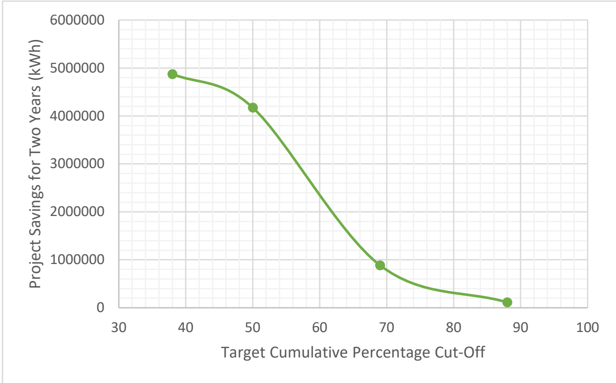


Sugar

Sugar

Hotels

Hotels



Flower Farms

Dairy Industry

These simulations play an important role in determination of performance cut-off benchmarks for each of the studied sectors.

1. INTRODUCTION

1.1 Background

Energy Efficiency and Conservation is one of the key pillars of sustainable development. Energy consuming facilities can achieve efficient operation regimes through reducing their energy consumption per unit product, without compromising on quality and quantity of outputs.

This report comprises 4 chapters. The current chapter discusses the background and objectives. The methodology employed is presented in the second chapter. The third chapter presents the results of the study while the final chapter concludes and makes recommendations for the energy performance benchmarks.

This can be achieved through measures geared towards reducing avoidable energy waste and losses, improving productivity, reducing costs of goods and services and combating climate change.

In Kenya, energy management programmes are being implemented through the Energy (Energy Management) Regulations 2012 (the Regulations). The regulations provide for designation of energy consuming facilities and spell out provisions that designated facilities should comply with. The designation, which was published in the Kenya Gazette Notice in 2013, specifies that facilities that consume more than 180,000 kWh of energy per year should comply with the provisions of the Regulations. Over the implementation period, it has been noted that there is a need for development of sector specific energy utilisation benchmarks. The benchmarks provide a baseline for improvement and comparison of energy performance among similar facilities.

The Energy Act 2019 (the Act) mandates the Energy and Petroleum Regulatory Authority (EPRA) to develop and enforce minimum energy performance benchmarking metrics. These metrics should be references against which energy performance of designated facilities is evaluated. It is in view of this that EPRA contracted Rencon Associates Ltd (Consultant) to collect industry specific data for purposes of setting the benchmarks. The study focused on seven industry sectors: Cement; Tea; Hotel; Dairy; Fast Moving Consumer Goods (FMCG); Flower farming and Sugar industrial sectors. These sectors were prioritized based on their energy consumption share and their contribution to the economy. This report presents the findings of the study.

1.2 Objectives of the Study

The overall objective of the study was to develop energy consumption benchmarks for seven energy consumption categories in Kenya.

The specific objectives were:

i. To benchmark on existing energy performance benchmarking models and standards in other jurisdictions and related practices

ii. To determine product-based energy utilization indices for the identified sectors

iii. To develop an energy performance benchmarking model for each of the sectors
iv. To recommend the minimum energy use index for each category of the sectors studied
v. To develop a benchmarking model software complete with a user guide

1.3 Organisation of the Report

This report comprises 4 chapters. The current chapter discusses the background and objectives. The methodology employed is presented in the second chapter. The third chapter presents the results of the study while the final chapter concludes and makes recommendations for the energy performance benchmarks.

2. METHODOLOGY

2.1 Introduction

This chapter presents the approach that was used to meet the study objectives. The first section discusses the population, sampling and data collection. The last section presents the data analysis method.

2.2 Review of Case Studies

The following countries and organizations were selected for review given that they have existing benchmarking programs and guidelines:

i. USA
i. India
ii. Japan
iii. UNIDO
iv. European Union

2.3 Population and Sampling

The population for this study was obtained from designated energy consuming facilities. The study focused on cement, tea, hotel, dairy, fast moving consumer goods, flower farms and sugar sectors. The population size is presented in Table 2.1.

Table 2.1: Population Size

Category	Population Size	Products
Tea	94	Tea
Cement	11	Cement
Flower Farms	70	Flowers and Fillers
Hotels	165	Food and Accommodation
Dairy	29	Processed Milk
Fast Moving Consumer Goods	55	Soap, Cooking Oil, Detergents, Margarine
Sugar	13	Sugar

The population sizes were obtained from registered members of Kenya Tea Development Agency, Kenya Tea Board, Kenya Association of Hotelkeepers & Caterers, Kenya Dairy Board, Kenya Flower Council and Kenya Association of Manufacturers. The study used stratified random sampling technique to determine representative samples for some sectors. In sectors with less than 30 facilities, a census approach was used. This was the case for Cement, Sugar and Dairy sectors.

Where the survey population was over 30, stratified random sampling was employed to determine the minimum sample size.

The population was stratified by facility category and geographical region. The regions were Coast, Central, Rift Valley, Western, Nairobi, North Eastern and Nyanza. The aim of geographical stratification was to ensure every region is represented in the study.

To ensure the statistical significance of the data, a confidence interval of 95% with a z-score of 1.96 was used. The margin of error was 5% and the population proportion was assumed to be 95%. The following formula was then applied:

$$n_0 = \frac{nN}{n+N};$$

Where;

n_0 is the sample size

N is the population size

n is the assumed sample, determined by the equation:

$$n = \frac{z^2\rho(1-\rho)}{\varepsilon^2};$$

$$\rho = population\ proportion;$$

$$\varepsilon = margin\ of\ error;$$

$$n = assumed\ sample\ size;$$

$$N = population\ size$$

$$z = confidence\ interval$$

For example, to get the sample size for hotels:

$$n = \frac{1.96^2 \times 0.95(1-0.95)}{0.05^2}$$

n= 72.99

$$n_0 = \frac{72.99 \times 165}{72.99 + 165}$$

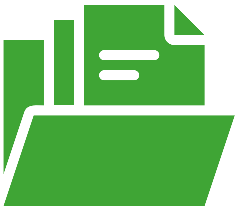
n_0=50.6

The minimum sample size to get statistically significant results with an error margin of 5 % for hotel industry was thus determined to be 50. The same treatment was applied to the other sectors. Table 2.2 presents the population, the computed sample size and the actual sample size used in the study.

Table 2.2: Population and Sample Sizes

Category	Population Size	Computed Sample Size	Sample Size Used
Tea	94	41	84
Cement	11	11	11
Flower Farms	70	36	36
Hotels	165	50	52
Dairy	29	29	29
Fast Moving Consumer Goods	55	31	31
Sugar	13	13	13

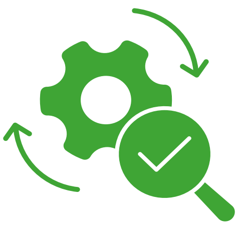
The sample size used for the tea sector was more than double the computed size because the data was available from KTDA. The research team also added two more facilities in the hotel sector.



2.4 Data Collection

Literature on the benchmarking case studies was obtained from the websites of target countries and agencies. The data used for modelling the energy performance was collected from the sampled facilities using checklists. The variables that significantly affect energy performance were collected. These included the production and the ambient temperature. The energy consumption, in terms of electricity, automotive diesel oil, industrial diesel oil, heavy fuel oil, bagasse, LPG, woody biomass and briquettes, was collected too. The data and information for the study was collected through a field survey over a six-month period.

The electricity consumption data considered two categories of sources, the grid and self-generation. Self-generation consisted of standby diesel generator sets, solar photovoltaic (PV) systems and cogeneration. The solar PV, cogeneration and grid data were obtained directly from the facility records. The electrical energy from the generator set was computed using the diesel consumption data.



2.5 Data Processing and Analysis

The data collected was segregated for analysis. The generator diesel data was converted into electrical energy generated, using a conversion factor of 3 kWh per litre[1]. This method was adopted because facilities do not meter the electrical energy generated by their generator sets. For example, where the monthly diesel consumption for the generator was 456 litres, the energy consumed per month was determined as:

$$Electrical\ Energy = 456\ liters \times 3\ kWh = 1356\ kWh$$

[1]Roy, Naruttam (2017). Optimal design of hybrid microgrids for readymade garments industry of Bangladesh: A case study

of self-generation and grid supply, the total electrical energy was added to come up with total monthly consumption. Thermal energy consumption was processed using the commercial units. For example, woody biomass was processed in terms of cubic metres (m3) instead of gigajoule while HFO and IDO was processed in terms of litres. This data was used to determine the Energy Efficiency Ratio (EER). The approach used to determine EER was determined from the literature review conducted across different jurisdictions. The method used by the Environment Protection Agency (EPA) in United States of America was adopted.

To get the EER for each facility, the measured facility Energy Use Index (EUI) was divided by the predicted group EUI, as presented in the following equation:

$$EER = \frac{Measured\ EUI}{Group\ Predicted\ EUI}$$

The measured EUI was determined using:

$$Measured\ EUI = \frac{24\ month\ energy\ consumption}{24\ month\ production}$$

The group predicted EUI was determined by:

$$Group\ predicted\ EUI = \frac{Group\ predicted\ energy\ consumption}{24\ month\ production}$$

To get the predicted energy consumption, a regression model was used. This model represented the energy consumption of the facilities in each category. The model was in the form:

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots \beta_n x_n + \varepsilon$$

Where;

$\boldsymbol{Y}$	Predicted monthly energy consumption for the sector
$\boldsymbol{\beta_0}$	Predicted monthly consumption for the sector when production and other variables are zero
$\boldsymbol{\beta_1}$	Coefficient of production that affects energy consumption for the sector
$\boldsymbol{x_1}$	Average monthly consumption for the facilities
$\boldsymbol{\beta_2}$	Coefficients of variables that are likely to affect energy consumption, like relative humidity and temperature
$\boldsymbol{x_2}$	Monthly variables that are likely to affect energy consumption
$\boldsymbol{\varepsilon}$	The error term of the model

Predicted monthly energy consumption for the sector	Coefficients of variables that are likely to affect energy consumption, like relative humidity and temperature
Predicted monthly consumption for the sector when production and other variables are zero	Monthly variables that are likely to affect energy consumption
Coefficient of production that affects energy consumption for the sector	The error term of the model
Average monthly consumption for the facilities	

The monthly data for 24 months from responsive facilities was used to develop the sector linear regression models. To get the predicted group annual energy consumption, the dependent and independent variables were substituted in the model.

For statistical significance of the data, three indicators were used:

i. T statistic

ii. F statistic

iii. coefficient of determination

The significance threshold for the model was a coefficient of determination of 0.75. Based on the coefficient of determination, the obtained model was either improved by excluding outliers or the model rejected for further studies. The statistical significance for the independent variables was confirmed where p-values of the models was less than 0.05. To determine the EUI thresholds for facilities, an ogive with EERs for all the facilities in each sector was plotted. Cut-off points for EERs was used to determine performance benchmarks for the facilities.

2.6 Software Development

The accepted regression models were coded into algorithms for computation of EERs for each facility. A spreadsheet based software was developed for the purposes of computing the energy performance of a facility relative to the benchmarking metrics established for each sector.

3. RESULTS AND DISCUSSION

3.1 Energy Performance Benchmarking Models and Incentives

This section presents different benchmarking models used by different jurisdictions and agencies including; United states, Canada, India, Japan, UNIDO, and the European union.

3.1.1 United States of America and Canada

The U.S. Environmental Protection Agency (EPA) works on consensus with stakeholders to develop sector specific benchmarking tools. The first step is the collection of data from facilities in each sector, for use in development of linear regression model. The data includes all the independent variables likely to affect energy use. The regression model is tested for statistical significance, for model reliability. The model coefficients are then used to predict the energy use for any facility within the identified sector, using available data that correspondents to the independent variables. The predicted energy use is compared to the actual production, to get the predicted EUI. The predicted EUI is then compared to the actual EUI of the facility. The actual EUI is determined using the ratio of the actual energy consumed over the actual production. The performance metric is determined using the EER, where the actual EUI is divided by the predicted EUI.

Once the EER for each facility has been determined, a distribution is generated, using an ogive, as illustrated in Figure 3-1.

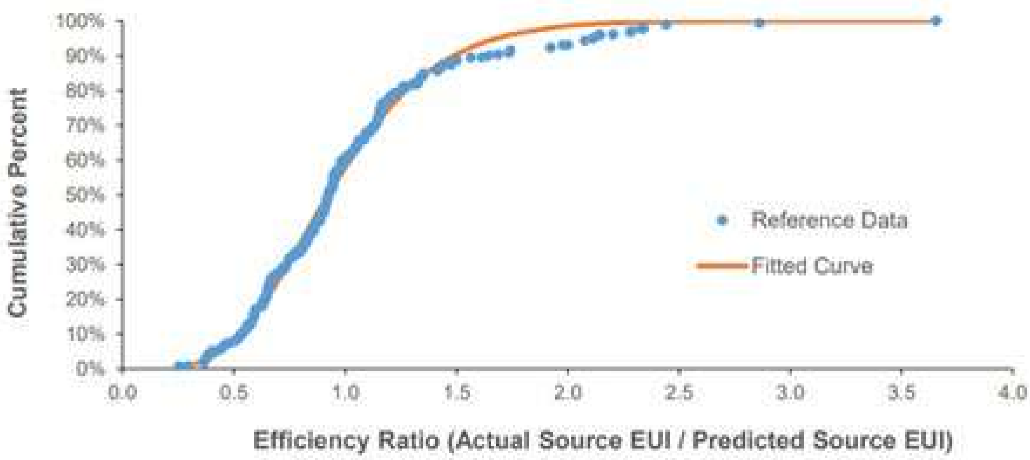
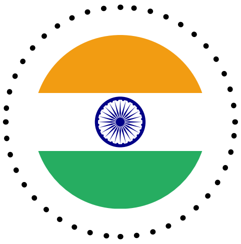


Figure 3-1: Distribution of EERs for Supermarkets in USA (Source, EPA)

From Figure 3-1, an EER of more than 1 means that the actual energy performance of the facility is lower than the predicted (industry average) performance. This system is also used in Canada.

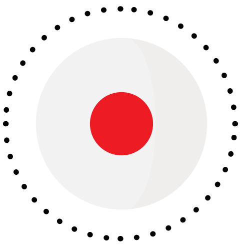
In the USA, incentives vary between states and cities for achieving and exceeding Energy Star benchmarks. EPA issues star ratings to facilities that are below the 75 % line. This is meant to encourage the low performing industries to improve. Tax credits and rebates are most common incentives [2,3]. They usually apply for achieving an EPI of 75%. The incentives appear to be targeted at efficient appliances and buildings energy efficiency rather than manufacturing industries. The Government of Canada offers energy rebates. A company that attains an EPI of 75% in the Energy Star program receives a rebate for energy audits. The Canada Green Building council offer technical support, training, and free guideline to enhance energy benchmarks [4,5].

3.1.2 India



India, through the Bureau of Energy Efficiency (BEE) which was supported by USAID mainly adopted the US EPA model. The required data and information is collected from the industry but unlike the Energy Star whose main consideration is energy inputs, the Indian model takes into account technical, economic and environmental factors into account in the determination of baselines and best practices that are then used for benchmarking the energy performance. In manufacturing sector, the model has been revised to consider other independent variables; Labor Intensity (LI), Repair Intensity (RI), Technology Development Intensity (TDI), Raw Materials Intensity (RMI), Outsourcing Intensity (OI), Software Intensity (SI), Plant and Machinery Intensity (PMI) and Profit After Tax Intensity (PATI) leading to development of an econometric energy benchmarking model. There are no known incentive schemes in India for the benchmarking.

3.1.3 Japan



Japan's energy benchmarking models are also developed using data gathered from industry. The models are also based on EUI. The Japan benchmarking model compare EUIs of industrial sectors. The EUI is defined differently for different sectors depending on how the unit of production is measured. Japan introduced the Energy Efficiency Act in 1979 which designated facilities and obligated designated facilities to implement and report annually on energy consumption. Several revisions over the years have introduced new obligations, energy savings targets and penalties for noncompliance [6]. The Japanese approach to energy efficiency is regulatory rather than incentives driven.

3.1.4 United Nations Industrial Development Organisation

The United Nations Industrial Development Organisation (UNIDO) energy benchmarking models are developed using data gathered from industry. The model computes and compares EUIs of facilities and presents energy performance in a benchmarking curve which is a plot of energy intensity and cumulative production. This curve presents most efficient facilities to the bottom left of the curve and least efficient to the top right of the curve, just like cumulative frequency curves. This model directly compares the absolute values of EUIs at differing production levels and its only industry specific. Hence it can be used for facility, country, regional and international benchmarking.

3.1.5 European Union

European Union (EU) countries similarly use product based benchmarks, using models developed by industry data. The EU benchmarking model compares EUIs of sectors. The EU issues energy efficiency directives [7] that guide member states on policies and obligations, measures and energy saving targets for member states and for the union. The 2018 Energy Efficiency Directive ((EU) 2018/2002) is the latest directive which above all established EU energy efficiency target for 2030 of at least 32.5%. EU has joint programs that offer grants for financing initiatives that promote energy efficiency across the Eurozone. One such program is the EE-10-2018-2019: Mainstreaming energy efficiency finance program. This is an 80 million Euro energy efficiency research and development grant program aimed at aiding the development of frameworks for the standardization and benchmarking of energy investments in various sectors. In the EU therefore, regulatory and financing are main incentives for promoting energy efficiency and energy benchmarking is just part of the energy efficiency programs.

3.1.6 Summary of Benchmarking Review

The review of benchmarking models shows that all the jurisdictions used product-based energy performance benchmarking models. These models are based on production and energy performance. Statistical methods such as means, correlation analysis using linear regression and frequency distribution patterns are used to define the trends, baselines, best practices, and energy indices. This review therefore suggests that product based benchmarking, using EER tool, should be adopted as the benchmarking tool in the Kenyan market. Incentive schemes differ per country and state (in case of USA). Some countries however have no incentive schemes.

3.2 Development of Benchmarking Models

3.2.1 Response Rate

The response rate for the sampled facilities is presented in Table 3.1. The study considered the response rates adequate for representability. The lowest response rate, 48%, from the dairy industry, was acceptable because it was a census approach.

Table 3.1: Response rate for the sampled facilities

Category	Targeted Sample Size	Response	Response Rate (%)
Tea	84	84	100
Cement	11 (Census)	10	91
Flower Farms	36	25	69
Hotels	52	28	54
Dairy	29 (Census)	14	48
Fast Moving Consumer Goods	31	16	52
Sugar	13 (Census)	9	69

A list of all the facilities that participated in the study is provided in **Annex 1.**

3.2.2 Benchmarking Model for Tea Industry

The study developed two benchmarking models for the tea industry: woody biomass model and the electrical energy consumption model. The total monthly production, electricity and wood data used for the sector model is presented in Table 3.2.

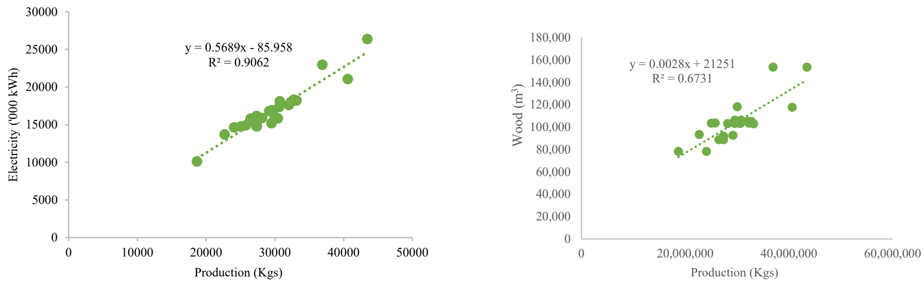
Table 3.2: Monthly Production and Energy Consumption for Tea Sector

Month	Made Tea (Kgs)	Electricity (kWh)	Firewood (m3)	Month	Made Tea (Kgs)	Electricity (kWh)	Firewood (m3)
Jul. 19	18,687,754	10,105,940	78,516	Jul.20	24,083,730	14,634,399	78,368
Aug.19	36,912,339	22,972,793	153,826	Aug.20	43,449,016	26,374,377	153,826
Sept.19	22,695,082	13,715,217	93,508	Sep.20	29,202,259	16,798,599	92,766
Oct.19	25,766,951	14,911,302	103,852	Oct.20	33,161,269	18,217,137	103,111
Nov.19	25,027,884	14,751,531	103,592	Nov.20	32,296,681	17,957,667	103,591
Dec.19	30,030,965	16,054,872	118,431	Dec.20	40,601,633	21,055,750	117,954
Jan.20	32,036,427	17,631,342	105,402	Jan.21	32,756,882	18,311,601	105,272
Feb.20	27,418,711	14,788,012	92,036	Feb.21	27,326,016	14,793,379	92,008
Mar.20	30,460,879	15,842,991	103,434	Mar.21	29,534,469	15,189,115	103,425
Apr.20	30,635,165	17,355,814	103,501	Apr.21	28,157,616	15,888,300	103,401
May.20	30,749,506	18,102,986	106,316	May.21	29,540,256	16,909,308	106,376
June.20	26,486,554	15,803,659	88,993	Jun.21	27,353,115	16,171,088	89,001

The data in Table 3.2 was used to determine the average EUI for the tea sector and to generate regression models for electricity and firewood use. The average electrical energy EUI for the tea sector was 0.57 kWh/kg of made tea while for wood energy, the EUI was 3.83 m3 /ton of made tea. The combined EUI for tea processing in Kenya was 31.96 GJ/ton. This is more than India, which records 30.6 GJ/ton[2] and Sri Lanka, at 31.23 GJ/ ton[3]. There is need for Kenyan tea industry to improve on their EUI in order to better compete with their counterparts from these countries. The total electrical energy consumption for the two years under study was 404,337 MWh, while the wood consumption was 2,204,968 m3. Figure 3-2 illustrates the models developed from the data.

2 *Kumar , S. ., & Pou, K. J. . (2016). Assessment of Bio-Energy Potential in Tea Industries of India. Asian Journal of Agriculture and Rural Development, 6(5), 83–89.*

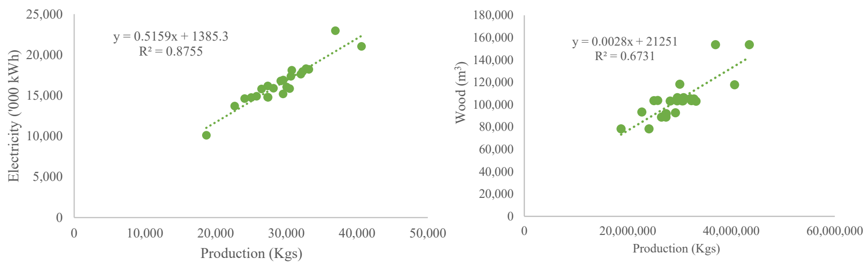
3 *Energy Consumption Benchmark Analysis, Sri Lanka Sustainable Energy Authority ,2020 accessed on 10th April 2024 via https://www.energy.gov.lk/images/energy-management/energy-consumption-benchmark-analysis.pdf*



Electricity vs Production Regression   Wood vs Production Regression

Figure 3-2: Primary Regression Models for Electricity and Wood Consumption

The regression models for electricity and wood consumption in Figure 3-2 were adjusted to improve the coefficient of determination (for wood) and to correct the negative baseline (electricity). The adjustment involved removing the outlier data points. The data for August 2019 and December 2020 was omitted for the wood consumption modeling. This was to improve the coefficient of determination from 0.67 to more than 0.70. For electricity model, data for the month of August 2020 was omitted. The monthly data is a summation from all the facilities. This omission therefore applied to all the facilities, negating the likelihood of model biasness. The adjusted models are presented in Figure 3-3.



Electricity vs Production Regression   Wood vs Production Regression

Figure 3-3: Adjusted Regression Models for Electricity and Wood Consumption

The models in Figure 3-3 were determined to be statistically significant for benchmarking in the tea sector. The coefficients of determination were used as the decision factor. The study used 0.7 as the minimum acceptance value. The EERs for all the sampled facilities in the tea sector are presented in the ogive in Figures 3-4 and 3-5.

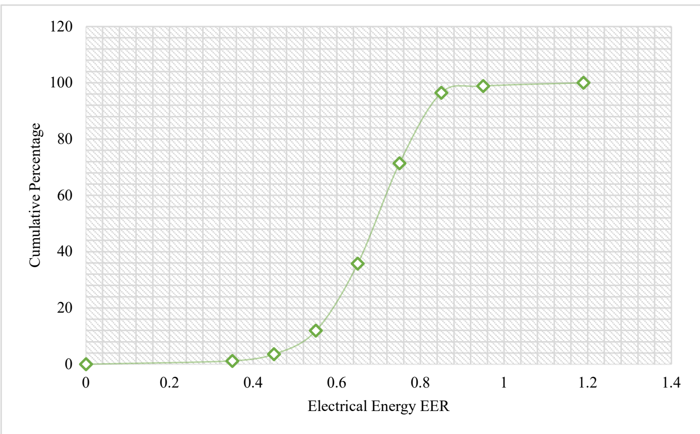


Figure 3-4: Tea Facilities' EER for Electrical Energy Consumption

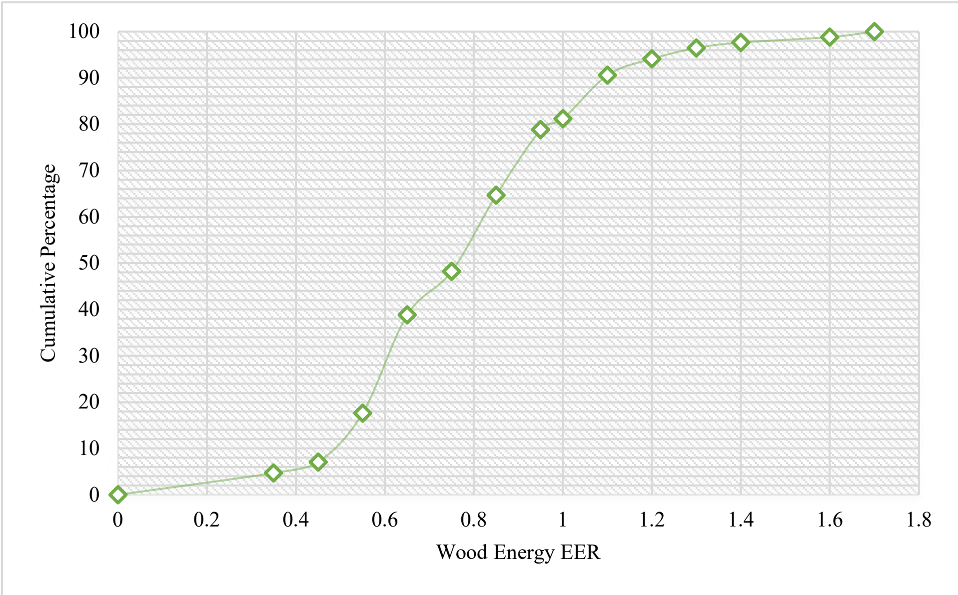


Figure 3-5: Tea Facilities' EER for Wood Energy Consumption

The study observed a distinct difference in the behavior of wood EER from that of electrical energy EER. Whereas only one facility had an EER above 1 for electrical energy consumption, 15 facilities had EER above 1 for the wood consumption. This implies that the performance spread for electrical energy is much closer compared to the performance of wood energy. If the 15 facilities improved to achieve an EER of 1, the savings could be higher, compared to if the same improvement was recorded for electrical energy consumption.

Benchmarking program targets well beyond achieving an EER of 1. Other facilities with EER less than 1 can improve too, by aiming to achieve the performance of the lower bands in the cumulative percentage. Total energy savings can be used as a guide to selecting the cut-off benchmarks. Figures 3-6 and 3-7 were presented, the assist in the consensus for benchmark targets.

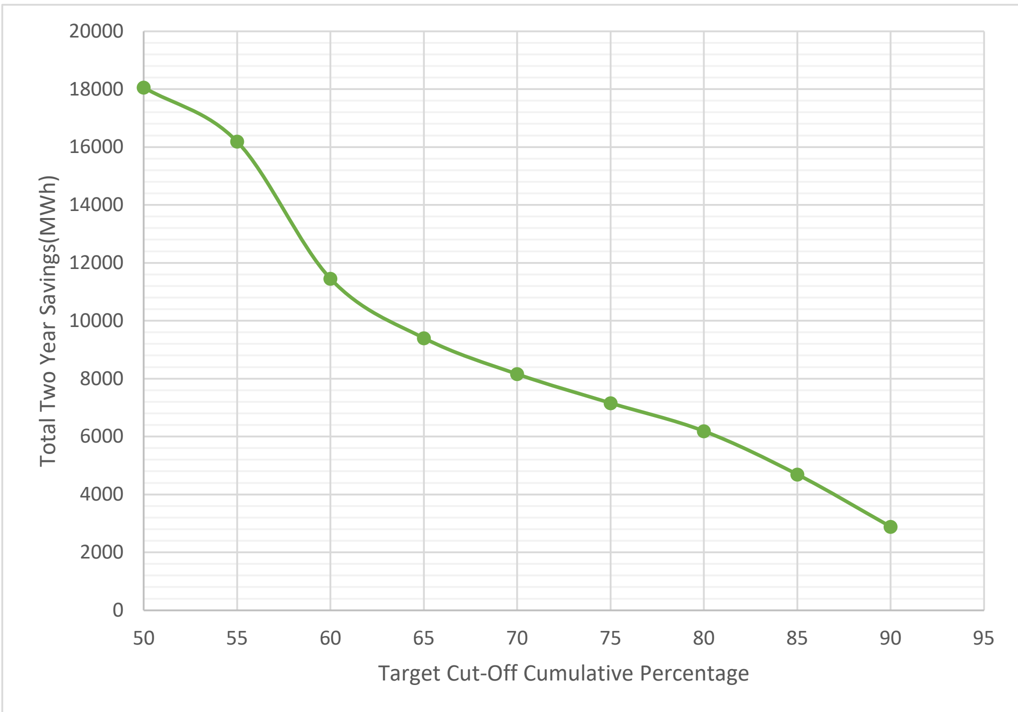


Figure 3-6: Simulation of Possible Electrical Energy Savings from different Benchmarks

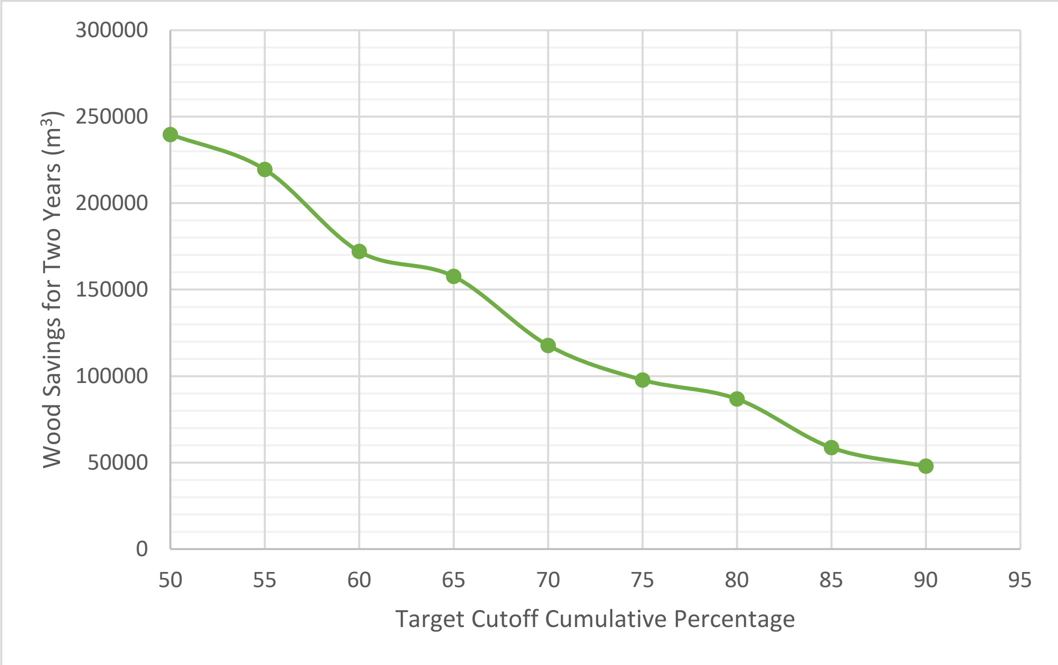


Figure 3-7: Simulation of Possible Wood Energy Savings from different Benchmarks

From Figures 3.3 and 3.4, it is illustrated that savings will depend on the cut-off EER agreed upon by the stakeholders. The cutoff EER corresponds to specific cumulative percentages, as presented in the ogives. The percentage of electrical energy savings, computed against the total energy of the sampled facilities, will vary between 1.2%, for the 90% cutoff point, and 7.8%, for the 50% cutoff point. For wood energy supply, for the same cutoff points, the savings were computed to be between 3.1% and 15.6%. The savings for both energy categories could be more, given that this computation does not take into account the continuous improvement of the facilities already in the desired EER bands. Energy performance of thermal duty in the tea industry presents a bigger potential for efficiency improvement, compared to electrical energy use.

3.2.3 Benchmarking Model for Fast Moving Consumer Goods

Fast moving consumer goods industry uses different sources of energy for their processes. The total monthly production, electricity and wood data used for the sector model is presented in Table 3.3.

Table 3.3: Monthly Production and Energy Consumption for FMCG

Month	Production (kgs)	Total Electricity Consumption	Electrical Power (KPLC kWh)	Diesel IDO (Liters)	Diesel Standby Genset (Liters)	Wood (Kgs)	Briquettes (kgs)
Jan-18	20,941,206	1,732,166	1,710,626.00	3,301.00	7,180.00	1,798,930.00	14,856
Feb-18	18,741,688	1,523,197	1,485,556.00	3,924.00	12,547.00	1,559,700.00	13,242
Mar-18	24,551,711	1,658,816	1,607,867.00	2,628.00	16,983.00	1,978,325.00	15,290
Apr-18	17,161,722	1,507,913	1,460,315.00	3,087.00	15,866.00	2,225,947.00	14,960
May-18	23,999,267	1,716,098	1,673,921.00	3,614.00	14,059.00	2,184,871.00	14,551
Jun-18	26,626,452	1,819,447	1,769,215.00	3,879.00	16,744.00	2,013,710.00	12,871
Jul-18	25,798,899	1,766,990	1,735,940.00	3,654.00	10,350.00	1,608,561.00	15,297
Aug-18	31,446,371	2,048,453	1,986,662.00	3,816.00	20,597.00	2,273,767.00	13,937
Sep-18	28,669,290	1,963,774	1,907,866.00	2,773.00	18,636.00	1,872,860.00	12,193
Oct-18	32,893,225	2,273,404	2,202,448.00	3,040.00	23,652.00	1,864,110.00	12,209
Nov-18	34,704,986	2,155,073	2,111,528.00	2,910.00	14,515.00	2,468,165.00	11,924
Dec-18	33,155,825	2,130,729	2,064,627.00	3,750.00	22,034.00	1,977,602.00	11,099
Jan-19	44,658,364	3,303,860	3,257,339.00	3,875.00	15,507.00	3,064,154.00	14,151
Feb-19	41,168,227	3,288,720	3,255,621.00	3,835.00	11,033.00	2,311,702.00	13,143
Mar-19	51,241,773	3,790,677	3,753,876.00	4,414.00	12,267.00	2,399,776.00	14,494
Apr-19	49,290,372	3,728,221	3,666,289.00	3,214.00	20,644.00	1,644,394.00	15,667
May-19	46,234,841	3,762,440	3,731,249.00	3,875.00	10,397.00	2,077,598.00	13,024
Jun-19	52,984,804	3,705,722	3,665,207.00	3,920.00	13,505.00	2,202,400.00	14,873
Jul-19	49,050,148	3,729,860	3,689,069.00	3,920.00	13,597.00	2,808,491.00	15,534
Aug-19	48,579,738	3,679,178	3,640,277.00	3,883.00	12,967.00	2,151,782.00	13,562
Sep-19	49,937,573	3,756,696	3,693,174.00	3,430.00	21,174.00	2,815,514.00	13,083
Oct-19	50,623,005	4,067,881	4,014,718.00	3,543.00	17,721.00	2,734,643.00	12,971
Nov-19	58,908,860	4,241,870	4,203,992.00	3,301.00	12,626.00	3,144,886.00	12,104
Dec-19	56,228,512	4,201,159	4,170,895.00	3,280.00	10,088.00	1,915,243.00	11,763

From the data presented in Table 3.3, the EUI for the FMCG sector was computed. Data for wood, IDO and briquettes was not considered for determination of the EUIs. The study omitted this data because of the disparities in the application of the technologies across the different plants considered. Some plants were using IDO, others wood and others briquettes. It is therefore not practical to come up with a benchmark measure for thermal energy that can be applied across all the plants. The average EUI for electricity consumption for the sector was determined to be 0.151 kWh per kg of product. The total electrical energy consumption for the 24 months of study was 41,082,326 MWh. Combined EUI for thermal and electrical energy was 3.73 GJ/ton. Nepal records 3.78 GJ/ton in the FMCG sector4. These results are comparable, thus lending validity to the data collected for the Kenyan FMCG sector. A regression model was developed from the data and is presented in Figure 3-8.

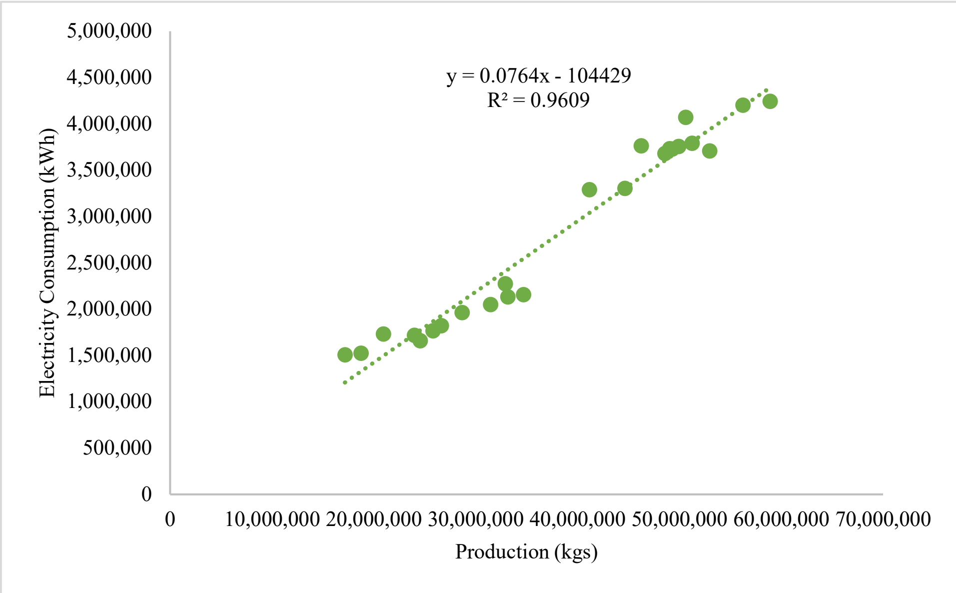


Figure 3-8: Regression Model for the FMCG Sector

The coefficient of determination for the model was considered satisfactory and the model was used for determination of the EER for the FMCG sector. The intercept was negative. However, its consequence to the model was considered marginal because the data sets do not spread below the 1,500,000 consumption mark on the y axis. The class limit ogive for electricity consumption EER for the FMCG sector was generated and is presented in Figure 3-9.

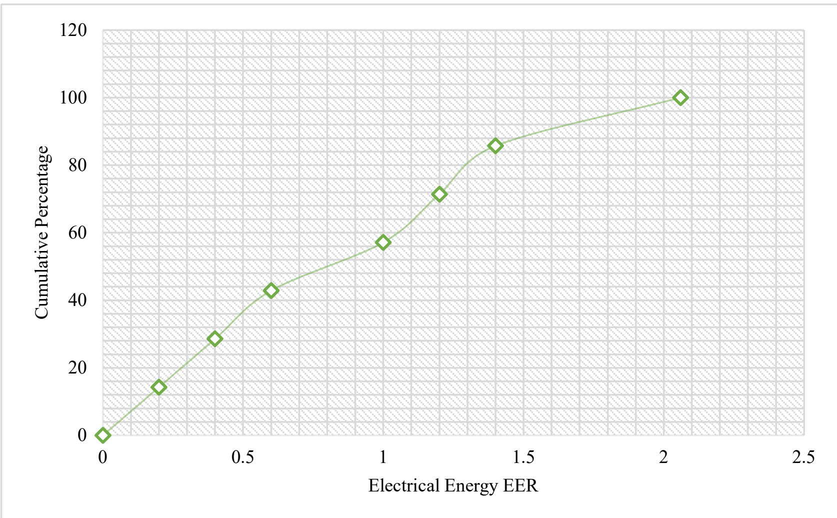


Figure 3-9: Ogive for EERs in the FMCG Sector

4. Report on Baseline Study of Selected Sector Industries to assess the Potentials for more Efficient use of Energy- Nepal Energy Efficiency Programme (NEEP)/ GIZ National Trust for Nature Conservation,2012.

Three out of the total firms investigated have an EER of more than 1. One of the firms has an EER of more than 2. FMCG plants have different operation modes and this could explain the spread in performance. For example, one could be more into soap than cooking oil making, and this could lead to differences in performances. However, this observation of a high range between the lowest and the highest EER potent a chance for cross-firm learning and an opportunity for the EERs to converge towards the mean, with more energy efficiency programs. Designation of benchmarks will work towards improving this.

This study simulated potential energy savings that can be achieved in the FMCG sector, if the benchmarks are adopted. The simulation is presented in Figure 3-10.

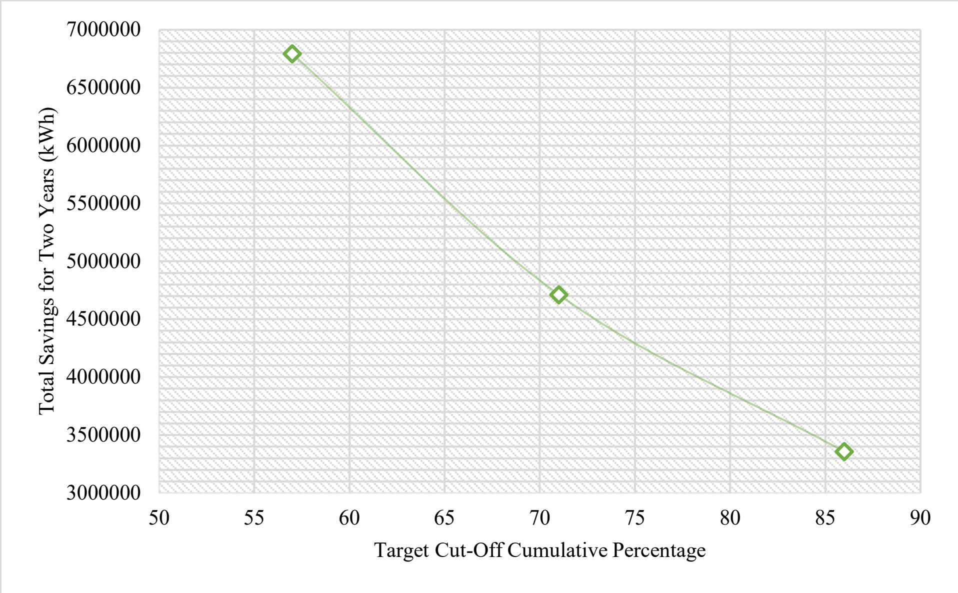


Figure 3-10:Simulation of Possible Savings with different Cut-Off Levels

The cut-off of 57% potent to reduce energy consumption in this industry by 27%, while cut-offs of 71% and 86% will reduce consumption by 19% and 13%, respectively. The reduction percentage is based on the total recorded two-year consumption of the sampled facilities.

3.2.4 Benchmarking Model for Cement

The cement industry is segmented into three categories: hybrid, grinding and clinker. Some facilities combine the process of firing clinker and grinding it into cement, thus the hybrid type. Others do these processes separately. There were only two plants of the hybrid type. Benchmark models for the two plants were found to have poor coefficients of determination, at 35% for electricity and 5% for thermal energy. This can be attributed to the combination of the two disparate processes. The two plants were however also included in the population that was used to develop separate models for grinding and clinker firing. Cement industry's two years' production and energy consumption data for grinding and clinker firing facilities is presented in Tables 3.4 and 3.5, respectively.

Table 3.4: Production and Energy Consumption Data for Cement Grinding

Month	Production (tonnes)	Electricity (kWh)	Diesel (litres)	HFO (litres)	Coal (kgs)
Jan 18	460,680.28	14,963,940.36	9,660.00	144,086.02	791.55
Feb 18	427,068.93	13,415,421.55	8,070.00	153,763.44	712.85
Mar 18	416,953.70	13,669,357.45	8,869.00	217,204.30	552.95
Apr 18	421,701.77	13,887,729.97	7,964.00	305,376.34	607.13
May 18	401,842.02	14,142,974.08	9,071.00	330,107.53	614.55
Jun 18	408,788.02	13,682,536.17	7,040.00	235,483.87	565.35
July 18	448,654.52	15,314,540.28	8,990.00	301,075.27	601.11
Aug 18	441,438.06	15,171,854.59	9,085.00	196,774.19	554.16
Sept 18	420,863.15	14,533,989.94	8,824.00	219,354.84	525.13
Oct 18	426,430.42	14,902,138.47	13,183.00	105,376.34	536.83
Nov 18	427,675.75	14,531,234.65	10,784.00	251,612.90	649.38
Dec 18	427,188.89	15,291,373.73	7,150.00	201,075.27	617.32
Jan 19	430,818.43	13,984,575.97	10,173.00	228,358.00	712.11
Feb 19	446,628.81	13,167,928.94	6,671.00	79,783.00	895.97
Mar 19	438,923.26	14,182,588.51	6,763.00	67,580.00	545.48
Apr 19	452,037.54	14,280,010.86	6,240.00	153,507.00	692.40
May 19	466,589.57	14,449,246.60	6,763.00	146,321.00	811.23
June 19	413,311.96	13,174,847.78	7,106.00	111,483.00	714.87
July 19	502,701.14	15,450,725.98	6,556.00	139,434.00	855.97
Aug 19	488,741.82	16,208,284.05	6,435.00	114,745.00	737.03
Sept 19	488,833.79	15,482,098.31	7,903.00	151,650.00	851.51
Oct 19	430,661.16	13,482,136.01	5,014.00	152,779.00	626.51
Nov 19	446,485.54	13,492,100.07	7,184.00	106,365.00	844.16
Dec 19	429,150.92	13,444,395.75	7,572.00	209,238.00	881.50

Table 3.5: Production and Energy Consumption Data for Clinker Firing

Month	Production (tonnes)	Electricity (kWh)	Diesel (liters)	HFO (liters)	Coal (kgs)
Jan 18	460,680.28	14,963,940.36	9,660.00	144,086.02	791.55
Feb 18	427,068.93	13,415,421.55	8,070.00	153,763.44	712.85
Mar 18	416,953.70	13,669,357.45	8,869.00	217,204.30	552.95
Apr 18	421,701.77	13,887,729.97	7,964.00	305,376.34	607.13
May 18	401,842.02	14,142,974.08	9,071.00	330,107.53	614.55
June 18	408,788.02	13,682,536.17	7,040.00	235,483.87	565.35
Jul 18	448,654.52	15,314,540.28	8,990.00	301,075.27	601.11
Aug 18	441,438.06	15,171,854.59	9,085.00	196,774.19	554.16
Sept 18	420,863.15	14,533,989.94	8,824.00	219,354.84	525.13
Oct 18	426,430.42	14,902,138.47	13,183.00	105,376.34	536.83
Nov 18	427,675.75	14,531,234.65	10,784.00	251,612.90	649.38
Dec 18	427,188.89	15,291,373.73	7,150.00	201,075.27	617.32
Jan 19	430,818.43	13,984,575.97	10,173.00	228,358.00	712.11
Feb 19	446,628.81	13,167,928.94	6,671.00	79,783.00	895.97
Mar 19	438,923.26	14,182,588.51	6,763.00	67,580.00	545.48
Apr 19	452,037.54	14,280,010.86	6,240.00	153,507.00	692.40
May 19	466,589.57	14,449,246.60	6,763.00	146,321.00	811.23
June 19	413,311.96	13,174,847.78	7,106.00	111,483.00	714.87
Jul 19	502,701.14	15,450,725.98	6,556.00	139,434.00	855.97
Aug 19	488,741.82	16,208,284.05	6,435.00	114,745.00	737.03
Sept 19	488,833.79	15,482,098.31	7,903.00	151,650.00	851.51
Oct 19	430,661.16	13,482,136.01	5,014.00	152,779.00	626.51
Nov 19	446,485.54	13,492,100.07	7,184.00	106,365.00	844.16
Dec 19	429,150.92	13,444,395.75	7,572.00	209,238.00	881.50

The thermal energy sources used for the clinker firing differed across the sampled facilities. This means whereas some facilities used coal, others used car tyres, HFO or diesel. The regression model developed for electricity energy used in clinker firing processes is presented in Figure 3-11.

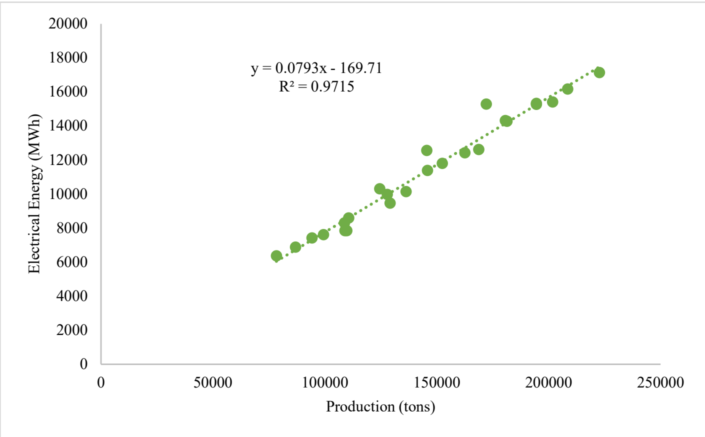


Figure 3-11: Regression Model for Firing of Clinker

The model in Figure 3-11 was adjusted by removing two months which were considered to lie outside the line of fit. The months of September and December 2018 were omitted. The corrected model was used to develop the EER class limit ogive, presented in Figure 3-12.

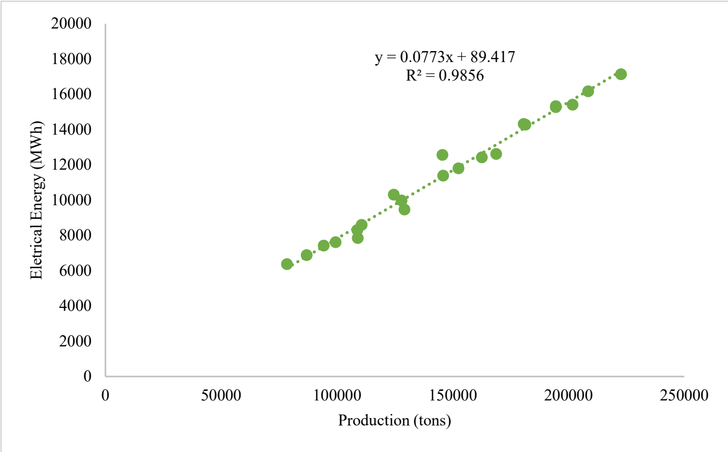


Figure 3-12: Adjusted Regression Model for Firing of Clinker

The adjusted regression model was used to determine the EER for the facilities that fire clinker. The EERs were plotted on an ogive, and have been presented in Figure 3-13.

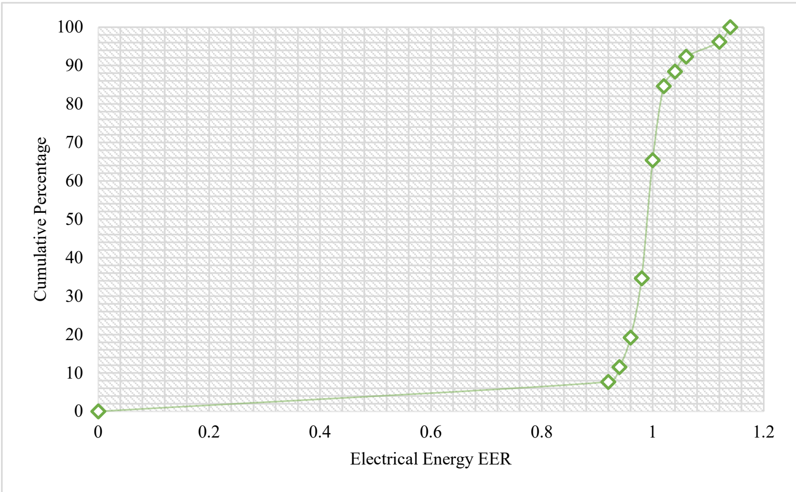


Figure 3-13: Class Limit Ogive for Clinker Firing Electrical Energy

The ogive reveals that 43% of the facilities lie below the expected group performance. There is therefore room for these facilities to improve their EUIs, by improving their efficiencies, to attain the EER of 1. To understand the possible sector savings from such improvement, this study plotted a curve, simulating savings versus the percentage cut-off benchmarks. The simulation is illustrated in Figure 3-14.

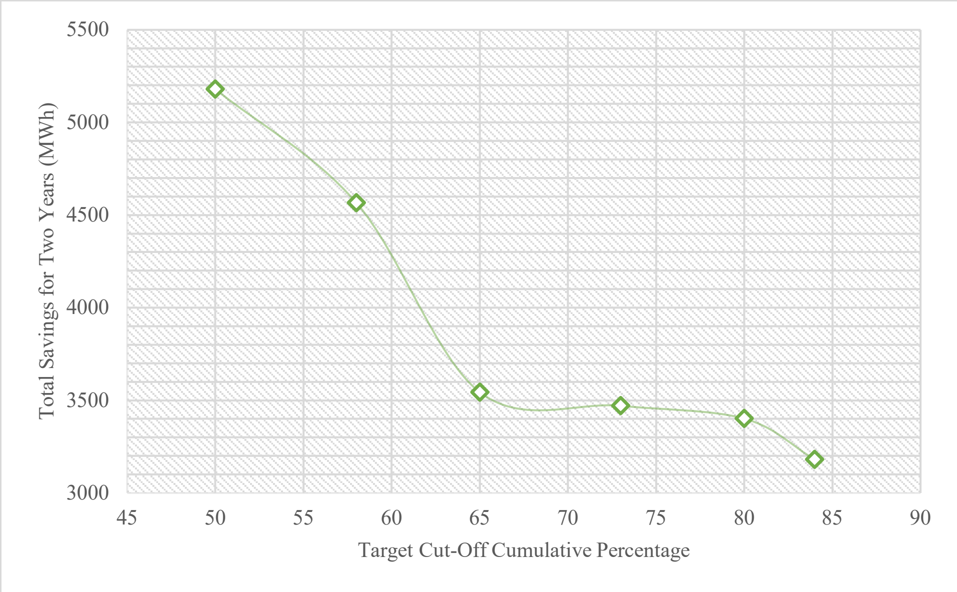


Figure 3-14: Possible Benchmark Savings for Clinker Firing

The figure shows that a cut-off of 85% will lead to a 1.12% reduction of the total energy consumed for the two years. The percentage savings increases, with increase of the cut-off percentage. A cut-off of 50% is estimated to save 1.82% of the total energy consumed for two years. A regression model presented in Figure 3-15 was used to determine benchmarks for clinker grinding.

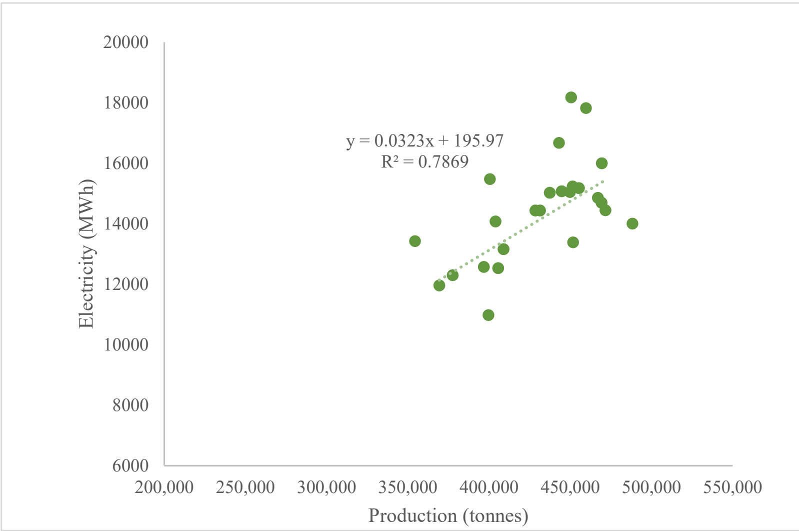


Figure 3-15: Regression Model for Clinker Grinding Process

The regression model in Figure 3-15 was used to develop EER ogive for the facilities. The class limit ogive for clinker grinding is presented in Figure 3-16.

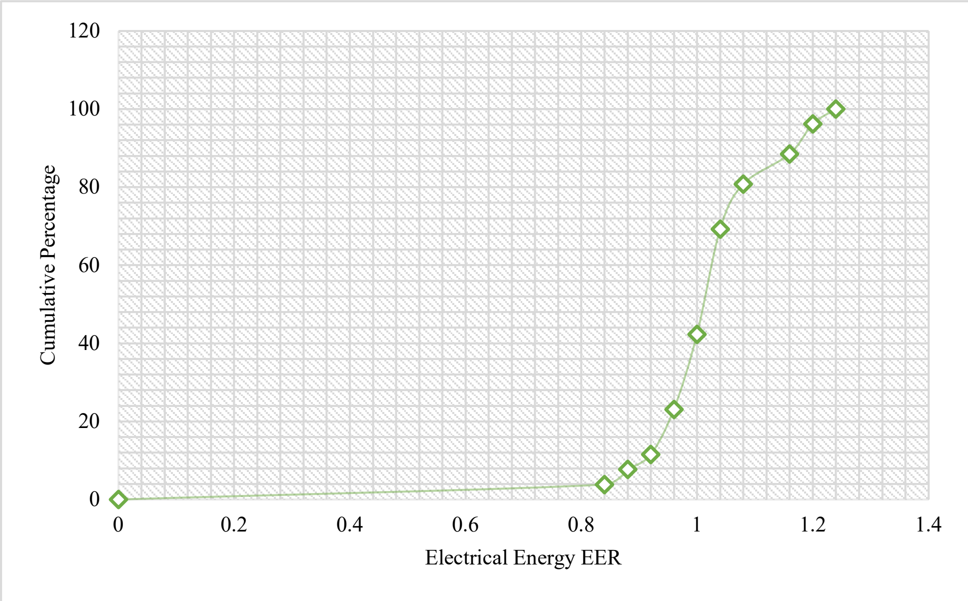


Figure 3-16: Class Limit Ogive for Clinker Grinding

Only 42% of the facilities have an EER of less than 1. There is an opportunity for the facilities above this EER, which make up the 58%, to improve and lead to sector energy savings. A simulation of these savings, based on different cut-off benchmarks, is presented in Figure 3-17.

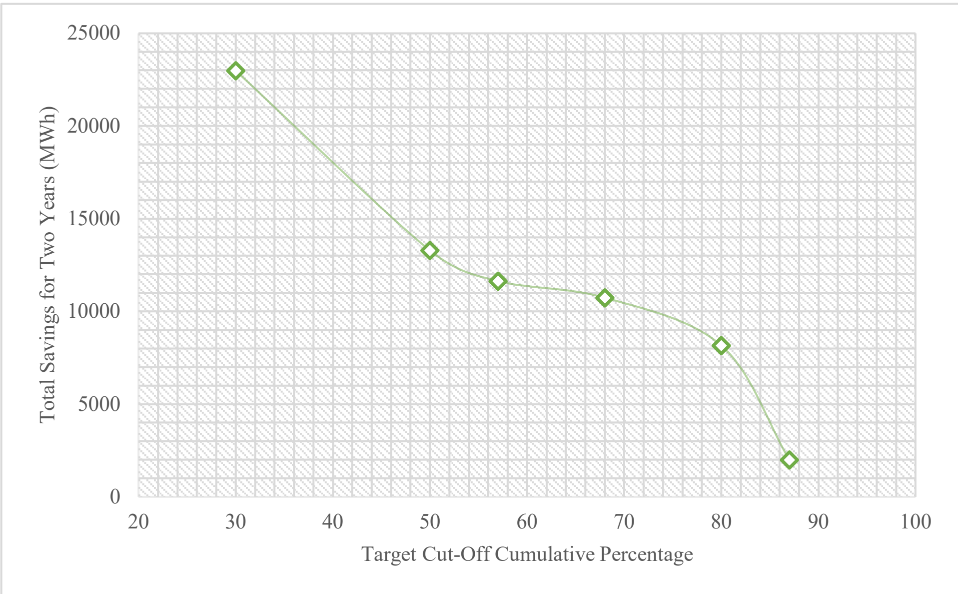


Figure 3-17: Possible Benchmark Savings for Clinker Grinding

The grinding function of the cement industry in Kenya can save up to 3.68% of the total energy consumed for two years, if the bottom 50% of the factories improved their performance to meet the average benchmark EER of 1.01.

3.2.5 Benchmarking Model for Sugar Industry

The sugar industry uses both thermal and electrical energy. Thermal energy is mostly supplied using bagasse. The steam from bagasse fired boilers is used in a combined heat power system, where some is used to generate power, in high pressure turbines, while low pressure steam is used in the processing of sugar. The data combined from the factories is presented in Table 3.6.

Table 3.6: Production and Energy Consumption Data for Sugar Industry

Month	Production Sugar (Tonnes)	Electrical Power(KPLC kWh)	Electricity (Own generation) (kWh)	Diesel Standby Genset (Ltrs)	Total Electrical Energy (MWh)	Biomass (tons)
Apr 18	20127.12	1,043,022.55	8,258,466.24	15,425.00	9,347.76	64,362.27
May 18	25326.71	969,769.23	8,700,185.98	16,660.00	9,719.94	50,319.07
Jun 18	14738.66	768,640.22	8,006,656.93	15,579.00	8,822.03	54,421.02
July 18	17102.67	719,238.85	8,912,926.87	21,654.00	9,697.13	61,436.95
Aug 18	20905.7	962,439.95	9,490,316.07	11,619.00	10,487.61	79,643.20
Sept 18	23117.64	1,060,543.47	9,407,814.38	21,183.00	10,531.91	82,965.48
Oct 18	28028.29	1,178,186.13	11,771,864.25	24,306.00	13,022.97	99,319.75
Nov 18	26470.61	1,204,959.56	10,738,716.05	29,764.00	12,032.97	88,536.79
Jan 19	31013.762	1,203,023.96	14,310,617.61	16,524.00	15,563.21	25,513,877.27
Feb 19	31184.633	996,620.13	13,684,047.06	19,504.00	14,739.18	23,871,661.00
Mar 19	44644.227	1,001,255.97	18,058,881.45	11,361.00	19,094.22	24,648,847.30
Apr 19	28651.103	896,408.85	12,777,297.90	14,383.00	13,716.86	25,390,851.14
May 19	21627.448	831,990.39	12,667,917.69	15,440.00	13,546.23	24,733,381.44
June 19	21,905.90	588,091.51	12,562,439.82	7,830.00	13,174.02	24,757,361.44
July 19	22092.882	563,393.39	11,541,587.09	5,370.00	12,121.09	25,366,260.81
Aug 19	24563.727	601,382.51	11,756,555.30	6,180.00	12,376.48	26,191,116.43
Sept 19	29702.208	696,690.40	13,899,441.26	13,785.00	14,637.49	38,224,124.20
Oct 19	29529.067	772,727.86	13,284,704.01	17,890.00	14,111.10	29,052,883.45
Nov 19	24728.003	767,839.75	11,308,403.24	18,430.00	12,131.53	18,632,247.06
Dec 19	25101.326	801,917.38	11,827,042.71	23,796.00	12,700.35	22,364,169.35

The information was used to develop simple regression models, as predictors to thermal and electrical energy use in the sector. The combined EUI for Kenyan sugar industry was determined to be 23.84 GJ/ton. Thailand and Brazil have values of 16.52 GJ/ton and 11.12 GJ/ton[5], respectively. The disparity between Kenya on one hand and the two countries on the other hand is high, with differences of more than 50 %. Regression model for electrical energy consumption is presented in Figure 3-18.

5 *Sathitbun-anan, S., Fungtammasan, B., Barz, M., Sajjakulnukit, B., & Pathumsawad, S. (2014). Energy efficiency and greenhouse gas emission reduction potentials in sugar production processes in Thailand. Energy for Sustainable Development, 23, 266–274. https://doi.org/10.1016/j.esd.2014.09.010*

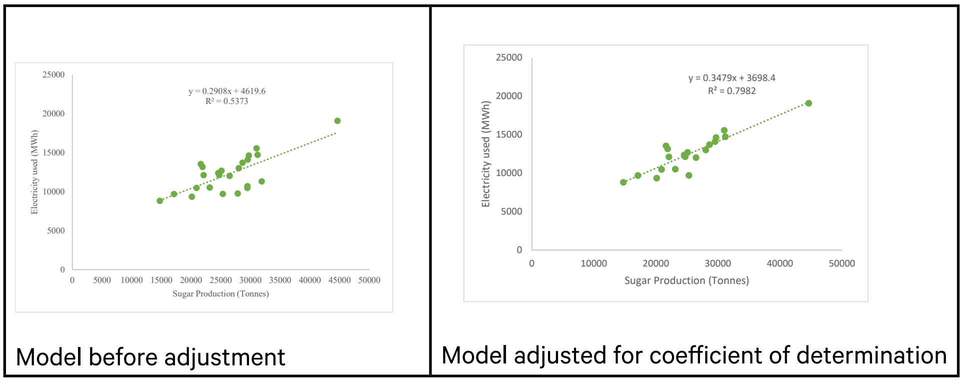


Figure 3-18: Regression model for electricity use in Sugar Industry

The model in Figure 3-18 was used to develop the ogive for EERs for the studied factories. The ogive is presented in Figure 3-19.

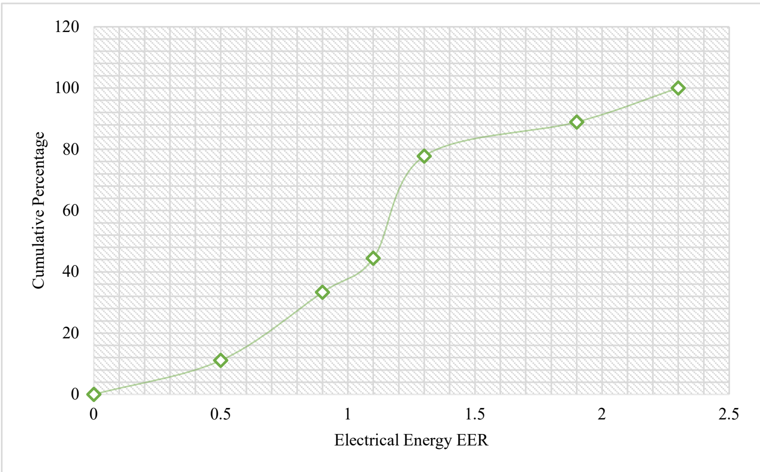


Figure 3-19: EER Ogive for Electrical Energy use for Sugar Industry

More than half of the studied facilities are performing below the industry average. About 66 % of the facilities were found to have an EER above the class limit of 1.1. These findings suggest that there is room to make savings, should the facilities improve their energy performance, above the industry average. Figure 3-20 simulates the possible industry savings, under different benchmarks, relative to industry performance.

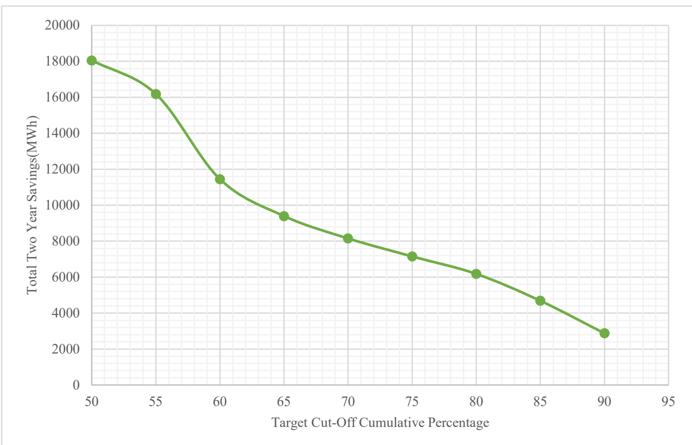


Figure 3-20: Simulation of possible savings for Sugar Industry

Improvement of facilities in energy performance can save from 88378 MWh, if they all fell within the performance bracket of the first 33 % best performers, to 9125 MWh, if they were within the first 90 % best performers. This ranges from 30 % savings to 3.1 % savings, depending on the benchmarks to be adopted.

Treatment similar to the electrical energy was applied to thermal energy, starting with development of the energy use predictor model. The model is presented in Figure 3-21.

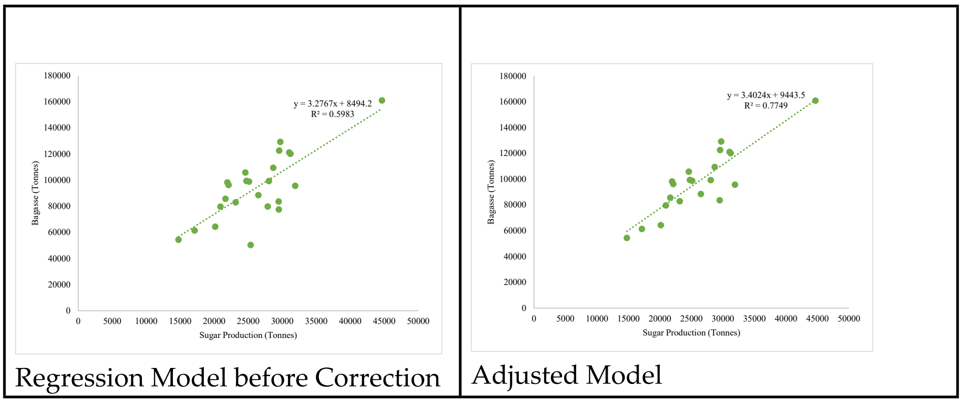


Figure 3-21: Regression Model for Thermal Energy use in Sugar Industry

The model with the coefficient of determination of 0.7749 was used to compute the EERs for the sugar processing facilities. An ogive with EER class limits was developed and is presented in Figure 3-22.

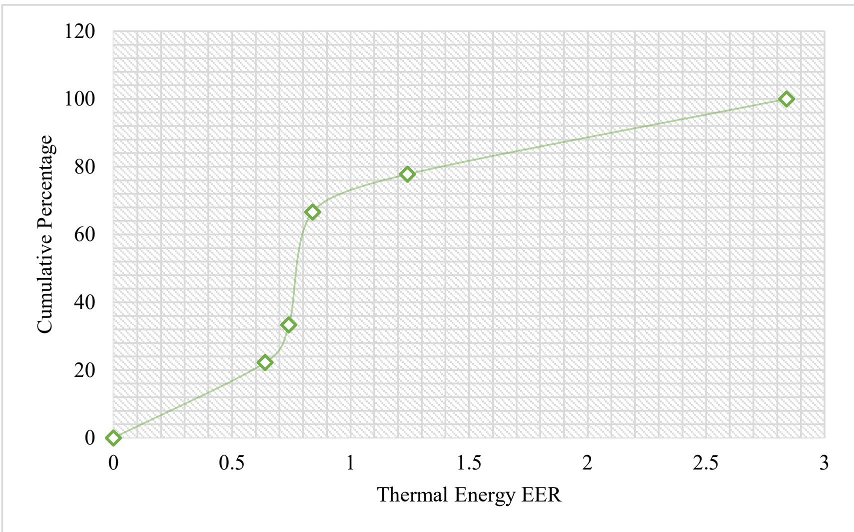


Figure 3-22: EER Class Limit Ogive for Thermal Energy in Sugar Industry

As opposed to the electrical energy use, the most facilities have EERs that fall below the industry average, indicating unity of operations that ensure good energy performance. However, some facilities still have EERs above the industry average, raising the case of an opportunity for improvement. Figure 3-23 simulates the likely benefits, should facilities improve their performance, to catch up with their best performing peers.

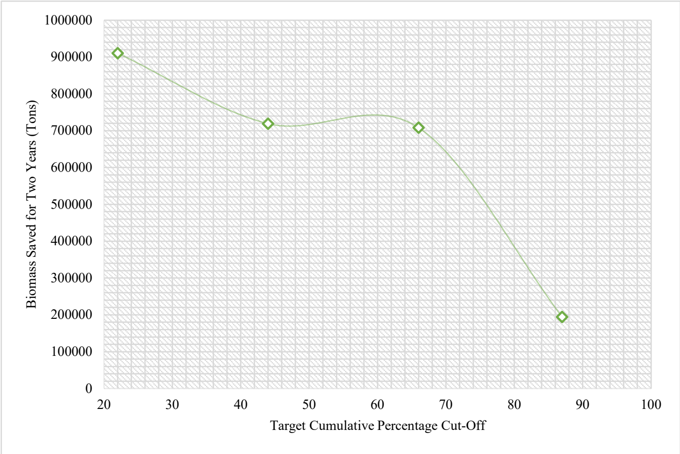


Figure 3-23: A Simulation of Likely Savings for different Cut-Off Points

Close performance range among the facilities notwithstanding, the simulation reveals that energy can be saved should some facilities improve their performance. A highly ambitious target, where 78% of the facilities would improve to match the ones in the 22% category, there would be 40% energy savings. In less ambitious target, where only 13% of the facilities would be targeted for improvement, only 8.6% of the biomass currently in use would be saved.

3.2.6 Energy Performance Model for Hotel Industry

The data for the hotel industry considered consumption in terms of occupancy, ambient temperate and energy use. The energy consumption analysis factored both electrical and thermal energy consumption. The monthly aggregate two-year data used for modeling performance is presented in Table 3.7.

Table 3.7: Production and Energy Consumption Data for Hotels

Month	Electrical Energy (MWh)	Occupancy (Bednights)	Temperature Difference (°C)	Month	Electrical Energy (MWh)	Occupancy (Bednights)	Temperature Difference (°C)
Jan-18	1184.79	25610.95	2.9	Jan-19	1633.80	35241.19	4
Feb-18	1108.70	24868.51	4	Feb-19	1652.67	37117.92	4.5
Mar-18	1152.74	22429.03	3.7	Mar-19	1538.22	29518.90	5
Apr-18	1276.47	28064.27	3.3	Apr-19	1606.85	37482.50	5.4
May-18	1018.71	18584.08	1.8	May-19	1281.69	20322.61	2.3
Jun-18	1051.60	21252.07	1.1	Jun-19	1163.48	23423.00	1.9
Jul-18	1199.68	29598.40	0.2	Jul-19	1218.24	31001.04	1.1
Aug-18	1432.96	41420.31	0.6	Aug-19	1544.67	39258.95	1.2
Sep-18	1209.55	23147.70	1.5	Sep-19	1318.97	27741.00	1.6
Oct-18	1369.57	32783.96	1.9	Oct-19	1483.47	38560.43	2.1
Nov-18	1433.31	33599.47	3.1	Nov-19	1557.41	37531.07	3.1
Dec-18	1741.60	53114.37	4	Dec-19	2020.48	53620.94	3.8

A multiple regression model was developed, regressing energy consumption against occupancy and temperature difference. The electrical and thermal energy use indices were 61.94 kWh/bed night per year and 89.15 MJ/bed night, respectively. The regression model is presented in Table 3.8.

Table 3.8: Multiple Regression Model for Electricity Consumption in Hotels

Regression Statistics					
Multiple R	0.936230696				
R Square	0.876527917				
Adjusted R Square	0.864768671				
Standard Error	90.4505318				
Observations	24				
ANOVA					
	Df	SS	MS	F	Significance F
Regression	2	1219659.272	609829.6359	74.53947	2.89382E-10
Residual	21	171807.2728	8181.298704		
Total	23	1391466.545			
	Coefficients	Standard Error	t Stat	P-value	
Intercept	565.821646	69.45396869	8.146714388	6.15E-08	
Occupancy (Bednights)	0.021671959	0.002093351	10.35275895	1.05E-09	
Temperature Difference (°C)	47.33996274	13.6820238	3.460011723	0.002343	

Statistical significance indicators for the model reveal that the relationship between energy consumption and occupancy on one hand and temperature difference on the other hand, is statistically significant. The coefficient of determination, the p-value and the F-statistic are within acceptable limits. Specifically, the p values for the intercept and the independent variables are less than 0.05. The F statistic is more than the F critical value. The model was therefore use to develop the EER ogive, presented in Figure 3-24.

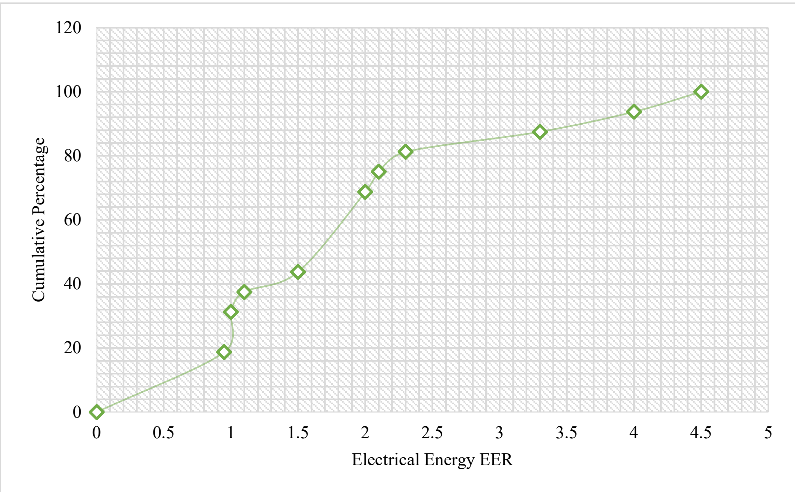


Figure 3-24: Electricity use EER Ogive for Hotel Industry

From the ogive, it was revealed that 43% of the hotel facilities operate under the average industry performance. There are opportunities therefore for the facilities to improve their performance and save energy, which will reduce the cost of operation. Simulation in Figure 3-25 illustrates the possible savings that can be achieved in this industry.

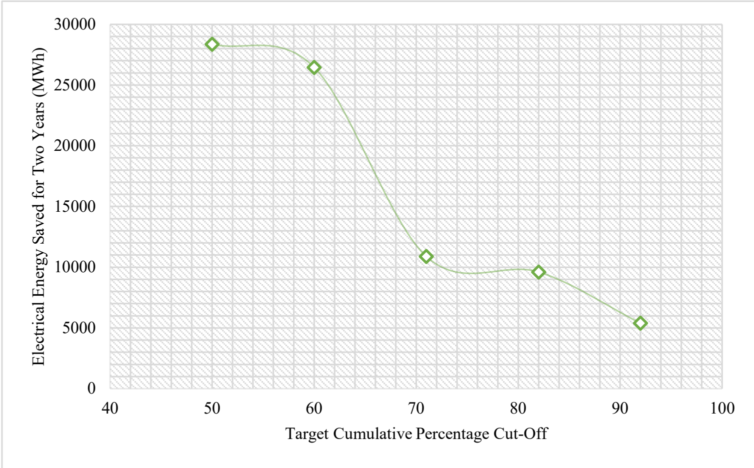


Figure 3-25: Possible Benchmark Savings for Electrical Energy in Hotels

The possible savings could range from 45%, if 50% of the facilities shifted to the performance of the best facilities. If the benchmarks target only 8% of the bottom performing facilities, only 8.6% savings will be realized. The data for thermal energy consumption was aggregated and is presented in Table 3.9.

Table 3.9: Thermal energy consumption for hotel industry

Month	Boiler Diesel (liters)	LPG (kgs)	Average Electrical Energy (kWh)	Total Thermal Energy (MJ)	Electrical Energy Intensity (kWh/ Occupancy)	Thermal Energy Intensity (kWh/ Occupancy)	Month	Boiler Diesel (liters)	LPG (kgs)	Average Electrical Energy (kWh)	Total Thermal Energy (MJ)	Electrical Energy Intensity (kWh/ Occupancy)	Thermal Energy Intensity (kWh/ Occupancy)
Jan-18	6956	1442	80542	336639	50	209	Jan-19	8386	1689	98499	403515	54	221
Feb-18	6472	1391	78138	315505	49	196	Feb-19	7188	1724	96892	358839	51	188
Mar-18	7149	1539	82317	348646	53	226	Mar-19	7011	1562	99568	344360	57	198
Apr-18	7177	1563	87138	350831	50	202	Apr-19	6948	1713	102404	349063	52	177
May-18	7467	1621	74403	364786	54	267	May-19	6941	1659	92611	346222	64	241
Jun-18	7577	1512	81100	363927	54	242	Jun-19	7869	1671	85946	382696	57	252
Jul-18	8301	1991	87497	414370	45	214	Jul-19	8987	1952	91835	439085	49	233
Aug-18	9210	2443	98330	470760	40	193	Aug-19	8849	1996	101964	435802	45	194
Sep-18	8252	1820	89809	404466	53	240	Sep-19	8465	1938	95762	418235	53	233
Oct-18	8760	2204	97701	442109	51	229	Oct-19	8371	2050	100801	419879	47	196
Nov-18	8544	2179	97435	432626	51	225	Nov-19	9047	2062	101844	446556	48	212
Dec-18	8903	2245	109578	449602	41	169	Dec-19	8780	2175	117937	441552	45	167

The study modelled thermal energy use separately, that is, for diesel and for LPG. The simple regression models are presented in Figures 3-26 and 3-27.

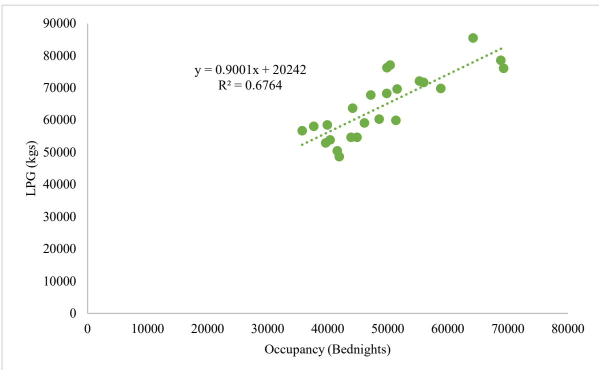


Figure 3-26: Regression model for LPG use in Hotels

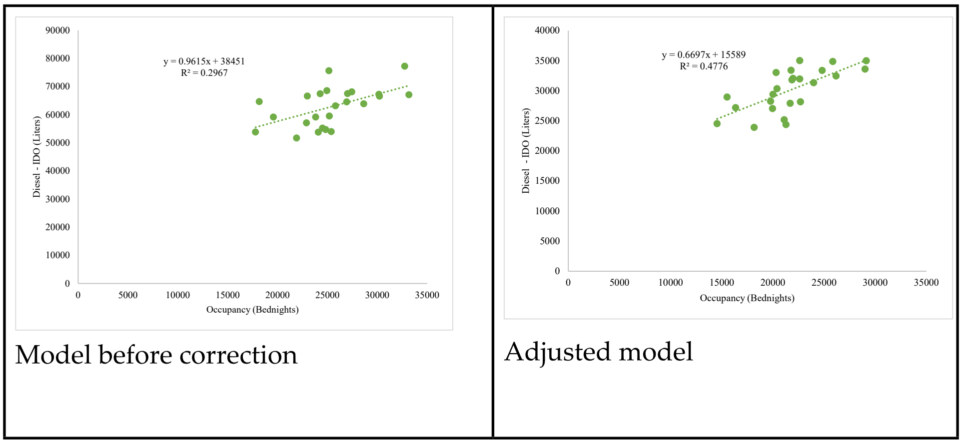


Figure 3-27: Regression Models for Diesel use in Hotels

The two models in Figures 3-26 and 3-27 were used to come up with the EER ogive for diesel and LPG use in the studied hotels. The IDO model had a poor coefficient of determination, at 0.47, against the desired value of 0.75. This made it difficult to use it for setting benchmarks. For information purpose however, EER was computed for both sources and ogives were generated. They are presented in Figures 3-28 and 3-29.

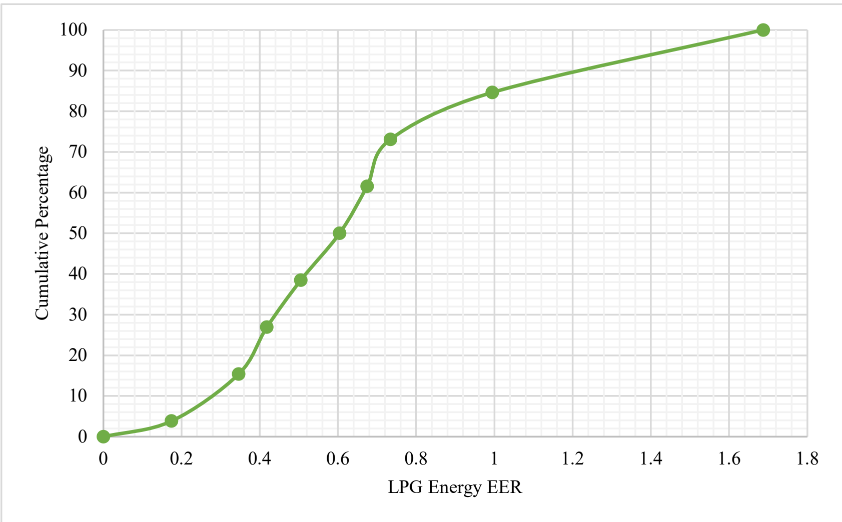


Figure 3-28: EER Ogive for LPG use in Hotels

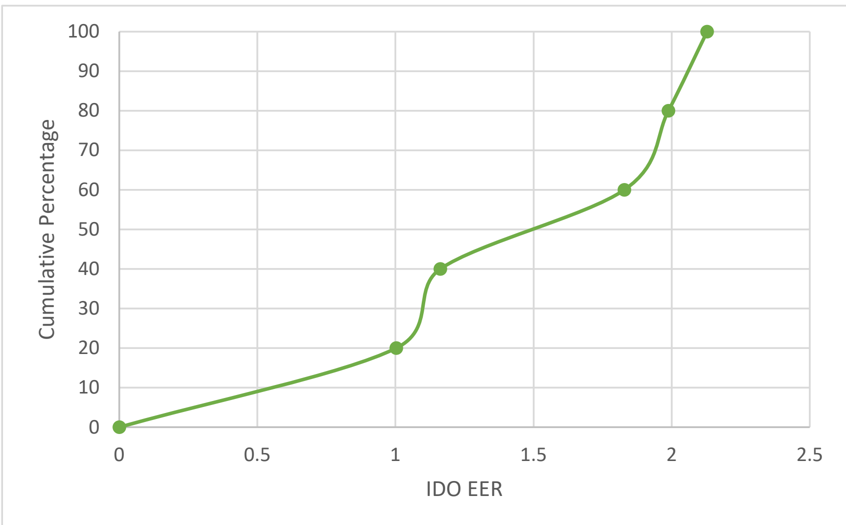


Figure 3-29: EER Ogive for IDO use in Hotels

The two ogives were used to forecast the thermal energy that would be saved, if hotel facilities implemented measures to improve their energy performance to specific EER benchmarks. Given the low coefficient of determination for IDO use in hotels, simulation of savings was not considered. The forecast for savings in LPG are presented in Figure 3-30.

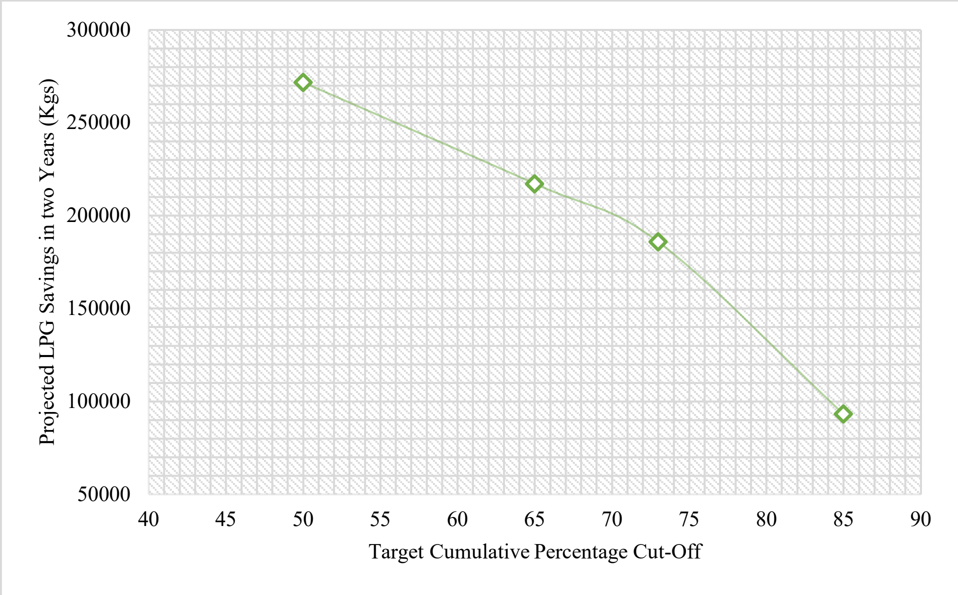


Figure 3-30: Possible Benchmark Savings for LPG Energy in Hotels

The potential savings, should the energy benchmarks be adopted at 50%, is 25%, and should this be lowered to target 15%, the savings would be 8.6%. The possible savings are lower compared to electricity savings. This could be alluded to almost standardized ways of using LPG cookers, compared to the variety of uses of electrical energy in the hotels, which could introduce variations in efficiencies. In addition, the variations in electricity could be attributed to cooling systems, whose energy requirements vary per geographical region. A typical hotel at the coastal region would deploy air conditioners the entire day, while a hotel in the Kenya Highlands region would not need the same.

3.2.7 Energy Performance Model for Flower Farms

Flower farms use electricity for water pumping and cooling of the flowers. They do not have thermal energy uses. The combined data, for 24 months, for production and energy consumption from the studied farms is presented in Table 3.10.

Table 3.10: Production and Energy Consumption Data for Flower Farms

Month	Production (stems)	Electrical Power	Diesel Standby Genset (liters)	Total Energy (kWh)	Energy Intensity (kWh/1000 stem)	Month	Production (stems)	Electrical Power	Diesel Standby Genset (liters)	Total Energy (kWh)	Energy Intensity (kWh/1000 stem)
Jan-18	79989527	1654437	42839	1782954	22.29	Jan-19	94322823	1949345	58618.50	2125200.5	22.531138
Feb-18	92879060	1706869.4	53601	1867672.4	20.11	Feb-19	92273380	1943952.3	57252.00	2115708.3	22.928697
Mar-18	81598630	1664764.9	69860.5	1874346.4	22.97	Mar-19	88932897	2101626	56580.75	2271368.3	25.540249
Apr-18	65405564	1588472.8	63367	1778573.8	27.19	Apr-19	71710971	1915036.3	66270.18	2113846.8	29.477314
May-18	67703485	1564470	66256	1763238	26.04	May-19	77416197	1997983.6	57196.50	2169573.1	28.024796
Jun-18	60431693	1559512	37554	1672174	27.67	Jun-19	68387584	1697470.1	36660.50	1807451.6	26.429528
Jul-18	55715001	1602468.6	38110	1716798.6	30.81	Jul-19	72811232	1880842.8	40024.00	2000914.8	27.480853
Aug-18	57113936	1546777.2	44965	1681672.2	29.44	Aug-19	73944752.51	1753347.6	41267.50	1877150.1	25.385846
Sep-18	61744549	1578132.4	42374.5	1705255.9	27.62	Sep-19	63394235.29	1678539.7	45550.70	1815191.8	28.633389
Oct-18	70247597	1709254.1	54764	1873546.1	26.67	Oct-19	78969096.27	1797069.1	40699.50	1919167.6	24.302768
Nov-18	65980527	1704904.4	48200.5	1849505.9	28.03	Nov-19	82431063.68	1763204.6	46722.00	1903370.6	23.090453
Dec-18	73371066	1672426	41564.4	1797119.2	24.49	Dec-19	83803967.51	2044875.9	32271.00	2141688.9	25.555937

The EUIs for flower farms varied widely, from 1 kwh per stem to 120 kwh per stem. It was therefore not possible to statistically represent the average EUI for the industry. The data was used to develop a regression model between production and energy consumption, as presented in Figure 3-31.

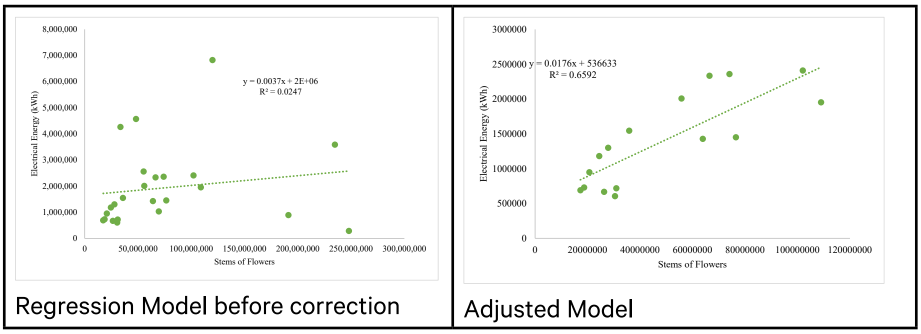


Figure 3-31: Regression Models for Electrical Energy Consumption in Flower Farms

EER ogive from the adjusted model was developed, as a performance guide for the flower farms. The ogive is presented in Figure 3-32.

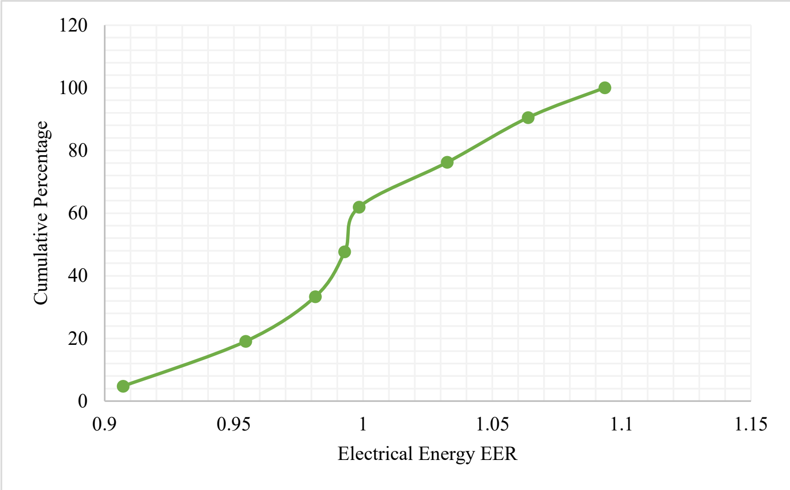


Figure 3-32: EER Class Limit Ogive for Electrical Energy Consumption in Flower Farms

The ogive in Figure 3-32 could make a good guide for setting benchmarks for energy consumption in Flower Farms. However, for estimate of total energy saved under different cut-off EERs, a simulation was done and is presented in Figure 3-33.

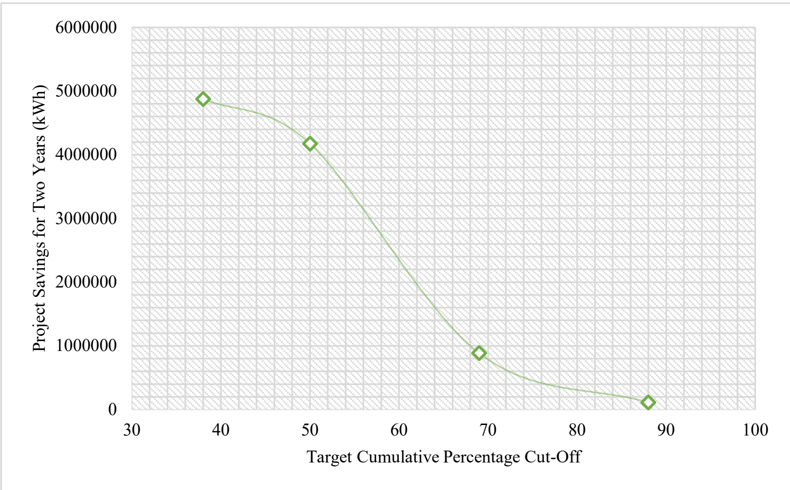


Figure 3-33: A Simulation of Energy Savings for Flower Farms

There is an opportunity to save between 0.5% to 21.8% electrical energy in flower farms, if benchmarks are adopted, across various cumulative percentage levels. The highest simulated improvement was for 62% of the facilities to improve while the lowest considered improvement of 12% of the facilities.

3.2.8 Energy Performance Model for Dairy Industry

The dairy industry uses thermal and electrical energy for milk processing. The energy is used for ultra-heat treatment, pasteurization, cooling and motorized processes. The energy consumption for 24 months for the dairy sector, collected in the study, is presented in Table 3.11.

Table 3.11: Production and Energy Consumption Data for Dairy Industry

Month	Production (Litres)	Electricity Total	HFO (litres)	Biomass (m3)	Month	Production (Litres)	Electricity Total	HFO (litres)	Biomass (m3)
Jan-18	40033604	2882679	2090380	0	Jan-19	53030838	3537723	3444524	343.9
Feb-18	35168837	2439246	1452230	0	Feb-19	47604289	3494842	2523339	330.4
Mar-18	37833980	2486421	1378637	0	Mar-19	45462582	3458138	1659397	463.5
Apr-18	39537731	2821843	1776355	0	Apr-19	38384872	3341000	1311427	312
May-18	39891598	2556644	2292450	0	May-19	40138608	3316592	1236092	411.7
Jun-18	40073227	2625576	2334021	126	Jun-19	41346925	3154528	1653918	393.6
Jul-18	42061731	2746120	1937680	128	Jul-19	44330218	3186347	2150955	302.2
Aug-18	43267650	3241703	1757238	142	Aug-19	48365789	3284095	3523906	349.6
Sep-18	42442178	3276800	1657719	162	Sep-19	47440327	3279307	3165078	462.4
Oct-18	44957247	3117333	2019808	151	Oct-19	48103211	3369189	3282297	484
Nov-18	44308897	3036716	1934953	146	Nov-19	48204243	3494414	3060120	506
Dec-18	50322056	3091684	3410052	143	Dec-19	44387948	3430093	2479373	468

In some of the months, the facilities that use biomass in their processes did not have data for biomass, thus the zero value. Some did not also provide data for HFO. This contributed to significant challenges in developing the regression and EER ogives for thermal energy. Table 3.11 was used to develop simple regression models for electrical energy use. The model is presented in Figure 3-34.

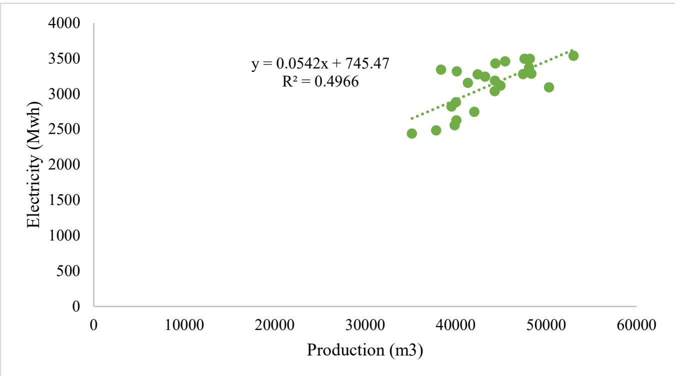


Figure 3-34: Regression Model for Electrical Energy use in Dairy Industry

The model in Figure 3-34 has coefficient of determination below 0.75. This was even after correction, which involved removal of some months that were deemed to be outliers. The poor coefficient notwithstanding, the model was used to develop EER for the electrical energy use. The EER ogive is presented in Figure 3-35.

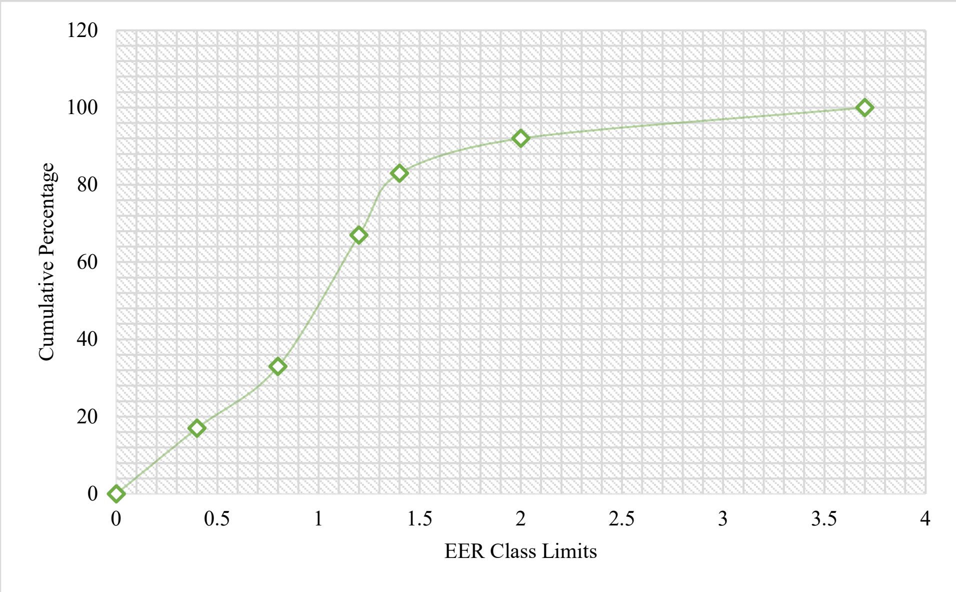


Figure 3-35: EER Ogive for Electricity use in Dairy Industry

In the ogive, more than half of the studied industries perform below the industry average, at an EER of more than 1. This is an indicator of potential for improvement in energy performance. The study simulated the possible energy savings, should these industries improve and move closer or even beyond the industry average. The savings simulation is indicated in Figure 3-36.

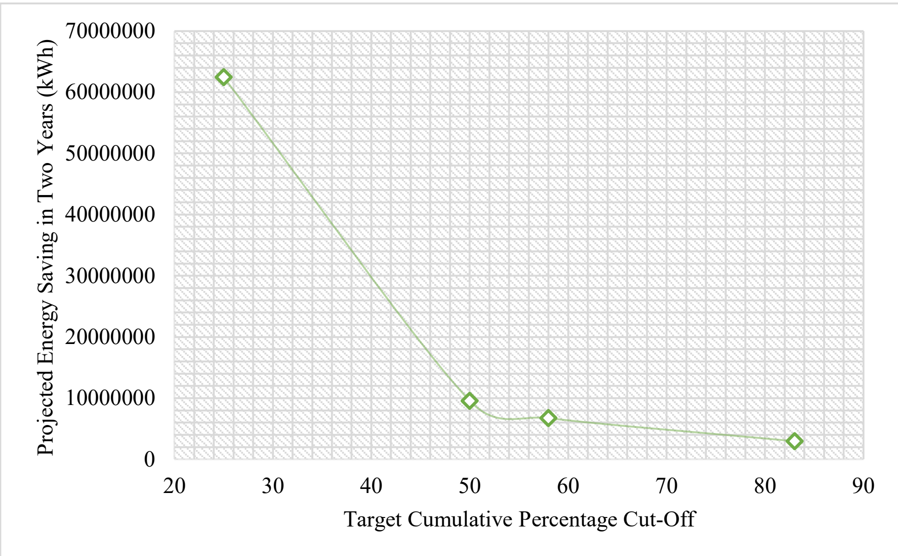


Figure 3-36: Simulated Electrical Energy Savings in Dairy Industry

There is a possible saving opportunity in the dairy industry, should facilities improve their energy performance to various benchmarks. From Figure 3-36, the savings range from 7 % to 23 % of the total energy consumption for two years.

4. CONCLUSION AND RECOMMENDATION

This study intended to develop energy consumption benchmarks for seven energy consumption industry categories in Kenya.The work concludes the following:

i. Most countries in the world use product based benchmarking tool to set energy consumption targets for their economies and offer few to none fiscal incentives scheme to encourage compliance.

ii. The Cement, Hotel, Dairy and Flower industries use diverse thermal energy sources. It was not possible therefore to develop models that could be used for the benchmarks in thermal energy usage.

iii. Some of the industries in Kenya perform poorly in terms of energy use index while others perform better, when compared to other jurisdictions. For Tea Sector, Kenya performs poorly compared to Sri Lanka and India. The same is observed for Sugar, where Kenya performs poorly compared to Brazil and Thailand. In the Cement Sector, Kenya performed well compared to Egypt and Canada. The same trend was observed in FMCG, where Kenya did well when compared to Nepal.

iv. The regression models for Flower, Hotel and Dairy industries had less than 0.7 coefficients of determinations, making it difficult to come up with statistically representative targets.

v. The EER scores observed in different sectors reveal that most of the facilities lie above 1. This indicates that few facilities contribute in improving the EUIs in the selected sectors. This thus gives room for the facilities above 1 to improve their energy performance.

This work therefore recommends that the Authority adopts the EER benchmarks, once agreed upon by the stakeholders.

ANNEX 1 – LIST OF FACILITIES

SNo.	Name of Facility
Tea Factories	
1	KTDA Ndarugu
2	KTDA Kangaita
3	KTDA Igembe
4	KTDA Olenguruone
5	KTDA Ragati
6	KTDA Gacharage
7	KTDA Mungania
8	KTDA Motigo
9	KTDA Mataara (Chania)
10	KTDA Ikumbi
11	KTDA Rukuriri
12	KTDA Toror
13	KTDA Weru
14	KTDA Kinoro
15	KTDA Momul
16	KTDA Tebesonik
17	KTDA Kapkoros
18	KTDA Ndima
19	KTDA Kiegoi
20	KTDA Mununga
21	KTDA Njunu
22	KTDA Ngere (Kplc+Chania)
23	KTDA Rianyamwamu
24	KTDA Tirgaga
25	KTDA Eberege
26	KTDA Kiamokama
27	KTDA Rorok
28	KTDA Kionyo
29	KTDA Litein
30	KTDA Makomboki
31	KTDA Nyansiongo
32	KTDA Kaptumo
33	KTDA Mogogosiek
34	KTDA Nduti
35	KTDA Iriaini (Gura)
36	KTDA Gathuthi (Gura)
37	KTDA Theta
38	KTDA Kapset
39	KTDA Kimunye
40	KTDA Tombe
41	KTDA Kapkatet

SNo.	Name of Facility
42	KTDA Chelal
43	KTDA Boito
44	KTDA Nyankoba
45	KTDA Githambo (Metumi)
46	KTDA Kanyenyaini (Metumi)
47	KTDA Gitugi (Gura)
48	KTDA Gachege
49	KTDA Tegat
50	KTDA Gatunguru (Metumi)
51	KTDA Kambaa
52	KTDA Kobel
53	KTDA Nyamache
54	KTDA Kagwe
55	KTDA Kathangariri
56	KTDA Kebirigo
57	KTDA Gianchore
58	KTDA Githongo
59	KTDA Imenti
60	KTDA Ogembo
61	KTDA Chebut
62	KTDA Kiru (Metumi)
63	KTDA Chinga (Gura)
64	KTDA Thumaita
65	KTDA Kapsara
66	KTDA Michimikuru
67	KTDA Sanganyi
68	KTDA Itumbe
69	KTDA Mudete
70	Chepchomo
71	Savani
72	Chemomi
73	Kapsumbeiwo
74	Kibwari
75	Kipkoimet
76	Siret
77	Kirirana
78	Jamji
79	Torror
80	Keritor
81	Kericho - Ekatarra
82	Laiten Oleguruene
83	Kapchebet

SNo.	Name of Facility
84	Kuresoi
Sugar Companies	
85	Chemelil
86	Muhoroni
87	Kwale
88	Sukari
89	Busia
90	Sony
91	West Kenya
92	Nzoia
93	Butali
Hotels	
94	The Panari
95	Sarova Panafric Nairobi
96	Nairobi Serena
97	Hemmingways Nairobi
98	Sport View Kasarani
99	The Heron
100	Safari Park
101	Paradise Hotel
102	Kakamega Golf
103	Hemmingways Watamu
104	Neptune Village
105	Palm Hotel
106	Jacaranda Hotel
107	Aberdere Country Club
108	Mayfair Imperial Hotel - Express
109	Mayfair Hotel-Kisumu
110	Neptune Beach Resort
111	Tropical Village Malindi
112	Sarova Shaba Lodge
113	Spire Diani Reef Beach Resort
114	Tamarind Village Mombasa
115	Ocean Beach Resort
116	Ocean Sports Watamu
117	Turtle Bay Watamu
118	Baobab Hotel and Spa
119	Marble Arch Hotel
120	Four Point by Sheraton
121	Heritage Hotel-Voyager Beach
Flower Farms	

SNo.	Name of Facility
122	Desire Flower Farms
123	Isinya Roses
124	Sygenta Pollen -Kenya Cutting
125	Akina Farm
126	Bilashaka Farm
127	Fontana Farm
128	Golden Tulips
129	Kariki Farm-Liverwire
130	Kongoni Farm-Gorge Division
131	Mahee Flowers
132	OL Njorowa Farm
133	Rimi Flora
134	Shalimar Farm
135	Sian Roses
136	Zena Farm-Asai
137	Zena Farm -Sosiani
138	Equinox Farm
139	Batian Roses
140	Timaflor Roses
141	PJ Dave Isinya
142	PJ Dave Timau
143	Kongoni Farm-Liki Division
144	KABUKU FARM
145	Mwanzi Farm
Dairy Companies	
146	Afrodane Dairies
147	Githunguri Fresha Diary
148	New KCC-Kiganjo
149	New KCC-Eldoret
150	New KCC Kitale
151	New KCC Nanyuki
152	New KCC Nyahururu
153	Brookside Dairy
154	New KCC Miritini
155	Devyani Food Industries
156	New KCC Dandora
157	New KCC Sotik
158	Meru Dairy
159	Highland Cremaries
FCMG	
160	Edible Oil Products

SNo.	Name of Facility
161	Henkel
162	Golden Africa Products
163	Imperial Foods
164	Spice World Limited
165	Pwani Oil
166	Menengai Oils
167	Diamond Industries
Cement	
168	Bamburi Cement - Mombasa
169	Savannah Cement
170	East Africa Portland (Athi River Plant)
171	Rai Cement
172	National Cement Company (Lukenya)
173	Bamburi Cement NGP (Athi River)
174	Mombasa Cement (Athi River Plant)
175	Mombasa Cement (Vipingo)
176	ARM Cement Company- Kaloleni
177	ARM Cement Company-Athi River

Energy & Petroleum Regulatory Authority

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