Market Assessment Report

Market Assessment Report on Residential Refrigerators and Distribution Transformers in Eswatini

23 November 2021

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ABBREVIATIONS

CO2	Carbon dioxide
CTCN	UN Climate Technology Centre and Network
COMESA	Common Market for Eastern and Southern Africa
DT	Distribution Transformer
EDM	Electicidade de Mocambique
EEC	Eswatini Electricity Company
ESERA	Eswatini Energy Regulatory Authority
ESI	Electricity Supply Industry
GCF	Green Climate Fund
GWP	Greenhouse Warming Potential
HEPS	Higher Energy Performance Standards
IEC	International Electrotechnical Commission
IPP	Independent Power Producer
MEPS	Minimum Energy Performance Standards
MNRE	Ministry of Natural Resources and Energy
MVE	Monitoring, Verification and Enforcement
NEES	National Energy Efficiency Strategy
ODS	Ozone Depleting Substance
RSA	Republic of South Africa
REU	Rural Electrification Unit
SACU	Southern African Customs Union
SADC	Southern African Development Community
SADCAS	Southern African Development Community Accreditation Services
SANS	South African National Standard
SWASA	Eswatini Standards Authority
TOU	Time of use
U4E	United for Efficiency
UNEP	United Nations Environment Programme
USAID	United States Agency for International Development
WASCO	Water and Sewerage Company

Executive Summary

According to the Eswatini Energy Regulatory Authority (ESERA) annual report for 2020, Eswatini boasts an electrification rate of approximately 84%. 90% of the population living in the urban areas of Eswatini have access to electricity [1] while 69% of the rural population have access to electricity. Universal access to electricity in Eswatini is expected by the end of 2022. The electricity network in Eswatini is growing due to the electrification drive, as well the expansion of the energy sector in Eswatini. Transformers will be required to facilitate the distribution of this energy to industrial and residential customers. Distribution transformers account for a large percentage of energy losses in Eswatini, hence the need for regulation. Adoption of energy efficiency policies for distribution transformers can significantly increase asset lifecycles, reduce energy losses, CO_2 footprints and operating costs for consumers.

Likewise, the Independent Power Producers (IPP's) in Eswatini stand to gain from improved transformer efficiencies, as the decrease in losses will result in a reduction in the generation requirement. For these users the improved transformer efficiencies will result in financial gains related to the cost of generation. Unfortunately, the IPP's in Eswatini were unable to provide a database of their transformers. It is hoped that the report can be updated in the future to include an analysis of the transformers installed on the IPP's networks. Ubombo Sugar Mill did provide a response to the transformer survey, that was very much in alignment with the Eswatini Electricity Company (EEC), i.e., transformers are procured on capital cost only, losses are not capitalised, and transformers are ordered in accordance with the SANS 780 specification.

The refrigeration industry in Eswatini is dominated by imports. The imports are primarily from South Africa. One local manufacturer exists, however, with its own testing capabilities. This manufacturer is Palfridge, and it is located in the Manzini region. The majority of Palfridge's market is also based in South Africa. The majority of the refrigerators in Eswatini are of the refrigerator/freezer combination. The new refrigerator market uses new refrigerants which contain no Ozone Depleting Substances (ODS) and have low Greenhouse Warming Potential (GWP). However, the older refrigerators that are still in the re-sale market use older refrigerants. The country is committed to the move towards more energy efficient refrigerators, and this has been shown through its signing of the Montreal Protocol and its ratification of the Kigali agreement.

The responses from the consumers gathered during the market assessment indicated that the majority of them (72.5%) did not find energy efficiency an important factor when choosing a refrigerator. Price was the 3rd most important factor behind quality and capacity. Therefore, a reasonable inference would be that if consumers were aware that they would in fact save money on an energy efficient refrigerator over the lifetime of the project it would become a much more important factor during purchases.

There are indications however that the perception towards energy efficient refrigerators is changing. The retailers seem to believe that it will be one of the key purchasing factors in the future and with the correct financial support mechanisms to assist with the initial increased cost of the appliance and the correct awareness of the benefits of energy efficient refrigerators real changes could be implemented relatively quickly.

The path to improved energy efficiency begins with an assessment of the status quo of the energy system within Eswatini. The EEC is responsible for the generation, transmission and distribution of electricity. Analysis of EEC's 2020 transformer database and annual reports up to 2020 revealed the following key findings:

KEY FINDINGS

Electricity Generation, Power Imports and Energy Demand

According to a 2020 USAID report on energy development in Eswatini, the country has been on a drive to improve its electricity generation capacity to diminish its dependence on imported power from South Africa and to provide greater security of supply. A National Energy Policy was developed in 2018 to facilitate this process. An IPP Policy was established under the Ministry of Natural Resources and Energy (MNRE) to increase the utilisation of solar and biomass generation plants. The Lavumisa 10 MW solar plant project is nearing completion while there are 40 MW solar and 40 MW biomass generation plants planned for construction in 2021.

At present, power generation and the transmission and distribution of electricity to the general population of Eswatini is the responsibility of the Eswatini Electricity Company (EEC), a state-owned power utility. According to the ESERA annual report from 2020 the country's peak demand was 245 MW and the energy supplies to customers was approximately 1,580 GWh. The customers were predominantly industry (50%) and domestic (36%). The EEC can provide 60.4 MW of power to the grid via the operation of four hydro power plants. However, the hydropower plants contribute only around 17 percent of the total energy required in Eswatini. The remaining power is purchased from Eskom in South Africa and on rare occasions from Electicidade de Mocambique (EDM).

In addition to the 60.4 MW hydropower plants operated by the EEC, there is 110 MW of independently produced power within Eswatini. Ubombo Sugar Mill produces 41 MW of biomass generated power, 13 MW of which is made available to the grid. The Royal Eswatini Sugar Corporation also produces 65.5 MW of power via biomass generation, while USA Distillers and Wundersight produce a combined 2.3 MW of power from coal and solar generation respectively [1].

The EEC also owns 9 MW of diesel generation but the plants at Edwaleni Power Station have been mothballed due to their high operational costs, that renders their function economically unviable.

Electrification Rate, Energy losses and Tariff Increases

The 2019-2020 ESERA annual report shows that 534.8 GWh of electricity was generated in Eswatini [1]. The total demand was 1578.65 GWh, necessitating the import of 1043.77 GWh from South Africa and the Southern African Power Pool.

Eswatini imports approximately 80% of its power from South Africa and the Southern African Power Pool. The tariff changes from these suppliers are therefore closely monitored by ESERA.
Electricity in Eswatini is distributed by the EEC and sold using two types of tariffs, namely non-time of use (non-TOU), and time of use (TOU) tariffs. Non-TOU tariffs are applied to domestic and small commercial customers. TOU tariffs are applied to all other customers.
The ESERA annual report shows that in the period from 2015-2017 the average tariff charged by the EEC was 9 United States cents per kilowatt hour. In the period 2017-2018 the average tariff increased by 4.72 United State cents per kilowatt hour to is 13.72 United State cents per kilowatt hour.

The 2020-2021 report has yet to be published but the Tariff Increase Proposal published by the EEC on the 30th of October 2020 indicates an unchanged tariff for the period 2020-2021. EEC lodged the application with ESERA to increase tariffs by 7.16% for the 2021-2022 and 2022-2023 periods. ESERA declined the application from the EEC and instead reduced tariffs in 2021-2022 by 1.33%, and in 2022-2023 by 1.27%.

Table 1-1 Annual average tariffs for Eswatini

Average Tariffs in US c/kWh						
2015-2016	2016-2017	2017-2018	2018-2019	2020-2021	2021-2022	2022-2023
9	9	13.72	13.72	13.72	13.54	13.37

Transformer Database

The EEC transformer database was last updated in 2020 and contains asset information that is well documented, and almost complete. While the transformer manufacturer's details are not captured, the database is only missing kV ratings for 21 transformers. The database indicates that EEC has ownership of 21599 transformers.

Refrigeration Market

The refrigerating appliance market in Eswatini is largely comprised of imports as there is only one local manufacturer, Palfridge (Pty) Ltd. Most of the imports are from South Africa, which is to be expected as it is the largest economy in the region and a key trade partner of Eswatini. The market is comprised of almost 30 000 units being imported on an annual basis. There is a growing demand for refrigerators. This can be seen in the growth of imports at between 10% and 11% over the past 5 years. From the market study it has been found that the predominant refrigerant for newer units is R600a. There were some older units that used R134a.

The dominant brands in the market include Defy, Kelvinator, KIC, Hisense and Russel Hobbs with LG and Samsung also present, typically amongst the more affluent clientele. The most popular refrigerators are the fridge/freezer sets with the freezer unit typically at the bottom. Chest freezers are also popular. The price of refrigerators typically links to the volume although there are variations with brands and some additional functionalities. Eswatini does not currently have any Minimum Energy Performance Standards (MEPS) or Higher Energy Performance Standards (HEPS). There are energy efficiency labels on many of the refrigerators in Eswatini, but these are the South African energy labels. A calculation on the possible improvements of energy efficiency of refrigerators from the business-as-usual model by 15% or more (the U4E model) has shown that it would be significant both to individuals and to the country.

1 BACKGROUND AND INTRODUCTION

The 'Leapfrogging to Energy Efficient Appliances and Equipment in Eswatini (Refrigerators and Distribution Transformers)' project is funded by the Green Climate Fund (GCF) and being implemented under the guidance of the government of the Kingdom of Eswatini (Eswatini). The project is also being implemented simultaneously within 7 other countries of the Southern African Development Community (SADC) region, namely Botswana, Zimbabwe, Namibia, Malawi, Lesotho, Zambia and Tanzania. The aim of the project is to focus on distribution transformers and household refrigeration appliances and attempt to establish a framework in order to improve the energy efficiency of these appliances. This is to be done through the establishment of national standards for both refrigerators and distribution transformers and development of Minimum Energy Performance Standards (MEPS) as well as an energy labelling scheme for refrigerators. The project will also engage with all of the key stakeholders within the country to create a system through which the necessary legislation can be developed related to the implementation of the MEPS and also to create a national implementation plan that will both enable the implementation of the MEPS but also create a framework within Eswatini for future development of related standards and legislation. Furthermore, the project will investigate the possible financing mechanisms available to assist the implementation of the project and the respective training programmes to enable transition into a self-sustained and managed implementation of the project in the future. Pegasys was contracted by the United Nations Environment Programme (UNEP) through the UN Climate Technology Centre and Network (CTCN) to implement this initiative in Eswatini and Lesotho. The CTCN is overseeing the project together with United for Efficiency (U4E) as a technical partner. This report outlines the market assessment aspect of the project that was conducted in Eswatini.

In summary, the main aims of the project are therefore to:

1. Develop mandatory MEPS and labelling schemes
2. Assist in the development of national standards for refrigerators and distribution transformers
3. Enable the continued implementation of the policies, labels and standards through focused training
4. Develop an implementation plan and a full MV & E plan for the efficient and effective integration of the developed standards and any associated legislation labels
5. Develop a consumer awareness campaign to inform the public about the energy efficiency MEPS for refrigerators and distribution transformers and to introduce the Eswatini energy label
6. Propose appropriate financing mechanisms to accelerate deployment of energy efficient refrigerators and distribution transformers; and
7. Strengthen the national capacity to develop standards and labels for other appliances in future.

Eswatini has no independent access to the coast/sea. Therefore, it is heavily reliant on use of South African ports for the import of essential commodities, including electricity, which is purchased from Eskom, the state-owned utility in South Africa. The electrification rate in Eswatini is currently around 84% with universal access to electricity projected by the end of 2022 [2] The government of Eswatini has embarked on a drive to improve its electricity generation capacity to diminish its dependence on imported power from South Africa and to provide greater security of supply. A National Energy Policy was developed in 2018 to facilitate this process. An IPP Policy was established under the MNRE to increase the utilisation of solar and biomass generation plants. The Lavumisa 10 MW solar plant project is nearing completion while there are 40 MW solar and 40 MW biomass generation plants planned for construction in 2021. The expansion of the grid will result in an increase of transformers on the network. Any improvement in the technical losses present on distribution transformers will have an immediate impact on energy efficiency improvements for the entire network and has direct cost savings for the country.

Refrigeration appliances, in particular household refrigerators are also a major contributor to technical electrical losses. Refrigeration appliances are always operating and therefore consume electrical energy constantly. Therefore, energy efficiency improvements in these appliances have a continuous impact on energy efficiency improvements for the country.

Given the focus on the abovementioned equipment the aim of this market assessment is to perform a comprehensive data collection to understand the current base as related to energy efficiency of both refrigeration appliances and distribution transformers. This is a foundation for the formation of the MEPS. It also shows the national stakeholders the potential savings in a financial, energy and greenhouse gas aspects and enables one to plot the various savings scenarios as compared to the established national baseline for these parameters.

2 METHODOLOGY AND APPROACH

2.1 OBJECTIVE AND SCOPE

The scope of the market assessment was to conduct a data collection exercise through primary and secondary data collection methods. Primary data collection was conducted through questionnaires conducted in both the transformer and refrigeration sectors. The following data collection was performed:

- Household surveys were conducted to obtain the information on household refrigeration appliances
- Surveys of the supply chain were conducted by obtaining completed questionnaires from the major retailers in Eswatini (international companies) and from local retailers
- Engagements with the EEC to gain an understanding of the current distribution transformer numbers, their age, loading profiles, losses, expansion plans (number of new customers brought onto the network), etc.
- Stakeholders' engagements conducted through physical meetings during a visit to Eswatini by the international consultants, which enabled a more accurate stakeholder mapping and an understanding of the in-country processes related to standards development, development and promulgation of legislation and the mechanisms that enable change management within the country. This included a meeting with the only local refrigerator manufacturer, Palfridge.

Secondary data was also collected through desktop research of various stakeholders and information relevant to the project that was available online or through other references and written sources. Importantly, the stakeholder engagements conducted through a physical visit to Eswatini also aided in identifying key stakeholders whose information would be valuable to the project and this further enhanced the secondary data collection process.

The primary objective of the data collection stage of the project and the subsequent market assessment was to gain an understanding of the base levels of energy efficiency of the current refrigerators and distribution transformers in Eswatini. Additionally, the objective was to understand the market size (both current and future) so that the gains can be quantified over time. The market assessment also gathered valuable information related to the various stakeholders within the country to provide insight into the most efficient development of the MEPS and national standards and the most effective implementation of the improvements that will be proposed/developed.

Pegasys also utilised the services of local consultants in the form of Dr Nicollete Mhlanga-Ndlovu. Dr Nicollete Mhlanga-Ndlovu is an Eswatini based consultant well versed in governmental and environmental projects. Additionally, the Pegasys international consultant visited Eswatini and embarked on numerous stakeholder engagements to introduce the project and gather a thorough understanding of the role-players within the country as well as to gather invaluable data. Further Dr Nicollete Mhlanga-Ndlovu and associates gathered over 100 household surveys of refrigeration appliances. The international consultants managed to meet with the EEC remotely, as it is the biggest buyer and user of distribution transformers in the country and a key stakeholder. Furthermore, through meetings and review of the governmental reports an excellent understanding of the various governmental and private entities was obtained. Pegasys was able to analyse the data gathered to understand the market size, the roles of the various stakeholders, the overall energy sector within the country and its relationship with South Africa related to energy as well as the characteristics of the products (both refrigerators and distribution transformers) used within the country.

The data collection was performed by Dr Nicollete Mhlanga-Ndlovu and associates in combination with the data gathered by the international consultant during the stakeholder visit to Eswatini. Dr Nicollete Mhlanga-Ndlovu managed to obtain the data related to household refrigerators and through engagements with the EEC data on the distribution transformers was gathered. It is important to note that not all the data required from the EEC was available and certain projections were made. The data was analysed by Pegasys to establish the baseline for the country for both refrigerators and distribution transformers as described in this report. Furthermore, data validation was performed through desktop studies and further data obtained from various reports (particularly the EEC and ESERA reports).

2.2 EXISTING INFORMATION SOURCES AND GAPS

The household refrigeration data was gathered for 100 households. The survey covered a mix or urban, semi-urban and rural areas. The following areas were covered: Mbabane, Manzini, Hhohho, Shiselweni and Lubombo. Additionally, data was gathered from retail chain stores. These included Game, Lewis, Bears, Ok Furniture, Bradlows, Lynds Distributors, Hi-fi Corporation and Best Electric. The stores were located in Mbabane, Manzini and Matata.

The EEC transformer database was last updated in 2020 and contains asset information that is well documented, and almost complete. While the transformer manufacturer's details are not captured, the database is only missing kV ratings for 21 transformers. The database indicates that EEC has ownership of 21599 transformers. The EEC was able to confirm that total cost of ownership and capitalization of losses are not incorporated into the EEC procurement policy at present. In addition, all transformers were purchased in accordance with the South African Standard SANS 780.

Unfortunately, the IPP's in Eswatini were unable to provide a database of their transformers. It is hoped that the report can be updated in the future to include an analysis of the transformers installed on the IPP's networks. Ubombo Sugar Mill did provide a response to the transformer survey, that was very much in alignment with the EEC, i.e., transformers are procured on capital cost only, losses are not capitalised, and transformers are ordered in accordance with the SANS 780 specification.

Apart from the direct data gathered through questionnaires, information was gathered from many state-owned entities of governmental departments through interviews conducted during the week-long visit to the country.

This included the understanding of the standards development process through an engagement with the Eswatini Standards Authority, the understanding of the import monitoring structure through discussions with the Eswatini Revenue Service, the energy and environmental regulators, etc. These are described in more detail in the sections that follow.

2.3 INFORMATION GATHERING METHODOLOGY, MARKET SEGMENTATION & SAMPLE SELECTION ANALYSIS

To obtain the necessary current market situation related to refrigerators in Eswatini the strategy was to interview households and complete the related household questionnaires. The household questionnaires were performed across a variety of household median incomes, geographical locations and in urban, semi-urban and rural locations. The surveys were conducted in Mbabane, Manzini, Hhohho, Shiselweni and Lubombo regions. In terms of the supply chain of refrigerators a desktop study was initially performed to identify the layout of the supply chain and thereafter a targeted survey followed, explained in more detail below.

To gain understanding of the transformers market in Eswatini, the team interviewed the EEC, the Department of Energy and Ubombo Sugar.

To gather well rounded and verifiable data the team embarked on data collection through a desk study, through stakeholder engagements (conducted primarily during the country visit) and through questionnaires filled in during surveys.

Desktop research

The literature review included analysis of the technical standards employed by the EEC for the procurement of Distribution Transformers (DT's) including the South African Standard, SANS 780. Reports from Government Agencies such as ESERA and the EEC were studied to understand the size of the network, rate of new electrification and maximum demand forecasts. A transformer database provided by the EEC, accurate to 2020, was studied for data analysis. Furthermore, the research also included the analysis of the refrigerator retailer market in Eswatini to understand which of the major companies were operating in the country and how many smaller retailers were present. It also included the analysis of the various national and private entities that are effectively the stakeholders of the project. It provided a preliminary understanding of the various key institutions such as the SWASA, the regulators, the consumer protection agencies, the revenue authority, the central bank, etc. This preliminary understanding was then used to develop a stakeholder engagement plan that was implemented as part of the stakeholder interviews described below.

Stakeholder interviews

The key stakeholder interviews were primarily conducted during the stakeholder engagements that were conducted during the visit to Eswatini by the international consultant. The stakeholder engagements were conducted jointly with the representative from the MNRE. During the visit the following entities were visited:

- Ministry of Natural Resources and Energy
- Ministry of Tourism and Environmental Affairs
- Ministry of Commerce, Industry and Trade
- Eswatini Standards Authority
- Eswatini Revenue Services
- Eswatini Environmental Authority
- Eswatini Energy Regulatory Authority
- Eswatini Electricity Generation Company (telephonically)
- Eswatini Centre for Sustainable Energy Research

These engagements provided us with an excellent understanding of the layout of the Eswatini ministries and their jurisdictions as related to this project. Additional invaluable information was that the SWASA had recently undergone a process of revising the national refrigeration standard. The meeting was extremely valuable and provided insight into the standards development process and the manner in which the technical committees are assembled.

From the discussions with the EEC, it was evident that there are no transformer manufacturing facilities within Eswatini. Transformers are almost exclusively purchased from South Africa. Interviews were conducted with the key stakeholder from the EEC but at present information on the costs of transformers is outstanding. The EEC transformer database was last updated in 2020 and contains asset information that is well documented, and almost complete. While the transformer manufacturer's details are not captured, the database is only missing KV ratings for 21 transformers. The database indicates that EEC has ownership of 21599 transformers. The EEC was able to confirm that total cost of ownership and capitalization of losses are not incorporated into the EEC procurement policy at present. In addition, all transformers were purchased in accordance with the South African Standard SANS 780.

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Additionally, from the stakeholder engagements it was also evident that there is one manufacturing facility of refrigerators in Eswatini. Additionally, this manufacturer, Palfridge, possesses a fully accredited energy efficiency testing laboratory. During the stakeholder engagement in Eswatini a visit to the Palfridge factory was conducted together with the MNRE. During this factory visit interviews were held with the technical director and the sales and testing teams. It was found that the Palfridge factory exports the majority of its refrigerators to South Africa. Additionally, Palfridge also exports to other SADC countries such as Botswana and Zimbabwe. Sometimes the exports are through South African based resellers, however. Therefore, Palfridge stressed that it is critical for them that there is alignment in the region in terms of the MEPS and the energy labels as well as regulations to a large extent. Their laboratory is accredited by the Southern African Development Community Accreditation System (SADCAS) and they perform testing to the South African national standard at the moment. They have performed tests to IEC 62552:2015 also and their laboratory is capable of such testing, however they are not accredited for such testing as yet. In order to obtain the data related to market size interviews were conducted with the retailers and information was gathered from the major chains operating in Eswatini as well as the smaller retailers operating independently. It was found that the local retailers do not purchase from importers but rather import their own refrigerators. Additionally, the large retailers are typically multi-national companies based in South Africa and they import in bulk for the region and then transfer the related products to Eswatini. From the visits to the various retailers the types of refrigerators and brands could be ascertained from the shop floors as well as the usage of energy labels (typically from South Africa). Through interviews with local store managers the attitudes of the people to energy efficiency was also gathered. More details on the filed surveys are presented in the next section. Finally, Comtrade data was used to validate the information received.

Field surveys

The field surveys were conducted through the use of local consultants and their enumerators. They visited numerous households and collected refrigerator data. The data was collected in rural, semi-rural and urban areas. The data was collected in the following regions:

- Mbabane central,
- Manzini,
- Hhohho,
- Shiselweni and
- Lubombo

The data collection was performed to generate information from a variety of household incomes, to have a good regional distribution across the country and to cover both the urban areas with more choice in refrigerators and rural areas with fewer choices and the higher probability of repaired or second-hand refrigerators being used. It was not always possible to gather data from the households directly and often the enumerators gathered model numbers and photographs of the refrigerators from the households. This provided the background for the team to enable an internet search for the specific information on those refrigerators (e.g., volume, type of refrigerant, etc.). Certain refrigerators used in Eswatini also utilise the South African energy label as they are imported from

South Africa or via South Africa. As such there is useful information available on the energy label that the team utilised wherever possible. In addition to the refrigeration data the enumerators also collected data on the types of households, the number of persons living in the respective households, the household sizes, the income levels, the electricity usage or electricity bills, their attitudes towards energy efficient appliances, energy label knowledge, whether they purchased refrigeration appliances on loans and the types of loans. It must be noted that the respondents did not want to disclose their accurate incomes but in these cases the enumerators categorised the respondents into an income bracket (lower, medium and upper) based on their household size, general affluency of the area where the house is located and the general levels of affluency in the household.

In terms of the data collection related to the supply chain of refrigerators it was assessed during the online study that there are two types of retailers in the country, namely the smaller local retailers and the large retail chains. The large retailers have their head offices in South Africa. They import the refrigerators for the entire SADC region throughout which they operate. However, they don't import refrigerators for specific countries but import in bulk for the region. Through visits to these retail chains (both at the head offices in South Africa and in the branches in Eswatini) an understanding was gained that there are regional buyers that have the data for the specific countries. Therefore, there are regional buyers that have the data for that retailer for all of the refrigerators sold in Eswatini. Attempts were made thereafter to gather the data from the regional buyers. This was done through email communication, telephonic conversations with various management and administrative structures within the retailers and through visits to the physical offices. Each time the regional buyers were not available for meetings and did not respond to emails. Their assistants continuously indicated that they would arrange a meeting, but this was never fulfilled. Additionally, during physical visits an opportunity was not provided to meet with the regional buyers but only with their assistants or receptionists. Each time an indication was given that the regional buyers were unavailable or out of the town on business and that they would provide the required information in due course. After more than 8 months of engagements no information was forthcoming. This process was extremely lengthy and did not yield the required results. The retailers did not provide the required data and the regional buyers refused to respond to the numerous contacts made. In addition, during the visit to Eswatini a number of the retailers were visited in Mbabane (the capital) and Manzini (the largest city). The store managers again made referrals to the regional buyers. In certain instances, the consultants were informed that the Eswatini branches were not allowed to provide information and that the information would only be provided by the head office in South Africa. However, the head office in South Africa did not respond to the enquiries.
As an alternative, during the visits to the physical stores, information was gathered on the refrigerators on the store floor. The following retail stores were visited:

- Best Electric - Mbabane
- Lewis store in Manzini
- Hi-fi Corporation in Mbabane
- OK Furniture in Matata
- OK furniture in Mbabane
- Lewis store in Matata

- Bradlows store in Manzini
- Bradlows store in Mbabane

In addition to the large retailers there are smaller, local retailers operating in Eswatini. These include companies such as Hoageys and the Swaziland supply centre. These companies typically import from wholesalers in South Africa or distributors in Eswatini.

3 OVERVIEW OF THE COUNTRY

3.1 SOCIO-ECONOMIC SITUATION

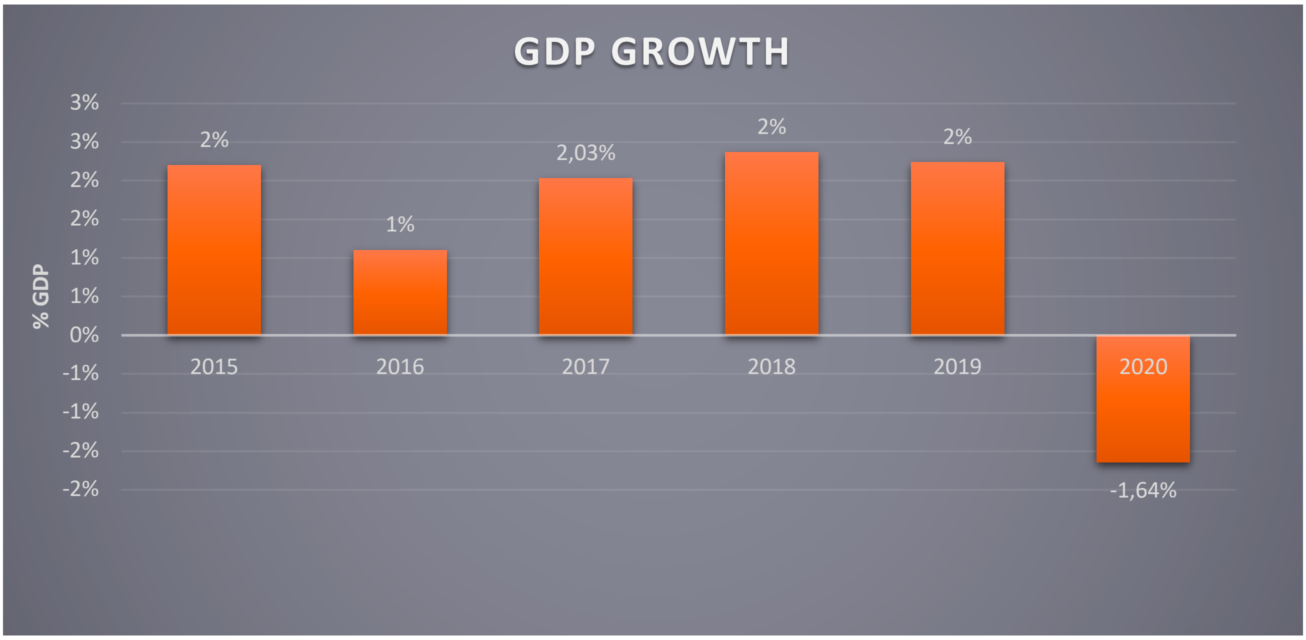
The Kingdom of Eswatini is largely surrounded by the Republic of South Africa (RSA). It also shares a border with Mozambique and covers approximately 17,364 km^2 of land. The Kingdom is one of the smallest countries in Africa. However, even with its small size it has a diverse climate and topography, ranging from a cool and mountainous highveld to a hot and dry lowveld. The country is the last absolute monarchy in Africa and has been ruled by King Mswati III since 1968. Eswatini is a developing country and a lower-middle income economy. Eswatini is also a member of the Southern African Customs Union (SACU) and the Common Market for Eastern and Southern Africa (COMESA) as well as Southern African Development Community (SADC), the African Union, the Commonwealth of Nations, and the United Nations. The main trading partner of Eswatini is South Africa. The local currency is the Lilangeni and it is linked in a 1:1 relationship with the South African Rand.

The economy of Eswatini's is fairly diverse. Agriculture, forestry and mining make up approximately 13% of GDP. The largest contributor is services with 50% of the GDP and manufacturing (textiles and sugar-related processing) representing 37% of GDP. The population of eSwatini is approximately 1.2 million [3].

The established Eswatini Energy Regulatory Authority regulates the Electricity Supply Industry (ESI) within Eswatini. ESERA has adopted the following strategic objectives [4]:

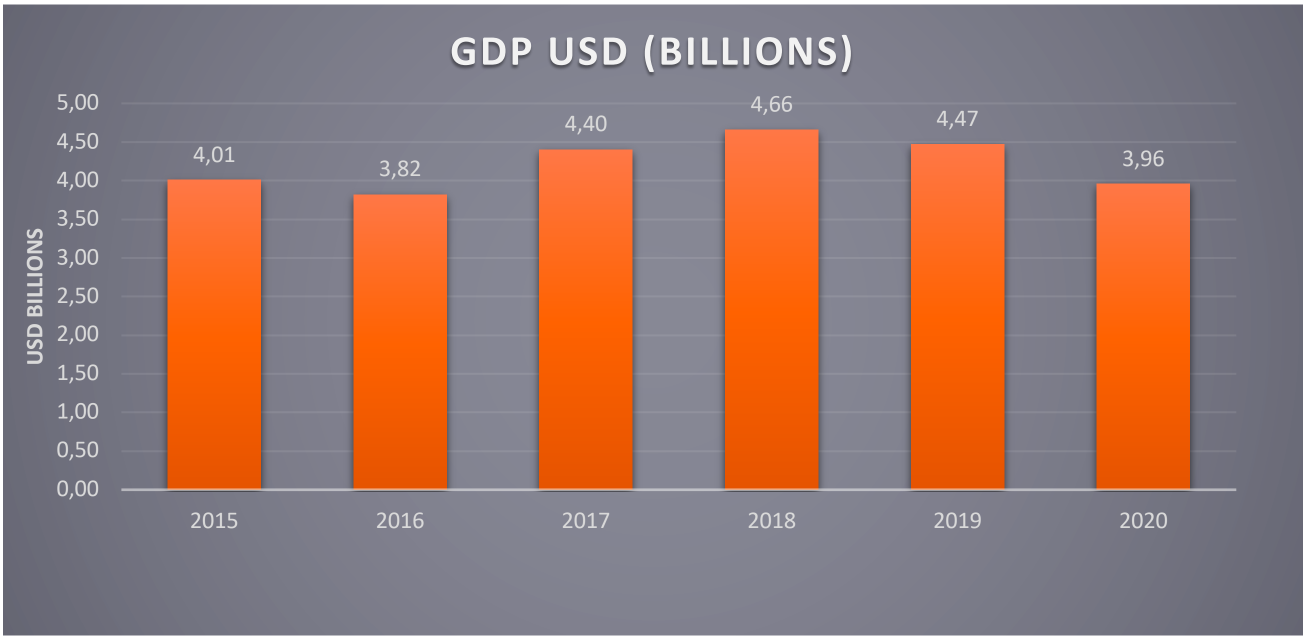
- To regulate the electricity industry in a manner that is transparent, fair, and predictable.
- To promote an environment that will ensure universal access to electricity services and products.
- To regulate in a manner that ensures security of supply and promotes the integrity and sustainability of the electricity industry.
- To promote a regulatory environment that ensures fair competition in the electricity industry.
- To regulate in a manner that ensures efficiency of service provision and that regulated entities have the ability to finance their activities.
- To promote the interest of the public and customers in respect of prices, charges and quality of supply.
- To be an effective organisation that delivers on its mandate and mission.

Over the last six years, the economy of Eswatini has experienced a mixture of growth and decline. Between 2015 and 2019 there was a growth rate from 1% to over 2%. In 2020 there was a 1.64% decline in GDP as is shown in Figure 3-1 below [5]. Figure 3-2 shows the GDP in billions of USD over time. This is attributed to the COVID 19 pandemic and the resulting impact on the economy.



Source: World Bank 2021

Figure 3-1 GDP annual growth of Eswatini



Source: World Bank 2021

Figure 3-2 Eswatini GDP in Billions of USD

3.2 ENERGY CONTEXT

3.2.1 GENERAL ELECTRICITY SITUATION IN ESWATINI

According to a 2020 United States Agency for International Development (USAID) report on energy development in Eswatini, the country has been on a drive to improve its electricity generation capacity to diminish its dependence on imported power from South Africa and to provide greater security of supply. A National Energy Policy was developed in 2018 to facilitate this process. An IPP Policy was established under the MNRE to increase the utilisation of solar and biomass generation plants. The Lavumisa 10 MW solar plant project is nearing completion while there are 40 MW solar and 40 MW biomass generation plants planned for construction in 2021.

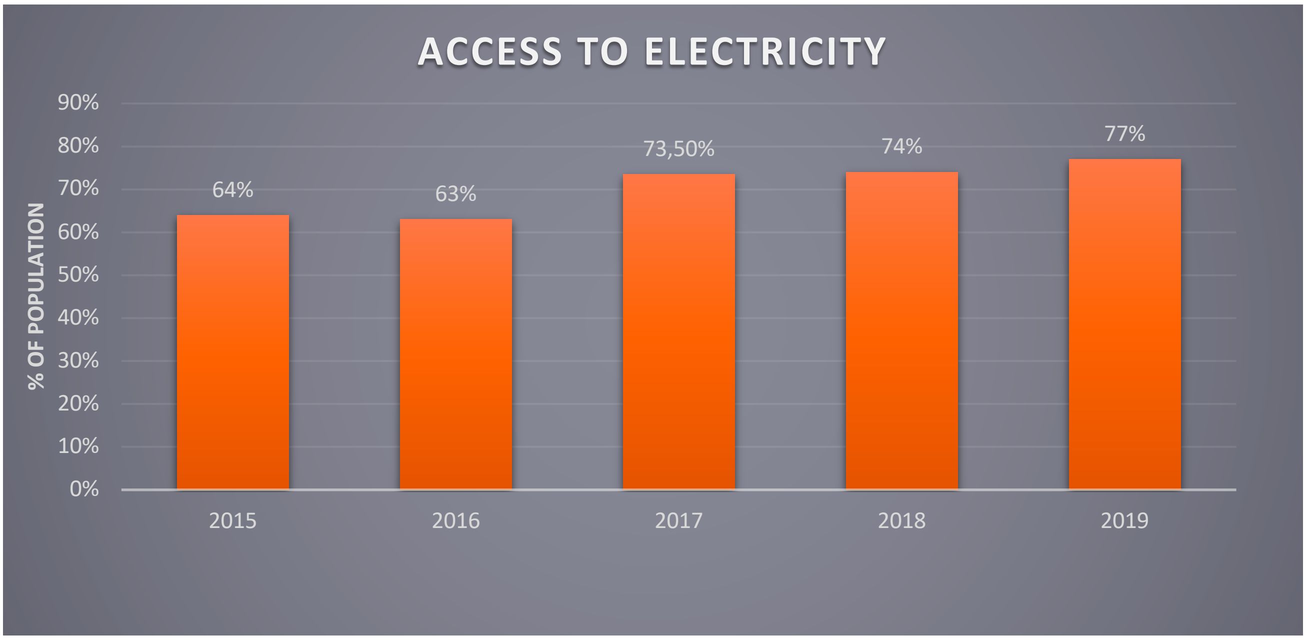
At present, power generation and the transmission and distribution of electricity to the general population of Eswatini is the responsibility of the EEC, a state-owned power utility. According to the ESERA annual report from 2020 the country's peak demand was 245 MW and the energy supplies to customers was approximately 1,580 GWh. The customers were predominantly industry (50%) and domestic (36%). The EEC can provide 60.4 MW of power to the grid via the operation of four hydro power plants. However, the hydropower plants contribute only around 17% of the total energy required in Eswatini. The remaining power is purchased from Eskom in South Africa and on rare occasions from EDM.

In addition to the 60.4 MW hydropower plants operated by the EEC, there is 110 MW of independently produced power within Eswatini. Umbombo Sugar Mill produces 41MW of biomass generated power, 13 MW of which is made available to the grid. The Royal Eswatini Sugar Corporation also produces 65.5 MW of power via biomass generation, while USA Distillers and Wundersight produce a combined 2.3 MW of power from coal and solar generation respectively.

The EEC also owns 9 MW of diesel generation but the plants at Edwaleni Power Station have been mothballed due to their high operational costs, that renders their function economically unviable.

3.2.2 ELECTRIFICATION RATE

Error! Reference source not found.3 shows the World Bank data on access to electricity, where in 2019 it indicated that 77% of the population had access to electricity. The percentage taken from the ESERA annual report for 2020 was 7% higher with an 84% access to electricity [1].



Source: World Bank

Figure 3-3 Access to electricity per year

Error! Reference source not found.4 below shows the number of customers electrified per annum from 2017 to 2020.

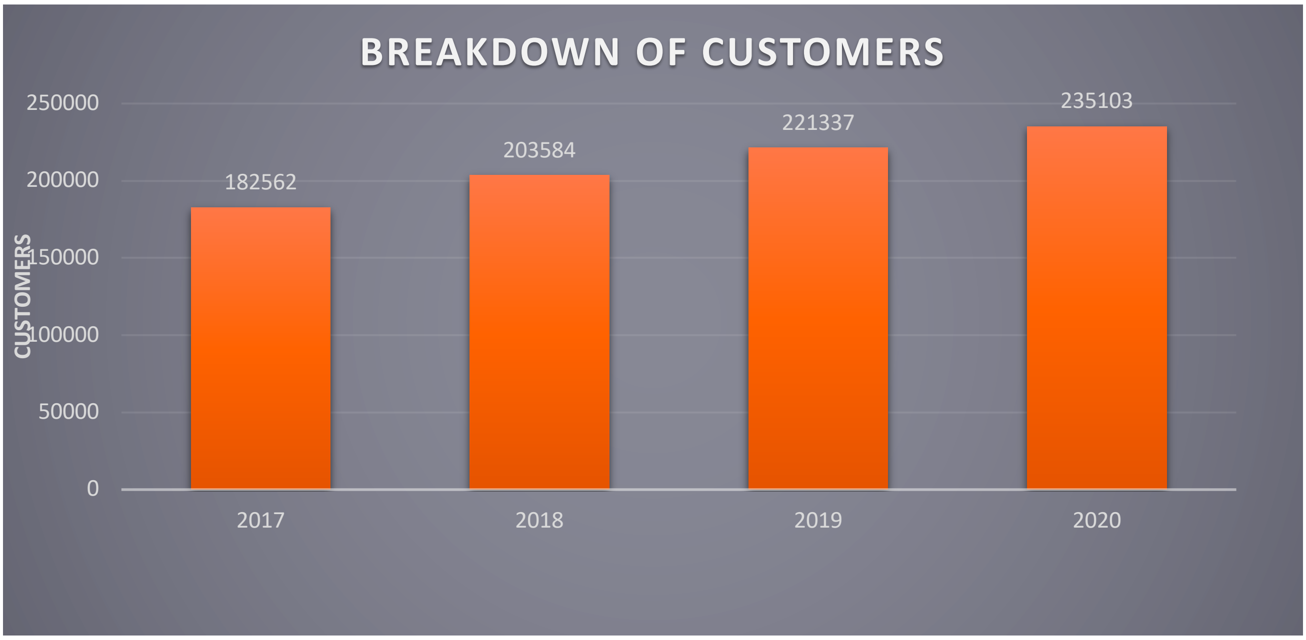


Figure 3-4 Number of customers electrified per year

Source: ESERA annual report 2020

There is a growth in access to electricity of 13% from 2015 to 2019. This correlates to the growth of customers on the ESERA database where there was an approximate 30% growth in customers from 2017 to 2020. This further correlates to the EEC transformer database in Section 4.

3.2.3 MAXIMUM DEMAND

Error! Reference source not found. below shows the maximum energy demand for Eswatini from 2016 to 2020.

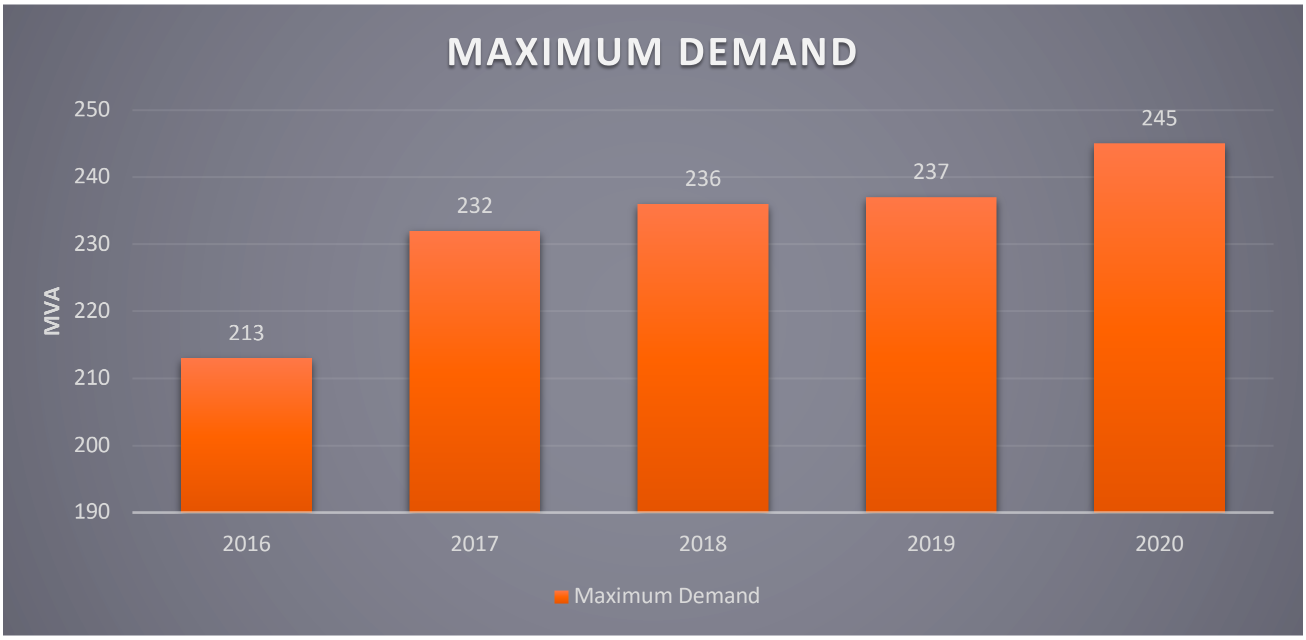


Figure 3-5 Eswatini's maximum power demand per year

Source: ESERA Annual Report 2020

As shown in **Error! Reference source not found.** Eswatini's power demand as a country has increased over the past five years and is still on the rise. The 2016 to 2017 year saw a 9% increase in demand from the previous year whilst 2019 to 2020 only showed a 3.4 % increase.

3.2.4 ELECTRICITY GENERATED AND IMPORTED

Error! Reference source not found. below shows the energy generated and energy imported to Eswatini for the period 2016 to 2020.

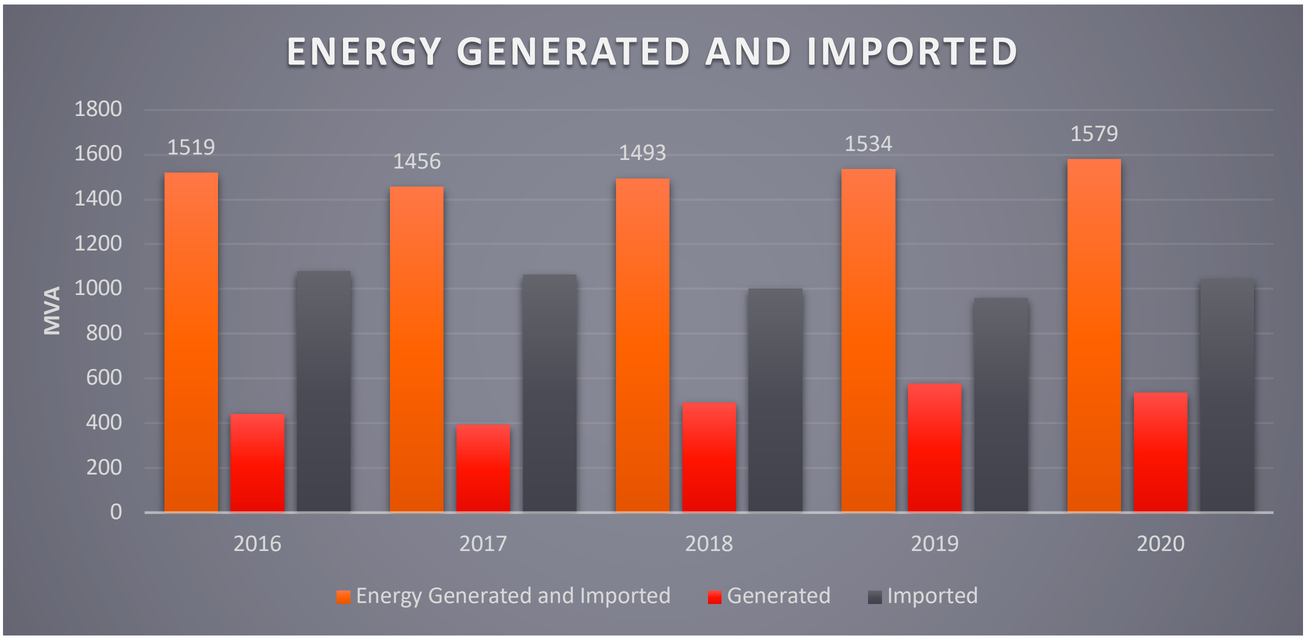


Figure 3-6 Eswatini generated and imported energy.

Source: ESERA Annual Report 2020

Analysis of the above statistics show that Eswatini has imported more power than its generation capability over the past five years and that the reliance on imported power is growing.

3.2.5 DEMAND FORECAST

The projections from the Eswatini Energy Master Plan 2034 [6] are for continued rise in demand. As per the master plan the energy demand is expected to rise significantly as is the generation capacity to meet this demand. The estimated generation growth is depicted in Figure 3-7 below.

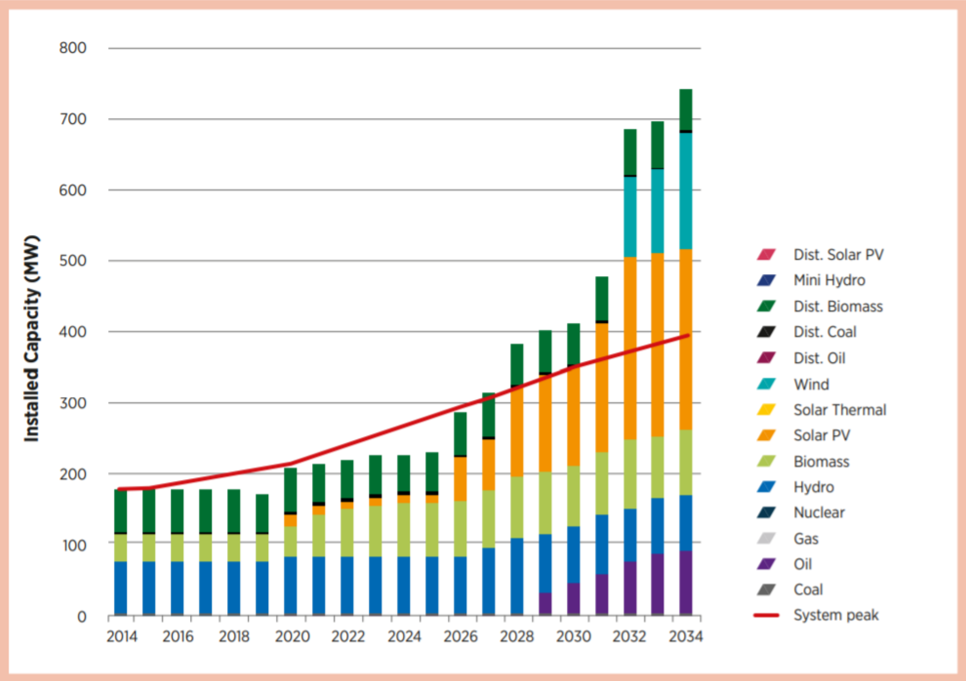


Figure 3-7 Projected electricity generation growth

The total energy demand projection is also available in the Energy Master Plan. From it is evident that there is a projection for a substantial increase in electrical energy demand in the coming years. This is shown in Figure 3-8 below.

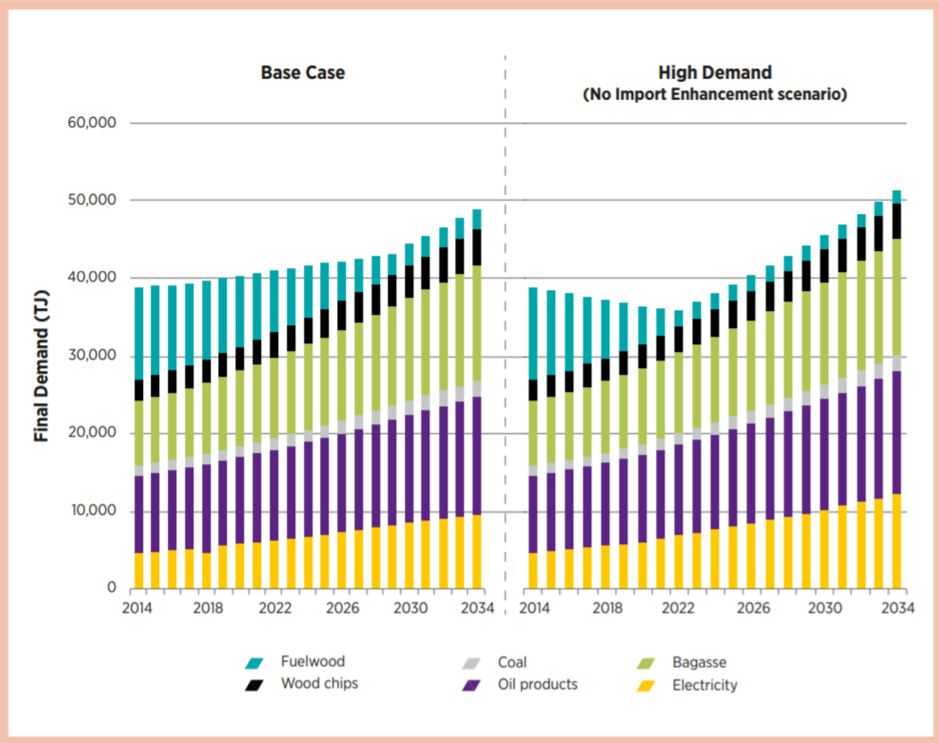


Figure 3-8 Energy demand

3.2.6 ENERGY CONSUMPTION SECTOR

Error! Reference source not found.9 below shows the percentage energy consumption per sector in 2020. The energy consumption within Eswatini is made up of four major categories. The domestic and industrial sectors consume the main share of energy.

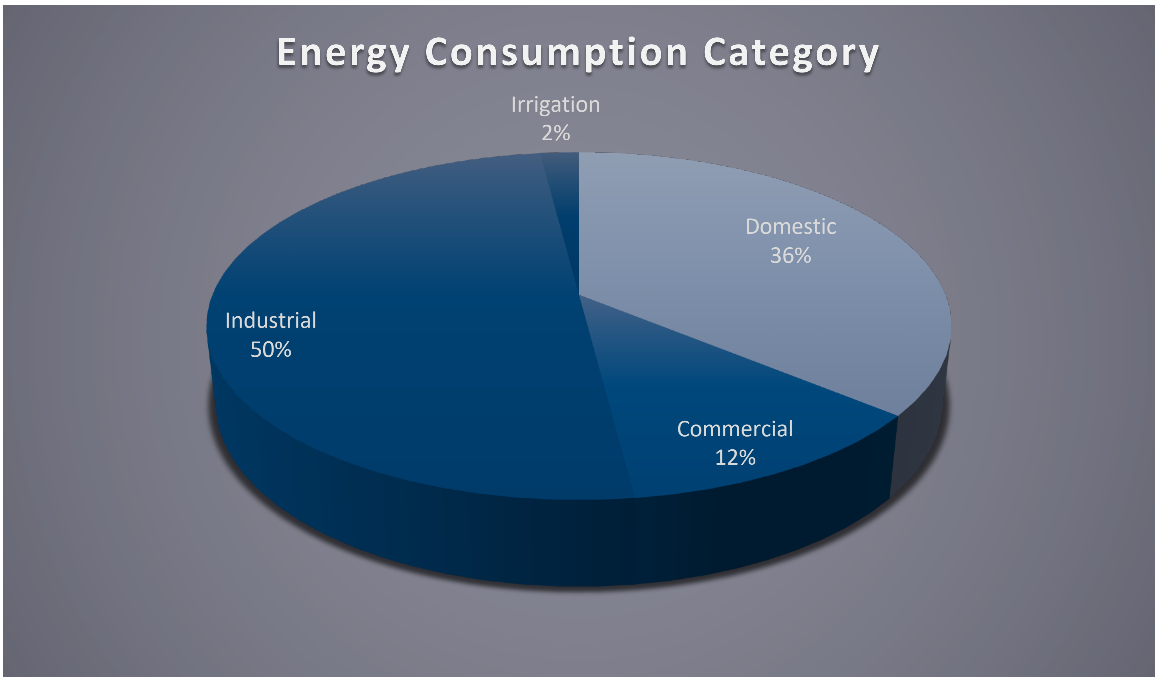


Figure 3-9 Eswatini's energy consumption per sector

3.2.7 POLICY, INSTITUTIONAL AND REGULATORY FRAMEWORKS & STAKEHOLDERS RELATED TO ENERGY EFFICIENCY

In order to effectively implement the MEPS and the national standards related to distribution transformers and refrigerators it is important to understand the current framework within which the standards will be developed and implemented. The understanding of the standards development process enables the quickest development of the standards and any regulations if necessary and for the most effective implementation of the MEPS and national standards. The MEPS are critical in the establishment of regulation that will drive the improvement of energy efficiency of products that enter the Eswatini market, particularly distribution transformers and refrigerators in this case. There are a number of sectors of society and government that are required to be understood and which need to support the establishment and implementation of the MEPS in order to realise real benefits from such a project. These include:

- Standardisation processes within the country. This includes the framework for standard development and standard maintenance.
- The financial support mechanism. Once the MEPS are developed there is a cost to their implementation. These costs are across multiple sectors, from consumers buyers of energy efficient appliances to the costs of establishing and implementing the related regulations to the cost of marketing the benefits of energy efficiency.
- Regulatory framework. The effective implementation of MEPS usually requires accompanying regulation. Importantly, this regulation needs to be implementable once developed.

In recent times Eswatini has been involved in energy efficiency projects. It is participating in the Energy Efficient Lighting and Appliances project in the SADC region. This project is aimed at supporting markets for energy efficient lighting and appliances in east and southern Africa [7]. This is done through various initiatives, such as, market incentives (including financial incentives and technical assistance to the supply chain participants), development of policies and regulations such as MEPS, increasing awareness through consumer awareness campaigns and capacity building of governmental institutions (including laboratories and other conformity assessment bodies). This is critical as these elements are key aspects of this project and thus support for the implementation of the project is available. Additionally, Eswatini is the signatory to the Montreal Protocol and the ratification of the Kigali Amendment. Eswatini is also a part of the United Nations Environment Programme that is attempting to reduce the amount of PCBs in use in the country and region. The programme is run through the PCB Elimination Network, which is raising awareness related to the harmful effects of PCBs. As PCBs were present in transformer oils and continue to be present in some older transformer oils this is an area that is closely linked to the work of the increased energy efficiency of transformers in this project. The project for the reduction and eradication of PCBs in Eswatini is currently underway. There is a need for alignment between these projects, especially since some of the information on the transformers in the network, their age, condition and usage can be shared and is common to both projects.

Eswatini has issued a National Energy Policy in 2018 and the National Climate Change Policy in 2016. In the National Energy Plan the eSwatini government and in particular the Ministry of Natural Resources and Energy is committed to energy efficiency and energy conservation as important policies of the country [1]. Cooling and heating appliances have been identified as major sources of energy inefficiency. The National Energy Policy also indicates the desire to draft standards and related labelling to ensure high efficiency products enter the country. There is particular mention of heating, ventilation and air conditioning, building energy management systems, hot water generation, lighting and appliances. Furthermore, the National Energy Policy, although not explicitly listing specific appliances, mentions that Eswatini Government will encourage development of an energy appliance labelling programme at a regional level. The MNRE is also committed in this policy to initiate, in co-operation with the local manufacturers and SWASA, a programme for labelling their products as a way of encouraging a regional programme. This is highly encouraging as it indicates that the government is well aware of the impact of inefficient appliances and that the development of the relevant standards, labels and regulations will be supported.

The National Climate Change Policy, issued in 2016, aims to provide the enabling policy framework to guide Eswatini to address the challenge posed by climate change [8]. Climate change has already had a profound negative impact on the Eswatini agriculture and food security. The Climate Change Policy outlines the aim to support economic development through access to electricity whilst at the same time reducing the intensity of energy use through energy efficiency programmes. One of the plans is to collaborate with IPP to provide more renewable energy into the Eswatini energy mix.

There are also a number of acts that govern the operation and formation of key state-owned entities related to electricity supply. These are:

- Eswatini Public Procurement Act 2011. This act governs the manner in which state-owned companies, such as the EEC purchase equipment, e.g., transformers. Through this Act the state-owned enterprises in Eswatini are given directives with regard to purchasing mechanisms. The Act also governs the rules that state owned enterprises have to follow when purchasing items. This is designed in order to prevent corruption, ensure purchase of adequate equipment, enable purchase of equipment at competitive prices and in order to support local manufacturers. The purchase of transformers by the EEC would therefore be governed by this Act.
- Swaziland Electricity Company Act 2007. This is a key act as it established the EEC as the electricity generation, transmission and distribution monopoly in eSwatini
- The Electricity Act 2007. This act in combination with the Swaziland Electricity Company Act paved the way for the formation of the EEC and their mandate of electricity supply
- The Energy Regulatory Authority Act 2007. This act enabled the establishment of the Eswatini Energy Regulatory Authority (ESERA)
- The Public Enterprises (Control and Monitoring) Act, 1989. This act enabled the establishment of various public enterprises and their responsibilities to the various ministries that they report to.

The Dedicated financing is often a barrier to the implementation of energy efficiency policies and programmes. At the moment there are no dedicated financing mechanisms in Eswatini for the funding of such policies and programmes. A number of institutional stakeholders insist within Eswatini that are key to the successful development and implementation of this project. Eswatini possesses a regulator in this environment namely the Eswatini Energy Regulatory Authority. Additionally, the Eswatini Standards Authority is established and has the capability to administer the formation of local standards. This is key as the organisation has formalised structures for the development of the national standards.

The other key institutions and/or ministries related to this project are: Ministry of Natural Resources and Energy, Ministry of Tourism and Environmental Affairs, Eswatini Electricity Company, the Eswatini Revenue Service, and the Eswatini Central Bank.

In Table 3-1 below is a list of the entities listed above and their importance/role in the development and implementation of MEPS.

Table 3-1 Entities and roles in development of MEPS in Eswatini

Organisation	**Role**
Ministry of Natural Resources and Energy	Driver of the MEPS development and implementation. Formation of energy related initiatives
Ministry of Tourism and Environmental Affairs	The support ministry to the Ministry of Energy in this project. Can facilitate governmental support for legislation and implementation support
Eswatini Electricity Company	The main buyer and user of distribution transformers. Also, the importer and seller of electricity and as such a key to the implementation of the project and one of the project's biggest beneficiaries

Eswatini Energy Regulatory Authority	Energy regulator and as such governs the operations of the EEC and is key to the implementation of energy efficiency initiatives and possible legislation implementation.
Eswatini Central Bank	Responsible for the governance of the financial sector and would be able to support initiatives that finance the implementation of the project from a regulatory perspective
Eswatini Environmental Authority	Regulator of environmental affairs and heavily involved in refrigeration technician training
Eswatini Standards Authority	National body responsible for standards development and administration
Eswatini Revenue Service	Amongst other functions it governs the imports and exports into the country and will be key, especially for refrigerator movement and assessment of the labelling scheme at the border

There are also other important stakeholders that are going to be involved in the implementation and/or development of the MEPS or will have an influence on the overall project. These include:

- Ubombo Sugar (owners of distribution transformers and generator of electricity)
- The University of Eswatini (in particular the Energy Research Centre)
- The retailers (both local and large international organisations)
- Repair centres and technicians
- Palfridge (the local refrigerator manufacturer)
- Financial institutions (specifically the banks as possible lenders supporting the implementation of energy efficient appliances)

3.2.8 SUMMARY

The electrical energy layout of Eswatini is one in which, at the moment, relies on imports of power from South Africa. The legal, regulatory and standardisation frameworks are generally inexperienced and untried with regard to energy efficiency matters. As a result, the appliances that are installed in Eswatini are not monitored and do not have minimum energy efficiency thresholds. However, there is enthusiasm within the ministries that will be directly involved with the project of the development of the MEPS and the corresponding regulators and primary stakeholders. The cooperation between key governmental departments in Eswatini appears to be smooth and SWASA has experience in standards development and a well-established process for the operation of technical committees. The SRA appears capable of implementing the MEPS at border levels with adequate controls. The EEC has an established procurement process and as such the control of purchasing would be possible. Additionally, the regulatory framework and the close alignment between the regulators and key ministries in Eswatini could make the policy transition efficient.

4 MARKET ASSESSMENT ON RESIDENTIAL REFRIGERATORS

4.1 REFRIGERATOR SUPPLY CHAIN

4.1.1 SUMMARY OF SUPPLIERS, END-USERS, OFFICIALS AND OTHER STAKEHOLDERS

The majority of the retailers operating in Eswatini are a part of larger international retailer chains. These organisations have their main offices in South Africa typically. The refrigerators that such retailers sell are therefore either manufactured in South Africa or imported by the head office. They are not imported directly into Eswatini and for the Eswatini market. This is dictated by market size, as the market size of Eswatini does not warrant customised importing of refrigerators. The retailers, who are effectively the suppliers of refrigerators, therefore have regional buyers that decide on the types and volumes of refrigerators that are assigned to specific countries in the region with Eswatini being one of them. Typically, therefore the regional buyer for one of these large retailers based in South Africa would be responsible for supplying countries such as: eSwatini, Lesotho, Botswana, Zimbabwe, Namibia and Zambia (although the exact combination of countries would vary from retailer to retailer). The most prominent large retailers in Eswatini are:

- Lewis
- Bears
- Hi-fi Corporation
- OK Furniture
- Bradlows
- Russels

However, some of the retailers above are owned by the same parent companies and have targeted market segments. Lewis and Bears are both owned by the Lewis Group operating out of South Africa. Lewis stores are designed to cater for the upper and upper middle-class markets and the Bears stores cater for the lower middle class market segment. Similarly, Game and Hi-fi Corporation are both part of the Massmart Group (a South African subsidiary of the American giant Walmart).

In addition to the international suppliers/retailers there are also local retailers. These are smaller companies although some have several shops throughout Eswatini. These include the following companies:

- Hoageys
- Swaziland Supply Centre
- Viva
- Fridge Masters and Electrical

These retailers typically have local area clients and import the refrigerators from South Africa. They do have a loyal client base however and some (such as Hoageys) have been operating for decades. Refrigerators are not regulated products in eSwatini. Therefore, there is no direct governmental involvement in the prescription of the types of refrigerators or their energy efficiency at present. The governmental stakeholders related to refrigerators are however quite complex. The reason being that Eswatini is a relatively small country with a population of less than 1.2 million people [9]. Therefore, many of the governmental departments share resources. The ministries that are involved in refrigeration and energy efficiency in particular as stakeholders are the following:

- Ministry of Natural Resources and Energy (in particular the Department of Energy)
- Ministry of Tourism and Environmental Affairs (in particular the Department of Meteorology)
- Ministry of Commerce, Industry & Trade

Additionally, there are regulators within Eswatini that are important to the implementation of energy efficiency initiatives within the country. The main regulators in this regard are:

- Eswatini Energy Regulatory Authority
- Eswatini Environment Authority

The Eswatini Environment Authority also indicted during stakeholder engagements that they have undertaken training for refrigeration technicians with the aim of promoting energy efficiency and use of more environmentally friendly refrigerants. Apart from the regulators the Eswatini Standards Authority (SWASA) and the Swaziland Revenue Authority (eSwatini Revenue Service) are important stakeholders within the drive towards energy efficiency in terms of standards development and implementation of regulation related to MEPS, if developed.

4.1.2 MANUFACTURING OF REFRIGERATING APPLIANCES

Eswatini has one local manufacturer of refrigerators, namely Palfridge Limited (Fridge Factory). This manufacturer is located in Matsapha (central Eswatini) and supplies customers within Eswatini and throughout the neighbouring countries. The information on their sales and exports is not available but during the visit and interview with their sales and technical staff it was indicated that over 80% of their market is exported to South Africa (where they also have offices and warehouses). The remainder of their market is in eSwatini and also in other neighbouring countries such as Zimbabwe and Botswana. Palfridge also owns a test laboratory, which includes the capability of energy efficiency testing of refrigerators. This is unique as it is only one of 2 such laboratories in the region (the other being the laboratory of the South African Bureau of Standards). The Palfridge laboratory is also accredited by the Southern African Development Community Accreditation Services (SADCAS). This means that it provides reliable and repeatable data and can be used to assist Palfridge to improve the energy efficiency offering of its products. The laboratory is currently used by Palfridge to conduct testing on its own refrigerators only. During discussions with Palfrige a possibility of using the laboratory to conduct testing for external clients has been mentioned. Palfridge have indicated that they would assess the possibility and would engage with the Ministry of Energy further on this topic during the project. Furthermore, the Palfridge laboratory is currently accredited for the South African National Standard (SANS) 62552. This is based on the IEC 62552:2007 standard. However, Palfridge regularly tests refrigerators to the latest version of the IEC 62552:2015 standard. They are capable of testing to this standard (testing at both 16°C and 32°C as per the requirements of that standard. They are however, not accredited to this standard. This point was discussed with Palfridge and the indication was that they would be willing to add the IEC 62552:2015 standard to their scope of accreditation. The process for this is relatively simple as Palfridge would need to indicate this addition to SADCAS and for it to be reviewed by SADCAS. Palfridge is already performing the testing and thus has a track record of testing and on-the-job training for its test personnel on this standard and also the testing methods are almost identical to the IEC 62552:2007 version, which Palfridge is accredited to. This would be highly valuable as Palfridge would have the only accredited laboratory capable of testing to IEC 62552:2015 in the region.

4.1.3 OVERVIEW OF THE SUPPLY CHAIN

a) Import

Through interviews with the stakeholders in the supply chain it was found that 2 distinct processes or distribution channels existed for getting the refrigerators to the consumers in Eswatini. These were divided into furniture retailer chains (of large companies typically with headquarters in South Africa), of individual (or small chains) smaller retailers based in Eswatini and the supply directly to the public by the local manufacturer. The large retailers based in South Africa import refrigerators in bulk or purchase them from South African manufacturers and then distribute them from South Africa to the respective countries in the region with Eswatini being one of them. Therefore, these companies have the supply chain as shown in **Error! Reference source not found.** below:

Figure 4-1 Supply chain of large international retail stores operating in Eswatini

The local retailers however purchase directly from the wholesalers that are based in South Africa. Their supply chain is shown in **Error! Reference source not found.** below.

Figure 4-2 Supply chain of Eswatini's local retailers

As mentioned, eSwatini has one manufacturer of refrigerators, Palfridge. Palfridge supplies the retailers directly (both local and South African based) and thus conforms to the process outlined in Figure 4-1. From discussions with Palfridge it has been discovered that at times Palfridge will supply directly to the buyers, but this is more related to industrial clients rather than household refrigerators. Additionally, Palfridge indicated that the vast majority of its market is in South Africa.

The majority of the refrigerators are therefore imported into eSwatini. The import numbers of refrigerators are shown in Figure 4-3.

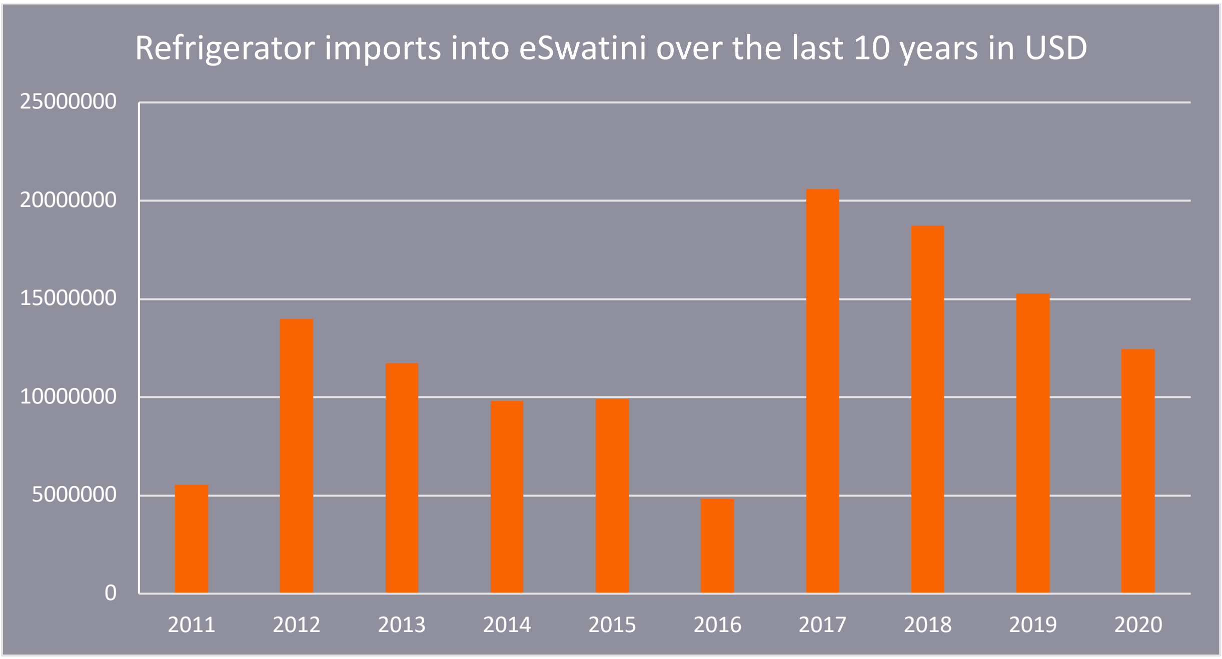


Figure 4-3 Refrigerator imports in Eswatini over the past 10 years (https://comtrade.un.org/Data)

It is evident from the figure above that there are what appear to be cycles of imports in Eswatini. This can be linked to both variations in actual demand and also errors in reporting. The data was obtained from Comtrade and it is evident that for certain years the dollar value of imports is reported but the quantity is captured as 0. This poses a question as to the reliability of the data. If the data is however accurate a possible link to the pattern is that of cycles related to economic stability although these could not be correlated with economic data for the country. Considering the data from the Eswatini Revenue Authority and presented in the Regional SADC_EAC Market Assessment, on the number of refrigerators imported into Eswatini the trend correlates to the numbers in 2017 – 2020 [10]. It is therefore likely that the data can be trusted but that the quantity was not captured on the system although it was captured in monetary terms.

b) Refrigerant

The Kingdom of Eswatini is a signatory of the Montreal Protocol and has also ratified the Kigali Amendment to the Montreal Protocol. It is committed to meeting the targets set out in these agreements. Eswatini aims to completely phase out ozone depleting substances (ODS) by 2030. It has made tremendous progress in this regard. There has been a reduction from 1.02 to 0.32 Ozone Depleting Potential (ODP) tonnes between 2015 and 2019. This is well ahead of the targets that were set by Eswatini for this period [11]

The refrigeration sector is one of the major contributors of this success. In this regard there are two contributing

factors. One is that the local manufacturer, Palfridge, has committed to reducing ODS in its manufacturing and is delivering on this promise and the other is that the majority of the imports of refrigerators are from South Africa, where there is a control of ODS imports. The refrigerators that enter eSwatini are therefore mostly compliant to a great reduction of ODS, with reference to the refrigerants used. The imports from South Africa (even of refrigerators that are not manufactured in South Africa but are imported from further abroad) and the refrigerators manufactured in Eswatini generally use the R600a refrigerant. The R600a (iso-butane) refrigerant is not ozone depleting and has a very low global warming potential. This refrigerant was found in the 40% of the refrigerators seen during the surveys. R134a was found in 41% of the refrigerators and was generally aligned to the older makes. The results of the surveys of the households provided an insight into the types of refrigerants used in the refrigerators in Eswatini and are shown in **Error! Reference source not found.** below.

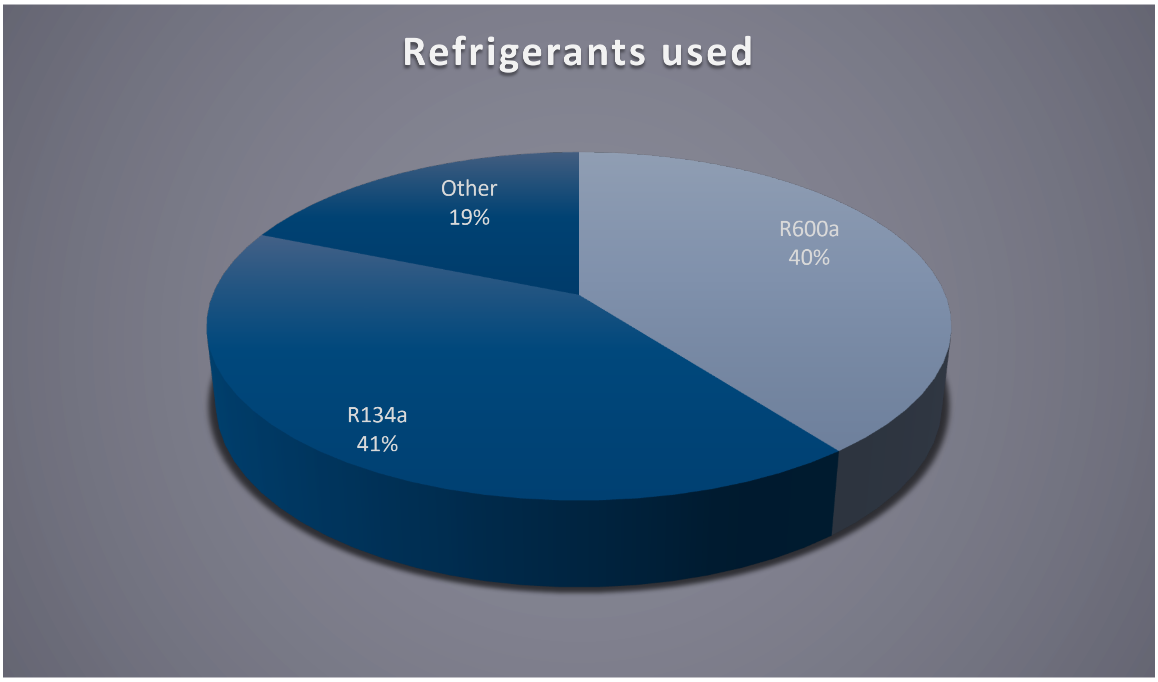


Figure 4-4 Types of refrigerants used in Eswatini

4.1.4 BEST-SELLING EQUIPMENT

a) Brands

Top selling refrigerator brands in Eswatini were identified from the data obtained in the market assessment surveys. The data obtained from retailers obviously relates to new refrigerators, whereas the household surveys point to trends of second-hand refrigerators and as such household data identifies historical trends related to brand preference rather than the current trends seen at the retailers. The retailer data is hence more reliable and current in portraying brand preference. The major brands on sale in eSwatini include:

- KIC (35%)
- Defy (23%)
- Kelvinator
- Hisense

Some of the other popular brands include:

- LG
- Russel Hobbs

b) Refrigerator Type

By far the most popular type of refrigerator in Eswatini is the fridge/freezer combination. In the case of freezer units, they are almost exclusively chest freezers. The chest freezers are typically popular with small shops that operate from houses and store perishables within them. These small/micro shops utilise household freezers for this purpose and are thus included in this survey. The remaining refrigerators are almost exclusively the double door fridge/freezer combination units (typically with the freezer at the bottom). In some households there are also single door refrigerators, but these are rare. The results of the types of refrigerators encountered in households within the survey are shown in **Error! Reference source not found.** below.

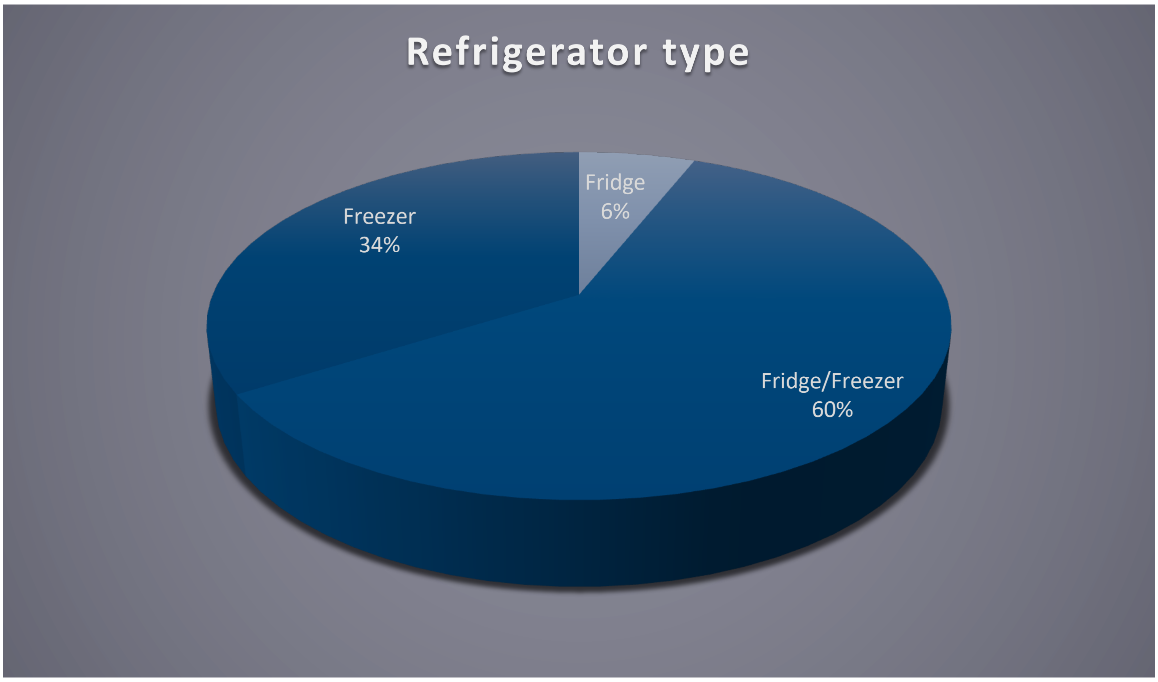


Figure 4-5 Refrigerator type

It is also important to note that there is a greater variety of refrigerators in stores than what was found during household surveys. The new side-by-side four or two door refrigerators with larger capacities are available in the market. They are significantly more expensive and are thus still very rare in households. These refrigerators are included in some of the capacity and pricing calculations below as they are entering the market at the moment.

c) Defrosting technology

The majority of refrigerators in Eswatini are either manually cooled (direct cool) or have auto defrost (frost fee) technology. Where information was given, it was found that the majority of the older refrigerators within households have direct cooling (manual cooling) and the majority of the newer refrigerators in the shops have auto defrost. This is however not exclusive at all and there are still a number of new refrigerators with manual cooling.

From the household surveys the split of defrost technology is shown in Figure 4-6 below.

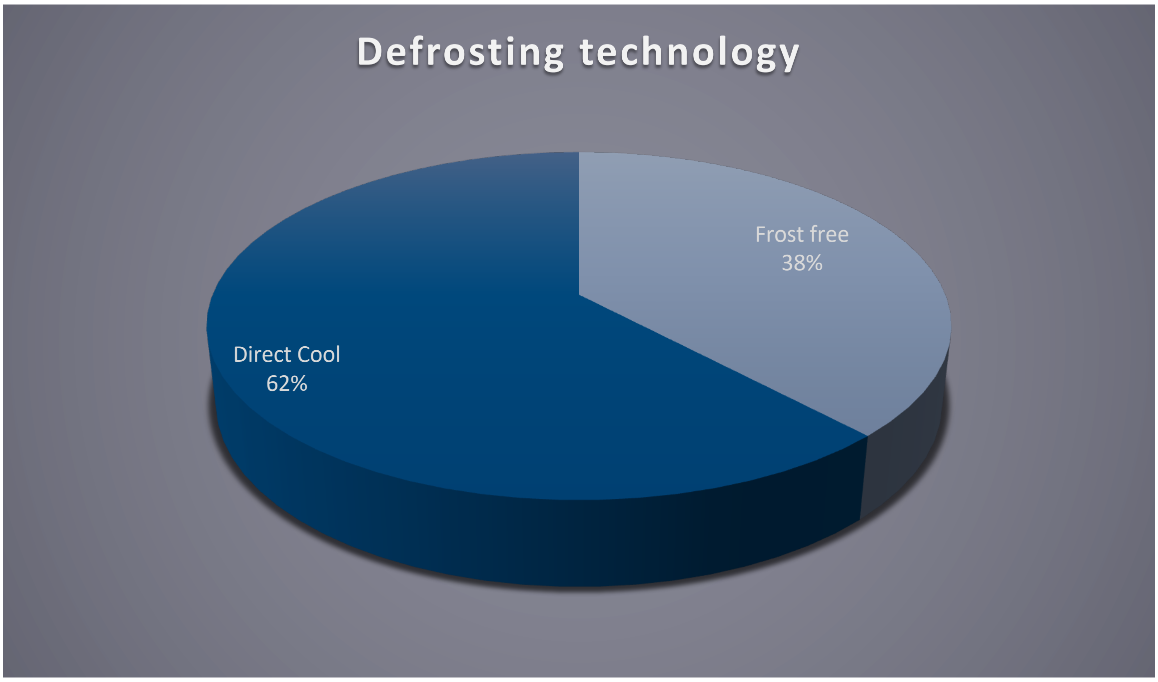


Figure 4-6 Defrosting Technology

d) Capacity

The capacity of refrigerators available at the retailers varies greatly. However, there are trends that can be gathered from the research. The most popular type of refrigerator is the fridge/freezer combination set. The typical capacity of these refrigerators is between 160 litres to 320 litres. The most common capacity is in the region of 260 litres. The chest freezers are typically between a 200 litre and 500 litre capacity. The most common capacity is in the region of 250 litres. The breakdown of refrigerator capacity averages per type of refrigerator (for the most common refrigerator types sold at retailers) are shown in Figure 4-7 below.

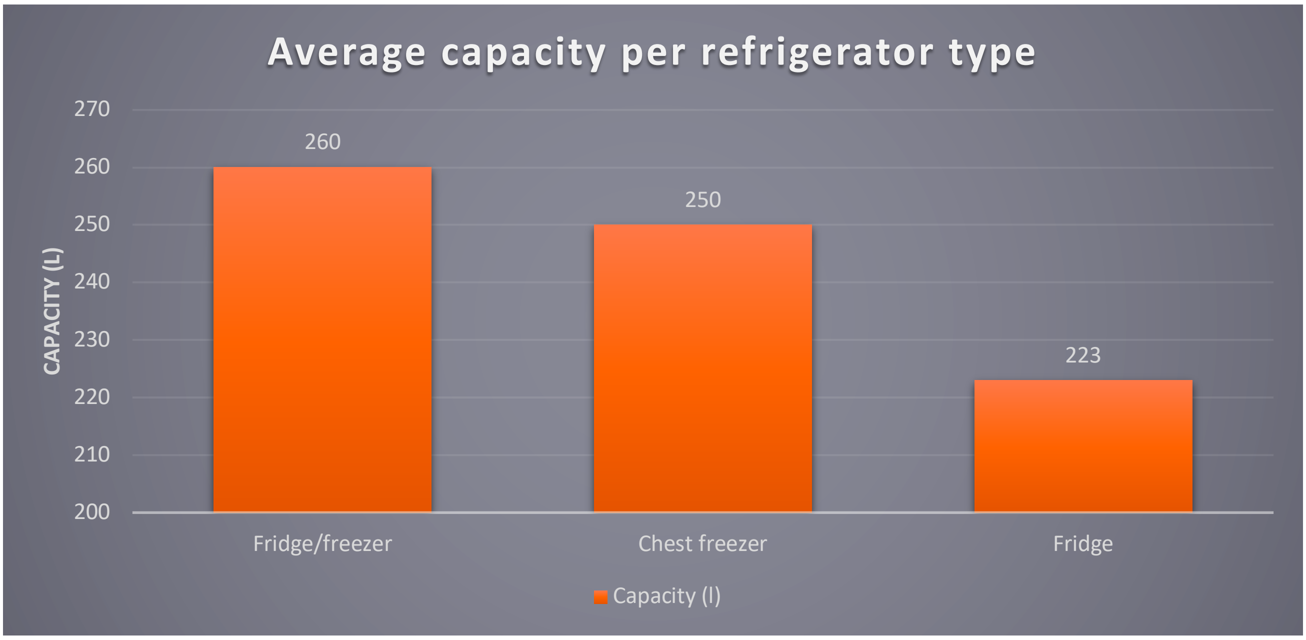


Figure 4-7 Capacity per refrigerator type

e) Price Analysis

Price data of refrigerators was collected from both retailers and households. The average price of the refrigerators purchased by households interviewed in the surveys is EL4 678 = $298. Given that the average volume of refrigerators can also be calculated an average value of cost per volume can be calculated. If one considers the average volume of a fridge/freezer at 260 litres the average price per volume at the retailers is $1.15/litre. The data from the retailers is more accurate as it is more current. The data reived from households is provided for refrigerators that were purchased several years ago. It must be stressed that the prices from households are purchase prices and that they are not adjusted for time value of money. Therefore, the price from the retailers is immediate and is aligned with the prices of all refrigerator types at the same point in time and with the latest technology (depending on refrigerator type of course). From the retailer surveys and store visits, it was evident that the price of refrigerators is dependent on several factors, including volume, functionality, design, brand and energy efficiency. From the discussions with the manufacturer Palfridge, it was explained that the manufacture of more energy efficiency refrigerators in general simply means using better materials. The better insulation, better sealing, better materials used result in lower losses and greater efficiency. Therefore, there is a direct cost increase with the increasing energy efficiency of refrigerators, and this was also evident in the investigation into the retailer prices. The prices from the retailers showed an increase of approximately 8% - 10% for an increase of one to two energy ratings (based on the South African energy label). This is shown in Figure 4.8 below. It is of course very difficult to get an exact price correlation for this metric as the refrigerators that are compared are not exactly the same, i.e., there are no two refrigerators in the market with exactly the same features but with the only difference being energy efficiency. More energy efficient refrigerators tend to have additional features or more modern designs as they are higher quality products, and this often adds to the price.

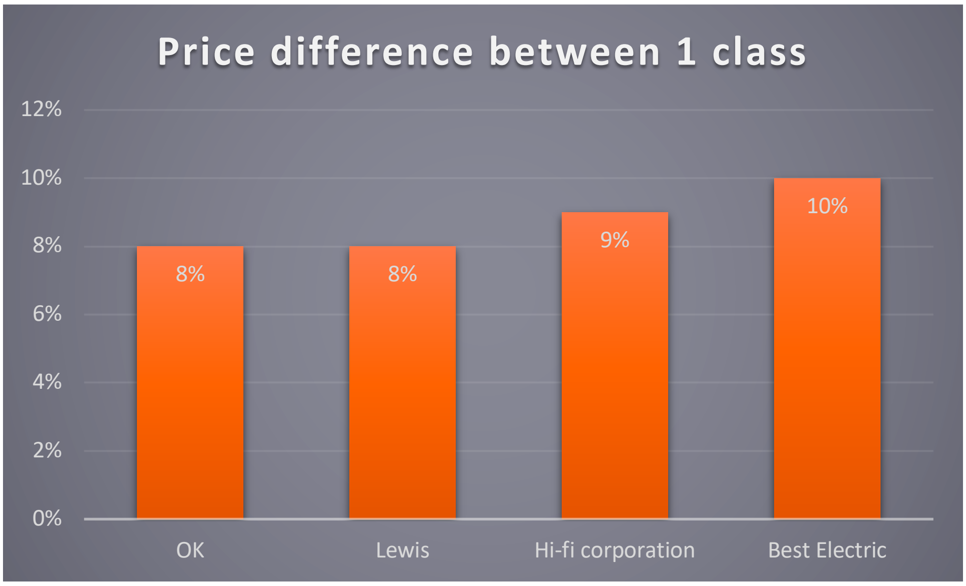


Figure 4-8 Average price increase for increase in energy efficiency class (as per RSA energy label)

f) Energy Consumption/Energy efficiency

There is no energy labelling scheme for refrigerators in eSwatini at present. An energy efficiency labelling scheme does exist in South Africa for refrigerators and thus the majority of those imports do reach Eswatini with a South African energy label. Additionally, the one local manufacturer (Palfridge) has the majority of its market based in South Africa. As such it complies with the South African mandatory energy efficiency requirements and also manufactures the majority of its refrigerators according to the same requirements. The South African regulations are based on testing to IEC 62552:2007. Palfridge therefore performs its testing at its own, accredited laboratory to the methods outlined in IEC 62552:2007. The proposed regional standard is based on the updated version, namely the IEC 62552:2015 standard. The testing methodology is different and comparison of results from one version to the next is not direct. Therefore, if the move towards the latest version of the IEC standard is implemented the testing at Palfridge would need to be updated. In the interview with Palfridge they indicated that the laboratory is capable of testing to IEC 62552:2015 but that it is not accredited to this standard. Additionally, this is the only laboratory in the region capable of testing to IEC 62552:2015 as the South African laboratory is not capable of such testing at present.

It was very interesting to note that the vast majority of the retailer respondents (88%) answered that energy efficiency is one of the most significant factors affecting selection of refrigerator purchases. This is quite different to the responses from the consumers, as discussed later in this chapter, in section 4.2. 90% of retailers also indicated that they felt that energy efficient technology would be one of the key factors driving customer satisfaction related to refrigerator purchases in the future. 52% of them also agreed that an environmentally friendly refrigerant with a reduced negative effect on ozonosphere would be one of the key driving factors affecting refrigerator purchases in the future. The reasons for this difference could be that the store managers (the majority of the retailer respondents) have had training on energy efficiency from their organisation.

Therefore, they have a better understanding of their importance. Additionally, they are aware of the technology that is planned in the near future from their suppliers and thus have an understanding of their importance in the future product offerings of the various manufacturers. There is an understanding from some of the retailer managers that in the future the only options will be energy efficient refrigerators and of course that only environmentally friendly refrigerants can be used,

Energy consumption of refrigerators available at retailers in Eswatini varies greatly. However, there are trends and averages that can be extracted from the data. The average annual energy consumption of refrigerator/freezer combination sets is 306 kWh/year and the average annual energy consumption of freezers is 411 kWh/year. This is also backed by the data showing that the energy rating of fridge/freezer combination sets at the retailers is typically A or A+ and the energy rating of chest freezers is A or B, as per the South African energy label. From discussions with the retailers, it was uncovered that chest freezers are not seen as front of the house appliances and as such their design and additional features are not as important as price and reliability/durability. Refrigerators are however more visible and hence design and additional features such as water dispensers and higher energy efficiencies are more important.

It has also been evident in the recent online brochures and refrigerator advertising that retailers have started highlighting the energy efficiency of the refrigerators. This is now presented with volume and other features of the refrigerator as a distinguishing factor. It is definitely a positive step and one that can be expanded on by a customer awareness campaign. The retailers can be trained on how to portray the energy efficiency savings over the lifetime of the product into a monetary figure that would drive the purchases of more efficient refrigerators.

4.1.5 BARRIERS TO THE SALE OF EFFICIENT RESIDENTIAL REFRIGERATORS

Eswatini falls into a lower middle-class country. As such there are large number of households that have very little disposable income. It must be stressed that none of the households were willing to disclose their annual income. Without this information it is difficult to ascertain their disposable income accurately but from conversations with stakeholders from Eswatini the general consensus is that the disposable income is in the region of 200 – 300 USD per month. This is related to upper middle-class persons and therefore a disposable income of 100 USD or less is probable for lower income and middle to lower income households. Even though this is the case refrigerators are seen as key appliances and are present in almost all households. However, the lack of large amounts of disposable income mean that the refrigerator market is extremely price sensitive. It is evident from the research that the higher the energy efficiency of refrigerators the higher their price. This was confirmed by the local manufacturer in Eswatini (Palfridge). Palfridge indicated that they use better insulation and sealing materials for more energy efficient refrigerators. The cost of manufacturing increases for more energy efficient refrigerators. Palfridge indicated that this increase in manufacturing cost is in the region of 15% to 20% when moving up 2 classes as per the South African energy label (of course this varies with the size of the refrigerator, design, other functionality/features, etc.). In the stores however the price increase is often reduced due to market competition. At times it is also masked by additional features added to the refrigerator. As mentioned, energy efficient refrigerators are seen as the top of the market and they have additional features, making them more expensive.

Additionally, it was found that the store sales personnel were not knowledgeable in the field of energy efficiency. The sales personnel indicated that they had an understanding that a higher rating on the energy label meant that the refrigerator was more efficient but that they did not know how to quantify that and how to interpret the differences accurately. As such it is difficult to relay the information to the customers and therefore the general consensus amongst sales personnel was that they would not mention energy efficiency unless prompted by the customer. There is thus a definite lack of training and awareness on the part of the sales personnel. Additionally, they were definitely unable to quantify the energy savings to a customer and project savings over the lifetime of the refrigerator. This is important as the public awareness campaign needs to be addressed to both the consumers and the retailers. What is not known at this stage is why the top management of the retailers did not implement training programmes for its sales personnel related to energy efficiency. The response from the store managers was that the most important purchasing decision for consumers was price and that discussions on energy efficiency would only make the refrigerator appear more expensive and less desirable. This is definitely a mindset that can be addressed through awareness campaigns and with comprehensive information on the cost of owning a refrigerator over its product lifetime.

4.2 REFRIGERATOR DEMAND-HOUSEHOLDS

4.2.1 GENERAL HOUSEHOLD INFORMATION

The average household size in Eswatini has been decreasing steadily. It was at 9.52 in 1997 and in 2020 it stands at 5.84 [12]. This is a significant drop and given that in the same time the Eswatini population has increased from 963 426 people to close to 1.2 million it means that there are more people living in more households. Therefore, this results in a larger number of refrigerators. As reported in [10] in the 2017 census in Eswatini there were 143 827 refrigerators in use in households. The U4E estimate is that by 2030 Eswatini will have approximately 240 000 refrigerators [10]. During the surveys conducted the average number of household occupants was 2.85. Therefore, it is likely that the average household size in Eswatini is decreasing further. This would imply that in the demand for refrigerators is expected to grow in the future.

All of the respondents that were interviewed indicated that they are employed at the moment. The employment ranges from self-employed entrepreneurs to professionals with a wide variety of professions. The current official unemployment rate in Eswatini is 23.40%. This figure has been between 22% and 24% for the last 5 years [13] However, this could also indicate that the number of respondents in surveys are officially unemployed but are self-employed in the informal sector as traders, etc. This is common in southern Africa. The respondents did not want to indicate their monthly earning. Not one of the respondents indicated this figure. However, the interviewers did note whether the respondents were in a lower, middle or upper income class. Regardless of income class however, the refrigerator was present in the households, and this would be an indication that there is enough disposable income for refrigerators as they are seen as one of the key household appliances.

4.2.2 LEVEL OF FINANCIAL INCLUSION

Only 9% of the respondents indicated that they did not own a bank account. This is refreshing because it means that the majority of the population have access to loans that could be used to purchase refrigerators and to possible financial support for more energy efficient appliances. This is because having a bank account often provides you access with a loan from that particular bank. However, even if one is unable to obtain a loan from the bank there are numerous loan agencies that are willing to provide loans to persons that have bank accounts. Out of the respondents 52% indicated that they had never taken a loan. Furthermore, 68% indicated that they had purchased the refrigerator for cash without any financial support. This again shows that the population has access to banks and there is a potential for financial support of energy efficient appliances. The following banks operate and are licensed in Eswatini:

- Standard Bank
- Nedbank
- FNB
- eSwatini Bank
- eSwatini Building Society
- Swazi Bank

The first three banks on the list above are South African with branches in Eswatini and the last three banks are local Eswatini banks. The banks also operate under the regulatory function and license provided by the Central Bank of Eswatini. This is important as the opportunity for funding for energy efficient refrigerators can be agreed upon with all banks with the support of the Central Bank and would mean that 90% of the potential buyers would have access to these loans, as explained in the paragraph above.

4.2.3 CURRENT EXPENDITURE ON ELECTRICITY

The distribution of electricity in Eswatini is done by the Eswatini Electricity Company (EEC). It is the state-owned company that performs the generation, transmission and distribution functions and operates as a monopoly within the country. It also imports a significant amount of its electrical energy needs from South Africa. From the household data collected the majority of the households (51%) pay between USD 6 and USD 13 per month for electricity. It was previously outlined that no responses were received as to the income and disposable income of respondents. However, from certain discussions with national stakeholders in the middle to upper classes a disposable income of USD 200 per month is common and disposable income of USD 100 is common for middle to lower classes and it can be much lower for the poor. Also, it is important to consider that this is the disposable income per family and therefore considering the average household size of almost 6 persons once can see that the amount spent on electricity is significant. The size of the households influences the electricity charges. In **Error! Reference source not found.** below is the breakdown of the percentages of households that fall within the various electricity payment brackets. The rate below is in Eswatini Lilangeni with the exchange rate currently at E15.75 = 1 USD.

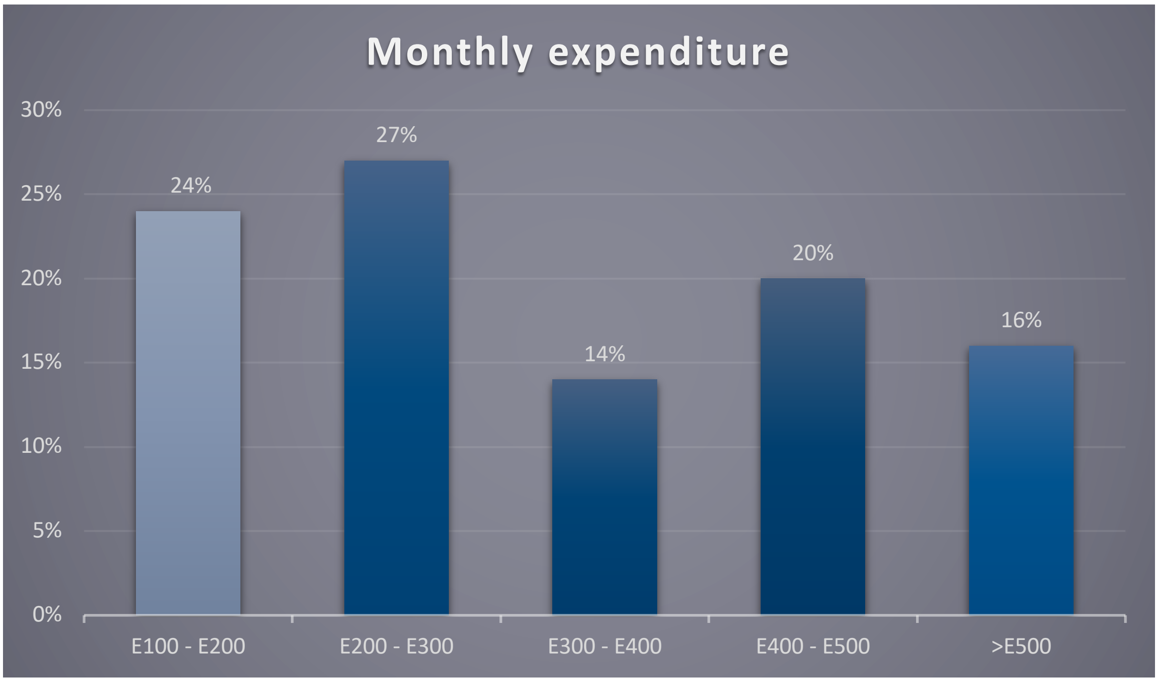


Figure 4-9 Breakdown of electricity monthly payments per household

The electricity payment methods in Eswatini are generally still traditional and payments are made on a monthly basis through invoicing from the EEC. However, electricity prepaid meters have been introduced in recent history. The prepaid electricity meter project rollout started in 2008 and has had limited success. Currently less than 20% of the respondents have prepaid electricity meters and the figure is similar in the remainder of Eswatini.

4.2.4 OWNERSHIP OF REFRIGERATING EQUIPMENT

a) Type

The majority of the refrigerators owned were of the fridge/freezer combination. In addition, there is also a large number of chest freezers. The other types of refrigerators are rare and are comprised of stand-alone fridges. **Error! Reference source not found.** below shows the breakdown of the types of refrigerators owned.

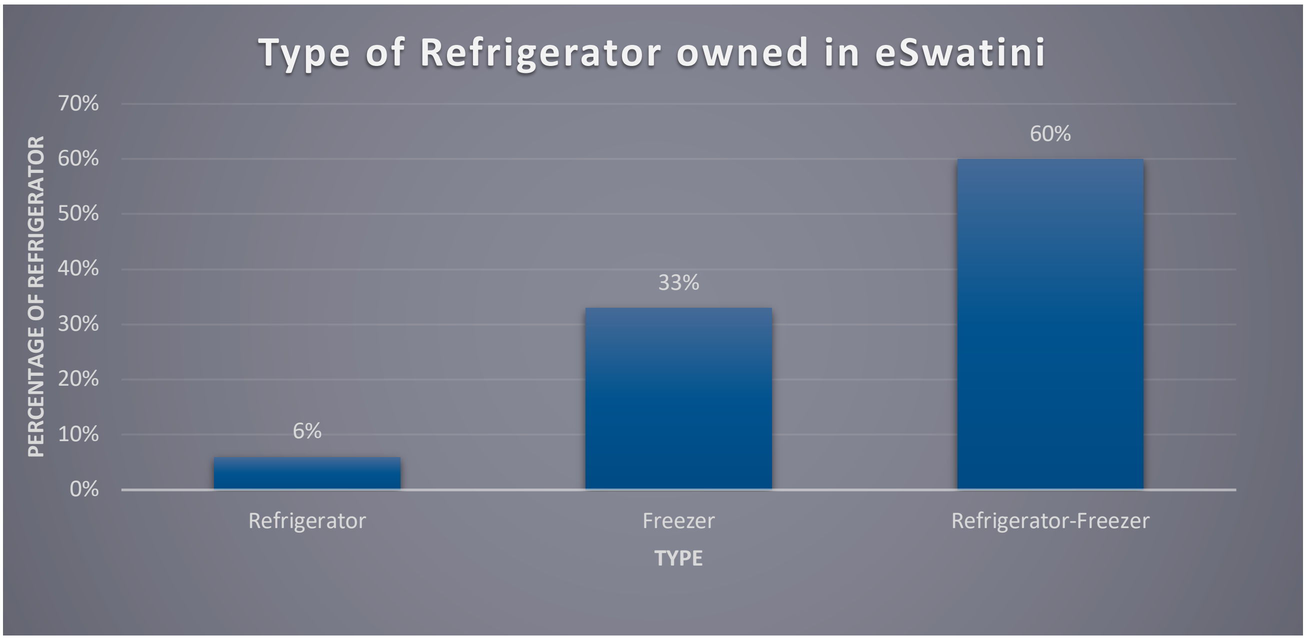


Figure 4-10 Breakdown of ownership in eSwatini per refrigerator type

b) Capacity

The capacity of the current refrigerators in Eswatini (both currently in the shops and in households) is presented in **Error! Reference source not found.** below.

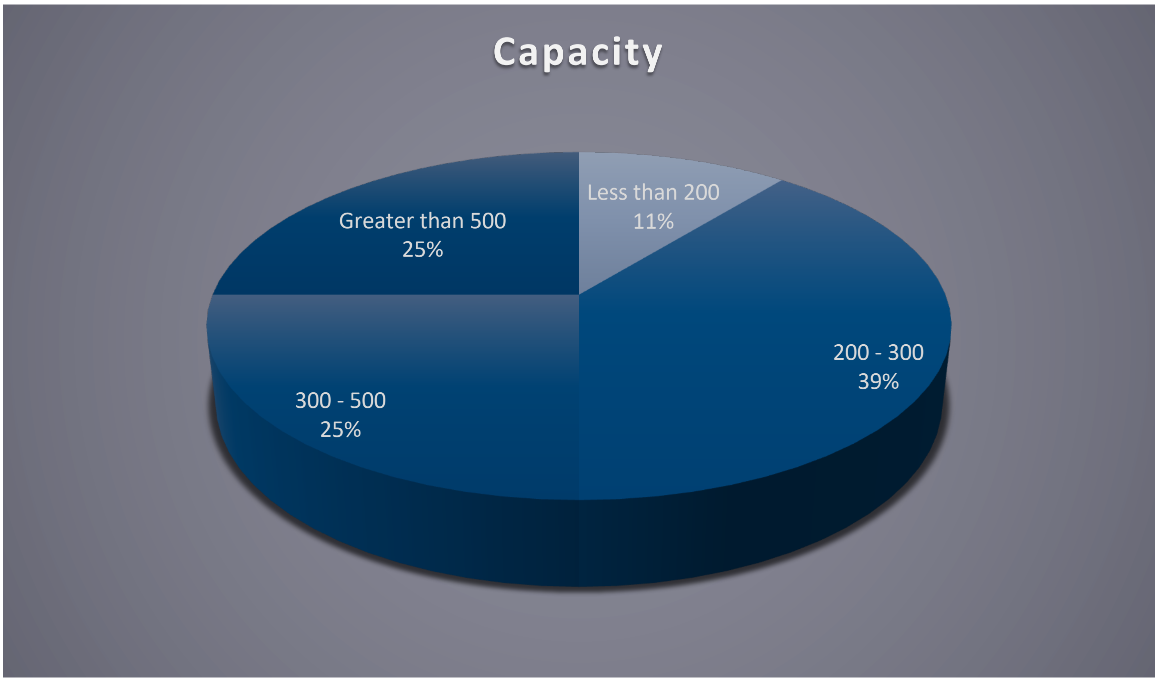


Figure 4-11 Market share of various refrigerator capacities

As can be seen from the figure above 64% of the refrigerators have capacity between 200 and 500 litres. The capacities indicated above include the combined capacity of the fridge/freezer combination. Therefore, it is evident that there are very few side by side door refrigerators and other large refrigerator varieties. This is typical in the majority of households in the region and aligns with the average household income in Eswatini and the region. Typically, the average household has a medium to lower income and thus a single refrigerator, most commonly being a fridge/freezer combination set is used as it is the most cost effective for the purpose.

The capacity or the refrigerators varies based on type. However, there are typical capacities of the various types that were discovered during the surveys.

- The fridges were in the range of 80 to 150 litres.
- The majority (81%) of the chest freezers were in the 200 litre to 350 litre range.
- The majority (70%) of the fridge/freezer combination sets were in the range of 200 to 400 litre capacity.

c) Technology

It was found that the majority of the refrigerator units in households still have manual defrost technology. However, the newer units tend to have the auto-defrost technology. The gap is not that wide though as almost 40% of the units surveyed have auto-defrost technology.

Error! Reference source not found. below shows the breakdown between manual cooling and auto defrost. Additionally, it is noted that no automatic ice makers were found in the questionnaires amongst the households.

These are available in shops in small quantities, but none have been found during the surveys (in either rural or urban regions).

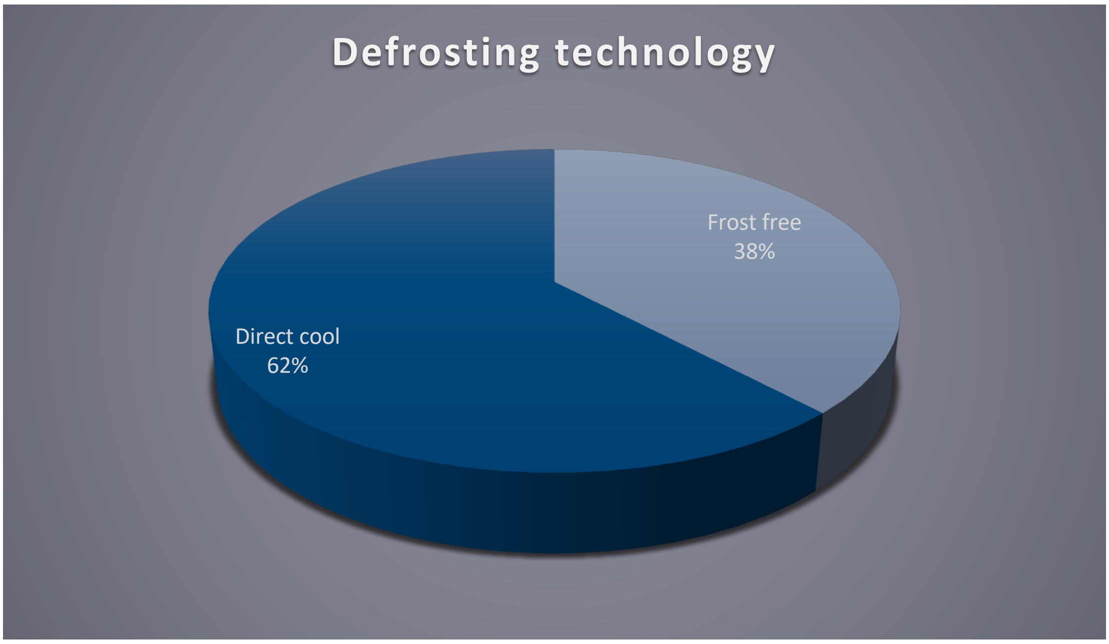


Figure 4-12 Defrosting technology found during the survey

d) Refrigerant

The majority of the refrigerants in the newer refrigerators in Lesotho were of the R600a type. This is partly as a result of the refrigerators being imported from South Africa and through South Africa and the R600a being prevalent in most refrigerators used in South Africa. The older refrigerators had R134a refrigerants in them which led to the higher percentage of this refrigerant (also see **Error! Reference source not found.**) and there were other refrigerants that were also discovered, such as the C-Pentane but these were rare. The R600a refrigerant was found in 40% of the refrigerators seen during the surveys. R134a was found in 42% of the refrigerators and was generally aligned to the older makes. The results of the surveys of the households provided an insight into the types of refrigerants used in the refrigerators in Eswatini and are shown in Figure 4-13 below.

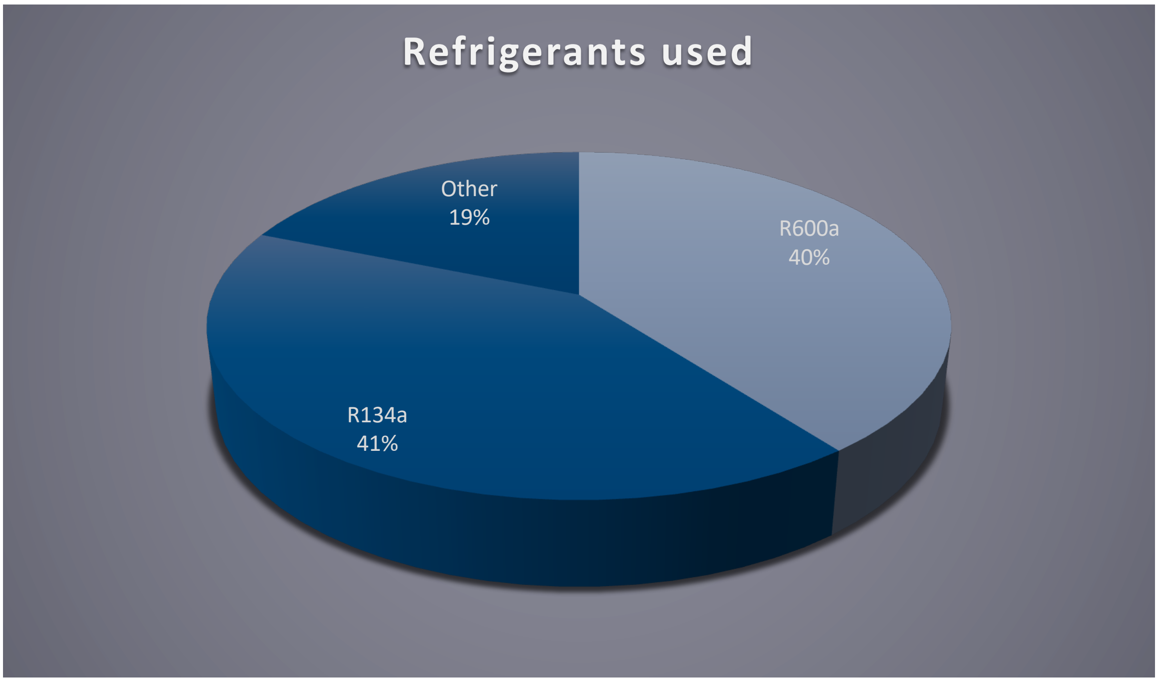


Figure 4-13 Types of refrigerants used in Eswatini

e) Typical Age & Purchased New/Second-Hand

The majority of the households surveyed indicated that they purchased new refrigerators. This is shown in **Error! Reference source not found.** below.

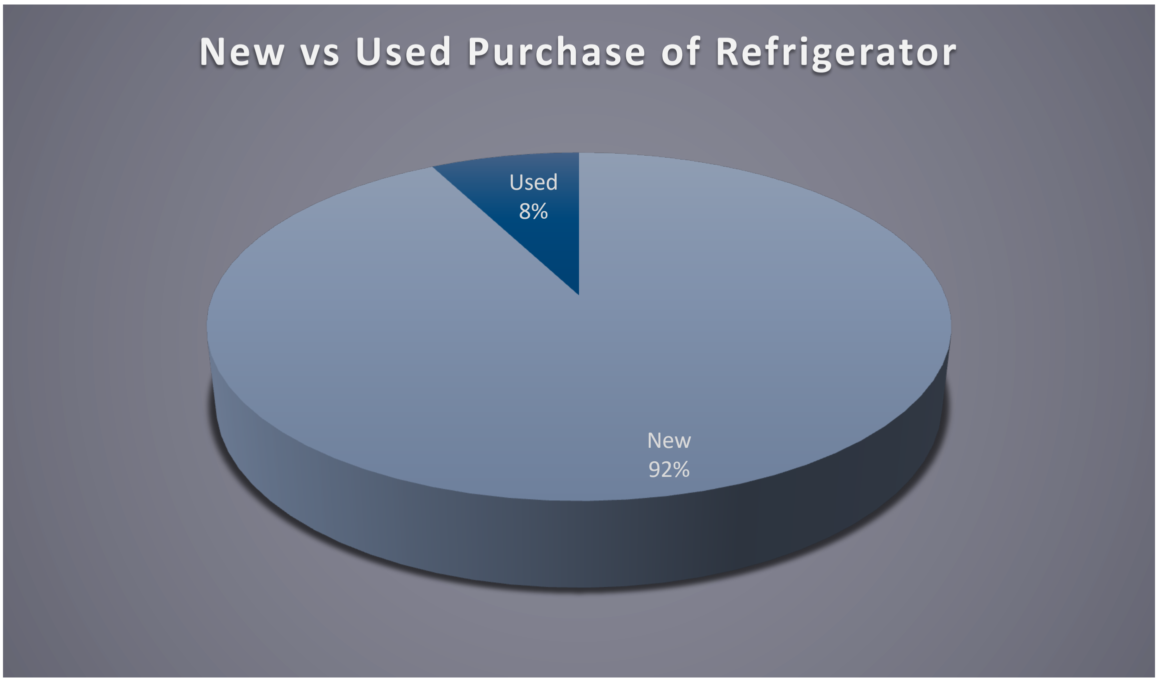


Figure 4-14 New vs used purchase of refrigerators

Furthermore, the age of the most common range of refrigerators was greater than 10. This is shown in **Error! Reference source not found.** below.

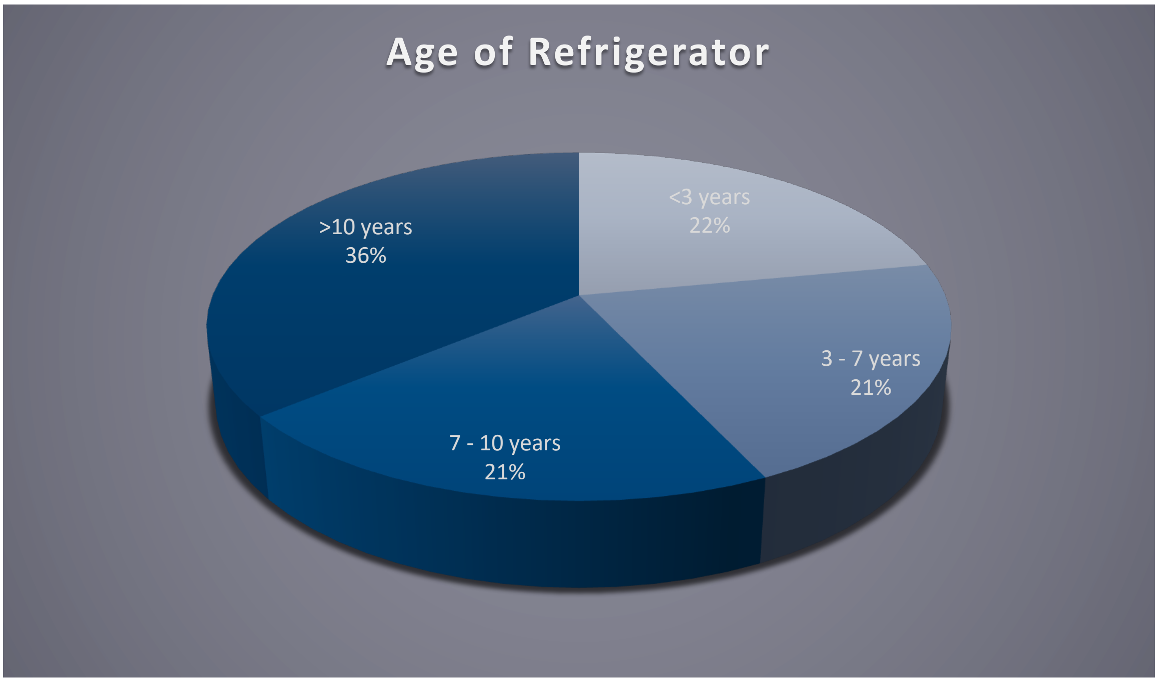


Figure 4-15 Age of refrigerators gathered from the surveys

f) Purchase price and purchase channel

The purchase price did vary based on the age of the refrigerator. Additionally, some of the refrigerators were purchased second hand and as such the purchase price can be skewed. From the surveys conducted 8% of the respondents indicated that they purchased their refrigerator units second hand. The purchase prices varied from less than E3,000 with 33% of fridges to greater than E10,000 with only 4% of fridges. The majority of the refrigerators were however purchased for E3,000 – E10,000. The price also depends primarily on the volume as previously discussed. The price breakdown in presented in Figure 4-16 below.

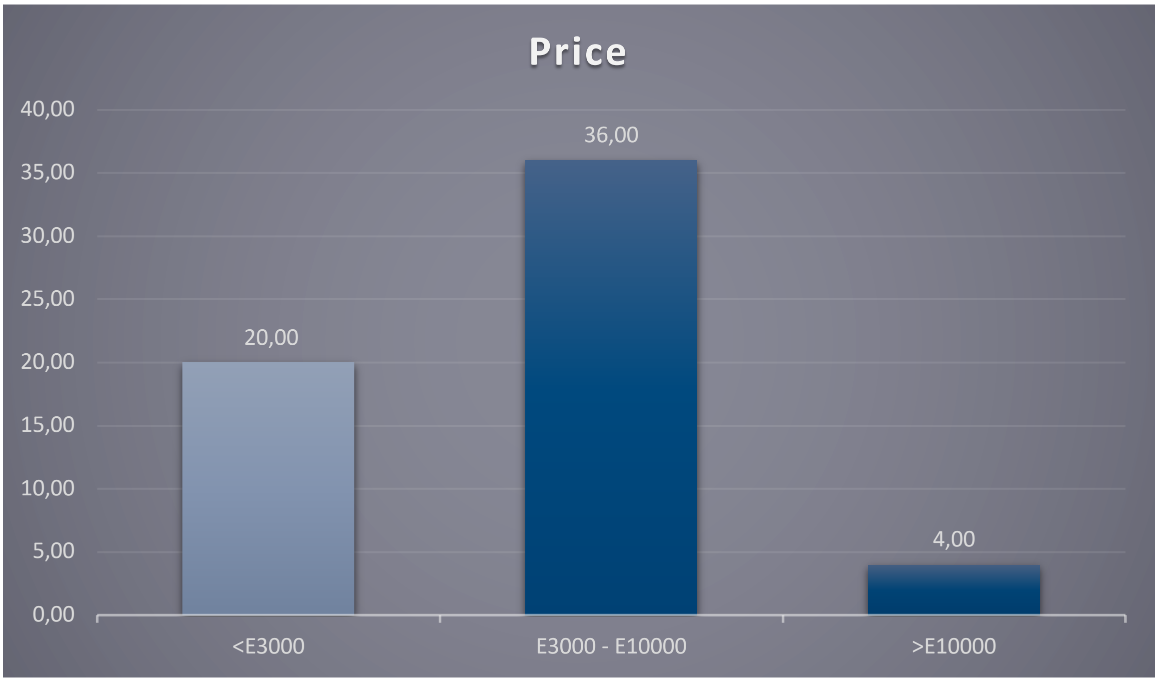


Figure 4-16 Price of refrigerators per type and volume from households

Also, there were no respondent who indicated that they purchased their refrigerators online. This is a possible functionality in Eswatini, but the respondent indicated that they preferred to see and touch the refrigerator before making such a large and important purchase for their household. As indicated in the retailers' analysis the price of more energy efficient refrigerators increases. As can be seen in the breakdown above of the purchase price the majority of the purchases are not higher than E10,000. Therefore, the increase in price for increased energy efficiency cannot be such that it will drive the purchase price out of the affordability range for purchasers. As mentioned, the majority of Eswatini falls in the lower-middle income class and as such there is not an abundance of disposable income for refrigerator purchases. The disposable income is estimated to be in the range of USD 100 to USD 300 for households per month. Therefore, it is understood that there is an increase in price for more energy efficient refrigerators, but the retailers and the manufacturers also understand that they cannot price the standard refrigerators too high purely due to energy efficiency as the market would not be able to afford this. This is an example of where the market plays a role in setting unofficial price limits. In discussions with Palfridge, the Eswatini manufacturer, this was well understood. They indicated that their cost of production increases by approximately 15% when their efficiency increases but that the same refrigerator is sold for a maximum of 10% higher price due to market affordability and, of course, competition.

The ways in which this can be addressed are either through:

- Financial support of energy efficient refrigerators
- Consumer awareness drive to explain the cost saving over lifetime of a product with higher energy efficiency to consumers

- The regulation specifying an increased energy efficiency rating in terms of MEPS, which would set the baseline and eventually market competition will dictate lower prices

g) **Energy efficiency**

As mentioned, there is no energy label for Eswatini and of course the energy label is not mandatory. However, the majority of the refrigerators arrive from South Africa and as such it was possible to ascertain some of the energy classes from the South African energy labels on the refrigerators. The majority of the information was gathered post survey through the analysis of model types on the internet. The energy consumption typically followed the volume/capacity of the refrigerator.

It was found that for the fridge/freezer combination sets the average kWh per year per litre of consumption was 1.09 kWh/year/l for the chest freezers this value was higher, at 1.27 kWh/year/l. The concerning finding from the surveys conducted was that the majority of consumers did not find energy efficiency an important factor when choosing a refrigerator. In fact, 72.5% indicated that it is not a consideration at all when in the market for a new refrigerator. The probable reason for this is the lack of understanding of the savings that a more energy efficient unit would bring to the household. An indicator of this is that the price was the 3rd most important factor behind quality and capacity. Therefore, a reasonable inference would be that if consumers were aware that they would in fact save money on an energy efficient refrigerator over the lifetime of the project it would become a much more important factor during purchases.

There are indications however that the perception towards energy efficient refrigerators is changing. The retailers seem to believe that it will be one of the key purchasing factors in the future and with the correct financial support mechanisms to assist with the initial increased cost of the appliance and the correct awareness of the benefits of energy efficient refrigerators real changes could be implemented relatively quickly.

4.2.5 DESIRED FEATURES OF EQUIPMENT

As part of the household questionnaire the respondents were asked to rate certain factors that would influence their decisions when purchasing refrigerators. The following factors were listed:

- Price of the equipment
- Warranty
- Look/Design/colour
- Functional/Practical
- Energy consumption
- Access to financing
- Capacity / size
- Brand

- Quality
- Recommendation from people you know
- Availability of transport, installation and maintenance services

The respondents were asked to rate the importance of these factors from high, medium, low or none (not important at all). The following were the most important factors based on the surveys conducted (listed in order of importance):

- Quality
- Capacity

- Price
- Brand
- Availability of transport, installation and maintenance services

The details of the responses are shown in Table 4 - 1 below.

Table 4-1 Ranking of desired features

Desired Features	TOTAL			
Importance	**None**	**Low**	**Medium**	**High**
Quality	0%	6%	18%	76%
Capacity/size	2%	0%	29%	69%
Price	0%	16%	24%	61%
Brand	2%	16%	27%	55%
Availability of Transport, installation and maintenance services	0%	4%	41%	55%
Warranty	0%	12%	37%	51%
Functional/Practical	2%	2%	51%	45%
Look/Design/Colour	4%	31%	25%	39%
Energy consumption	73%	6%	10%	12%
Access to Financing	16%	29%	43%	12%
Recommendation from people you know	14%	29%	51%	6%
Other (Specify)	0%	0%	0%	0%

The respondents were asked to rate the importance of features to them as per not important at all (none), low, medium or high. Table 1 indicates the percentage of respondents that indicated various aspects as the most important or least important. It can therefore be seen that quality scored the highest with 76% of respondents indicating it as a high desired feature. Energy consumption was chosen as a high desired feature by only 12% of respondents. This is a worrying scenario but one that leaves room for improvement.

The respondents were also asked whether they would be willing to pay more for energy efficient refrigerators. The responses in terms of percentage of respondents who would be willing to pay more and the increase in the buying price in terms of percentage that they would be willing to spend is shown in Table 4 - 2.

Table 4-2 Willingness to pay more for energy efficient refrigerators

Extent to which you can pay extra for an energy-efficient refrigerator:	% of respondents
No	18%
Yes (up to 10% of Average cost)	20%
Yes (20-40% above average cost)	39%
Yes (above 40% of average cost)	24%

4.2.6 CONSUMER PREFERENCE ON PURCHASE OF A REFRIGERATOR

The overwhelming majority of the respondents in Eswatini indicated that they would prefer to own the refrigerator at the time of their next purchase. The majority of respondents who preferred loaning their next refrigerators were the small shop owners who would want to pay for the refrigerator (typically a chest freezer) over time as the business generates revenue and profit. The outcome of this question is presented in **Error! Reference source not found.** below.

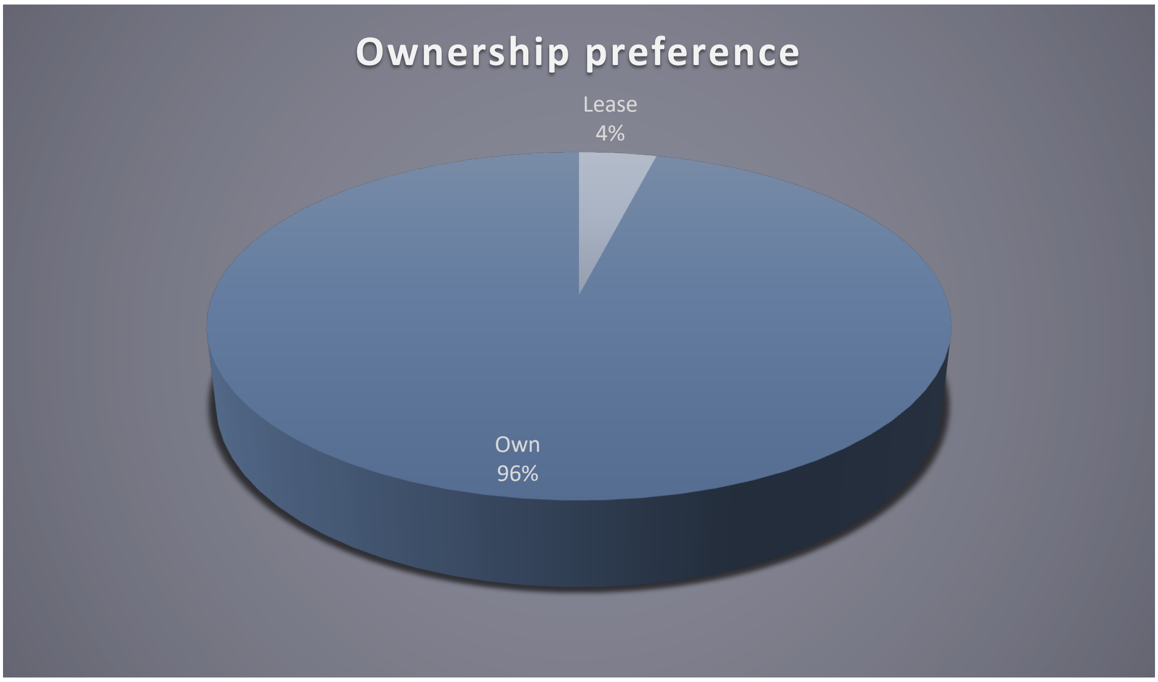


Figure 4-17 Preference of purchase of next refrigerator

4.2.7 BARRIERS TO THE PURCHASE OF EFFICIENT REFRIGERATORS

The GDP per capita in Eswatini was USD 3 416 in 2020. This puts Eswatini into the lower-middle income country as per the world bank definition/categorisation. Therefore, the cost of the refrigerator is one of the main purchase decision drivers. It was also noted from the questionnaires that a substantial part of the respondents indicated that they would be willing to pay more for a more efficient refrigerator (shown in **Error! Reference source not found.**). The price increase for a more efficient model of refrigerator is in the region of 8% - 12%. This is obtained from pricing at the retailers. However, the price increase is difficult to gauge directly because refrigerators that have higher energy efficiencies often also have additional features, such as water dispensers, etc.

However, this is also linked to the lack of awareness campaigns and the lack of marketing of energy efficiency at the retailers. In recent times the retailers have started indicating the energy efficiency of the refrigerators on some of their sales brochures, but it is important to note that not one of the respondents indicated that they had any knowledge of any energy efficiency standard & labelling policies/schemes. Hence, a well organised and executed awareness campaign would be highly beneficial in Eswatini.

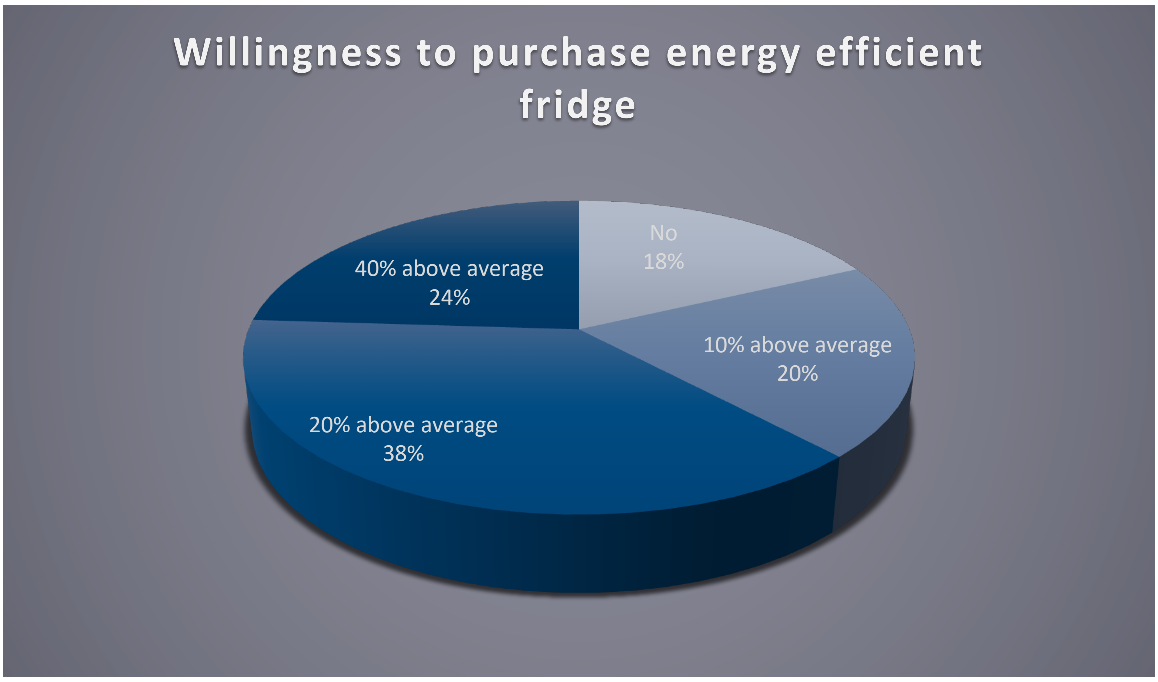


Figure 4-18 Willingness to purchase energy efficient refrigerator

4.3 EQUIPMENT STOCK AND PROJECTIONS

4.3.1 SUMMARY OF RESIDENTIAL REFRIGERATORS IN THE MARKET BASED ON HOUSEHOLD DEMAND

The majority of refrigerator items in stock in Eswatini are of the fridge/freezer combination variety. These are items that are the most in demand and the ones that are also most common in households as indicated in the surveys. There are also a large number of chest freezers and smaller quantities of double door side by side fridges and units with ice dispensers and water dispensers. It is critical to note that the stock information from the retailers was not received at the time of the report. This information gathering has been in process for 9 months. As mentioned, the majority of the retailers in Eswatini are large international corporations based in South Africa. As such they have regional buyers that are in charge of all the stock and provision of refrigerators for the various “regions”, which are actually countries in this case. The regional buyers of various organisations such as the Lews Group (Lewis and Bears stores), OK Furnitures and Massmart (owners of Game and Hi-fi Corporation stores) were located and contacted but no information was provided by them to date. Furthermore, during the visit by the consultant to eSwatini local stores such as Hoageys and Swaziland supply centre were visited, and discussions held with the general managers and owners of these organisations. Again, after further approaches no information has been forthcoming from such entities. Therefore, the information provided in relation to stock at stores is based on physical visits to the retailers and the examinations of stock as well as discussions with store managers. In total 8 retailers and 1 distributor were interviewed. The following entities were interviewed:

- Best Electric – Mbabane
- Lewis – Manzini
- Hi-Fi Corporation – Mbabane
- OK Furnitures – Matata
- Lewis – Matata
- Bradlows – Manzini
- Lynds Distributors
- Hoageys – Mbabane
- Swaziland supply centre – Mbabane

Further information was also gathered through internet searches on the retailers, the types of refrigerators sold, the prices, the energy efficiency levels, etc. Additionally, Comtrade was used to gain an understanding of the imports of refrigerators and exports, as Eswatini does have a local manufacturer. As mentioned, the vast majority of the stock on the shelves was imported from South Africa and thus carried the South African energy efficiency label. It was found that 68% of the stock (which had an energy label) had an A rating or higher. Additionally, the refrigerants used are typically the R600a in the stock. The local manufacture Palfridge has undergone a process of removing all HCFCs in the insulating foam used in refrigerator manufacturing and have also transitioned to refrigerants that are not potent greenhouse gases. This process has been supported by the Eswatini government, and in particular the UNDP. With this support Palfridge managed to completely eliminate HCFCs and meet the targets set out by the manufacturer and the government (since Palfridge is the only manufacturer of refrigerators in Eswatini) [14]. Therefore, all refrigerators produced in Eswatini are ODS free and have low GWP. The project was supported by the UNDP and some of its partners. UN Environment assisted in the training programmes and the German international development agency (GIZ) provided funding that assisted the move to refrigerants that are not greenhouse gases. The UNDP assisted with the move towards removal of HCFCs in the insulation foam. This shows that there are successfully implemented projects and that coordination through UNDP with willing manufacturers such as Palfridge can be successful.

4.3.2 TECHNOLOGY TRENDS

From the research conducted several trends could be identified. They are listed below.

1. Trends Noted

The following trends have been noted during the market research:

- Energy efficiency is not one of the main purchasing decision drivers when it comes to refrigerators.
- The majority of the refrigerators are the fridge/freezer combo sets
- The majority of households has one refrigerator
- Some micro enterprises (small shops) make use of a refrigerator (typically small chest freezers)
- The majority of new appliances have the R600a refrigerant
- The majority of the refrigerator volume is around the 300 l mark
- None of the respondents was aware of any energy efficiency schemes available
- The majority of respondents indicated that they would not be willing to pay extra for increased energy efficiency

From the trends noted and from discussions with the retailers and households some possible trends that we are likely to see in the future can be identified. These are:

- Solar powered refrigerators (this initiative has already been started by Palfridge)
- Larger refrigerators would be introduced into the market
- More refrigerator sales with ice dispensers and water dispensers in particular

4.3.3 STOCK AND SALES

The refrigerator market in Eswatini is approximately at 35 000 units per year (this is taking into account the number of units imported and the units sold by Palfridge) [15] In the past 3 years there has been a growth of over 12%. This is shown graphically in Figure 4-19 below. Prior to that for 2018, 2017 and 2016 no quantities were reported by eSwatini. There are financial figures reported however and these indicate that a 10% year on year growth estimate is reasonable. If one takes this into account 10 years and using a 10% growth estimate the estimate is that the market size will be 65 487 units by 2030. There is thus a clear growth in the number of refrigerators in Eswatini and there is also a clear indication that this growth will continue. Additionally, considering the information provided in [10] published in 2015, data is presented as obtained by the Eswatini Revenue Authority (SRA) and this shows a smaller number of refrigerators present in the country, but still a growing trend. One of the possible reasons for this is that not all the varieties of HS codes related to refrigerators are presented in this survey. However, importantly the trend of an increasing number of refrigerators is present in the country.

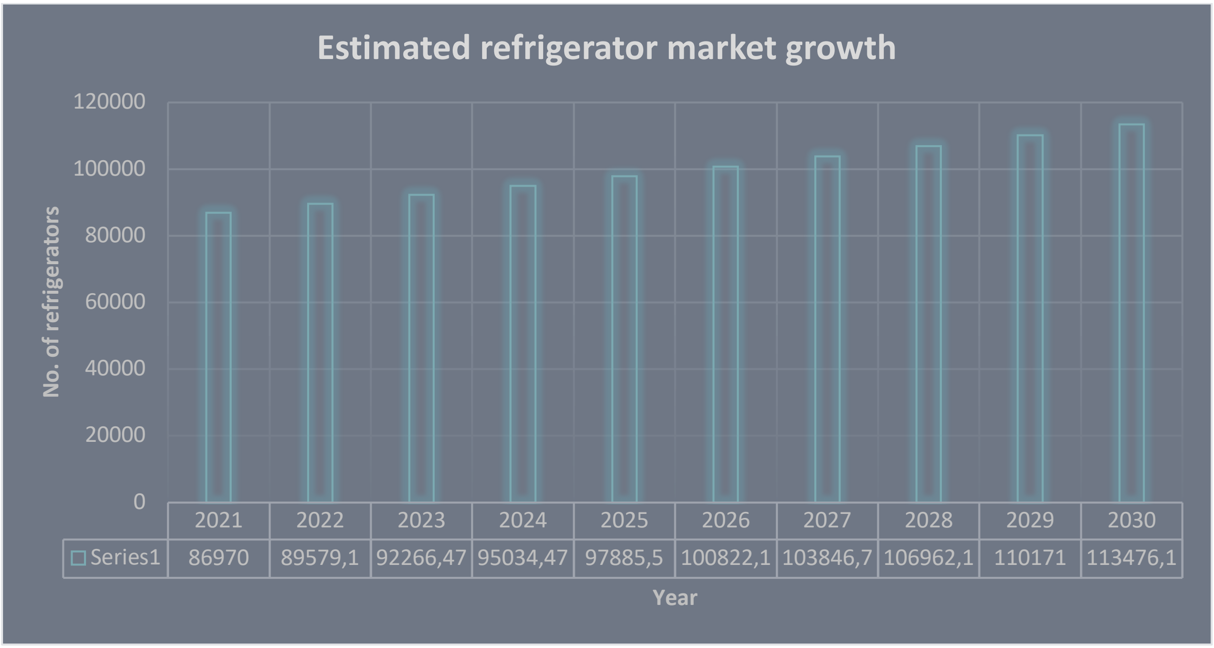


Figure 4-19 Projection of growth of the refrigerator sector (estimated at 3%)

4.4 POLICIES AND PROGRAMME LANDSCAPE

4.4.1 CURRENT AND PLANNED REFRIGERATOR POLICIES AND PROGRAMS

There are currently no energy efficiency policies implemented in Eswatini. There are however numerous policies that have been implemented that are related to the refrigeration sector and that assist in improved efficiency and reduction of ODS. Eswatini has managed to meet and exceed the targets of the Montreal protocol by reducing of HCFC consumption from 1.02 to 0.32 Ozone Depleting Potential (ODP) tonnes between 2015 and 2019, which is 82 percent below the baseline for compliance [11].

This project is part of the greater initiative undertaken by the country to improve its refrigeration impact on the environment. As indicated in its Energy Efficiency and conservation Policy, the government of Eswatini has developed a policy aimed at conserving energy across various economic and industrial sectors and through this policy aims to create a sustainable and growing economy. This policy is also backed by ESERA. As there is a drive for electrification in the country, driven by the MNRE and EEC there is an understanding that the usage of electricity will grow and that the losses associated with inefficient energy consuming appliances will increase. Household refrigerators have been identified as one of the key areas in this. Additionally, the government is aiming to reduce the impact in the services sector apart from managing to reduce impacts in the manufacturing sector. The Eswatini Environmental Authority has also conducted training programmes for refrigeration technicians educating them about the impact of various refrigerants on the environment.

4.4.2 STATUS OF ELECTRONIC-WASTE MANAGEMENT IN THE COUNTRY

There are a number of regulations and initiatives related to electronic waste (e-waste) in Eswatini. Eswatini has the Waste Regulations established in 2000 and the Environmental Management Act of 2002. These documents, together with the Swaziland National Waste Management Strategy all in general stipulate that any person or organisation whose activities generate waste shall collect, segregate and dispose or cause to be disposed of such waste in the manner provided for under the law[16] The Act establishing the Swaziland Environment Authority (SEA) empowers SEA to issue orders and to apply in a court of law compelling any individual or organisation to immediately stop the generation, handling, transportation, storage, or disposal of any waste where such activity presents an imminent and substantial danger to public health, the environment or natural resources.

Additionally, the Southern African Telecommunications Association has issued a guideline for e-waste disposal. These guidelines identify various e-waste sources, including refrigerators, and propose methods of disposing the e-waste.

4.4.3 STAKEHOLDER PERSPECTIVES ON OPPORTUNITIES AND BARRIERS TO TRANSFORM THE MARKET TOWARD MORE ENERGY EFFICIENT AND CLIMATE-FRIENDLY REFRIGERATORS

This project related to energy efficiency of refrigerators and distribution transformers is headed by the Ministry of Natural Resources and Energy as well as the Ministry of Tourism. There is a substantial commitment from the government to proceed with the project. Other key entities that are involved and interested are the Eswatini Standards Authority (SWASA) and the Eswatini Revenue Service (Swaziland Revenue Authority SRA), who will be key in the project development and implementation. Some of the important aspects of the project and opportunities for driving the message of the benefits of energy efficiency within the country are:

- Development of the national standards and accompanying regulations related to energy efficiency
- Development of the national labelling scheme and the associated awareness campaigns
- Development of financial models that can support the implementation of energy efficiency initiatives
- Training of the relevant personnel (whether they be at the SRA or at other public or private organisations).

There has also been interest in the project by the local manufacture Palfridge and one of the local tailers, Hoageys. However, there is a level of reservation regarding the implementation of the project by the government even though they agree with the idea. The relationships with all stakeholders, especially private entities will have to be carefully managed.

4.5 EXISTING FINANCIAL INSTITUTIONS AND FINANCING INSTRUMENTS FOR APPLIANCES

There are currently no obvious finding mechanisms for energy efficient appliance purchases in Eswatini. As could be seen from the market assessment the move towards more energy efficient refrigerators comes at a greater initial investment cost. This is a point that has been acknowledged by the Eswatini government and one that it is keen to address. The financial benefits of increased energy efficiency on the country are clear as it would mean a reduction in electricity imports at inflated prices. As such the government of Eswatini has indicated the following:” The Government shall explore all viable funding mechanisms and identify the most suitable or combination of, taking cognizance the country’s context and the specific needs of the preferred funding mechanisms to promote energy efficiency and conservation” in its ENERGY EFFICIENCY and CONSERVATION POLICY[r].[17]. In this document the government identifies the need for funding mechanisms and outlines certain possible funding mechanisms such as government budget allocation, grants, energy or environment taxes, system public benefit charges, carbon financing, fees for service, donor funding and international development assistance. In terms of international development assistance there are numerous funds from the World Bank, African Development Bank and various other “green” funds that can be tapped into. Investigations into the details of these funding possibilities will be performed during the project. The government has also indicated that the funding mechanism could include small surcharges on fuel or electricity that would support such initiatives through governmental channels.

Currently, however, the funding for purchases of refrigerators typically comes in the form of store credit or bank loans. There are 6 banks operating in Eswatini at present, namely:

- Eswatini Bank
- Nedbank
- Standard Bank
- FNB
- Eswatini Building Society
- Swazi Bank

Three of these (Nedbank, FNB and Standard Bank) are South African banks with representation in Eswatini and the remaining three are local banks. None of these banks offer loans related to energy efficient appliances or any similar funding mechanisms for consumers, apart from standard loans. Furthermore, the majority of respondents indicated that they purchase refrigerators for cash. This is therefore definitely an area that requires further investigation as funding support could be the key to the increase in purchases of energy efficient refrigerators.

4.6 EMBEDDING AND DEPENDENCIES OF THE NATIONAL REFRIGERATOR MARKET IN THE REGIONAL CONTEXT

As mentioned, Eswatini imparts a majority of its refrigeration appliances from South Africa. It also has a local manufacturer, Palfridge. The local manufacturer also exports the majority of its products to South Africa. From discussions with Palfridge over 80% of its market is in South Africa and the rest of southern Africa. From data obtained from local retailers 99% of the refrigerators that they sell are imported and only 1% is sourced locally.

There is thus a great interdependency on South Africa and southern Africa in terms of refrigerator flow. In terms of Eswatini this importance is related to both import and export flows as they have a manufacturer. Therefore, it is critical that there is alignment in the regional context for ease of trade of refrigerators. It was particularly mentioned by Palfridge that a concern would be if the Eswatini energy label and requirements were different from South Africa. This would mean that their exports and products for local markets would need to be manufactured differently and this would greatly increase production costs. Furthermore, Palfridge indicated that their first point of export is South Africa but that from there they have a distribution network that further exports into Botswana, Zimbabwe and other SADC countries. It would therefore be extremely difficult for them to export to these countries through South Africa if all the countries had different labels and different legal requirements related to energy efficiency.

4.7 POSSIBLE IMLPEMENTATION SCENARIOS

Pegasys has used the CLASP tool called MEPSY to develop certain possible implementation scenarios based on the data gathered during the surveys conducted. We would like to thank CLASP for making the tool available for use. The MEPSY tool can be used to estimate the potential impacts and savings of specific policies. This would in turn allow the implementers to assess the impacts of the various policies and make informed choices regarding the selection of implementation plan. The tool evaluates the impact on both the consumers and the country on a national level.

From a consumer point of view the tool takes into account the purchase price of the equipment and also the price of electricity that will be consumed over the lifetime of the appliance in various scenarios (e.g., business as usual, improved energy efficiency).

From a country point of view the tool evaluates the savings in electricity generated and purchased by the country (EEC in particular) through the use of energy efficient appliances going forward (again in varying scenarios from business as usual to improve situations). MEPSY also considers the reduction of CO^2 emissions as a result of a reduction in the usage of electrical energy.

The model that was set up considers the business-as-usual scenario vs the improved scenario with increased energy efficiency and evaluated the difference between projections of the two scenarios.

MEPSY estimates the impacts of implementing policies that improve energy efficiency of new equipment by calculating the difference between a business-as-usual scenario (i.e., no policies implemented) and a policy scenario (i.e., U4E policy scenario). The model uses a bottom-up approach, based on a stock model and sales forecasts considering first purchase (increase in number of households and ownership levels) and replacement of retired appliances.

In the model, total energy consumption is estimated per year for the stock in use under each policy scenario. Emissions are estimated using an electricity CO^2-intensity emissions factor, CO^2/kWh. Costs consider appliance prices (defined for each scenario using a cost-efficiency curve reflective of the market) and local electricity prices to estimate total life cycle cost (purchase price and cost of electricity bill over appliance lifetime).

IMPACT ON CONSUMERS

An impact of the implementation of the various scenarios to consumers was calculated using MEPSY. A business-as-usual model was calculated in comparison with a 15% improvement in energy efficiency and a U4E model. The results of the impact for fridge/freezer sets and chest freezers are shown in **Error! Reference source not found.** and **Error! Reference source not found.** below:

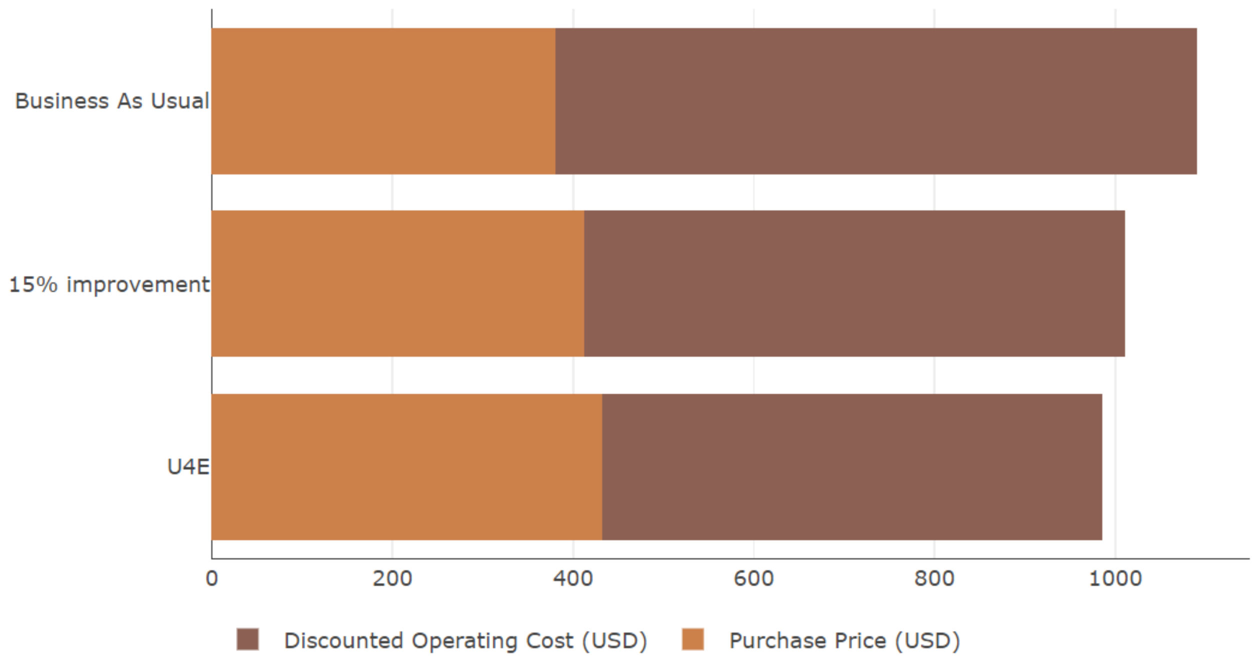


Figure 4-20 Impact of the various scenarios on consumers of fridge/freezer sets

It can be seen that there is an increase in the purchasing price of the more efficient refrigerators, however the payback period in both improved models is less than 6 years (not visible in the figure but displayed by software). With the chest freezers however, as shown in **Error! Reference source not found.** below, this payback period is extended to 8 years. This may mean that some financial support at the time of purchase of the freezers may be required for such consumers, specifically those who use chest freezers as part of the small shops (micro-enterprises).

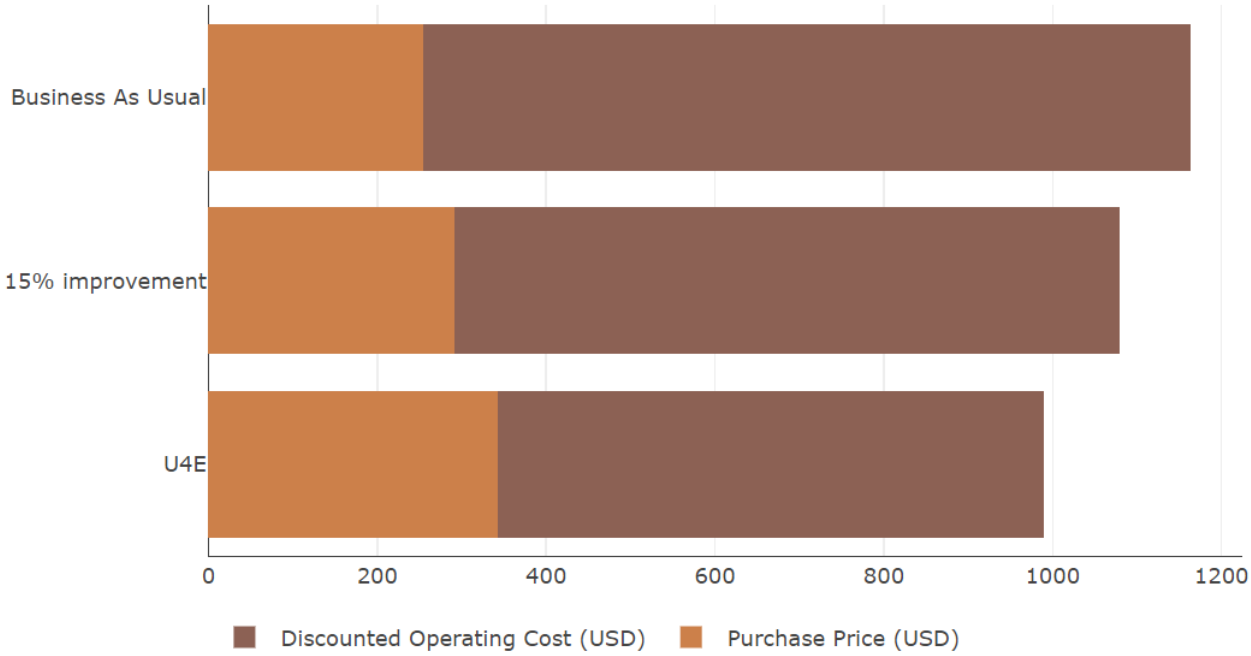


Figure 4-21 Impact of the various scenarios on consumers of chest freezers

a) IMPACT AT A NATIONAL LEVEL.

The impact on a national level is even more pronounced. **Error! Reference source not found.** below shows the reduction of CO^2 emissions until 2030 for fridge/freezer sets under the various scenarios. There is a significant reduction of over 0.12 million tons with the improved scenarios over the next decade.

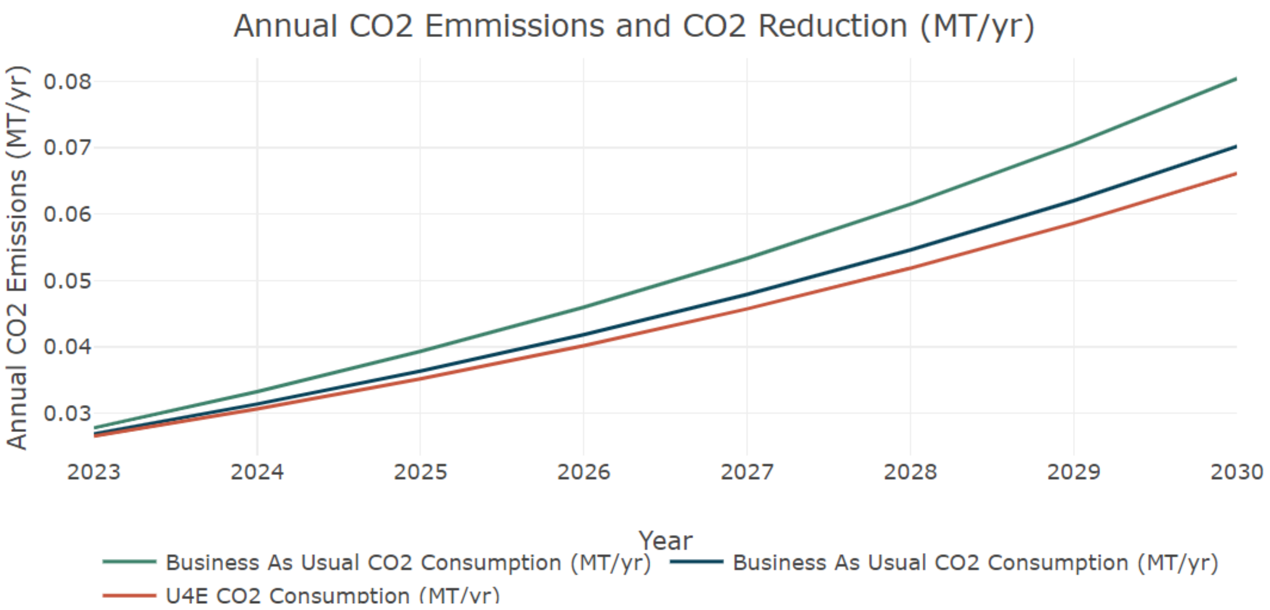


Figure 4-22 CO_2 reduction in the various scenarios on a national level until 2030

In terms of the energy consumption once again the difference is substantial. Using the U4E model there is a reduction of 0.24 TWh of energy consumed until 2030. This is shown in **Error! Reference source not found.** below.

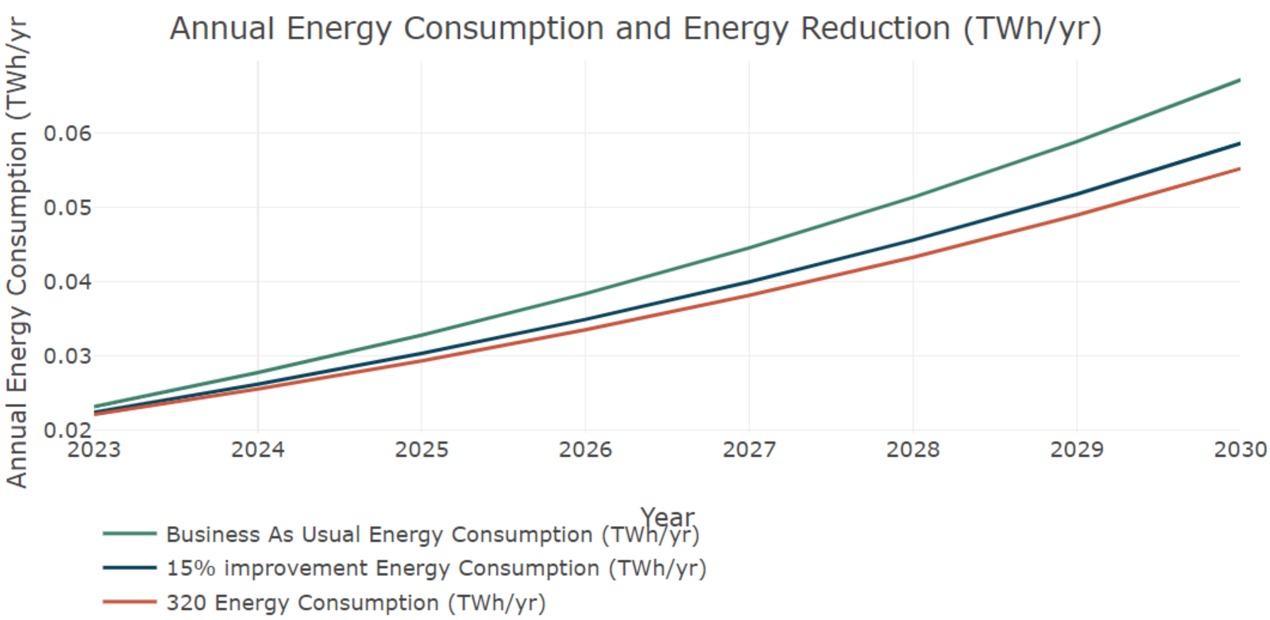


Figure 4-23 Energy reduction with various scenarios until 2030 on a national level

The situation is similar with the chest freezers. As can be seen in Figures 4-24 and 4-25 below the reductions in energy consumption and CO^2 emissions are significant over the lifetime of the product.

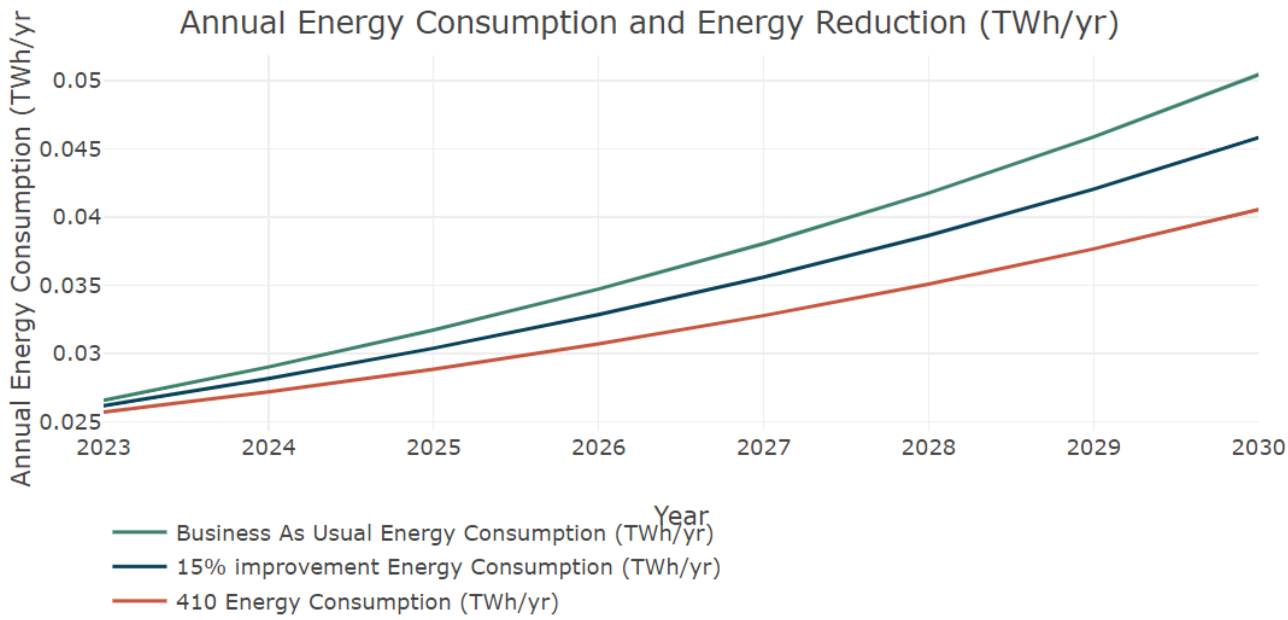


Figure 4-24 Energy consumption under various scenarios for chest freezers

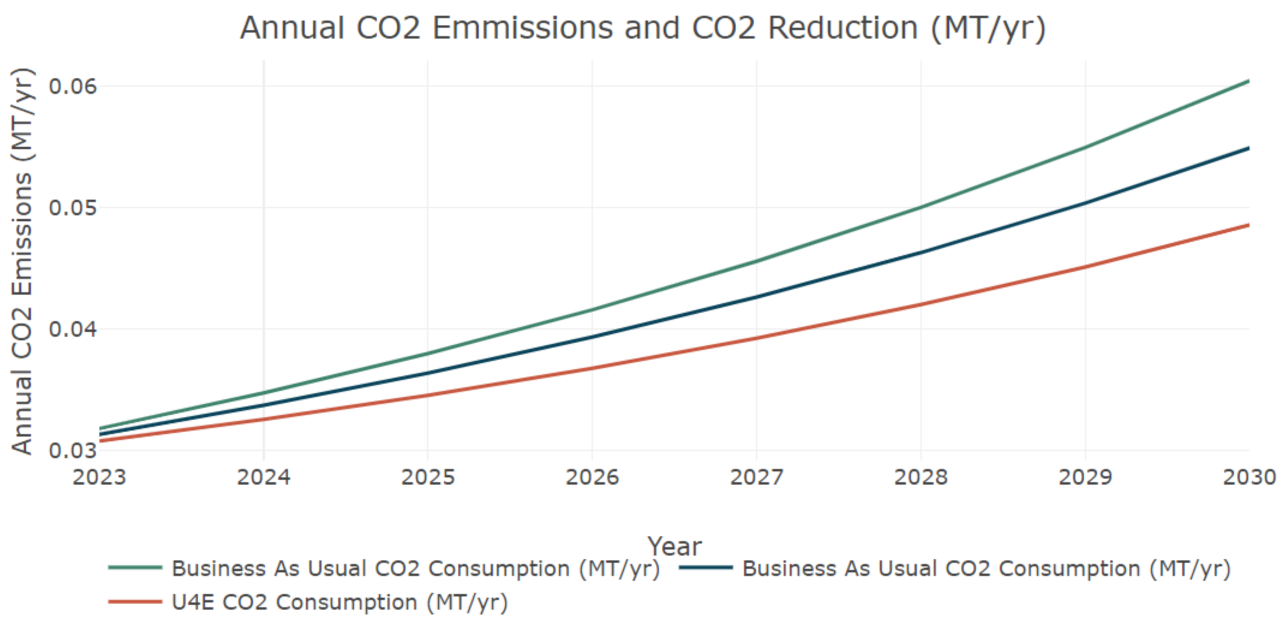


Figure 4-25 Reduction of CO_2 emissions under various scenarios for chest freezers

4.8 CONCLUSION OF REFRIGERATION MARKET ASSESSMENT

From the stakeholder engagements during the visit to Eswatini by the Pegasys implementation team it was evident that support for the development and implementation of the MEPS and associated processes is necessary. However, there is an abundance of enthusiasm within the public and private institutions mentioned earlier in this chapter, which is promising. Training will therefore be a key aspect of the project and additionally, it is imperative that knowledge transfer is such so that the local entities are able to continuously implement the project after the initial completion.

There are possible challenges, which were identified during the market assessment stage that could inhibit the development and implementation of the MEPS. The major potential challenges are listed below:

1. Lack of financing mechanisms to support the move to higher energy efficiency appliances
2. Limited household income available for the purchase of energy efficient refrigerators
3. Lack of experience in implementing energy efficiency programmes, specifically those that require customs inspections and related regulations

However, there are also a number of opportunities for a successful implementation of MEPS in the refrigeration environment. These could be as follows:

- Successful implementation of MEPS in the refrigeration sector could open up a pathway to implement similar projects in other sectors and with other appliances (e.g., washing machines and dishwashers, stoves and ovens, air conditioners, etc.)
- Successful training of the customs officials of the Eswatini Revenue Service in relation to energy efficiency compliance will make them more capable of enforcing other governmental initiatives related to energy efficiency and quality on a variety of products (e.g., air conditioners, power cables, etc.)
- Development of energy efficient appliances could lead to a green building revolution in Eswatini and align with the national energy policies
- Increasing public awareness related to energy efficiency would be beneficial to the general behaviour of the population towards energy use and could provide general energy saving benefits and an energy conscious behaviour beyond the confines of this project.

Additionally, the general population is largely unaware of the benefits of energy efficiency and much work will need to be undertaken on the public awareness campaigns related to this issue, especially in relation to household refrigerators. At present there is a lack of willingness from customers to spend more on energy efficient appliances but there has been no benefit calculation shown to the public to highlight the potential savings over time.

5 MARKET ASSESSMENT ON DISTRIBUTION TRANSFORMERS

5.1 TRANSFORMER SUPPLY

5.1.1 SUMMARY OF MARKET SIZE BASED ON CAPACITY

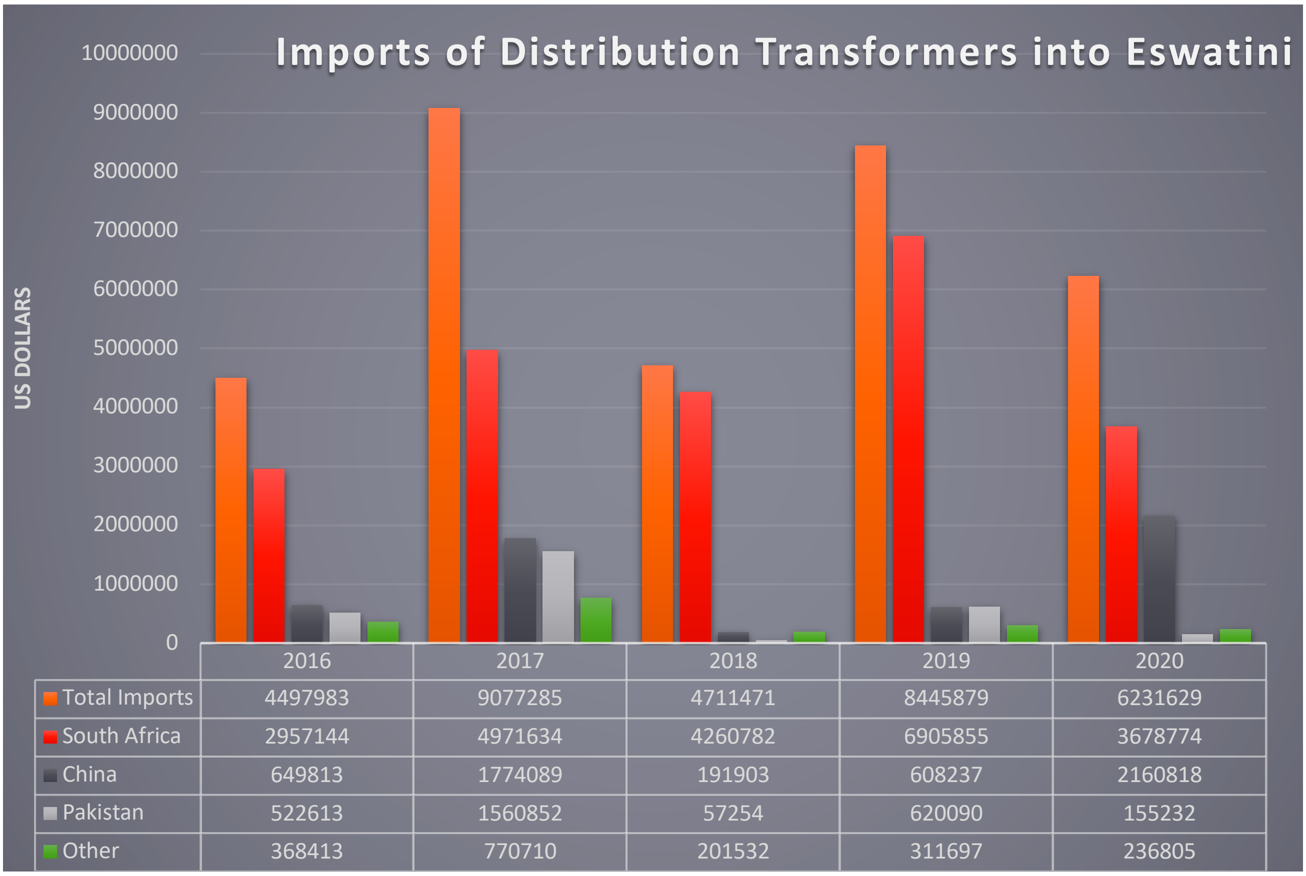
EEC transformer database was last updated in 2020 and contains asset information that is almost fully documented. The database indicates that EEC has ownership of 21,599 distribution transformers [18]. Our analysis of the information has shown that each transformer has an ID, rating, feeder data and no of customers. Only 21 transformers did not have kVA ratings.

Table 5-1 Stakeholders within the transformer industry in Eswatini

Category	Institution
Government Institutions	ESERA Eswatini Energy Regulatory Authority
	ECB Electricity Control Board
	EWURA Energy & Water Utility Regulatory Authority
	ERB Energy Regulatory Board
Parastatals	EEC Eswatini Electricity Company
	Energy & Water Utility Regulatory Authority
Academia	UNESWA University of Eswatini (NUL) Energy Research Centre (ERC)
NGOs and Associations	Eswatini Consumer Protection Agency
Private Sector for Distribution Transformers	ENIDC Eswatini National Industrial Development Corporation USL Ubombo Sugar Limited

5.1.2 OVERVIEW OF THE SUPPLY CHAIN,

The overview of the supply chain includes finished products and major components like core, winding, insulation, etc. (local manufacturers, imports including country of import, availability/experience with high-efficiency materials e.g., amorphous core materials, etc.)



	2016	2017	2018	2019	2020
Total Imports	4497983	9077285	4711471	8445879	6231629
South Africa	2957144	4971634	4260782	6905855	3678774
China	649813	1774089	191903	608237	2160818
Pakistan	522613	1560852	57254	620090	155232
Other	368413	770710	201532	311697	236805

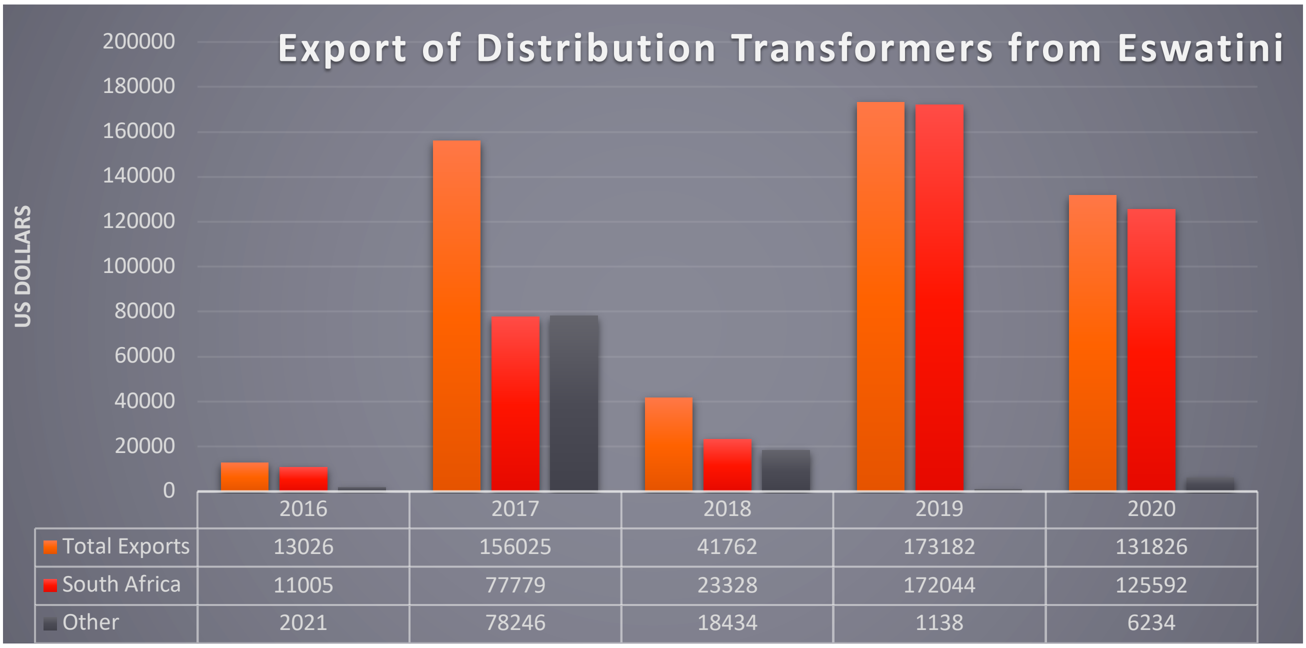
Data from COMTRADE, a United Nations (UN) global trade data repository.

Figure 5-1 Imports of distribution transformers into Eswatini

The trade data, seen in **Error! Reference source not found.** above, shows that in the period from 2016 – 2020, South Africa was the largest importer of transformers into Eswatini. China was the minority partner in this period and has significantly increased their imports into Eswatini in 2020 [15].

Eswatini does not have any local transformer manufacturing capabilities. A local distribution transformer refurbishment facility that was supported by the EEC and other transformer operators had recently closed. In March 2022 Ubombo Sugar and Royal Eswatini Sugar Corporation informed us that the facility had reopened under a new name. It is unclear how many transformers are being repaired at present. It must be noted that according to the EEC, not all failed transformers are repaired. Some are sold to salvage dealers as scrap. The trade data shows that transformer exports were insignificant when compared to imports.

The only exports are those transformers that are bought and then resold. South Africa is the biggest trade partner for distribution transformers with Eswatini. This is shown in the figure below.



	2016	2017	2018	2019	2020
Total Exports	13026	156025	41762	173182	131826
South Africa	11005	77779	23328	172044	125592
Other	2021	78246	18434	1138	6234

Data from COMTRADE, a United Nations (UN) global trade data repository.

Figure 5-2 Exports of distribution transformers from Eswatini

5.2 EXISITING TRANSFORMER BASE AND THE FORECASTED TRANSFORMER DEMAND

Analysis of the transformer database revealed a total capacity of 973 MVA based on 21,599 transformers from the most recent information from 2020. Eswatini has in place a rural electrification program that has produced excellent results. The national regulators' report for 2019/2020 shows that 90% of people in urban areas have access to electricity while 64% of people in the rural areas have access to electricity [1]. According to the Energy Masterplan 2034 published in 2018, universal access to electricity is forecast to be achieved by the end of 2030, with that being 2022 for a high growth scenario and 2034 for a low growth scenario.

These results correlate with the steady increase of new customers onto the EEC network, as well as an increase in the number of transformers onto the network. The customer numbers have increased by approximately 10% from 2015. This is shown in Figure 5-3 and Figure 5-4.

16 kVA transformers have increased by 10%, 50 kVA transformers by 9% and 100 kVA transformers by 7%.

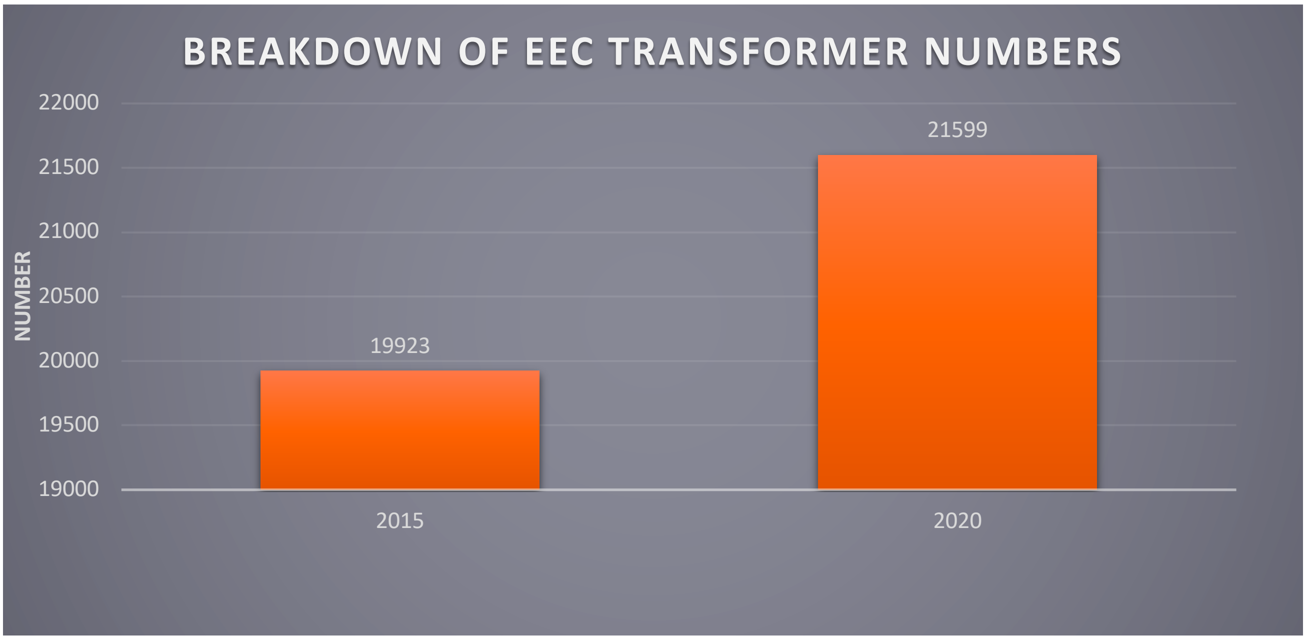


Figure 5-3 EEC transformer numbers

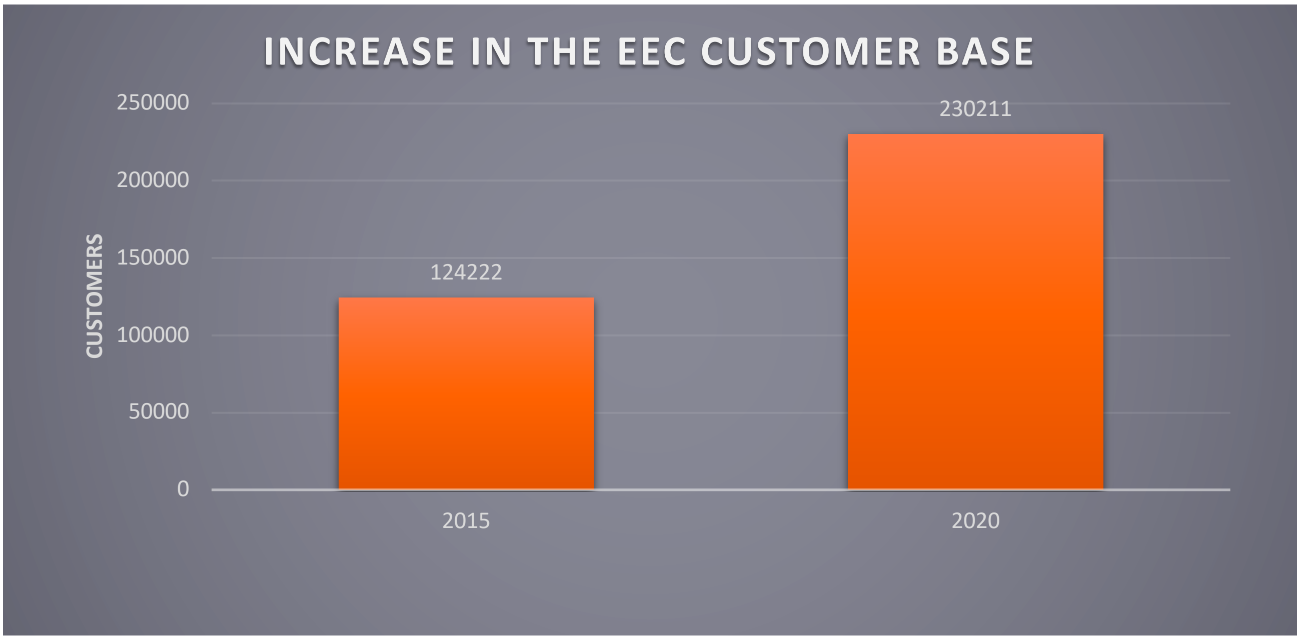


Figure 5-4 EEC customer numbers

There has been approximately 8% growth in transformer numbers over 5 years, while there has been close to 50% growth in customer numbers (or 10% growth in customers since 2015). Discussions with the EEC and ESERA have revealed that the electrification process in Eswatini operates from other Southern African countries where the cost of electrification is borne by the utility, and customers pay a utility bill in accordance with their usage. In Eswatini's electrification process, the first customer that requires electrification pays for the cost of the transformer and its installation. All customer's connected to the transformer the pay a utility bill according to the usage. Therefore, electrification is driven by the consumer's requirement and the kVA capacity of the transformer is chosen accordingly. The smallest capacity, and thus cheapest transformer available from the EEC is a single phase 16 kVA transformer and the large number of 16 kVA transformers on the network correlate with the impact of electrification, and the high percentage access to electricity.

This is an important consideration for the execution of the project as more efficient transformers would cost the first customer in terms of an increased capital cost of purchasing and having a transformer installed.

It is unknown at this stage if EEC will add new transformers on their grid or connect to already existing transformers when new customers are electrified as has been done.

5.2.1 TECHNICAL STANDARDS/REGULATIONS FOR DISTRIBUTION TRANSFORMERS IN ESWATINI

Eswatini sets the technical standards and specifications for distribution transformers to SANS 780 which itself refers to IEC TS 60076. Until 2020, the losses as stipulated by SANS 780:2009 remained unchanged since the inception of the SANS 780 standard in the 1960's [19].

The maximum permissible losses in accordance with table 1 of SANS 780:2009 are shown in **Error! Reference source not found.**below. The standards consider transformers from 5 kVA to 50 kVA single phase and 16 kVA to 2000 kVA for various voltages. Of importance to Eswatini would be the 16 kVA and 50 kVA transformers as the largest number of their fleet falls into these categories.

Table 5-2 Maximum Permissible Losses as stipulated by SANS 780:2009

Rated no-load secondary voltage V	Rated power kVA	Component losses			
		No-load Loss W			Load loss W
		Up to 12 kV	24 kV	36 kV	
121 or 242, single-phase	5	40	_	_	160
	16	80	100	_	400
	25	110	140	160	530
	50	180	220	250	900
420 or 550, three-phase	16	95	120	-	410
	25	120	150	170	570
	50	180	220	250	1000
	100	300	360	400	1700
	200	520	600	650	2700
	315	720	840	890	3800
	500	1100	1180	1230	5400
	630	1300	1400	1450	6400
	800	1600	1650	1700	8000
	1000	1900	1950	2000	9500
	1250	2250	2300	2350	11000
	1600	2750	2770	2820	13500
	2000	3250	3250	3300	16000
3300 or 3450, three-phase	2500	3800	3800	3800	19000
	3150	4500	4500	4500	22000

In 2019, the SANS 780 specification was revised with a greater emphasis placed on improving transformer losses. The specification was eventually published after comments in 2021.

The maximum permissible losses in accordance with Table 1 and Table 2 of SANS 780:2019 are shown in the **Error! Reference source not found.** below [20]. When compared to the 2009 specification above it can be seen the losses are lower and there is the addition specification for the amorphous core transformer. Of importance again are the 16 kVA and 50 kVA. The no load losses for the 16 kVA single phase unit have been reduced from 100 W to 49 W and for the 50 kVA have been reduced from 220 W to 110 W. The load losses have been reduced from 400 W to 320 W. for the 16 kVA and from 1000 W to 880 W for the 50 kVA.

Table 5-3 Maximum Permissible Losses as stipulated by SANS 780:2019

Rated power	Component losses		Amorphous losses
	No-load loss (Po)	Load loss (Pll)	
kVA	W	W	W
Um = 24 kV, Single-phase			
5	23	130	10
16	49	320	23
32	76	540	36
64	119	910	57
Loss constant A	8	40	3.5
Loss constant B	0.65	0.75	0.673
Three-phase			
25	70	520	30
50	110	880	40
100	190	1500	70
160	270	2200	100
200	320	2600	120
250	380	3100	140
315	450	3600	170
400	540	4400	200
500	630	5200	230
630	750	6200	280
800	900	7500	330
1000	1070	8900	390
1250	1260	10500	460
1600	1520	12800	550
2000	1790	15100	640
2500	2120	18000	760
3150	2520	21500	890
Loss constant A	6	43.5	2.5
Loss constant B	0.75	0.77	0.73

In 2017, the IEC published IEC TS 60076-20 Power transformers – Part 20: Energy efficiency, which provided requirements for the energy performance of distribution transformers [21]. They provided two levels of performance, where level 2 is a higher efficiency transformer. The maximum permissible losses are shown in the **Error! Reference source not found.**. It should be noted here that when compared to the SANS780, there are no specifications for the 16 kVA units and IEC TS 60076-20 recommends losses for units less than 25 kVA. When comparing the 50 kVA units the no load losses for level 1 are slightly lower than the SANS780:2019 specifications, while the level 2 are significantly lower.

Table 5-4 Maximum Permissible Losses as stipulated by IEC TS 60076-20:2017

Rated power kVA	Level 1		Level 2	
	No-load loss (Po) W	Load loss (Pll) W	No-load loss (Po) W	Load loss (Pll) W
≤25	70	900	63	600
50	90	1100	81	750
100	145	1750	130	1250
160	210	2350	189	1750
250	300	3250	270	2350
315	360	3900	324	2800
400	430	4600	387	3250
500	510	5500	459	3900
630	600	6500	540	4600
800	650	8400	585	6000
1000	770	10500	693	7600
1250	950	11000	855	9500
1600	1200	14000	1080	12000
2000	1450	18000	1305	15000
2500	1750	22000	1575	18500
3150	2200	27500	1980	23000

Transformers ordered from 2021 onwards by customers in Eswatini in accordance with SANS 780:2019 or IEC TS 60076-20:2017 will therefore by default, have higher efficiencies.

5.2.2 ENERGY-EFFICIENT DISTRIBUTION TRANSFORMERS

A study on the efficiencies of the SANS 780:2009, SANS 780:2019 and IEC TS 60076-20:2017 was undertaken. The standards were compared against various other standards across the world. While the SANS 780:2009 has defined the efficiencies that are most commonly in use in Eswatini, the SANS 780:2019 specification shows better performance, with the highest efficiency occurring when the transformer is 40% loaded.

When compared with the IEC TS 60076-20:2017, SANS 780:2019 is similar to the level 1 efficiencies, with level 2 being high performance transformers. These efficiencies are shown in **Error! Reference source not found.** below.

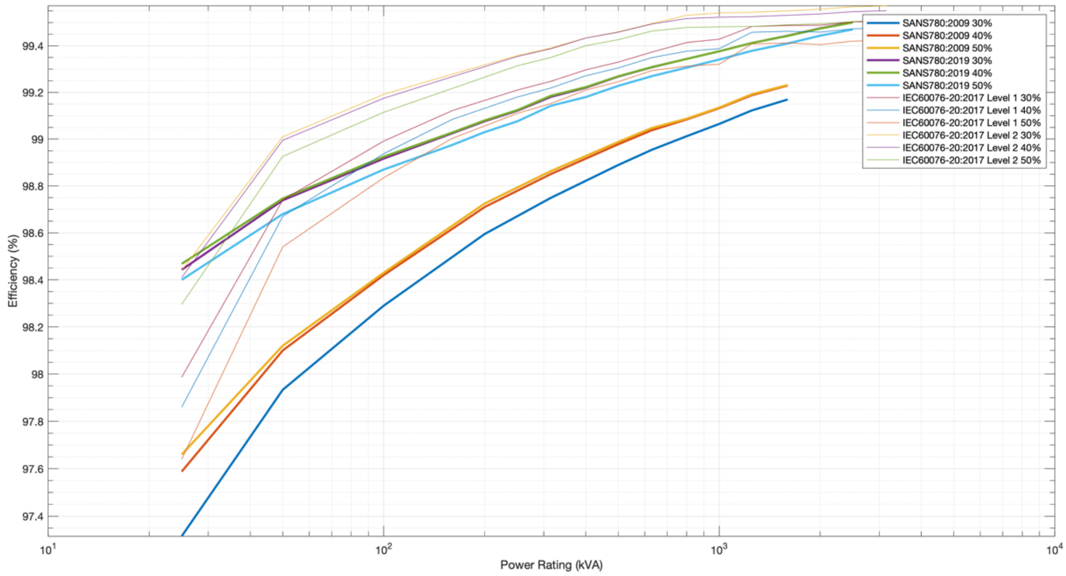


Figure 5-5 Efficiencies for three-phase liquid immersed medium power transformers based for loadings of 30%, 40% and 50% for SANS 780:2009, SANS 780:2019, and IEC TS 60076-20:2017 level 1 and level 2

The efficiencies for the loading from 0 to 100% of a 50 kVA transformer is shown below. It can be seen that the highest efficiencies occur for all the listed specifications between 30 and 40%. This would be the typical loading range for rural electrification. It is noted that IEC TS 60076-20:2017 Level 2 has the highest efficiency across its loading while SANS780:2019 is more efficient when loaded to 30% and over when compared to IEC TS 60076-20:2017.

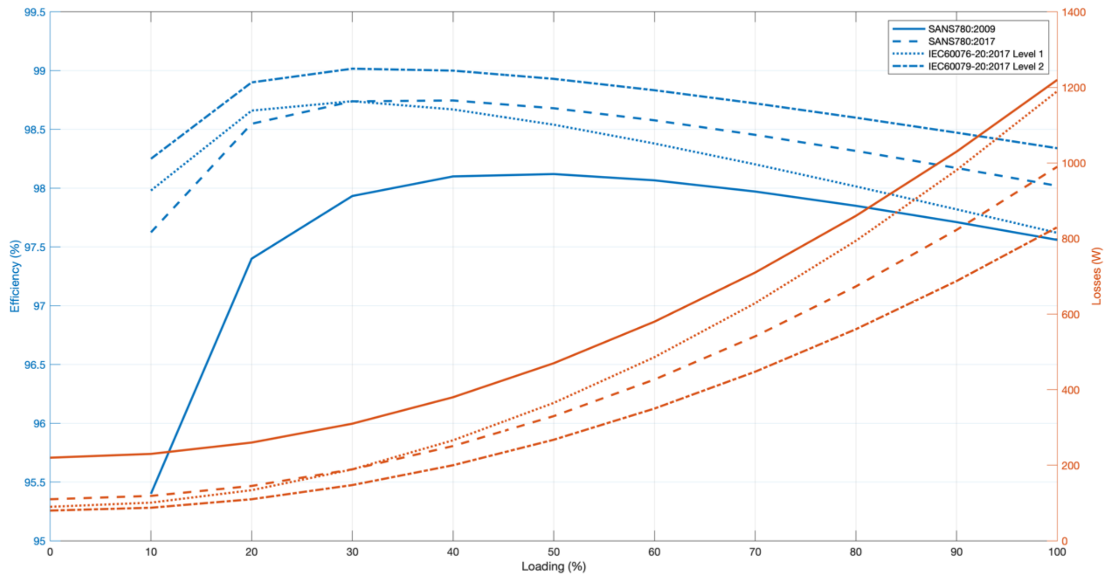


Figure 5-6 Efficiencies for loading of a 50 kVA three-phase liquid immersed medium power transformers based for loadings of SANS 780:2009, SANS 780:2019, and IEC TS 60076-20:2017 level 1 and level 2

The efficiencies of transformers the most commonly used in Eswatini were benchmarked against other standards and specifications from other countries for 50% loading (as per the losses reported by the SEAD Distribution Transformers Report Part 4: Country Profiles, 2013) [22]. The results are shown in **Error! Reference source not found.** below.

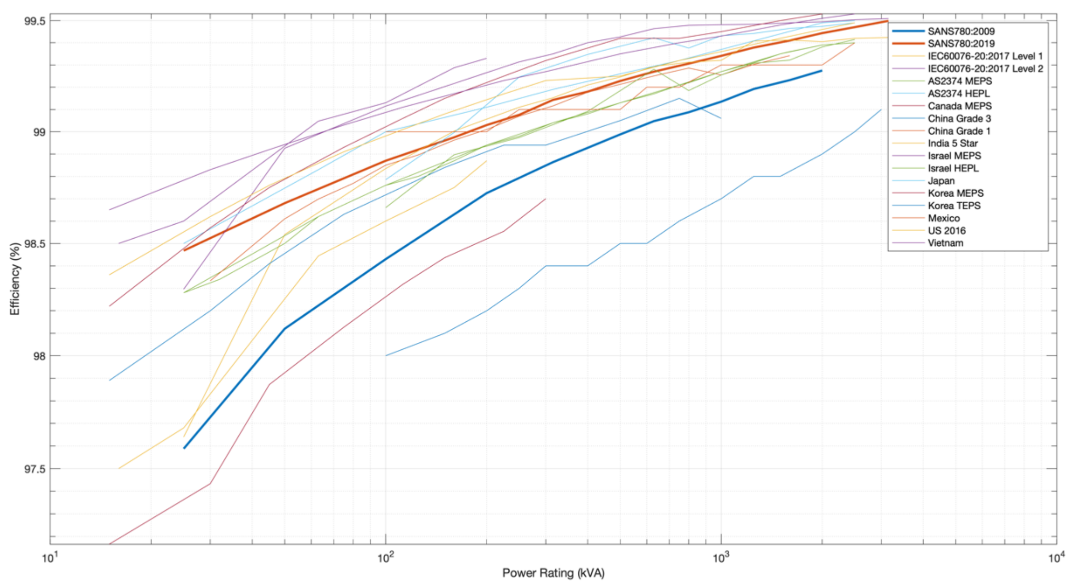


Figure 5-7 Efficiencies for three-phase liquid immersed medium power transformers according to numerous standards and in numerous countries for 50% loading

A closer look at the IEC, Chinese and Indian standards demonstrates that SANS 780:2019 falls in line with IEC TS 60076-20:2017 Level 1 and GB 20052:2013 Grade 3 with IEC TS 60076-20:2017 Level 2, GB 20052:2013

Grade 1 and India 5 Star being the highest efficiency transformers. SANS 780:2009 has the lowest efficiency in the comparison.

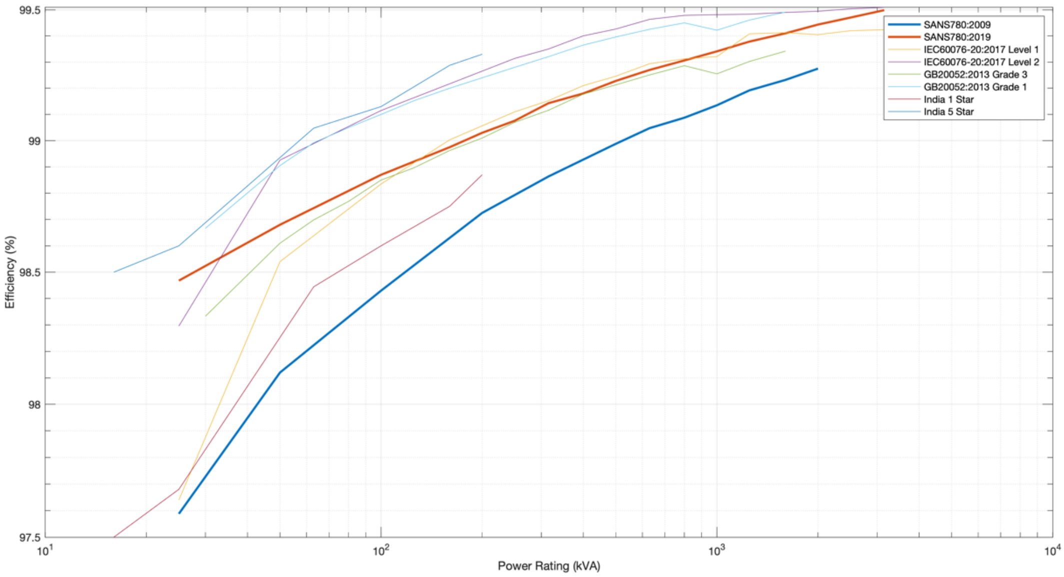


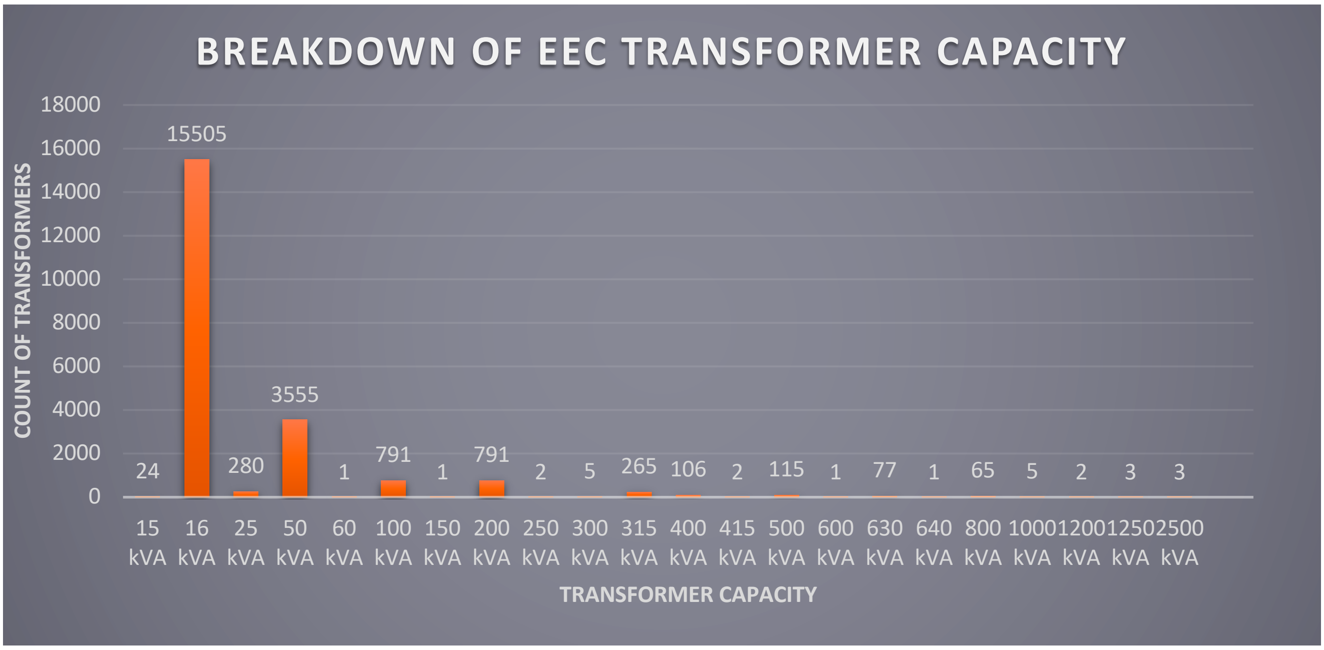
Figure 5-8 Efficiencies for three-phase liquid immersed medium power transformers according to the South African, IEC, Chinese and Indian standards for 50% loading

5.3 EQUIPMENT STOCK AND PROJECTIONS

5.3.1 EEC TRANSFORMER DATABASE

Based on the database from the EEC, the company contains 21,599 reticulation transformers that vary between 16 kVA and 2500 kVA (The largest capacity distribution type transformer in the network. The database provided by EEC does not list the transformer manufacturers but the database for importation of distribution transformers into Eswatini indicates that the bulk of transformers on the EEC network are sourced from South African manufacturers.

Figure 5-9 below shows the count of EEC transformers categorised according to capacity. The EEC consists mainly of 16 kVA and 50 kVA transformers, which make up more than 50% of their total transformer base. The database provided by the EEC was well maintained with only 21 transformers missing information pertaining to the kVA rating. For the purposes of the study, the unknown transformers were assigned kVA ratings in proportion to the known transformers.



Source : 2020 transformer database

Figure 5-9 EEC's transformers categorised according to capacity

5.4 ENERGY PERFORMANCE OF DISTRIBUTION TRANSFORMERS

A study on the potential energy losses is presented, where the following standards are used in the study:

- SANS 780:2009 – Distribution transformers
- SANS 780:2019 – Distribution transformers
- IEC TS 60076-20:2017 – Power transformers – Part 20: Energy efficiency

The distribution of transformers shown in **Error! Reference source not found.** was used to determine the approximate annual transformer energy losses in the network, where the following assumptions were used for the study:

- The high voltage rating of the transformer was 24 kV. The no-load, load and efficiencies were taken for this rating from the standards listed above.
- The transformer parameters were the three-phase parameters. Where there were no parameters for the power rating, the single-phase parameters were used.
- For non-standard power ratings, the no-load, load and efficiencies were interpolated so that the study could be completed.
- All transformers had a CRGO core and no transformers were amorphous core.
- There were a total of 21,599 transformers in the listed transformers, where there was no information the transformers were distributed proportionally across the range.
- The loading used for the study was fixed at 30%, 40% and 50%.

- Referring to the distribution of transformers, it can be seen that the distribution transformers are predominantly 16 kVA and 50 kVA. It must be noted that SANS 780:2019 specifies the losses for a 16 kVA transformer but IEC TS 60076-20 only defines levels for <25kVA and not specifically for 16 kVA. This has been extrapolated in other documents however has been left as the <25 kVA value in this study.

Table 5-5 lists the energy losses for the transformers on the network for loadings of 30-50% where the annual losses were compared according to the relevant SANS and IEC standards. Transformers specified to SANS780:2019 or IEC TS 60076-20 Level 1 result in a significant energy loss reduction, ~40%, when compared to SANS780:2009. A further reduction should be achieved by transformers specified to IEC TS 60076-20 Level 2, however there is no specification for a 16 kVA transformer, and this leads to the result using more energy. An adoption of this standard should include a specification for the 16 kVA as this is the most common transformer on the network.

Table 5-5 Annual energy losses based in the transformer numbers in 2020

Loading	Total transformers	Energy Losses			
		SANS780:2009	SANS780:2019	IEC TS 60076-20:2017 Level 1	IEC TS 60076-20:2017 Level 2
30 %	21,599	49,457 MWh	27,740 MWh	36,836 MWh	28,957 MWh
40 %		59,724 MWh	36,394 MWh	51,868 MWh	39,226 MWh
50 %		72,926 MWh	47,520 MWh	71,196 MWh	52,428 MWh

Table 5-6 lists the annual energy losses against the predicted transformer numbers in 2025 for numerous growth rates, where the load factor used was 0.4. The table demonstrates that a move towards the energy efficient specifications would result in significant energy loss reduction. The adoption of SANS780:2019 would result in an almost 40% reduction in energy losses. The adoption of the IEC standards and limits would also result in energy losses. These could be further reduced should there be a specification for the 16 kVA transformers, the most common transformer in Eswatini’s network. SANS780:2019 addresses the maximum allowed losses for 16kVA single phase transformers specifically, while the IEC standards refer generally to transformers under 25kVA, and this is why SANS780:2019 appears to be more stringent on losses than IEC TS 60076-20 Level 2 – the EEC network is dominated by 16 kVA transformers.

Table 5-6 Annual energy losses based on the predicted transformer numbers in 2025

New Transformer Growth	Total transformers	Energy Losses			
		SANS780:2009	SANS780:2019	IEC TS 60076-20:2017 Level 1	IEC TS 60076-20:2017 Level 2
0%	21,599	59,724 MWh	36,394 MWh	51,868 MWh	39,226 MWh
5 %	26,253	72,595 MWh	44,237 MWh	63,046 MWh	47,679 MWh
10 %	31,622	87,443 MWh	53,284 MWh	75,940 MWh	57,430 MWh
15 %	37,775	104,458 MWh	63,653 MWh	90,718 MWh	68,606 MWh

5.4.1 CAPITALISATION OF ENERGY LOSS COSTS OF DISTRIBUTION TRANSFORMERS

The total cost of ownership is an important concept when purchasing a transformer. The capitalisation cost of losses is a method for quantifying what the better purchase of a transformer is. An example studies on the capitalisation costs of a 16 kVA, a 25 kVA and a 50 kVA transformer were completed and are shown below. The capitalisation cost accounts for the cost of the losses over the lifetime of the transformer and is used by utilities to determine the most cost-effective transformer over its lifetime.

The methodology in IEC TS 60076-20 was used for this study through the UNEP U4E TCO calculator. Key parameters considered for this study were:

- Operating hours of 8760 per year.
- A 7% discount rate per year.
- Life expectancy of the transformer of 30 years
- A 0% growth rate of electricity per year
- A fixed load factor of 0.4, with no variable load.
- An energy price of 30 $/MWh (taken from the Eswatini Energy Masterplan)
- The energy generated in Eswatini is a blend of hydropower and biogases, while the energy imported from South Africa would be coal driven. A factor for CO_2 emissions was excluded in the study.

These parameters resulted in:

- A capitalisation of no-load losses factor, A, of 2.48 $/MWh
- A capitalisation of load losses factor, B, of 1.15 $/MWh

The results comparing the transformers according the to the specifications in SANS780:2009, SANS 780:2019 and IEC TS 60076-20:2017 are shown below. It is evident that the savings presented by the higher efficiency specifications result in significant savings over its lifetime, noting that the purchase price has not been included here.

Table 5-7 Capitalisation of Energy loss Costs of a 16 kVA transformer

Parameter	SANS780:2009	SANS780:2019	IEC60076-20:2017 Level 1	IEC60076-20:2017 Level 2
No load loss	120 W	49 W	70 W	63W
Load loss	410 W	320 W	900 W	600 W
Capitalisation of Losses Cost	$ 877	$ 539	$ 1294	$ 916

Table 5-8 Capitalisation of Energy loss Costs of a 25 kVA transformer

Parameter	SANS780:2009	SANS780:2019	IEC60076-20:2017 Level 1	IEC60076-20:2017 Level 2
No load loss	150 W	70 W	70 W	63W
Load loss	570 W	520 W	900 W	600 W
Capitalisation of Losses Cost	$ 1164	$ 844	$ 1294	$ 916

Table 5-9 Capitalisation of Energy loss Costs of a 50 kVA transformer

Parameter	SANS780:2009	SANS780:2019	IEC60076-20:2017 Level 1	IEC60076-20:2017 Level 2
No load loss	220 W	110 W	90 W	81W
Load loss	90 W	79.2 W	99 W	67.5 W
Capitalisation of Losses Cost	$ 1902	$ 1401	$ 1596	$ 1152

From the tables it can be seen that for the 16 kVA transformers that the SANS780:2019 specified transformer will have the lowest cost of losses over its lifetime. It must be noted that IEC TS 60076-20:2017 does not specifically set losses for a 16 kVA transformer. For the 25 kVA transformer, SANS780:2019 again has the lowest cost of losses over its lifetime, followed by IEC TS 60076-20:2017 level 2. The SANS780:2019 appears to be better for the lower rated transformers. For the 50 kVA transformer the lowest cost of losses is the transformer specified to IEC TS 60076-20:2017 Level 2, followed by that specified to SANS780:2019.

In general, the analysis of the transformers in service on the Eswatini grid shows that both the public and private sectors in Eswatini stands to benefit financially and environmentally should higher efficiency distribution transformers in conjunction with the capitalisation of transformer losses be adopted as a norm.

5.5 CONCLUSION OF DISTRIBUTION TRANSFORMER MARKET ASSESSMENT

From the market assessment it is evident that there are a number of challenges related to the development and implementation of MEPS in the distribution transformers sector. There are also a number of opportunities that have been identified and benefits that could be realised by Eswatini in the medium to long term. Some of the major challenges are:

1. Limited information on the distribution transformer fleet
2. Lack of experience to implement the cost to ownership aspects of standards in distribution transformers and to thoroughly assess all suppliers

The opportunities that have been identified include:

1. Successful training of the EEC technical and procurement teams in relation to energy efficiency compliance and total cost of ownership will make them more capable of enforcing other governmental initiatives related to energy efficiency in their sector on a variety of products (e.g., power cables, switchgear, etc.).
2. The understanding of the total cost of ownership by not only the EEC but also some of the large electricity users and suppliers will make them aware of the importance of efficient (and generally higher quality products) and therefore could increase the general purchasing related to total cost of ownership, which could in turn mean a more reliable electrical grid with fewer outages, due to better products being utilised.
3. The market assessment process and the impact of implementation of MEPS has shown the EEC and other large users the importance of understanding the network, the status and number of the transformer fleet. It is possible that this will drive them to maintain a better record of transformers on the network in the future.

Furthermore, the distribution of electricity is solely the responsibility of the EEC and although this can be problematic from a monopoly point of view it makes it easier to implement the distribution transformer aspect of the MEPS as effectively there is only one buyer that needs to align its procurement procedure to consider the total cost of ownership taking into account the reduction of losses.

6 CONCLUSION

The market assessment report of Eswatini provides insight into the current status of the distribution transformer and household refrigerator markets. It is based on a data collection exercise conducted across households and the supply chain in the case of refrigerators and the EEC and other, smaller transformer users within the country, such as Ubombo Sugar. Information was also gathered from various governmental organisations and ministries related to the project through physical interviews conducted during a visit to the country by the international consulting team. The results produced as part of this market assessment can be used to support the need for the development of MEPS for refrigerators and distribution transformers and to quantify the potential benefits of the implementation of such standards on a consumer and national levels.

Some of the key findings include:

- The majority of refrigerators in Eswatini are fridge/freezer combination sets and chest freezers
- The dominant refrigerant in Eswatini is R600a, especially in new appliances
- There is a significant energy saving to be gained for both consumers and the country in general by moving towards energy efficient appliances
- There is a general lack of awareness of the positive impact of energy efficient refrigerators and the positive financial impact over the lifetime of the refrigerator
- Eswatini has one refrigerator manufacturer, Palfridge, which is also possesses its own, accredited laboratory for energy efficiency testing.
- The EEC is the main user of distribution transformers in Eswatini
- Currently the EEC purchases distribution transformers based on up-front cost alone and the total cost of ownership is not considered
- The market assessment shows that Eswatini stands to benefit financially and environmentally should higher efficiency distribution transformers in conjunction with the capitalisation of transformer losses be adopted as a norm.

The structure of public entities (primarily ministries and regulators) is such that there is close interaction and general cohesion between departments. This is a positive since it will be easier to develop and implement any new regulations in the future related to energy efficiency. This is also underpinned by the commitment to energy efficiency improvements and related projects, as evident from the stakeholder engagements. There are significant advantages to be gained by developing and implementing MEPS in Eswatini. It is important that the development of MEPS is underpinned by a thorough implementation plan, which will allow the national stakeholders to sustain the implementation and develop the required legislation. It is also key that a financial backing for the implementation is planned and that there is a thorough skills transfer process in place as part of the implementation.

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