Green Climate Fund Readiness Project

Malawi

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Market Assessment Report for Energy-Efficient Residential Refrigerators and Distribution Transformers

By

Basel Agency for Sustainable Energy (BASE), International Copper Association (ICA), and Southern African Development Community's (SADC) Centre for Renewable Energy and Energy Efficiency (SACREEE)

For

UNEP-CTCN GCF Readiness Project on "National framework for leapfrogging to Energy Efficient Appliances and Equipment in Malawi (Refrigerators and Distribution Transformers) through regulatory and financing mechanism"

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Acronyms and Abbreviations

BASE	Basel Agency for Sustainable Energy
BAT	Best Available Technics
CEM	Community Energy Malawi
COMESA	Common Market for Eastern and Southern Africa
CRGO	Cold Rolled Grain Oriented silicon steel
CTCN	Climate Technology Centre and Network
DSM	Demand Side Management
DT	Distribution Transformer
EAC	East African Community
EAD	Environmental Affairs Department
EGENCO	Electricity Generation Company
ESCOM	Electricity Supply Corporation of Malawi Limited
GCF	Green Climate Fund
GDP	Gross Domestic Production
GNI	Gross National Income
GoM	Government of Malawi
GWh	Gigawatt hour
GWP	Global Warming Potential
HFC	Hydrofluorocarbon
IEC	International Electrotechnical Commission
IPP	Independent Power Producers
IRP	Integrated Resource Program
kV	Kilovolt
kVA	Kilovolt Amperes
kWh	Kilowatt hour
MAREP	Malawi Rural Electrification Program

MBS	Malawi Bureau of Standards

Acronyms and Abbreviations Cont'd

MCC	Millennium Challenge Corporation
MEGA	Mulanje Electricity Generation Agency
MEPS	Minimum Energy Performance Standards
MERA	Malawi Energy Regulatory Authority
MGDS	Malawi Growth and Development Strategy
MITC	Malawi Investment and Trade Centre
MRA	Malawi Revenue Authority
MW	Megawatt
NAIP	National Agriculture Input Program
NBM	National Bank of Malawi
NCST	National Commission of Science and Technology
NDE	National Designated Entity
NEP	National Energy Policy
NSO	National Statistics Office
ODS	Ozone Depleting Substances
PCB	Polychlorinated byphenyls
PPA	Power Purchase Agreement
PPP	Power Purchasing Parity
SACREEE	SADC Centre for Renewable Energy and Energy Efficiency
SADC	Southern African Development Community
SADCSTAN	SADC Standards
SITC	Standard International Trade Classification (SITC). UN classification for statistical purposes.
TFR	Total Facility Rate
U4E	United for Efficiency
UNEP	United Nations Environmental Program

1. Executive Summary

The network partners Basel Agency for Sustainable Energy (BASE), International Copper Association (ICA), and Southern African Development Community's (SADC) Centre for Renewable Energy and Energy Efficiency (SACREEE) are providing technical services for the implementation of a GCF Readiness project with Climate Technology Centre and Network (CTCN) through United Nations Environment Programme's (UNEP) United for Energy (U4E) as technical partner on national frameworks for leapfrogging to energy-efficient appliances and equipment in Malawi through regulatory and financing mechanisms. The objectives of the technical assistance project are to improve the country programming process regarding refrigerators and distribution transformers and strengthen climate finance strategies.

The readiness project aims to put in place mandatory Minimum Energy Performance Standards (MEPS) and a labeling scheme, which will create an enabling policy and regulatory environment for more efficient refrigerators and distribution transformers in Malawi and help reduce the strain on the electricity grid; increase disposable income for householders; and potentially reduce greenhouse gases (GHG) emissions. The project will include key components such as national policy roadmaps and enabling environment for the implementation of standards and labels, appropriate financing mechanisms to accelerate deployment of the energy efficient refrigerators and distribution transformers and strengthened national capacity to develop standards and labels for other appliances in future.

The market size for new refrigerators is projected to increase from 34,000 in 2021 to 77,000 in 2040 annually, comprising annual requirement for replacements increasing from 22,000 in 2021 to 50,000 in 2040; and annual requirement to meet the growing demand increasing from 12,000 in 2021 to 27,000 in 2040. Total stock is projected to increase from 289,000 in 2021 to 750,000 in 2040 (**Appendix 10**) and **Table 19** refer. The market size for residential refrigerators is assumed to be driven by the need to replace the old ones at the end of life and to supply new demand. The new demand is assumed to be proportionate to the economic growth. Based on regional experience, a life span of 12 years translates to 8% annual replacement rate while average economic growth rate during the period 1990 to 2019 is estimated at 4.35% (World Bank, 2021).

The survey established that there were no manufacturers for residential refrigerators in Malawi. The suppliers' list comprised importers, wholesalers, retailers and repairers. These were, largely, private traders ranging from specialized retail shops, supermarkets, individual shops, private individuals and individual repair shops. The assessment of NSO's residential refrigerators Trade Data showed a growth in imports of 27%, largely, driven by imports from South Africa with a market share of over 70%, followed by China with a growing market share ranging from 12% in 2016 to 16% in 2020. Annual

average imports and the equivalent monetary value for the period 2016 to 2020 were estimated at 552 tons and US$ 1.7 million, respectively (**Table 3**). No re-exports were recorded.

A few of the more energy efficient residential refrigerator types were supplied on the market and some of them used high GWP refrigerant contrary to aspirations and commitments on sustainable Energy for All (SE4ALL) initiatives to achieve energy savings by 2025, 2030 and 2040; Sustainable Development Goals (SDGs) to double the global rate of improvement in energy efficiency by 2030; and as a signatory to various protocols (the United Nations Framework Convention on Climate Change (UNFCCC); and the Kyoto Protocol and the 2015 Paris Agreement), to strengthen the global response to the threat of climate change and limit the temperature increase (EAD, 2021). 50% were of low energy efficiency (the direct cool type) compared to 20% of manual defrosting and 30% of automatic defrosting types (**Figure 38**). 30% used R134A and R404A refrigerants of high global warming potential (GWP) of 1430 and 3922, respectively, not compliant with the Kigali Amendment to the Montreal Protocol and comparing with the EU maximum limit of 150 (EU, 2015). 65.1% used R600A refrigerant of low GWP (**Figure 39**).

The energy efficient refrigerators were not necessarily using the environmentally safe refrigerants of low GWP, although the proportion using the high GWP refrigerants was small. 11% of the automatic defrost type used R134A compared with 31% of the direct cool and 45% of the manual defrost (**Table 12)**.

More of the automatic defrosting residential refrigerators were of low energy consumption. 93% were rated at less than 400kWh per year, compared to 82.1% of the manual defrost and 81.3% of the direct cooling (**Table 15**).

Higher proportion of the older residential refrigerators were of energy consumption of equal or more than 400kWh/year. 32% of residential refrigerators aged over 10 years were of annual energy consumption of equal or more than 400kWh/year compared with 20% of aged 3 to 7 years and 13% of aged less than 3 years (**Table 13);** and energy consumption was noted to be directly proportional to volume (size) of the refrigerator. The bigger the more energy consumption **(Figure 40).**

The following factors were noted to be barriers to the sale of energy efficient residential refrigerators, namely: a) **Lack of awareness** – there were mixed perceptions among stakeholders on whether energy efficiency was either the most or among the most significant factors affecting refrigerator selection **(Figure 6)**. 98% of the respondents were not aware of energy efficiency and labelling standards for residential refrigerators (**Figure 22**) and the survey recorded mixed preferences on purchase of refrigerators with majority rating low preference on energy consumption **(Figure 23);** b) **Financial** – low unit price was considered among the preferred factors affecting the selection of residential refrigerators **(Figure 7)**; Despite over 81% having bank accounts (**Figures 12 and 13**), 84% did not find bank loan terms and conditions attractive (**Figure 14**) and 91% purchased their residential refrigerators using own capital (**Table 10);** c) **Capacity –** Lower sales proportions of the high energy efficient residential refrigerators were recorded than sales of the low energy efficient units. 85% of the refrigerator types reported by supply chain stakeholders were non-inverter manual defrost type compared to 15% of non-inverter automatic defrost and 0.3% inverter type (**Table 7).** 100% of the lowest level of monthly income of less than USD 64 preferred other options than the hire purchase, own capital and leasing. Notably, people in this level of income cover the majority of the rural mass that were not targeted and likely to face challenges in raising finances. **Table 11** refers.

The survey established that the distribution transformers supply chain comprises foreign suppliers, importers, local manufacturers, local refurbishing companies and end users (Figure 46). The end users were, largely, the power utility, industry and at a small scale, mini grids. Assessment by weight of NSO's imports statistics of distribution transformers indicated annual average imports of 471 tons at an average cost of US$ 2.5 million during the period 2016 to 2020 (**Table 21**). No re-exports were recorded.

Approximately 4% of the total volume of distribution transformers supplied on the market during the period 2015 to 2020 were produced locally while 55% were imported by ESCOM and 41% were imported by the Malawi Rural Electrification Program (MAREP) (**Figure 49**). Over 3,000 distribution transformers were installed in the ESCOM's distribution network with a total installed capacity of around 647 MVA (**Appendix 12**). The transformers were of capacity ranging from 10kVA to 3000kVA. 78% were of capacity rating ranging from 100kVA to less than 1000kVA (**Table 25)**. The data based included MAREP transformers installed under the rural electrification programme. The survey estimated a total stock of 4,000 transformers in 2020 comprising, largely, over 3,400 installed in ESCOM's distribution system; 400 planned for phase 9 of the rural electrification programme (MAREP) in 2021 and a few installed by the two mini grids surveyed (**Table 25**).

Demand for distribution transformers is estimated to be directly proportional to growth in energy demand. The latest power and energy demand forecasts in the Integrated Resource Plan (IRP) are way above the actual trajectory of system demand. Even the low forecast scenario is very much above the actual maximum demand in 2021 (**Table 30)**. The projections for demand of distribution transformers has, nevertheless used the based scenario and compared with the low scenario with updated figures on the actual demand.
The Base Scenario projections for the market size of distribution transformers indicate that demand for capacity of new distribution transformers will increase from 80 MVA in 2021; to 500 MVA in 2030; and 2,000 MVA in 2040 estimated at a market value of USD 3 million in 2021 increasing to USD 17 million in 2030; and USD 64 million 2040. The distribution transformers will be required for annual replacement of old DTs at the end of their life increasing from 35MVA in 2021; to 56 MVA in 2030; and 127 MVA in 2040; and to increase capacity of DTs to meet the growing demand for electricity increasing from 44 MVA in 2021; to 477 MVA in 2030; and 1,900 MVA in 2040 annually (**Table 33). Appendix 18** refers.

The Low Scenario projections require the new DTs to increase from about 7 MVA in 2021; to 100 MVA in 2030; and 300 MVA in 2040 estimated at a market value of USD 0.2 million in 2021 increasing to USD 3 million in 2030; and USD 9 million 2040. The new capacity for annual replacement of old DTs increases from 4 MVA in 2021; to 8 MVA in 2030; and 16 MVA in 2040; and the capacity for growing demand increases from 3 MVA in 2021; to 92 MVA in 2030; and 257 MVA in 2040 annually (**Table 34). Appendix 18** refers. The two scenarios may be used subject to improvements in the generation capacity, which has in the long past lead to constrained demand.

Significant variances were noted in the Total Owning Cost (TOC) of distribution transformers calculated using actual losses recorded on the test certificates for a sample of ESCOM transformers when compared with standard maximum allowable losses in the UN - Model Regulation Guideline 2019. The No Load Losses were higher than standard while the Load Losses were lower (**Table 26**). The calculations were based on ESCOM samples of pre-inspection test repots for some of its

distribution transformers of ratings 315kVA, 11/0.4kV; 200kVA, 11/0.4kV; 100kVA, 11/0.4kV; 100kVA, 33/0.4kV; and 200kVA, 33/0.4kV **(Appendix 15)**.

The capitalized total owning cost (TOC) for a million distribution transformers procured by MAREP during 2016 to 2017 (**Table 28)** was compared for the loss levels declared by ESCOM against the Fire Standards level 1 and level 2. Significant variances in TOC for the MAREP procurements were noted in the order of above 30% when compared with the Fire Standard Level2. Insignificant variances were noted when compared with the Fire standard level 1 at -2% on 200kVA 33/0.4kV transformers and +5% on the 100kVA 11/0.4kV transformers (**Table 29)**. The TOC for MAREP procurement was lower than the Fire standard Level 1 by US$ 16.0 million but higher than the Fire Standard Level 2 by US$ 1,524 million (**Table 29).**

The effective date for the Fire standard Level 1 (1 January 2020) has since passed and energy performance of ESCOM's distribution transformers is generally compliant. The performance, however, falls short from complying with Level 2 Fire standard, which will be effective from January 2025. The Fire standard applies to transformers that are without any measure to limit flammability. The Model Regulation Guidelines specifies a higher Standard, the Fire Safer standard, where flammability is restricted and emission of toxic substances and opaque smoke are minimized (UN Model Regulation Guidelines, 2019). The fire standard has been used to compare the losses performance levels of the ESCOM distribution transformers.

Malawi needs regulations in place to enforce the minimum energy performance standards. The survey established that standards become mandatory when enforced by regulations. As much as there are government policies on energy efficiency, respective regulations on the same are not available for enforcement. It was observed that the electricity bylaws rarely made reference to any of the Malawi Standards and international standards, which implies the standards remain voluntary. A gap that need to be addressed to achieve the energy policy objectives.

The IEC TS 60076 – 20 standard, the internationally adopted standard on energy efficiency for power transformers should be adopted in Malawi and included on the MBS lists of standards and ESCOM list of specifications for distribution transformers. As much as the survey established that ESCOM's specifications for procurement of distribution transformers were comprehensive, the crucial standards was missing on the list and ESCOM specifications did not refer to all relevant standards in the MBS's catalogue while some standards referred to were not seen in MBS catalogue (**Appendix 20**). MBS requires to be moved by industry to update the Malawi standards lists and this would require industry to collaborate and work with the MBS.

The existing Malawi Standards (MS) on energy efficiency are voluntary and lack necessary regulation to enforce (MBS, 2021). The grid code excludes the distribution system for compliance by both end users and supply chain stakeholders. There were no specific standards on energy efficiency for refrigerators. Instead, a general standard for household electrical appliances was used where need arose.

The National Energy Policy (NEP) supports the objective of the project. Section 3.8.1.3 of NEP sets out different policy actions, including, among others, "to promote Demand Side Management (DSM), instituting appliance testing, labelling and standards and minimum energy performance standards (MEPS)" (NEP, 2018).

2. Background and Introduction

Malawi is among the eight countries[1] in Southern Africa that have embraced a common approach for the implementation of the Green Climate Fund (GCF) Readiness projects on 'Developing a national framework for leapfrogging to energy efficient refrigerators and distribution transformers'.

The National Commission for Science and Technology, the National Designated Entity (NDE); the Environmental Affairs Department, the National Designated Agency (NDA); and the Ministry of Energy provided the overall guidance on policy and execution of the survey for household refrigerators and the supply chain for refrigerators and distribution transformers. They acted as the contact points linking the Malawi Government with the implementers.

Two local experts, the Local Policy Expert and a Communication Expert, were engaged to lead the project in Malawi. The two experts reported directly to SACREEE but worked in liaison and under the guidance of the NDE, NDA and the Ministry of Energy.

Malawi has been experiencing adverse impacts of climate change including: "frequent occurrence of climate related hazards like severe floods, strong winds, drought episodes, protracted dry spells, and outbreaks of pests and diseases". Malawi, therefore, signed and ratified the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol, "to reduce the onset of global warming by reducing greenhouse gas concentrations in the atmosphere to a level that would prevent dangerous anthropogenic interference with the climate system". Malawi is a signatory to the 2015 Paris Agreement, "to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius" (EAD, 2021).

Malawi developed the National Climate Change Management Policy (2016) in order to enhance coordination and implementation of climate change activities; to foster development and transfer of climate related technologies and capacity building. Further, Malawi Government formulated a Strategy on Climate Change Learning in 2013 to address knowledge gaps that are key for formulating informed policies and climate change interventions (EAD, 2021).

"Malawi submitted its first Intended Nationally Determined Contributions (INDCs) in 2015 covering a period of 25 years to 2040 (EAD, 2020). Energy, among others, was identified as one of the main sectors contributing to GHG emissions in Malawi with sectoral emissions forecast to increase from 4% in 2015 to 17% in 2040. The policy-based mitigation (on energy utilization) were limited to energy saving cook stoves, to distribution and increase number of households using them; the adaptation actions (also on energy utilization) were limited to promoting the use of energy efficient bulbs. Consultative meetings with key stakeholders (**Appendix 8**) established efforts lead by the Malawi

[1] Botswana, Eswatini, Lesotho, Malawi, Namibia, Tanzania, Zambia and Zimbabwe

Bureau of Standards (MBS) developing specific standards for energy efficient refrigerators; efforts lead by the energy sector to finalize the distribution code and specify minimum energy efficient standard for mandatory compliance to harmonize best practice among the industry stakeholders; and intentions to have in place regulations on both safety and minimum energy aspects. Further, Government was yet to advance implementation of the national energy policy actions on energy efficiency.

The focus in the energy sector is noted on the fossil fuels, which contributed 11% of total national greenhouse gas emissions in 2017. Malawi's report on National Greenhouse Gas Inventory System (GHG-IS) indicates three major contributors of greenhouse gas emissions. Namely the fossil fuels of diesel, coal and petrol. Wood fuels is reported to contributing to the energy sector emissions of 38% but is noted that it could be a sustainable and renewable source of energy if responsibly managed and sourced. The energy sector green investment opportunities identified, among others, introducing policies that promote technologies that lower emissions (EAD, 2017)

The Malawi National Environmental Policy, 2004 provides for economic incentives for Sustainable environmental management to, among others, ensure that individuals and economic entities are given appropriate incentives for sustainable resource use, conservation and environmental management. The policy strategies include: a) to ensure that the opportunity cost of using natural resources and the economic values of conserving natural resources are reflected in market prices or non-market mechanisms used to allocate or regulate their use and conservation; and b) to provide for tax incentives for production or importation of environmentally friendly products and disincentives for production or importation of products that pollute or have adverse effects on the environment (EAD, 2004).

Government, through the ministry of Forestry and Natural Resources, launched the "Malawi's Strategy on Climate Change Learning" on Tuesday, 9th February 2021 in Lilongwe, with the objective to contribute to the National Climate Change Resilience Programme through the strengthening of human resources skills development and institutional arrangements for the advancement of green, low emission and climate resilient development (EAD, 2021).

Section 3.8.1.3 of the Malawi National Energy Policy (NEP) sets out different policy actions. Among them, "a) to promote Demand Side Management (DSM) including: Instituting appliance testing, labelling and standards, which will include minimum energy performance standards (MEPS)" (NEP, 2018). To this effect, the national power utility is undertaking a program replacing the energy consuming incandescent bulbs and the compact fluorescent lamps (CFLs) with light emitting diodes (LEDs).

In line with the international requirements, Government of Malawi embarked on a participatory process to revise its INDCs, which was posted on its website and open to the public for review contributions. The contributions were due for submission by 15th December 2020 (EAD, 2020).

Malawi stands to be guided by the regional practice set by East African Community (EAC) and Southern African Development Community (SADC). Reference is made to a draft Technical Note on quality and performance metrics of cooling Products for EAC and SADC, Part I: Refrigerating Appliances. The Note

refers to the Montreal Protocol which evolved to address climate change mitigation as well, with the 2016 Kigali Amendment establishing a framework for reducing global hydrofluorocarbon (HFC) use (W.Y. Park et al, 2020), where Malawi is a signatory to both. The note supports the effort of EAC and SADC to establish and improve energy-efficiency standards for room air conditioners (ACs) and refrigerating appliances by providing an overview of global market and policy trends and technical recommendations in a harmonized way across the region.

The regional practice on refrigerating appliances is to adopt the IEC 62552 2015 standard to improve standards and labeling for the appliances in EAC and SADC countries and facilitating harmonization with international refrigerator-efficiency efforts (CA Gov., 2021).

The United for Efficiency (U4E) Model Regulation Guideline 2019, on energy performance requirements for distribution transformers, requires that distribution transformers be reassessed for conformity as follows: a) with minimum energy performance in terms of maximum allowed load and no-load losses; b) polychlorinated biphenyls (PCB) contamination that products should not contain PCB fluids or other hazardous materials as defined in the relevant international, regional and national regulations; c) product and technical information to include free access to websites of manufacturers and to durably mark on or near the rating plate of the distribution transformers; and d) on certification and registration to test transformer's energy performance in accordance with IEC 60076-1 and its fire performance in accordance with IEC 60076-11, for instance, for dry-type transformers and related reference test standards (UN Model Regulation Guidelines, 2019).

Since 2020 Malawi has been part of an additional regional effort which is the harmonization of energy efficient policies on residential refrigerators and air conditioners. The countries of the Eastern African and Southern African regions are working together with the project partners SACREEE, EACREEE and UNEP-U4E to develop harmonized MEPS and labelling. The project is particularly noteworthy in this context as it focusses on the same appliance as the national project for Malawi, namely on energy efficient refrigerators. As of August 2021, the regional MEPS had been drafted and are currently under review with the regional Technical Committees that had been formed for this purpose. Anteriorly, the project has also conducted a regional market assessment across both region and developed technical notes that include technical recommendations on the MEPS development. More information and the related documents can be accessed here. The MEPS and labels development for Malawi within the national GCF project will happen in synergy with the regional policies developed under this project.

3. Methodology and Approach

3.1. Objective and Scope

The objective of this market assessment is to provide detailed information to inform the development and subsequent adoption of national policy roadmaps for the promotion of higher efficiency refrigerators and distribution transformers, including MEPS-HEPS, labelling scheme, consumer awareness, end-users' education, capacity building for custom officials and procurement officers, and MV&E framework, as well as financing mechanisms and strategies, adopted by the government in Malawi.

The scope of this assessment was limited to the below stakeholders:

a) Middle income households and shop owners in urban areas (for easier accessibility) who have access to electricity; importers, wholesalers, retailers; servicing and repairing shops (for residential refrigerators only);
b) Manufacturers, importers and retailers, servicing and repairing firms, utilities including ESCOM and mini grid operators, the Malawi rural electrification program (MAREP) and industrial users, (for distribution transformers);
c) Government ministries, standards and regulatory bodies, the National Statistical Office (NSO) of Malawi and the Consumers Association of Malawi (CAMA);
d) Private sectors including technology providers and local retailers; and
e) Banks and other financial institutions.

3.2. Existing Information Sources and Gaps

Labelling

The name plates were used to source details of the refrigerators and distribution transformers. Alternatively, data base provided by the users, where available, was referred to. However, the name plates and, largely, for local manufacturers of distribution transformers lacked important information including the standards used. Some labels were illegible and name plates for most of the refrigerators had peeled off. This was very common for household refrigerators. About 93% of the total samples of residential refrigerators collected still had their labels on. Out of a total of 250 entries, 232 were considered. Internet search was used to obtain the missing details and this is how we managed to improve to 232 entries of residential refrigerators, although still with some gaps as shown with yellow and red highlights in **Appendix 6a**.

Inconsistences were noted in the reference temperature for impedance voltage of distribution transformers. Imported units used 75^{o}C in line with IEC standards while locally produced units used 70^{o}C but without referenced to any standard.

Limited Information Due to Lack of Reporting Framework and Awareness

Data collection was through questionnaires, which were distributed online and it was incumbent upon the respondents to provide full information as per the questionnaire. Both the refrigerators and distribution transformers supply chain had no framework imposing suppliers to report details of their products and trading volumes. Consequently, the responses obtained were very limited with few responding and others (especially refrigerators supply chain stakeholders) declining to give any response for various reasons including lack of time. Some committed but failed to fulfil their commitment. There was lack of cooperation from the refrigerators suppliers and the few that responded, provided with gaps skipping most of the questions.

The awareness of the program was limited to the key stakeholders to the extent that the supply chain stakeholders were not adequately informed, which contributed to their lack of cooperative in the provision of data. It is anticipated of the Malawi Investment and Trade Centre (MITC), a One Stop Service Centre mandated to registers investments (local and foreign), to impose reporting requirements on all investors for all the products traded with Malawi. This would ease the monitoring and control of the types of products traded with Malawi. MITC provided on its website an Investors' Guide which was more of a guide to facilitating investors' registration but did not specify any reporting obligations on the investors (MITC, 2021).

Import Data Missing Information on Energy Efficiency and Environmental Safety

Detailed import data for refrigerators and distribution transformers was available and provided by the National Statistical Office (NSO). However, the type of information coded by the Malawi Revenue Authority (MRA) and posted on NSO portal did not adequately cover information to show compliance with energy efficiency and environmental safety requirements. The NSO portal provided the following information among others: Quantities in tons, exporting countries and cost (NSO, 2021) which were limited.

The data on transformers in this report was based on few transformers that were accessible by ESCOM and MAREP. ESCOM stores were out of stock and had limited number of transformers to provide name plate details.

The Sampling Method

The sampling method was limited due to the following constraints:

a) Many household refrigerators had no name plate details to extract the required information. 18 of the 250 residential refrigerators were, therefore, skipped;
b) In the absence of any registration for the supply chain stakeholders, data collection was biased to households within the locality of the enumerators;
c) The survey was conducted during Covid 19 pandemic and data collection methods were restricted to online and travel was not accepted to avoid infections. Due to budget constraints, only 13 enumerators were appointed and these were limited to work in the 4 cities of Malawi and a selection of 12 districts out of a total of 28 where they resided;

d) Data collection was limited within the urban areas, largely, due to the small number of enumerators to reach outside the urban areas and due to very low access to electricity and facilities for online communication by the rural communities.

The Accuracy of Data

The accuracy of data was compromised. The quality of data was subject to proficiency of the respective respondents to the effect that some data was erroneously recorded and submitted with gaps, especially where the respondents failed to understand the questions. Due to time limits, it was not possible to follow up with all respondents.

3.3. Information Gathering Methodology

The following activities were planned to be conducted under the market assessment:

- Collection of primary data through stakeholder outreach, identification and interviews through a bottom-up approach for residential refrigerators and a hybrid approach (bottom-up and top-down) for distribution transformers;
- Collection of secondary data that is already in existence on the subject matter;
- Analysis, validation and interpretation of data collected and
- Compilation of the market assessment report.

Four types of surveys were conducted to assist in data collection for the market assessment. These included; household surveys on residential refrigerators; supply chain of residential refrigerators; the distribution transformer survey; and financing of residential refrigerators and distribution transformers to local financial institutions.

In view of the requirement to avert the impacts of Covid – 19, the surveys were conducted online and the household survey was limited to urban areas. Minimum sample sizes comprised: a) 200 households for the survey on residential refrigerators; and b) 20 stakeholders each for the supply chain of refrigerators and distribution transformers, making a total of 40.

The supply chain stakeholders comprised the following: manufacturers, importers, wholesalers, repairers and users for both refrigerators and distribution transformers. The users were the households for refrigerators, the national power utility, mini grid operators and industry for the distribution transformers. The Consumers Association of Malawi (CAMA), a non-Governmental Organization established in 1994 and mandated to promote and protect consumer interests (CAMA, 2021) were considered part of the stakeholders.

Consultations and interviews were conducted, and secondary data collected from regulators, government ministries and departments, financial institutions, non-governmental organizations, and

industry. This was in addition to desk research. The list of supply chain stakeholders planned to be consulted and interviewed is provided in **Appendix 4**.

Primary data collection

Survey on residential refrigerators

A random sampling method was used for the residential refrigerators survey. However, where data was not available, the household was skipped. A total of 13 enumerators were engaged to conduct a door-to-door survey for residential refrigerators and samples were obtained from districts respective of the ratios of their population to the total population of Malawi (**Appendix 5**). 12 out of 28 districts were selected for the refrigerator household survey, comprising: Karonga, Nkhata Bay and Mzuzu City in the northern region; Kasungu, Mchinji, Salima and Lilongwe City in the central region; and Blantyre City, Machinga, Zomba, Chikwawa and Mulanje in the Southern Region. **Appendix 6** gives details on the geographical spread of the selected districts.

Over 250 questionnaires were sent out for the household survey and a total of 211 questionnaires were completed, returned and used in the analysis (**Appendix 6a**). The questionnaires provided data for 232 residential refrigerators owing to the fact that some households owned more than one.

The NSO required the following sample sizes in order to consider national survey:

a) 400 samples for the household survey on residential refrigerators;

b) 150 samples for business owners of residential refrigerators;

c) 15 samples for importers; and

d) 3 samples for Distributors of components.

It was noted that these requirements were beyond the scope of the project and available budget of 200 interviews. Following further discussions, it was agreed with NSO to proceed with the minimum sample size of 200 questionnaires.

Supply Chain for Residential Refrigerators

Random samples were collected from key stakeholders in the supply chain of residential refrigerators across the country. These comprised importers, wholesalers, retailers and repairers. There were no manufacturers in Malawi.

A total of 21 questionnaires were sent out for the residential refrigerators supply chain survey. 4 questionnaires out of the 21 were not completed in full.. In summary, responses were received from 1 stakeholder involved in importation and retailing and 3 questionnaire responses from repairers of refrigerators. A summary of responses received is provided in **Appendix 6(b)**.

Supply Chain - Distribution Transformers

Samples for distribution transformers were collected from all stakeholders in the supply chain, which comprised manufacturers, importers and retailers, users and repairers. The users included the national power utility, mini grids operators, the rural electrification program, private grid operators and industry.

A total of 15 questionnaires were sent out for the distribution transformers supply chain survey. 7 out of the 15 questionnaires were incomplete. In summary, responses were received from 2 manufacturers; 2 importers/repairers; the national power utility, the Electricity Supply Corporation of Malawi (ESCOM) Limited; 2 mini grid operators and none from the industry. A summary of responses received is provided in **Appendix 6(c)**.

Government Ministries, Departments and Agencies (MDAs)

Further, information was sought from government ministries, departments and agencies (MDAs), which included: the Ministry of Energy (MoE) and Environmental Affairs Department (EAD) being policy makers on the energy sector and environment, respectively; the Ministry of Industry and Trade (MoIT), responsible for certification of investors including: manufacturers, importers, wholesalers and retailers of refrigerators and distribution transformers; the Malawi Bureau of Standards (MBS); the Malawi Energy Regulatory Authority (MERA); the National Statistical Office (NSO) of Malawi and the Consumers Association of Malawi (CAMA). In summary, the list is of relevant stakeholders in the supply chain of both refrigerators and distribution transformers. CAMA was selected to represent the consumers.

Questionnaires were sent to government Ministries, Departments and Agencies (MDAs). Responses were received from the following: the Ministry of Energy (MoE) on rural electrification program; the Environmental Affairs Department (EAD) provided the national policy, laws and regulations on environment management including: regulation of polluting substances, waste management and disposal. Searched online websites of the Malawi Investment and Trade Centre (MITC) under the Ministry of Industry and Trade (MoIT) on investors and product registration; the Malawi Bureau of Standards (MBS) on Malawi Standards; the Malawi Energy Regulatory Authority (MERA) on mandatory standards for the regulation of energy efficiency requirements; the NSO of Malawi on the sample size and accessed its website for details on international trade. The responses are summarized and provided in **Appendix 6(d)**.

Financial Institutions

A total of 5 Questionnaires, specifically tailored for financing institutions, were sent to the following institutions to establish the terms available to their respective customers:

- FINCA, a micro-financing institution;
- National Bank of Malawi (NBM);
- FDH Bank;
- First Capital Bank; and
- Vision Fund Malawi Limited.

Commercial banks stand out to be the most important stakeholder to finance energy efficient residential refrigerators and distribution transformers because of their readily availability across the country and ability to handle large sums of money in serving corporate customers. Informal sector also exists, where communities agree to save money and lend each other at agreed interest rates. This trend is growing with a drive to get formal registration, which when well established may be the major option for residential refrigerators purchases in the rural areas, even in urban areas. Responses were received from the National Bank of Malawi (NBM) and FDH Bank [**Appendix 6(e)**]

Several virtual meetings using the Zoom platform were organized for stakeholders' awareness, consultations and orientation. The list of key stakeholders consulted is presented in **Appendix 7** while reports of consultation meetings held with the key stakeholders are presented in **Appendix 8**.

3.4. Key Assumptions

The survey was guided by the following key assumptions:

a) That power utility, the Electricity Supply Corporation of Malawi (ESCOM) Limited and the Malawi Rural Electrification Program (MAREP) were the main drivers in the development and operation of the distribution system across the country;
b) That the samples collected for the households from the 12 districts from the four regions of the country would provide a true indication of the geographical representation of the country;
c) That the demographic trends of population growth, household size and percentage of households with refrigerators, as per 2018 census, will not change significantly;
d) That the economic growth as projected in this report; and
e) The quality of both distribution transformers and household refrigerators on the market to last for the estimated life spans.

4. Overview of the Country

4.1. Socio-economic situation

Malawi is one of the most densely populated countries in Sub-Saharan Africa. The Population and Housing Census of 2018 pegged Malawi's population at 17,563,749 and an average annual/intercensal growth rate of 2.9% for the period between 2008 and 2018 (NSO, 2018). Malawi occupies an area of 118.484 square kilometers (Malawi Government, 2021) and a population density of 192.4 (World Bank, 2020). Land accounts for 79% of the total area at 94,080 square kilometres and the rest is covered by Lake Malawi. Of this total landmass, 53,070 square kilometres or some 5.3 million hectares are suitable for cultivation. According to the Fifth Integrated Household Survey, the mean household size is 4.4 at national, urban, and rural levels (NSO, 2020). The total number of households estimated at national level were 3,984,929 (NSO, 2018).

In 2020 Malawi recorded a per capita Gross National Income (GNI) of US$580[2] (World Bank, 2020). Overall, 41.5% of the households reported that their current income only met their expenses and 19.2% reported that their income was not sufficient so they needed to use savings. About 6% of the households reported that their current income allowed them to build savings. 42.0% of the households in rural areas reported that their current income only met their expenses compared to 38.5 % in urban areas. The majority of the poor households are in rural areas (59.5 %) in contrast to 17.7 % in urban areas[3]. Female-headed households at the national level are at 29.6 %. In rural areas, male-headed homes stand at 68.6 %, while females head 31.4 %. Approximately 70 % of the population still lives below the international poverty line of $1.90 per day in 2011 PPP prices[4] (World Bank, 2019).

The Malawi 2063 Vision (MW2063) is the long-term development strategy which aspires to foster youth-centric "inclusive wealth creation and self-reliance". It aims to propel the country to an industrialised upper middle-income country by 2063. The MW2063 is anchored on three key pillars, namely: 1) Agriculture Productivity and Commercialization; 2) Industrialization; and 3) Urbanization. The attainment of the three pillars will be catalyzed by seven enablers, which includes Economic Infrastructure under the second pillar of Industrialization and energy is grouped under this enabler. The aspiration under energy is to build a diversified range of affordable energy sources that will increase energy supply, ensure energy reliability and focuses on renewable and sustainable energy to reduce the overdependence on hydro-generated power. The vison, further, commits to address inefficiencies in the sector (NPC, 2020).

The Malawi Growth and Development Strategy (MGDS) III is the medium term (5 years from 2017 to 2022) strategy to contribute to the MW2063. The strategy will, however, focuses on five key priority areas, namely: 1) Agriculture, water development and climate change management; 2) Education and skills development; 3) Transport and ICT infrastructure; 4) Energy, industry and tourism development; and 5) Health and population (Malawi Government, 2017). MGDS III is, however, phased out with the

[2] World Development Indicators, 2019

[3] Ibid

[4] World Development Indicators, 2019.

launch of MW2063 and is being replaced by the first 10-year implementation plan, which is currently undergoing cabinet approval.

GDP growth is estimated to have weakened to 0.9% in 2020 from 5.1% recorded in 2019, reflecting the slowdown in local and cross-border economic activity caused by the Covid-19 pandemic. At this level, the 2020 growth is the lowest since 2001. The resultant negative demand and supply shocks proved to be unfavourable to most sectors in the economy. In particular, the accommodation and food sector, transportation, wholesale and retail, and manufacturing sectors were hit hard. In 2021, however, the economy is expected to rebound modestly and GDP growth is projected at 3.8% (RBM, 2020).

Malawi's economy is noted to have been more resilient than the region, which equally suffered from the effects of Covid-19 which, as noted by the Reserve Bank of Malawi, "the negative growth was due to disruptions in economic activities as a result of the Covid-19 pandemic, leading to reduced commodity prices that have lowered disposable incomes in the region". The big economies in the Sub-Saharan region of Nigeria (the leading oil producer in Africa) and South Africa contracted to negative GDP growth figures in 2020 of -1.8% and -7.0%, respectively. The Sub-Saharan region is, however, expected to rebound to 3.4% in 2021 and 4.0% in 2022 like the Malawi's economy to 3.8% in 2021 (RBM, 2020). **Table 1**, below, refers.

	GDP Growth (%)			
	2019	2020	2021	2022
Malawi	5.1	0.9	3.8	
Sub-Saharan African Region	3.2	-1.9	3.4	4.0
Nigeria	2.2	-1.8		
South Africa	0.2	-7.0		

Table 1: Comparative GDP Growth Rates for Malawi, the Sub-Saharan Region, Nigeria and South Africa (RBM, 2020).

Assessing the balance of payment by the Reserve Bank of Malawi, leaves the country in a net importing position. According to the Reserve Bank "merchandise exports contracted by 14.5% whilst imports shrank by 6.1% in 2020". Further, the bank observed that "although the closure of borders in trading partners' countries as well as low disposable income led to a fall in imports, the same adversely affected domestic exports, such that the merchandise trade balance remained in deficit". (RBM, 2020). The bank listed tobacco, tea, cotton and sugar as the main exported commodities for the country.

4.2. Energy (Electricity) Context

Malawi is one of the countries in the world with the lowest electricity per capita consumption averaging 84 kilowatt-hours (kWh) per capita as of 2020[5]. As of April 2021, Malawi's installed

[5] Sales Statistics and Population Census projections.

generation capacity was at 519.95 Megawatts (MW), of which 75% was hydro-based generation. Diesel generators cover the remaining 25%. The total capacity comprised 441.95MW of the Electricity Generation Company (EGENCO) of Malawi and 78MW of diesel of Aggreko, an Independent Power Producer (EGENCO, 2021).

Electricity in Malawi is transmitted at 400, 132, and 66 kilovolts (kV) and distributed at 33kV and 11kV. Distribution transformers are used to step down the voltage level to 400 volts (V) for the 3 phase network and 230V for the single phase network.

In January 2017 Malawi's electricity sector underwent reforms to create a conducive environment for private sector investment. This led to the institutionalization of a new power market structure shown in **Figure 1.**

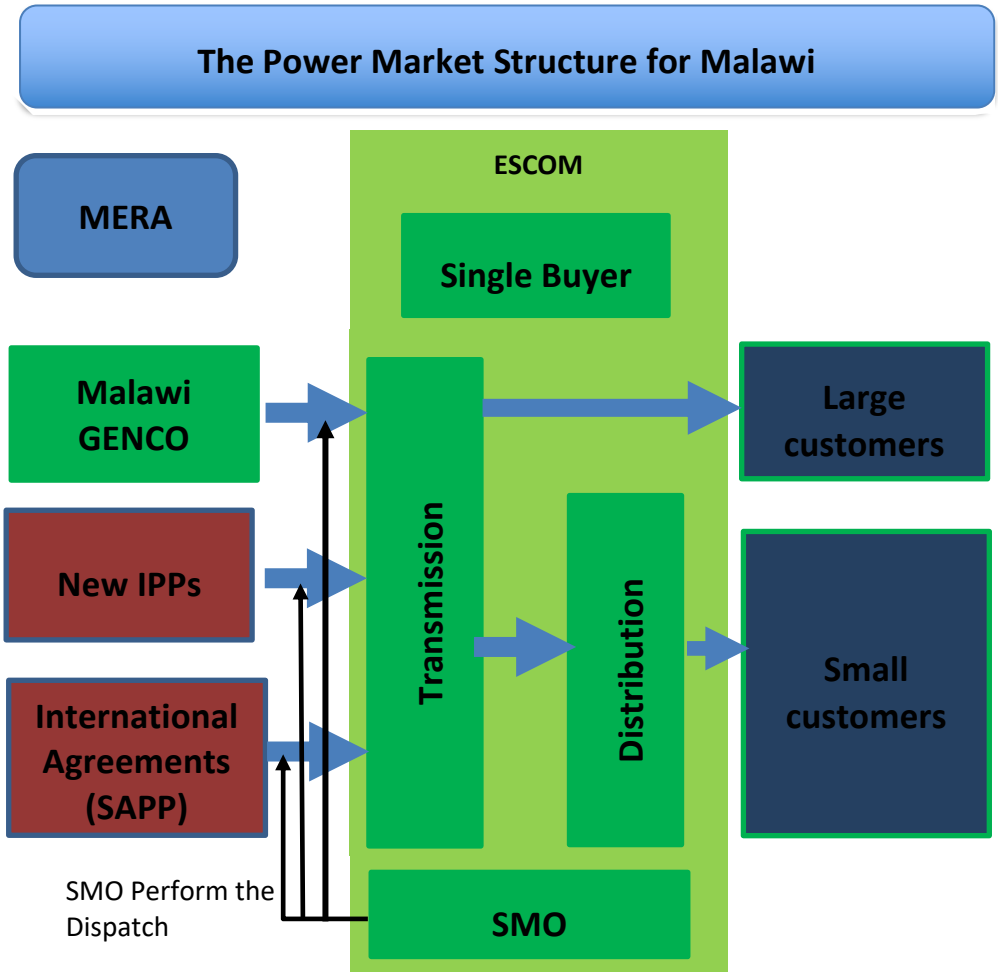


Figure 1: Power Market Structure in Malawi (MERA, 2016)

The reforms unbundled the power utility, the ESCOM,Limited company, creating a separate Electricity Generation Company (EGENCO). ESCOM remained with the mandates of system operation, electricity transmission and distribution. The unbundling separates the generation function with the aim of making it competitive with other Independent Power Producers (IPPs). Later in 2018, the Government created another company called Power Market Limited (PML), whose primary role was to operate as a single buyer responsible for power purchases, system planning and power trade.

Electricity Demand

The IRP projected an increase in electricity demand from 1,800 GWh in 2015 to 10,600 GWh in 2030 of the Base case scenario. However, the demand projections have not been commensurate with actual power generated or sold. During the period 2015-2019, ESCOM generation increased from 1,800 GWh to 2,000 GWh[6]. Total sales during the same period rose from 1,500 GWh to 1,700 GWh in 2019. This was against an estimated demand of 3,500 GWh in 2019 (IRP Vol. 1, 2017). **Figure 2** provides a synopsis of the demand projections.

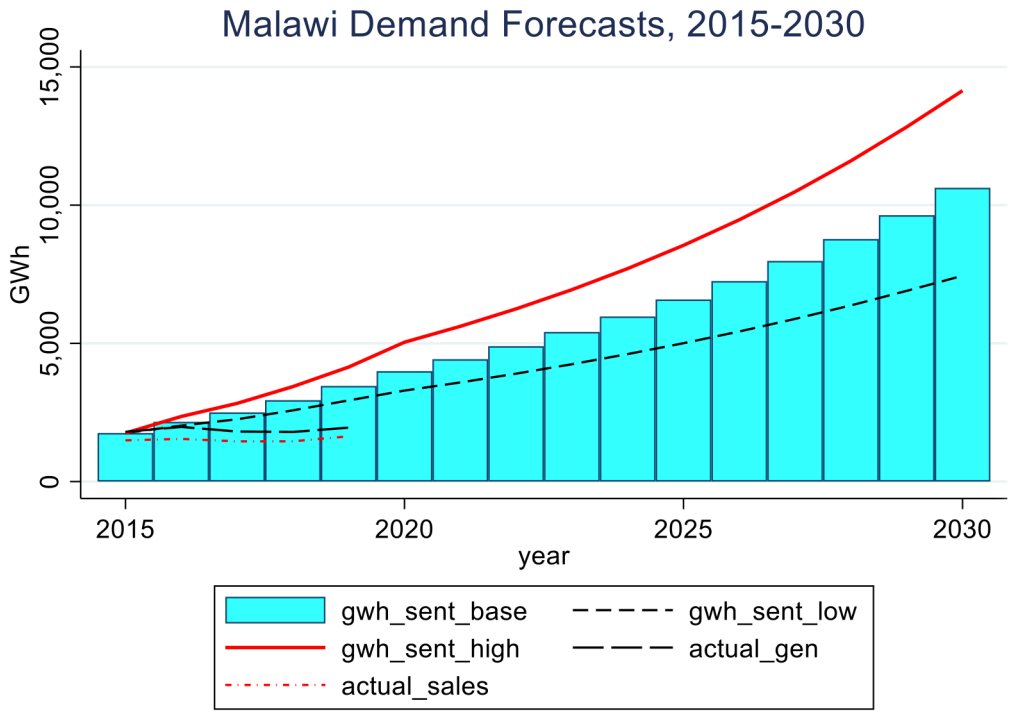


Figure 2: Electricity Demand Forecast for Malawi (MNREM, 2017)

[6] ESCOM Generation Statistics, 2015-2019

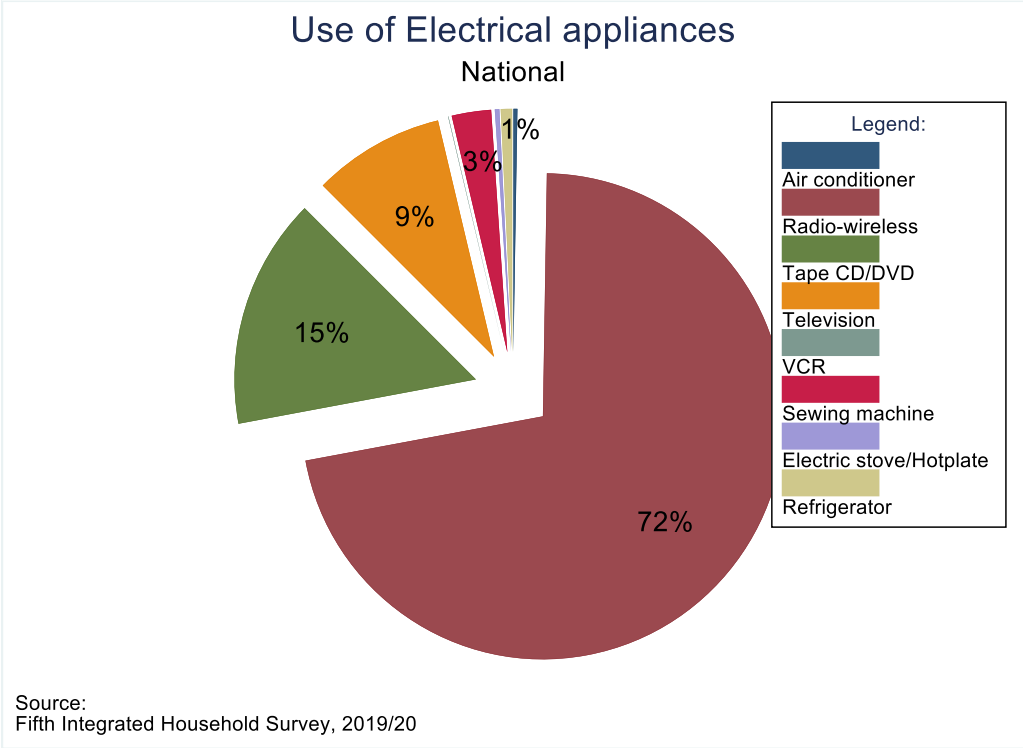
Access to Electricity

Malawi has one of the lowest access to electricity in Sub-Saharan Africa at 11.2% (NSO, 2020) with access to the national grid and as of 2019, almost doubling since 2010. According to the Third Integrated Household Survey of 2010/2011, it estimated about 6.48% of households had access to electricity. This was against an installed generation capacity of 287 MW (Republic of Malawi, 2012a). Considering rural and urban dimensions, access to electricity in the cities stands at 47 % compared to 5 % in the rural areas (NSO, 2018)

Use of Electrical Appliances

Figure 3 illustrates based on data from the Integrated Household Survey of 2019/20 that the use of refrigerators was very minimal, pegged at 1% of the population.

The situation improves when we consider rural-urban dimensions. In urban areas 2 % own a refrigerator. In contrast, in the rural areas there was no record of ownership of a refrigerator at a household level.



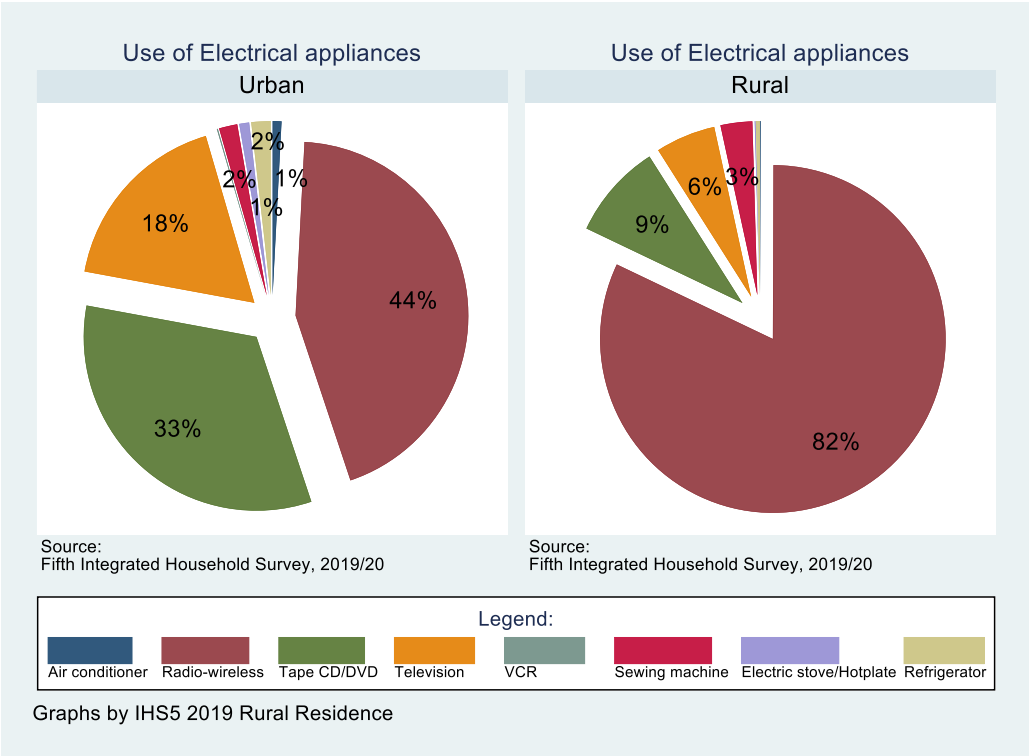


Figure 3: Percentage of Population in Urban and Rural Areas that Used Refrigerators (NSO, 2020)

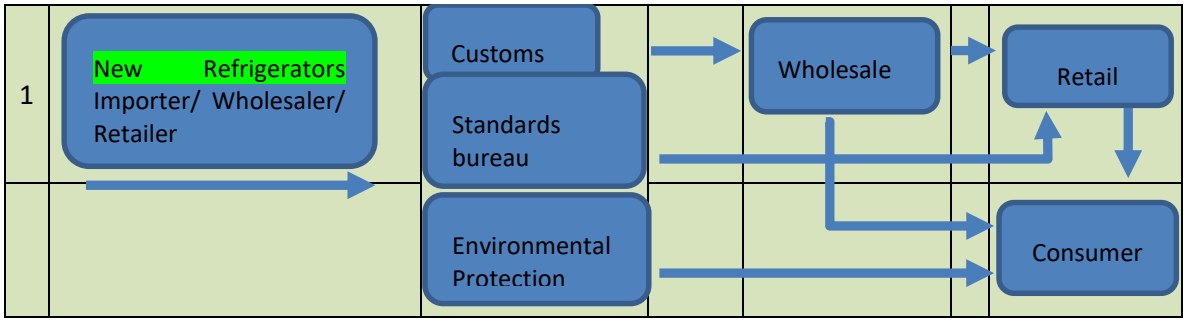
5. Market Assessment on Residential Refrigerators

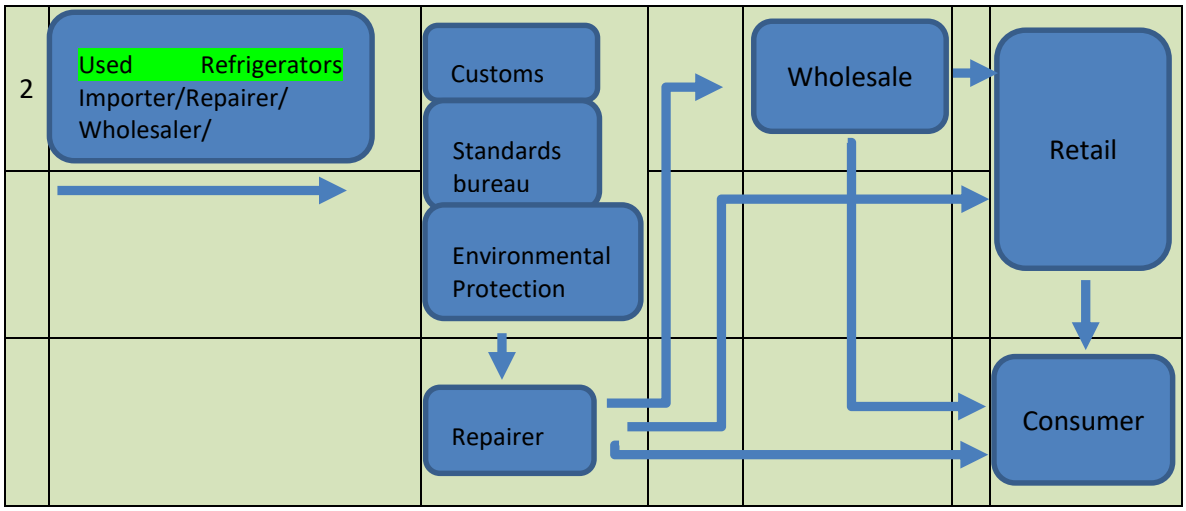
5.1. Supply Chain

5.1.1. Summary of suppliers, end-users, officials and other stakeholders

The survey findings indicate that there are no manufacturers of residential refrigerators in Malawi.

The commercial suppliers of residential refrigerators in Malawi are largely, private traders which ranged from specialized retail shops, supermarkets, individual shops, private individuals and individual repair shops. The relevant distribution channels used, based on the survey results, showed that the suppliers' list comprised importers, wholesalers, retailers and repairs in the combinations as presented in distribution channels 1, 2 and 3. **Figure 4,** below, refers.





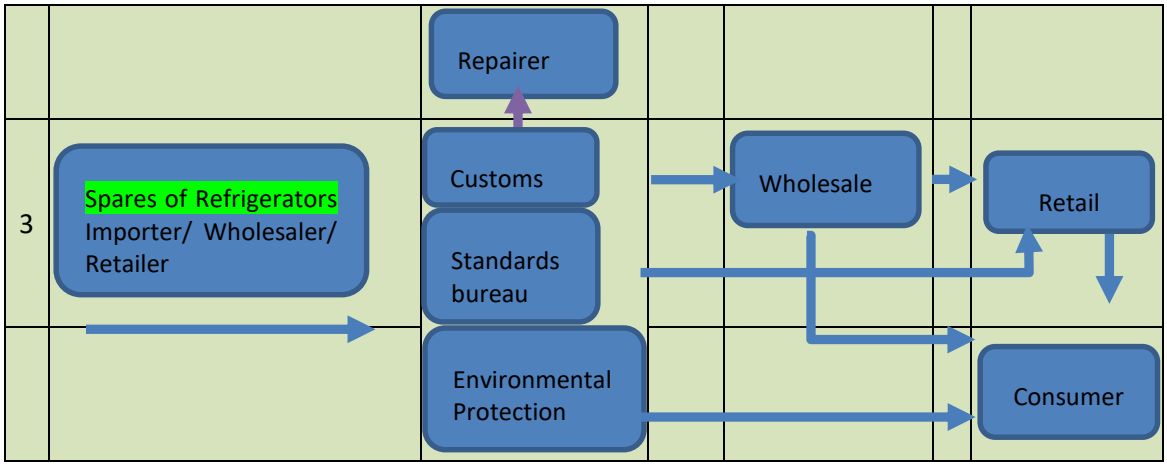


Figure 4: Relevant Distribution Channels Used in Malawi (Source: Supply Chain Survey, 2021)

In Distribution Channel **1**, the traders import new residential refrigerators and sell them either on wholesale to retailers or on retail to customers. In channel **2,** repair shops import used residential refrigerators, repair them and sale either on wholesale to retailers or on retail to customers. In Distribution Channel **3,** the traders import spare parts for residential refrigerators and sell them either on wholesale to retailers or on retail to customer. All imports are subject to Malawi Standards compliance requirements, environmental protection regulations and customs import taxes.

The consumer, or end users, in this survey comprise households and shop owners.

The Malawi Bureau of Standards (MBS) with a mandate to develop Malawi Standards in collaboration with stakeholders worked with the Malawi Revenue Authority (MRA) at the borders to carry out compliance checks on imported products.

The Environmental Affairs Department (EAD) under the Ministry of Natural Resources and using the regulatory framework checks all imports for compliance of Ozone Depletion Substances (ODS). The EAD registers and issue permits for importation of cooling appliances and refrigerators. The EAD work with MRA at the borders.

5.1.2. Manufacturing of refrigerating appliances

The economic environment, so far, has not attracted investments in manufacturing of residential refrigerators. The market is, instead, flooded with imports.

5.1.3. Overview of the Supply Chain

The survey established that 45% of household refrigerators were supplied from South Africa. The distribution by suppliers was as presented in **Tables 2** below.

Place of Purchase (Retailers)	Quantity
Game stores	24.6%
South Africa, Shop	20.2%
Mzuzu Shops	9.3%
Supermarkets	8.7%
Karonga/Shop	7.7%
Lilongwe, shop	6.0%
Unknown	5.5%
Chipata, Shop	5.5%
Blantyre, Shops	4.9%
MZUZU CHIMETO	3.8%
Online	3.8%

Table 2: Suppliers of Refrigerators (Source: Household Survey, 2021)

The NSO Trade Data for Malawi showed that **imports of residential refrigerators were increasing on average at 27%** and the growth was consistently driven by imports from South Africa with a market share of over 70%, followed by China with a growing market share ranging from 12% in 2016 to 16% in 2020. Annual average imports and the monetary values for the period 2016 to 2020 were on average at 552 tons and US$ 1.7 million as shown in **Table 3**. No re-exports were noted.

Exporters	2016	2017	2018	2019	2020	Annual Average
Total Imports (Tons)	436	549	442	647	684	552
Total Imports (US$'000)	1,581	1,469	1,507	2,016	1,915	1,697
Annual Increase on Quantity (%)						27%
South Africa (Tons)	316	412	305	480	528	408
South Africa (US$'000)	1,025	904	894	1,358	1,367	1,110
Annual Increase on Quantity (%)						29%
China (Tons)	51	77	87	115	108	87.6
China (US$'000)	306	378	378	474	400	387
Annual Increase on Quantity (%)						72%
South Africa's Market Share (%)	72%	75%	69%	74%	77%	
China's Market Share (%)	12%	14%	20%	18%	16%	

Table 3: Refrigerators Imports and Highest Exporting Countries (NSO, 2021)

5.1.4. Best-selling equipment

Leading Refrigerator Brands

The survey established the five best selling brands were Defy, KIC, Hisense, Samsung and LG as shown in **Table 4**.

Supplier's Name	Best Selling Brands
Westgate Investments	Defy
Nat Electronics	KIC
Smart Zone	Hisense
Game Store	KIC, Defy
Electrade	KIC
Bul Africa	KIC
Sellfast Trading	Defy
Grandprix	Defy
Zomba City Electronics	Hisense
FC Electronics	Samsung, LG, Defy

Table 4: Best Selling Refrigerator Brands (Source: Supply Chain Survey, 2021)

Type of Refrigerant Used

The supply chain survey recorded the type of refrigerants used, during the period 2010 to 2015, that it comprised some of high GWP including R134a, R22, R404a and R507. The trend improved during

the period 2016 to 2020, where the use of refrigerators equipped with low GWP refrigerants with, such as the R600a were reported, as shown in **Table 5**.

List of refrigerant gases by model number used in residential refrigerators manufactured/sold			
2010 2015		2016 2020	
Model	Refrigerant	Model	Refrigerant
ALL	R134A	ALL	R600a
HJ150807A	R134a	HJ150807A	R410
WH141210	R600a		
HJ161101A	R22		
WH141210	R404A		
KSDI 150330	R507		
Inverter	R134a	Inverter	R600a
Non – Inverter	R134a	Non Inverter	R600a
KIC	R134a	LG	R600a
Defy	R134a	Samsung	R600a
Cool master	R134a	Defy	R600a

Table 5: Type of Refrigerators Mostly Used (Source: Supply Chain Survey, 2021)

Ranking of Refrigerators by Technology Used

Findings of the household survey and supply chain survey for residential refrigerating appliances established the following product categories were available in the market and in use by households:

- Refrigerators only;
- freezers only; and
- combined refrigerator and freezer type.

Some refrigerating appliances were equipped with the direct cool type that produces the cooling effect by the natural process of convection, which happens from the cooled surfaces in the insulated compartment that is being cooled. Manual defrost freezers contain refrigeration coils located inside the walls of the cabinet and require to be manually defrosted to avoid the freezer working overtime wasting energy and exacerbating ice buildup. The other type is the automatic defrost type.

The household survey established the refrigerator-freezers were the mostly used type by the households, comprising 59% compared with 32% freezers and 10% refrigerators as shown in **Figure 20**. Further, the survey established that residential refrigerators were mostly equipped with the direct cooling type comprising 50% compared to 20% of manual defrosting and 30% of automatic defrosting. (**Figure 37).**

The supply chain survey established that non-inverter refrigerator types were bestselling compared to the inverter types. The refrigerator-freezer non-inverter and freezer types were best-selling ranked 1st and 2nd with respective market shares of 43% and 39%. The refrigerator non-inverter, refrigerator-freezer inverter and refrigerator inverter types were ranked 3rd, 4th and 5th with market shares of 10%, 5% and 4%, respectively as depicted in **Table 6**.

Technology	Rank	% use
Refrigerator-freezers – Non-inverter	1	43%
Freezer	2	39%
Refrigerator – Non-inverter	3	10%
Refrigerator-freezers – Inverter	4	5%
Refrigerator – Inverter	5	4%

Table 6: Ranking and Market Share of Refrigerators by Technology Used (Source: Supply Chain Survey, 2021)

The distribution by energy efficiency of residential refrigerators showed Class A type refrigerators were the most used at 63% followed by Classes B and N at 11%; and Class A+ at 6%. **Figure 5** refers.

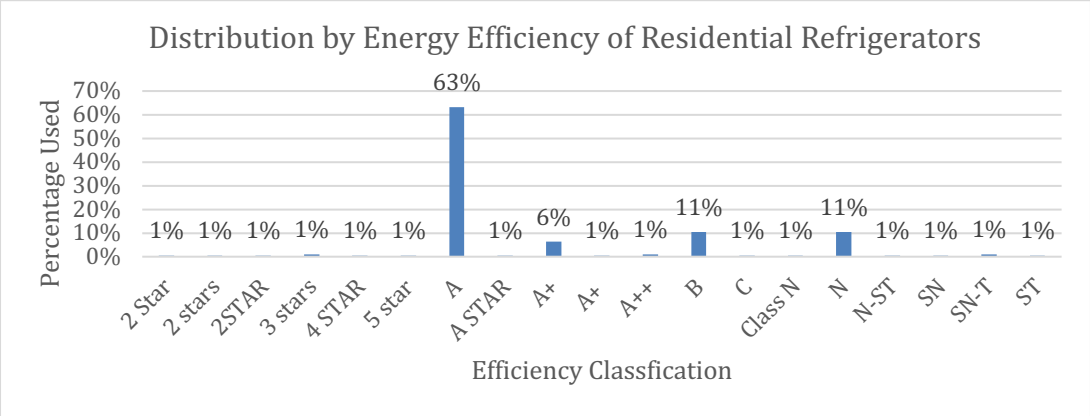


Figure 5: Distribution of Residential Refrigerators by Energy Efficiency Classification

The supply chain survey recorded a few of the more energy efficient inverter refrigerator types in the market. Consistently, the household survey established there were more of the less energy efficient direct cool refrigerator types used by households with energy efficiencies dominated by Class A type at 63%. The results show a trend contrary to aspirations and commitments on sustainable Energy for All (SE4ALL) initiatives to achieve energy savings by 2025, 2030 and 2040; and on Sustainable Development Goals (SDGs) to double the global rate of improvement in energy efficiency by 2030.

As a signatory to various protocols (the United Nations Framework Convention on Climate Change (UNFCCC); the Kyoto Protocol and the 2015 Paris Agreement) , to strengthen the global response to the threat of climate change and limit the temperature increase (EAD, 2021), Malawi needs to

strengthen enforcement on importation and use of energy efficient refrigerators and ozone friendly refrigerants.

The inverter refrigerator types are estimated at 40% more energy efficient compared to the regular types (RefrigeratorPro, 2021). The inverter types are fitted with a variable speed compressor that changes speed according to atmospheric temperature and loading on the refrigerator. The compressor motor does not start and stop as in the non-inverter type.

The GCF Readiness project on national frameworks for leapfrogging to energy-efficient refrigerators and distribution transformers in Malawi will expand the policy based mitigation programs to reduce emissions of Green House Gas (GHG) due to energy utilization. Malawi's programs were more focused on promotion of energy saving cook stoves and energy efficient bulbs.

5.1.5. Barriers to the sale of efficient residential refrigerators

The survey established as follows:

That demand for the energy efficient types of refrigerators was very low and very few proportions of the inverter types of refrigerators were recorded as inferred from **Table 6**. The automatic defrost type were reportedly sold in low proportions compared to the manual defrost **(Figure 37)**.

Responses to the questionnaire indicated mixed perceptions among stakeholders on whether energy efficiency was either the most or among the most significant factors affecting refrigerator selection. 14% chose to be neutral, 43% strongly disagreed while another 43% somewhat agreed.
Figure 6, below, refers.

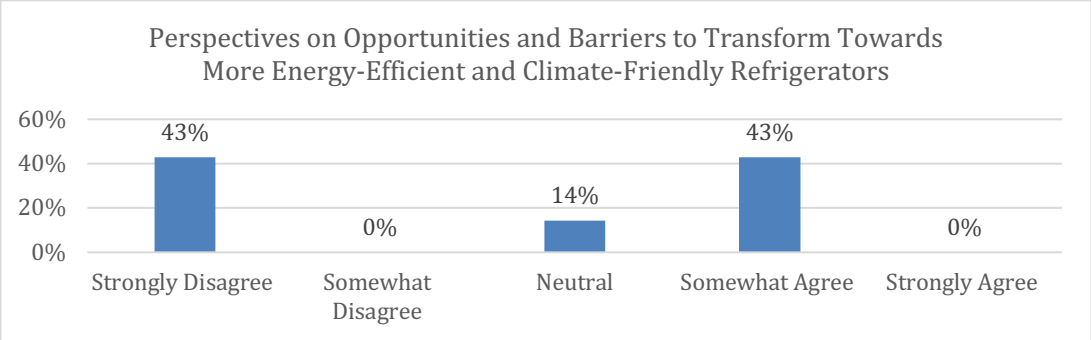


Figure 6: Stakeholders Perceptions Whether Energy Efficiency will Affect Selection of Refrigerators (Source: Supply Chain Survey, 2021)

Low Unit Price - 50% strongly agreed and 25% somewhat agreed while 13% somewhat disagreed and 13% were neutral on the question that low price will in future impact customers' satisfaction, as shown in **Figure 7**. The results were biased towards low unit price which is contrary to high energy efficient refrigerators that are likely to cost more than the low energy efficient units. Implementing proper

financial instruments could unlock economies of scale and would result in low prices of energy efficient refrigerators.

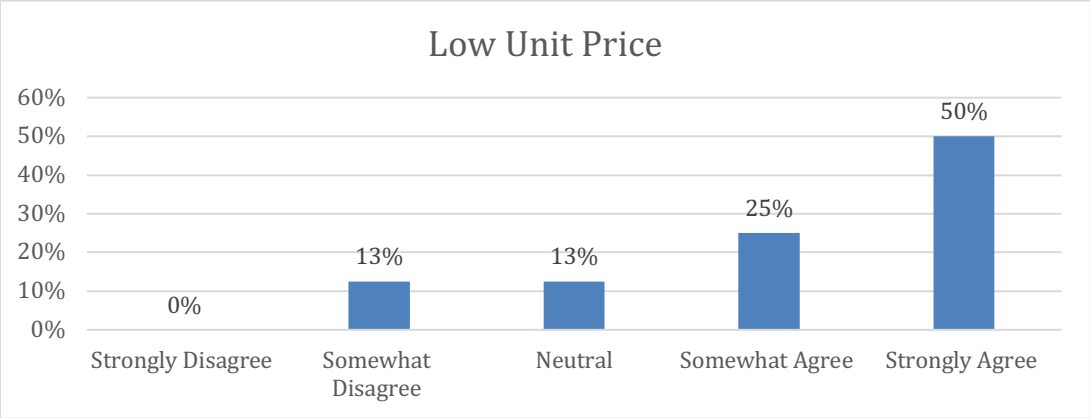


Figure 7: Stakeholders Perceptions Whether Low Unit Price will Affect Selection of Refrigerators (Source: Supply Chain Survey, 2021)

Efficient Technology Types - Lower proportions of the high energy efficient refrigerator types than the low energy efficient types were recorded. 85% of the refrigerator types reported by supply chain stakeholders were non-inverter manual defrost type compared to 15% of non-inverter automatic defrost and 0.3% inverter type (**Table 7)**.

Refrigerator Type	Inverter	Non-Inverter		Total
		Manual Defrost	Automatic Defrost	
Refrigerator Only	0.0%	33.8%	9.4%	**43.2%**
Freezer Only	0.0%	30.2%	0.4%	**30.6%**
Refrigerator - Freezer	0.3%	20.9%	5.0%	**26.2%**
Record of Total Units Sold	**0.3%**	**85.0%**	**14.7%**	**100.0%**

Table 7: Distribution by Technology Type of Residential Refrigerators (Source: Supply Chain Survey)

5.2. Demand

5.2.1. General consumer information

The survey established the following:

Distribution by the Size of the Households– Over 70% of the households lived in 2 to 3 bedroomed houses and 21% lived in houses of more than 3 bedrooms. **Figure 8** refers.

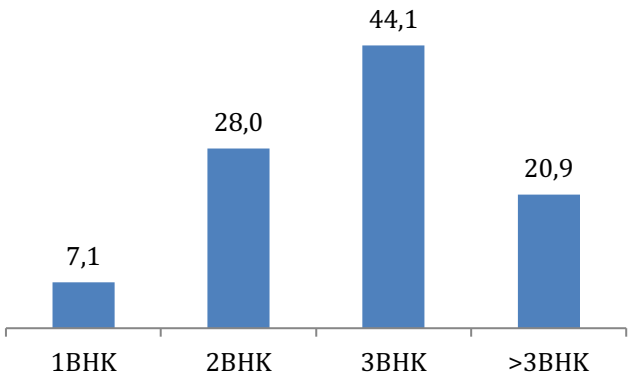


Figure 8: Distribution by Size of House (%) – (Source: Household Survey, 2021)

Distributions by employment – 41% were public sector employed, 34% were self-employed and 25% were employed in the private sector**. Figure 9** refers.

Figure 9: Distribution by Employment (%) – (Source: Household Survey, 2021)

Distributions by monthly income - Over 70% of the households interviewed earned in the higher levels with an average monthly income in the range of USD128 to USD1924 an equivalent of Malawi Kwacha (MK) 100,000.00 to 1.5 million (**Figure 10)**

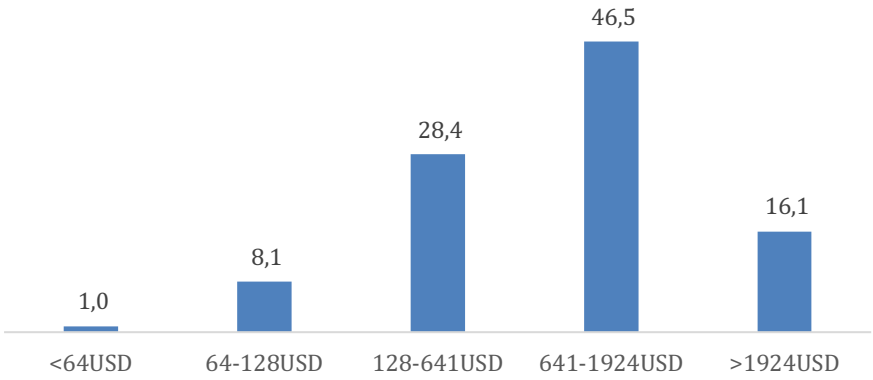


Figure 10: Distribution by Monthly Income (%) – (Source: Household Survey, 2021)

Distributions by Size of Households and Level of Electricity Monthly Payments –

91% of households with one member paid electricity bills in the ranges of over USD13 (equivalent of MK10,000.00) a month while 96% of households with two members paid in the same range. This is compared with 88% of households with three members, 68% with 4 members and 69% with 5 members. In summary, more households with fewer members paid more for electricity than households with more members. See Table 8.

HH-size	<USD13	USD13 –USD 26	>USD26	Total
1 member	9.5	47.6	42.9	100
2 members	4.0	64.0	32.0	100
3 members	12.5	35.0	52.5	100
4 members	32.3	35.5	32.3	100
5 members and above	30.9	45.7	23.4	100
Total	**22.3**	**44.6**	**33.2**	**100**

Table 8: Distribution by Size of Households and Level of Electricity Monthly Payment (%) - (Source: Household Survey, 2021)

5.2.2. Level of financial inclusion

The survey reached established the following:

Distribution by household ownership– 43% of the respondents lived in own houses while 57% were in rented houses **(Figure 11)**.

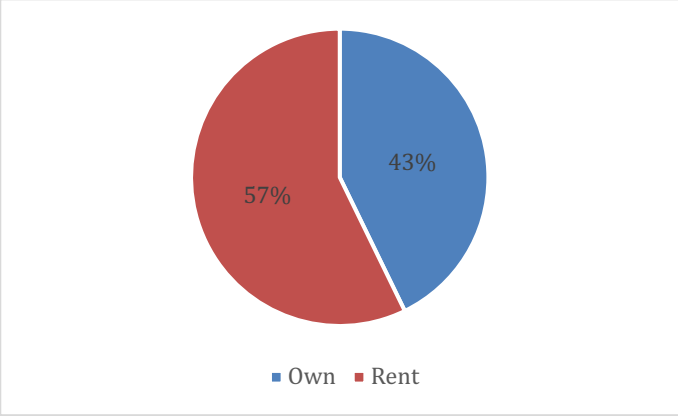


Figure 11: Distribution by Households Living in Own Houses (%) – (Source: Household Survey, 2021)

Distribution by Households ownerships with Bank Accounts – Over 90% of the respondent, whether living in their own house or not, had bank accounts (**Figure 12)**

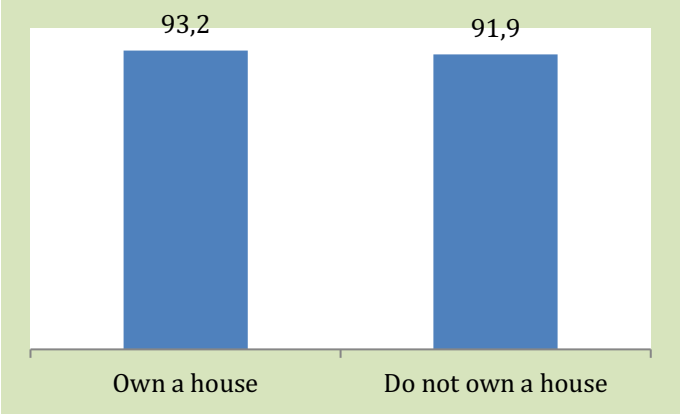


Figure 12: Distribution by Households in Own Houses with a Bank Account (%) – (Source: Household Survey, 2021)

Distribution by type of Employment and Bank Account Ownership – Over 81% had bank accounts whether employed in the public sector, private sector or self-employed (**Figure 13)**

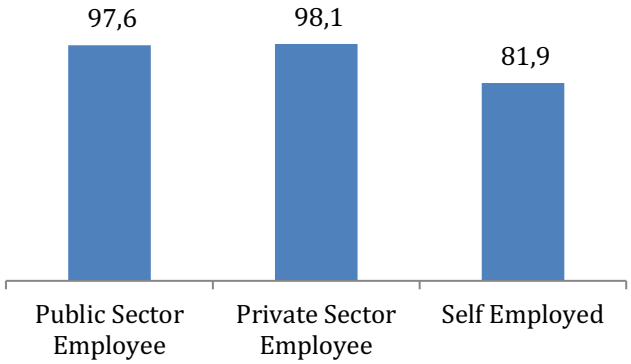


Figure 13: Distribution by Type of Employment and Bank Account Ownership (%) – (Source: Household Survey, 2021)

Distribution by perceptions on Terms for Bank Loans - 84% found the bank loans terms and conditions unattractive **(Figure 14)**

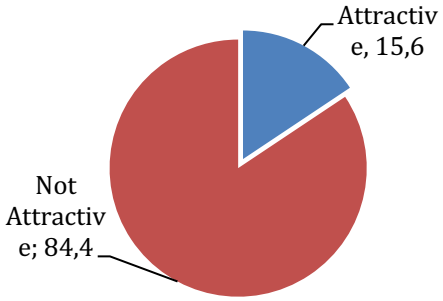


Figure 14: Distribution by Perceptions on Terms for Bank Loans (%) – (Source: Household Survey, 2021)

Distribution by Financial Institutions Used - The National Bank of Malawi at 67% was the most preferred institution among the respondents followed by Standard Bank at 10%, NBS at 10% and FDH at 9% in that order. **Figure 15** refers.

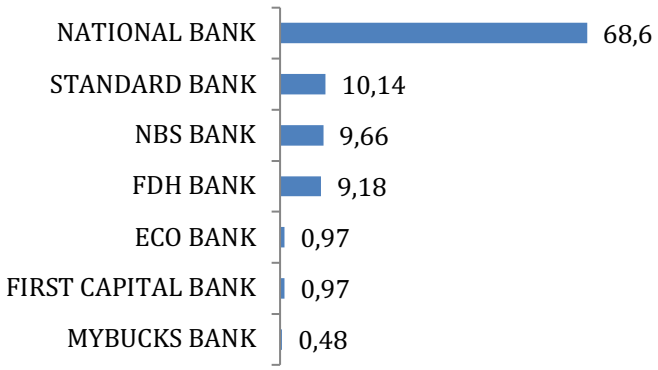


Figure 15: Distribution by Financial Institutions Used (%) – (Source: Household Survey, 2021)

5.2.3. Current expenditure on electricity

Distribution by expenditure on Electricity - 67% of the households paid over 13USD (equivalent of MK10,000.00) on electricity bills. Figure 16 refers.

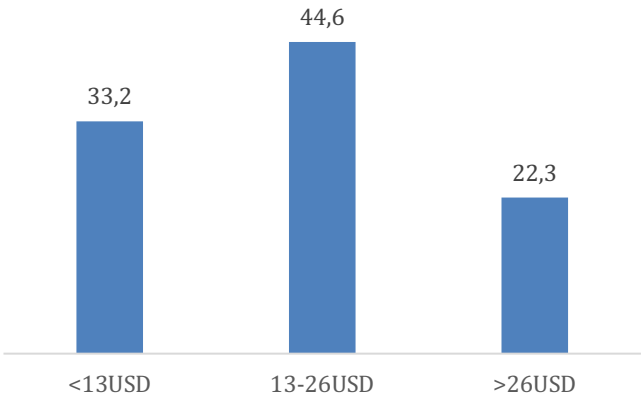


Figure 16: Distribution by Expenditure on Electricity (%) – (Source: Household Survey, 2021)

Distribution by metering type - 84% of the surveyed households were on prepayment metering. **Figure 17** refers. The power utility embarked on a project to migrate all domestic customers to pre- payment metering, where customers buy units in advance and are provided a voucher with a unique number to charge the meter.

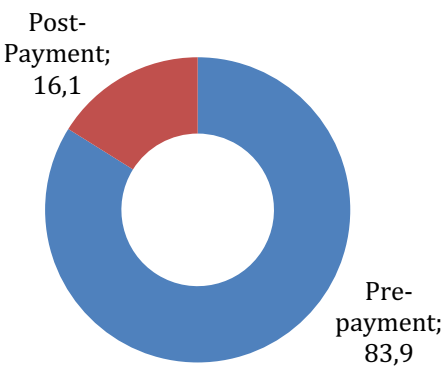


Figure 17: Distribution by Metering Type Used (%) – (Source: Household Survey, 2021)

5.2.4. Ownership of residential refrigerating equipment

Distribution by number of refrigerators owned per household - 85.3% owned 1 refrigerator, 12.3% owned 2 and 2.4 % owned 3**. Figure 18**, refers.

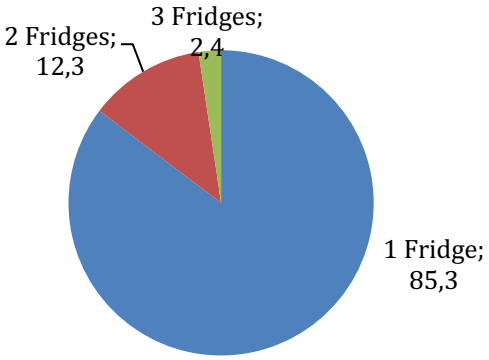


Figure 18: Distribution by Number of Residential Refrigerators Owned (%) – (Source: Household Survey, 2021)

5.2.5. Desired Features of Equipment

The survey established the following:

Distribution by the Condition of Refrigerators on Purchase - 85% of the refrigerators were bought new. **Figure 19** refers.

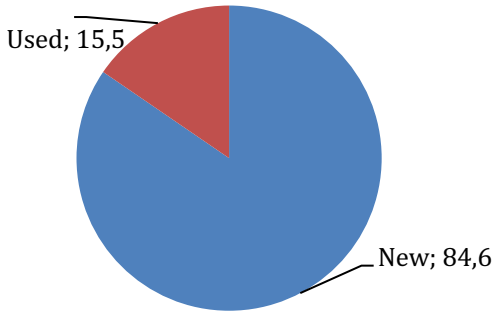


Figure 19: Distribution by Condition of Refrigerators on Purchase (%) – (Source: Household Survey, 2021)

Distribution by function of Residential Refrigerators - 59% were refrigerator freezers type, 32% were freezers and 10% were refrigerators. **Figure 20** refers.

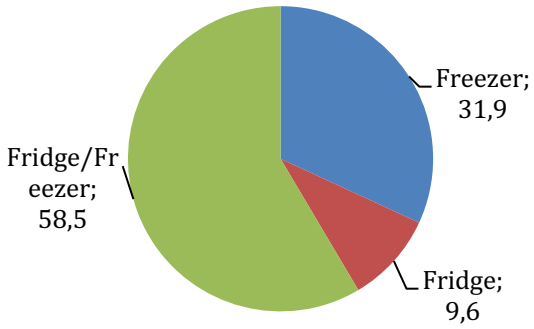


Figure 20: Distribution by Function of Residential Refrigerators (%) – (Source: Household Survey, 2021)

Distribution by Unit Price of Residential Refrigerators - 69% of the residential refrigerators were bought at less than USD 400.00 (equivalent of MK300,000.00) a unit. **Figure 21** refers. The survey recorded unit prices ranging from a minimum of USD 26 (equivalent of MK20,000.00 and aged over 10 years) to a maximum of USD 1,100.00 (equivalent of MK900,000.00 and aged 7 to 10 years.

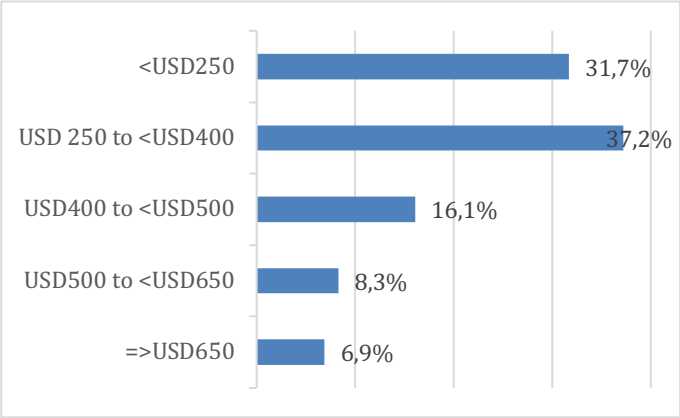


Figure 21: Distribution by Unit Price of Residential Refrigerators – (Source: Household Survey, 2021)

Distribution by size (volume in Litres) of Residential Refrigerators and technology type - 75% of the residential refrigerators were of capacity ranging from 200 to 400 litres. The distribution by size was uniform across the different types of technologies. 74% of the automatic residential refrigerators had sizes in the same range of 200 to 400 litre compared to 80% of the manual defrost and 74% of the direct cool. **Table 9** refers.

Energy Consumption	Automatic	Manual	Direct Cool	Total
<200L	19.3	2.6	7.5	10.2
200-<300L	**28.1**	**35.9**	**40.0**	**35.2**
300-<400L	**45.6**	**43.6**	**33.8**	**39.8**
400-<500L	0.0	7.7	8.8	5.7
>=500L	7.0	10.3	10.0	9.1
Total	**100**	**100**	**100**	**100**

Table 9: Distribution by Volume in Liters of Residential Refrigerators and Technology Type– (Source: Household Survey, 2021)

5.2.6. Consumer Preference on Purchase of a Refrigerator

Features with Low Preference by the Majority - 35% indicated low preference on energy consumption. See **Figure 23**; and a majority of 40% indicated low preference on noise level. **Figure 22** refers.

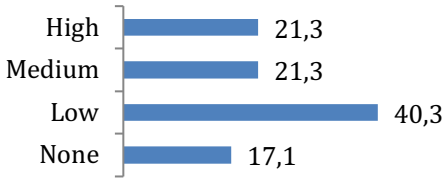


Figure 22: Noise Level (%) – (Source: Household Survey, 2021)

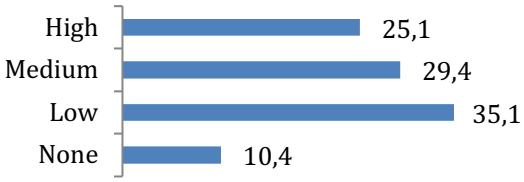


Figure 23: Energy Consumption (%) – (Source: Household Survey, 2021)

Features with Medium Preference by the Majority - A majority of 41% indicated medium preferences on people's recommendations. See **Figure 24** and a majority of 35% indicated medium preference on availability of transport and installation facility. **Figure 25** refers.

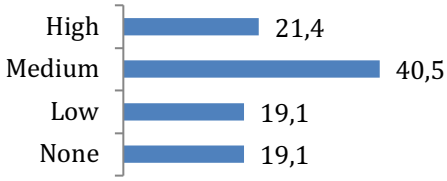


Figure 24: On People's Recommendation (%) – (Source: Household Survey, 2021)

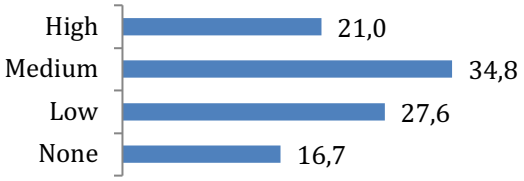


Figure 25: Availability of Transport and Installation facilities (%) – (Source: Household Survey, 2021)

Features with High Preference by the Majority - The majority indicated high preferences on the following features: equipment price by the majority of 63%. See **Figure 26**; warranty by the majority of 50%. See **Figure 27**; color by the majority of 42%. See **Figure 28**; functionality by the majority of 63%. See **Figure 29**; capacity by the majority of 45%. See **Figure 30**; and brand by the majority of 48%. See **Figure 31.**

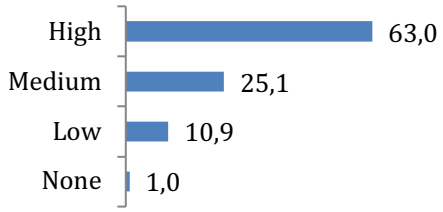


Figure 26: Equipment Price (%) – (Source: Household Survey, 2021)

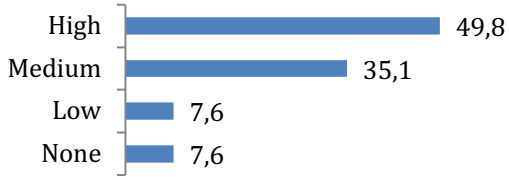


Figure 27: Warranty (%) – (Source: Household Survey, 2021)

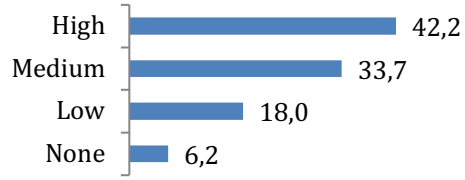


Figure 28: Colour (%) – (Source: Household Survey, 2021)

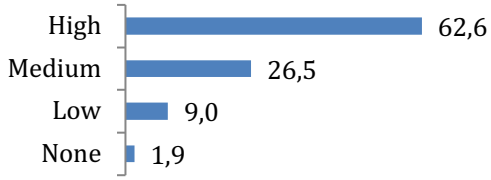


Figure 29: Functionality (%) – (Source: Household Survey, 2021)

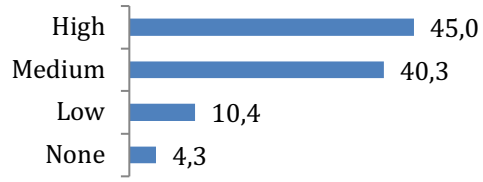


Figure 30: Capacity (%) – (Source: Household Survey, 2021)

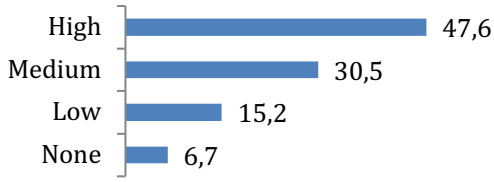


Figure 31: Brand (%) – (Source: Household Survey, 2021)

Additionally, the majority of 55% indicated high preferences on access to financing. See **Figure 32.** Further, 41% were willing to pay more for a 10% reduction in energy consumption while 34% were willing for a 20 to 40% reduction**. Figure 33** refers.

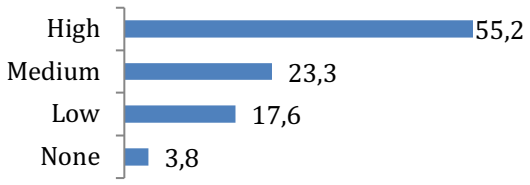


Figure 32: Access to Financing (%) – (Source: Household Survey, 2021)

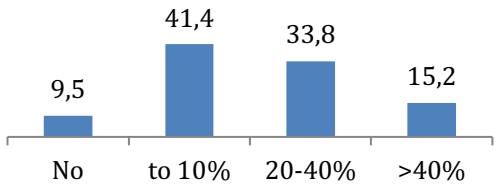


Figure 33: Willingness to Pay for Energy Efficiency (%) - (Source: Household Survey, 2021)

In summary the desired features were not consistent with the national energy policy actions on energy efficiency; the country's obligations to the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol, "to reduce the onset of global warming by reducing greenhouse gas concentrations in the atmosphere; and the National Climate Change Management Policy (2016) in order to enhance coordination and implementation. High preference was noted on the price, warranty, colour, brand, capacity, access to finance and functional practicalities of the refrigerators.

5.2.7. Barriers to the purchase of efficient refrigerators

Distribution by Level of Awareness of Efficiency Standards – 98% of the respondents were not aware of energy efficiency and labeling standards for refrigerators, which made it difficult for customers to make informed decisions on purchase. **Figure 34** refers. Mixed preferences on purchase of refrigerators were noted with majority at 35% rating low preference on energy consumption. **Figure 22** refers.

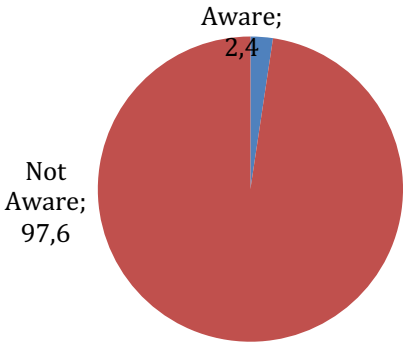


Figure 34: Level of Awareness of Efficiency Standards (%) – (Source: Household Survey, 2021)

Distribution by Type of Employment of Those who Borrowed – 23% of public employees borrowed from the banks. 7% of the self-employed borrowed and 4% of private employees borrowed. The pattern shows around 70% did not use bank loans. **Figure 35** refers. This was despite over 81% of the respondents having bank accounts**.** See **Figures 12 and 13** of section 5.2.2.

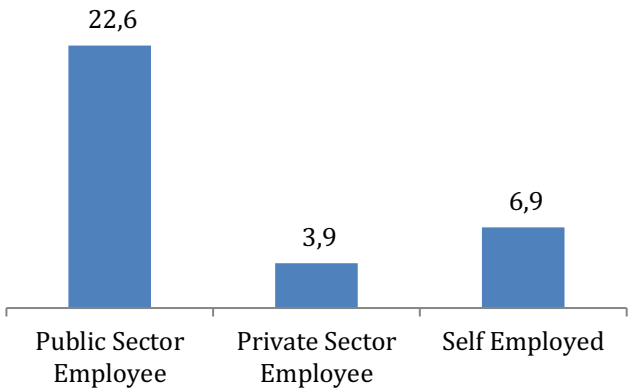


Figure 35: Distribution by Type of Employment of those who Borrowed from the Bank (%) – (Source: Household Survey, 2021)

Distribution by mode of purchase, whether used a bank loan - 84% did not find bank loan terms and conditions attractive. **Figure 12** of section 5.2.2 refers; and 91% purchased their refrigerators using own capital. See **Table 10**, below.

Mode of Purchase	Loan	No loan	Total
Own Capital	96.0	90.8	91.4
Hire Purchase	4.0	4.3	4.3
Leasing	0.0	2.2	1.9
Other	0.0	2.7	2.4
Total	**100**	**100**	**100**

Table 10: Distribution by Mode of Purchase, Whether Used a Bank Loan or Not (%) - (Source: Household Survey, 2021)

Capacity

High preference on price – 63 % indicated high preference on equipment price as a deciding factor on purchase (**Figure 25)**, which poses a major challenge, considering that energy efficient refrigerators could cost more than the conventional products and the preference on purchase of residential refrigerators could be greatly impacted by customers' financial capacity who are likely to be inclined towards the less costly refrigerators.

Distribution by Income and mode of purchase – over 80 % of all income levels, apart from the lowest level of monthly income of less than USD64 (equivalent of MK50,000.00), preferred to purchase their refrigerators using own capital. 100% of the lowest level preferred other means outside the three options provided. Notably, the group in the lowest level of monthly income represents the majority of the rural mass that were not targeted and likely to face challenges in raising finances. **Table 11** refers.

Income	Mode of Purchase				
	Own Capital	Hire Purchase	Leasing	Other	Total
<64USD	0.0	0.0	0.0	100.0	100
64-128USD	82.4	5.9	11.8	0.0	100
128-641USD	91.7	3.3	3.3	1.7	100
641-1924USD	92.8	5.2	0.0	2.1	100
>1924USD	97.1	2.9	0.0	0.0	100
Total	**91.4**	**4.3**	**1.9**	**2.4**	**100**

Table 11: Distribution by Monthly Income and Mode of Purchase (%) - (Source: Household Survey, 2021)

5.3. Equipment Stock and Projections

5.3.1. Summary of Residential Refrigerators in the Market Based on Household Demand

Distribution by Refrigerator Brands Sold - The best-selling brands were Defy at 38%, Hisense at 19% and KIC at 17% in that order and 15% could not be classified due to missing labels (**Figure 36**).

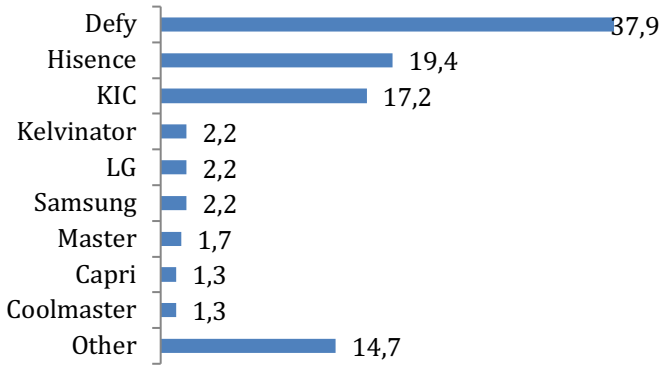


Figure 36: Distribution by Refrigerator Brands (%) – (Source: Households Survey, 2021)

Distribution by age of residential refrigerators - 43% of the refrigerators were of less than 3 years old and 28% between 3 to 7 years old. (**Figure 37)**

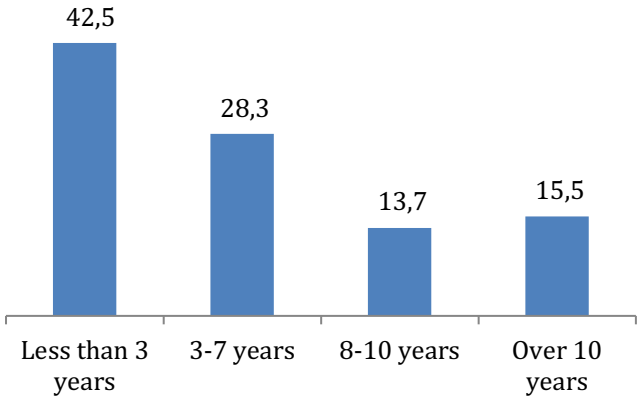


Figure 37: Distribution by Age of Refrigerators (%) – (Source: Household Survey, 2021)

Distribution by Technology of residential refrigerators - 50% of the surveyed refrigerators were of direct cool type. Thus, of low energy efficiency. 20% were of manual defrosting and 30% of automatic defrosting. (**Figure 38)**

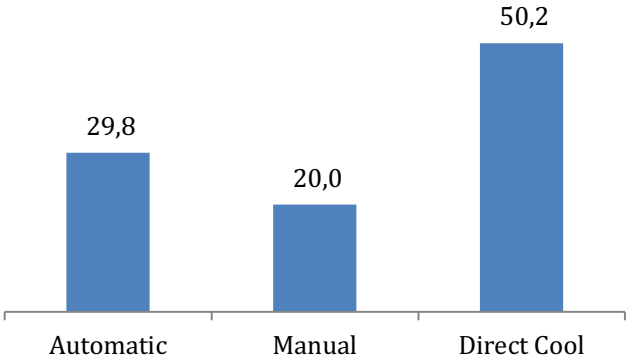


Figure 38: Distribution by Technology of Refrigerators (%) – (Source: Household Survey, 2021)

Distribution by Refrigerant Type Used in the Residential Refrigerators - 30.1% used R134A and R404A, refrigerants of high GWP of 1430 and 3922, respectively, and these were way out of the recommended maximum GWP limit set by the European Union (EU) MAC directive of 150 or less by 2015 for residential air conditioning and refrigeration (EU, 2015). 65% used R600A refrigerant of low GWP, to be encouraged (**Figure 39)**

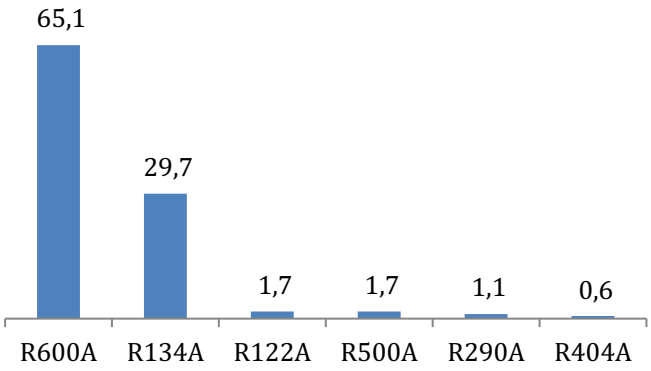


Figure 39: Distribution by Refrigerant Type Used (%) – (Source: Household Survey, 2021)

Distribution by Refrigerant Type and Technology of Residential Refrigerators - 31% of the direct cool, 45% of the manual defrost and 11% of the automatic defrost used the R134A refrigerant, of high GWP. In summary, the energy efficient refrigerators were not necessarily using the environmentally safe refrigerants of low GWP. However the proportion of the energy efficient refrigerators using the R134A was small. **Table 12** refers.

Refrigerant	Automatic	Manual	Direct Cool
R122A	1.8	2.5	1.5
R134A	10.5	45.0	30.9
R290A	3.5	0.0	0.0
R404A	1.8	0.0	0.0
R500A	0.0	2.5	2.9
R600A	82.5	50.0	64.7
Total	**100**	**100**	**100**

Table 12: *Distribution by Refrigerant Type and Technology Used (%) - (Source: Household Survey, 2021)*

Distribution by Age and Energy Consumption of Residential Refrigerators– 87% of residential refrigerators aged less than 3 years were to have an annual energy consumption of equal or less that 400kWh; This is compared to 80% of those aged 3 to 7 years; 100% of those aged 8 to 10 years; and 68.2% of those aged over 10 years. In other words, 13% of refrigerators aged less than 3 years had an annual energy consumption of equal or more than 400kWh/year, compared with 20% of aged 3 to 7 years; and 32% of aged over 10 years. Higher proportion of the older residential refrigerators had an energy consumption equal or more than 400kWh/year. See **Table 13**.

Energy Consumption	Age of the refrigerator in years				Total
	< 3 years	3-7 years	8-10 years	Over 10 years	
<200kWh	5.8	14.8	19.1	4.6	9.8
200-<300kWh	39.5	33.3	38.1	31.8	36.6
300-<400kWh	41.9	31.5	42.9	31.8	37.7
400-<500kWh	7.0	9.3	0.0	4.6	6.6
>=500kWh	5.8	11.1	0.0	27.3	9.3
Total	**100**	**100**	**100**	**100**	**100**

Table 13: Distribution by Age and Energy Consumption of Residential Refrigerators (%) - (Source: Household Survey, 2021)

Distribution by Volume, Age and Energy Consumption of Residential Refrigerators– Refrigerators of capacities equal to or greater than 100 litres and less than 350 litres recorded both highest maximum and lowest minimum energy consumption of 1800kWh/yr and 39kW, respectively. 21% in this range were aged more than 7 years while 42% were less than 3 years (**Table 14**).

Volume (Ltrs)	Energy Consumption (kWh)		Distribution by Age (%)				Total
	Maxi	Min	<3	(3 - 7)	(7 - 10)	>10	
<100 Ltrs	146	43	0	2	0	0	2
100-<200 Ltrs	1200	113	24	16	4	5	49
200-<350 Ltrs	1813	39	18	8	6	6	38
350-<600 Ltrs	635	100	6	2	1	1	10
>=600 Ltrs	686	358	1	0	0	1	2
							100

Table 14: Distribution by Volume, Age and Energy Consumption of Residential Refrigerators (%) (Source: Household Survey, 2021)

Distribution by Volume and Energy – The survey results showed a general trend, where energy consumption is directly proportional to volume of the refrigerator. Some outliers are noted as presented in **Figure 40**.

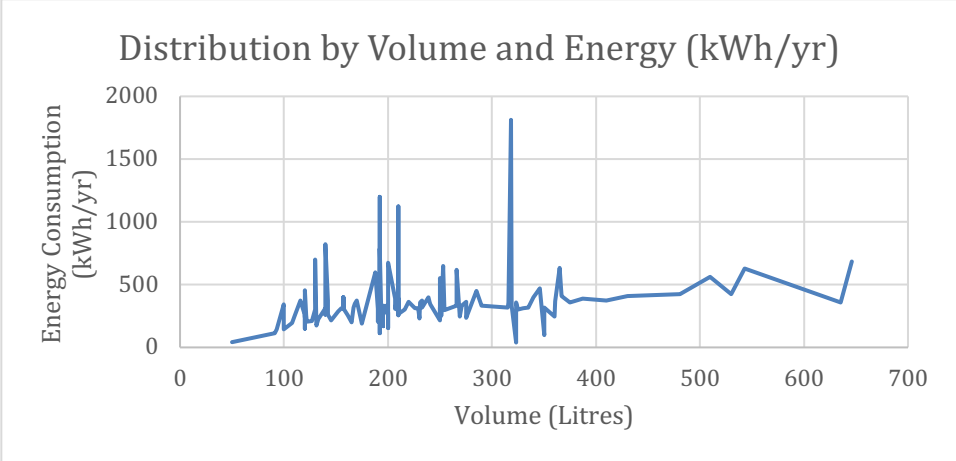


Figure 40: Distribution by Energy Consumption and Volume in Litres (Source: Household Survey)

Distribution by energy consumption and technology type of Residential Refrigerators –93% of the automatic defrost were of annual energy consumption of equal or less that 400kWh; This is compared to 82.1% of the manual defrost and 81.3% of the direct cooling. More of the automatic defrosting refrigerators were of low energy consumption. See **Table 15**.

Energy Consumption	Technology			Total
	Automatic	Manual	Direct Cooling	
<200kWh	19.3	2.6	7.5	10.2
200-<300 kWh	28.1	35.9	40.0	35.2
300-<400 kWh	45.6	43.6	33.8	39.8
400-<500 kWh	0.0	7.7	8.8	5.7
>=500 kWh	7.0	10.3	10.0	9.1
Total	**100**	**100**	**100**	**100**

Table 15: Distribution by Energy Consumption and Technology Type of Residential Refrigerators (%) - (Source: Household Survey, 2021)

Distribution by energy consumption and type of residential refrigerators –95.4% of refrigerator types were of annual energy consumption of equal or less that 400kWh; This is compared to 82.6% of the refrigerator-freezer type and 87.9% of freezer type. More of the refrigerator type were of low energy consumption. See **Table 16**.

Energy Consumption	Type of Residential Refrigerator		
	Refrigerator	Refrigerator/Freezer	Freezer
<200 kWh	39.9	7.0	3.4
200-<300 kWh	33.3	22.1	58.6
300-<400 kWh	22.2	53.5	25.9
400-<500 kWh	5.6	7.0	6.9
>=500 kWh	0.0	10.5	5.2
Total	**100**	**100**	**100**

Table 16: Distribution by Energy Consumption and Type of Residential Refrigerators (%) - (Source: Household Survey, 2021)

A list of various brands of residential refrigerators used by households is provided based on the household survey findings and it includes pictures of rating plates (**Appendix 9).**

5.3.2. Technology Trends and Market Projections

Technology Trends

Distribution by age of residential refrigerators and technology type used – **55%** of the automatic defrost were of less than 3 years. This is compared to **19.5%** of the manual defrost; and **48%** of the direct cool.

Further, **83.3%** of the automatic defrost were aged up to 7 years. This is compared to **53.7%** of the manual defrost; and **70.6%** of the direct cool. The trend show there is no particular attention to energy efficiency on the purchase of residential refrigerators. Nearly 50% of the direct cool were of less than 3 years old. However, the majority of the automatic defrost were also of less than 3 years. **Table 17** refers.

Age of the fridge	Title			Total
	Automatic	Manual	Direct Cool	
Less than 3 years	55.0	19.5	48.0	44.3
3-7 years	28.3	34.2	22.6	26.6
8-10 years	10.0	14.6	13.7	12.8
Over 10 years	6.7	31.7	15.7	16.3
Total	**100**	**100**	**100**	**100**

Table 17: Distribution by Age of Residential Refrigerators and Technology Type Used (%) - (Source: Household Survey, 2021)

Market Projections

Malawi Population and Housing Census 2018 pegged the population at 17,563,749 with an average annual/intercensal growth rate of 2.9% during the period 2008 to 2018 (NSO, 2018). Projecting to the year 2020 gives a total population of 18.6 million and 4.2 million households, considering an average household size of 4.4 (NSO, 2020). The 5th Integrated Household Survey (IHS5) 2019-2020 estimated that 5.6% of households owned refrigerators (NSO, 2020) which translates to 237,000 households. The household survey established the distribution by number of refrigerating appliances per household comprising 85.3% with 1 refrigerator, 12.3% with 2 and 2.4 % with 3 refrigerating appliances**. Figure 17**, section 5.2.4 refers. The total number of residential refrigerators is, therefore, estimated at 277,000. See **Table 18,** below.

Estimated No. of Refrigerators (2020)	Percentage Holding	No. of Households	No. of Refrigerators
No. of Households with Refrigerators		236, 692	

with 1 at 85.3% (2021 Survey)	85%	201,898.16	201,898
with 2 at 12.3% (2021 Survey)	12.3%	29,113.10	58,226
with 3 at 2.4% (2021 Survey)	2.40%	5,680.60	17,042

Stock of Residential Refrigerators (2020 Estimate)		277,166

Table 18: Approximate Total Number of Refrigerators (Source: Market Assessment, 2021)

The market size for residential refrigerators is assumed to be driven by the need to replace the old ones at the end of life and to supply new demand. The new demand is assumed to be proportionate to the economic growth. Based on regional experience, a life span of 12 years translates to 8% annual replacement rate while the average economic growth rate during the period 1990 to 2019 is estimated at 4.35% (World Bank, 2021). Following the above assumptions, the market size for new refrigerators is projected to increase from 34,000 in 2021 to 77,000 in 2040 annually, comprising annual requirement for replacements increasing from 22,000 in 2021 to 50,000 in 2040; and annual requirement to meet the growing demand increasing from 12,000 in 2021 to 27,000 in 2040. Total stock is projected to increase from 289,000 in 2021 to 750,000 in 2040 (**Appendix 10**). **Table 19** refers.

Market Projections for Residential Refrigerators in Malawi to 2040		
	2021	2040
New Refrigerators to replaced old ones (end-lifetime)	22,173	49,795
New Refrigerators for market growth	12,057	27,076
Total Market Size	34,230	76,871
Total Stock	289,223	649,515
Distribution by H/holds with Refrigerators (%)	6.7%	8.7%
Market Value (Est. Cost in MUSD)	11.2	25.2

Table 19: Market Projections for Residential Refrigerators to 2040 (Market Assessment, 2021)

The pattern for the projections are presented in **Figure 41** below.

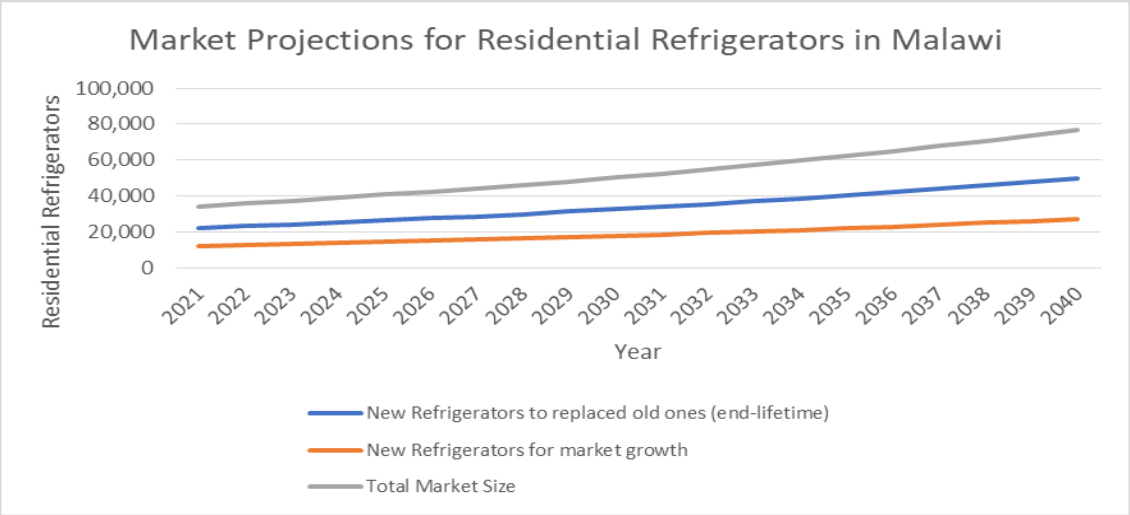


Figure 41: Market Projections for Residential Refrigerators in Malawi (Market Assessment, 2021)

The projections, further, indicate the distribution by households owning refrigerators will increase from 5.60% in 2021 to 8.7% in 2040. See **Figure 42** below.

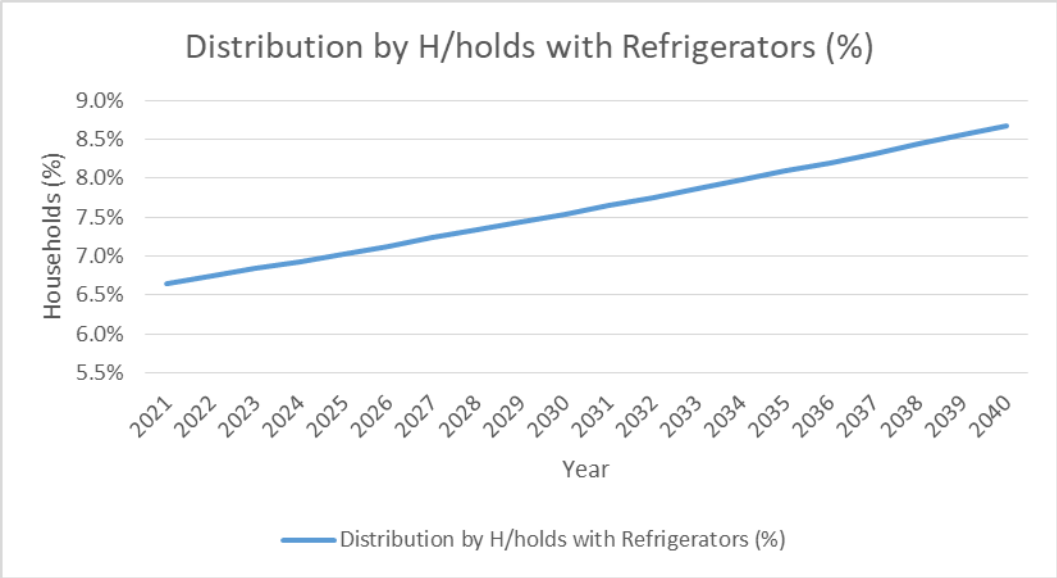


Figure 42: Distribution by Households with Refrigerators (Market Assessment, 2021)

5.4. Policies and Programme Landscape

5.4.1. Current and Planned Refrigerator Policies and Programmes

Policy on Energy Efficiency

The market assessment project is consistent with the energy policy statement on priority area No 8 that, "Demand Side Management (DSM) is an important means of improving energy efficiency at the end-use level of the energy supply chain. Currently in Malawi, there is a lot of wastage of electrical energy and biomass in end-use activities such as cooking, water and space heating, and lighting occasioned by use of inefficient appliances and devices. This priority area focuses on savings in electricity and biomass consumption". Section 3.8.1.3 of the policy on government actions states that, "Government actions to promote DSM include the following: a) Instituting appliance testing, labelling and standards, which will include minimum energy performance standards (MEPS)". Among other actions, the policy lists the following to promote DSM: a) Instituting appliance testing, labelling and standards, which will include MEPS; and b) Enforcing Government procurement rules that ensure energy-consuming products such as air conditioners and refrigerators meet or exceed minimum energy performance standards (NEP, 2018).

Malawi National Environmental Policy

Section 5.6 of the Malawi National Environmental Policy 2004 provides the energy objective, among others, "to meet national energy needs with increased efficiency and environmental sustainability". Section 5.6.9 indicates the policy strategies, among them to, "promote environmentally friendly energy technologies to reduce greenhouse gas emitting fuels" (EAD, 2004).

Environmental Laws and Regulations

The Environment Management Act 2017 section 40(C) requires compliance with minimum standards for emission of noise and vibration pollution, section 52 (c) promotes conservation of energy and use of renewable energy sources and section 56 provides for waste management while section 59 provides for guidelines for management of toxic and hazardous substances (EAD, 2017).

The Environment Management (Management of Ozone Depleting Substances), (ODS) Regulations, 1998 prohibits importation of refrigerators designated to use *CFC-/2* (R-12) or CFC-II (R-I/) as coolant effective 1st April 1998 (EAD, 1998).

The ODS regulations, however, do not provide the levels of the GWP of the allowable coolant and the MBS were yet to establish and enforce Minimum Energy Performance Standards (MEPS) and other standards on refrigerators.

Planned refrigerator policies and programs

a) Planned policies and Programs

There are no specific standards available for household refrigerators. The MBS is, currently, the secretariat of the SADC Cooperation in Standards (SADCSTAN). In collaboration with UNEP-U4E, SACREEE and EACREEE, SADCSTAN has embarked on project to develop regionally harmonised MEPS for cooling appliances, refrigerating appliances and air conditioners. The project is registered to develop standards for cooling appliances, including refrigerators (MBS, 2021).

MBS use a general standard, MS-IEC 60335-1:2005 on household and similar electrical appliances – safety part 1: General requirements (m) to certify compliance of refrigerators imported in Malawi, which is limited on issues to do with energy efficiency (MBS, 2021). MBS carries out compliance checks at the borders on imported products.

b) The SADC and EAC - Technical Note on Quality and Performance Metrics of Cooling Products

Malawi stands to be guided by the international practice set by East African Community (EAC) and Southern African Development Community (SADC). Reference is made to a draft Technical Note on quality and performance metrics of cooling Products for EAC and SADC, Part I: Refrigerating Appliances. The Note refers to the Montreal Protocol which evolved to address climate change mitigation as well, with the 2016 Kigali Amendment establishing a framework for reducing global hydrofluorocarbon (HFC) use (W.Y. Park et al, 2020).

The note supports the effort of EAC and SADC to establish and improve energy-efficiency standards for room air conditioners (ACs) and refrigerating appliances by providing an overview of global market and policy trends and technical recommendations in a harmonized way across the region. Preliminary recommendations were made for further discussion amongst the EAC and SADC member countries (W.Y. Park et al, 2020). Namely, establishing regionally harmonized -

i. Energy-efficiency standard and compliance infrastructure;
ii. Labeling requirements and test standards aligned with international standards and U4E Model Regulation Guidelines;
iii. Energy-efficiency standards that consider low-Global Warming Potential (GWP) refrigerants along with improvement of safety standards;
iv. An appropriate infrastructure for product certification and registration by harmonizing databases regionally and allow data sharing;
v. Establish an appropriate infrastructure for testing or verifying energy-efficiency performance; and
vi. Strengthen the compliance regime.

c) Global Warming Potential of Cooling Appliances

i) Consideration of the GWP of Refrigerating Appliances

The international practice on refrigerating appliances is to adopt the IEC 62552 2015 standard to improve standards and labelling for the appliances in EAC and SADC countries and facilitating harmonization with international refrigerator-efficiency efforts (CA Gov., 2021).

ii) Low GWP hydrofluorocarbon (HFC) refrigerants

Despite availability of HFCs with lower GWP, such as R-32 and R-152a, the HFCs were being phased out and a selection of a natural hydrocarbon or hydrofluoroolefin (HFOs) refrigerant for new equipment design were being advised. The European Union (EU) MAC directive mandated the use of GWP of 150 or less by 2015 for residential air conditioning and refrigeration (EU, 2015). **Figure 43**, below, provides a selection of refrigerants for a range of GWP and those recommended with a low GWP. In the EU, low GWP refrigerants have a GWP of 150 or less. medium GWP refrigerants are between 150 and 2,500 and high GWP gases have GWP greater than 2,500 (Kardys, 2017).

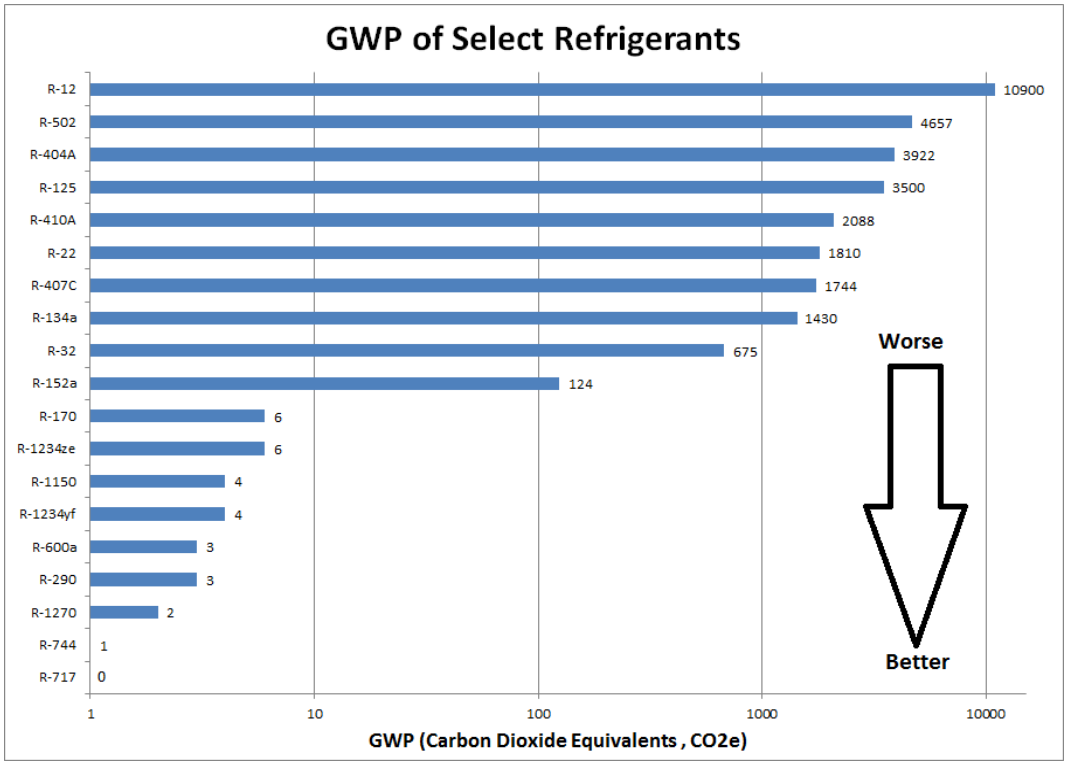


Figure 43: Low GWP Refrigerants (Kardys, 2017)

5.4.2. Status of electronic-waste management in the country

The treatment of all hazardous waste is in accordance with the Environment Management (Chemicals and Toxic Substances) Regulations (EAD, 2008). On disposal, the Environment Management (Waste Management and Sanitation) Regulations apply (EAD, 2008). In addition, Malawi refers to international standards agreed under the Stockholm Convention, the Stockholm Convention Guidelines on Best Available Techniques (BAT) and Best Environmental Practices.

Monitoring is done using the manufacturers' material data sheets and random sampling of transformers. Malawi, currently, lacks testing equipment and samples are sent outside the country, whenever a test is required.

5.4.3. Stakeholder perspectives on opportunities and barriers to transform the market toward more energy-efficient and climate-friendly refrigerators

The survey findings showed mixed perceptions among the respondents on whether energy efficiency is either the most or among the most significant factors affecting refrigerator selection. 14% were neutral; 43% strongly disagreed; and 43% somewhat agreed. See **Figure 5** in section 5.1.5.

Majority of the responses leaned towards the conceptions that, a) low unit price; b) more energy efficient technology; c) modern designs; and d) environmentally friendly refrigerants, will in future impact customers' satisfaction. 50% strongly agreed and 25% somewhat agreed while 25% somewhat disagreed that low unit price will in future impact customers' satisfaction. (**Figure 6**, above refers). 25% strongly agreed; and 38% somewhat agreed while 25% strongly disagreed and 13% were neutral that more energy efficient technology will in future impact customers' satisfaction. See **Figure 44** below.

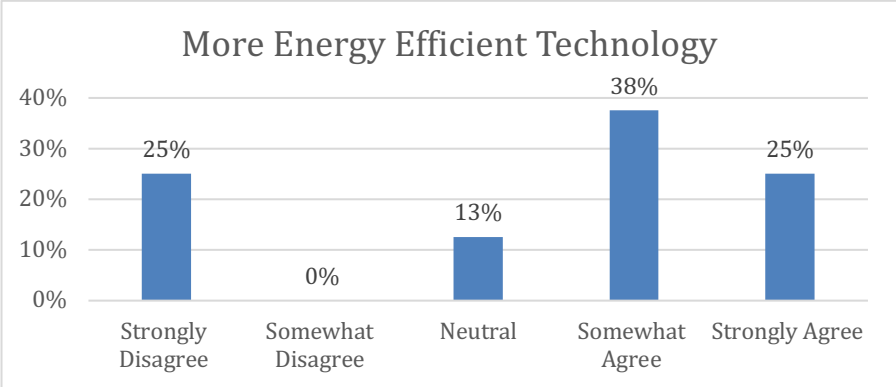


Figure 44: Stakeholders Perceptions Whether More Energy Efficient Technology will Affect Selection of Refrigerators (Source: Supply Chain Survey, 2021)

About 25% of the stakeholders strongly agreed, 38% somewhat agreed while 25% were neutral and 13% somewhat disagreed that modern design will in future impact customers' satisfaction. See **Figure 45** below.

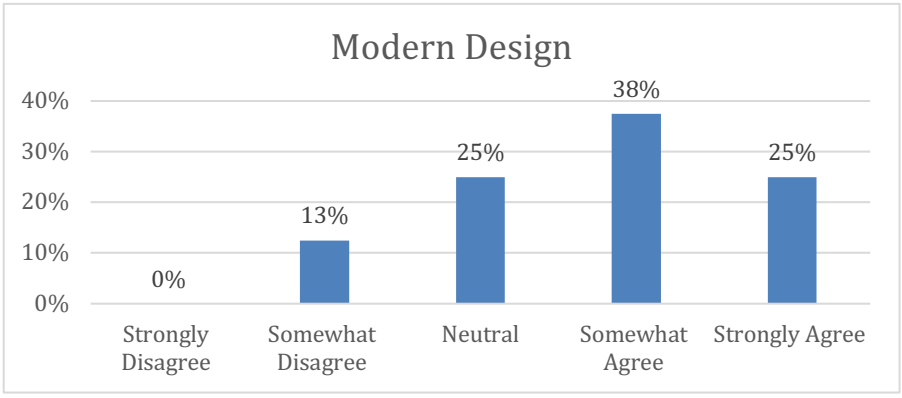


Figure 45: Stakeholders Perceptions Whether Modern Design will Affect Selection of Refrigerators (Source: Supply Chain Survey, 2021)

About 25% strongly agreed, 38% were neutral and 13% strongly disagreed that environmentally friendly refrigerants will in future impact customers' satisfaction. See **Figure 46** below.

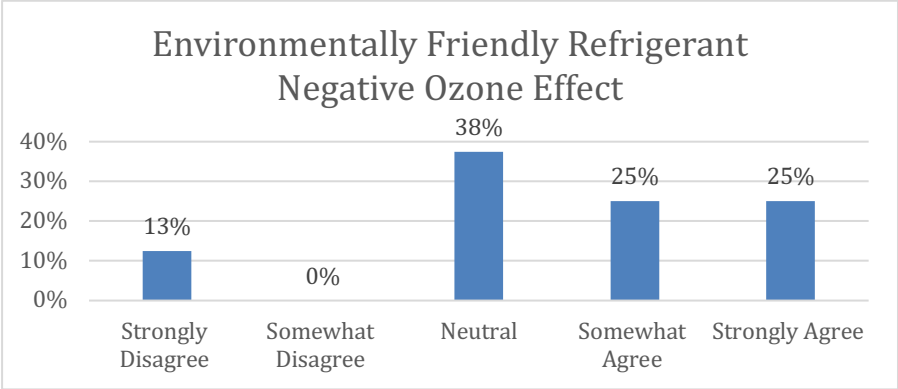


Figure 46: Stakeholders Perceptions Whether Environmentally Friendly Refrigerators will Affect Selection of Refrigerators (Source: Supply Chain Survey, 2021)

Further, the findings showed that for the majority size will, in future, have no impact on customers' satisfaction. 57% were neutral on whether bigger size will in future impact customers' satisfaction. See **Figure 47**.

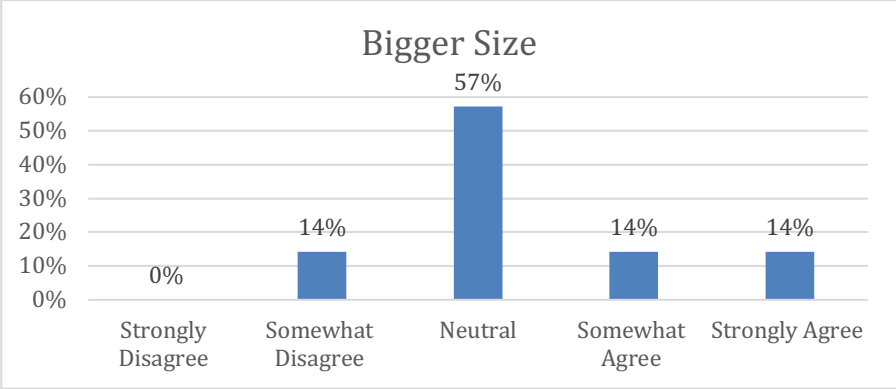


Figure 47: Stakeholders Perceptions Whether Bigger Size will Affect Selection of Refrigerators (Source: Supply Chain Survey, 2021)

5.5. Existing Financial Institutions and financing instruments for appliances

According to responses received from the National Bank of Malawi (NBM) and FDH Bank, (**Appendix 11**)**,** the following instruments were being offered:

a) General Consumer and Business loan by both banks; and
b) An Asset Based Scheme by NBM.

FDH indicated that their service was accessible through mobile money and online banking and did not mention any strings while NBM service required employer's letter of undertaking for the employed and a tangible security for the self-employed to access the general customer and business loan. To access the Asset Based Scheme, NBM required the customer proof of capacity to repay and an offer of property as security (**Appendix 11).**

5.6. Embedding and Dependencies of the National Refrigerator Market in the Regional Context

Trade in residential refrigerators was noted, albeit at very low levels, between Malawi and 5 other countries in the SADC region also implementing the GCF project, namely: Zimbabwe, Botswana, Zambia, Tanzania and Eswatini. **Table 20,** below**,** refers.

Exporters	Units	2016	2017	2018	2019	2020
Zimbabwe	Tons				2	1
	(US$'000)	2	2	3	13	1
Tanzania	Tons	2		1	10	1
	(US$'000)	5	2	2	2	5
Botswana	Tons	1	1	2	2	
	(US$'000)	2	3	4	5	-
Zambia	Tons	6	2			2
	(US$'000)	2	2	-	1	6
Eswatini	Tons					-
	(US$'000)	-	-	-	-	1

Table 20: Exporting Countries in the Region also Implementing GCF Project (NSO, 2021)

6. Market Assessment on Distribution Transformers

6.1. Supply

6.1.1. Summary of suppliers, government officials and other stakeholders

Users and Suppliers of Distribution Transformers

The survey established that the supply market for distribution transformers comprised product suppliers, government officials and other stakeholders. In summary, users of distribution transformers in Malawi comprise the following:

a) **The Electricity Supply Corporation of Malawi (ESCOM) Limited** – ESCOM is a national power utility company licensed to transmit and distribute electricity in all the regions in Malawi. It was commercialized in 1998 under the Electricity Act 1998 (Ministry of Energy, 1998) and incorporated as a limited company with 100% shares owned by Government.

ESCOM is mandated to sign Connection Agreements (CA) with the electricity generating companies. Malawi operates the Single buyer model where general rights and obligation of market participants are defined by the market rules for the Malawi Electricity Supply Industry (MERA, 2016). Namely, generation companies, open to independent power producers; ESCOM as a monopoly apart from off-grid mini grids who are licensed to generate and distribute electricity within the boundaries of their licensed area; the Single Buyer, Power Market Limited (PML), licensed to buy all the power from generators and sell to the distribution company (ESCOM) and large customers; System and Market Operator (SMO), to operate the electricity supply industry (ESI) and the Malawi Energy Regulatory Authority (MERA) as the energy sector wide regulator (Ministry of Energy, 2018).

ESCOM installs, operates and maintains the transmission systems at 400,000, 132,000 and 66,000 volts; and the distribution system at either 33,000 or 11,000 volts, which is stepped down to 400Volts for customers' consumption (MERA, 2012). Procures the bulk of its transformers either directly from foreign manufacturers or through traders. Use local refurbishing companies for servicing and repairing its defective transformers, and provides projects that requires connection to the national grid based on the types of contracts used.

ESCOM uses detailed specifications to procure its transformers and makes reference to several IEC Standards, which to the contrary excludes the internationally used IEC 60076-20 on losses. However, ESCOM uses the international best practice to capitalize the future values of no-load losses and load losses. They use the A and B factors to evaluate the total owning cost of their distribution transformers. The A values are an estimate of and the B values a discounted cost of future load losses. Their specifications require bidders to supply distribution transformers of either cold rolled grain oriented (CRGO) silicon steel or Amorphous core type, which are the energy efficient type (**Appendix 14**).

b) **Malawi Rural Electrification Program (MAREP)** – Operating under the ministry of energy to increase access to electricity through grid extension and mini grids development, MAREP is financed through the rural electrification levy, which collects at 4.5% of all energy sales including on fuels defined by law as liquid fuels and gas. The levy is gazetted in the principle legislation, the Energy Regulation Act 2004 (Ministry of Energy, 2004).

MAREP procures and installs, among others, distribution transformers through competitive bidding from foreign suppliers and through local traders. MAREP contracts ESCOM and private contractors to carry out extension of its transmission and distribution networks. MAREP is the second largest importer of distribution transformers after ESCOM and borrow their specifications and evaluation formulae from ESCOM for transformers and power lines. **Appendix 14** refers.

c) **Industry -** supplied from the main grid at 33kV and 11kV, with dedicated transformers. The survey established that the industrial energy users procure and install own transformers, which are bought and supplied either from foreign suppliers or could be supplied by ESCOM. Some industries, such as Limbe Leaf Tobacco Company for instance, indicated that operation and maintenance of the distribution remains with the power utility to manage while they concentrate on their core business.

d) **Mini Grids** - There were two established and operational mini grids in Malawi as follows:

i. **Illovo Sugar Company** – The company is supplied through a bulk metering and is connected to the national grid system at a medium voltage of 11kV. The company operates and maintains a 13.53MW, 11kV network complete with distribution transformers to step down voltage to 400 volts. The network is used for irrigation and producing sugar. It is in the southern region district of Chikwawa at Nchalo and processes sugarcane to produce sugar. A second plant of installed capacity of 8.24MW and grid connected, is in the central region district of Nkhotakota at Dwangwa.

ii. **Community Energy Malawi (CEM)** – "is a Malawian led and membership driven organization formed as part of the Community Energy Development Programme (CEDP) under the Malawi Renewable Energy Acceleration Programme (MREAP) funded by Scottish Government. CEM are incorporated as Non -Governmental Organization with Government" (CEM, 2021)

The first project is an 80kW off-grid community based renewable energy mini grid, at Sitolo Village in the central region district of Mchinji. It was installed and operated with donor support from the people of Scotland. It produces electricity from solar photo voltaic (PV) modules; transforms the direct current and voltage (dc) to alternating type (ac) at 50Hz and distributed at a medium voltage of 33kV.

It has in total six (6) transformers installed comprising one step up to 33kV and 5 step down to 400Volts. These were all supplied new from K2 Transformers, a local manufacturing company.

iii. **Mulanje Electricity Generation Company (MEGA)** – is a social enterprise funded by international donor agencies. It was developed with support from the British

Government's Department for International Development through the Business Innovation Facility. It is wholly owned by Mulanje Mountain Conservation Trust (MMCT), an endowment trust supporting conservation and development around the mountain (MEGA, 2021)

MEGA is a 220kW off-grid renewable energy installed at Bondo Village in Mulanje Mountain the southern region district of Mulanje, is a micro hydro-based power generation plant. It distributes power at a medium voltage of 11kV and use transformers to step down the voltage to 400 volts.

It has in total thirteen (13) transformers installed comprising one step up to 11kV and step down to 400Volts. These were bought from a foreign supplier in India and through a competitive tender.

e) **Suppliers** – Include foreign suppliers, local traders accredited by the national power utility (ESCOM), local manufacturers and local refurbishing companies. The survey established the leading suppliers as listed below:

K2 Transformers - is a leading local manufacturing and refurbishing company for distribution transformers in Malawi. Their services include: manufacturing, repairing and servicing while their manufactured products comprise 16 kilovolt amperes (kVA) 25, 50, 100, 200, 315, 500, 800 and 1 to 3.5MVA (K2 Transformers, 2021).

Yemurai Pvt Ltd T/A Hawker Siddeley Electric - engages in both manufacturing and refurbishing of distribution transformers with an annual turnover of about 20 units on manufacturing. Their customers comprised: the power utility, construction companies and housing industry. Their manufactured products ranged from 25 kVA to 2000kVA of distribution transformers and from 2500kVA of system transformers while refurbished transformers ranged from 50kVA to 1000kVA (**Appendices 3c and 6c**); and

Global Trans-electric Services - engages in refurbishing of distribution transformers of sizes ranging from 50kVA to 1000 kVA. They reported annual turnover of about 35 in 2020 to 80 in 2021 and projected to over a 100 in 2022 and thereafter. Their customers comprised the power utility and industry in general.

The survey findings indicated that out of service units are reconditioned and put back in service. The type of refurbishing was, largely, draining and replacing oil and changing of bushings. Based on the national power utility (ESCOM's) submission, 15% of installed distribution transformers were refurbished (**Appendix 6c**).

Officials and Other Stakeholders

a) **The Malawi Bureau of Standards (MBS)** - through collaboration with industry develops and adopts standards for the country. The standards are voluntary. The end users make reference to the Malawi Standards (MS) developed by the MBS when making procurements.

b) **The Malawi Energy Regulatory Authority (MERA)** – is the energy sector regulator with a mandate to enforce the standards wherever required. Based on the responses received from the

questionnaires, MERA is currently not monitoring and enforcing compliance with the standards. A Distribution Code is being developed by MERA in collaboration with the industry players which may incorporate the requirement to comply with relevant standards including the MEPS.

c) **The Environmental Affairs Department (EAD)** – is a Department under the Ministry of Natural Resources. They are responsible for the Environment Management (Chemicals and Toxic Substances) Regulations and the Waste Management and Sanitation Regulations.

In summary, the distribution channels emerging from the survey show that the distribution transformers supply chain comprises foreign suppliers, importers, local manufacturing and refurbishing companies and end users in the combinations as presented in **Figure 48**, below, which implies that all imports are subjected to regulations and codes imposed by the EAD and MERA, where applicable.

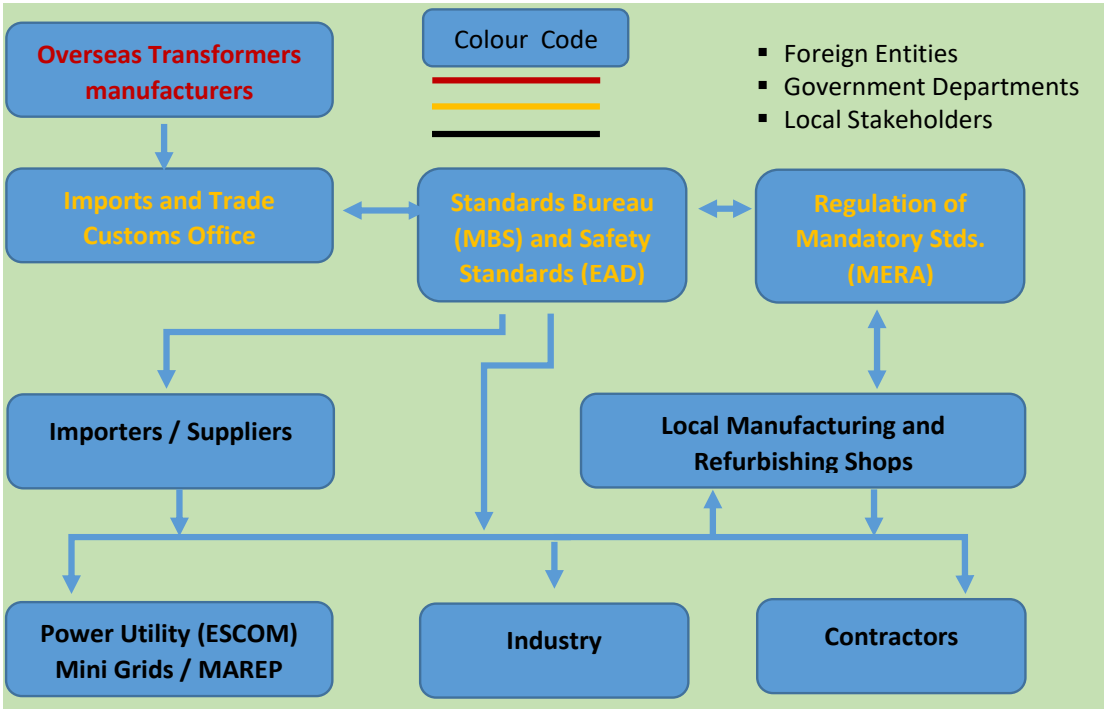


Figure 48: Emerging Distribution Channels for Distribution Transformers (Source: Supply Chain Survey, 2021)

All imports are subjected to the Import and Trade Customs Office, EAD Regulations and Malawi Standards. Compliance with the Malawi Standards is either voluntary or mandatory depending on MERA regulations. Local suppliers are also subject to compliance with the EAD Regulations, Malawi Standards and MERA regulation on the same basis as importers.

6.1.2. Overview of the supply chain, including finished products and major components like core, winding and insulation

Suppliers of Distribution Transformers

The number of new distribution transformers manufactured locally was very small compared to imports. The proportion of the new transformers manufactured locally during the period 2015 to 2020 was at 4%. 55% were imported by ESCOM and 41% by MAREP. **Figure 49** refers.

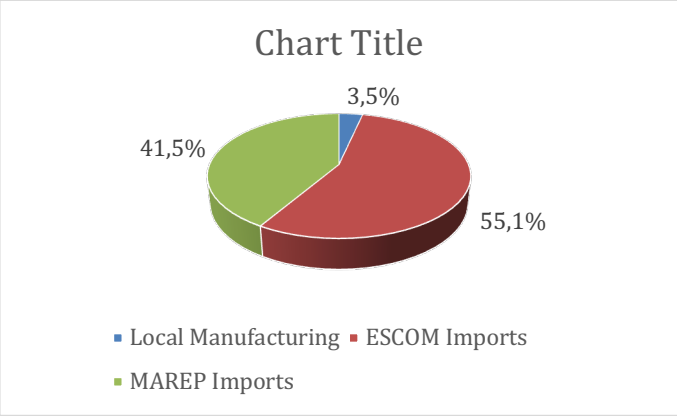


Figure 49: Distribution by Suppliers of Distribution Transformers (Source: Supply Chain Survey, 2021)

By weight, imports of distribution transformers were recorded at an annual average of 471 tons, costing at US$ 2.5 million. **Table 21** refers.

Imports	2016	2017	2018	2019	2020	Annually
	Imported quantity (Tons)					
Annual Imports (Tons)	845	810	490	107	102	471
Annual Imports (US$'000)	3,512	5,445	2,387	707	495	2,509

Table 21: Importation of Distribution Transformers (Markey Assessment, 2021)

6.2. Demand

6.2.1. Assessment of Main Purchasers of Distribution Transformers

Main Purchasers

The main purchasers were noted as presented in **Table 22**, below. In summary, the survey established the following:

a) **ESCOM and MAREP** – remained the major importers of distribution transformers. In addition to importing, ESCOM purchased from all local manufacturers including servicing and repairing using the local service providers.

b) **Illovo Nchalo, a Grid Connected Mini Grid,** despite being supplied bulk power and operating own distribution system, bought from ESCOM;

c) **Industry,** the water boards and tobacco companies, connected to ESCOM at medium voltage levels of 11kV and 33kV, bought from ESCOM;

d) **CEM Off Grid Solar Mini Grid -** bought from the local manufacturer, K2 Transformers, but the volume of trade was limited due to small size of their system with installed capacity of 80kW and had six transformers installed in its system; and

e) **Contracting Companies** and commercial suppliers purchased from the local manufacturers.

Suppliers →		**K2 Transformers**	**Yemurai Pvt Ltd**	**ESCOM Ltd**	**Global Transelectric Services**
Type of Service Provided		**Manufacturing & Repairing**	**Manufacturing**	**Electricity Distribution**	**Servicing and Reparing**
Customers	**Power Utility**	ESCOM (Central)	ESCOM	ESCOM	ESCOM
	Mini Grid - (Grid Connected)			Illovo	
	Mini Grids - (Off - Grids)	Community Energy Malawi (CEM)			
	Industry/		Malawi Housing	Limbe Leaf Tobacco	Shayona Cement
	Individual Entities			Limbe Leaf	
				Alliance One Tobacco	
				Alliance One,	
				JTI	
				Kanengo Tobacco	
				Processors	
				Water Boards	
	Contracting Companies	Sharma Electricals	Sharma Electricals		TT Power Line
		Gracest Engineering	SR Nicholus		Power L.
		Coolite Engineering	Hualong Construction		C & A Engineering
	Importers/Suppliers	Lido Electricals			
	MAREP			MAREP	

Table 22: Suppliers and Main Customers of Distribution Transformers (Supply Chain Survey, 2021)

Brands, Models, Product type and Capacity

Distribution by brand names of distribution transformers – ESCOM's asset register for the national grid provides over 90 different brands of distribution transformers (ESCOM, 2021) **(Appendix 12**). See **Figure 50**, below.

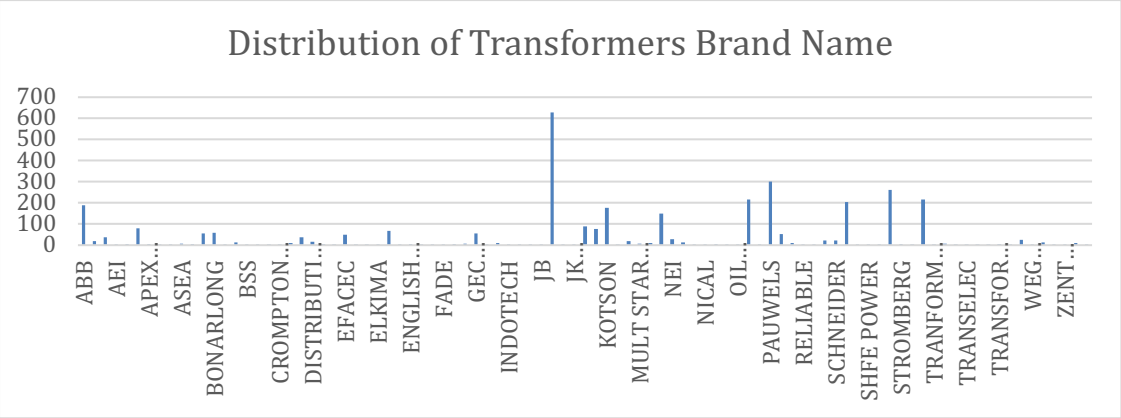


Figure 50: Distribution by Brand Names of Distribution Transformers Used in Malawi (Source: (ESCOM, 2021))

The common brands of distribution transformers were noted as presented in **Table 23**, below, and Jinshanmen Electrical had the biggest number installed.

Brand Name	**No. Installed**	**Brand Name**	**No. Installed**
JINSHANMEN ELECTRICAL	629	KOTSON	176
PAUWELS	301	JOKO	88
SOUTH WALES	260	JSB	76
TANALEC	217	GEC ALSTHOM	54
SHENDA	205	POWER ENGINEERING	53
ABB	190		

Table 23: The Most Common Brands of Distribution Transformers (Source: (ESCOM, 2021))

Pictures of rating plates for samples of distribution transformers were collected during the survey for records and reference (**Appendix 13)**. The following details were noted:

a) A mixture of brands were in use by all industry players;

b) The Labelling omitted the crucial parameters anticipated for the survey. The Load and No Load losses, for instance. However, the labelling was compliant with the international standard IEC 60076
c) The labelling for the locally manufactured transformers was faint and not legible from the rating plates pictures;
d) There were differences in the reference temperature used for impedance voltage between locally manufactured and imported transformers. The local manufacturer used 70°C and 75°C for the imported units;
e) Rating plates for locally manufactured transformers did not include any standards reference.

Mounting Set Ups Used for Distribution Transformers

Practice on mounting of distribution transformers was noted as presented by both the suppliers and end users. Two practices were noted on the limitations for pole mounting. The first is by weight and the second by voltage rating of the transformer as follows.

ESCOM and MAREP specified in terms of capacity rating while the suppliers specified by weight. Pad mounting was rarely used and none was noted. **Table 24** refers.

	Limitations for Mounting Set Ups		
	Pole Mounted	Ground Mounted	Pad Mounted
K2 Transformers	1500kg	> 1500kg	Not Used
Yemurai Pvt Ltd	1500kg	> 1500kg	Not Used
Mini Grid (CEM)	1000kg	> 1000kg	Not Used
ESCOM	315kVA	> 315kVA	Not Used
MAREP	200kVA	> 200kVA	Not Used

Table 24: Mounting Set-Ups Used for Distribution Transformers (Source: Supply Chain Survey, 2021)

6.2.2. Technical standards and regulations for distribution transformers in public utilities

Regulations

The powers and functions of MERA include, among others, "to develop and enforce performance and safety standards for energy exploitation, production, transportation and distribution" (MoE, 2004). MERA derives its mandate from the Energy Regulation Act 2004.

MERA gazetted electricity bylaws to guide on the performance and safety of power supply to safeguard electrical equipment and users and to ensure efficient use of electricity. The electricity bylaws require, among others: standard type of current and number of phases to be alternating voltage and current, 1 or 3 phases type; standard frequency of 50 hertz or cycles per second; standard

voltage of 230 volts phase to neutral and 400 volts phase to phase; and standard variations of frequency of alternating current and voltage not exceeding 1.25% above or below the nominal values; and voltage variations not exceeding 6% above or below the nominal values (bylaw 21) (MERA, 2012).

In general, electricity bylaws require efficient and effective designs that are safe and fit for the purpose. The by-laws require, "that works be designed, constructed, installed and protected, where necessary, with such material and of such quality as to prevent danger" and "to be sufficient in size and rating to perform their intended functions" (bylaw 29). The 7th Schedule of the bylaws provides minimum section clearances at different normal operating voltages between bare line conductors (MERA, 2012).

Standards

The survey established following interviews with the Malawi Bureau of Standards (MBS) that a series of standards were adopted on transformers comprising IEC, SADC and COMESA harmonized standards (MBS, 2021). Following a review of a catalogue of Malawi Standards available with MBS, the standards on distribution transformers were noted as presented in **Appendix 14**. It was noted during interviews with the Malawi Energy Regulatory Authority (MERA) that some standards were locally adopted upon specification in the Grid Code by thee regulator. However, the Grid Code excludes the distribution system and is silent on energy efficiency.

The MBS list is exclusive of the IEC TS 60076 – 20, the internationally adopted standard on energy efficiency for power transformers and it is not explicit whether the standard is on the list of the standards adopted on MERA's specification. The Malawi standards are normally voluntary but can be enforced through a regulation gazetted by the regulator, MERA. It was observed that the electricity bylaws rarely made reference to any of the Malawi Standards and international standards, which implies the standards remain voluntary. A gap that need to be addressed to achieve the energy policy objectives.

To this effect, no evidence was established that imported and locally produced transformers were subjected to standards compliance tests. The only test reported were factory tests before shipment for imported transformers. The findings confirmed the need for a coordinated approach among the key stakeholders to conform to the minimum energy performance standards. The following were established from the various authorities in Malawi:

i. **Malawi Bureau of Standards (MBS)** – That distribution transformers are used in the energy delivery service and hence fall under the mandate of the Malawi Energy Regulatory Authority (MERA). To this effect, MBS does not monitor compliance of distribution transformers with the Malawi Standards;

ii. **Malawi Energy Regulatory Authority (MERA)** – indicated there were no clear mandatory requirements or other regulatory policies to promote energy-efficient distribution Transformers; and could not confirm existence of any certification process for the distribution transformers used in the country; and

iii. ESCOM provided specifications used for procurement of distribution transformers, which provided evidence of compliance with requisite standards on a voluntary basis. The survey

established a list of comprehensive procurement specifications used by the utility (**Appendix 14**). **Table 28** refers.

6.2.3. Electrical connection regulations/rated frequency for distribution transformers applicable to private MV users

One of the principal legislation, the Energy Regulation Act 2004 requires that all energy undertakings be carried out under a license. The legislation requires that "that no person may establish, operate, carry on or be involved in any manner in an energy undertaking in Malawi, without a licence issued by the Malawi Energy Regulatory Authority (MERA) (MoE, 2004). Section 28 refers. The Electricity Act 2004, another principal legislation, defines electricity undertakings as "any installation works or services for the commercial generation, transmission, wheeling, distribution or supply of electricity which is owned or operated by a licensee". The Act, further, defines distribution as, "conveyance of electricity at less than 66,000 volts." (MoE, 2004). 33,000 volts (33kV) and 11,000 volts (11kV) are the commonly used primary distribution voltages, which implies that primary and secondary voltages for distribution transformers are 33/0.4kV and 11/0.4kV and operating at the frequency of 50Hz (MERA, 2012). Section 6.2.2, refers.

6.3. Equipment stock and Projections

6.3.1. Data on Available Distribution Transformers in the Market

Distribution by KVA rating and total capacity per kVA rating of distribution transformers - ESCOM provided their data base (**Appendix 12**) of over 3,000 transformers installed in their distribution network with a total installed capacity of around 647 MVA. 78% of the distribution transformers were of capacity rating ranging from 100kVA to less than 1000kVA and presented 86% of total installed capacity of distribution transformers (**Table 25)**. The data based included MAREP transformers installed under the rural electrification programme.

Capacity Rating (kVA)	Frequency of Capacity Rating (Nos)	Distribition by Frequecny of Capacity Rating (%)	Total Capacity per Rating (kVA)	Distribition by Total Capacity per Rating (%)
<100	647	20%	28,339	4%
100 - <400	2,257	70%	416,405	64%
400 - <1000	261	8%	141,400	22%
1000 - <2000	51	2%	55,750	9%
>=2000	2	0%	5,000	1%
Total Installed	**3,218**	**100%**	**646,894**	100%

Table 25: Distribution by Frequency of Capacity Rating and by Total Capacity Rating of Distribution Transformers (Source: (ESCOM, 2021))

Distribution Losses

ESCOM provided samples of pre-inspection test repots for some of its distribution transformers of ratings 315kVA, 11/0.4kV; 200kVA, 11/0.4kV; 100kVA, 11/0.4kV; 100kVA, 33/0.4kV; and 200kVA, 33/0.4kV **(Appendix 15)**. The losses measured during the tests were compared with the UN - Model Regulation Guideline 2019. The general trend showed that No Load Losses were higher than standard while the Load Losses were lower (**Table 26**).

The UN Environment –Model Regulation Guideline 2019 requires that energy performance of transformers in the scope of the regulation (of capacities up to 3150kVA) comply with the energy performance requirements in terms of maximum allowed load and no-load losses values in accordance with the IEC TS 60076-20 standard. The maximum allowed losses are set out in **Tables 1 and 2** of **Appendix 16**. Correction factors are provided in **Table 3** of the same, to take into account of variations in equipment highest voltage rating; and in **Table 4** to take into account of variations due to dual voltage windings.

Compliance with energy performance requirements is to be in two levels, starting with level 1 to take effect from 1 January 2020; and Level 2 from 1 January 2025. Further, the regulation specifies two sets of standards. The fire standard, where no measure is provided to limit flammability and the fire safer standard, where flammability is restricted and the emission of toxic substances and opaque smoke are minimized (UN Model Regulation Guidelines, 2019).

The regulation guideline provides that maximum allowable losses for distribution transformers with capacities that fall in between the given values be obtained by linear interpolation. (UN Model Regulation Guidelines, 2019).

The fire standard has been used to compare the energy performance levels of ESCOM distribution transformers.

Capacity Rating (kVA)	Voltage Rating (kV)	NLL (Watts)	LL (Watts)	UN Guideline (Standard) - Level 1				UN Guideline (Standard) - Level 2			
Source: ESOM Database				Fire Standard		Fire Safer		Fire Standard		Fire Safer	
				NLL	LL	NLL	LL	NLL	LL	NLL	LL
315	315kVA, 11kV	454	3,602	360	3,900	620	4,537	324	2,800	558	3,877
200	200kVA, 11kV	320	2,547	250	2,750	453	3,300	225	2,017	408	2,956
100	100kVA, 11kV	194	1,497	145	1,750	280	2,050	130	1,250	252	1,800
100	100kVA, 33kV	257	1,651	167	1,925	322	2,255	150	1,375	290	1,980
200	200kVA, 33kV	368	2,860	288	3,025	521	3,630	259	2,218	469	3,251

Table 26: No Load Losses and Load Losses for ESCOM Distribution Transformers Compared with the UN Model Regulation Guidelines 2019 in Accordance with EC TS 60076-20 Standard (Source: (UN Model Regulation Guidelines, 2019) and ESCOM Data Base)

6.3.2. Technology Trends and Market Projections

Technology Trends

a) Existing Stock

The survey established that ESCOM distribution system had a total of 3,374 distribution transformers installed in its network, comprising 3,218 transformers as shown in **Table 25** under section 6.3.1. and additional that were not fully labeled (**Appendix 12**). Further, the mini grids had a total of 19 transformers (Distribution Transformers Supply Chain Survey) making a total stock of **3393** during the year 2020. MAREP presented that they were planning to implement Phase 9 of rural electrification programme in 2021 requiring additional **364** new transformers.

ESCOM stock comprised a mixture of new and old distribution transformers. Based on the specification used, it is assumed that the new ones were the energy efficient type considering that

ESCOM standard specifications referred to the energy efficient transformer types, the Amorphous and the CRGO transformers.

b) Energy Efficient Transformers on the Market

Two types of transformer core materials are noted. The Cold Rolled Grain Oriented (CRGO) and the amorphous transformers are energy efficient types found on the market and used in electric grids. The CRGO is, however, said to be of lower cost between the two (Singh, 2010).

c) Benefits Due to Use of More Energy Efficient Transformers

Following data from the Ministry of energy on procurements made during 2016 to 2017 by the Malawi Rural Electrification Program (MAREP) (**Appendix 17**), the initial unit cost for distribution transformers translates to USD32.00 per kVA. The batch comprised capacity ratings of 50kVA, 100kVA and 200 kVA; and voltages ratings of 11/0.4kV and 33/0.4kV.

Distribution transformers procured under MAREP were installed and handed over to ESCOM to operate and maintain. MAREP use similar specifications as ESCOM for procurement of distribution transformers. The A and B factors provided by ESCOM are, therefore, applied on MAREP transformers. The A and B factors for a range of transformers given in **Table 26**, are the same at 7600 $/kW and 2500 $/kW, respectively.

The Total Owning Cost (TOC) for the distribution transformers, taking into account the cost of losses is defined by the following formula (Copper Development Association Incorp., 2021):

TOC = NLL x A + LL x B + C

Where,

TOC = capitalized total owning cost,
NLL = no-load loss in watts,
A = capitalized cost per rated watt of NLL (A value),
LL = load loss in watts at the transformer's rated load,
B = capitalized cost per rated watt of LL (B value),
C = the initial cost of the transformer including transportation, sales tax, and other costs to prepare it for service.

The No Load Losses and Load Losses for a sample of MAREP distribution transformers are given in **Table 26.** The TOC per unit transformer are, therefore, as presented in **Table 27**, below.

Capacity and Voltage Rating (kVA, kV)	MAREP DTs (US$)	Fire Standard - L1 (US$)	Fire safer - L1 (US$)	Fire Standard - L2 (US$)	Fire safer - L2 (US$)
315kVA, 11kV	12.47	12.50	16.06	9.47	13.94
200kVA, 11kV	8.81	8.78	11.70	6.76	10.50
100kVA, 11kV	5.22	5.48	7.26	4.12	6.42
100kVA, 33kV	6.08	6.08	8.09	4.58	7.16
200kVA, 33kV	9.95	9.75	13.04	7.52	11.70

Table 27: Total Owning Cost (TOC) per Unit Transformer (Source: Supply Chain Survey)

During 2016 to 2017, MAREP procured about a million distribution transformers. The TOC for the whole purchase is presented in **Table 28** below.

Capacity Rating	Qnty	MAREP DTs	Fire Standard - L1	Fire safer - L1	Fire Standard - L2	Fire safer - L2
		Sum of TOC (MUS$)				
200kVA, 11kV	24	211.34	210.75	280.84	162.19	251.91
100kVA, 11kV	116	605.53	635.70	841.72	477.48	744.53
100kVA, 33kV	787	4,788.03	4,787.32	6,365.18	3,602.02	5,631.52
200kVA, 33kV	66	656.91	643.76	860.87	496.24	772.21
Totals	**993**	**6,262**	**6,278**	**8,349**	**4,738**	**7,400**

Table 28: Total Owning Cost for MAREP 2016 - 2017 Procurement Compared with Standard (Source: Supply Chain Survey)

Comparing TOC based on loss levels declared by ESCOM and maximum allowed losses for Fire Standards level 1 and level 2 shows notable variances in total cost for the MAREP procurements including: -2% on 200kVA 33/0.4kV; and +5% on the 100kVA 11/0.4kV. The variances at level 1 of implementation are quiet small to be considered. However, for level 2 significant variances in the order of above 30% are noted. **Table 29** refers.

Capacity and Voltage Rating (kVA, kV)	Qnty	Fire Standard - L1 (US$)	Variation for Std - L1 (%)	Fire Standard - L2 (US$)	Variation for Std - L1 (%)
		Std Cost - MAREP Cost (US$'000)			
200kVA, 11kV	24	588	-0.3%	49,148	-30.3%
100kVA, 11kV	116	30,172	4.7%	128,052	-26.8%
100kVA, 33kV	787	708	0.0%	1,186,009	-32.9%
200kVA, 33kV	66	13,154	-2.0%	160,675	-32.4%
Total Forgone Cost (US$'000)	993	15,722		1,523,884	

Table 29: Variances in Total Owning Cost Between Existing and Standards (Source: Supply Chain Survey)

According to Level 1 of the regulation guideline and fire standard values, MAREP purchases achieved a gain in cost below the standard of US$ 16.0 million. According to Level 2, fire standard, the analysis shows an increased cost above standard of US$ 1,524 million (**Table 29)**. The findings present a justification for the power utility, MAREP and all importers of distribution transformers to switch to energy efficient transformers in all future purchases to gain from the anticipated technological improvements.

d) Market Projections

The market size for new distribution transformers is estimated based on, largely, three aspects. The need to replace the old ones at the end of their life span; to replace due to theft; and to meet the growth in demand for electricity. The power utility did not report any thefts of transformers. The Integrated Resource Plan (IRP) by the ministry of energy made three forecast for demand growth. Namely: the Base, High and Low Scenarios (MNREM, GoM, 2017). The actual demand growth in 2020 of 339 MW was closer to the Low Scenario, although much lower than the forecast. **Table 30** refers.

Year	Actual	Low Scenario	Base Scenario	High Scenario
2020	339	567	719	982
2030		1236	1873	2591
2037		2245	3566	5217
2040		2841	4620	6946

Table 30: Power Demand Growth Projections (Source - IRP2017)

Demand projections for the sake of this report used the base scenario and the following assumptions: **Distribution by customer category** – that 50% of customers are residential and the other 50% comprises industrial customers (power MV) at 26%; commercial customers (power LV) at 16%; and general customers at 8% (MNREM, GoM, 2017). **Figure 51** refers.

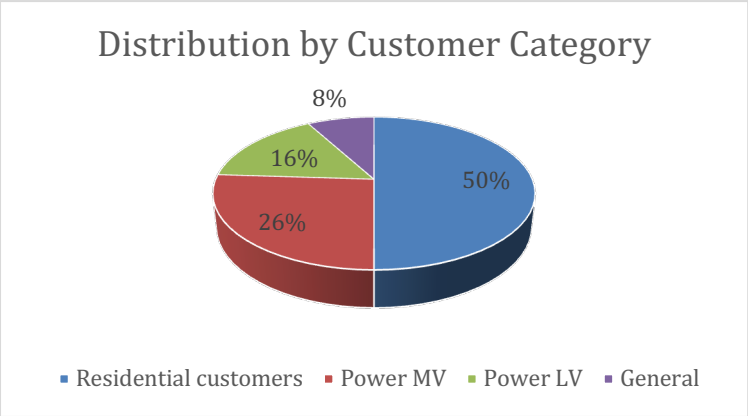


Figure 51: Distribution of Energy Sales by Customer Category (Source - IRP2017)

Historical Demand Growth – The base scenario load forecast was updated to use the actual recorded maximum demand of 443MW in 2018; 335MW in 2019; and 339MW in 2020 (**Table 31**).

Maximum Demand (Suppressed	2018	2019	2020
Jan.	274.1	297.7	295.8
Feb.	301.3	316.5	294.4
March	281.7	296.3	308.5
April	260.9	310.5	293.6
May	255.4	304.1	324.2
June	443.1	310.5	316.1
July	314.4	313.0	324.1
Aug.	287.3	318.1	323.0
Sept.	280.3	335.2	328.2
Oct	273.0	291.5	339.1
Nov.	268.0	288.4	330.6
Dec	291.4	279.2	328.6
Annual Maximum Demand	**443.1**	**335.2**	**339.1**

Table 31: ESCOM's Historical System Power Demand (Source - ESCOM Demand Data)

Demand Forecast Growth Rate – that annual average growth rates were 17.5 % through to 2020 (reflecting suppressed demand in its various forms) and 10 % per annum from 2020 to 2030 (MNREM, GoM, 2017). The 2018 to 2021 forecasts were updated with actual recorded maximum demand figures.

Demand Forecast in the Base scenario – that maximum demand will reach 1,873 MW by 2030 and 4,620 MW by 2040; and energy sent out was estimated at 9659 GWh in 2030 and 18842 GWh in 2036. The energy was extrapolated to 26,662 GWh in 2040. The 2018 to 2021 forecasts were replaced with actual recorded maximum demand figures.

Demand Forecast in the Low Scenario - that demand growth will be gradual starting from the actual maximum demand recorded by ESCOM in 2020 and 2021; and that demand shall equal to the forecast in the low scenario in 2030 of 1236MW in 2030; 2245MW in 2037 MW; and 2841 MW in 2040 (MNREM, GoM, 2017). The energy sent out from generation was calculated based on estimated system the Load Factor of 65% (MNREM, GoM, 2017) and power factor of 85% based on Grid Code requirements (MERA, 2016)**.**

System Losses – that technical and non-technical losses were relatively high at 21.8% of sent-out energy. The business as usual approach (BAU) was adopted in this case, despite various measures that were expected to reduce the losses gradually reaching the assumed levels of ***18% by 2020 and 15% by 2030 i****n* the base scenario (MNREM-GoM, 2017).

Life Span of Distribution Transformers – that replacement will be after 20.

Projection of Distribution Transformers – that demand for transformers will be directly proportional to growth in energy demand. ESCOM register in 2020 had 3374 distribution transformers with a total installed capacity of 647000 kVA and had estimated sales of 3053 GWh.

Demand forecast - for the above two scenarios is estimated as presented in **Figure 52** below.

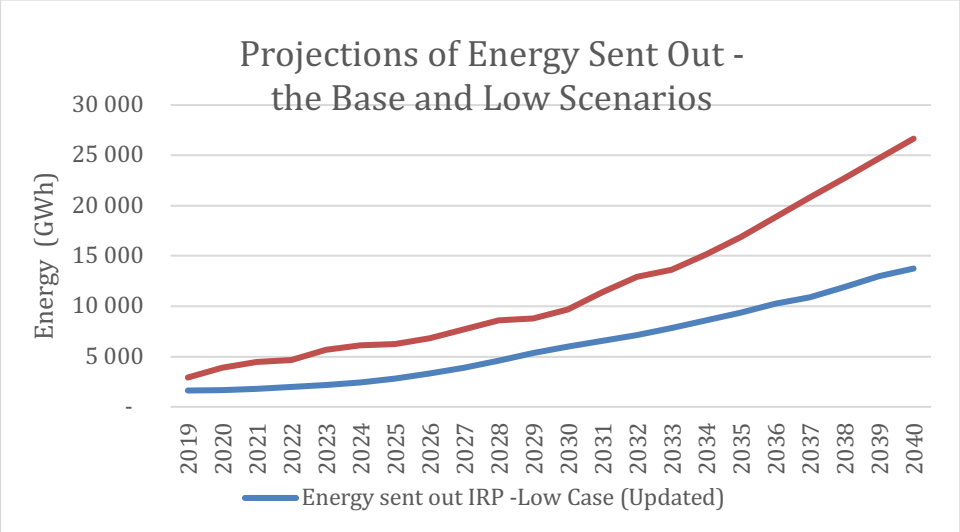


Figure 52: Energy Sent Out Projections - the Base and Low Scenarios (Source: DTs Supply Chain Survey)

System Energy Demand Projections - Following the projections, system energy demand is expected to grow from 4437 GWh in 2021 to 9659 GWh in 2030 and 26662 GWh in 2040 in the Base Scenario. Similarly, system energy demand is expected to grow from 1805 GWh in 2021 to 5982 GWh in 2030 and 13750 GWh in 2040 in the Low Scenario **(Table 32)**.

	2021	2030	2040
Scenario	Energy (GWH)		
Base	4437	9659	26,662
Low	1805	5982	13,750

Table 32: System Energy Demand Projections (Source: Supply Chain Survey)

Projections for Distribution Transformers – Base Scenario - The survey projects annual market size, in the Base Scenario, for new DTs to increase from about 80 MVA in 2021; to 500 MVA in 2030; and 2,000 MVA in 2040 estimated at a market value of USD 3 million in 2021 increasing to USD 17 million in 2030; and USD 64 million 2040. The new capacity of DTs will be for annual replacement of old DTs at the end of their life increasing from 35MVA in 2021; to 56 MVA in 2030; and 127 MVA in 2040; and to increase capacity of DTs to meet the growing demand for electricity increasing from 44 MVA in 2021; to 477 MVA in 2030; and 1,900 MVA in 2040 annually (**Table 33). Appendix 18** refers.

Market Projections for Distribution Transformers in Malawi to 2040			
Base Scenario	2021	2030	2040
New transformers penetrating	44,166	476,881	1,885,813
Replaced transformers at end of life	34,558	56,194	126,641
Total market size for distribution transformers (kVA)	78,725	533,075	2,012,453
Total market value for distribution transformer (MUSD)	2.5	17	64

Table 33: Market Projections for Distribution Transformers to 2040 – Base Scenario (Source: Supply Chain Survey)

Projections for Distribution Transformers – Low Scenario - The survey projects annual market size, in the Base Scenario, for new DTs to increase from about 7 MVA in 2021; to 100 MVA in 2030; and 300 MVA in 2040 estimated at a market value of USD 0.2 million in 2021 increasing to USD 3 million in 2030; and USD 9 million 2040. The new capacity of DTs will be for annual replacement of old DTs at the end of their life increasing from 4 MVA in 2021; to 8 MVA in 2030; and 16 MVA in 2040; and to increase capacity of DTs to meet the growing demand for electricity increasing from 3 MVA in 2021; to 92 MVA in 2030; and 257 MVA in 2040 annually (**Table 34). Appendix 18** refers.

Low Scenario			
Capacity for New transformers for penetrating (kVA)	3,482	92,117	256,952
Capacity for Replaced transformers at end of life (kVA)	3,656	8,088	16,330
Total market size for distribution transformers (kVA)	7,138	100,205	273,282
Total market value for distribution transformer (MUSD)	0.2	3.2	8.7

Table 34: Market Projections for Distribution Transformers to 2040 – Low Scenario (Source: Supply Chain Survey)

6.4. Policies and Programme Landscape

6.4.1. Current and Planned Electrification Policies and Programs

Policy on National Electrification

The National Energy Policy (NEP) goal for Malawi is "to increase access to affordable, reliable, sustainable, efficient and modern energy for every person in the country." Section 2.1 refers. The NEP identified electricity as a priority area covering, among others, distribution, rural electrification and electricity from renewable energy. On distribution, section 3.1.3, the government intends to intensify the expansion and rehabilitation of the distribution network in a socially inclusive manner (NEP, 2018).

The NEP is linked with existing policies, laws and international obligations. Among other areas include:

a) **Sustainable Energy for All (SE4ALL) Initiative 2011 - b**y the United Nations launched in September 2011 which aims to achieve three main goals of ensuring universal access to modern energy services; doubling the global rate of energy efficiency; and doubling the share of renewable energy in the global energy mix by the year 2030; and

b) **Sustainable Development Goals -** Goal Number 7 which aims at ensuring universal access to affordable, reliable, and modern energy services by 2030; increasing substantially the share of renewable energy in the global energy mix by 2030; and doubling the global rate of improvement in energy efficiency by 2030.

The Integrated Resource Plan (IRP 2017) provides the overall program for increasing the installed power generation capacity to support increasing access to electricity (MNREM, 2017).

Electrification Programs

On rural electrification – Government intended to use both on grid and off grid options. The Malawi Rural Electrification Program (MAREP) was a major engine financed from the Rural Electrification Fund for rural and peri-urban areas in the country; development of renewable energy; and mini grids (NEP,

2018). Government continued with MAREP and was planning for Phase 9 according to responses received from the ministry of energy.

ESCOM pursued a number of programs to increase access to electricity in the urban and per-urban areas. These included Peri-Urban electrification program, to electrifying areas not connected but close to the distribution network; and the Ndawala project to connect households that need only a drop service wire and terminal equipment.

The Mini Grid Framework – provides guidelines for the development and operation of mini grids. The framework was developed for both grid connected and off grid mini grids which could be implemented by either public sector or private sector entities. The government policy target was to develop 50 mini grids and Annex 1 of NEP provides the energy mix with increasing access to electricity from both renewable and non-renewable energy sources to 30.5% by 2030 (NEP, 2018).

6.4.2. Environmental Regulations for Oil-filled Transformers and Current Program Status

The environmental policy, laws and regulations stipulated in section 5.4 apply.

6.4.3. Stakeholder perspectives on opportunities and barriers to transform the market toward more energy-efficient distribution transformers

Responding to the question, if there were any mandatory requirements or other regulatory policies that promote energy efficient distribution transformers, the 8 respondents indicated on the various aspects as presented in **Figure 53**, below.

Positive responses - were received on safety standards at 88%; utility standard procurement specifications at 63%; labelling; and certification at 50%, respectively.

Poor responses - were received on minimum energy performance standards at 38%; voluntary programs; and tax breaks or other incentives at 13%, respectively.

The standards can be mandatory through appropriate regulation, which is the mandate of the energy regulator, MERA.

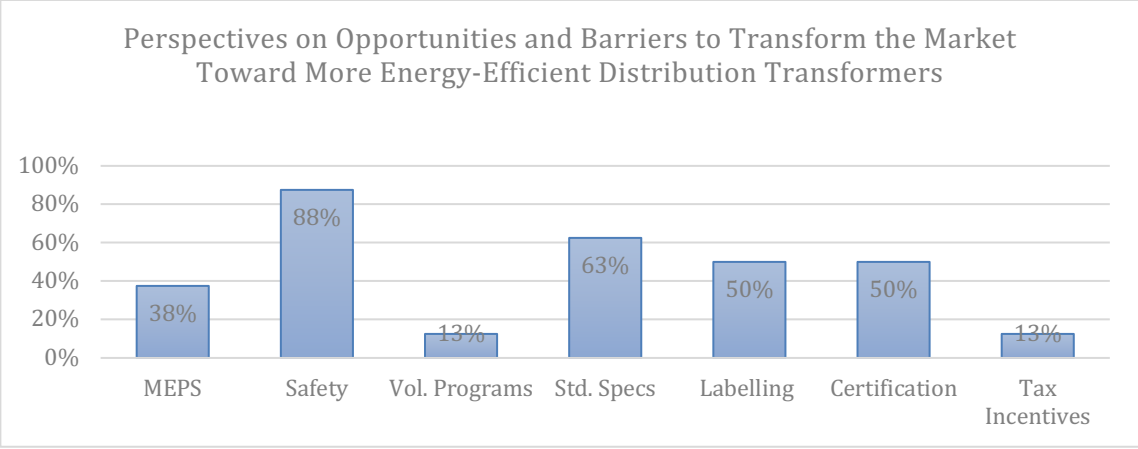


Figure 53: Stakeholders Perspectives to Transform the Market Towards More Energy Efficient Distribution Transformers (Source: Supply Chain Survey, 2021)

6.5. Utility's Procurement Specifications

A review of specifications for procurement of the power utility (ESCOM) distribution transformers noted they were very comprehensive and made reference to IEC standards. The specifications reflected both aspects of safety and energy efficiency, among other major areas, as presented in **Table 35,** below. Sample copies of the specifications were provided and are presented in **Appendix 19.**

Environmental Conditions	IEC 60296	Specifications for new insulating oils for transformers and switchgear;
	IEC	Requirement to maintain low to medium pollution levels;
Losses		The bidder to provide the losses;
		ESCOM provides the bidder the A and B factors, for the capitalization of losses (Table 32);
Core material		Cold Rolled Grain Oriented silicon steel (CRGO) or amorphous metal transformer.
Labelling	IEC 60076-1	Specification of name plate details and to include the country of origin

Table 35: Important Aspects not Declared on Name Plates of Distribution Transformers (Supply Chain Survey, 2021)

Regarding energy efficiency, the specifications require routine tests by the manufacturer to include No Load Losses (NLL) and Load Losses (LL) compliant with IEC 60076-1 standard on Power Transformers – Part 1: General. Bidders are asked to provide test certificates which indicate, among other parameters, the NLL and LL. The power utility has calculated the A and B factors for capitalization of losses. **Table 36**, below refers. It is noted the A factor is constant for all transformer sizes and voltage rating while the B factor is the same for transformers of the same capacity rating but with different voltage ratings.

As much as the power utility specified low loss and energy efficient transformers core materials (**Table 35**), the survey did not verify with the stock currently installed in the distribution system.

33kV Transformers		Rating	11kV Transformers	
A Factor ($/kW)	B Factor ($/kW)	(kVA)	A Factor ($/kW)	B Factor ($/kW)
7,600	2,100	50	7,600	2,100
7,600	2,500	100	7,600	2,500
7,600	2,500	200	7,600	2,500
7,600	2,500	315	7,600	2,500
7,600	3,000	500	7,600	3,000
7,600	3,400	800	7,600	3,400
7,600	3,400	1000	7,600	3,400

Table 36: A and B Factors for Different Transformer Types (Source: Supply Chain Survey)

The following further observations were made on the specifications -

a) ESCOM specifications did not refer to all relevant standards in the MBS's catalogue and some standards were not found in MBS catalogue (**Appendix 20**).

b) ESCOM specifications did not include the IEC TS 60076 – 20 standard, the internationally adopted standard on energy efficiency for power transformers. The same could not be traced in MBS catalogue during the time of visit**.** Normally, MBS awaits to be moved by industry to update its standards lists.

6.6. Financial environment and government procurement for both replacements and network expansion

Malawi has a dedicated levy and program for rural electrification, the Malawi Rural Electrification Program (MAREP). The Rural Electrification Act 2004 and Rural Electrification Regulations 2009 provide for the identification and selection of sites for rural electrification. The program caters for procurement of materials (distribution transformers, conductor, meters and necessary accessories) and installations up to service connections to the customers meter board. The Act establishes the Rural Electrification Management Committee with objectives, among them, to achieve electrification levels stipulated in the energy policy. The Committee is mandated to raise and receive funds for the benefit of rural electrification in Malawi (Rural Electrification Act 2004). It approves in phases rural electrification programs and uses the Rural Electrification Levy established under the Energy Regulation Act 2004 to execute the programs. The levy provides steady financial resources to support procurement of new distribution transformers to replace, at the end of life time, of old ones; and to expand capacity to service the growing demand for electricity.

7. Conclusion

In summary the survey established the following on both residential refrigerators and distribution transformers:

Findings on Residential Refrigerators

The household survey and supply chain survey on residential refrigerators established as follows: that there are no manufacturers of residential refrigerators in Malawi. The commercial suppliers are, largely, private traders ranging from specialized retail shops, supermarkets, individual shops, private individuals and individual repair shops. The market includes importation, wholesaling, retailing and repairing of new and uses residential refrigerators and new spares **(Figure 4)**. 45% of household refrigerators were supplied from South Africa **(Table 2)**.

Imports of residential refrigerators were increasing on average at 27% and the growth was consistently driven by imports from South Africa with a market share of over 70%, followed by China with a growing market share ranging from 12% in 2016 to 16% in 2020 **(Table 3)**.

A few of the more energy efficient refrigerator types were supplied on the market and the efficient ones used high GWP refrigerant contrary to aspirations and commitments on Sustainable Energy for All (SE4ALL) initiatives to achieve energy savings by 2025, 2030 and 2040; Sustainable Development Goals (SDGs) to double the global rate of improvement in energy efficiency by 2030; and as a signatory to various protocols (the United Nations Framework Convention on Climate Change (UNFCCC); and the Kyoto Protocol an d the 2015 Paris Agreement), to strengthen the global response to the threat of climate change and limit the temperature increase (EAD, 2021).

50% of the residential refrigerators were of low energy efficiency (the direct cool type) compared to 20% of manual defrosting and 30% of automatic defrosting (**Figure 38**). 30% of the household refrigerators used R134A and R404A refrigerants of high global warming potential (GWP) of 1430 and 3922, respectively, not compliant with the Kigali Amendment to the Montreal Protocol and comparing with the EU maximum limit of 150 (EU, 2015). 65.1% used R600A refrigerant of low GWP (**Figure 39**).

Higher proportion of the older residential refrigerators were of energy consumption of equal or more than 400kWh/year. 32% of residential refrigerators aged over 10 years were of annual energy consumption of equal or more than 400kWh/year compared with 20% of aged 3 to 7 years and 13% of aged less than 3 years (**Table 13);** and energy consumption was noted to be directly proportional to volume (size) of the refrigerator. The bigger the more energy consumption **(Figure 40).**

More of the automatic defrosting residential refrigerators were of low energy consumption. 93% were rated at less than 400kWh per year, compared to 82.1% of the manual defrost and 81.3% of the direct cooling (**Table 15**). Further, the energy efficient refrigerators were not necessarily using the environmentally safe refrigerants of low GWP, although the proportion using the high GWP refrigerants was small. 11% of the automatic defrost type used R134A compared with 31% of the direct cool and 45% of the manual defrost (**Table 12)**.

The technology trend shows that there has not been particular attention to energy efficiency on the purchase of residential refrigerators. **48%** of the direct cool (the low energy efficiency type) were of

less than 3 years old, compared with **55%** of the automatic defrost and **20%** of the manual defrost of the same age. Further, **71%** of the direct cool were of less than 7 years old, compared with **83.3%** of the automatic defrost and **53.7%** of the manual defrost (**Table 17**).

The following factors were barriers to the sale of energy efficient residential refrigerators, namely: a) **Lack of awareness** – There were mixed perceptions among stakeholders on whether energy efficiency was either the most or among the most significant factors affecting refrigerator selection **(Figure 6)**; b) **Financial** – Stakeholders perceptions were biased towards low unit price, being among the factors that will affect selection of residential refrigerators **(Figure 7)**; c) **Capacity –** Lower sales proportions of the high energy efficient residential refrigerators were recorded than sales of the low energy efficient units. 85% of the refrigerator types reported by supply chain stakeholders were non-inverter manual defrost type compared to 15% of non-inverter automatic defrost and 0.3% inverter type (**Table 7)**.

Similarly, the following factors were also noted as barriers to the purchase of energy efficient residential refrigerators, namely: a) **Lack of awareness** – The survey established that 98% of the respondents were not aware of energy efficiency and labelling standards for residential refrigerators (**Figure 22**) and mixed preferences on purchase of refrigerators were recorded with majority rating low preference on energy consumption **(Figure 23)**; b) **Financial** – Despite over 81% having bank accounts (**Figures 12 and 13**), 84% did not find bank loan terms and conditions attractive (**Figure 14**). Consequently, 91% purchased their residential refrigerators using own capital (**Table 10);** and c) **Capacity** – 100% of the lowest level of monthly income of less than USD 64 preferred other options than the hire purchase, own capital and leasing. Notably, people in this level of income represents the majority of the rural mass that were not targeted and likely to face challenges in raising finances. **Table 11** refers.

Findings on Distribution Transformers

The survey on the supply chain of distribution transformers established as follows: that the distribution transformers supply chain comprises foreign suppliers, importers, local manufacturers, local refurbishing companies and end users (**Figure 48**). The end users were, largely, the power utility, industry and mini grids.

The new distribution transformers on the market during the period 2015 to 2020 were supplied from 3 major sources comprising **3%** from local production; **55%** imported by ESCOM and 41% imported by the Malawi Rural Electrification Program (MAREP) (**Figure 49)**.

Over 3,000 transformers were installed in ESCOM's distribution network with a total installed capacity of over 600 MVA. 78% of the transformers were of capacity rating ranging from 100kVA to 1000kVA and comprised 86% of total installed capacity (**Table 25)**. The distribution system comprised over 90 different brands with a mixture of new and old transformers (**Figure 50**), of voltage ratings 11/0.4kV 3 phase, 11/0.23kV 1 phase, 33/0.4kV 3 phase and 33/0.23 1 phase (**Table 25**). Some transformers were procured for rural electrification under MAREP during 2016 to 2017 at an average initial cost of USD 32.00 pre kVA (**Appendix 17**).

The power and energy demand forecasts in the Integrated Resource Plan (IRP) are way above the actual trajectory of system demand. Even the low forecast scenario is very much above the actual maximum demand in 2021 (**Table 30)**.

The Base Scenario projections for the market size of distribution transformers indicate that demand for capacity of new distribution transformers will increase from **8**0 MVA in 2021; to 500 MVA in 2030; and 2,000 MVA in 2040 estimated at a market value of USD 3 million in 2021 increasing to USD 17 million in 2030; and USD 64 million 2040. The distribution transformers will be required for annual replacement of old DTs at the end of their life increasing from 35MVA in 2021; to 56 MVA in 2030; and 127 MVA in 2040; and to increase capacity of DTs to meet the growing demand for electricity increasing from 44 MVA in 2021; to 477 MVA in 2030; and 1,900 MVA in 2040 annually (**Table 33). Appendix 18** refers.

The Low Scenario projections require the new DTs to increase from about 7 MVA in 2021; to 100 MVA in 2030; and 300 MVA in 2040 estimated at a market value of USD 0.2 million in 2021 increasing to USD 3 million in 2030; and USD 9 million 2040. The new capacity for annual replacement of old DTs increases from 4 MVA in 2021; to 8 MVA in 2030; and 16 MVA in 2040; and the capacity for growing demand increases from 3 MVA in 2021; to 92 MVA in 2030; and 257 MVA in 2040 annually (**Table 34). Appendix 18** refers.

Significant variance was noted in the Total Owning Cost (TOC) of distribution transformers calculated using actual losses recorded on the test certificates for a sample of ESCOM transformers when compared with standard maximum allowable losses in the UN - Model Regulation Guideline 2019. The No Load Losses were higher than standard while the Load Losses were lower (**Table 26**). ESCOM provided samples of pre-inspection test repots for some of its distribution transformers of ratings 315kVA, 11/0.4kV; 200kVA, 11/0.4kV; 100kVA, 11/0.4kV; 100kVA, 33/0.4kV; and 200kVA, 33/0.4kV **(Appendix 15)**.

The UN Environment –Model Regulation Guideline 2019 provides maximum allowable load and no-load losses for distribution transformers of capacities up to 3150kVA to comply with the energy performance requirements in accordance with the IEC TS 60076-20 standard. The maximum allowed losses are set out in **Tables 1 and 2** of **Appendix 16**. Correction factors are provided in **Table 3** to take into account of variations in equipment highest voltage rating; and in **Table 4** to take into account of variations due to dual voltage windings.

The capitalized total owning cost (TOC) for a million distribution transformers procured by MAREP during 2016 to 2017 (**Table 28)** was compared for the loss levels declared by ESCOM against the Fire Standards level 1 and level 2. Significant variances in TOC for the MAREP procurements were noted in the order of above 30% when compared with the Fire Standard Level2. Insignificant variances were noted when compared with the Fire standard level 1 at -2% on 200kVA 33/0.4kV transformers and +5% on the 100kVA 11/0.4kV transformers (**Table 29)**. The TOC for MAREP procurement was lower than the Fire standard Level 1 by US$ 16.0 million but higher than the Fire Standard Level 2 by US$ 1,524 million (**Table 29).**

The effective date for the Fire standard Level 1 (1 January 2020) has since passed and energy performance of ESCOM's distribution transformers is generally compliant. The performance, however, falls short from complying with Level 2 Fire standard, which will be effective from January 2025. The Fire standard applies to transformers that are without any measure to limit flammability. The Model Regulation Guidelines specifies a higher Standard, the Fire Safer standard, where flammability is restricted and emission of toxic substances and opaque smoke are minimized (UN Model Regulation Guidelines, 2019). The fire standard has been used to compare the losses performance levels of the ESCOM distribution transformers.

Malawi requires to have regulations in place to enforce the minimum energy performance standards. The survey established that standards become mandatory when enforced by regulations. As much as there are government policies on energy efficiency, respective regulations on the same are not available for enforcement. It was observed that the electricity bylaws rarely made reference to any of the Malawi Standards and international standards, which implies the standards remain voluntary. A gap that need to be addressed to achieve the energy policy objectives.

The IEC TS 60076 – 20 standard, the internationally adopted standard on energy efficiency for power transformers should be adopted in Malawi and included on the MBS lists of standards and ESCOM list of specifications for distribution transformers. As much as the survey established that ESCOM's specifications for procurement of distribution transformers were comprehensive, the crucial standards was missing on the list. Further, the specifications did not refer to all relevant standards in the MBS's catalogue while some standards referred to were not seen in MBS catalogue (**Appendix 20**).

MBS requires to be moved by industry to update the Malawi standards lists and this would require the industry to collaborate and work with the MBS.

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Appendix 1 – Overview List of Data Sources

The sources used in the report include:

- Data formally submitted from organizations;
- The national vision and growth strategies;
- The national policy documents and legal instruments;
- Books, articles and online reports from credible websites;
- Online databanks (such as the World Bank – World Development Indicators);
- Manufacturers, importers, wholesalers, retailers and repairers of residential refrigerator and distribution transformers;
- Organizations websites;
- Interviews with financial institutions, the electricity distribution company (the Electricity Supply Corporations of Malawi (ESCOM) Limited); and
- Online trade data for Malawi, surveys and Census reports by the National Statistical Office (NSO) of Malawi;

Appendix 2

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Appendix 3 - Answered Questionnaires (zip file sent separately)

Appendix 4 - Supply chain stakeholders planned to be interviewed

Market Assessment of Residential Refrigerators and Distribution Transformers (5 kVA to 3150 kVA) to Deliver Information in Formulating Minimum Energy Performance Standards (MEPS) and Labels.

Supply Chain Stakeholders Identified to be Interviewed in Malawi

1	**Household Refrigerators - Private Sector**		
1.1	**Manufacturers**		
	None were identified		
1.2	**Importers and Suppliers**		
1.2.1	Game Stores, +265 999 55 74 34, stevec@game.co.za, Lilongwe Store		Steve Chiwaya, agreed to follow up on **Monday 29th March 2021**
1.2.2	Sana superettes +265 996199948,		Attn. Adil Javid, Lilongwe
1.2.3	Tikambe shops		Lilongwe
1.2.4	Nat Electronics in Blantyre		Blantyre
1.2.5	Lords Best Collection in Lilongwe		Lilongwe
1.2.6	Defy - WestGate Inv, +265 999866410, yunus@globemw.net, Lilongwe Area 1		Yunus Pandor, agreed to follow up on **Monday 29th March 2021**
1.2.7	Seketsani Banda		Blantyre
1.3	**Refurbishers/ Repairers/**		
1.3.1	Mr Phillip Chirunga, Repair with an association. Training Soche Technical College students		Zomba
1.3.2	Mr. Kapinda		Kasungu
1.3.3	Mr. Lusayo		Chikwawa
1.3.4	Mr. Gift Ngaibvale		Lilongwe
1.3.5	Mr. Adam H. Malikebu		Blantyre
1.3.6	Henry		Zomba Market
1.3.7	Brave Makina		
1.3.8	Tilinga Mawa		
1.3.9	Willy Chomombo		
1.3.10	Raphael Kumilonde		
1.3.11	Dickson Mulowa		
1.3	**Refrigerant Suppliers**		
1.3.1	Power Cool, +265 999 8888 88		Blantyre
1.3.2	InterGlobe Traders, +265 1 845 874		Blantyre
1.3.3	O.G. Issa, +265 88 00 80088, info@ogelectricals.com, Lilongwe at Maula		Agreed to follow up on **Monday 29th March 2021**

Market Assessment of Residential Refrigerators and Distribution Transformers (5 kVA to 3150 kVA) to Deliver Information in Formulating Minimum Energy Performance Standards (MEPS) and Labels.

	Supply Chain Stakeholders Identified to be Interviewed in Malawi		
2	**Distribution transformers - Private Sector and Quasi Government**		
2.1	**Manufacturers**		
2.1.1	K2 Transformers (Repairing, Servicing, Manufacturing) - Area29/18 Kanengo, Lilongwe, Malawi; +265 888818888; Email songdoh777@gmail.com;		Agreed to follow up on **Monday 29th March 2021**
2.1.2	Global Trans Electric. +265 999950851		Blantyre
2.1..3	Joko Transformers (were not functional)		Lilongwe
2.2	**Importers/Retailers / and repairers**	4 x	Suppliers
2.2.1	James Zalira - Yiannakis General Import, +265 99846 8468		Blantyre
2.2.2	C & A Electrocal , Don Kasondowe, +265 999 7698 40	2 x	Refurbishers
2.2.3	Hawker Siddeley, johnson.hse@yemurai.com, +265 991795036		Transformers, Switchgear Products, electric motor rewinds. 178 Haytor Road, Ginnery Cnr, BT.
2.4	**Power Utilities**		
2.4.1	The Electricity Supply Corporation of Malawi Limited (ESCOM		Messrs Kagona (+265 88 83 56858) and Mwale (+265 88 44 19999), Blantyre Head Office. To send within the weekend and discuss on **Monday 29tth March**
2.5	**Mini Grids Operators**		
2.5.1	Mulanje Electricity Generation Agency (MEGA)		Mulanje
2.5.2	Illovo - Dwangwa, +265 887 0951 06		Dwangwa
2.5.3	Illovo - Nchalo, +265 884 17 5288		Chikwawa
2.5.4	Community Energy Malawi (a solar mini grid)		Lilongwe
2.6	**Industrial Customers**		
2.6.1	Limbe Leaf Tobacco		Lilongwe
2.6.2	Blantyre Water Board		
2.6.3	Lilongwe Water Board		Lilongwe
2.6.4	Northern Water Board		
3	**Government Ministries, Departments and Agents**		
3.1	Ministry of Energy		Energy Affairs
3.2	Ministry of Energy		Malawi Rural Electrification Program
3.3	Ministry of Natural Resources and Mines, +265 9999 57550		Environmental Affairs Deaprtment
3.4	Ministry of Industry and Trade		The Malawi Bureau of Standards
3.5	Energy Regulator		The Malawi Energy Regulatory Authority
3.6	**City Councils**		
3.6.1	Lilongwe		
3.6.2	Mzuzu		
3.6.3	Blantyre		
4	**Consumers Association of Malawi (CAMA)**		
5	**Financial Institutions** (Micro-Financing and Banks)		
5.1	National Bank of Malawi		
5.2	FINCA - micro financing		
5.3	FDH		
5.4	First Capital		
5.5	Vision Fund Malawi Ltd.		

Appendix 5 - Household Survey Sample Sizes for the Selected Districts Based on Population Ration by District

No.	District - ***Enumerator***	Target Areas	Sample Size	No. of Interviews	No. of Enumerators Used
1	Mchinji - ***Sydney Kazembe***	Mchinji Urban;	18	21	1
2	Lilongwe - ***Nyengo Phoso***	Lilongwe Urban1	29	10	1
3	Lilongwe - ***Walikonadi Sichinga***	Lilongwe Urban2		17	1
	Sub - Totals		**47**	**48**	**3**
4	Chikwawa - ***Amin Phiri***	Chikwawa Urban	17	8	1
5	Mulanje - ***Keith Magwira***	Mulanje Urban	21	12	1
6	Blantyre - ***Maureen Nsapato***	Blantyre Urban	24	21	1
	Sub - Totals		62	41	3
7	Mzuzu - ***Pius Mkandaire***	Mzuzu Urban	7	20	1
8	Nkhata Bay - ***Abigail Mwale***	Nkhata Urban	9	16	1
9	Karonga - ***Blessings Nyirenda***	Karonga Urban	11	18	1
	Sub - Totals		27	54	3
10	Machinga - ***Clement Thombozi***	Machinga Urban	22	16	1
11	Zomba - ***Leah Gondwe***	Zomba Urban	3	19	1
	Sub - Totals		25	35	2
12	Kasungu - ***Modester Mtapaonga***	To Kasungu	25	25	1
13	Salima - ***Stanely Chikuni***	To Salima	14	8	1
	Sub - Totals		39	33	2
	Grand Total		**200**	**211**	**13**

Appendix 6 - Map of Malawi showing the geographical spread of the selected districts

Key:

- Urban Cities
- South
- Eastern
- Central Rural
- North Rural

Appendices 6(a) to 6(e) – Household Survey - Summary Responses - Duly Filled (Sent Separately)

6(a) – Household Survey - Summary of Responses;

6(b) – Refrigerators Supply Chain Survey - Summary of Responses;

6(c) – Distribution Transformers Supply Chain Survey - Summary of Responses;

6(d) – Gov. Ministries, Departments and Agents Survey - Summary of Responses;

6(e) – Financial Institutions Survey - Summary of Responses

Appendix 7 – List of Key Stakeholders Consulted

1	**Household Refrigerators - Private Sector**
1.1	**Manufacturers** (There were no manufacturers in Malawi)
1.2	**Importers and Suppliers**
1.2.1	Yunus Pandor, Defy - WestGate Inv, +265 999866410, yunus@globemw.net, Lilongwe Area 1
1.2.2	Seketsani Banda (+265 265 88 8 641 076); sekebanda@gmail.com;
1.3	**Refurbishers/ Repairers/**
1.3.1	Mr Phillip Chirunga, Repair with an association. Training Soche Technical College students, phillipchilunga1@gmail.com; (+265 888 571 700)
1.3.2	Raphael Kumilonde, kumilonderaphael@gmail.om; (+265 888 304 990 / 993 599 148)
1.4	**Refrigerant Suppliers**
	Did not respond
2	**Distribution transformers - Private Sector and Quasi Government**
2.1	**Manufacturers**
2.1.1	K2 Transformers (Repairing, Servicing, Manufacturing) - Area29/18 Kanengo, Lilongwe, Malawi; +265 888818888; Email songdoh777@gmail.com;
2.1.2	Global Trans Electric. +265 999950851
2.2	**Importers/Retailers / and repairers**
2.2.1	Hawker Siddeley, johnson.hse@yemurai.com, +265 991795036 / Transformers, Switchgear Products, electric motor rewinds. 178 Haytor Road, Ginnery Cnr, BT.
2.3	**Power Utilities**
2.3.1	The Electricity Supply Corporation of Malawi Limited (ESCOM)/ Messrs Kagona (+265 88 83 56858) and Mwale (+265 88 44 19999), Blantyre Head Office.
2.4	**Mini Grids Operators**

2.4.1	Illovo - Nchalo, +265 884 17 5288
2.4.2	Community Energy Malawi (a solar mini grid) - edgarbayani@gmail.com; / kumwendalusungu2014@gmail.com; (+265 995 256258)
2.5	**Industrial Customers**
2.5.1	Limbe Leaf Tobacco. Lilongwe.
	Responded through a phone call, after receiving the questionnaire, that had nothig to contribute. Pelle Lupiya (+265 9999 31466)
3	**Government Ministries, Departments and Agents**
3.1	Ministry of Energy
3.2	Environmental Affairs Department (EAD), +265 9999 57550
3.3	Malawi Bureau of Standards under the Ministry of Industry and Trade
3.4	Malawi Energy Regulatory Authority (MERA)
3.5	National Statistical Office of Malawi (NSO)
3.6	National Commission for Science and Technology (NCST)
3.7	Ministry of Finance
3.8	**City Councils**
3.8.1	Lilongwe - Responded in writing, after receiving the questionnaire, that had nothing to contribute
3.8.2	Mzuzu (attended consultative zoom meetings)
5	**Financial Institutions** (Micro-Financing and Banks)
5.1	National Bank of Malawi
5.3	FDH

Appendix 8 - Reports of Consultation Meetings Held with the Key Stakeholders - (Compiled Separately)

Appendix 9 - Pictures of rating plates for various brands of residential refrigerators from household survey findings (Compiled separately)

Appendix 10 – Market Projections for Residential Refrigerators to 2040

Total stock & Market size (projections)																				
Years	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Number of residential refrigerators replaced (end-lifetime)	22,173	23,138	24,144	25,195	26,291	27,434	28,628	29,873	31,172	32,528	33,943	35,420	36,961	38,568	40,246	41,997	43,824	45,730	47,719	49,795
Additional number of residential refrigerators acquired (market growth)	12,057	12,581	13,128	13,700	14,295	14,917	15,566	16,243	16,950	17,687	18,457	19,260	20,097	20,972	21,884	22,836	23,829	24,866	25,947	27,076
Total market size for residential refrigerators	**34,230**	**35,719**	**37,273**	**38,894**	**40,586**	**42,352**	**44,194**	**46,116**	**48,122**	**50,216**	**52,400**	**54,679**	**57,058**	**59,540**	**62,130**	**64,833**	**67,653**	**70,596**	**73,667**	**76,871**
Total market value for residential refrigerators (USD)	**11,219,259**	**11,707,297**	**12,216,564**	**12,747,985**	**13,302,522**	**13,881,182**	**14,485,013**	**15,115,111**	**15,772,618**	**16,458,727**	**17,174,682**	**17,921,781**	**18,701,378**	**19,514,888**	**20,363,786**	**21,249,610**	**22,173,968**	**23,138,536**	**24,145,062**	**25,195,373**
Total stock of residential refrigerators	**289,223**	**301,804**	**314,933**	**328,632**	**342,928**	**357,845**	**373,411**	**389,655**	**406,605**	**424,292**	**442,749**	**462,008**	**482,106**	**503,077**	**524,961**	**547,797**	**571,626**	**596,492**	**622,439**	**649,515**
% of households with residential refrigerator	**6.65%**	**6.74%**	**6.84%**	**6.94%**	**7.03%**	**7.13%**	**7.23%**	**7.33%**	**7.44%**	**7.54%**	**7.65%**	**7.76%**	**7.87%**	**7.98%**	**8.09%**	**8.20%**	**8.32%**	**8.44%**	**8.55%**	**8.68%**

Compiled separately

Appendix 11 - Responses on Financing Instruments Offered by the Financial Institutions

Appendix 12 - Database of ESCOM's Installed Distribution Transformers and Lines

Appendix 13 - Pictures of rating plates for a sample of distribution transformers

Appendix 14 - List of Malawi Standards for Distribution Transformers

Appendix 15 - ESCOM Distribution Transformers (DTs) Test Certificates

Appendix 16 - Standards No Load Losses (NLL) and Load Losses (LL) UN – Environment

Appendix 17 - MAREP 2016 -2017 Purchases of Distribution Transformers

Appendix 18 - Market Projections for Distribution Transformers to 2040

Total stock & Market size (projections)																				
Years	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**
Capacity (kVA) of DTs for replaced of failed units (annualy)	12,938	18,244	23,188	28,527	34,294	40,522	47,248	54,513	62,358	70,831	79,982	89,866	100,539	112,067	124,517	137,963	152,484	168,168	185,105	203,398
MAREP Phase 9, Capacity (kVA) of DTs to be installed during 2021	36,400																			
Additional capacity (kVA) of DT acquired (market growth)	228,890	247,201	266,977	288,335	311,402	336,314	363,219	392,277	423,659	457,552	494,156	533,689	576,384	622,494	672,294	726,077	784,163	846,897	914,648	987,820
Total market size capacity (kVA) for DTs	**278,228**	**265,445**	**290,165**	**316,863**	**345,696**	**376,836**	**410,468**	**446,790**	**486,017**	**528,383**	**574,138**	**623,554**	**676,923**	**734,561**	**796,811**	**864,040**	**936,648**	**1,015,064**	**1,099,754**	**1,191,219**
Total market value for DTs (USD)	**8,823,519**	**8,418,128**	**9,202,084**	**10,048,756**	**10,963,163**	**11,950,721**	**13,017,285**	**14,169,174**	**15,413,213**	**16,756,776**	**18,207,824**	**19,774,956**	**21,467,458**	**23,295,361**	**25,269,495**	**27,401,561**	**29,704,192**	**32,191,033**	**34,876,821**	**37,777,473**
Total Capacity (kVA) stock of DTs	**912,184**	**1,159,385**	**1,426,362**	**1,714,697**	**2,026,099**	**2,362,414**	**2,725,633**	**3,117,910**	**3,541,569**	**3,999,121**	**4,493,277**	**5,026,966**	**5,603,349**	**6,225,843**	**6,898,137**	**7,624,215**	**8,408,378**	**9,255,275**	**10,169,923**	**11,157,743**
Electrification rate (%)	12.4%	13.7%	15.1%	16.7%	18.5%	20.4%	22.6%	25.0%	27.6%	30.5%	33.7%	37.3%	41.2%	45.5%	50.3%	55.6%	61.5%	68.0%	75.1%	83.1%

Compiled separately

Appendix 19 - Procurement Specs for Distribution Transformers Used by the Power Utility and Test Certificates

Appendix 20 - Comparison of Standards List in MBS Catalogue and in ESCOM's Procurement Specifications for Distribution Standards