Demand forecast, loss reduction and energy efficiency plan final report

REPUBLIC OF MALAWI

MINISTRY OF ENERGY

Demand Forecast, Loss Reduction and Energy Efficiency Strategies Final Report

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Contributors

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Abbreviations and acronyms

CAGR	Cumulative Average Growth Rate
DR	Demand Response
DSM	Demand Side Measures
ECA	Economic Consulting Associates
EE	Energy Efficiency
ESCOM	Electricity Supply Corporation of Malawi Limited
GDP	Gross Domestic Product
GEAPP	Global Energy Alliance for People and Planet
GNI	Gross National Income
HV	High Voltage
IMF	International Monetary Fund
IRP	Integrated Resource Plan
LV	Low Voltage
MEAP	Malawi Electricity Access Project
MV	Medium Voltage
PMO	Project Management Organisation
SADC	Southern Africa Development Community
SAPP	Southern Africa Power Pool
SDG	Sustainable Development Goals
USWG	Utility Scale Working Group

Executive Summary

Introduction

The main objective of the *Demand forecast, loss reduction and energy efficiency plan final report* was to develop a demand forecast for Malawi building on the *2017 IRP demand forecast* and incorporate a properly costed energy efficiency (EE) and loss reduction plan spanning 5-20 years. The forecast was developed in collaboration with the Utility Scale Working Group, which included experts from MERA, ESCOM, PML (before dissolution) and Ministry of Energy who validated all input assumptions, methodologies and outputs.

The demand forecast was developed for the next 20 years under three scenarios:

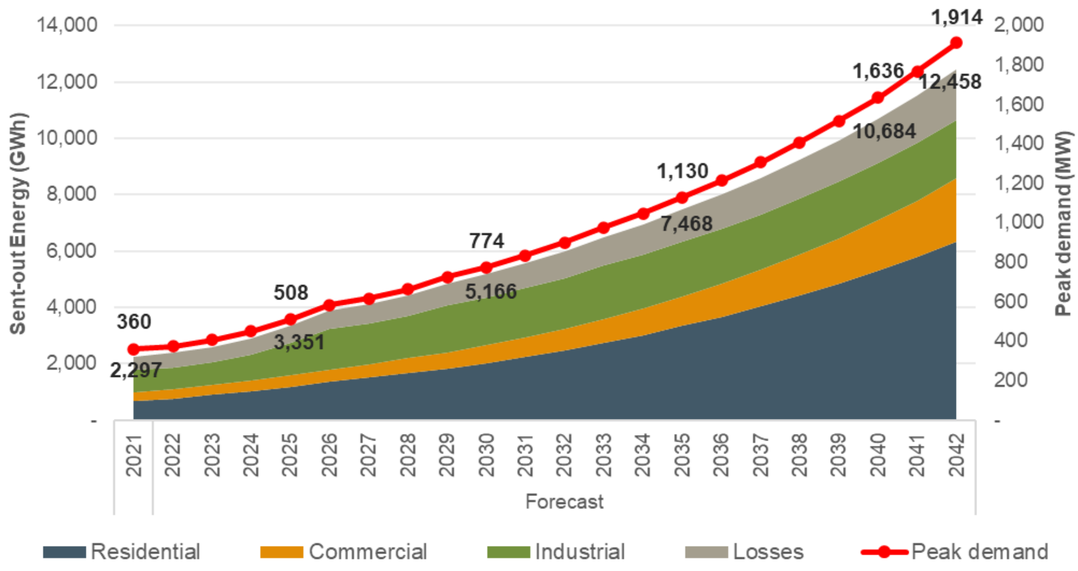
- a *base case scenario* which reflects current projections on national economic development, as well as ongoing policy commitments and electrification targets;
- a *high case scenario* which forecasts rapid economic growth and a quick bounce-back from the economic shocks in the last few years, along with 100% electrification and rapid loss reduction actions; and
- a *low case scenario* reflecting low economic growth and constrained capacity to implement policy targets and loss reduction measures.

The scope of this demand forecast is to be used as an input to the update of the Integrated Resource Plan (IRP) in Malawi. For least cost power development planning purposes, a forecast of sent-out energy (MWh or GWh) and sent-out maximum demand (MW) is required in the medium to long run. The geographical distribution of the demand is also necessary to assess capacity requirements by region for the transmission development plan. The forecast was prepared for the next 20 years (up to 2042) by economic activity, at national level and by region. It also accounts the impact of energy efficiency measures and loss reduction plans.

Base case demand forecast

The Base case demand forecast has been developed to reflect current policy targets, including the electrification targets set by the National Electrification Programme, the implementation of the 2021 Loss Reduction Roadmap, as well as the current long-term economic forecasts and industrial, agriculture and mining developments in the country. The annual energy and peak demand forecast results can be seen in Figure 1 below.

Figure 1 Base case updated demand forecast 2022-2042

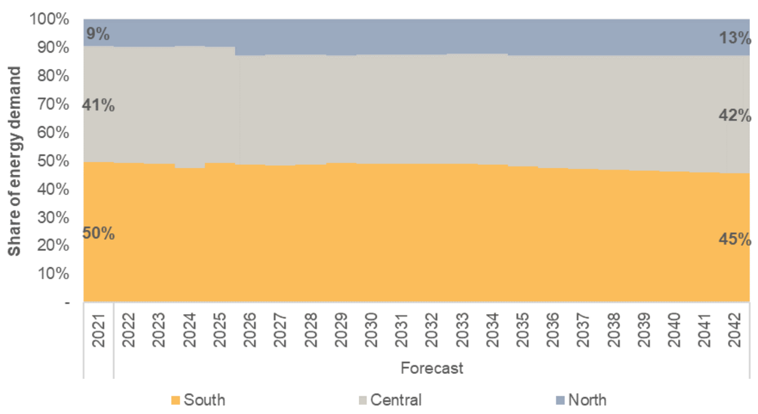


Source: ECA analysis

It is estimated that the energy demand at the entry points of the grid (eg sent-out generation) will reach 12,458 GWh with a peak demand of 1,914 MW by 2042.This increase represents an average annual growth of above 8% from 2021 (2,297 GWh and 360 MW in 2021). The forecast growth rates in energy and peak demand are higher than the 4% average annual growth recorded between 2016 and 2021. The updated forecast considers suppressed demand from previous years as well as current electrification targets that foresee a rapid increase of residential connections compared to previous years.

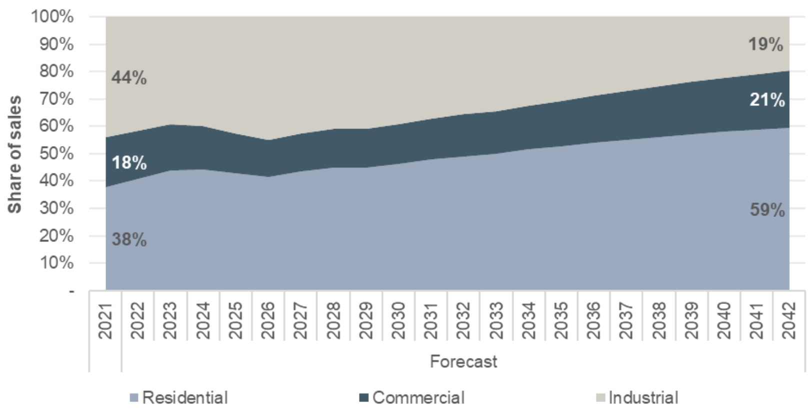
It is estimated that the North region will increase its share of demand from 9% in 2021 to 13% in 2042 due to relatively high urbanisation and population growth rates compared to the other regions (see Figure 2). Demand from all sectors (residential, commercial, and industrial) is expected to grow in the next 20 years, however, residential demand will increase more rapidly as rural households gain access to electricity, and all households increase their average consumption over time. As a result, residential sales are expected to account for 59% of total electricity sales by 2042, compared to 38% in 2021 (see Figure 3).

Figure 2 Regional demand split 2022-2042 – Base case Demand Forecast



Source: ECA analysis

Figure 3 Sectoral sales split 2022-2042 – Base case Demand Forecast



Source: ECA analysis

Approach and key considerations

The table below summarises the approach taken for the update of the demand forecast.

Table 1 Approach used for the 2022-2042 demand forecast

Bottom-up approach that adds the demand by economic activity, losses and impact of DSM to derive energy and capacity that needs to be injected to the grid.

Residential sales	
Rural households	**Average consumption per household in rural areas** *(kWh/month * 12 months)* χ **Income elasticity** *(to estimate the increase in consumption relative to economic growth and efficiency improvements)* χ **Electrification rate of rural areas** *(% of rural households with access to electricity)* χ **Number of households in rural areas** *(=Population in rural areas / Persons per household in rural areas)*
Urban households	**Average consumption per household in urban areas** *(kWh/month * 12 months)* χ **Income elasticity** *(to estimate the increase in consumption relative to economic growth and efficiency improvements)* χ **Electrification rate of urban areas** *(% of urban households with access to electricity)* χ **Number of households in urban areas** *(=Population in urban areas / Persons per household in urban areas)*

Productive sector sales	
Commercial	**Econometric equation** linking sales with GDP per capita, tariff level and number of commercial consumers.
LV Industrial	**Econometric equation** linking existing LV industrial sales with GDP per capita.
MV Industrial	**Econometric equation** linking existing MV industrial sales with Industrial GDP.
New large projects *(Agriculture, Megafarms, Manufacturing, Mining, Water pumping)* **and Self-generation**	The demand of new large loads / expansions / shutdowns that cannot be identified in historical information (econometric equation) is identified separately and **added/subtracted to/from the demand forecast with a probability adjustment**. Self-generation is also accounted using a similar approach as with new step loads. *A survey was conducted to identify new industrial loads and plans for self-generation.*

Exports, losses and DSM	
Exports	Firm commitments for exports are added to the demand.
Losses	Sales are increased by forecast loss factors accounting the loss reduction roadmap to identify energy and capacity requirement at the entry points of the grid (eg generators sent out level).
DSM	The impact selected demand response and energy efficiency measures is subtracted from the demand forecast. Efficiency improvements of appliances are accounted in the income electricity of residential customers.
Peak demand	Peak demand is estimated from forecast energy demand using the system load factor.

Source: ECA analysis

The above approach incorporates the following key considerations from stakeholders:

- Step loads and self-generation from mining companies, various upcoming rock aggregate quarry plants, manufacturing firms, mega-farms, agriculture and water pumping projects.
- Population growth and urbanization rates from the 2018 Census
- Economic growth anticipated
- National electrification targets including universal access by 2030
- The fact that rural areas consume less electricity than urban areas and most of new customers that will be connected will be in rural areas
- Policy targets and national plans
- Technology improvements
- Expected tariff increases
- Firm commitments for exports
- System network losses (technical and commercial) and expected loss reductions

Low and high demand forecasts

The Low case and High case scenario follow a different set of input assumptions summarised in Table 2 below. The low case scenario is structured to account for low economic growth, slow electrification, and lower probability for the development of new large loads. The high case scenario considers a positive outlook on economic growth, ambitious electrification and loss reduction rollouts, and high likelihood of new mines, manufacturing firms, mega-farms, agriculture and water pumping projects development.

Table 2 Summary of input assumptions for the 2022-2042 demand forecast

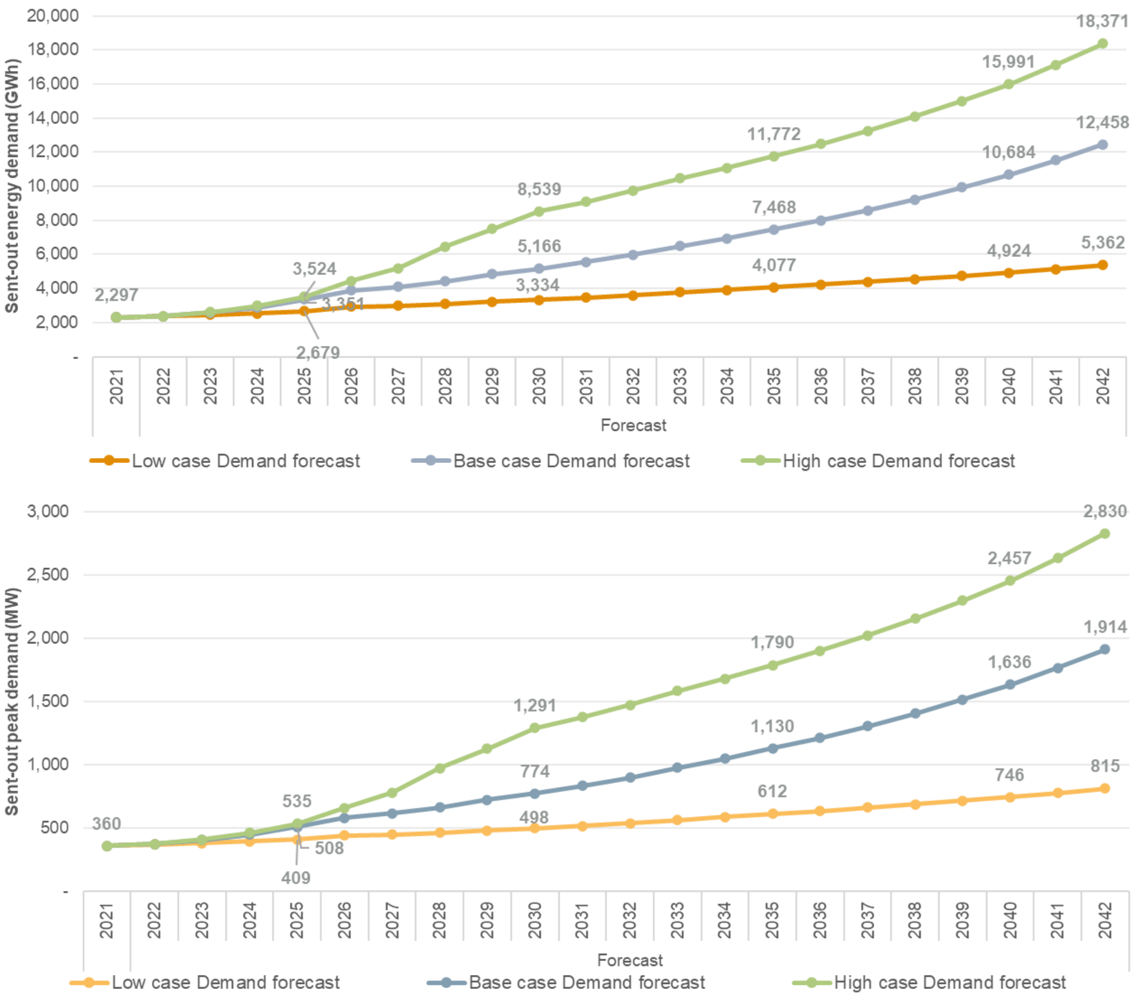
<table>
<tr><th></th><th>Low scenario</th><th>Base scenario</th><th>High scenario</th></tr>
<tr><td></td><td>Business as usual</td><td>Market expectations and NEP electrification plan with current WB and MREP support supplementing ESCOM</td><td>High economic growth with universal access assuming no resource constraints</td></tr>
<tr><td>Economic development</td><td>Assumes that economic growth in Malawi will be affected by global conflicts, other unforeseen events (eg cyclones, etc) and that Covid-19 pandemic has longer lasting impacts on economic growth. GDP growth is assumed to be closer to the average growth over the past 3 years (3.9%).</td><td>This scenario uses the IMF GDP growth projections up to 2028. For the 2028-2042 period, the long term GDP growth rate from IMF has been adopted (4.5%).</td><td>Assumes that from 2023, GDP growth will be higher than the IMF GDP growth projection (and closer to historical high GDP growth rates). This represents a quick recovery from COVID-19 pandemic as well as high economic growth conditions in Malawi.</td></tr>
<tr><td>Electrification targets</td><td>Applies ESCOM's historical new connection abilities (~35,000 per annum).</td><td>National Electrification Policy (NEP) targets by 2030 (32.4%) followed by linear increase of electrification by 2042 (56%).</td><td>Applies universal electricity access by 2030 following SE4ALL Integrated Energy Plan for Malawi</td></tr>
<tr><td>Average consumption per household</td><td><table><tr><th></th><th>Unit</th><th>2021</th><th>2030</th><th>2040</th></tr><tr><td>Urban</td><td>kWh/month</td><td>160</td><td>172</td><td>203</td></tr><tr><td>Rural</td><td>kWh/month</td><td>47</td><td>51</td><td>60</td></tr></table></td><td><table><tr><th></th><th>Unit</th><th>2021</th><th>2030</th><th>2040</th></tr><tr><td>Urban</td><td>kWh/month</td><td>160</td><td>188</td><td>252</td></tr><tr><td>Rural</td><td>kWh/month</td><td>47</td><td>56</td><td>75</td></tr></table></td><td><table><tr><th></th><th>Unit</th><th>2021</th><th>2030</th><th>2040</th></tr><tr><td>Urban</td><td>kWh/month</td><td>160</td><td>203</td><td>309</td></tr><tr><td>Rural</td><td>kWh/month</td><td>47</td><td>60</td><td>92</td></tr></table></td></tr>
<tr><td>Network Losses</td><td>Slow implementation of the Loss Reduction Roadmap (LRR).</td><td>Base case implementation of the LRR.</td><td>Rapid implementation of the LRR and additional ESCOM measures.</td></tr>
<tr><td>Step load and self generation</td><td>Low probability of new projects to materialise and high probability of self-generation to be installed.</td><td>Moderate probability of new projects to materialise and low probability of self-generation to be installed.</td><td>High probability of new projects to materialise and low probability of self-generation to be installed.</td></tr>
</table>

Source: ECA analysis. ** For the base year (2021) the average consumption per household is based on ESCOM data, information from other countries in Southern Africa, and a bottom-up approach to alleviate suppressed demand. For the growth of the average demand per household an income elasticity of 1.2, 0.9 and 1.4 is assumed for the base, low and high scenarios, respectively, relative to the GDP per capita growth.*

The sent-out energy and peak demand forecasts for the Low, Base and High case scenarios were modelled following the above assumptions and approach, which have been developed with the support of the Utility Scale Working Group[1], chaired by the Ministry of Energy, and validated with stakeholders during the Final Workshop held in Lilongwe on 27 April 2023. The three scenarios developed for this demand forecast are illustrated in Figure 4.

[1] The Utility Scale Working group included technical experts from MERA, ESCOM, PML (before dissolution) and the Ministry of Energy

Figure 4 2022-2042 Updated demand forecast

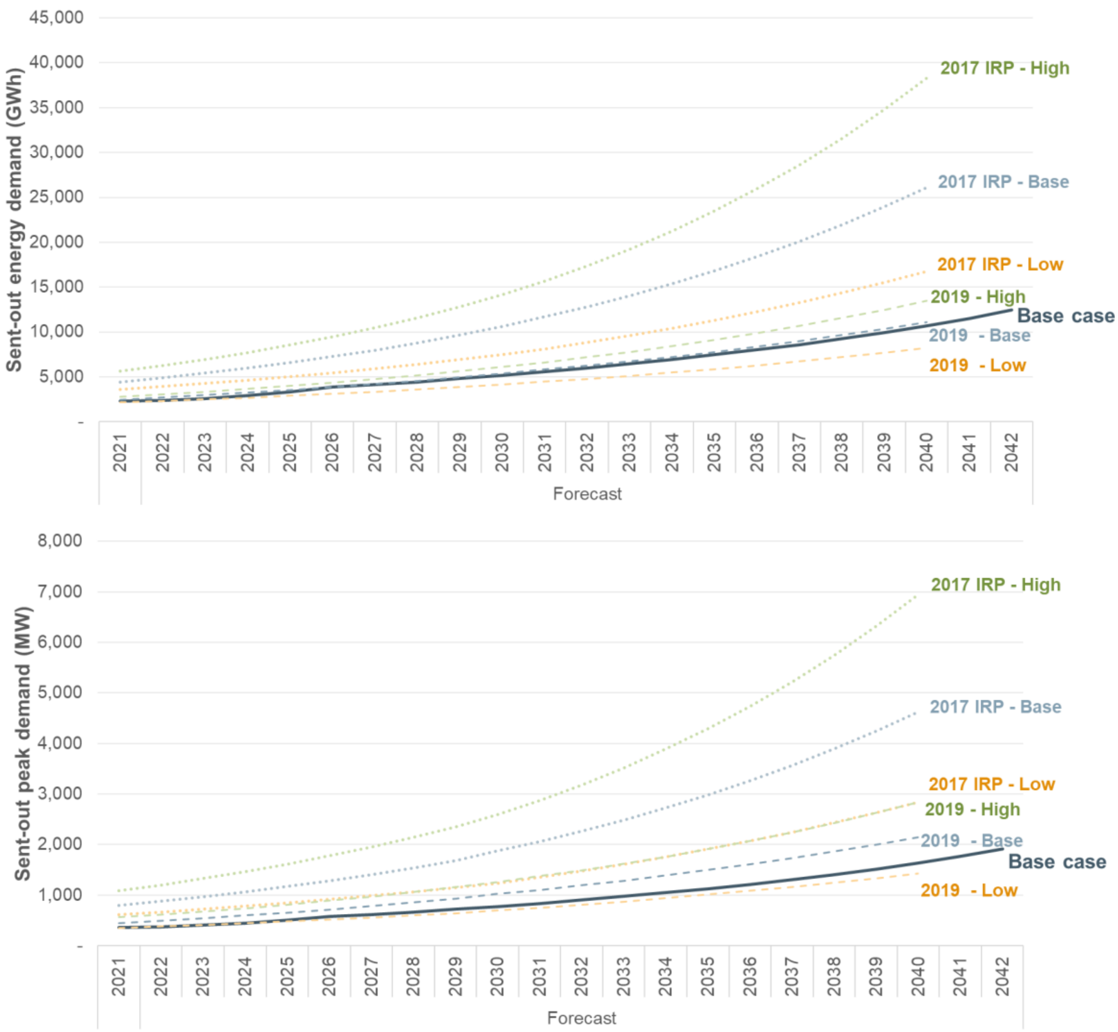


Source: ECA analysis

Comparison with previous forecasts

Compared with previous forecasts, the updated demand forecast is lower than the 2017 IRP demand forecast (see Figure 5). While the methodology used in the 2017 IRP demand forecast was satisfactory, the forecasted input assumptions varied significantly from outturn actual figures (mainly the forecasts of GDP growth, population growth, average household consumption, and electrification rates). These differences are also explained by the occurrence of socio-economic shocks due to the 2020 Covid-19 pandemic, load shedding, and recent natural disasters that have constrained demand growth. On the other hand, we find that World Bank's 2019 IRP Demand forecast update is in similar rage with the current update of the demand forecast.

Figure 5 Base case updated demand forecast vs previous forecasts



Source: ECA Analysis, 2017 IRP, 2019 WB Update

Loss reduction plan

As part of the assignment, 34 initiatives from ESCOM's 2021 Loss Reduction Roadmap (LRR) have been assessed in order to advice on its implementation. The initiatives from the LRR were found to be comprehensive, as they cover areas related to hardware, software, processes and personnel. The LRR also provides evaluations with respect to criteria such as budget and impact on losses.

For the purposes of this study, these initiatives have been ranked along three criteria: budget (low, mid, and high), impact on losses (low, mid, high, and very high), and dependency on other initiatives (0 if the initiative does not need any previous one to be implemented, up to 3). Prioritization is then done through a combination of these three criteria and illustrated in Table 3, where the initiatives' priorities are higher in the top-left corner subject to any other initiative that is ought to be implemented before.

Table 3 Initiatives subject to budget, impact on losses, and dependence criteria

Budget	Impact on losses			
	Very high	High	Medium	Low
Low		2b. New Losses Calculation methodology	8b. Instructional Workshops with stakeholders	4 a. Improvements in the Meter Life Cycle
Low		4e. Strengthen the Customer Service processes	4b. Building a role for maintaining customer data	8 a. Round table with MERA
Low		5b. Acquisition of Mobile APPs	4 g. Written Procedure on Fraud Management	5f. Improve Free-Tokens process
Low		2e. Perform Regional Balances	8c. Periodic Regulatory Internal Committees	5 g. Convert “Suprima” customers
Low			6 a. Assessment for rehabilitating the grid	4f. Improve reporting and establish KPIs
Low			4c. Review the Debt Recovery process	7b. Smart Meter Regulation
Low			4h. Establish a Centralized Quality Control areas for key processes	5 d. Document management system
Low				8 d. Attraction of Private Investment
Medium	3c. Large customer and public institutions audit	3 a. Metering in Distribution Transformers	2c. Strengthen the EBM team	4 d. Review the current Organization of the Distribution Directorate
Medium	1 a. Establishing PMO	4i. Reorganization of the Revenue Protection area	5 a. Implementing a Meter testing laboratory	
Medium	2 a. Metering in Injection Points, Substations and Feeders	5e. Internal Training for CMS and Commercial Processes	6c. Technical Losses calculation process	
High	3b. End-customers audit	7 a. Smart metering for residential and commercial customer	6b. Piloting different technical configurations on the MV-LV grid	
High	3 a. Metering in Distribution Transformers	5c. Persons in Vulnerable Situations	7c. Establishment of a Metering Data Control Center	

Colour coding indicates initiative dependence on implementation of other initiatives, as follows:

No dependency	Depends on 1 initiative	Depends on 2 initiatives	Depends on 3 initiatives

Source: Loss Reduction Roadmap, ECA Analysis

Demand Side Measures (DSM) plan

The analysis of potential DSM measures, including Demand Response (DR) as well as Energy Efficiency (EE), has considered initiatives in the residential, commercial, and industrial sectors of Malawi. The analysis suggests that additional demand response measures such as (I/C) service and demand bidding/buyback programs could be considered by ESCOM, while others such as Ancillary Services market programs could not be applicable in Malawi with the current market structure.

With respect to Energy Efficiency, the main options considered are the introduction of MEPR as well as replacement/upgrading of appliances, including air conditioning (AC) units, solar water heaters, and lighting. The analysis describes the expected impacts of options that can be applied horizontally, thus the impact from additional measures for industrial users have not been assessed as their impact would vary depending on the customer. Table 4 lists the measures to be considered as candidate options in the IRP and showcases the estimated potential impact and pay-back period of each measure.

Table 4 Shortlisted DSM measures and estimated impact and pay-back periods

Demand Side Measure (DSM)	Target Groups	Earliest year of implementation
Replacement of fluorescent bulbs with LED lights	Residential, Commercial, Public	2022
Replacement of AC units with high efficiency ones	Commercial	2023
Replacement of fans with high efficiency ones	Residential, Commercial	2023
Replacement of electric water heaters with solar	Residential, Commercial	2023
Introduction of Minimum Energy Efficiency Requirements	Residential, Commercial, Industrial	2025

Sector – end use	Total potential (GWh/year)	Capacity impact (MW)	CO2 savings (ton/year)	Pay-back period (years)
Domestic - Water heater	185.2	63.4	11,480.0	4.4
Commercial - Water heater	76.5	36.7	4,742.0	2.0
Domestic – CFL	24.0	9.2	1,487.3	1.1
Commercial – Fans	23.2	7.2	1,437.0	8.9
Commercial - FTL	19.7	6.3	1,219.0	1.1
Commercial - AC	7.7	3.9	476.0	2.7
Domestic - Fans	5.0	2.2	308.5	27.4
Commercial - CFL	4.4	1.4	273.0	0.4

Source: ECA calculations. Note: Measures highlighted in light orange indicate high pay-back period. For these measures, financial assistance for consumers might be needed to make these replacements.

1 Introduction

The *Demand forecast, loss reduction and energy efficiency plan final report* has been prepared by Economic Consulting Associates (ECA) for the *Update of the 2017 IRP Demand Forecast for Malawi* study. The primary objective of the study was to develop a demand forecast for Malawi building on the *2017 IRP demand forecast* and incorporate a properly costed energy efficiency (EE) and loss reduction plan spanning 5-20 years. A secondary but equally important objective is to provide capacity building and validate work with stakeholders.

The *final report* discusses the updated electricity demand forecast for the power sector in Malawi under three scenarios. The scope of this demand forecast is to be used as an input to the update of the Integrated Resource Plan (IRP) in Malawi. For least cost power development planning purposes, a forecast of sent-out energy (MWh or GWh) and sent-out maximum demand (MW) is required in the medium to long run. The geographical distribution of the demand is also necessary to assess capacity requirements by region for the transmission development plan. The forecast was prepared for the next 20 years (up to 2042).

In previous steps, ECA and the Utility Scale Working Group (USWG) have agreed on a set of input assumptions (*Input assumptions report*) to be used for the development of the demand forecast and on the demand forecasting approach (*Inception report*). The USWG was composed by technical experts from MERA, ESCOM, PML (before dissolution) and Ministry of Energy.

The *Demand forecast draft report* is structured as follows:

- **Section 2** describes historical energy and peak electricity demand in Malawi and comments on the historical customer and sales mix. Historical data presented in this section were used for regression analysis and to set other input assumptions for the demand forecast.

- **Section 3** presents the most recent demand forecasts that were developed for Malawi for power system planning and comments on their performance to predict the demand.

- **Section 4** provides the agreed methodology for the update of the 2017 IRP demand forecast. It also presents the proposed methodology for the development of the EE measures and loss reduction plan.

- **Section 5** presents the input assumptions used for the development of the demand forecast and the EE and loss reduction plan, including socio-economic, technical, and demographic parameters, as well as policy targets.

- **Section 6** includes the results of the regression analysis that was conducted to estimate econometric equations that link the electricity demand with macroeconomic and other parameters.

- **Section 7** discusses the Loss Reduction Roadmap and ranks loss reduction projects for implementation by ESCOM.

- **Section 8** assesses potential Demand Side Measures for the power sector in Malawi and shortlists DSM to be analysed in the update of the IRP.

- **Section 9** presents the updated demand forecast in Malawi for the period 2022 to 2042. This includes aggregate sent-out energy and peak demand forecasts at a national and regional level. It also includes a demand forecast by economic activity. The impact of potential Demand Side Measures (DSM) on the demand forecast is also shown in the results.

2 Historical demand

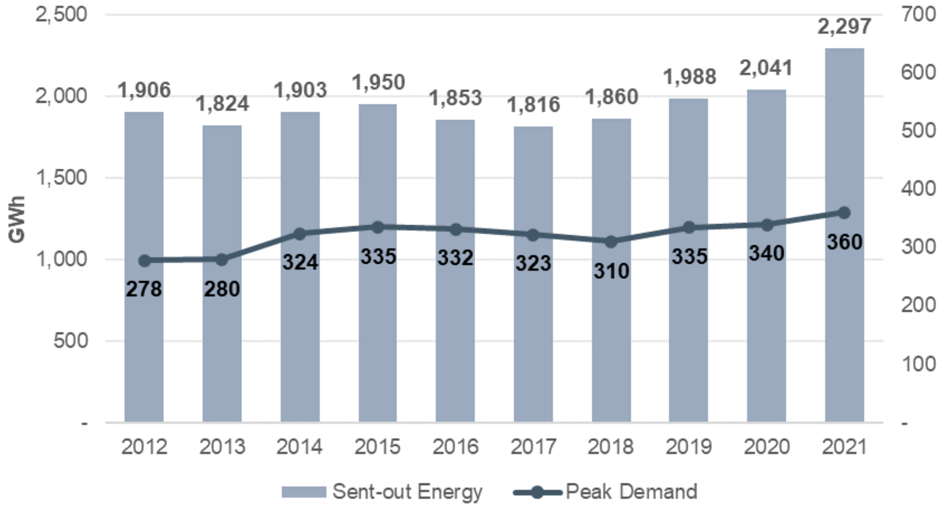
This section analyses the evolution of the demand for electricity in Malawi and unravels key changes in the consumption and customer mix over the years. It presents historical data that were used for regression analysis, demand data for the base year of the forecast (2021) and information relevant to the preparation of the demand forecast.

2.1 System historical sent-out energy and peak demand

Over the past 10 years, served energy demand grew at an average rate of 2.3% per year and peak demand at an average rate of 3.1% per year. As can be seen in Figure 6, sent-out energy demand has increased from 1,906 GWh in 2012 to 2,297 GWh in 2021. Similarly, peak demand, has increased from 278 MW in 2012 to 360 MW in 2021, an overall 20.5% increase in ten years.

In contrary to the overall increasing trend of the demand over the 10-year period, from 2015 to 2018 served demand was decreasing. The drop in sent-out energy during those years was mainly the result of increased load shedding due to unavailable energy generation from hydro power plants. Malawi in that period had experienced droughts which resulted in low water levels in reservoirs of hydro power plants (see Annex A1 for more details). From 2017 an upward trend in energy demand was observed, but growth appeared to have slowed down again in 2020 impacted from the Covid-19 pandemic[2]. In 2021, economic growth rates rebounded from Covid-19, which coupled with negligible levels of load shedding, resulting in a higher increase in sent-out energy and peak demand by 12.5% and 5.9% respectively.

Figure 6 Sent-out energy (GWh) and peak demand (MW) in 2012-2021

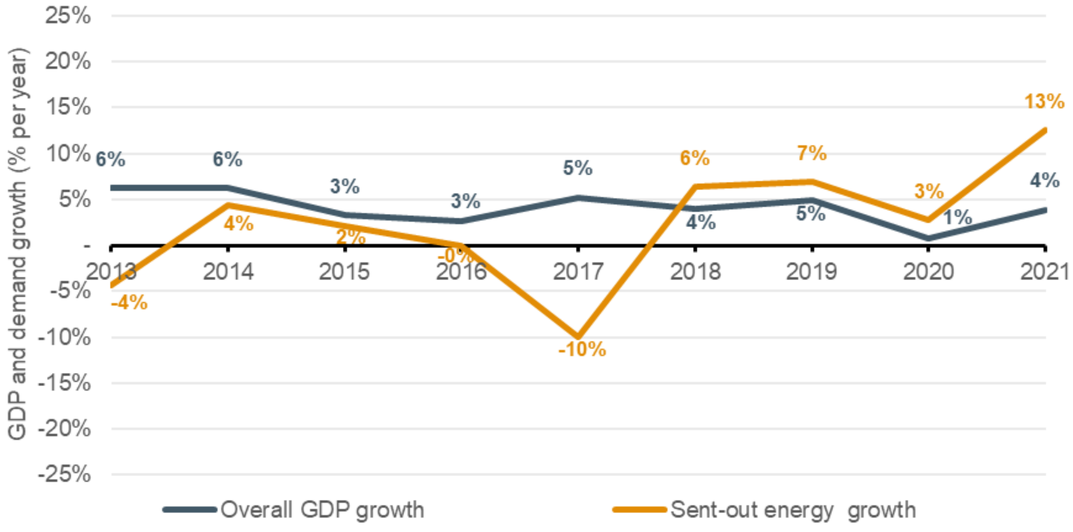


Source: ESCOM data and 2017 IRP. Note: The demand shown is the actual demand served and does not include suppressed demand or load shed.

[2] GDP growth declined from 5% in 2019 to 1% in 2020 (*Source: Annual Economic Report 2022, National Accounts*)

Figure 7 shows the evolution of economic growth (GDP growth) and energy demand growth (at generation sent-out level) over the past 10 years in Malawi. As can be seen in Figure 7, energy demand growth is aligned with GDP growth. A 1% increase in GDP growth was associated with an 0.3% increase in energy demand growth on average over the past 10 years. However, during the drought periods demand growth was not aligned with GDP growth due to the constraints imposed to the demand by unavailable supply[3].

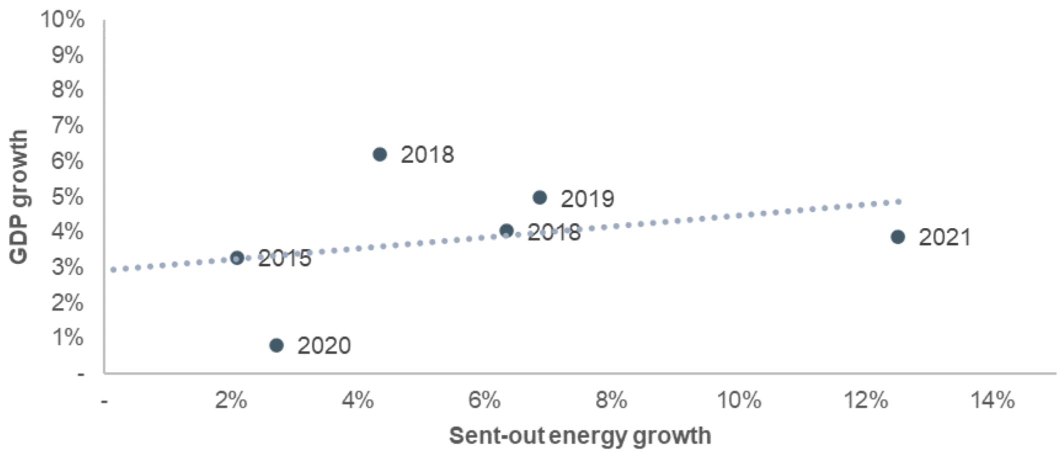
Figure 7 GDP growth rate vs sent-out energy demand growth rate in 2013-2021



Source: Annual Economic Report 2022, National Accounts 2010-2019, Sent-out energy growth calculated from ESCOM data

Excluding the years of drought (2013, 2016 and 2017 growth) from the data, the positive correlation between sent-out energy and GDP can be seen in Figure 8.

Figure 8 Sent-out energy growth vs. GDP growth 2013-2021



Source: Annual Economic Report 2022, National Accounts 2010-2019, ESCOM data

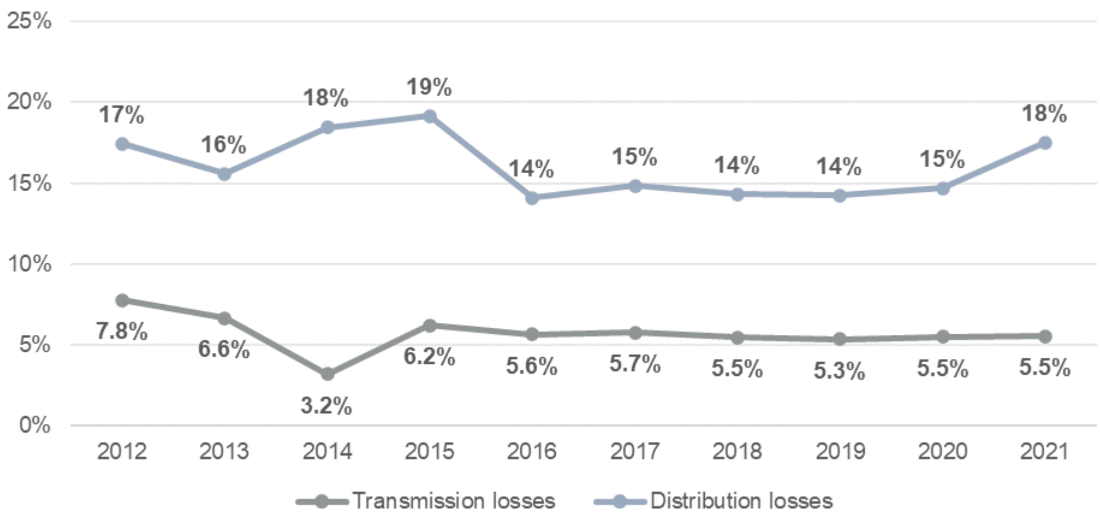
[3] The Guardian, 2017.The day the lights went out: the terrible toll of Malawi's power cuts

2.2 Historical system losses

Transmission losses have reduced over the past five years in comparison to the levels observed between 2012 and 2016. As can be seen in Figure 9, transmission losses have remained at around 5.5% since 2018 with a period of instability in 2016 and 2017. On average transmission losses were 5.7% between 2012 and 2021, which is high compared to less than 3% in most European countries[4] and less than 4% in other countries from the SADC region such as Botswana (3.7%), Namibia (3.2%) or South Africa (0.1%)[5].

Distribution losses fluctuated between 14% and 19% from 2012 until 2021. Distribution losses reached a maximum of 19% in 2015 and a minimum of 14% in 2018. A spike in distribution losses is also noticeable in 2021 reaching 18%, the highest level in five years. Distribution losses presented below cover both commercial and technical losses.

Figure 9 Transmission and distribution losses (% of incoming energy)



Source: ESCOM

2.2.1 Historical sales and number of customers

As of 2022, Malawi had 11 tariff categories which are presented in Table 5 below. ESCOM tariff categories were grouped by economic activity into four main groups – Residential (ET1, ET2, ET3, ET4), Commercial (ET5, ET6, ET7, ET8), Industrial (ET9, ET10, ET11 and large users with special tariffs).

Table 5 Current electricity tariff categories in Malawi

Groups by economic activity	Tariff Code	Description
Residential	ET1	Domestic, 1-Phase, Prepaid
	ET2	Domestic, 1-Phase, Postpaid
	ET3	Domestic, 3-Phase, Prepaid

[4] Council of European Energy Regulators, 2020. 2nd report on Power Losses
[5] Southern African Power Pool, 2021. 2021 Annual Report

Groups by economic activity	Tariff Code	Description
	ET4	Domestic, 3-Phase, Postpaid
Commercial	ET5	General, 1-Phase, Prepaid
	ET6	General, 1-Phase, Postpaid
	ET7	General, 3-Phase, Prepaid
	ET8	General, 3-Phase, Postpaid
Industrial	ET9	Maximum Demand, LV
	ET10	Maximum Demand, MV
	ET11	Essential Service, 3-Phase, Prepaid

Source: ESCOM Current Tariffs. Note: ESCOM is planning to phase out ET11 and incorporate ET11 customers to ET9 or ET10.

ESCOM total sales and number of customers by economic activity over the past 10 years is shown in the table below. The number of customers grew at a compound annual growth rate (CAGR) of 10% per year and sales grew at an average rate of 2% per year. In 2019, ET11 Essential Service category was introduced, incorporating users previously categorised as residential or commercial. Following discussions with the USWG it was agreed that these customers should be categorised as Industrial for the purpose of this analysis, resulting in a large increase in the number of customers in 2019 and 2020.

Table 6 Historical sales and number of customers 2012-2021

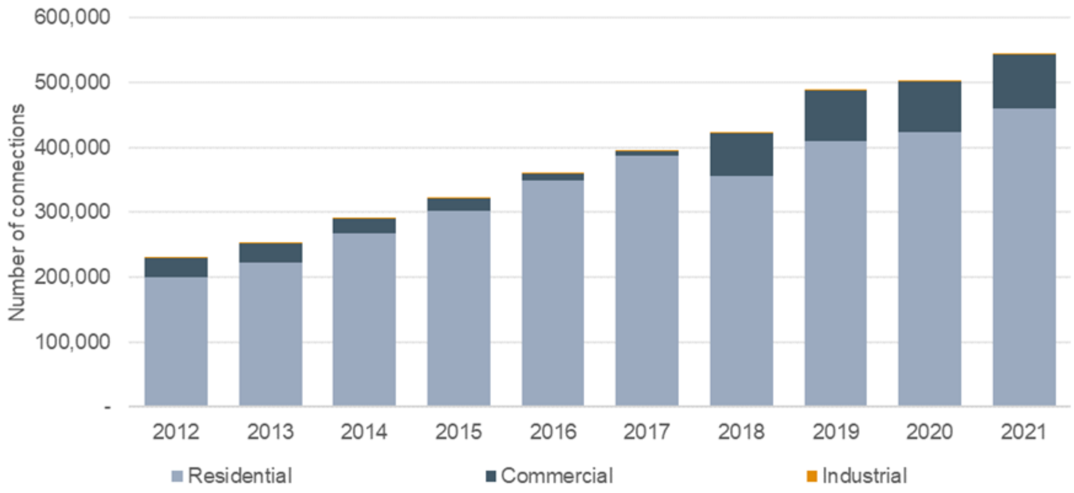
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Average
Number of customers (‘000 customers)											
Residential	199.8	223.3	267.1	301.9	349.8	387.7	355.3	409.7	424.5	459.8	337.9
Commercial	30.5	28.4	22.9	18.8	9.6	7.3	67.2	78.2	77.3	83.8	42.4
Industrial	0.80	0.84	0.85	0.89	0.90	0.92	0.96	1.19	1.81	1.90	1.1
Total	**231.1**	**252.5**	**290.8**	**321.6**	**360.2**	**395.9**	**423.4**	**489.1**	**503.6**	**545.5**	**381.4**
Number of customers growth (% per year)											
Residential	-	12%	20%	13%	16%	11%	-8%	15%	4%	8%	10%
Commercial	-	-7%	-19%	-18%	-49%	-24%	822%	16%	-1%	8%	12%
Industrial	-	5%	1%	5%	1%	2%	4%	24%	52%	5%	10%
Total	**-**	**9%**	**15%**	**11%**	**12%**	**10%**	**7%**	**16%**	**3%**	**8%**	**10%**
Sales (GWh)											
Residential	589.9	583.6	664.3	721.2	755.5	745.5	544.9	551.1	598.2	663.6	641.8
Commercial	237.0	196.0	169.4	132.6	96.9	58.0	270.7	300.4	307.4	329.2	209.8
Industrial	602.6	634.4	645.7	602.6	627.2	633.3	672.0	742.3	722.3	777.0	665.9
Total	**1,429**	**1,414**	**1,479**	**1,456**	**1,480**	**1,437**	**1,488**	**1,594**	**1,628**	**1,770**	**1,517.5**
Sales growth (% per year)											
Residential	-	-1%	14%	9%	5%	-1%	-27%	1%	9%	11%	1%
Commercial	-	-17%	-14%	-22%	-27%	-40%	367%	11%	2%	7%	4%
Industrial	-	5%	2%	-7%	4%	1%	6%	10%	-3%	7%	3%
Total	**-**	**-1%**	**5%**	**-2%**	**2%**	**-3%**	**4%**	**7%**	**2%**	**9%**	**2%**

Source: ESCOM. Note: The large increases of the number of Industrial customers in 2019 and 2020 is the result of adding those categorised previously as "Essential services" to the Industrial category. The large increases/decreases of commercial and residential users are explained below

Number of connections

The aggregate number of connections has steadily increased annually from 231,116 customers in 2012 to 545,490 customers in 2021 (see Figure 10). Residential consumers remain the largest group in Malawi, accounting for 84% of current connections, whereas industrial consumers have remained consistently below 1% of total connections. In 2018 there was a sharp increase of commercial connections which coincided with a sharp decrease of residential connections. This was due to ESCOM moving commercial customers previously grouped under the residential category to the commercial category.

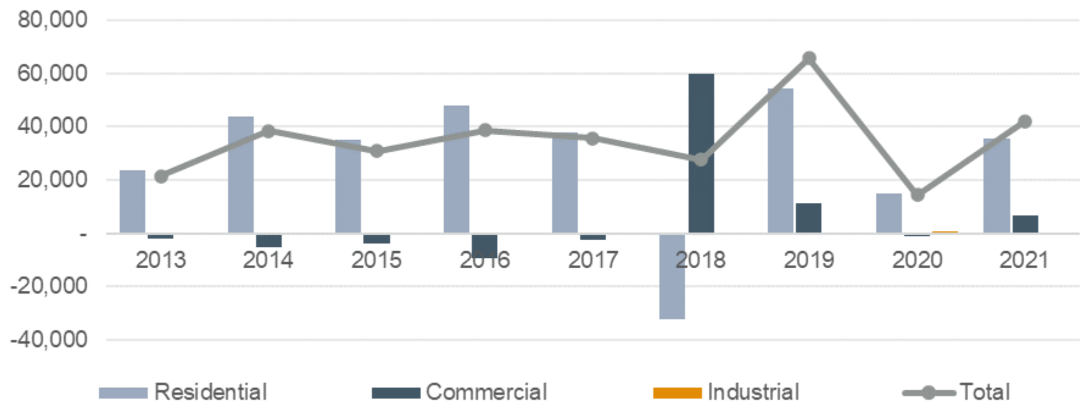
Figure 10 Number of connections by consumer group 2012-2022



Source: ESCOM

The average number of new connections between 2013 and 2021 was 34,390 customers per year, with the vast majority being new residential users (see Figure 11). Without taking into account the move of customers from the residential to the commercial category, each year an average of 33,992 residential connections were added, while 5,624 commercial users were added on average in 2020 and 2021.

Figure 11 New connections by consumer group

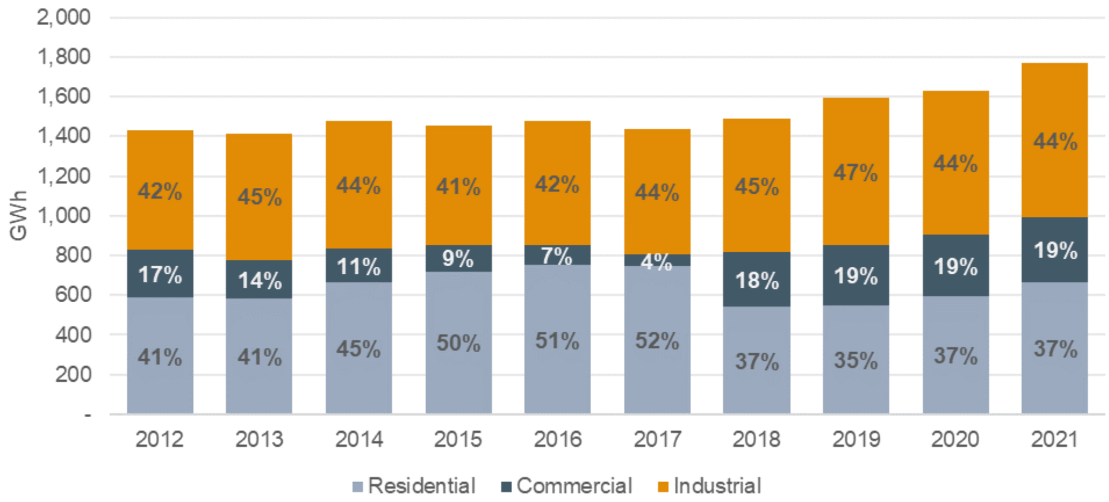


Source: ESCOM Note: Negative new connections are due to ESCOM moving commercial customers previously grouped under the residential category to the commercial category and vice-versa.

Sales

In terms of energy sales, industrial consumers are, along residential consumers, the largest groups in the country (see Figure 12). In 2021, residentials sales accounted for 37% of total sales, industrial 44% of total sales and commercial 19% of total sales. The consumption mix has remained relatively stable over the past 4 years. The step change observed in 2018 is due to ESCOM moving commercial customers previously grouped under the residential category to the commercial category.

Figure 12 Sales by consumer group 2012-2021



Source: ESCOM

Consumption per connection varies widely depending on the type of customer as seen in the table below. For residential users, the average annual consumption per customer between 2012 and 2022 was 2,026 kWh per year (or 169 kWh per month). Commercial users consumed 6,549 kWh on average per year per customer and industrial consumers 645,574 kWh on average per year per customer. For all three consumer groups the average consumption per year per user was reducing from 2012 to 2021. This is a result of new customers connected to the grid, who used less electricity.

Table 7 Average annual consumption per customer by consumer group (MWh)

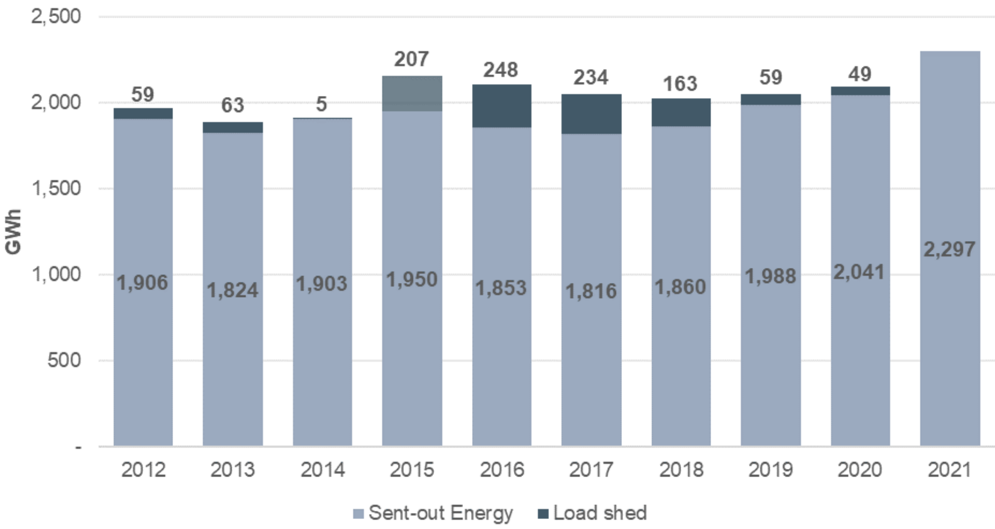
Consumer group	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Average
Residential	3.0	2.6	2.5	2.4	2.2	1.9	1.5	1.3	1.4	1.4	2.0
Commercial	7.8	6.9	7.4	7.1	10.1	8.0	4.0	3.8	4.0	3.9	6.5
Industrial	751.3	753.5	758.8	674.0	694.5	686.9	701.4	625.8	399.5	410.0	645.6

Source: ESCOM

2.3 Historical load shedding

Load shedding has been a chronic problem in the Malawi's power sector. Energy lost from load shed ranged between 5 GWh and 248 GWh from 2012 to 2020 (see figure below). However, a positive trend with negligible load shedding was observed in 2021. The annual values of energy not served due to load shedding for the 2012-2021 period can be seen in Figure 13.

Figure 13 Lost load and sent-out energy served by year (GWh)



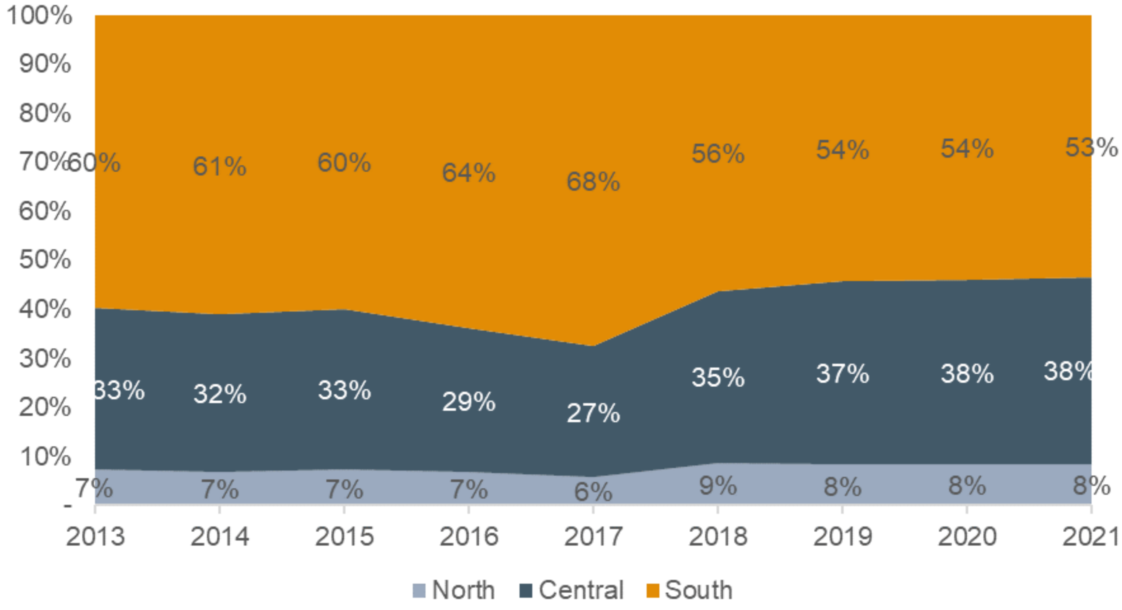
Source: ESCOM. Note: For 2015 the load shed value does not include the months of February-June

The years with the highest load shed were 2015, 2016, 2017 and 2018. This seems to confirm discussions with relevant stakeholders, who point to widespread load shedding between 2015 and 2017 as a result of low rainfall curtailing hydropower generation. Nonetheless, following discussions with ESCOM, it was agreed that 2021 experienced little to no load shedding and can be used as a representative base year for the demand forecast.

2.4 Historical geographical split of demand

Historically, most of the energy demand has come from the Southern region (more than 53% of total demand). The Central region accounts for around a third of energy demand and the Northern region accounts less than 10%. However, as seen in Figure 14, energy demand from the Central region has increased substantially, reaching 38% of the overall energy demand in 2021.

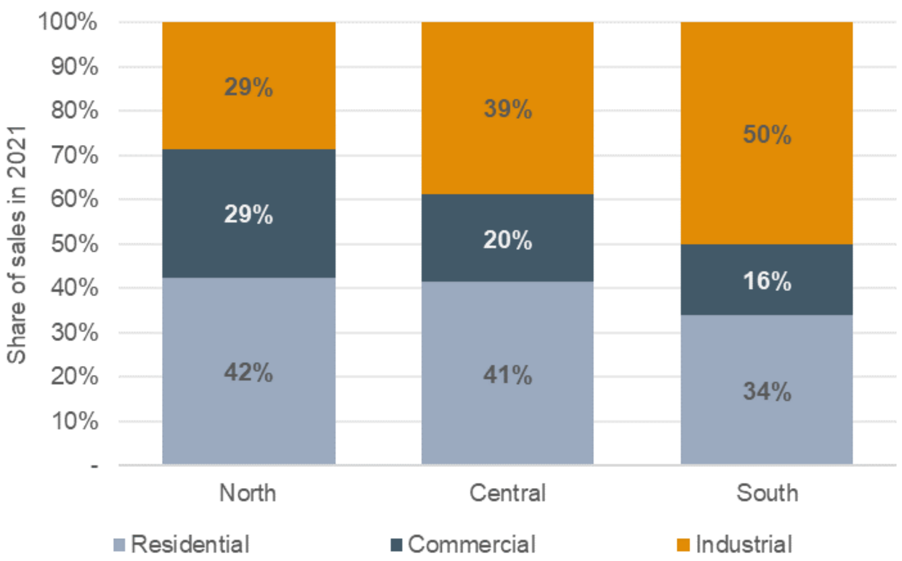
Figure 14 Energy sales by region 2012-2021



Source: ESCOM.

Industrial sales in the Northern region are lower compared to the other two regions, as shown in Figure 15. This is due to lower industrial activity in the Northern region and due to higher outages rates of the network. As of 2021, energy sales from industrial consumers accounted for 28% of the region's total sales, compared to 38% in the Central region and 50% in the Southern region. Residential share of consumption is similar across the three regions at around 34-42%. The share of commercial consumption in the Northern region (29% of total Northern region sales) is higher compared to the share of commercial consumption in the Central and Southern regions (20% and 16%, respectively).

Figure 15 Energy demand composition by region in 2021



Source: ESCOM.

2.5 Energy balance

The following table presents the energy balance[6] for Malawi for 2012 to 2021.

Table 8 Malawi's historical energy balance

Item	Unit	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Energy (sent-out)	**GWh**	**1,906**	**1,824**	**1,903**	**1,950**	**1,853**	**1,816**	**1,860**	**1,988**	**2,041**	**2,297**
Transmission losses	GWh	148	121	60	121	104	104	101	106	112	127
Share	%	7.8%	6.6%	3.2%	6.2%	5.6%	5.7%	5.5%	5.3%	5.5%	5.5%
Energy exiting transmission network	GWh	1,758	1,703	1,843	1,829	1,749	1,712	1,758	1,882	1,930	2,170
Sales at transmission network	GWh	-	-	-	-	-	-	-	-	-	-
Energy entering distribution network	**GWh**	**1,758**	**1,703**	**1,843**	**1,829**	**1,749**	**1,712**	**1,758**	**1,882**	**1,930**	**2,170**
Distribution losses	GWh	306	265	340	350	246	254	252	268	283	380
Share	%	17%	16%	18%	19%	14%	15%	14%	14%	15%	18%
Distribution network sales	**GWh**	**1,452**	**1,437**	**1,502**	**1,478**	**1,502**	**1,458**	**1,507**	**1,614**	**1,646**	**1,789**
Export	GWh	22	23	23	22	23	21	19	20	18	20
Domestic	GWh	**1,429**	**1,414**	**1,479**	**1,456**	**1,480**	**1,437**	**1,488**	**1,594**	**1,628**	**1,770**
Residential	GWh	590	584	664	721	755	745	545	551	598	664
Commercial	GWh	237	196	169	133	97	58	271	300	307	329
Industrial	GWh	603	634	646	603	627	633	672	742	722	777

Source: ESCOM and 2017 IRP. Note: In 2018 ESCOM identified that some commercial customers were included in the residential category in previous years, and they were allocated to the commercial category.

[6] In this section, Energy Balance refers to the flow of electricity from generation to transmission and supply. The generated electricity should be balancing the electricity consumed or lost.

3 Review of previous demand forecasts

In the past few years, one demand forecast has been developed for the power sector in Malawi for planning purposes. This was developed in 2017 for the *2017 Malawi Integrated Resource Plan (IRP)*. In 2019, the *2017 Malawi Integrated Resource Plan (IRP)* demand forecast was updated by the World Bank, but this was for its internal usage. The *2017 Malawi Integrated Resource Plan (IRP)* demand forecast and the 2019 update of the Integrated Resource Plan demand forecast are discussed below.

3.1 2017 Malawi IRP demand forecast

The demand forecast developed for the 2017 Integrated Resource Plan follows a mix of forecasting approaches. For residential consumption, demand is determined by population growth, electrification rates and consumption per urban or rural user. Non-residential consumption is forecasted using an econometric equation linked to GDP growth. New Industrial step loads were identified separately and added to the demand forecast. Probabilities were assigned for the likelihood of this projects to materialise.

Some key assumptions of the 2017 IRP demand forecast are shown in the table below.

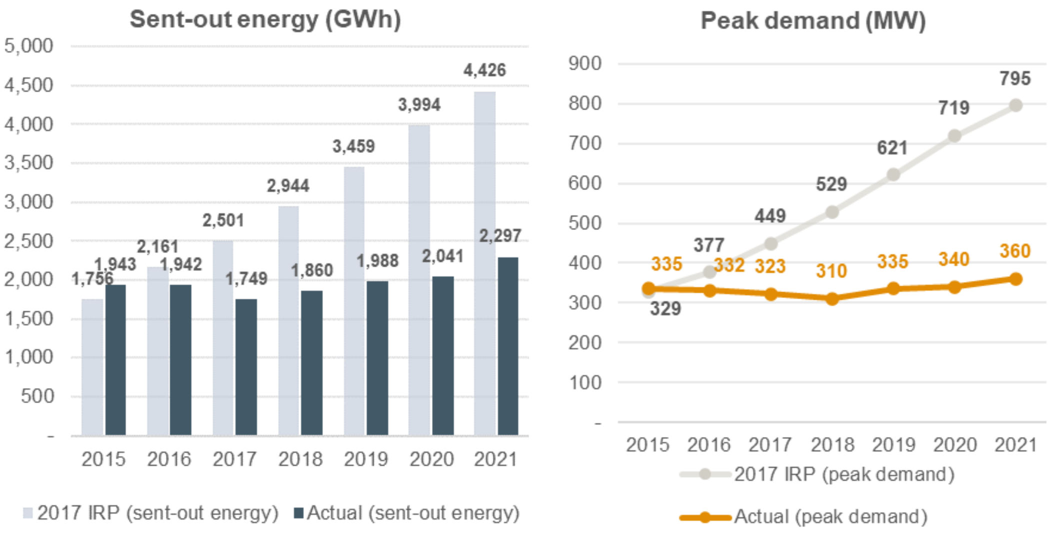
Table 9 2017 IRP demand forecast key input assumptions

Assumption	Low	Base	High
Population growth	Population growth rate was assumed to be 3.4% per year declining to 2.4% per year by 2050		
Electrification rate	2020 – 12.4% 2030 – 20.4% 2040 – 42.0%	2020 – 15.9% 2030 – 29.5% 2040 – 53.0%	2020 – 22.7% 2030 – 35.9% 2040 – 58.0%
Average consumption per household	Average monthly consumption per household was assumed to increase from 218 kWh in 2015 to 248 kWh in 2020, reaching 267 kWh in 2040		
GDP growth rate	0.5% p.a. lower than the base case up to 2021 1% p.a. lower than the base case after 2021	~4.0 – 4.5% p.a. up to 2021 5.0% p.a. up to 2030 4.5% p.a. up to 2040	0.5% p.a. higher than the base case up to 2021 1% p.a. higher than the base case after 2021
Losses	16% by 2020 12% by 2030	18% by 2020 15% by 2030	22% by 2020 18% by 2030
Suppressed demand (load shedding)	50 GWh	100 GWh	200 GWh
Step loads	130 GWh	200 GWh	260 GWh
Connection of existing loads (2016-2020)	147 GWh	147 GWh	147 GWh

Source: 2017 IRP

As can be seen in Figure 16, actual energy and peak demand served was lower than the demand projected in the 2017 IRP, with sent-out energy accounting for around a half of the projected value in 2021 (2,297 GWh vs. 4,426 GWh) and peak demand accounting for less than half (360 MW vs. 795 MW). The impacts of COVID-19 pandemic were not foreseen in the 2017 demand forecast which had assumed much higher GDP growth rates than actuals. Additionally, the 2017 IRP demand forecast had reflected policy targets for electrification rates of the country which did not materialise[7]. The luck of foreseen infrastructure improvements and developments failed to alleviate suppressed demand that was assumed that it would be served.

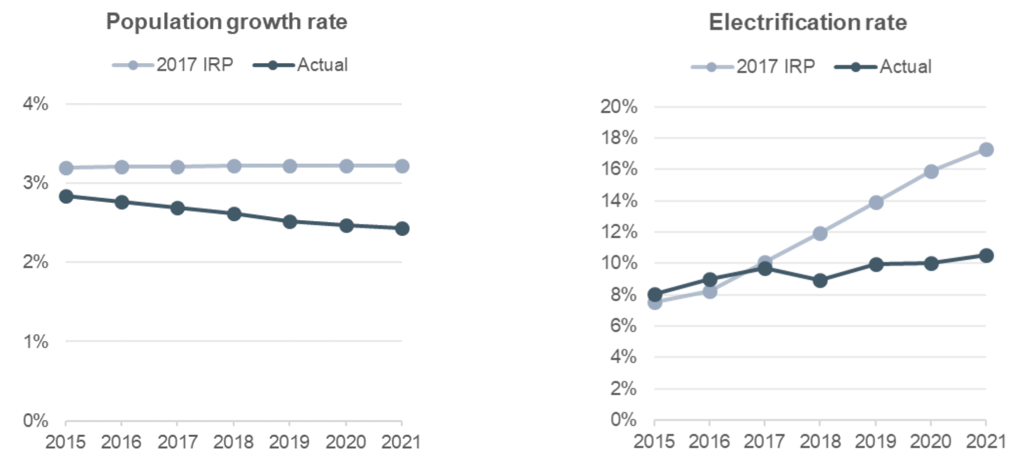
Figure 16 2017 IRP demand forecast (base case scenario) vs actual served demand



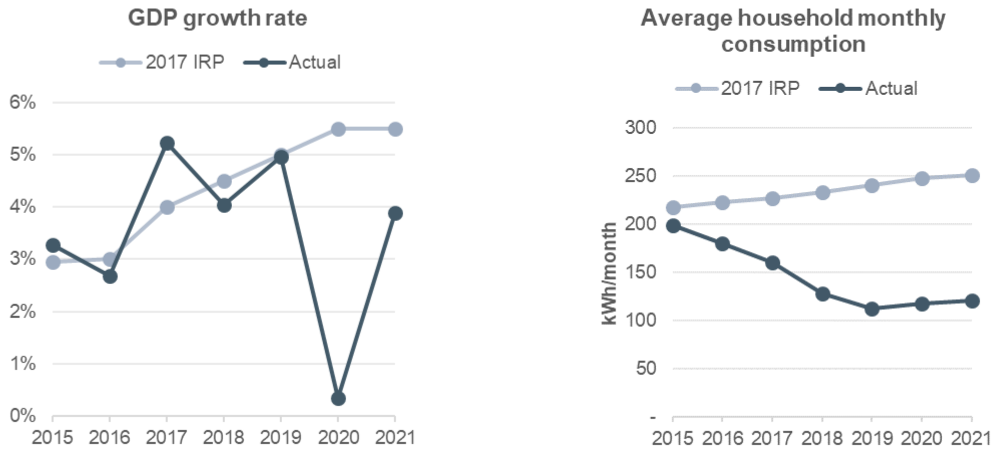
Source: 2017 IRP, ESCOM data

A comparison of the assumption used in the forecast with respect to the actual values for 2015-2021 is presented in Figure 17.

Figure 17 2017 IRP demand forecast assumptions vs actual values 2015-2021



[7] ESCOM reported that failure to connect new customers (both industrial and residential) is due to constrained supply chain management of materials needed for connections including transformers.



Source: 2017 IRP Base case scenario

3.2 2019 Malawi IRP demand forecast update

The World Bank in 2019 updated the demand forecast of the IRP for its internal use. The updated demand forecast followed the same approach as the 2017 IRP but updated some assumptions as shown in Table 10 below.

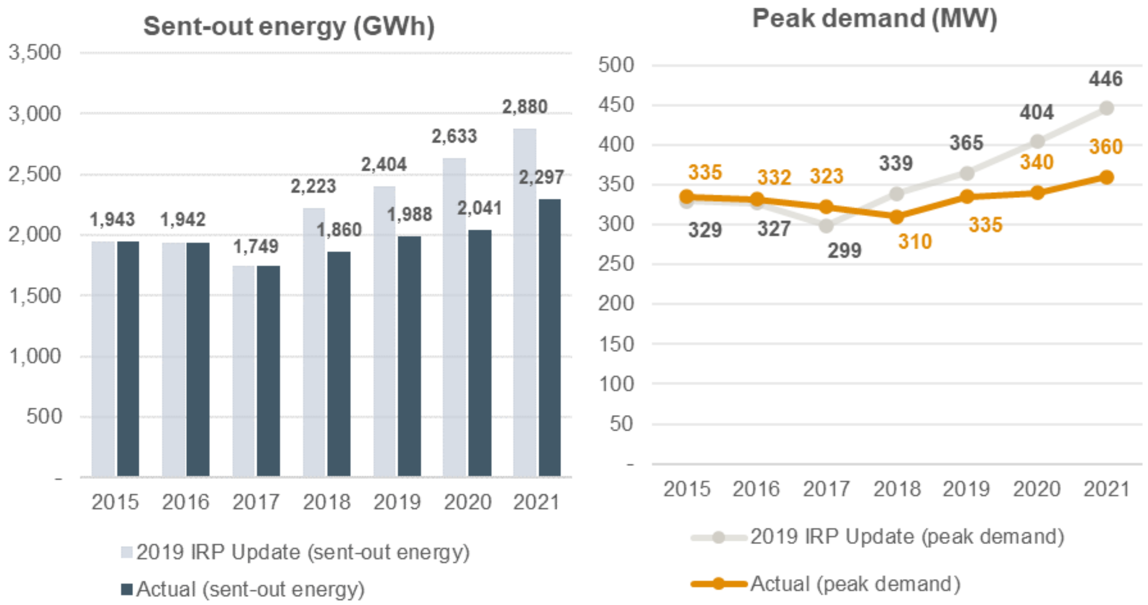
Table 10 2017 IRP vs 2019 IRP Update assumptions (base case scenarios)

Assumption	2017 IRP	2019 IRP Update
Electrification rate	• 15.9% in 2020 • 29.5% in 2030 • 53% in 2040	• 13.5% in 2020 • 30.0% in 2030 • 50.3% in 2040
GDP growth rate	• 4-4.5% per year until 2021 • 5% per year until 2030 • 4.5 per year until 2040	• 4.5% per year (2018-2040)
Losses	• 18% per year until 2020 • 15% per year until 2030	• 16% per year until 2020 • 15% per year until 2030
Suppressed demand	100GWh	400GWh

Source: 2019 Malawi IRP Update

The updated demand forecast is shown in Figure 18 and is also compared with actual historical energy and peak demand recorded in the system. The updated demand forecast was much closer to the actual demand indicating that the input assumptions of the base case demand forecast of the 2017 IRP were probably overly optimistic.

Figure 18 2019 IRP demand forecast update (base case scenario) vs actual demand



Source: 2019 Malawi IRP Update

4 Forecasting approach

4.1 Demand forecasting approach

The demand forecast was developed for the following 20 years (2022 to 2042) and was prepared for a low, base and high scenario based on alternative assumptions relating to the key drivers such as GDP growth, electrification policies, industrial development, self-generation and others (see Section 5). The starting year of the forecast (base year) was proposed to be the most recent year with representative data. 2021 was considered by stakeholders as a year without significant load shedding, with minor impacts from COVID-19 pandemic and with available data to be considered as the base year for the forecast. However, it was noted that adjustments may have to be considered on the 2021 data to account for load shed or suppressed demand not reflected in the 2021 data.

The approach for the development of the demand forecast of each economic activity is summarised in the table below. The forecast of each economic activity is then aggregated to form the national demand forecast. Using locational information the national demand forecast is then disaggregated by region. More information regarding the demand forecast approach and the reasoning for the chosen methodologies are described in the *Inception report* and the *Input assumptions report*.

Table 11 Methodology for the demand forecast

Activity	Approach	Description
Domestic	Bottom-up	*Domestic energy demand is estimated separately for urban and rural households using the following equation:* ***Average consumption per urban or rural household per year x number of urban or rural domestic connections per year*** • *Average consumption per household per year uses as a basis the average consumption of 2021.* • *The growth of the average consumption per household per year is estimated using the income elasticity of demand for residential customers. Thus, we quantify the relationship between GDP per capita and electricity consumption per household and adjust it to reflect the adoption of energy efficiency measures and the increasing efficiency of household appliances.* • *The number of connections is estimated as* ***Electrification rate x number of households*** – *The forecast electrification rate varies by scenario and seeks to incorporate policy targets, ESCOM's connection targets and the historical performance of ESCOM to achieve those targets.* – *The number of households is estimated using population forecasts and the average number of persons per household forecast.*

Activity	Approach	Description
Commercial	Econometric	*Econometric equation describing the relationship between commercial sales and independent variables. Combinations of several parameters were analysed for the independent variables (eg total GDP, services GDP, population growth, GDP per capita, etc) to identify the highest statistical significance.*
Industrial LV	Econometric	*Econometric equation describing the relationship between Industrial LV sales and independent variables. Combinations of several parameters were analysed for the independent variables (eg total GDP, services GDP, population growth, GDP per capita, etc) to identify the highest statistical significance.*
Industrial MV	Econometric and bottom-up	*Econometric equation describing the relationship between Industrial MV sales and independent variables. Combinations of several parameters were analysed for the independent variables (eg total GDP, services GDP, population growth, GDP per capita, etc) to identify the highest statistical significance.* *The demand of new large industrial loads and shutdowns that cannot be identified in historical information (econometric equation) can be identified separately to be added/subtracted to/from the demand forecast. Probabilities were assigned to each new project for each year to obtain probability adjusted demand.* *Self-generation is also accounted using a similar approach as with new step loads.* *A survey was conducted to identify new industrial loads and plans for self-generation.*
Exports	Bottom-up	*No firm export commitments were identified to be considered in the demand forecast.*

Note: ESCOM specifies that the Maximum Demand LV and MV categories are intended to cover "Large power for industrial users"

4.2 Energy efficiency and loss reduction plan approach

The energy efficiency and loss reduction analysis focused on the identification and analysis of potential energy efficiency and loss reduction measures to reduce electricity consumption, the demand for electricity and losses in Malawi.

The approach for the examination of energy efficiency measures was planned along two axes:

- Measures that have been applied in the past in Malawi and their effectiveness could be considered ex post, based on actual changes to the load curve, and/or the level of annual or seasonal consumption.
- Measures that have not been applied in Malawi yet, and their effectiveness could be considered ex ante, in the context of this study.

Loss reduction measures have been extensively and exhaustingly reviewed in the context of the *Loss Reduction Roadmap 2021*. The proposed loss reduction measures were considered for implementation by ESCOM and were accounted in the demand forecast.

The impact of the identified energy efficiency and loss reduction measures were then added to the demand forecast in different combinations according to the scenario assumed.

5 Input assumptions for the forecast

Section 5 presents the input assumptions that were used for the development of the demand forecast and for the energy efficiency and loss reduction plan. These were also discussed in detail in the *Input assumptions report* which was subsequently validated by stakeholders. Annual values for all years in the forecasting period are presented in Annex A2.

5.1 Forecast period

The scope for the development of the demand forecast is to be used in the update of the Integrated Resource Plan for Malawi. For power sector assets that have lives of 25 years or more it is important to have a long-range demand forecast typically of 20 years or more to assess the investments throughout their lifetime.

The demand forecast will cover the period 2022-2042 with 2021 as the base year of the forecast. As indicated in Section 4.1 and 2.3, 2021 is considered a year without significant load shedding, with minor impacts from COVID-19 pandemic and with available data and could be considered as the base year for the forecast. However, adjustments were considered on the 2021 data to account for load shed or suppressed demand as indicated in the subsections below.

5.2 Forecast domestic customer connections

The 2018 Census provides historical and forecast (2018-2050) population in Malawi and the average number of persons per household. The information from the 2018 Census can be used to estimate the number of households in urban and rural areas by region. The number of connections is estimated combining information for the number of households and forecast electrification rates. The population forecast is assumed to be the same for the three scenarios and the key variance is the forecast electrification rate in each scenario. Historical domestic connections up to 2021 have been obtained from ESCOM.

5.2.1 Historical and forecast population growth

The following table presents the estimated urban and rural population growth used in the demand forecast for the period 2022-2042. According to the 2018 Census, the urbanisation rate has remained stable in the last few decades, with the share of urban population increasing by 0.7% between 2008 and 2018. Thus, we have assumed this trend will continue until 2042.

Table 12 Population forecast summary

	Unit	2021	2025	2030	2035	2040	2042
Urban population	million	3.1	3.4	3.9	4.4	4.9	5.2
Urban population growth	%*	2.8%	2.7%	2.5%	2.4%	2.3%	2.3%

	Unit	2021	2025	2030	2035	2040	2042
Rural population	million	15.8	17.3	19.2	21.2	23.2	24.2
Rural population growth	%*	2.3%	2.1%	2.0%	1.9%	1.8%	1.8%
Total population	million	**18.9**	**20.7**	**23.1**	**25.6**	**28.2**	**29.2**
Total population growth	%*	**2.4%**	**2.2%**	**2.1%**	**2.0%**	**1.9%**	**1.9%**

Source: 2018 Census. Note: * Average of the period starting from the indicated year and ending one year prior to the next indicated year.

5.2.2 Historical and forecast household size and number of households

As with the population forecast, there is no variation among the three demand forecast scenarios for the number of persons per household. The forecast of the average number of persons per household follows the 2018 Census and the trend observed between 2008 and 2018 for the growth of the number of average persons per household is assumed. An average annual reduction of 0.2 persons per household (from 4.6 to 4.4 persons per household) is assumed until 2042, where the household size is expected to be 3.9 persons per household. These values vary slightly between regions, with the North region household size starting at 4.7 persons per household in 2021 and decreasing to 4.1 persons per household in 2042; for the Central region, the household size is expected to fall from 4.3 to 3.9 persons per household in the same time period, while for the South region it will slightly decrease from 4.3 to 4.1 persons per household. The assumed household size and number of households is shown in Table 13 below.

Table 13 Number of households and household size summary

	Unit	2021	2025	2030	2035	2040	2042
Household size	Average persons	4.3	4.3	4.2	4.1	4.0	3.9
Number of households	million	4.4	4.9	5.6	6.3	7.1	7.5

Source: Malawi Statistical Yearbook 2020 and 2018-2050 Population Projections

5.2.3 Electrification targets

Following discussions with members of the Utility Scale Working Group, the following assumptions for electrification targets by scenario were agreed:

- **Low scenario:** In this scenario electrification targets are constrained by ESCOM's historical capacity to connect new domestic consumers. Historically (from 2013 to 2021), ESCOM was connecting 35,000 domestic customers on average per year. The same number of new domestic connections is assumed for the forecast period per year reaching an electrification rate of 16.8% in 2042.

- **Base scenario:** This scenario is determined by the Ministry of Energy's Guidelines for Implementation of the National Electrification Programme. This includes a target electrification rate of 32.4% by 2030. From 2030 to 2042, it was assumed that the electrification rate will increase linearly to reach 55.5% by 2042, which reflects the trend from the 2022-2030 period.

- **High scenario:** This scenario uses the electrification targets set by the SE4ALL electrification plan, which aims to reach 100% electrification by 2030. However, as these estimates include households covered by off-grid solar PV and SHS, we have only used the estimates for grid expansion and grid intensification. These represent annual increases reaching over 900,000 in 2028, achieving 72.7% electrification (excluding off-grid) by 2030. For 2031-2042, we assume that every new household will represent a new grid connection.

The assumed domestic connections and electrification rates for each scenario of the demand forecast are shown in Table 14.

Table 14 Electrification targets

Scenario	Item	2021	2025	2030	2035	2040	2042
Low	Total domestic connections	459,776	654,600	829,600	1,004,600	1,179,600	1,249,600
	New domestic connections per year	35,294	35,000	35,000	35,000	35,000	35,000
	Electrification rate	10.6%	13.4%	14.9%	15.9%	16.6%	16.8%
Base	Total domestic connections	459,776	999,600	1,669,600	2,563,072	3,647,650	4,140,081
	New domestic connections per year	35,294	150,000	130,000	193,219	233,225	240,656
	Electrification rate	10.6%	21.5%	32.4%	40.7%	51.3%	55.5%
High	Total domestic connections	459,776	1,122,441	4,038,622	4,784,978	5,594,908	5,937,678
	New domestic connections per year	35,294	256,894	475,330	154,056	167,171	172,884
	Electrification rate	10.6%	23.1%	72.7%	75.9%	78.7%	79.6%[8]

Source: Guidelines for Implementation of the National Electrification Programme, SE4ALL Electrification Plan

5.3 Average consumption per household

The average consumption per household was estimated separately for urban and rural consumers. Rural households consume on average less than the urban households and this needs to be captured in the demand forecast as most new connections are expected to be for rural households (as was the case historically). The increase of rural connections from 2012

[8] This refers to grid-connected households only. Full electrification achieved by 2030 with the remaining households expected to be electrified though off-grid systems.

has resulted in a decreasing trend on the average consumption per household per year and this is expected over the coming years as well.

In 2021, the billed average monthly consumption per household was 120kWh. However, consumption was higher for urban households than for rural households. Historical information on the average consumption per urban and rural household in Malawi was not available and the following approach was adopted to estimate the average consumption per household separately for urban and rural consumers.

The average monthly consumption for rural households was assumed to be close to 50kWh in 2021 based on information of rural households in other countries (see Table 15).

Table 15 Monthly consumption per rural household in Ethiopia and Zambia

Country	Monthly electricity consumption
Ethiopia	45.1 kWh (rural), 149.7 kWh (urban)
Zambia	~50 kWh (rural, estimated based on reported affordability levels)

Sources: Ethiopia - Beyond Connections: Energy Access Diagnostic Report Based on the Multi-Tier Framework, World Bank, 2018; Zambia - Beyond Connections: Energy Access Diagnostic Report Based on the Multi-Tier Framework, World Bank, 2019

The indicated average monthly consumption for rural households (~50 kWh per month) was also supported by a bottom-up analysis on the amount of electricity rural households are likely to consume. Table 16 below provides an overview of assumed rural household's electricity consumption while a full list of appliances considered is provided in Annex A2. 50 kWh per month would be adequate to cover lighting needs, sporadic operation of a small TV or a radio, ironing once per week, a small fridge and small power needs (ie mobile phone charging, computer charging, fan, etc.). The indicated level of consumption for rural households also aligns with observations of rural households in the region and falls within the ESMAP Tier 3 level of service.

Table 16 Indicative rural households' monthly electricity consumption

Item	No of items	Capacity *(W per month)*	Hours used *(h per day)*	Days used *(days per month)*	Energy used *(kWh per month)*
Light					
Fluorescent tube lamps	4	10	6	30	7.2
TV					
25" color TV	1	150	3	30	13.5
Other					
Radio	1	4	3	30	0.4
Iron	1	1,000	2	4	8
Kettle	1	2,200	0.1	10	2.2
Fridge (small)	1	100	4.7	30	14.3
Fan	1	10	3	10	0.3

Item	No of items	Capacity *(W per month)*	Hours used *(h per day)*	Days used *(days per month)*	Energy used *(kWh per month)*
Laptop	1	35	2	30	2.1
Phone charging	1	5	1	30	0.15
Total					**48.15**

Source: http://www.energuide.be/en/questions-answers/how-much-energy-do-my-household-appliances-use/71/, http://www.greatbowden.org/documents/TypicalEnergyUsageforHouseholdAppliances.pdf ,http://www.wholesalesolar.com/solar-information/how-to-save-energy/power-table

The average urban monthly consumption was then back-calculated from the total average monthly domestic consumption in 2021 in Malawi and the assumed average monthly consumption for rural households shown above. The results indicated that urban households consume a third more than the total average consumption per household (a ratio which was also used in the 2017 demand forecast), obtaining a monthly urban consumption around 160kWh. This consumption level is also similar to values observed in urban areas in Ethiopia and Zambia (see Table 15) and falls in the Tier 4 level of service as defined by the World Bank ESMAP Multi-tier Framework for Access to Household Electricity Supply.

The exact values that resulted from the calculations were 47kWh on average per month for rural households and 160kWh on average per month for urban households in 2021.

To estimate the forecast growth of the average consumption per household, we calculated the income elasticity of residential demand as percentage change of GDP per capita over percentage change in average annual consumption per household. This resulted in an income elasticity of residential demand of 1.7, meaning that average consumption per household will increase by 1.7% for a 1% increase in GDP per capita. However, the income elasticity that was calculated was reduced to reflect:

- An increase in household disposable incomes will lead to higher electricity consumption from the purchase of new appliances.
- New appliances are expected to be more energy efficient; this includes the phasing out of incandescent lightbulbs that has been undergoing since 2011.

For the base case scenario, we assumed an income elasticity of 1.2, for the low case scenario an income elasticity of 0.9 and for the high scenario 1.4. The resulting average monthly consumption per urban and rural household is shown in Table 17.

Table 17 Average consumption per household (kWh per month)

Scenario		2021	2025	2030	2035	2040	2042
Low	**Urban**	160	163	172	187	203	211
	Rural	47	48	51	55	60	63
	Residential	**120**	**113**	**115**	**122**	**130**	**134**
Base	**Urban**	160	165	188	217	252	268
	Rural	47	49	56	64	75	79

Scenario		2021	2025	2030	2035	2040	2042
	Residential	**120**	**96**	**99**	**108**	**121**	**127**
High	**Urban**	160	170	203	250	309	337
	Rural	47	51	60	74	92	100
	Residential	**120**	**93**	**94**	**114**	**140**	**153**

Source: ECA

5.4 Historical and forecast economic growth

Economic growth is considered a key driver of electricity demand. For the 2022-2042 period real GDP growth forecasts were used to capture the anticipated economic growth. For the development of the demand forecast the following economic growth scenarios were adopted:

- **Low scenario:** Assumes that economic growth in Malawi will be affected by global conflicts, other unforeseen events (eg cyclones, etc) and that Covid-19 pandemic has longer lasting impacts on economic growth. GDP growth is assumed to be closer to the average growth over the past 3 years (3.9%).
- **Base scenario:** This scenario uses the IMF GDP growth projections up to 2028. For the 2028-2042 period, the long-term GDP growth rate from IMF has been adopted (4.5%).
- **High scenario:** Assumes that from 2023, GDP growth will be higher than the IMF GDP growth projection (and closer to historical high GDP growth rates). This represents a quick recovery from COVID-19 pandemic as well as high economic growth conditions in Malawi.

The forecast GDP growth rates that were used for the development of the demand forecast are shown in Table 18.

Table 18 Real GDP forecast by sector (billion MWK) and forecast GDP growth (%)

Scenario	GDP	2021	2025	2030	2035	2040	2042
Low	Agriculture	1,696	1,815	2,047	2,341	2,678	2,826
	Industry	1,461	1,584	1,826	2,141	2,510	2,676
	Services	3,909	4,341	5,224	6,427	7,906	8,590
	Total	**7,499**	**8,260**	**9,799**	**11,866**	**14,367**	**15,510**
	Average growth*	**3.9%**	**3.1%**	**3.9%**	**3.9%**	**3.9%**	**3.9%**
Base	Agriculture	1,696	1,824	2,128	2,484	2,900	3,085
	Industry	1,461	1,593	1,912	2,296	2,758	2,968
	Services	3,909	4,373	5,544	7,036	8,929	9,823
	Total	**7,499**	**8,316**	**10,353**	**12,902**	**16,078**	**17,558**
	Average growth*	**3.9%**	**3.9%**	**4.5%**	**4.5%**	**4.5%**	**4.5%**

Scenario	GDP	2021	2025	2030	2035	2040	2042
High	Agriculture	1,696	1,848	2,183	2,601	3,099	3,324
	Industry	1,461	1,617	1,971	2,425	2,983	3,241
	Services	3,909	4,461	5,767	7,549	9,881	11,005
	Total	**7,499**	**8,470**	**10,738**	**13,770**	**17,658**	**19,505**
	Average growth*	**3.9%**	**4.4%**	**5.1%**	**5.1%**	**5.1%**	**5.1%**

Source: Malawi National Accounts 2017-2022, 2022-2027 IMF real GDP growth forecast Note: * Average of the period starting from the indicated year and ending one year prior to the next indicated year.

5.5 Historical and forecast tariffs

Increases or decreases of tariff levels may have an impact on the level of consumption. The elasticity between historical electricity tariffs and consumption was estimated for each consumer category and if the identified relationship was significant then the electricity tariff forecasts was used to estimate the impact on the forecast demand. In this forecast only the commercial sector has been found to have a statistically significant relationship between demand and tariffs.

Historical tariff data, as well as forecasted tariffs by consumer category have been provided by ESCOM until the year 2027. ESCOM's forecasted tariffs are set to increase substantially in 2024, with a real term increase of 46%. For the demand forecast study, we have assumed a linear tariff increase between the nominal tariffs of 2022 and 2027.

Table 19 Average tariff (2017 real terms in MWK/kWh)

	2021	2025	2030	2035	2040	2042
Domestic	39.0	60.2	66.4	73.3	80.9	84.2
Commercial	85.3	95.1	106.1	117.1	129.3	134.5
LV Industrial	54.2	61.1	67.4	74.4	82.1	85.5
MV Industrial	47.6	55.1	60.7	67.0	74.0	77.0

Source: ESCOM forecasted tariffs, ECA assumptions

5.6 Large consumers new step loads or closures

New projects, expansions, closures, or self-generation plans from large customers will have a one-step impact on the overall energy and peak demand forecast in Malawi. These have to identified separately to be added/subtracted to/from the demand forecast as they occur once, in specific years, they are big loads, and they cannot be extrapolated from historical observations.

Following discussions with the USWG a list of 39 large customers was agreed including the Agro-Industrial sector, Water pumping boards, Manufacturing, and Mining companies. A questionnaire was drafted and sent to the identified large customers in order to understand their plans for expansions, closures or self-generation and the likelihood of these plans to materialise. The assumptions for large industrial loads that are used for the development of the demand forecast and are based on the survey results are presented in Table 20 below.

Table 20 Large Industries' expansions and closures

Industry	Project	Status	Sector	Region	Incremental step load (MW)	Expected year of implementation	Low	Base	High
Agriculture and water pumping									
Southern Region Water Board[9]	Mangochi Expansion	Candidate	Water pumping	South	0.6	2023	25%	75%	100%
	Projects under Indian Credit	Candidate	Water pumping	South	4.0	2024	25%	75%	100%
	Improvements in Liwonde and Balaka	Candidate	Water pumping	South	1.1	2024	25%	75%	100%
Lilongwe Water Board	Bunda Plant	Planned (Financial closure)	Water pumping	Central	0.6	2023	100%	100%	100%
	Treatment Works	Planned (Financial closure)	Water pumping	Central	1.5	2024	100%	100%	100%
	Malingunde Water Supply Project	Candidate (Feasibility)	Water pumping	Central	1.0	2025	25%	75%	100%
Illovo Sugar Ltd	SVTP Project	Candidate	Agriculture	South	-15.7	2026	0%	0%	50%
JTI Leaf Malawi	Line upgrade	Planned (Financial closure)	Agriculture	Central	0.1	2024	100%	100%	100%
Milambe water Users Association	Nkopola farm	Candidate	Agriculture	South	0.2	2023	50%	75%	100%
Chombe Foods Ltd	New building	Candidate	Agriculture	South	0.1	2024	25%	75%	100%
Greenbelt projects	North projects	Candidate	Agriculture	North	0.8	2025	25%	75%	100%
	Central projects	Candidate	Agriculture	Central	6.1	2025	25%	75%	100%
	South projects	Candidate	Agriculture	South	5.0	2025	25%	75%	100%
Manufacturing									
Bakhresaa Malawi Ltd	Processing facility expansion	Planned (Financial closure)	Manufacturing	South	3.0	2024	100%	100%	100%
PressCane Ltd	Liquid discharge	Planned (construction)	Manufacturing	South	0.8	2023	100%	100%	100%

[9] No data has been provided for current demand

Industry	Project	Status	Sector	Region	Incremental step load (MW)	Expected year of implementation	Low	Base	High
	plant and expansions								
	Processing mill	Candidate	Manufacturing	South	2.5	2024	25%	75%	100%
Chibuku Products Limited	Chibuku Super Line – Blantyre Brewery	Candidate (Concept)	Manufacturing	South	0.1	2023	25%	75%	100%
	Super Shake MAHEU – Blantyre Brewery	Candidate (Feasibility)	Manufacturing	South	0.0	2023	25%	75%	100%
	Chibuku Super Glass Line – Lilongwe Brewery	Planned (Financial closure)	Manufacturing	Central	0.1	2023	100%	100%	100%
	Project X – Lilongwe Brewery	Planned (Financial closure)	Manufacturing	Central	0.1	2023	100%	100%	100%
Raiply Malawi Limited	Factory expansion	Candidate	Manufacturing	North	4.4	2025	25%	75%	100%
Malawi Mangoes Operations Ltd	Despatch Cold Rooms	Candidate (Concept)	Manufacturing	Central	0.7	2025	25%	75%	100%
	Additional Mango Ovens	Candidate (Concept)	Manufacturing	Central	0.1	2025	25%	75%	100%
Shayona Cement Corporation	Expansion to operations	Candidate	Manufacturing	Central	5.5	2026	25%	75%	100%
O.G Plastic Industries Ltd	Expansions	Candidate	Manufacturing	South	0.2	2023	25%	75%	100%
Easy Pack Ltd	Printer machine	Candidate	Manufacturing	South	0.1	2024	25%	75%	100%
	Injection machine	Candidate	Manufacturing	South	0.1	2025	25%	75%	100%
	PVC pipe machine	Candidate	Manufacturing	South	0.1	2026	25%	75%	100%
Ethanol Company Ltd	Effluent Treatment Plant	Candidate	Manufacturing	Central	2.3	2024	50%	75%	100%
	MK3 and MK4 boiler closure	Candidate	Manufacturing	Central	-0.1	2024	50%	75%	100%

Industry	Project	Status	Sector	Region	Incremental step load (MW)	Expected year of implementation	Low	Base	High
Mining									
Lotus (Africa) Limited – Kayelekera Uranium Mine	Kayelekera Restart	Candidate (Feasibility)	Mining	North	4.0	2026	50%	75%	100%
	Kayelera mine expansion	Candidate (Feasibility)	Mining	North	6.0	2029	50%	75%	100%
Malingunde Graphite and Kasiya Rutile	Mine expansion	Candidate (Feasibility)	Mining	Central	5.0	2026	0%	0%	50%
Globe Metals & Mining	Niobium mine opening	Candidate (Feasibility)	Mining	North	18.0	2026	50%	75%	100%
	Niobium mine expansion	Candidate	Mining	North	6.0	2035	50%	75%	100%
Mkango Resources Ltd	Rare Earths mine opening	Candidate (Feasibility)	Mining	South	25.0	2026	50%	75%	100%
	Mine expansion	Candidate	Mining	South	8.0	2033	50%	75%	100%
Bwanje Cement Products	Mine opening	Planned (Financial closure)	Mining	Central	15.0	2024	20%	75%	100%
Mawei Heavy Mineral Sands	Mine opening	Planned (Financial closure)	Mining	South	40.0	2025	20%	75%	100%
Tengani Heavy Minerals Sands	Mine opening	Candidate (Feasibility)	Mining	South	40.0	2030	5%	20%	50%
Chambe and Lichenya Basins Bauxite	Mine expansion	Candidate (Concept)	Mining	South	50.0	2028	5%	20%	50%
Kangankunde Rare Earth	Mine expansion	Candidate (Feasibility)	Mining	South	30.0	2028	5%	20%	50%
Cement Products Limited	Mine opening	Candidate	Mining	South	5.0	2025	10%	50%	50%
	Njereza plant	Planned	Mining	South	7.0	2025	75%	100%	100%
	Limestone quarry	Planned	Mining	South	0.3	2023	75%	100%	100%
Other quarry projects	Quarry plants operation	Candidate (Concept)	Mining	Central	3.0	2025	10%	25%	50%

Source: From questionnaires sent to large customers

5.7 Self-generation

5.7.1 Domestic rooftop solar

While rooftop solar generation is not significant enough in areas reached by the grid in Malawi, this technology, among other Solar Home Systems (SHS), are present in the country. These are marketed to rural areas where grid connection is uncertain, however, the frequent need for load shedding might incentivise some households that are either electrified or about to be electrified to purchase one of these systems, reducing their electricity demand from the grid. Nonetheless, this effect is expected to be temporary and vastly reducing once households are connected to the main grid. For the purposes of this demand forecast, we assume that this temporary effect is insignificant for annual demand in all scenarios.

Nonetheless, given the expected introduction of a net-metering scheme, which allows power generated with rooftop solar systems to be exported to the grid at a given tariff, we expect that some users will install these systems. The assumed impact from the net-metering scheme and the installation of rooftop solar PV on the demand forecast is shown in Section 9.5.

5.7.2 Large industries self-generation

The plans of large industrial consumers for the development of self-generators and the assigned probabilities of occurrence which are accounted in the demand forecast are shown in the table below. These are based on the surveys conducted by the USWG.

Table 21 Large industries' self-generation plans

Industry	Project	Status	Sector	Region	Capacity (MW)	Expected year of implementation	Probability		
							Low	Base	High
Agriculture and water pumping									
Southern Region Water Board	Liwonde and Balaka Self-Generation	Candidate	Water pumping	South	1	2024	0%	0%	25%
Lilongwe Water Board	PV solar for pump stations	Candidate (Feasibility)	Water pumping	Central	10	2025	0%	0%	50%
Illovo Sugar Ltd	Nchalo Project	Candidate	Agriculture	South	28	2026	0%	0%	25%
JTI Leaf Malawi	Solar power plant	Candidate (Feasibility)	Agriculture	Central	0.4	2024	0%	0%	25%
Chombe Foods Ltd	Self-generator	Candidate	Agriculture	South	0.2	2023	0%	0%	25%

Industry	Project	Status	Sector	Region	Capacity (MW)	Expected year of implementation	Probability		
							Low	Base	High
Manufacturing									
PressCane Ltd	Methane Self-Generation	Planned (financial close)	Manufacturing	South	3.2	2023	75%	100%	100%
	Steam Turbine Generator	Candidate	Manufacturing	South	3.0	2024	0%	0%	20%
Chibuku Products Limited	Generator – Lilongwe Brewery	Candidate (Concept)	Manufacturing	Central	0.7	2023	0%	0%	0%
Raiply Malawi Limited	Steam Engine Generator	Candidate	Manufacturing	North	10.0	2023	0%	0%	25%
Shayona Cements Corporation	2000KVA Diesel generator	Candidate	Manufacturing	Central	2.0	2023	0%	0%	25%
Malawi Mangoes Operations Ld	Solar Plant	Candidate (Pre-feasibility)	Manufacturing	Central	0.7	2025	0%	0%	25%
Ethanol Company Ltd	Steam Turbine alternators	Candidate	Manufacturing	Central	1.8	2024	0%	25%	50%
Mining									
Lotus (Africa) Limited – Kayelekera Uranium Mine	Acid plant steam turbine	Candidate (Feasibility)	Mining	North	2.5	2024	0%	0%	25%
	Solar generator	Candidate (Feasibility)	Mining	North	7.4	2024	0%	0%	10%
	BESS	Candidate (Feasibility)	Mining	North	5.5	2024	0%	0%	25%
Cement Products Limited	Njereza Plant self-generator	Candidate	Mining	South	3.0	2025	0%	0%	25%
	Quarry self-generator	Planned	Mining	South	0.3	2023	0%	25%	50%
Globe Metals & Mining	Niobium mine self-generation	Candidate	Mining	North	5.0	2026	0%	0%	25%
Mawei Heavy Mineral Sands	HFO Generator	Candidate (Feasibility)	Mining	South	22	2025	0%	25%	50%

Source: From questionnaires sent to large customers

5.8 System losses

The assumptions for the determination of system losses to be considered in the demand forecast are based on the Loss reduction plan presented in Section 7 below. The forecast network technical and non-technical losses are shown in Table 22.

Table 22 Forecast losses

Scenario		2021	2025	2030	2035	2040	2042
Low	**Transmission**	5.5%	4.8%	4.3%	4.2%	4%	4%
	Distribution	16.7%	14.6%	12.9%	12%	11%	11%
	Total	**22.2%**	**19.4%**	**17.2%**	**16.1%**	**15%**	**15%**
Base	**Transmission**	5.5%	4.7%	4.2%	4.1%	4%	4%
	Distribution	16.7%	14.2%	12.5%	11.7%	11%	11%
	Total	**22.2%**	**18.9%**	**16.6%**	**15.8%**	**15%**	**15%**
High	**Transmission**	5.5%	4.6%	3.8%	3.4%	3%	3%
	Distribution	16.7%	11.6%	11.7%	10.3%	9%	9%
	Total	**22.2%**	**16.6%**	**15.6%**	**13.8%**	**12%**	**12%**

Source: Loss Reduction Roadmap, ECA Assumptions

5.9 Exports

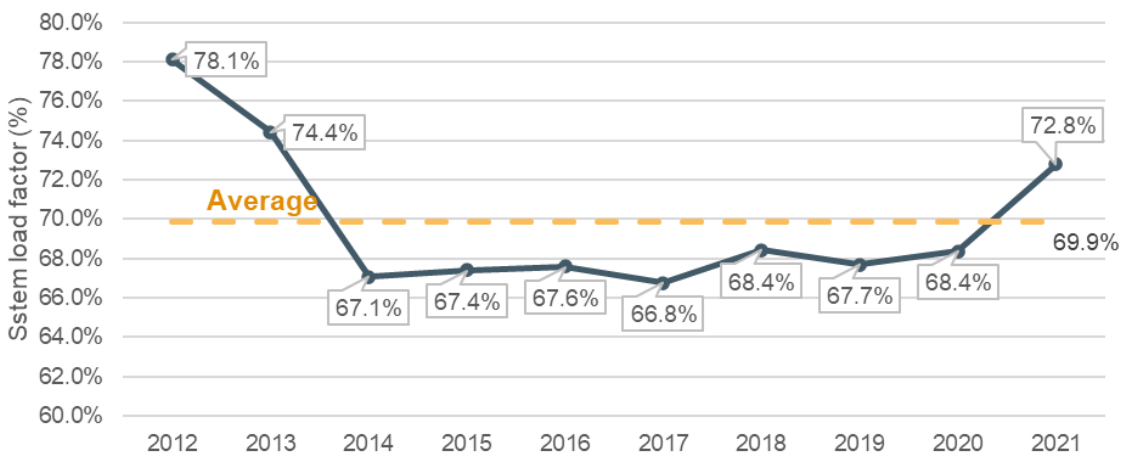
While ESCOM is a member of SAPP, the country's power system has remained mostly isolated from the other SAPP members with only minimal trade taking place. Malawi is now in the process of developing two interconnectors with Mozambique and Zambia, which will interconnect Malawi to other SAPP members. Additionally, *EU Malawi* is supporting EGENCO to become a member of SAPP. Once commissioned, these interconnectors will likely create new trade opportunities for Malawi, both bilaterally and through the Day Ahead Market. With enhanced connection to the SAPP, spare capacity from future Hydropower projects could be used to export electricity.

Currently there are no firm contracts for exports thus, no exports are included in the update of the demand forecast. Opportunities for exports should be analysed in the update of the IRP or regional studies.

5.10 System load factor

The historical system load factor is shown in the figure below. The average load factor over the past 10 years was 69.9%. However, the average load factor is affected by years with significant load shedding such as the 2015-2017 drought period and cannot be considered as a representative load factor for forward looking years. As it was discussed above, 2021 is considered as a representative year and the load factor of 2021 (72.8%) will be used to forecast the system peak demand from forecast sales and losses. Additionally, the consumption mix of the system is expected to remain similar to 2021. Thus, no significant variations on the load factor are expected.

Figure 19 Historical system load factor



Source: ESCOM data

5.11 Geographical split of the demand

In aggregate, as shown in Figure 14, the trend from the last three years does not point towards significant regional shifts in demand, though some trends, such as the decreasing prominence of the South region, are expected to continue. The geographical split of demand in the forecast is estimated separately for residential users given each region's urbanisation rates and household size, as well as for large industrial customers from their location. Peak demand is derived using the regional load factors for 2021, this are found to be 42% for the North region, 70% for the Central region, and 48% for the South region.

Table 23 Historical share of sales by region

	2013	2014	2015	2016	2017	2018	2019	2020	2021	Avg
North	7%	7%	7%	7%	6%	9%	8%	8%	8%	**8%**
Central	33%	32%	33%	29%	27%	35%	37%	38%	38%	**34%**
South	60%	61%	60%	64%	68%	56%	54%	54%	53%	**54%**

Source: ESCOM data Note: The Avg is the average of the past three years

5.12 Summary of input assumptions

Table 24 summarises the input assumptions for each scenario.

Table 24 Summary of input assumptions

Parameter			2021	2025	2030	2035	2040	2042
Population	As forecasted by the 2018-2050 population projections.							
	Urban growth		2.8%	2.7%	2.5%	2.4%	2.3%	2.3%
	Rural growth		2.3%	2.1%	2.0%	1.9%	1.8%	1.8%
	Total growth		**2.4%**	**2.2%**	**2.1%**	**2.0%**	**1.9%**	**1.9%**
Urbanization rate	16% in 2018, increasing by 0.07% each subsequent year.							
Household size	4.4 persons per household in 2018, decreasing by 0.02 each subsequent year. No distinction between urban and rural household sizes. Variation between regional household sizes							
	Average household size		4.3	4.3	4.2	4.1	4.0	3.9
Electrification rate (Grid connected only)	Low scenario follows ESCOM's historical new connection rates (on average 35,000 new connections per year), base scenario follows the Guideline of Implementation for the NEP (on average 135,000 new connections per year until 2030, followed by linear progression until 2042) and high scenario follows SE4ALL electrification targets (on average 260,000 new connections per year).							
	Low scenario		10.6%	13.4%	14.9%	15.9%	16.6%	16.8%
	Base scenario		10.6%	21.5%	32.4%	40.7%	51.3%	55.5%
	High scenario		10.6%	23.1%	72.7%	75.9%	78.7%	79.6%
Average consumption per household	Base year average consumption per household is based on information from similar countries and a bottom-up approach to alleviate suppressed demand included in historical data. For the growth of the average demand per household an income elasticity of 1.2, 0.9 and 1.4 is assumed for the base, low and high scenarios, respectively (relative to the GDP per capita growth).							
	Low scenario	**Urban**	160	163	172	187	203	211
		Rural	47	48	51	55	60	63
		Overall	**120**	**113**	**115**	**122**	**130**	**134**
	Base scenario	**Urban**	160	165	188	217	252	268
		Rural	47	49	56	64	75	79
		Overall	**120**	**96**	**99**	**108**	**121**	**127**
	High scenario	**Urban**	160	170	203	250	309	337
		Rural	47	51	60	74	92	100
		Overall	**120**	**93**	**94**	**114**	**140**	**153**
GDP growth rate	**Low scenario**		3.9%	3.1%	3.9%	3.9%	3.9%	3.9%
	Base scenario		3.9%	3.9%	4.5%	4.5%	4.5%	4.5%

<table>
<tr><th colspan="3">Parameter</th><th>2021</th><th>2025</th><th>2030</th><th>2035</th><th>2040</th><th>2042</th></tr>
<tr><td></td><td colspan="2">High scenario</td><td>3.9%</td><td>4.4%</td><td>5.1%</td><td>5.1%</td><td>5.1%</td><td>5.1%</td></tr>
<tr><td>Exports</td><td colspan="8">No firm commitments for the 2022-2042 period.</td></tr>
<tr><td rowspan="7">Losses</td><td colspan="8">Assuming the implementation of the Loss Reduction Roadmap and historical losses</td></tr>
<tr><td rowspan="2">Low scenario</td><td>Transmission</td><td>5.5%</td><td>4.8%</td><td>4.3%</td><td>4.2%</td><td>4%</td><td>4%</td></tr>
<tr><td>Distribution</td><td>16.7%</td><td>14.6%</td><td>12.9%</td><td>12%</td><td>11%</td><td>11%</td></tr>
<tr><td rowspan="2">Base scenario</td><td>Transmission</td><td>5.5%</td><td>4.7%</td><td>4.2%</td><td>4.1%</td><td>4%</td><td>4%</td></tr>
<tr><td>Distribution</td><td>16.7%</td><td>14.2%</td><td>12.5%</td><td>11.7%</td><td>11%</td><td>11%</td></tr>
<tr><td rowspan="2">High scenario</td><td>Transmission</td><td>5.5%</td><td>4.6%</td><td>3.8%</td><td>3.4%</td><td>3%</td><td>3%</td></tr>
<tr><td>Distribution</td><td>16.7%</td><td>11.6%</td><td>11.7%</td><td>10.3%</td><td>9%</td><td>9%</td></tr>
<tr><td>System load factor</td><td colspan="8">2021 is considered as a representative year and the load factor of 2021 (72.8%) will be used to forecast the system peak demand from forecast sales and losses. Additionally, the consumption mix of the system is expected to remain similar to 2021. Thus, no significant variations on the load factor are expected.</td></tr>
<tr><td rowspan="4">Geographical split of demand</td><td colspan="8">Based on the average consumption split of the past three years. Future deviations resulting from differences in urbanization rates, household size, and the location of large customers.</td></tr>
<tr><td colspan="3">North</td><td colspan="5">8% of total sales</td></tr>
<tr><td colspan="3">Central</td><td colspan="5">34% of total sales</td></tr>
<tr><td colspan="3">South</td><td colspan="5">54% of total sales</td></tr>
</table>

Source: Input assumptions report

6 Regression analysis

6.1 Residential consumers

Several regression analyses were conducted with the average consumption per household growth as the dependant variable and combinations of GDP growth, GDP per capita growth, GDP by sector growth, population growth, inflation growth, GNI, electrification rate and tariffs as the independent variables.

All possible combinations of the above independent variable were examined including lagged variables (see Annex A4). No econometric equation with statistical significance and reasonableness was observed for the reasons analysed in the *Input assumptions* report.

6.2 Commercial consumers

Similarly to the analysis conducted for residential consumers, several regression analyses were performed with the commercial sales growth as the dependant variable and combinations of GDP growth, GDP per capita growth, GDP by sector growth, population growth, inflation growth, GNI, electrification rate and tariffs as the independent variables. All possible combinations of the above independent variable were examined including lagged variables (see Annex A4).

The econometric equation with the highest statistical significance and logical reasoning was:

$$\boldsymbol{ln(CommSales_i) = -0.05 + 1.05 * \ln(RealGDPpc_i) + 0.63 * \ln(CommConenctions_i) - 0.21 * \ln\,(CommTariff_i)}$$

Where:

$CommSales_i$ = Total electricity sales for the “General” tariff categories in kWh for year i.

$RealGDPpc_i$ = Real GDP per capita in MWK for year i.

$CommConenctions_i$ = Number of commercial connections at the end of year i.

$CommTariff_i$ = Average nominal tariff for commercial users in MWK/kWh for year i.

Real GDP per capita can be used as a measure for the purchasing power of commercial consumers, the number of commercial connections as the measure for the estimation of number of commercial consumers, and the electricity tariff as the measure to explain reductions in demand from tariff increases. The logical reasoning that follows the econometric equation shown above is:

- **Purchasing power of the population.** As income (and disposable income) increase, consumption of all goods and services also increase. As a response, businesses expand consuming more electricity.

- **Commercial connections.** As the density of commercial areas increase, the demand for office space also increases, increasing the overall use of office appliances.

- **Cost of electricity.** Lower electricity tariffs incentivise businesses to increase electricity consumption, while higher electricity tariffs discourage non-essential use of electricity. Effectively this is measured of the price elasticity of demand.

The resulting econometric equation implies a population income elasticity of demand of 1.05, with a 1% increase in real GDP per capita resulting in an 1.05% increase of aggregate electricity sales from the commercial sector. In terms of commercial densification of urban areas, we notice that a 1% increase in the number of commercial connections results in a 0.63% increase in total commercial sales. Finally, the price elasticity of demand for commercial users is found to be -0.21, implying that a 1% increase in the commercial electricity tariff would result in a 0.21% decrease of demand.

The statistical results of the econometric analysis for the chosen equations are sown in Annex A4.1 together with a comparison of a historical forecast using the econometric equation against actual sales.

6.3 LV Industrial consumers

The regression analysis for LV industrial sales explored the relationship between LV industrial sales growth and combinations of GDP growth, GDP per capita growth, GDP by sector growth, population growth, inflation growth, and tariffs as the independent variables. All possible combinations of the above independent variable were examined including lagged variables (see Annex A4).

The econometric equation with the highest statistical significance and logical reasoning was:

$$\boldsymbol{ln(IndLVSales_i) = 9.08 + 0.35 * \ln(RealGDP_i)}$$

Where:

$IndSalesLV_i$ = Total electricity sales for the “Maximum Demand LV” tariff category in kWh for year i.

$RealGDPpc_i$ = Real GDP in MWK for year i.

No significant relationship was identified between electricity prices and LV industrial consumption and the total GDP had a better explanatory power than Industrial GDP which includes larger consumers as well.

The resulting econometric equation implies an income elasticity of demand of 0.35, meaning that a 1% increase in Real GDP would lead to a 0.35% increase in the aggregate electricity sales of the Industrial LV category.

6.4 MV Industrial consumers

The regression analysis for MV industrial sales explored the relationship between MV industrial sales growth and combinations of GDP growth, GDP per capita growth, GDP by sector growth, population growth, inflation growth, and tariffs as the independent variables. All possible combinations of the above independent variable were examined including lagged variables (see Annex A4).

The resulting econometric equation with the highest statistical significance and logical reasoning was:

equation is:

$$\boldsymbol{ln}(\boldsymbol{IndMVSales_i}) = \mathbf{5.07} + \mathbf{0.53} * \mathbf{ln}(\boldsymbol{IndustrialGDP_i})$$

Where:

$IndSalesMV_i$ = Total electricity sales for the “Maximum Demand MV” tariff category in kWh for year i.

$IndustrialGDP_i$ = Real Industrial GDP in MWK for year i.

In this case, the energy intensity of these industries is 0.53, with a 1% increase in real Industrial GDP associated with a 0.53% increase in Industrial MV electricity sales.

7 Loss reduction plan

The loss reduction plan for Malawi reflects the findings and recommendations of the LRR, developed by ESCOM in 2021. The LRR is the outcome document prepared from the findings and conclusions obtained during the Losses Reduction Initiative project (LRI) developed and supported by IFC.

According to the Utility Scale Working Group (that has representation of the key power sector institutions), loss reduction measures have been extensively and exhaustingly reviewed in the context of the Loss Reduction Roadmap 2021 and need not be further analysed in the context of this study. Therefore, the objective was to single out which roadmap activities to implement and package them appropriately in readiness for that. The loss reduction measures identified are also considered in the demand forecast analysis for the impact they will have on the reduction of system losses and consequently on the amount of energy/capacity that is needed to be injected to the grid.

7.1 Loss reduction plan

The Loss Reduction Roadmap was developed based on the review and analysis of a long list of 71 potential projects, from which a total of 34 initiatives with differing complexity, budget, duration, and impact on losses were eventually included in the Roadmap.

The individual initiatives identified in the Roadmap are grouped in eight *Large Projects,* described in Table 25. *Large Projects* cannot be fully implemented in isolation as there are several interdependencies and synergies among projects and initiatives, shown along with the timing for implementation in Figure 20. ESCOM has started implementing specific initiatives, as indicated in Table 25The total cost of the Loss Reduction Roadmap is estimated to USD 27.9 million and the expected revenues resulting from losses reduction to USD 34.8 million (ie the plan is expected to generate a net benefit of USD 6.8 million). To achieve this, an investment of around USD 10.5 million is needed.

Table 25 Initiatives included in the Loss Reduction Roadmap by Large Project

Initiatives	Description
1. Establishment of a Project Management Office (PMO) *The establishment of a PMO is needed in order to ensure that the different initiatives and activities are adequately executed. The project itself is not profitable (costing around USD 1.4 million) but is very useful at that the roadmap is implemented properly.*	
1 a. Setting up a PMO	PMO's objectives will be facilitating the implementation of the roadmap, following up on the progress of the projects and guiding the efforts of the company towards accomplishing them in the most efficient way. The PMO will drastically increase the chances of success of the roadmap, and thus obtain the intended results of each of the projects within.
2. Network Metering & Losses Calculation *The objective is to assess the losses in the system to target actions in network parts that have the highest losses. Many of the activities carried out in this project are key for the development of other activities and will lead to losses reduction, yielding a benefit of around USD 390,000.*	

Initiatives	Description
2 a. Metering in Injection Points, Substations and Feeders	Achieving the Metering of all injection points, substations and feeders will facilitate the control of energy flows and create accurate energy balances. This initiative aims to audit around 50 injection points, 64 substations and 311 feeders in order to understand their statuses and the need for meter installation. Additionally, the status of existing meters will be checked as well as their communication capabilities with the AMR systems. The metering in the HV-MV network will facilitate more accurate calculation of energy losses (technical and non-technical) in the network and determine hot points.
2b. New Losses Calculation methodology	To improve the calculation process using the "Baseline for losses" tool, as well as determine ways to make the information available to the entire organization. Calculating the losses with higher accuracy will allow ESCOM to better identify where the issues are (technical, non-technical) and establish actions to reduce them. Also, the appropriate calculation will facilitate the understanding of the impact and effectiveness of the ongoing Loss Reduction activities.
2c. Strengthen the EBM team	This initiative proposes the establishment of a dedicated team in charge of maintaining the EBM. If adequately maintained, the EBM can produce additional balances (per feeder, per substation, etc.). These balances will redirect the efforts to those areas where the losses are highest, increasing the productivity of the inspection teams.
2e. Perform Regional Balances	After consolidating the metering in the HV-MV network, ESCOM should start performing regional balances to identify the areas where the highest losses are and focus the effort on Loss Reduction activities. This initiative considers the installation of meters in the regional or administrative areas borders. Creating balances for smaller areas will facilitate the identification of key network sections where the losses are higher and focus the LR activities.
3. Feeder Based Loss Reduction Projects *This project strives towards auditing ESCOM customers. The necessity of this project has been proven in the FBLR pilot already executed by ESCOM, which found many issues in just one feeder. Despite the large project cost (over USD 18 million), the estimated revenues obtained lead to a breakeven on the fifth fiscal year and total benefits at the end of the fiscal year of almost USD 5 million.*	
3 a. Metering in Distribution Transformers	Installation of meters in the DTs. There are 5,132 distribution transformers. Approximately 10% are dedicated; therefore, there is a need to install meters in 4,619 DTs. However, when factoring in the future growth of the company, the number can increase to 5,000. Moreover, the installation must be followed by a validation of the communications and an update of the information into the system. Having balances on DT level, will allow ESCOM to identify the exact areas where the highest losses are and inspect more efficiently, focusing the limited resources on those areas where the monetary return is guaranteed.
3b. End-customers audit	This initiative considers a 4-year plan to visit all customers in a methodological way, prioritizing those areas with greater losses. It focuses on auditing and solving the issues from the customers (linking them with its DTs, removing illegal connections and fixing the sealing, improvement of PF and replacing faulty meters amongst others). A systematic inspection of all customers will allow elimination of fraud and issues that affect the Energy Losses.
3c. Large customer and public institutions audit	ESCOM is advised to have personnel specifically deployed to monitor maximum demand customers and public institutions. During the inspections, ESCOM will fix all the potential issues found with these customers and link them with the DTs or Substations. Solving potential issues in these

Initiatives	Description
	customers will facilitate the reduction of Non-technical losses and improve ESCOM's collection efficiency.
4. Distribution & Customer Services Operative Model Review *This project targets the Distribution & Customer Services area of ESCOM. focusing on improving and/or optimizing the different activities carried out by the area. It is estimated that it can derive a net benefit of over USD 4.4 million.*	
4 a. Improvements in the Meter Life Cycle	ESCOM should redefine the entire meter life cycle based on the enhancements identified. The new processes should be documented. It is worth highlighting the importance of following the procedures, the enhancements in the processes (sourcing, the distribution of goods and storing) and the functionalities that the system has, in order to boost the traceability of the meters. ESCOM has already established a plan for the set-up of the PMO under the Revenue Protection Department, to implement the relevant measures of the LRR.
4b. Building a role for maintaining customer data	The objective of the initiative is to maintain and update the required information in InCMS and Igea by creating a new role within the company. This role should clean up and update the database. (identify non-energy debts or contracts, and work orders that can be cancelled, erased or "put on hold" amongst others). Updating the information will result in better reports, balances, as well as a focus on the real problems of the operation. This initiative has already been implemented.
4c. Review the Debt Recovery process	This initiative aims to clarify the disconnection requirements (of customers that do not pay or are stealing energy) using a standard procedure that must be followed by all employees and taught in training sessions. Furthermore, ESCOM should update disconnection information in the system (disconnections and commercial agreements). The disconnection process must also consider periodic inspections to prevent or detect self-reconnections. The revenue protection process must segment ESCOM's debt and tackle them in different ways (ie sell the bad debt or follow up more often with large customers). The disconnection processes are an excellent tool to control losses and reduce the fraud. A more robust debt recovery process will prevent fraud and increase collection. The relevant procedures have been included in the Revenue Manual, developed by ESCOM in 2022.
4 d. Review the current Organization of the Distribution Directorate	ESCOM should redefine its operating model to better define the organization of the company. The structure should be homogeneous and incorporate the four different regions. The reorganization should improve productivity of the teams, which will in turn contribute to better performance in terms of loss reduction. A new structure implementing a zoning system was developed by ESCOM in 2023 and is now in place.
4e. Strengthen the Customer Service processes	The Customer Service processes should be reinforced, by increasing personnel and improving process efficiencies in order to reduce waiting times and improve the agility of the contracting process. This initiative aims to highlight the importance of customer service. ESCOM could benefit from a review and improvement of the current customer care services, especially related to issues found in the work request and contracting processes. Faster and accurate responses to user requirements should reduce fraud, particularly illegal connections. The relevant procedures have been included in the Revenue Manual,

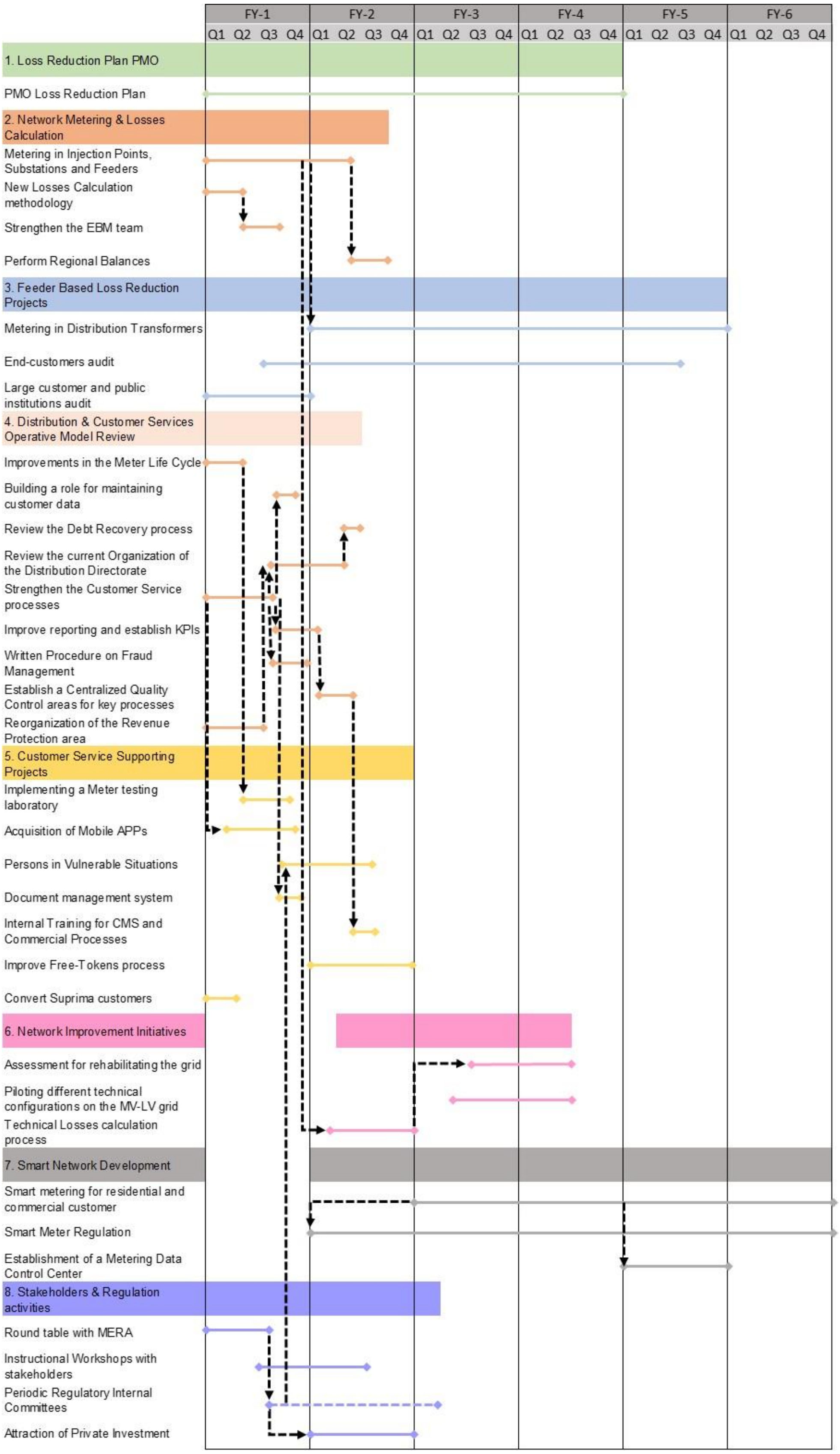
Initiatives	Description
	developed by ESCOM in 2022.
4f. Improve reporting and establish KPIs	Different Key Performance Indicators should be defined and their progress tracked and publicized at regular intervals. The objective of this initiative is to add new ways to control the evolution of the different processes of the company, using control panels (ie different reports to identify fraud). The impact is not direct to the losses, but in the overall productivity of the teams. Better productivity will allow a focus on the problems arising. KPIs developed by MERA and submitted to the Ministry of Energy cover this requirement. In addition, customer service KPIs have been published.
4 g. Written Procedure on Fraud Management	ESCOM is encouraged to create procedures for disconnection, fraud invoice and reconnection, as this would help homogenize Fraud Management activities and develop a knowledge base to be shared throughout the company. The better the fraud is managed, the more fraudulent activities will be discovered and the faster the corrective measures will be applied. Additionally, a robust methodology will facilitate the detection of more cases and discourage customers from fraudulent activities. Part of the Revenue Manual, developed by ESCOM in 2022 and revised in 2023, provides procedures for handling fraud. In addition, an Audit Manual has been developed, to monitor implementation of the Revenue Manual. An actual audit was carried out in 2022.
4h. Establish a Centralized Quality Control areas for key processes	The utility should improve and document the reading and debt management processes as well the quality of data originating from these. This initiative should focus on improving the efficiency and productivity of the processes based on benchmarking and disseminating best practices. Improvement of the reading process will enhance billing productivity, resulting in a reduction of losses caused by internal inefficiencies. Improvement of the debt management process will reduce fraud and increase collection. This initiative comprises part of the Revenue Manual, developed by ESCOM in 2022.
4i. Reorganization of the Revenue Protection area	The Revenue Protection area should be upgraded, that is, given more competencies and capabilities and their influence on other operational areas such as, Fraud management, Incentives management, Inspections and a coordination office between regions increased. A strong Revenue protection area improves fraud reduction and optimizes the required resources. To that effect, reorganisation of authority among the Revenue Protection management and regional offices is required, to ensure that implementation of the relevant LRR measures is practicable.
5. Customer Service Supporting Projects *This project consists of enabler initiatives that can improve the operational efficiency of ESCOM. The net benefit from the implementation of the project is estimated to around USD 1.3 million.*	
5 a. Implementing a Meter testing laboratory	ESCOM should develop the facilities necessary to carry out meter testing, put in place a systematic approach, and acquire the appropriate equipment. This is key in order to mitigate the existence of faulty meters and ensure that the meters in the field function appropriately. ESCOM will improve the quality of the meters deployed, as well as reduce non-technical losses resulting from metering failure. Additionally, ESCOM will obtain accurate results on fraud cases investigated.
5b. Acquisition of Mobile APPs	The use of already existing tools will facilitate operational activities such as updating work orders, collections and reading & billing. Using the mobile applications will increase productivity and reduce data inconsistencies. Improvement in the reading process and the automation of the field activities will enhance productivity and the quality of InCMS data, resulting in a

Initiatives	Description
	reduction of losses due to internal inefficiencies.
5c. Persons in Vulnerable Situations	This initiative aims to engage with the national government to evaluate the creation of future programs that help reduce the impact of electricity costs to people in vulnerable situations. This initiative will facilitate the payment of energy, reduction of fraud and improved citizen perception of ESCOM.
5 d. Document management system	ESCOM should consider the use of a Document Management System (DMS) where all documentation (procedures and reports) will be stored in order to ensure that they are accessible to the pertinent people. This measure will enable homogeneity amongst the ESCOM's personnel and should help build a knowledge base that will improve ESCOM's processes and activities. The existence of a DMS will reduce workload and control fraud, if properly used in areas such as Work Requests and Contracting Processes.
5e. Internal Training for CMS and Commercial Processes	Various trainings should be carried out for ESCOM employees in order to impart knowledge on all the CMS functionalities, changes in procedures, available tools, etc. Creating user awareness on the procedures, capabilities and processes will have a positive impact on the Commercial activities such as, reducing customer frustration, improving the identification of abnormal behaviours and effectively managing fraud / illegal connections.
5f. Improve Free-Tokens process	The free-token process must be reviewed, not to alter the benefit but to increase the accuracy of determining the energy consumed by the employees. An adequate accountability of the free-tokens will facilitate obtaining accurate balances, and improve the identification of Energy Losses. The Revenue Manual, developed by ESCOM in 2022, includes information on Free-Tokens, as well as back-end financial reconciliation process.
5 g. Convert “Suprima” customers	Customers using "Suprima" meters must be converted to InCMS meters to standardize the commercial activities as well as improve the energy sales calculation.
6. Network Improvement Initiatives *This project aims to prepare ESCOM for a controlled and sustainable expansion of the grid while also targeting technical losses. It is estimated to have negative revenues of around USD 2.6 million, but its indirect impact in terms of present and future losses is estimated to be high.*	
6 a. Assessment for rehabilitating the grid	During the technical losses analysis, the need to assess the expansion plan in High Voltage, Medium Voltage and Low Voltage network arose. This initiative must evaluate the potential improvements in the network, for instance, increasing voltages for the transmission grid, installing capacitor banks and studying the expansion of lines amongst others. As a general rule, transmission should be carried out at 132 KV, avoiding 33 kV. A long-term plan for the grid expansion supported by network simulation results will help target the reduction of Technical Losses in the Transmission and Distribution network and result in a more adequate evolution of the network growth.
6b. Piloting different technical configurations on the MV-LV grid	It is recommended that ESCOM uses different LV configurations (network shielding, Internal Control Point) that could reduce the network's manipulation. This initiative aims to control the non-technical losses in areas with greater losses or key risky areas. Creating a protected LV network will reduce illegal connections or network tampering, eventually reducing losses.
6c. Technical Losses calculation process	ESCOM should Implement periodic process reviews of the Technical losses using DigSilent as the main tool. An accurate calculation of the energy flows impact on ESCOM's network should result in the identification of technical losses, which can then be targeted for reduction.
7. Smart Network Development	

Initiatives	Description
This project targets the development of a smart metering framework, infrastructure and deployment of smart metering for all ESCOM customers.	
7 a. Smart metering for residential and commercial customer	ESCOM should consider developing a full AMI for all customers. The initial execution must start an analysis of the standards and protocols to be used in the AMI. The AMI will provide knowledge in real time (or almost real time) of the energy flows through the network, receive alerts for any incident that could produce Energy Losses, and remotely act on those customers that require any action on their meters.
7b. Smart Meter Regulation	This initiative aims to encourage the development of a Smart Metering regulation in coordination with MERA. The regulation will allow progression of the smart network implementation.
7c. Establishment of a Metering Data Control Center	This initiative aims to create a Control Center to update the AMI assets: the meters and the communications infrastructure. This Control Center should be built within the company, backed by a combination of a strong organizational structure, an experienced team, the required software and hardware and the physical space. Additionally, this team must be responsible for updating the metering system sketch, the meters' information in between AMR, IGEA and the integration between AMR and MDM (that is, validating the measurements of MD customers and balancing readings of energy). The MDCC will ensure that the AMI is operational, so that any grid incident is controlled and managed within the required timeframe.
8. Stakeholders & Regulation activities *This project focuses on opening communication channels with the regulator and with local communities, with the aim of improving the legal framework and engaging in communication campaigns with different stakeholders.*	
8 a. Round table with MERA	The legislation should be reviewed by ESCOM and MERA. The objective is to align the disparities between the regulation and ESCOM's procedures: unpaid bills notification, segmentation of customers, amendments to "Revised Standards Administrative Charges", estimation of consumption for identified fraud, penal charges, reconnection fees and the non-disconnectable policy for some meters. Better regulatory support will help the Loss Reduction.
8b. Instructional Workshops with stakeholders	Creating an awareness campaign will facilitate the reduction of illegal connections and fraudulent activities. This initiative aims to target specific and relevant individuals to promote good behaviour and show the potential consequences of fraudulent activities (both administrative, penal and physical ie electrocuted individuals or burned-down constructions). Part of the losses are due to the lack of awareness of the citizens. This initiative will help in sensitization. An annual plan for implementation of campaigns in villages, the police, communities, etc is in place and is being implemented.
8c. Periodic Regulatory Internal Committees	This initiative aims to encourage monthly or quarterly meetings between the regulatory body and business operation departments. The goal of these frequent meetings is to facilitate communication between MERA and ESCOM, to help reveal the problems that each department may be facing (fraud, disconnection, debtors and reconnection), and to, in collaboration, find potential solutions backed by the legislation. Better regulatory support will help the Losses Reduction activities.
8 d. Attraction of Private Investment	This initiative aims to facilitate the attraction of private investment in Malawi, by improving the network, network regulations and renewable energy guidelines.

Source: Loss Reduction Roadmap, Loss Reduction Initiative, February 2021

Figure 20 Interrelations among and timing of initiatives included in the LRR



Source: Loss Reduction Roadmap, Loss Reduction Initiative, February 2021

Considering that the implementation of the Roadmap requires significant investment and is a very complex exercise due to many interrelations and interdependence among many of the included 34 initiatives, Large Projects and initiatives were assessed looking at the following criteria:

- Budget – the amount of capital needed to implement the initiative. Budget variation are specified as Low, Medium, and High.
- Impact on losses – the level of the impact the implementation of the project will have on loss reduction. Impact on losses is classified as Low, Medium, High, and Very high.
- Complexity in terms of interdependence among initiative – the level of dependency of each project to other initiatives and the ease for implementation. The complexity is classified as 0 (no dependency in other initiatives), 1 (dependency in 1 initiative), 2 (dependency in 2 initiatives), 3 (dependency in 3 initiatives).

Ranking of initiatives by budget

In Table 29 we provide an overview of the initiatives, ranked first in accordance with their budget and then their impact on losses and their interdependency. Assuming that the primary restriction is budget availability, then among initiatives with similar budget level, preference is for those with a higher impact on losses, and lower dependence from other initiatives. As the Table illustrates, there are 19 initiatives with a low budget. Among them seven have zero interdependency on other initiatives and could be implemented by ESCOM immediately. Among the seven initiatives, three have high or mid impact on losses reduction and could be prioritised, namely:

1. 2b. New Losses Calculation methodology
2. 4e. Strengthen the Customer Service processes
3. 8b. Instructional Workshops with stakeholders

There are also three initiatives with medium budget requirements, very high impact on losses, and no dependence on other initiatives, namely:

4. 1 a. Establishing PMO
5. 2 a. Metering in Injection Points, Substations and Feeders
6. 3c. Large customer and public institutions audit

These could also be developed in priority, given budget availability.

Table 26 Ranking of initiatives by budget

Initiative	Budget			Impact on losses				Dependency on other initiatives			
	Low	Mid	High	Very high	High	Mid	Low	0	1	2	3
2b. New Losses Calculation methodology	Low				High			0			
4e. Strengthen the Customer Service processes	Low				High			0			
8b. Instructional Workshops with stakeholders	Low					Mid		0			
4 a. Improvements in the Meter Life Cycle	Low						Low	0			
5f. Improve Free-Tokens process	Low						Low	0			
5 g. Convert “Suprima” customers	Low						Low	0			
8 a. Round table with MERA	Low						Low	0			
2e. Perform Regional Balances	Low				High				1		
5b. Acquisition of Mobile APPs	Low				High				1		
4b. Building a role for maintaining customer data	Low					Mid			1		
4 g. Written Procedure on Fraud Management	Low					Mid			1		
4h. Establish a Centralized Quality Control areas for key processes	Low					Mid			1		
8c. Periodic Regulatory Internal Committees	Low					Mid			1		
4f. Improve reporting and establish KPIs	Low						Low		1		
5 d. Document management system	Low						Low		1		
7b. Smart Meter Regulation	Low						Low		1		
4c. Review the Debt Recovery process	Low					Mid				2	
6 a. Assessment for rehabilitating the grid	Low					Mid				2	
8 d. Attraction of Private Investment	Low						Low			2	
1 a. Establishing PMO		Mid		Very high				0			
2 a. Metering in Injection Points, Substations and Feeders		Mid		Very high				0			
3c. Large customer and public institutions audit		Mid		Very high				0			
4i. Reorganization of the Revenue Protection area		Mid			High			0			
2c. Strengthen the EBM team		Mid				Mid			1		
5 a. Implementing a Meter testing laboratory		Mid				Mid			1		
6c. Technical Losses calculation process		Mid				Mid			1		
4 d. Review the current Organization of the Distribution Directorate		Mid					Low			2	
5e. Internal Training for CMS and Commercial Processes		Mid			High						3
3b. End-customers audit			High	Very high				0			
7 a. Smart metering for residential and commercial customer			High		High			0			
6b. Piloting different technical configurations on the MV-LV grid			High			Mid		0			
3 a. Metering in Distribution Transformers			High	Very high					1		
7c. Establishment of a Metering Data Control Center			High						1		
5c. Persons in Vulnerable Situations			High		High					2	

Source: ECA analysis based on the 2021 Loss Reduction Roadmap

Ranking of initiatives by impact on loss reduction

Table 27 provides an overview of the initiatives, ranked first in accordance with their impact on losses and then their budget and interdependency. Assuming that the primary objective is to reduce losses, then among initiatives with the highest impact on loss reductions, preference is for those with a lower budget, and lower dependence on other initiatives. As the Table illustrates, there are five initiatives with very high impact on losses reduction. Among them four have zero interdependency on other initiatives and could be implemented by ESCOM immediately. Three out of the four have mid budget requirements and could be prioritised, namely:

1. 1 a. Establishing PMO
2. 2 a. Metering in Injection Points, Substations and Feeders
3. 3c. Large customer and public institutions audit

There is also 1 initiative with very high impact on loss reduction but with a high budget associated with it. Given availability of budget, this initiative could also be prioritised as it does not depend on any other initiatives:

4. 3b. End-customers audit

Finally there are three initiatives with high impact on losses and low to mid budget requirements which could be implemented immediately without the need to develop other initiatives:

5. 2b. New Losses Calculation methodology
6. 4e. Strengthen the Customer Service processes
7. 4i. Reorganization of the Revenue Protection area

These could also be developed in priority, given budget availability.

Table 27 Ranking of initiatives by impact on loss reduction

Initiative	Impact on losses				Budget			Dependency on other initiatives			
	Very high	High	Mid	Low	Low	Mid	High	0	1	2	3
1 a. Establishing PMO	Very high					Mid		0			
2 a. Metering in Injection Points, Substations and Feeders	Very high					Mid		0			
3c. Large customer and public institutions audit	Very high					Mid		0			
3b. End-customers audit	Very high						High	0			
3 a. Metering in Distribution Transformers	Very high						High		1		
2b. New Losses Calculation methodology		High			Low			0			
4e. Strengthen the Customer Service processes		High			Low			0			
4i. Reorganization of the Revenue Protection area		High				Mid		0			
7 a. Smart metering for residential and commercial customer		High					High	0			
2e. Perform Regional Balances		High			Low				1		
5b. Acquisition of Mobile APPs		High			Low				1		
5c. Persons in Vulnerable Situations		High					High			2	
5e. Internal Training for CMS and Commercial Processes		High				Mid					3
8b. Instructional Workshops with stakeholders			Mid		Low			0			
6b. Piloting different technical configurations on the MV-LV grid			Mid				High	0			
4b. Building a role for maintaining customer data			Mid		Low				1		
4 g. Written Procedure on Fraud Management			Mid		Low				1		
4h. Establish a Centralized Quality Control areas for key processes			Mid		Low				1		
8c. Periodic Regulatory Internal Committees			Mid		Low				1		
2c. Strengthen the EBM team			Mid			Mid			1		
5 a. Implementing a Meter testing laboratory			Mid			Mid			1		
6c. Technical Losses calculation process			Mid			Mid			1		
7c. Establishment of a Metering Data Control Center			Mid				High		1		
4c. Review the Debt Recovery process			Mid		Low					2	
6 a. Assessment for rehabilitating the grid			Mid		Low					2	
4 a. Improvements in the Meter Life Cycle				Low	Low			0			
5f. Improve Free-Tokens process				Low	Low			0			
5 g. Convert "Suprima" customers				Low	Low			0			
8 a. Round table with MERA				Low	Low			0			
4f. Improve reporting and establish KPIs				Low	Low				1		
5 d. Document management system				Low	Low				1		
7b. Smart Meter Regulation				Low	Low				1		
8 d. Attraction of Private Investment				Low	Low					2	
4 d. Review the current Organization of the Distribution Directorate				Low		Mid				2	

Source: ECA analysis based on the 2021 Loss Reduction Roadmap

Ranking of initiatives by dependency on other initiatives

Table 27 provides an overview of the initiatives, ranked first by projects that could be implemented without any dependency on other projects and then by budget and impact on loss reduction. Assuming that the primary restriction is budget availability, then among initiatives with similar dependency on other initiatives, preference is for those with a lower budget and then on the impact on losses.

There are 14 initiatives that do not depend on any other initiatives and could be implemented early on. Among the 14 initiatives, three have a low budget to implement and high to mid impact on loss reduction and could be prioritised:

1. 2b. New Losses Calculation methodology
2. 4e. Strengthen the Customer Service processes
3. 8b. Instructional Workshops with stakeholders

There are also 4 initiatives with very high impact or high impact on loss reduction but with a mid budget requirements. Given availability of budget, these initiatives could also be prioritised:

4. 1 a. Establishing PMO
5. 2 a. Metering in Injection Points, Substations and Feeders
6. 3c. Large customer and public institutions audit
7. 4i. Reorganization of the Revenue Protection area

Finally there are two initiatives with very high or high impact on losses but with high budget requirements:

8. 3b. End-customers audit
9. 7 a. Smart metering for residential and commercial customer

These could also be developed early on, given budget availability.

Table 28 Ranking of initiatives by dependency on other initiatives

Initiative	Dependency on other initiatives				Budget			Impact on losses			
	0	1	2	3	Low	Mid	High	Very high	High	Mid	Low
2b. New Losses Calculation methodology	0				Low				High		
4e. Strengthen the Customer Service processes	0				Low				High		
8b. Instructional Workshops with stakeholders	0				Low					Mid	
4 a. Improvements in the Meter Life Cycle	0				Low						Low
5f. Improve Free-Tokens process	0				Low						Low
5 g. Convert “Suprima” customers	0				Low						Low
8 a. Round table with MERA	0				Low						Low
1 a. Establishing PMO	0					Mid		Very high			
2 a. Metering in Injection Points, Substations and Feeders	0					Mid		Very high			
3c. Large customer and public institutions audit	0					Mid		Very high			
4i. Reorganization of the Revenue Protection area	0					Mid			High		
3b. End-customers audit	0						High	Very high			
7 a. Smart metering for residential and commercial customer	0						High		High		
6b. Piloting different technical configurations on the MV-LV grid	0						High			Mid	
2e. Perform Regional Balances		1			Low				High		
5b. Acquisition of Mobile APPs		1			Low				High		
4b. Building a role for maintaining customer data		1			Low					Mid	
4 g. Written Procedure on Fraud Management		1			Low					Mid	
4h. Establish a Centralized Quality Control areas for key processes		1			Low					Mid	
8c. Periodic Regulatory Internal Committees		1			Low					Mid	
4f. Improve reporting and establish KPIs		1			Low						Low
5 d. Document management system		1			Low						Low
7b. Smart Meter Regulation		1			Low						Low
2c. Strengthen the EBM team		1				Mid				Mid	
5 a. Implementing a Meter testing laboratory		1				Mid				Mid	
6c. Technical Losses calculation process		1				Mid				Mid	
3 a. Metering in Distribution Transformers		1					High	Very high			
7c. Establishment of a Metering Data Control Center		1					High			Mid	
4c. Review the Debt Recovery process			2		Low					Mid	
6 a. Assessment for rehabilitating the grid			2		Low					Mid	
5c. Persons in Vulnerable Situations			2				High		High		
5e. Internal Training for CMS and Commercial Processes				3		Mid			High		

Source: ECA analysis based on the 2021 Loss Reduction Roadmap

Summary of ranked initiatives

The following table summarises the initiatives and puts together the three criteria discussed above. On the vertical axis initiatives are ranked by budget, on the horizontal axis by the impact on loss reduction and the blue scale colouring indicates which projects depend on other initiatives to be developed and which projects can be implemented irrespective of other initiatives.

Table 29 Initiatives subject to budget, impact on losses, and dependence criteria

Budget	Impact on losses			
	Very high	High	Medium	Low
Low		2b. New Losses Calculation methodology	8b. Instructional Workshops with stakeholders	4 a. Improvements in the Meter Life Cycle
		4e. Strengthen the Customer Service processes	4b. Building a role for maintaining customer data	8 a. Round table with MERA
		5b. Acquisition of Mobile APPs	4 g. Written Procedure on Fraud Management	5f. Improve Free-Tokens process
		2e. Perform Regional Balances	8c. Periodic Regulatory Internal Committees	5 g. Convert “Suprima” customers
			6 a. Assessment for rehabilitating the grid	4f. Improve reporting and establish KPIs
			4c. Review the Debt Recovery process	7b. Smart Meter Regulation
			4h. Establish a Centralized Quality Control areas for key processes	5 d. Document management system
				8 d. Attraction of Private Investment
Medium	3c. Large customer and public institutions audit	3 a. Metering in Distribution Transformers	2c. Strengthen the EBM team	4 d. Review the current Organization of the Distribution Directorate
	1 a. Establishing PMO	4i. Reorganization of the Revenue Protection area	5 a. Implementing a Meter testing laboratory	
	2 a. Metering in Injection Points, Substations and Feeders	5e. Internal Training for CMS and Commercial Processes	6c. Technical Losses calculation process	
High	3b. End-customers audit	7 a. Smart metering for residential and commercial customer	6b. Piloting different technical configurations on the MV-LV grid	
	3 a. Metering in Distribution Transformers	5c. Persons in Vulnerable Situations	7c. Establishment of a Metering Data Control Center	

Colour coding indicates initiative dependence on implementation of other initiatives, as follows:

No dependency	Depends on 1 initiative	Depends on 2 initiatives	Depends on 3 initiatives

Source: Loss Reduction Roadmap, ECA Analysis

From the long list of 34 initiatives, the following projects have a relatively high impact on losses, low budget requirements and could be implemented immediately without the need to implement other initiatives first (as shown in the table below):

1. 1 a. Establishing PMO
2. 2 a. Metering in Injection Points, Substations and Feeders
3. 2b. New Losses Calculation methodology

4. 3c. Large customer and public institutions audit
5. 4e. Strengthen the Customer Service processes
6. 4i. Reorganization of the Revenue Protection area
7. 8b. Instructional Workshops with stakeholders

Table 30 Ranked initiatives by budget, impact on losses and dependency on initiatives

Criteria			Initiatives that fulfil the criteria
Budget	Impact	Dependency	
Low	Mid / High	0	2b. New Losses Calculation methodology 4e. Strengthen the Customer Service processes 8b. Instructional Workshops with stakeholders
Low / Mid	Very high	0	1 a. Establishing PMO 2 a. Metering in Injection Points, Substations and Feeders 3c. Large customer and public institutions audit
Low / Mid	High	0	2b. New Losses Calculation methodology 4e. Strengthen the Customer Service processes 4i. Reorganization of the Revenue Protection area
Mid	Very high / High	0	1 a. Establishing PMO 2 a. Metering in Injection Points, Substations and Feeders 3c. Large customer and public institutions audit 4i. Reorganization of the Revenue Protection area

Source: ECA analysis based on the 2021 Loss Reduction Roadmap

7.2 Forecast network losses

The LRR includes three scenarios illustrating the potential outcome from implementation of the LRR. The scenarios reflect varying expected success rates of the same set of proposed interventions, ie they do not comprise different sets of assumptions or parameters, or different sets of individual projects. The three scenarios are as follows:

- **High Potential Scenario**: This scenario anticipates rapid implementation of the LRR, assuming a 1.2% average yearly reduction of losses, resulting to a total reduction of 6% in the fifth fiscal year, as well as implementation of additional ESCOM measures.

- **Medium Potential Scenario**: This scenario reflects base case implementation of the LRR. The annual loss reduction in this scenario is 1.05% resulting to a total loss reduction of 5.25% in the fifth fiscal year.

- **Low Potential Scenario**: Based on this scenario, slow implementation of the LRR is assumed, by which losses are reduced by 0.9% yearly, resulting to a total loss reduction of 4.5% in the fifth fiscal year.

In the above scenarios the escalation of the total losses decrease compared to the maximum achieved in the 5th year, is assumed to be 34.53% in the first year, 28% in the second, 19% in the third, 13% in the fourth and 5.47% in the fifth.

Further possibilities for reduction of energy losses, beyond the horizon considered in the LRR will depend on the implementation and effectiveness of the measures included in the LRR, the expansion of the network and the actual operating conditions, which will need to be examined through further analysis of the sources of both technical and non-technical losses at the time. Based on the current level comparative to international network loss standards, losses may be further reduced over a 20 year planning period. It was assumed that losses could reach 12% in the High scenario, and 15% in the Low and Base scenarios by 2042. The measures implemented and the reduction achieved would depend on available financial resources and priorities set, considering also electrification targets.

Based on these assumptions, the forecast Transmission, Distribution, and total network technical and non-technical losses taken into consideration for the development of the demand forecast, are those presented in Table 31.

Table 31 Forecast Losses

Scenario		2021	2025	2030	2035	2040	2042
Low	**Transmission**	5.5%	4.8%	4.3%	4.2%	4%	4%
	Distribution	16.7%	14.6%	12.9%	12%	11%	11%
	Total	**22.2%**	**19.4%**	**17.2%**	**16.1%**	**15%**	**15%**
Base	**Transmission**	5.5%	4.7%	4.2%	4.1%	4%	4%
	Distribution	16.7%	14.2%	12.5%	11.7%	11%	11%
	Total	**22.2%**	**18.9%**	**16.6%**	**15.8%**	**15%**	**15%**
High	**Transmission**	5.5%	4.6%	3.8%	3.4%	3%	3%
	Distribution	16.7%	11.6%	11.7%	10.3%	9%	9%
	Total	**22.2%**	**16.6%**	**15.6%**	**13.8%**	**12%**	**12%**

Source: Loss Reduction Roadmap, ECA Assumptions. Note: as a percentage of total energy injected in the transmission system.

8 Demand Side Management (DSM) measures

Demand Side Measures (DSM) includes everything that is done on the demand side of the power system. This can include such simple things as increasing efficiency of a light bulb by replacing an incandescent light bulb with fluorescent light bulb to using sophisticated controllers to dynamically change the load.

Demand Side Measures can be broadly categorised into two different categories:

- ***Energy Efficiency (EE) –*** This includes improve efficiency of the appliances or of the building, so that energy losses are reduced. This approach towards achieving DSM is related to technical features, rather than changes in the consumer's personal comfort and behaviour.

- ***Demand Response (DR) –*** DR gives an opportunity for consumers to take part in the operation of the electric grid by shifting or decreasing their electricity usage during peak time in response to some financial incentives (price based or incentive based).

  DR programs are typically used by electric operators and system planners as an option to balance the supply and demand. These programs are capable to decrease the electricity cost in the system. Both price and incentive based programs involve customers being incentivised to change their energy consumption patterns.

Today's electricity systems complement their operation with distributed energy resources, such that these provide flexibility in emergency or other grid congestion situations. In this context, demand side management raises as one of the most attractive solutions for an easy flexibility implementation in power systems.

8.1 Historical, existing and planned DSM measures in Malawi

ESCOM, the Ministry of Energy and Mining (MEM) and MERA have designed and implemented several DSM projects over the years. There are also plans from the same entities to implement further measures. Historical, existing and planned DSM measures by ESCOM, MEM and MERA in Malawi are described in the subsections below.

2012-2013 MEM Energy Efficient Lighting Project (EELP)

The Government of Malawi, through the MEM implemented in 2012/13 an Energy Efficient Lighting Project (EELP) with the aim of reducing the evening system peak demand.

MEM was the Executing Agency of the project while ESCOM was the Implementing Agency. The project involved procurement of 2 million compact fluorescent light (CFL) bulbs, of which 1.3 million were distributed nationwide for free to residential customers, small enterprises and public buildings. This was done by direct replacement of existing incandescent bulbs with CFL bulbs. Commercial and industrial customers were required to purchase the remaining 700,000 energy saver bulbs at subsidised prices via retail outlets owned by Malawi Post Corporation, Farmers World and Rab Processors. A maximum of 6 CFL bulbs was installed per house by electrical contractors hired by ESCOM.

The project achieved an estimated saving of approximately 50 MW in peak demand, resulting to reduction of blackouts/load shedding, and enabling ESCOM to connect some more customers who had been on the waiting list for some time.

The project was supported by the UK Government's Department for International Development (DFID) with an amount in the order of £3 million.

2017-2019 ESCOM's LED bulbs distribution programme

According to ESCOM reports, 1,200,000 LED bulbs were distributed to residential sector customers, and 400,000 LED bulbs sold, between 2017-2019, saving about 29 MW in the peak.

2022-2023 ESCOM's Efficient Lighting (LED Tubes) project

Currently, ESCOM is implementing the Efficient Lighting (LED Tubes) project, for the period 2022-2023, which aims at reducing commercial lighting energy demand through the retrofitting of inefficient fluorescent tubes with modern Energy Efficient LED Tubes in commercial and public sector premises. Considering that a conventional fluorescent tube uses about twice as much energy as an efficient LED tube for the same output, ESCOM plans to replace 450,000 fluorescent tubes to achieve savings of over 9.4 MW at peak, ie about 21 W per bulb. The Project has already rolled out within ESCOM offices countrywide and public buildings.

In addition, the project will achieve a reduction of energy consumption, for the estimation of which we are making assumptions about the time that these lights are used. Malawi has a relatively long duration of daylight throughout the year, ranging from about 11:20 hours in June to about 13 hours in December, based on data about Lilongwe. Sunrise gets as late as about 06:10 in June, and sunset as early as about 05:25 in January. Considering that office hours are normally 8-12 and 13:30 to 16:30, and for most shops working hours are not further than 17:00, the artificial lighting requirements in the commercial and public sector seem rather limited to only a few hours per day. Apparently, the range of artificial lighting requirements is specific on the type of activity and the specific conditions in the premises. There are currently no statistics available to determine that range, and available international standards only refer to the required illumination per type of activity and cannot be readily translated into hours of required artificial lighting.

Existing Demand Response Measures (Time of Use charges)

ESCOM has implemented Time of Use tariffs for larger customers as it is depicted in the table below. The Time of Use energy charge provides signals to shift consumption from peak to off-peak periods and the demand charge provides signals to lower the peak demand on a monthly basis.

Table 32 ESCOM tariff design and time of use charges

Category		Type of charge					
		Fixed *(per month)*	Energy *(per kWh)*			Capacity charge *(per kVA)*	Demand charge *(per MW)*
			Blocks	Single rate	ToU	Fixed*	ToU**
ET1	Domestic, 1-Ph, Prepaid	x	√	x	x	x	x
ET2	Domestic, 1-Phase, Postpaid	√	√	x	x	x	x
ET3	Domestic, 3-Phase, Prepaid	x	x	√	x	x	x
ET4	Domestic, 3-Phase, Postpaid	√	x	√	x	x	x
ET5	General, 1-Phase, Prepaid	x	x	√	x	x	x
ET6	General, 1-Phase, Postpaid	√	x	√	x	x	x
ET7	General, 3-Phase, Prepaid	x	x	√	x	x	x
ET8	General, 3-Phase, Postpaid	√	x	√	x	x	x
ET9	Maximum Demand, LV	√	x	x	√	√	√
ET10	Maximum Demand, MV	√	x	x	√	√	√
ET11	Essential Service, 3-Ph, Prepaid	x	x	√	x	x	x

Source: ESCOM. Note: * Based on annual declared demand, ** Based on actual monthly demand reading.

MERA's Guidelines for promoting Energy Efficiency in Malawi

MERA has prepared guidelines for the promotion of energy efficiency in Malawi.. The draft Guidelines include:

- Energy efficiency standards and appliance labelling
- Guidelines for the development of energy management strategies by all facilities
- Directions for energy audits
- Energy accounting principles
- Demand Side Management principles
- Energy saving tips

MERA has submitted the Guidelines to the Ministry of Energy for approval and setting in effect.

Further ESCOM plans

ESCOM has indicated that an efficient lightbulb plan is expected to be implemented with the support of the World Bank and mainly targeted at residential consumers.

8.2 Options for DSM in Malawi

As it was discussed above, Demand Side Measures can be broadly categorised into EE and DR measures. The following subsections discuss EE and DR options that could be considered for the power sector in Malawi and comment on the applicability of those measures in Malawi.

8.2.1 Demand Response options

DR gives an opportunity for consumers to take part in the operation of the electric grid by shifting or decreasing their electricity usage during peak time in response to some financial incentives. DR options include retail price based and incentive based programs.

The following table describes potential DR measures (both retail price and incentive based) and comments on their applicability in Malawi.

Table 33 DR measures

DR Measure	Descriptions / Comments
A. Retail price based DR	
1. ToU tariffs	Retail price based programmes mainly concern implementation of time of use tariffs, varying by hour or season, incentivising customers to use electricity during non-peak hours, or away from periods of energy shortages. Such programmes would require the introduction of meters capable of registering the consumption of electricity at different times. Such programmes are already in place for categories of industrial customers in Malawi. However, considering the cost of needed metering equipment and the priority for Malawi to extend electrification to the significant part of the population currently off the main grid, this option is not considered applicable at present.
B. Incentive based DR	
1. Direct load control	The utility or network operator may remotely shut down or cycle a customer's electrical equipment (eg air conditioner, water heater), on short notice, to address system or local reliability contingencies. Customers often receive a participation payment, usually in the form of an electricity bill credit. A few programs provide customers with the option to override or opt-out of the control action. However, these actions almost always reduce customer incentive payments. Direct load control programs are primarily offered to residential and small commercial customers. Considering the very low average consumption in the domestic and commercial sector of Malawi, as well as the complexity of the operation and the increased capital cost requirements of such systems, they are not considered applicable in the country at this stage.
2. Interruptible / curtailable (I/C) service	This concerns programs integrated with the customer tariff providing a rate discount or bill credit for agreeing to reduce load, typically to a pre-specified firm service level during system contingencies. Customers that do not reduce load typically pay penalties in the form of very high electricity prices that come into effect during contingency events or may be removed from the program. Such arrangements could be examined by ESCOM with large industrial users. However, they will have to be considered carefully taking into consideration

	that ESCOM already sheds the load during some hours without any payments to consumers.
3. Demand bidding / buyback programs	These are programs targeted mainly to large customers, encouraging them to either bid into a wholesale electricity market and offer to provide load reductions at a price at which they are willing to be curtailed, or identify how much load they would be willing to curtail at a utility-posted price. Such tailor-made programs may be suitable for and of interest to certain large industrial customers, and should be further examined by ESCOM in the context of the development of a competitive wholesale electricity market.
4. Emergency demand response programs	Programs that provide incentive payments to customers for measured load reductions during reliability-triggered events; emergency demand response programs may or may not levy penalties when enrolled customers do not respond. The type of metering equipment required for this type of interventions might only concern certain large industrial customers in Malawi. Such arrangements could be examined by ESCOM with large industrial users. However, they will have to be considered carefully taking into consideration that ESCOM already sheds the load during some hours without any payments to consumers.
5. Capacity market programs	These programs are typically offered to customers that can commit to providing pre-specified load reductions when system contingencies arise. Customers typically receive day-of notice of events. Given the current market structure in Malawi this measure is not applicable.
6. Ancillary Services Market Programs	These programs allow customers to bid load curtailments in open markets as operating reserves. If their bids are accepted, they are paid the market price for committing to be on standby. Similarly, given the current market structure in Malawi this measure is not applicable.

Source: ECA analysis

8.2.2 Energy efficiency options

Domestic sector

According to the 2018 Malawi Population and Household Census, 453,592 households were using electricity for lighting, and 75,267 households for cooking and heating[10]. Moreover, 224,521 households owned a refrigerator, and 594,713 an iron, although there is no information regarding the percentage of those households connected to the distribution network. Households accounted for about 42% of electricity consumed in the country on the average during the period 2012-2021. Currently, there are no statistics concerning the average electricity consumption of households by end use.

For the purposes of this study, it is assumed that the main end uses of electricity in households are lighting, cooking, refrigeration, water heating, space heating/cooling, washing, vacuum cleaning, entertainment, information and education. It may be assumed that electricity

[10] As the census determines the use of electricity for these end uses distinctly from other energy sources (eg solar, battery, charcoal, firewood, etc), we are assuming that these numbers only concern households connected to the electricity distribution network of Malawi. We note though, that the total number of residential connections in 2018 was about 355,300, ie about 90,000 less than households using electricity for lighting. We are assuming that this may reflect multiple households using a single connection to the distribution network.

is used for lighting in almost all domestic customers, whereas most other typical uses are less widespread.

Considering the very low average consumption in rural areas it may be assumed that the possibilities for energy savings are very poor in such connections. Even in urban areas electricity consumption in the order of 160 kWh/month (corresponding to use of an average of 222 W continuously on a daily basis) can be assumed to only cover basic needs of the household.

The following measures aimed at the domestic sector may be considered in the context of this study.

Table 34 Options for EE measures for the domestic sector

EE Measure	Descriptions / Comments
Domestic sector EE options	
1. Substitution of low efficiency lighting with LED bulbs	As already mentioned in section 8.1, considerable assistance has been provided for the substitution of incandescent with fluorescent lamps, and the introduction of LED lamps. There is still considerable potential for substitution of fluorescent lamps with LED lamps. Depending on the type and efficiency rating of lamps, savings may be in the order of 50% for the replacement of fluorescent lamps.
2. Introduction of Minimum Energy Efficiency Requirements (MEPR) and/or a labelling scheme	Minimum energy performance requirements and energy efficiency standards (MEPR) have been prepared by MERA and are in the process of approval by the Ministry of Energy. Such standards would incentivise the gradual phasing out of low energy efficiency appliances currently in use, and their gradual substitution by high energy efficiency ones. This impact is of interest for the purposes of this study, as it would affect the energy consumption needs of households. The introduction of such requirements would also apply in the construction of new or rehabilitation of existing buildings with high energy efficiency standards and would then have an effect on mainly the heating and cooling requirements of those buildings. However, considering the very low share of electricity currently used for heating and cooling purposes in Malawi, this effect is not considered significant for the purposes of this study. Depending on the type of appliances, the energy savings from the introduction of MEPR may be considerable (eg a A class refrigerator may save up to more than 50% of an older refrigerators' electricity consumption, and a A class washing machine may save up to 35% of the electricity consumption of a class D or E model). The introduction of strict MEPR for home appliances would have an impact on electricity consumption in the medium to long-term.
3. Provision of incentives for the installation of solar water heaters	According to the 2016 IRP for Malawi, solar water heating had been proposed in the SE4ALL Agenda Action and the World Bank had proposed a programme focusing on replacing electric heaters with 2.5 kW elements combined with ripple control, but no specific programme had been elaborated by any of the stakeholders for a solar water heating programme. Based on World Bank and Agenda Action estimates included in the 2016 IRP study, installed electric heaters were in the order of 30,000 to 40,000 in 2015. According to the project proposers, launching a programme for

EE Measure	Descriptions / Comments
Domestic sector EE options	
	the installation of 16,000 partially subsidised solar hot water heaters for residential users, could be assumed to reduce peak demand by 21 MW within 5 years from implementation. Although the details for this estimate are not provided, it seems that coincident demand for water heating at peak was assumed to be approximately 50% of installed capacity for water heating. The annual reduction of electricity consumption would be 10,000 MWh at the end of programme implementation. The overall cost of the solar hot water heaters was estimated to about $11.2 million and would be partly covered by a subsidy.
4. Replacement of conventional technology fans with energy efficient ones	Although the number of households equipped with ceiling fans is not known, it may be estimated that there is a considerable number of fans in operation, which could be replaced with new technology units, capable of providing energy savings in the order of 60%.
5. Information dissemination and energy saving campaigns	An information dissemination programme, including an energy saving campaign should be complementary to any effort to improve the energy consumption pattern. However, the cost and benefit from the implementation of such programmes would depend on the specific characteristics and intentions of the programme, as well as the specific economic and cultural conditions and consumer segments it is aimed at. Considering the low electrification and relatively low energy consumption in the residential sector, the effectiveness and priority of such a programme for Malawi at the moment seems low.

Source: ECA analysis

Commercial and industrial sectors

Electricity consumption in the commercial and the industrial sectors accounted for about 14% and 44%, on the average, respectively, in the period 2012-2021,

Incentives for the penetration of efficient machinery and other appliances used in commercial and industrial premises may have a positive effect on energy consumption, although the impact of specific measures would depend on the object of the commercial or industrial activity.

Energy saving potential can be assumed to be relatively low in the commercial sector, considering the relatively small share of the sector in total electricity consumption in the country, and the small average electricity consumption per commercial connection. The potential savings in industry may be higher, although a horizontal assessment of the potential in industry cannot be reliable, due to the specific characteristics of the particular premises, technology in place, and maintenance status.

The following options may be considered in the context of this study for the commercial and industrial sectors.

Table 35 Options for EE measures for the commercial and industrial sectors

EE Measure	Descriptions / Comments
Commercial and industrial sectors sector EE options	
1. Energy efficient lighting	As discussed in section 8.1, the Government of Malawi has already implemented programs for the replacement of incandescent lamps, and ESCOM is currently implementing the LED Tubes project, for the replacement of fluorescent with LED tubes in commercial and public buildings. It may be assumed that there is still untapped potential for the introduction of energy efficient lighting in these sectors, although it should also be assumed that competition drives owners of commercial and industrial premises to upgrading energy consuming equipment in line with technological innovation, more often than households. There is no information regarding the electricity consumption for street lighting in Malawi, or the relevant installed capacity, or the length of the street lighting network currently in use in the country. Based on the available statistics of ESCOM sales the share of electricity consumption for street lighting can be assumed to be negligible. Accordingly, the potential for energy savings through introduction of LED lamps in street lighting is unknown but can be assumed to be negligible for the purposes of this study. LED lights are 40% to 60% more energy efficient than traditional lighting technologies, therefore, savings could be in that order of magnitude relative to current electricity consumption for street lighting, if a replacement programme was implemented.
2. Introduction of Minimum Energy Efficiency Requirements (MEPR) and/or a labelling scheme	Minimum energy performance requirements and energy efficiency standards (MEPR) have been prepared by MERA and are in the process of approval by the Ministry of Energy. As in the domestic sector, the introduction of MEPR may have an effect mainly in some commercial activities. However, the scope for this type of investment is unknown in Malawi, due to the lack of statistics regarding the electricity consuming appliances in use in the commercial sector.
3. Replacement of electric water heaters by solar water heaters	For certain commercial activities solar water heaters may be applicable (eg in hotels), but there is no data to allow the estimation of the amount of electricity that might be saved by the installation of solar water heaters, or the estimation of the potential for such investment in Malawi. Hot water preparation in such premises is usually done using fossil fuels instead of electricity, therefore the impact on electricity consumption from the introduction of solar water heaters in commercial activities appears to be small.
4. Upgrading of AC units	There are AC units used, to some extent, in commercial customer premises. Although there is no specific information about the number and type of units in operation, it may be assumed that there is a certain potential for replacement of units with higher energy efficiency, inverter technology units.
5. Replacement of conventional technology fans with energy efficient ones	As in the domestic sector, it is also assumed that fans are also in use in the commercial sector, which could be replaced with high efficiency units.

EE Measure	Descriptions / Comments
Commercial and industrial sectors sector EE options	
6. Introduction of variable speed drives for the operation of motors in commercial and industrial activities.	This could also have a significant energy saving potential, but the current technical conditions in such premises is unknown and therefore a safe conclusion may not be drawn. Considering that such technological improvement are normally associated with clear economic benefits and competitive advantages for the investor, such opportunities are normally utilised without any additional incentives or interventions. Where such clear advantages are limited by price or other market distortions, the introduction of MEPR with or without additional incentive schemes may be effective.

Source: ECA analysis

8.2.3 Summary of DSM options in Malawi

The DSM measures considered as possible options to implement in Malawi are summarised in Table 36.

Table 36 Summary of DSM options in Malawi

	Demand Side Measure (DSM)	Status	Unit	Capital costs *($/unit)*	Impact on peak demand *(kW/Unit)*	Impact on energy demand *(kWh/Unit/year)*	Target groups	Earliest year for implementation *(Year)*
1	Replacement of Fluorescent bulbs with LED lights	Committed and candidate	Bulb	0.7-5	0.006	11 13-40	Residential Commercial Public	2022
2	Replacement of AC units with high energy efficiency ones	Candidate	AC unit	300	0.52	915	Commercial	2023
3	Replacement of fans with high efficiency ones	Candidate	Fans	100	0.036	66 92	Residential Commercial	2023
4	Replacement of electric water heaters with solar	Candidate	Solar water	750-900	2	3000 3650	Residential Commercial	2023
5	Introduction of Minimum Energy Efficiency Requirements	Candidate	All consumers	-	-	71	Residential Commercial Industrial	2025

Source: ECA

8.3 Assessment of potential DSM options

The design of a plan for the improvement of EE in electricity consumption concerns the identification of relevant end uses of electric energy, where EE improvements through technological or other interventions are technically and economically feasible.

The first step for the assessment of the identified DSM options is to identify the DSM potential by end use and customer category. The objective is to evaluate how much energy may be saved by satisfying the same end use, at an equivalent qualitative level, yet with higher energy efficiency appliances or procedures, compared to those currently in use, thus by consuming less electricity:

- *Domestic and commercial users* - The estimation of the potential for DSM improvement in the consumption of electricity by residential and commercial customers is normally based on a bottom-up calculation. Under this approach, the potential for a particular end use and customer group is estimated as the product of the average level of ownership of the relevant end use appliances among that customer group, the average utilisation (in hours) of these appliances and the average saving of end use appliance capacity (in W) from switching to a high efficiency alternative, compared to those currently in use. This product provides the total potential savings in electricity consumption for that use and customer group from the switch to high efficiency appliances.

- *Industrial users* – The approach to estimating DSM potential for industrial customers is rather different. Much of the DSM potential for these customers lies in the ability to replace motors, pumps, chillers and other installations which are specific to individual industrial processes and facilities regarding size, use, age and efficient alternatives. In addition, energy savings may be possible without replacing equipment by, for example, redesigning processes. Therefore, simple comparisons of the numbers of appliances owned by individual customers are not a reliable measure of aggregate DSM potential for industrial customers. Usually, this would be addressed by specific walk-through EE audits for a representative sample of industrial premises. These can be used to estimate overall DSM potential as a share of current consumption and, from this, to scale up to national-level estimates based on the number of similar facilities in the same industries.

Once the DSM potential is determined, the pay-back period to customers from different measures is also analysed. The pay-back period is the time taken for the savings from lower electricity bills, as a result of substituting an existing appliance with a high efficiency one, to fully offset the relevant investment cost. The resulting estimated pay-back periods for DSM measures reveals weather a consumer would have the incentive to implement it on his own (if benefits exceed costs) or if incentives should be considered to implement the measure (costs exceed benefits and consumers would not have an incentive to implement it on their own).

The analysis leads to a shortlist of EE and DR measures that should be considered for implementation in Malawi. The shortlisted DSM measures should be further assessed in the context of the IRP to determine which cases are the least cost options to be considered for implementation.

8.3.1 DSM potential in Malawi

Electricity consumption by sector in Malawi, in 2021, is presented in Table 37. The data illustrates the low level of average consumption in the residential sector, at 120 kWh/month per connection (reaching as low as 47 kWh/month on the average in rural connections), and the relatively low average consumption in the commercial sector, at 327 kWh/month per connection[11]. One may also observe that despite the relatively small number of industrial customers, industry accounts for about 44% of total electricity consumption in Malawi.

Table 37 Electricity consumption in Malawi, 2021

Sector	Number of customers	Annual sales (GWh)	Average consumption (kWh)	
			Annual	Monthly
Residential	459,800	663.6	1,443	120
Urban	297,600	571	1,919	160
Rural	162,200	92	567	47
Commercial	83,800	329.2	3,928	327
Industrial LV	1,743	270	154,905	12,909
Industrial MV	152	420	2,763,158	230,263

Source: ESCOM

DSM potential in the residential and commercial sectors

As detailed Information on current ownership of electric appliances by customer type in Malawi is not available, the estimation of the potential savings is based on assumptions, about the average or typical size of appliances, the daily and annual use, the typical number of appliances per residential or commercial installation, and the penetration of appliances to the total of installations connected to the electric system of Malawi.

For example, it is assumed that the typical type of CFL lamps currently in place have a capacity of 15 W, and may be replaced by 9 W LED lamps. Average daily use in households is 5 hours, and such lamps are found in 90% of grid connected households. Considering there are about 298,000 urban and 162,000 rural residential connections, there are on the average about 5.4 CFL lamps per urban and 3.6 per rural household, respectively. The average capacity and energy savings by lamp are 6 W and 10.95 kWh/year respectively. Then, the total energy savings potential from the replacement of CFL by LED lamps in households is 23.99 GWh/year. Assuming an average CO2 emissions factor of 62 kg/MWh from existing power generation[12], the annual savings of CO2 emissions from the replacement of CFL by LED lamps is estimated at 1,487 ton.

Table 38 and Table 39 present the electricity and CO2 savings potential in the domestic and commercial sector of Malawi from the implementation of the identified EE measures. Within these, the replacement of electric water heaters by solar water heaters for residential and commercial customers has the greatest potential. The saving potential from the upgrading of AC systems in the commercial sector potential from upgrading of fans in the domestic sector are the lowest.

[11] For comparison, industry accounted for 36% in the EU(27) in 2021, ranging from 12% in Cyprus to 47% in Luxemburg. Also, the average monthly consumption per household in the EU(27) is about 300 kWh, ranging from about 160 kWh in Romania to 960 kWh in Sweden.
[12] Calculated using generation outputs from the 2017 IRP and assuming an emissions factor for diesel generators of 715kg/MWh, based on WAPP master plan.

Table 38 Electricity and CO2 savings potential in the domestic sector

	Appliance capacity (W)		Operation	Penetration (% of customers owning)		Average no of units per connection		Savings per appliance		Customers (million)		Total potential	Capacity impact	CO2 emissions saving	
Appliance	Existing	New	h/day	Urban	Rural	Urban	Rural	W	kWh/year	Urban	Rural	GWh/year	MW	kg/MWh	Ton/year
Fans	60	24	5	20%	10%	0.20	0.10	36	65.7	0.298	0.162	4.98	2.18	62	308
CFL	15	9	5	90%	90%	5.40	3.60	6	11.0	0.298	0.162	23.99	9.20	62	1,487
Water heater	2,084	0	4	15%	10%	0.15	0.10	2,084	3,042.6	0.298	0.162	185.16	63.41	62	11,480
Total												214.13	74.79		13,276

Source: ESCOM, 2017 IRP, ECA assumptions and calculations

Table 39 Electricity and CO2 savings potential in the commercial sector

	Appliance capacity (W)		Operation	Penetration (% of customers owning)	Average no of units per connection	Savings per appliance		Customers (million)	Total potential	Capacity impact	CO2 emissions saving	
Appliance	Existing	New	h/day			W	kWh/year		GWh/year	MW	kg/MWh	Ton/year
AC	1,200	680	8	5%	0.1	520	915	0.084	7.67	3.92	62	476
Fans	60	24	8	100%	3.0	36	92	0.084	23.17	7.24	62	1,437
FTL	35	18	6	42%	6.3	17	37	0.084	19.66	6.28	62	1,219
CFL	15	9	6	40%	4.0	6	13	0.084	4.41	1.41	62	273
Water heater	2,500	0	4	25%	0.3	2,500	3,650	0.084	76.48	36.67	62	4,742
Total									131.40	55.53		8,147

Source: ESCOM, 2017 IRP, ECA assumptions and calculations

The total estimated annual potential for each of the DSM options considered is as follows.

Table 40 Total energy and CO2 savings potential

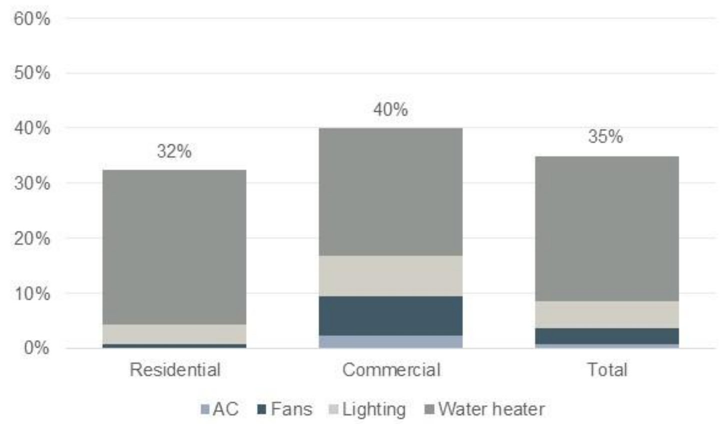
	Energy potential (GWh/year)	CO2 emissions potential (ton of CO2 per year)
Households		
Replacement of fans by energy efficient ones in households	4.9	308
Substitution of CFL by LED lamps	23.9	1,487
Substitution of electric by solar water heaters	185.2	11,480
Commercial premises		
Replacement of AC units with high efficiency inverter units	7.7	476
Replacement of fans by energy efficient ones	23.2	1,437
Substitution of FTL by LED tubes	19.7	1,219
Substitution of CFL by LED lamps	4.4	273
Substitution of electric by solar water heaters	76.5	4,742

Source: ECA analysis

The total technical DSM potential for residential customers is estimated at approximately 215 GWh/year and for commercial customers at 131 GWh/year, and the respective CO2 savings at 13,300 ton/year and 8,147 ton/year.

As illustrated in Figure 21, the electricity savings potential as a share of sales, by customer class is highest for commercial customers, where almost 50% of consumption may be saved, mainly through investment in lighting and water heating. The type of DSM measures considered in the residential and commercial sectors could reduce total electricity consumption by 23%.

Figure 21 DSM potential as a share of sales by customer class (2021)



Source: ECA calculations

DSM potential in Industry

The information provided in Table 37 confirms that, as discussed in section 8.2.2, generalisations on the average energy use of appliances, and the possibilities for their substitution by higher EE ones cannot be made for industrial premises. Instead, sound conclusions should only be drawn through audits, focusing on the specificities of each factory, or industrial process. Such audit data is not available for the industrial sector of Malawi, and the performance of such audits was not part of the scope of this project. Accordingly, relying on assumptions about the types of appliances and procedures used in industrial premises in Malawi would be unfounded and would defeat the purpose of the analysis for the preparation of an EE plan. Instead, it is proposed that a dedicated survey of the industrial sector through focused energy audits, is carried out, to feed the preparation of an EE plan for industry.

8.3.2 Pay-back period of DSM options

Further to estimates of the total EE potential, we have also prepared estimates of the pay-back period to customers from different measures. The pay-back period is the time taken for the savings from lower electricity bills, as a result of substituting an existing appliance with a high efficiency one, to fully offset the relevant investment cost. Pay-back periods provide a simple and rapid way of comparing different investments which is why they are used here. However, it should be noted that they are not the sole nor the best means of making investment decisions—better indicators are the internal rate of return (IRR) or the net present value (NPV) using cashflows discounted at the investor’s cost of capital.

The comparison only considers the costs and benefits to the customer. These are not the same as the costs and benefits to ESCOM or to Malawi as a whole. For example, if the tariff charged to a customer exceeds the marginal cost of supply to ESCOM, then an investment may well be profitable for the customer (the electricity bill saving exceeds the investment cost) but loss-making for ESCOM (the loss of electricity bill revenues exceeds the cost savings to ESCOM).

The assumptions used to calculate the change in investment costs and reduced electricity consumption are shown in the preceding tables. The calculation of the financial value of savings uses the consolidated retail tariffs for residential and commercial customers in 2021 (56.93 MWK/kWh and 124.52 MWK/kWh, respectively).

The resulting estimated pay-back periods for residential and commercial EE measures are shown in the following Table 41 and Table 42.

These show that replacing current lighting with LED offers extremely rapid returns to customers, in both the residential and commercial sectors. The next most cost-effective EE measures from the perspective of customers are the replacement of water heaters with solar heaters and upgrading of AC units in the commercial sector. Replacement of electric water heaters with solar heaters in the domestic sector also has a low pay-back period. The replacement of fans in both sectors has high pay-back periods, in the residential sector exceeding the expected technical lifetime of the appliances.

Table 41 Estimated pay-back periods for residential EE measures

End use	Unit cost (USD)	Pay-back period (years)
Fans	100	27.4
CFL	0.7	1.1
Water heater	750	4.4

Note: Red indicates that the pay-back period exceeds the appliance lifetime (ie that the additional investment will never recover its cost).

Source: ECA calculations

Table 42 Estimated pay-back periods for commercial EE measures

End use	Unit cost (USD)	Pay-back period (years)
AC	300	2.7
Fans	100	8.9
FTL	5	1.1
CFL	0.7	0.4
Water heater	900	2.0

Source: ECA calculations

8.4 Conclusions for the DSM plan

Utility-based EE programs should be focused on those EE measures that offer the greatest potential and that are less likely to be implemented by customers without external support. This rationale directs resources to those measures which are likely to have the greatest effect.

The likelihood that customers will implement EE measures on their own initiative is proxied, in this report, by the estimated pay-back periods to customers. Where measures have longer pay-back periods, it is assumed that customers are less likely to implement these without external support and incentives.

Rankings of the individual EE measures identified are shown in Table 43, in order of potential electricity savings (from most to least) along with the respective estimated CO2 savings and pay-back periods. The proper way to assess the shortlisted measures would be through the IRP. The IRP should assess the economic efficiency of those measures against increasing generation capacity and should also indicate which measures to prioritise.

The analysis for potential DSM measures has highlighted the following:

- Substitution of electric water heaters by solar heaters in both the commercial and residential sectors accounts for over 75% of total potential savings of all considered measures.

- All lighting related measures in both sectors account for about 44% of the total electricity saving potential.

- Of the five measures with the largest potential, investments in energy efficient lighting in both sectors and replacement of electric water heaters with solar water heaters in the commercial sector have a rapid pay-back (<3 years in all cases), implying customers will make these investments if aware of the savings. The same holds for high efficiency AC in commercial premises, although the potential savings from this measure are relatively small, compared to lighting and water heating.

- Replacement of electric heaters with solar water heaters in the domestic sector has a relatively low pay-back period of 4.4 years, which, in combination with the relatively high cost of a solar water heater for a household, might require some assistance for the implementation of the measure.

- Investments for the replacement of fans with high energy efficiency ones have longer pay-back periods and customers would need financial incentives to make these replacements.

Based on this assessment, the proposed priorities for utility-based EE programs are encouraging residential customers to shift from electric to solar water heating, and both residential and commercial customers to switch to higher-efficiency fans.

It is noted that this conclusion does not include measures applicable to industry, due to the focus on electrical efficiency of standard appliances. Facility-specific energy audits will likely identify many additional opportunities to reduce electricity consumption in industry.

Table 43 Estimated EE potential and pay-back periods by measure

Sector – end use	Total potential *(GWh/year)*	Capacity impact *(MW)*	CO2 savings *(ton/year)*	Pay-back period *(years)*
Domestic - Water heater	185.2	63.4	11,480.0	4.4
Commercial - Water heater	76.5	36.7	4,742.0	2.0
Domestic – CFL	24.0	9.2	1,487.3	1.1
Commercial – Fans	23.2	7.2	1,437.0	8.9
Commercial - FTL	19.7	6.3	1,219.0	1.1
Commercial - AC	7.7	3.9	476.0	2.7
Domestic - Fans	5.0	2.2	308.5	27.4
Commercial - CFL	4.4	1.4	273.0	0.4

Source: ECA calculations. Note: Measures highlighted in light orange indicate high pay-back period. For these measures, financial assistance for consumers might be needed to make these replacements.

Based on the above analysis, the DSM that present benefits for the power sector in Malawi would comprise a set of DR and EE measures as shown in Table 44.

Table 44 DSM plan for Malawi

Measure	Average annual potential per connection			Average cost per connection	Earliest commissioning
	Peak demand reduction (W)	Electricity savings (kWh)	CO2 emission savings (ton)	(EUR)	(year)
TOU tariffs in industry	Site specific				In place – may be further extended
Interruptible / curtailable (I/C) service with industrial users	Site specific, determined subject to system requirements				ESCOM to examine with large industrial users
Demand bidding / buyback programs for industry	Site specific, determined subject to system requirements				ESCOM to examine with large industrial users
Emergency demand response programs for industry	Site specific, determined subject to system requirements				ESCOM to examine with large industrial users
Energy efficient lighting in residential sector	24 – 36	44 - 66	2.7 - 4.1	2.8 – 4.2	2023
Energy efficient lighting in commercial sector	60 - 255	131 - 558	8.1 – 34.6	7 – 75	In place – could be further extended
Introduction of Minimum Energy Efficiency Requirements	Technology specific. Survey required				2025
Replacement of electric with solar water heaters in residential sector	2,084	3,042	188.6	750	2023
Replacement of electric with solar water heaters in commercial sector	2,500	3,650	226.3	900	
Replacement of conventional with EE fans in residential and commercial sectors	36 - 108	66 - 276	4.1 - 113	100 - 600	2023
Upgrading of AC units in commercial premises	1,040	1,830	113	600	2023
Variable speed drives in industry and commercial sector	Site specific. Survey required				2024

Source: ECA analysis

The plan will need to be further specified, following completion of the IRP for Malawi, when the economic feasibility of proposed measures will be possible, and financing plans can be drawn.

9 2022-2042 Demand forecast

This section presents the results of the 2022-2042 updated demand forecast for Malawi. It incorporates the lessons learned from previous approaches to demand forecasting in the country, including the one done in 2017 for the IRP, continuous engagement with the key stakeholders in the country represented by the USWG, as well as external stakeholders. The input assumptions and the methodology presented in Section 4 and Section 5 were validated by stakeholders and this represents the end deliverable of this project (eg the demand forecast).

Three scenarios have been developed, with variations centred around electrification plans, economic indicators, loss reduction initiatives, and probabilistic assessment. As a result, the following subsections are better understood as a range of energy and peak demand forecasts, rather than specific predictions. The full annual results are included in Annex A5.

The main outcomes from the results are:

- **Energy demand is expected to more than double in all scenarios until 2040.** When considering the entire forecasting period, the low case scenario forecasts annual growth rates higher to those in the last decade, including multiple occurrences of load shedding, at 4.1%; the base case scenario reflects the growth rate expected without load shedding and with the Ministry's electrifications targets at 8.4%; while the high case scenario forecasts annual growth rates of 10.4%, with many new connection up to 2030 to increase electrification to 100% by 2030, but slower increases in the second half of the forecasting period.

- **As with energy demand, peak demand is projected to more than double by 2042.** The low case scenario forecasts an increase of peak demand to 815 MW by 2042. The 2042 peak demand is projected to be 1,914 MW for the base case scenario, and 2,830 MW for the high case scenario.

- **High demand growth is expected in Malawi from the set electrification targets.** Given the low levels of access to electricity in the country and the commitment from the Ministry of Energy and development partners such as SE4ALL and the WB to accelerate electrification in Malawi, new connections are expected to increase substantially in the base and high case scenarios. While the low case scenario is based on ESCOM's historical performance to connect new customers, the existing support is expected to result in ambitious targets ranging from the Guidelines for Implementation of the National Electrification Programme, targeting 150,000 annual connections by 2025 (**base case**); to SE4ALL universal electrification target by 2030 (**high case**).

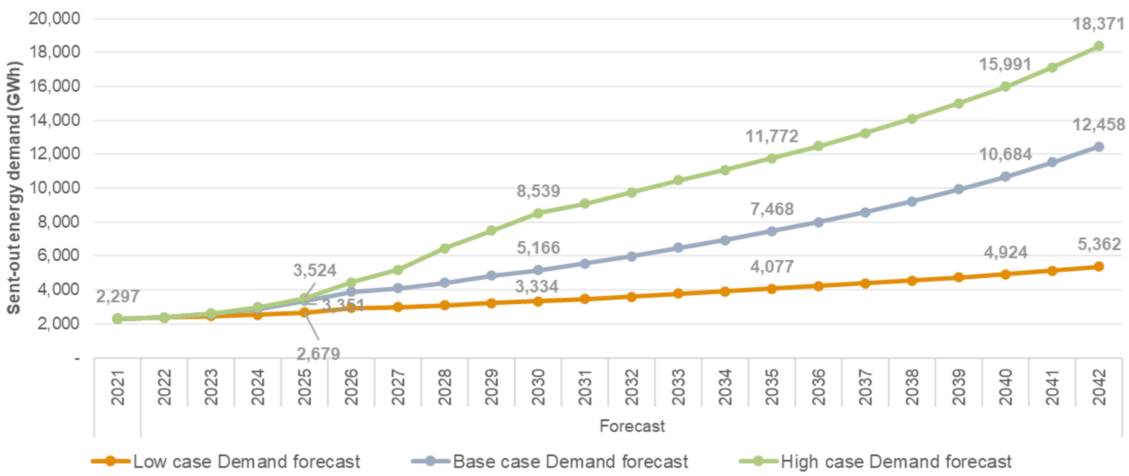
- **The geographical spread will slightly change, with the North region expanding faster than the South and Central regions.** While urbanization rates present a slower increase in the south, these are offset by the presence of the majority of large customers with expansion plans. Urbanization in the Central region (mainly towards Lilongwe) is expected to expand the regions' base of users with relatively high consumption. Nonetheless, most new connections are expected to occur in rural areas, which will also increase the size of residential demand in the North region.

The following subsections provide a detailed summary and analysis of each component of this demand forecast, followed by sectoral and geographical splits, as well as the expected impact of DSM in the forecasts.

9.1 Sent-out energy demand forecast

Energy demand is expected to more than double in all scenarios until 2040, as can be seen in Figure 22. The low case scenario, with lower electrification rates and high use of self-generation, foresees a 133% increase in total sent-out energy demand between 2021 and 2042, reaching 5,362 GWh. The base case scenario, on the other hand, projects a 442% increase of sent-out energy demand by 2042 with respect to the 2021 level. In this scenario, self-generation becomes less widespread, and some large customers implement their expansion plans to reach 12,458 GWh. The high case scenario presents an optimistic view of the possibilities in each sector to increase energy demand. A rapid increase of demand before 2030 is expected due to the achievement of the SE4ALL electrification target of 100%. In the high case scenario, an overall increase of 700% in sent-out energy demand, reaching 18,371 GWh in 2042, is forecasted.

Figure 22 2022-2042 Energy demand forecast (sent-out level)

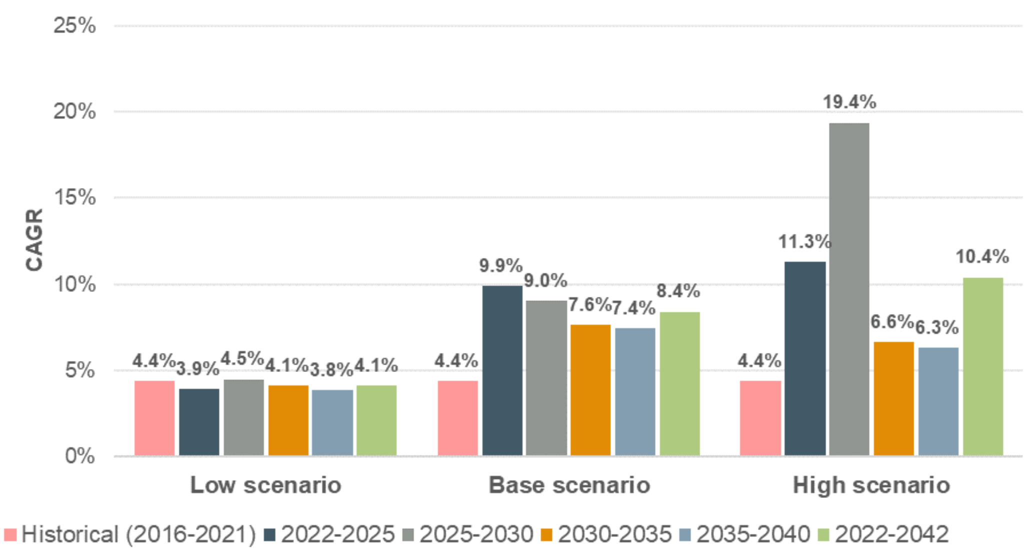


Source: ECA analysis

When considering the entire forecasting period, the low case scenario forecasts annual growth rates similar to those in the last few years at 4.1%; the base case scenario reflects the growth rate expected without frequent load shedding at 8.4%; while the high case scenario forecasts annual growth rates of 10.4%, with slower increases in the second half of the forecasting period (see Figure 23).

In the first 10 years of the forecast, growth in all scenarios is expected to be higher than after 2030. This is mainly due to electrification programmes and industrial expansions occurring before 2030. During the 2021-2025 period, energy demand is expected to grow at an annual rate of 3.9% for the low case scenario, 9.9% for the base case scenario, and 11.3% for the high case scenario. In the 2025-2030 period, the high case scenario projects annual energy demand growth rates of 19.4%, mainly driven by ambitious electrification targets that range between 200,000 to almost 900,000 each year.

Figure 23 Sent-out energy demand annual growth

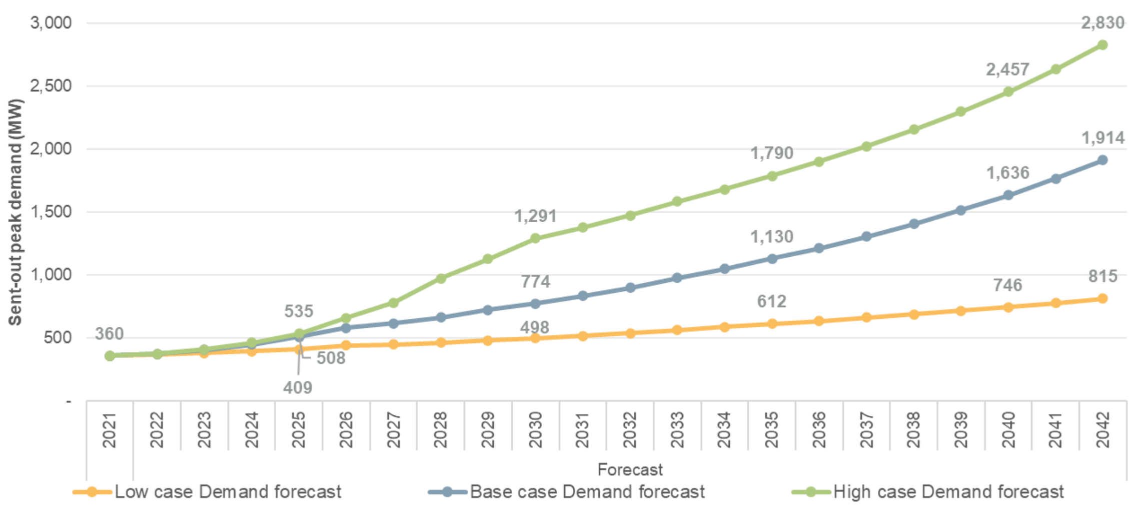


Source: ECA analysis

9.2 Sent-out peak demand forecast

As with energy demand, peak demand is projected to more than double by 2042 (see Figure 24). The low case scenario forecasts an increase of peak demand to 815 MW by 2042. For the base case scenario, the 2042 peak demand is projected to be 1,914 MW, reaching 2,830 MW in the high case scenario in 2042.

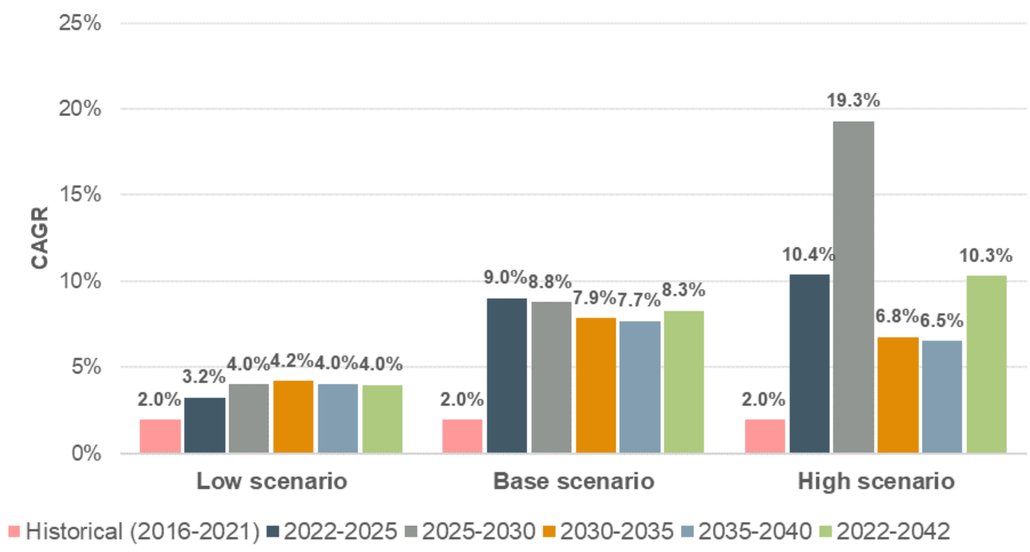
Figure 24 2022-2042 Peak demand forecast



Source: ECA analysis

The dynamics of growth of peak demand are almost identical to those of energy demand as the consumers' mix is expected to remail relatively stable. The rapid projected peak demand increases in 2021-2030 for the base and high case scenarios would be a challenge for the transmission system and generation capacity in the country. Figure 25 shows the growth rates of the peak demand by period and by scenario.

Figure 25 Peak demand annual growth



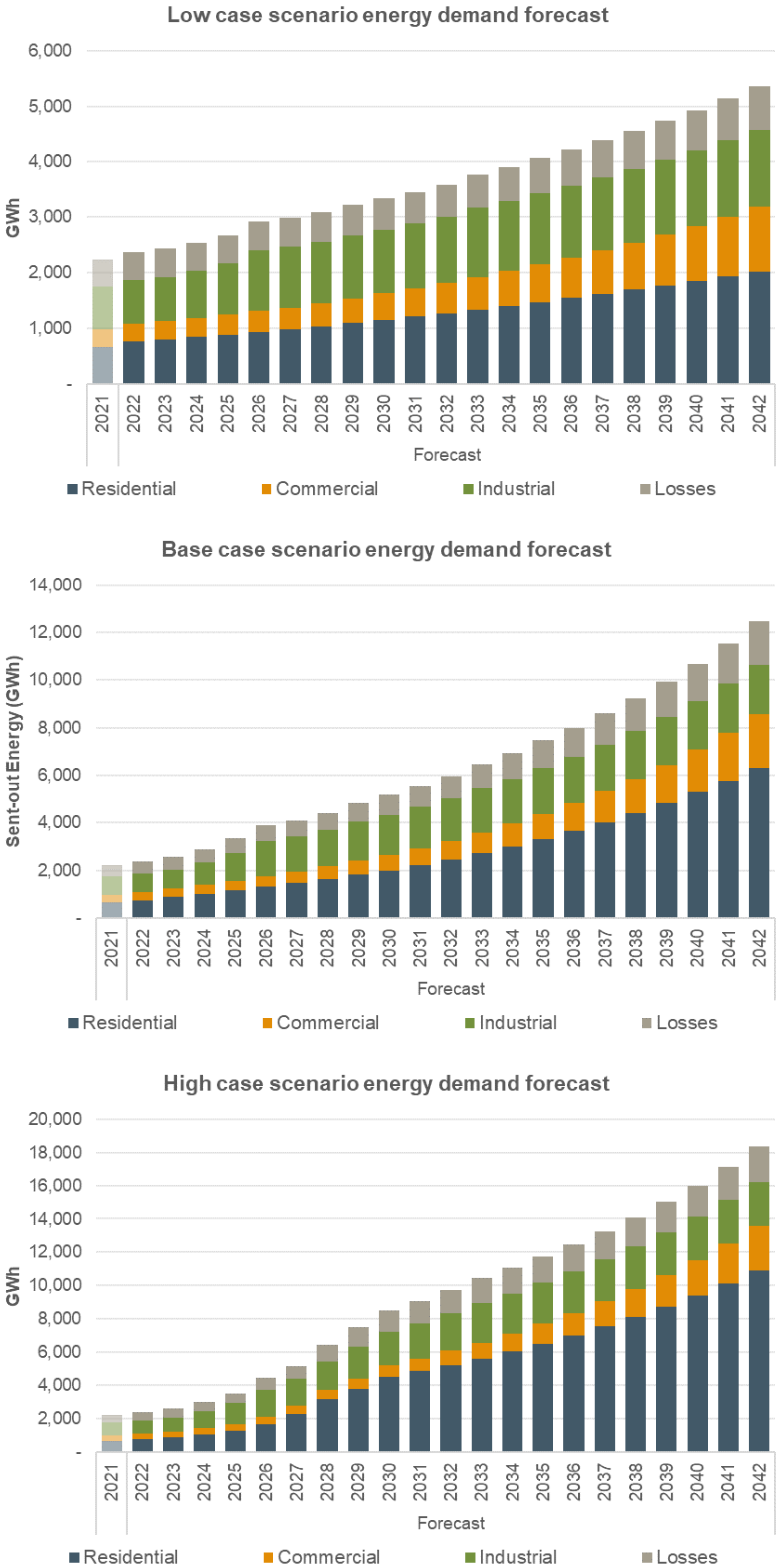
Source: ECA analysis

9.3 Demand forecast by economic activity

While the country-level results presented in Section 9.2 provide the aggregate demand for the power sector including losses, this section focuses on how this demand is formed. Electricity sales forecasts were developed for each economic activity[13] for each scenario. Economic activities were grouped in the following categories: Residential, Commercial, and Industrial (including agriculture). Figure 26 showcases the increasing demand of the residential sector in the base and high case scenarios, resulting from electrification targets.

[13] Economic activities were grouped in the following categories three categories: Residential, Commercial, and Industrial (including agriculture) – see section 2.2.1.

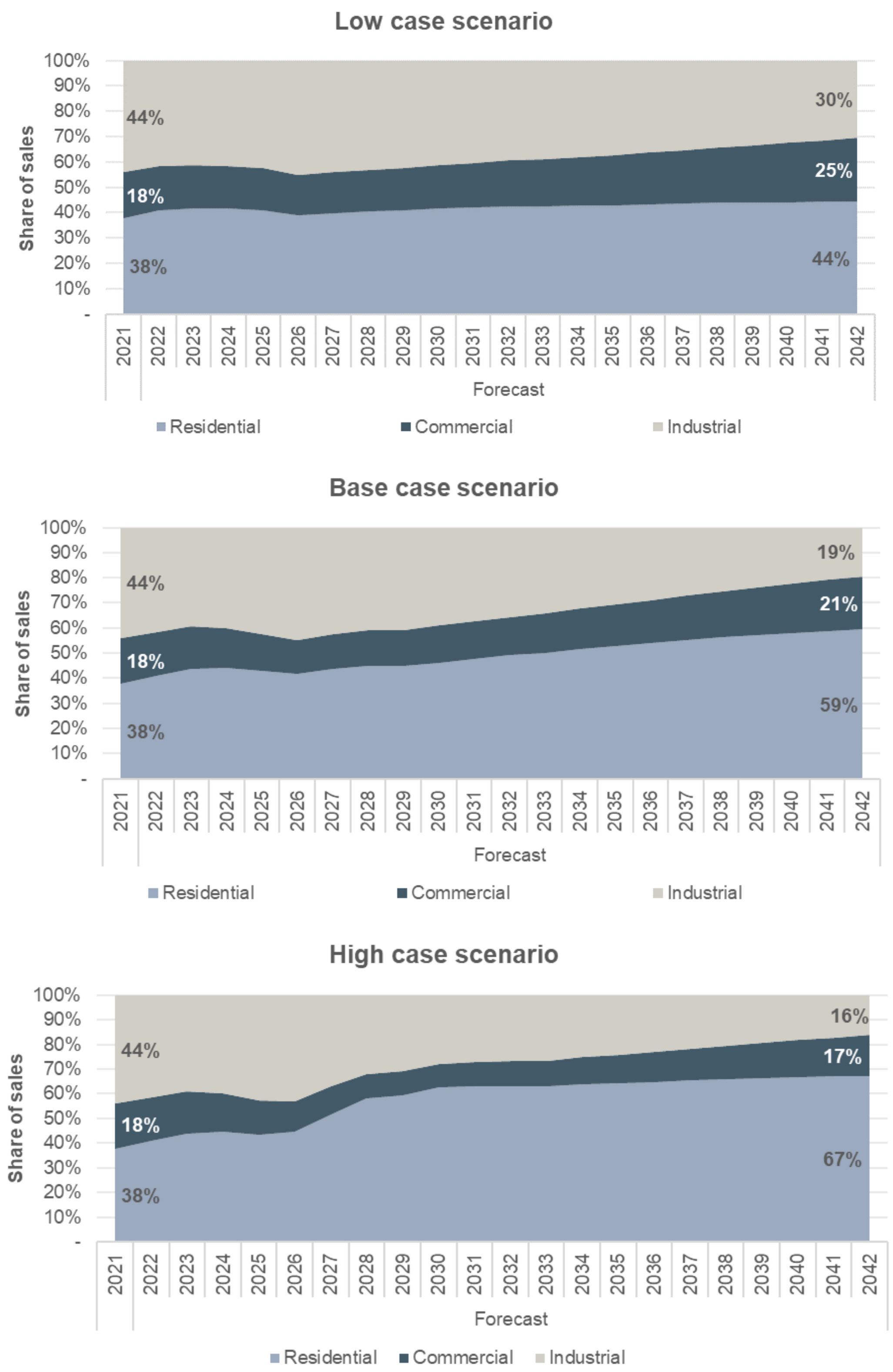
Figure 26 Energy demand forecast by consumer category



Source: ECA Analysis

In the overall split of demand, the residential sector increases its share, as seen in Figure 27, while the industrial sector holds the second largest share of demand on average.

Figure 27 Split of energy demand by customer category



Source: ECA Analysis

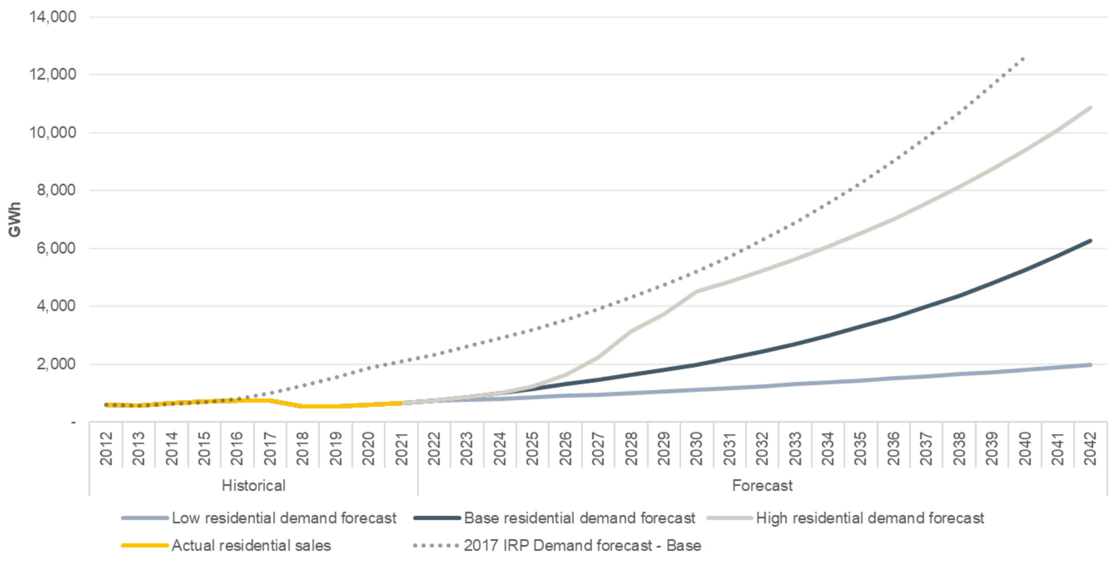
9.3.1 Residential demand

Residential demand will reach between 44% and 67% of overall demand in the 2022-2042 period. Figure 28 showcases the energy demand forecast of domestic consumers compared to historical data as well as the 2017 IRP base case residential demand forecast. While the base case scenario contemplates a maximum 150,000 new connections being added annually, the high case scenario forecasts values reaching almost 900,000 new connections in 2028 driven by the 2030 100% electrification target. From 2030 onwards, the main determinant of growth for the residential sector is the increase in the average consumption per household driven by the assumed economic growth and increases in households purchasing power.

By 2042, energy sales in the low case scenario are expected to grow by over 200% to 2,028 GWh; for the base case scenario the increases surpass 850% to reach 6,319 GWh; whereas the high case scenario expects residential sales reach levels 16 times the 2021 value, reaching 10,892 GWh.

As can be seen, all scenarios remain at lower levels than the base case scenario of the 2017 IRP demand forecast. The target electrification rates in the 2017 IRP demand forecast are similar to the ones contemplated in the base case scenario. However, the electrification of customers foreseen in the 2017 IRP demand forecast did not materialise between 2016 and 2021. Additionally, economic growth had slowed down during the same period due to COVID-19 pandemic which was not foreseen in the 2017 IRP demand forecast study.

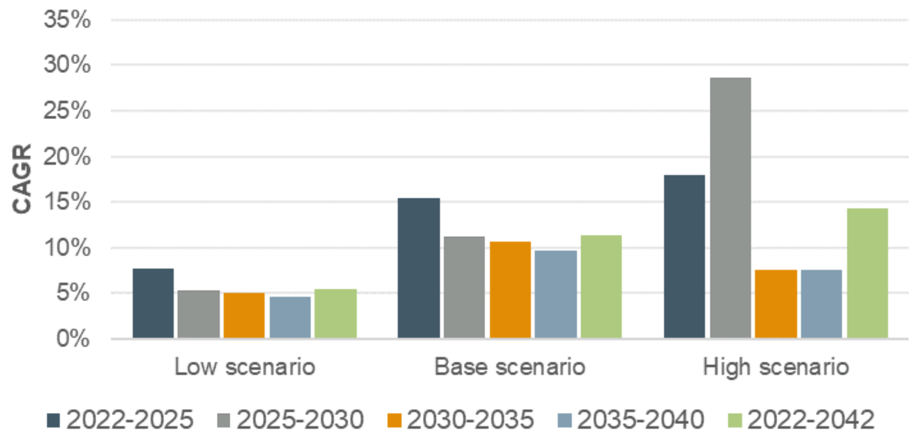
Figure 28 Domestic sales forecast



Source: ECA analysis

Similar to the overall demand forecast, domestic demand is expected to have higher growth rates in the first half of the forecasting period with annual growth expected to reach levels of between 7.8% and 18% in 2021-2025, and 5.2% and 28.6% in 2025-2030 (see Figure 29). Over the forecasting period, the annual growth rates for the three scenarios are 5.5%, 11.3%, and 14.3% respectively.

Figure 29 Residential sales average annual growth



Source: ECA analysis

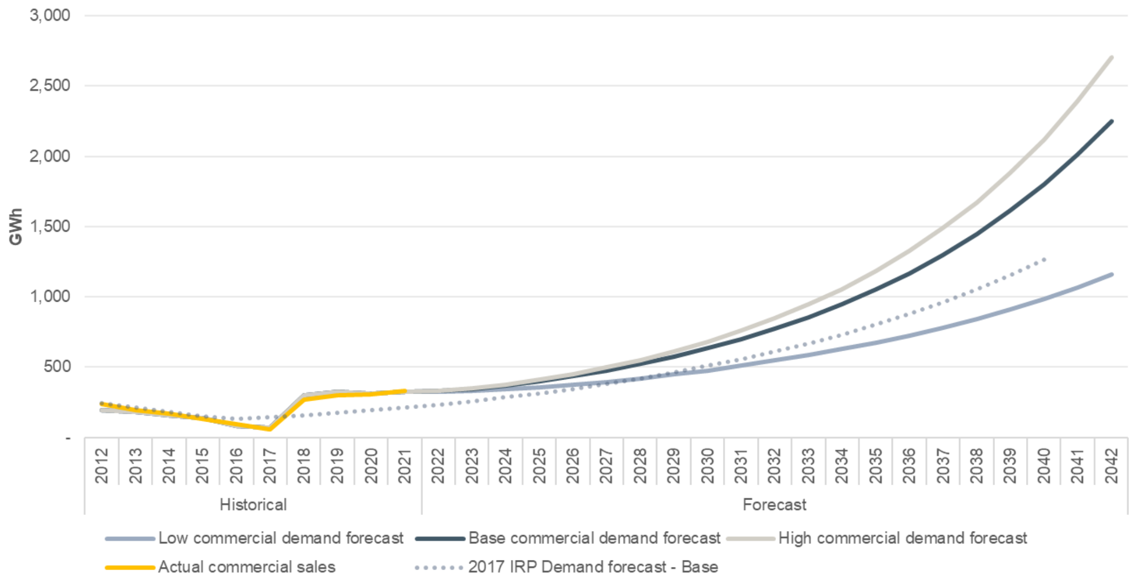
9.3.2 Commercial demand

Commercial sales forecast is expected to surpass the expectations from the 2017 IRP base case demand forecast for commercial consumers. There are three key assumptions that define the commercial sales forecast:

- Anticipated economic growth – For all scenarios, GDP per capita is expected to increase over time.
- Urbanisation and business densification – For the base and the high case scenarios, the positive economic outlook is also expected to increase the demand for office space, resulting in an increase of commercial connections. In the low case scenario, this is increase in demand is expected to be limited, as the economic effect of the Covid-19 pandemic leaves long-lasting effects in the demand for office space in urban areas, thus limiting the overall energy demand growth for the sector.
- Commercial electricity tariffs – For all scenarios, the price elasticity of demand is expected to start at a relatively high level of -0.21, meaning that a 1% increase in tariff will decrease demand by 0.21%. It is expected that this effect will decrease over time as businesses adopt the use of electricity for their productive activities, reducing the incentive to reduce consumption if tariffs increase. Therefore, by 2042 the price elasticity of demand is assumed to decrease to -0.08, as seen in other countries with more developed commercial sectors, such as South Africa or Ethiopia.

Figure 30 illustrates the commercial sector sales forecast for the 2022-2042 period. The low case scenario underperforms the 2017 IRP base case demand forecast, reaching 1,158 GWh by 2042. On the other hand, the base and high case scenarios reach levels of 2,249 GWh and 2,701 GWh, vastly outperforming the 2017 IRP demand forecast across the entire forecasting period.

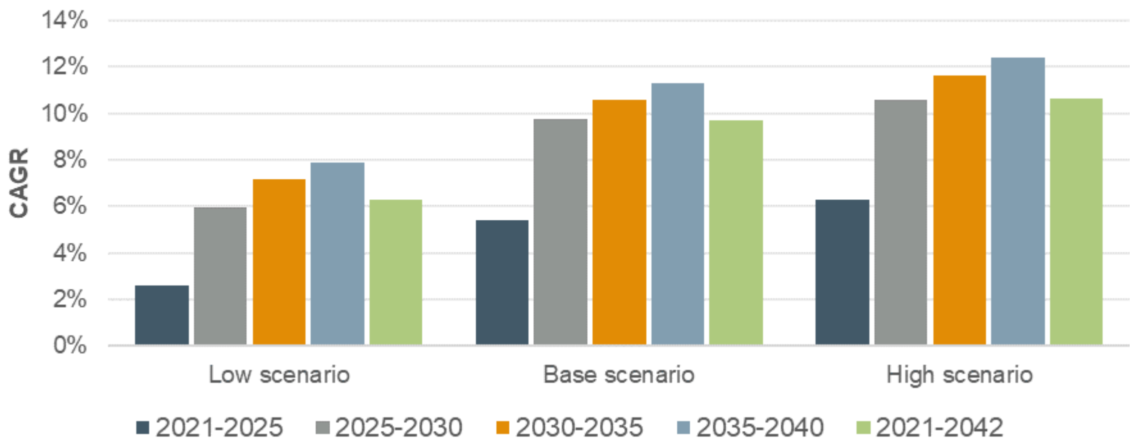
Figure 30 Commercial sales forecast



Source: ECA analysis

It is expected that growth will accelerate towards the end of the period with growth rates ranging from 2.6%-6.3% in 2021-2025, to 7.9%-12.4% in 2035-2040. As shown in Figure 31, the overall annual growth of the base case and high case scenarios (9.7% and 10.6% respectively) outpaces the growth expected in the low case scenario at 6.3%.

Figure 31 Commercial sales average annual growth

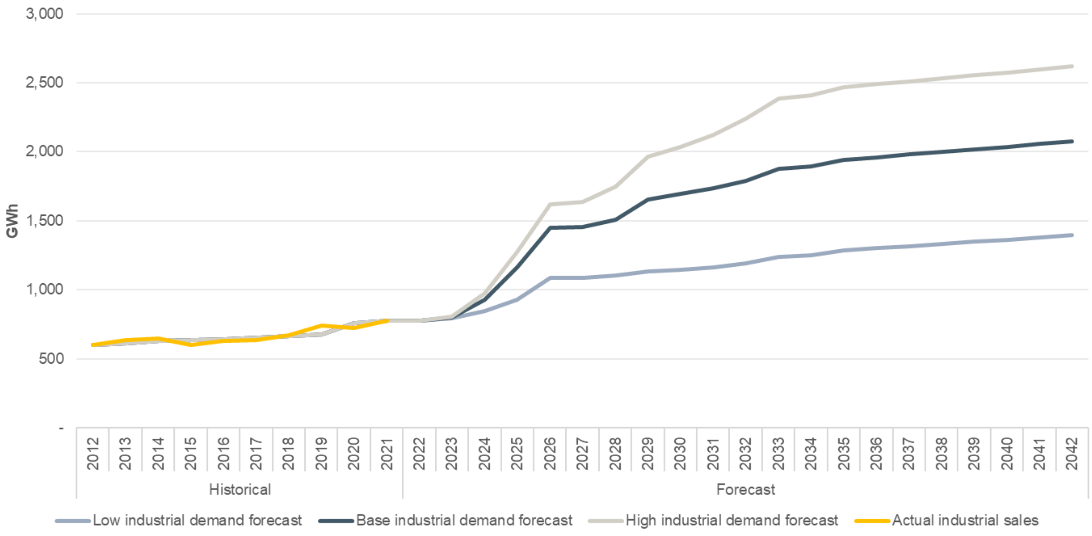


Source: ECA analysis

9.3.3 Industrial sales

As can be seen in Figure 32, industrial sales are expected to reach 1,395 GWh, 2,075 GWh, and 2,623 GWh in the low, base, and high case scenarios respectively by 2042.

Figure 32 Industrial sales forecast

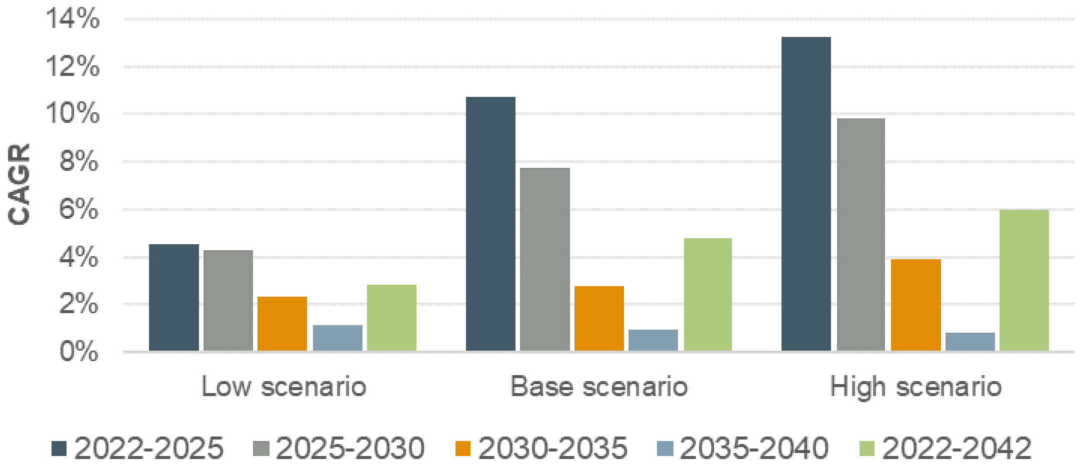


Source: ECA analysis

For all scenarios, the net impact (of New projects + Expansions – Closures - Self-Generation) of large customers is expected to be positive, reaching an extra 349 GWh, 974 GWh and 1,473 GWh in 2042 for the low, base and high case scenarios respectively.

The annual growth rates for the industrial sector, seen in Figure 33, are modest and mainly driven by large customers plans. During the 2021-2025 period, before most self-generation is expected to start, growth rates are considerably higher (4.6% to 13.2%) compared to the period immediately after (4.3%-9.8%), when self-generation is mostly adopted. In the long-term, growth becomes solely determined by GDP growth and a few expansion plans, reaching levels of less than 2% across scenarios. For the entire forecasting period, only the high case scenario results in an annual growth rate higher than 5%, compared to 2.8% and 4.8% for the base case and low case scenarios.

Figure 33 Industrial sales average annual growth



Source: ECA analysis

9.4 Demand forecast by region

One of the main trends that is expected to become relevant in the coming years, is the increasing share of demand by the North region (see Table 45), with no significant changes in the balance between the South and Central regions. The evolution of regional share in demand can be summarized as follows:

- North region – Expected to benefit from relatively high urbanisation rate growths, high initial share of new rural connections, as well as a rapidly increasing number of households from falling household sizes.
- Central region – While overall growth in the number of households is limited compared to the North region, increasing urbanization of the Lilongwe area results in higher average consumption.
- South region – Energy demand in this region is expected to benefit from the expansion plans of large customers, as well as from relatively stable household sizes and urbanization growth rates.

Table 45 Share of energy demand by region

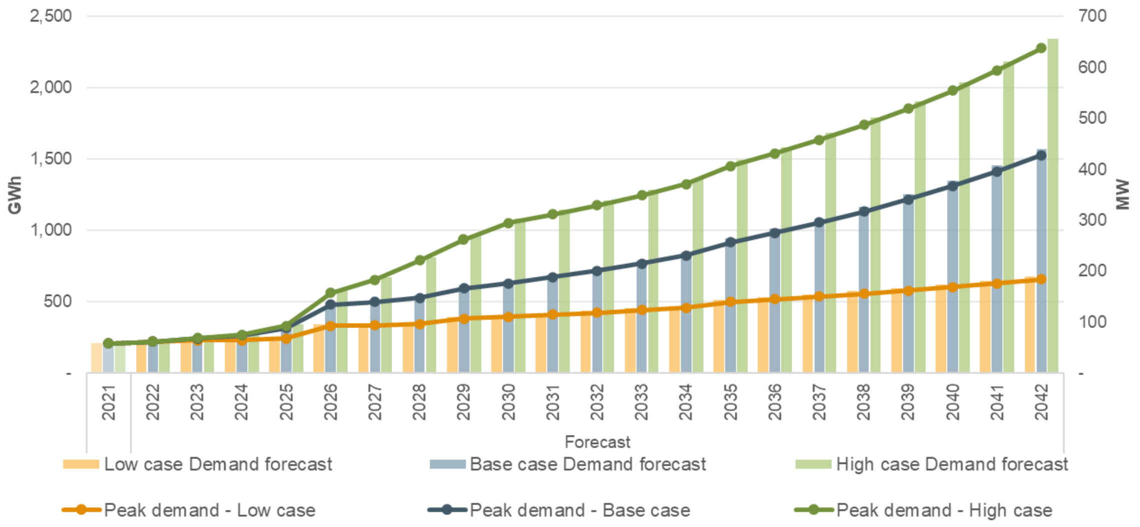
Scenario	Region	2022	2025	2030	2035	2040	2042
Low case	North	10%	9%	12%	13%	13%	13%
	Central	41%	41%	40%	40%	41%	41%
	South	49%	50%	48%	47%	46%	46%
Base case	North	10%	10%	13%	13%	13%	13%
	Central	41%	41%	38%	39%	41%	42%
	South	49%	49%	49%	48%	46%	45%
High case	North	10%	10%	13%	13%	13%	13%
	Central	41%	41%	40%	40%	42%	42%
	South	49%	49%	47%	47%	45%	45%

Source: ECA analysis

9.4.1 North region

While the North region represents the smallest share of overall demand, it presents the largest growth rates in the forecasting period. As can be seen in Figure 34, energy demand is expected to grow from 213 GWh in 2021 to 676 GWh, 1,575 GWh, and 2,345 GWh for the low, base and high case scenarios respectively, representing annual increases of between 5.6% and 12.1%. Peak demand is also expected to grow rapidly from 58 MW in 2021, reaching 184 MW, 429 MW, and 638 MW by 2042 respectively.

Figure 34 Demand forecast for the North region

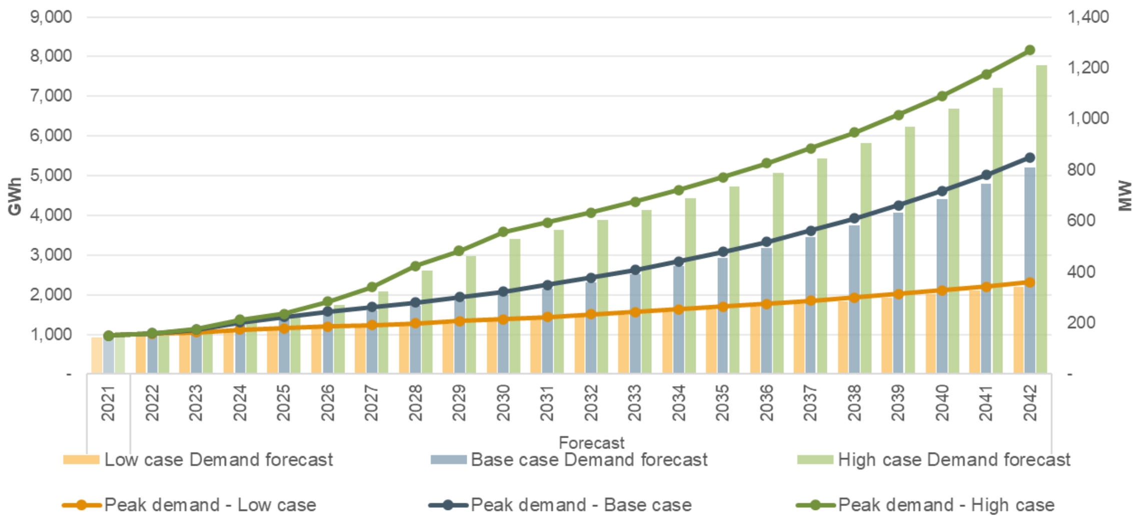


Source: ECA analysis

9.4.2 Central region

Most of the growth expected in the Central region is a result of relatively rapid urbanization in the Lilongwe area, which increases average household consumption. Energy demand is expected to increase from 926 GWh in 2021, to 2,209 GWh, 5,215 GWh, and 7,789 GWh for each scenario by 2042, representing annual increases of between 4.2% and 10.7%. For peak demand, it is expected that it will increase from 151 MW in 2021 to 356 MW, 846 MW, and 1,268 MW for each scenario (see Figure 35).

Figure 35 Demand forecast for the Central region

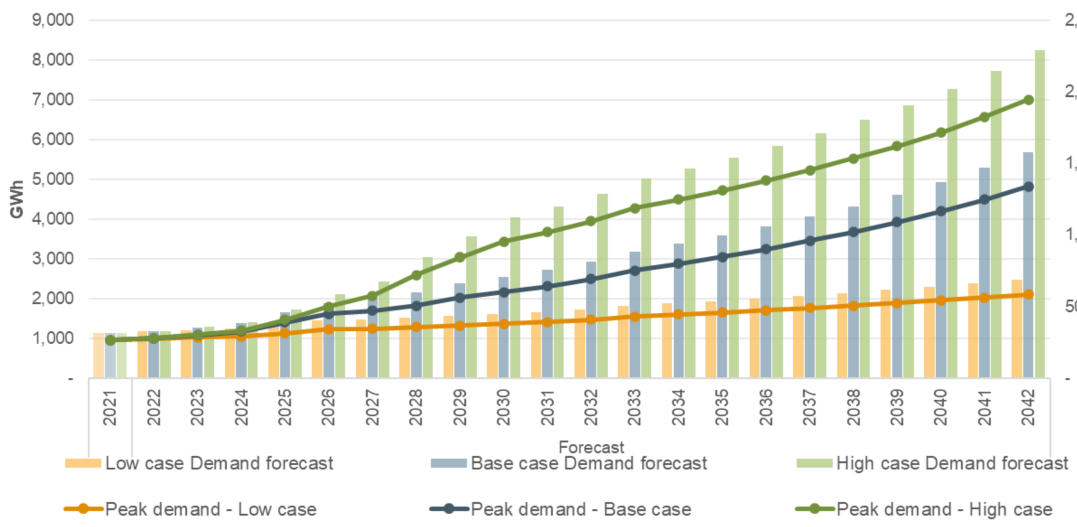


Source: ECA analysis

9.4.3 South region

The rate of the demand growth in the South region is expected to reduce over time, however, the South region is still expected to experience sustained growth in demand. As shown in Figure 36, energy demand in this region is expected to grow from 1,119 GWh in 2021, to 2,477 GWh, 5,668 GWh, and 8,237 GWh in the low, base, and high case scenarios respectively (with annual growth rates of between 3.9% and 10%). Similarly, peak demand is expected to grow from 264 MW in 2021, to 585 MW, 1,339 MW, and 1,946 MW for each scenario.

Figure 36 Demand forecast for the South region



Source: ECA analysis

9.5 Impact of DSM in the Demand Forecast

As mentioned in Section 8, we have incorporated the following DSM in this analysis:

- introduction of MEPR and/or labelling scheme,
- incentives for installation of solar water heaters,
- incentives for AC substitution,
- incentives for Fan substitution, and
- incentives for lightbulb substitution.

To model the impacts the above measures will have on the demand forecast, the following assumptions were considered (see Table 46). While the introduction of MEPR is expected to have a long-lasting impact after implementation, appliance substitution and the incentives for the adoption of solar water heaters will have a lasting impact if support is maintained above the scheduled implementation period. The share of new customers adopting these measures is expected to decrease after implementation, reducing the penetration rate over time.

Table 46 Assumptions for the modelling of DSM

Measure	Sector affected	Impact on energy and/or peak demand	Penetration rate
Introduction of MEPR and/or labelling scheme	All sectors	• 0.07 MWh per connection per year	• **Low:** 25% during the implementation period and beyond • **Medium:** 50% during the implementation period and beyond • **High:** 100% during the implementation period and beyond
Incentives for installation of solar water heaters	Residential Commercial	• 0.625 MWh per connection per year • 0.0013 MW per connection per year	• **Low:** increasing to 1.04% by 2027, decreasing to 0.36% by 2042 • **Medium:** increasing to 1.55% by 2027, decreasing to 0.70% by 2042 • **High**: increasing to 2.07% by 2027, decreasing to 1.22% by 2042
Lightbulb substitution	Commercial	• 0.004 MWh per connection per year • 0.03 MW per connection per year	• **Low:** increasing to 46% by 2027, decreasing to 11% by 2042 • **Medium:** increasing to 69% by 2027, decreasing to 34% by 2042 • **High:** increasing to 92.2% by 2023 and remaining at that level
AC unit substitution	Commercial	• 0.0915 MWh per connection per year • 0.000052 MW per connection per year	• **Low:** increasing to 4.6% by 2027, decreasing to 1.1% by 2042 • **Medium:** increasing to 6.9% by 2027, decreasing to 3.4% by 2042 • **High:** increasing to 9.2% by 2023 and remaining at that level
Fan substitution	Residential Commercial	• 0.00007 MWh per connection per year • 0.00003 MW per connection per year	• **Low:** 0% in the entire forecasting period • **Medium:** 0.1% in the entire forecasting period • **High:** 0.2% in the entire forecasting period

Source: ECA analysis

Under these considerations, and assuming the base case demand forecast, Figure 37 presents the expected energy and peak demand impact of all the measures under different penetration rates. As can be seen, under a low penetration rate annual savings amount to 113.9 GWh and 30 MW in 2042; with a medium penetration rate this savings increase to 256.3 GWh and 74 MW, while a high penetration rate would result in savings of 564 GWh and 168 MW.

Figure 37 DSM impact on the base case demand forecast

Source: ECA analysis

9.5.1 Net-metering scheme scenarios

A net-metering scheme has been proposed in Malawi, which allows the export of energy generated in solar rooftop systems to the grid. For the purpose of this analysis, we assume that these systems would be adopted by a small percentage of the residential population who can afford the relatively high initial capital costs.

Three scenarios were considered for potential penetration rates of rooftop solar PV under the net-metering scheme:

- **Low penetration rate:** Rooftop solar systems adopted by 0.1% of residential connections (1,000 per million connections), reaching this level in 2030 and remaining at that level until the end of the forecasting period.

- **Medium penetration rate:** Rooftop solar systems adopted by 0.25% of residential connections (2,500 per million connections), reaching this level in 2030 and remaining at that level until the end of the forecasting period.

- **High penetration rate:** Rooftop solar systems adopted by 0.5% of residential connections (5,000 per million connections), reaching this level in 2030 and remaining at that level until the end of the forecasting period.

Given that peak demand occurs during the late afternoon/early night, we expect no impact on peak demand. The savings for each scenario by penetration rate are presented in Table 47. Nonetheless, it is important to mention that these are just approximations, the real impact will depend on a deeper analysis on the number of beneficiaries, accessibility of the scheme, and the availability of suitable rooftop solar systems at an affordable price.

Table 47 Projected energy savings from rooftop solar systems (in GWh)

Scenario	Low penetration rate	Medium penetration rate	High penetration rate
Low case scenario	• 2025: 0.1 • 2030: 0.4 • 2035: 0.4 • 2042: 0.5	• 2025: 0.2 • 2030: 0.9 • 2035: 1.1 • 2042: 1.3	• 2025: 0.4 • 2030: 1.8 • 2035: 2.2 • 2042: 2.7
Base case scenario	• 2025: 0.1 • 2030: 0.7 • 2035: 1.1 • 2042: 1.8	• 2025: 0.3 • 2030: 1.8 • 2035: 2.8 • 2042: 4.5	• 2025: 0.6 • 2030: 3.6 • 2035: 5.5 • 2042: 8.9
High case scenario	• 2025: 0.1 • 2030: 1.7 • 2035: 2.1 • 2042: 2.6	• 2025: 0.3 • 2030: 4.3 • 2035: 5.2 • 2042: 6.4	• 2025: 0.7 • 2030: 8.7 • 2035: 10.3 • 2042: 12.8

Source: ECA analysis

Annexes

A1 Historical power shortages

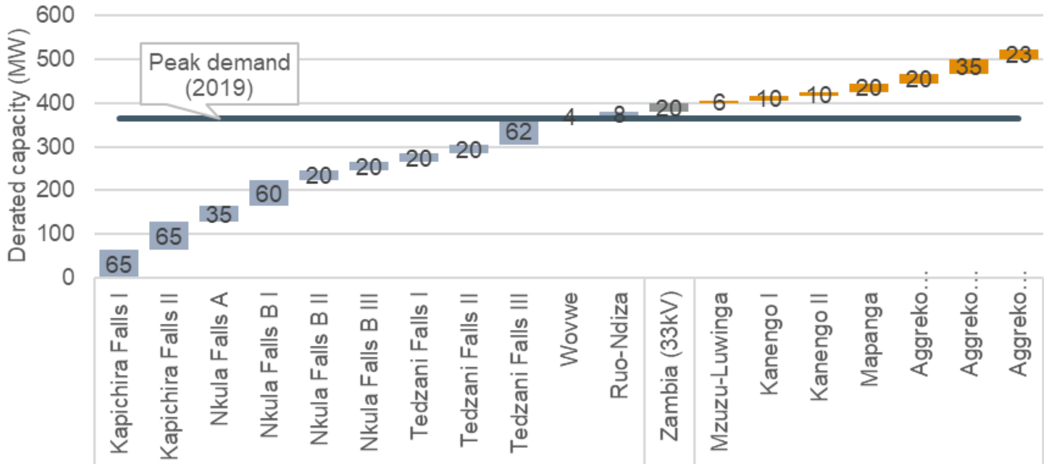
The backbone of Malawi's power system was, for many years, a series of small hydropower plants on the Shire River at Nkula and Tedzani that were developed between the 1960s and 1990s. In the year 2000 the first phase of the Kapichira hydropower plant was commissioned, also on the Shire River, with a capacity of 64 MW. No other new generation plants were implemented in the country until 2013, when a second phase at Kapichira of another 64 MW was commissioned.

Since 2013 some of the units at Nkula and Tedzani have been refurbished and upgraded but, apart from some new diesel units, no other substantial capacity has been added.

Malawi's interconnected system has a total connected net available capacity of 503 MW (as of 2019). It comprises 379 MW of hydro plants and 123 MW of reciprocating engines operating on diesel fuel. Of the reciprocating engines, 45 MW are EGENCO owned and were installed in recent years and are therefore in good condition. The remaining 78 MW of reciprocating engines were rented under a three-year contract with Aggreko, which expired in 2020 but was extended. In addition, 20 MW is imported from Zambia to parts of Lilongwe and Mchinji as an island supply (which is temporarily disconnected from ESCOM's network) and is not included in Malawi's load discussed above.

The following figure shows the total net available capacity in 2019 and the actual peak demand of 2018 against the stock of the available capacity in 2019. Even though the available installed capacity was higher than the peak demand in the past decade, the generation fleet was unable to meet the demand for electricity in drought years. With the exception of the small Wovwe and Ruo-Ndiza micro hydro plants, all of the hydro capacity is sited along the Shire river in the south of country and the annual output is sensitive to hydrological conditions. On average, the annual capacity factor of ESCOM's hydro generation is approximately 67%, but this fluctuates very significantly from year to year.

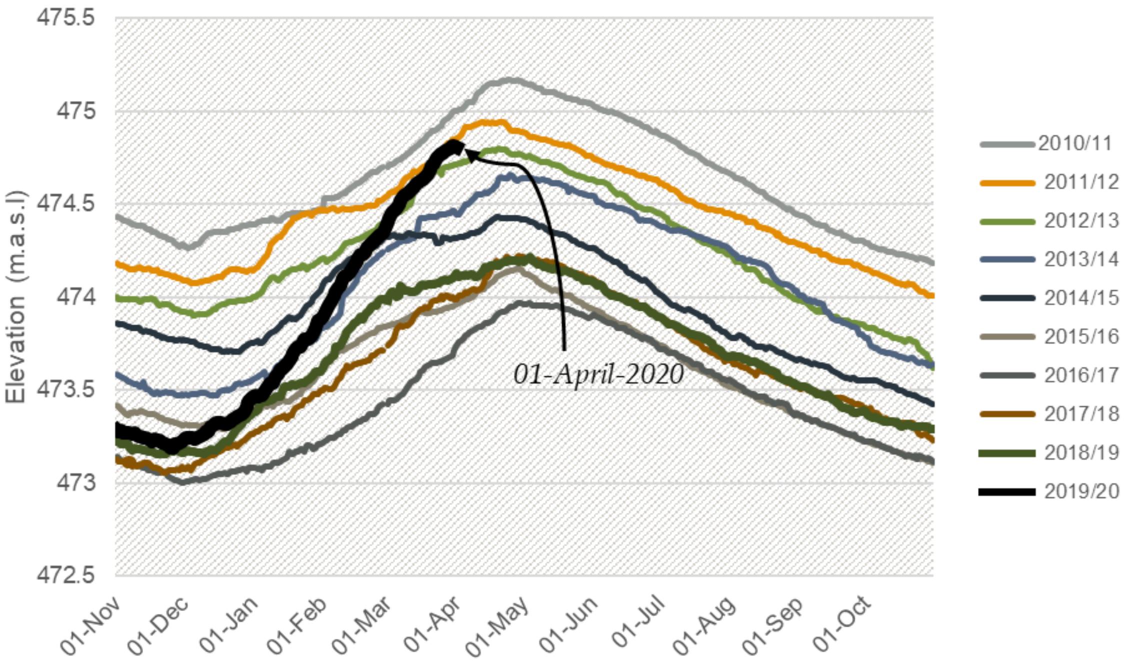
Figure 38 Total share of existing net available capacity, 2019



Source: ESCOM and the Integrated Resource Plan

From 2015 to 2019, Malawi has suffered chronic power shortages and electricity consumers have faced severe and frequent interruptions of power supply mainly due to very low water levels on Lake Malawi and low outflows on the Shire River following prolonged drought conditions. The following figure shows historical Lake Malawi water level variations from 2010 to 2019-20. Water levels have been at the lowest levels from 2015 to 2019.

Figure 39 Lake Malawi mean levels from 2010 to 2019-20



Source: EGENCO Malawi, 2020

A2 Household appliance electricity usage

Table 48 Consumption of household appliances

Item	No of items	Capacity *(W per month)*	Hours used *(h per day)*	Days used *(days per month)*	Energy used *(kWh per month)*
Light					
Incandescent bulbs	4	40	6	30	28.8
Fluorescent tube lamps	4	10	6	30	7.2
TV					
32” LED TV	1	41	3	30	3.6
25” color TV	1	150	3	30	13.5
19” color TV	1	70	3	30	6.3
12” black and white TV	1	20	3	30	1.8
Other					
Radio	1	4	3	30	0.4
Iron	1	1,000	2	4	8
Kettle	1	2,200	0.1	10	2.2
Hotplate	1	1,000	3	30	90
Fridge (small)	1	100	4.7	30	14.3
Fan	1	10	3	10	0.3
Laptop	1	35	2	30	2.1
Phone charging	1	5	1	30	0.15

Source: http://www.energuide.be/en/questions-answers/how-much-energy-do-my-household-appliances-use/71/, http://www.greatbowden.org/documents/TypicalEnergyUsageforHouseholdAppliances.pdf ,http://www.wholesalesolar.com/solar-information/how-to-save-energy/power-table

A3 Annual input assumptions

Table 49 Population forecast summary

Population			
Year	**Urban**	**Rural**	**Total**
2021	3,063,437	15,835,004	18,898,441
2022	3,150,488	16,201,404	19,351,892
2023	3,238,855	16,570,656	19,809,511
2024	3,328,427	16,942,141	20,270,568
2025	3,419,080	17,315,182	20,734,262
2026	3,510,991	17,690,644	21,201,635
2027	3,604,351	18,069,436	21,673,787
2028	3,699,054	18,450,970	22,150,024
2029	3,794,994	18,834,667	22,629,661
2030	3,892,055	19,219,912	23,111,967
2031	3,990,434	19,607,638	23,598,072
2032	4,090,344	19,998,844	24,089,188
2033	4,191,696	20,393,031	24,584,727
2034	4,294,396	20,789,695	25,084,091
2035	4,398,336	21,188,261	25,586,597
2036	4,503,675	21,589,459	26,093,134
2037	4,610,593	21,994,099	26,604,692
2038	4,719,004	22,401,709	27,120,713
2039	4,828,815	22,811,796	27,640,611
2040	4,939,915	23,223,794	28,163,709
2041	5,052,453	23,638,364	28,690,817
2042	5,166,606	24,056,276	29,222,882

Source: 2018-2050 Population Projections

Table 50 Number of households and household size

Year	Number of households	Household size	Household size – North	Household size – Central	Household size – South
		persons per household			
2021	4,354,479	4.34	4.7	4.3	4.3
2022	4,479,605	4.32	4.7	4.3	4.3
2023	4,606,863	4.30	4.7	4.3	4.3
2024	4,736,114	4.28	4.6	4.3	4.2
2025	4,867,198	4.26	4.6	4.3	4.2
2026	5,000,386	4.24	4.6	4.2	4.2
2027	5,135,968	4.22	4.5	4.2	4.2
2028	5,273,815	4.20	4.5	4.2	4.2
2029	5,413,794	4.18	4.5	4.2	4.2
2030	5,555,761	4.16	4.4	4.2	4.2
2031	5,700,017	4.14	4.4	4.1	4.2
2032	5,846,890	4.12	4.4	4.1	4.2
2033	5,996,275	4.10	4.4	4.1	4.2
2034	6,148,062	4.08	4.3	4.1	4.1
2035	6,302,117	4.06	4.3	4.1	4.1
2036	6,458,697	4.04	4.3	4.0	4.1
2037	6,618,083	4.02	4.2	4.0	4.1
2038	6,780,178	4.00	4.2	4.0	4.1
2039	6,944,877	3.98	4.2	4.0	4.1
2040	7,112,048	3.96	4.1	4.0	4.1
2041	7,281,933	3.94	4.1	3.9	4.1
2042	7,454,817	3.92	4.1	3.9	4.1

Source: Malawi Statistical Yearbook 2020 and 2018-2050 Population Projections

Table 51 Average consumption per household (in kWh per month)

Scenario	Low scenario			Base scenario			High scenario		
	Urban	Rural	Total	Urban	Rural	Total	Urban	Rural	Total
2021	160	47	120	160	47	120	160	47	120
2022	160	47	114	160	47	112	160	47	112
2023	160	48	113	160	48	103	162	48	103
2024	161	48	113	162	48	98	165	49	98
2025	163	48	113	165	49	96	170	50	93
2026	164	49	112	169	50	95	175	52	89
2027	164	49	112	174	52	96	181	54	86
2028	167	50	113	178	53	96	188	56	86
2029	169	50	114	183	54	97	195	58	88
2030	172	51	115	188	56	99	203	60	94
2031	175	52	116	194	57	100	212	63	97
2032	178	53	117	199	59	102	221	65	101
2033	181	54	119	205	61	104	230	68	105
2034	183	54	120	211	63	106	239	71	109
2035	187	55	122	217	64	108	250	74	114
2036	190	56	123	223	66	110	260	77	119
2037	193	57	125	230	68	113	272	81	124
2038	196	58	126	237	70	115	283	84	129
2039	200	59	128	244	72	118	296	88	134
2040	203	60	130	252	75	121	309	92	140
2041	207	61	132	259	77	124	322	96	146
2042	211	63	134	268	79	127	337	100	153

Source: ECA

Table 52 Electrification targets

	Number of residential connections			Electrification rate		
Scenario	**Low**	**Base**	**High**	**Low**	**Base**	**High**
2021	459,776	459,776	459,776	11%	11%	11%
2022	549,600	549,600	549,600	12%	12%	12%
2023	584,600	699,600	699,600	13%	15%	15%
2024	619,600	849,600	890,547	13%	18%	19%
2025	654,600	999,600	1,122,441	13%	21%	23%
2026	689,600	1,149,600	1,541,637	14%	23%	31%
2027	724,600	1,279,600	2,161,668	14%	25%	42%
2028	759,600	1,409,600	3,056,398	14%	27%	58%
2029	794,600	1,539,600	3,563,292	15%	28%	66%
2030	829,600	1,669,600	4,038,622	15%	30%	73%
2031	864,600	1,834,001	4,182,878	15%	32%	73%
2032	899,600	2,005,426	4,329,751	15%	34%	74%
2033	934,600	2,184,004	4,479,136	16%	36%	75%
2034	969,600	2,369,853	4,630,922	16%	39%	75%
2035	1,004,600	2,563,072	4,784,978	16%	41%	76%
2036	1,039,600	2,763,913	4,941,557	16%	43%	77%
2037	1,074,600	2,972,666	5,100,943	16%	45%	77%
2038	1,109,600	3,189,464	5,263,039	16%	47%	78%
2039	1,144,600	3,414,425	5,427,738	16%	49%	78%
2040	1,179,600	3,647,650	5,594,908	17%	51%	79%
2041	1,214,600	3,889,426	5,764,794	17%	53%	79%
2042	1,249,600	4,140,081	5,937,678	17%	56%	80%

Source: ESCOM Fourth Base submission, SE4ALL Electrification Plan. Note the electrification targets of the base case scenario vary slightly due to differences in the reporting period in the Guidelines for Implementation of the National Electrification Programme

Table 53 Real GDP forecast by sector (in billion MWK)

	Low scenario				Base scenario				High scenario			
	Total GDP	Agriculture GDP	Industry GDP	Services GDP	Total GDP	Agriculture GDP	Industry GDP	Services GDP	Total GDP	Agriculture GDP	Industry GDP	Services GDP
2021	7,499	1,696	1,461	3,909	7,499	1,696	1,461	3,909	7,499	1,696	1,461	3,909
2022	7,566	1,707	1,472	3,948	7,566	1,707	1,472	3,948	7,566	1,707	1,472	3,948
2023	7,755	1,737	1,503	4,055	7,755	1,737	1,503	4,055	7,808	1,745	1,511	4,085
2024	8,004	1,776	1,543	4,195	8,004	1,776	1,543	4,195	8,113	1,793	1,560	4,257
2025	8,260	1,815	1,584	4,341	8,316	1,824	1,593	4,373	8,470	1,848	1,617	4,461
2026	8,524	1,856	1,626	4,492	8,682	1,880	1,651	4,582	8,851	1,906	1,678	4,678
2027	8,737	1,888	1,659	4,614	9,072	1,939	1,712	4,805	9,249	1,966	1,740	4,907
2028	9,078	1,940	1,713	4,809	9,481	2,000	1,776	5,040	9,721	2,036	1,814	5,178
2029	9,432	1,993	1,769	5,012	9,907	2,063	1,843	5,286	10,217	2,108	1,891	5,465
2030	9,800	2,047	1,826	5,224	10,353	2,128	1,912	5,544	10,738	2,183	1,971	5,767
2031	10,182	2,103	1,885	5,445	10,819	2,195	1,983	5,815	11,286	2,261	2,054	6,086
2032	10,579	2,160	1,946	5,676	11,306	2,264	2,057	6,098	11,861	2,342	2,141	6,423
2033	10,992	2,219	2,009	5,916	11,815	2,335	2,134	6,396	12,466	2,425	2,232	6,778
2034	11,420	2,279	2,074	6,166	12,346	2,408	2,214	6,708	13,102	2,512	2,326	7,153
2035	11,866	2,341	2,141	6,427	12,902	2,484	2,296	7,036	13,770	2,601	2,425	7,549
2036	12,329	2,405	2,210	6,699	13,482	2,562	2,382	7,379	14,472	2,694	2,527	7,967
2037	12,809	2,471	2,282	6,982	14,089	2,643	2,471	7,740	15,210	2,790	2,634	8,408
2038	13,309	2,538	2,356	7,278	14,723	2,726	2,563	8,118	15,986	2,889	2,746	8,873
2039	13,828	2,607	2,432	7,586	15,386	2,812	2,659	8,514	16,801	2,992	2,862	9,364
2040	14,367	2,678	2,511	7,907	16,078	2,900	2,758	8,929	17,658	3,099	2,983	9,882
2041	14,928	2,751	2,592	8,241	16,802	2,991	2,861	9,365	18,559	3,209	3,109	10,429
2042	15,510	2,826	2,676	8,590	17,558	3,085	2,968	9,823	19,505	3,324	3,241	11,006

Source: Malawi National Accounts 2017-2022, 2022-2027 IMF real GDP growth forecast

Table 54 Forecast of average tariff (real terms in MWK/kWh)

Average tariffs (real terms in MWK/kWh)				
Year	**Domestic**	**Commercial**	**LV Industrial**	**MV Industrial**
2021	39.00	85.30	54.19	47.58
2022	32.94	87.74	45.77	40.19
2023	38.70	90.18	39.29	35.39
2024	56.65	92.63	57.52	51.80
2025	60.22	95.07	61.14	55.07
2026	61.31	97.51	62.25	56.07
2027	62.54	99.95	63.50	57.20
2028	63.79	101.95	64.77	58.34
2029	65.07	103.99	66.07	59.51
2030	66.37	106.07	67.39	60.70
2031	67.70	108.19	68.74	61.91
2032	69.05	110.35	70.11	63.15
2033	70.43	112.56	71.51	64.41
2034	71.84	114.81	72.94	65.70
2035	73.28	117.11	74.40	67.02
2036	74.75	119.45	75.89	68.36
2037	76.24	121.84	77.41	69.72
2038	77.77	124.28	78.96	71.12
2039	79.32	126.76	80.54	72.54
2040	80.91	129.30	82.15	73.99
2041	82.53	131.88	83.79	75.47
2042	84.18	134.52	85.47	76.98

Source: ESCOM forecasted tariffs, ECA assumptions

Table 55 Forecast losses

	Low scenario		Base scenario		High scenario	
Year	**Transmission**	**Distribution**	**Transmission**	**Distribution**	**Transmission**	**Distribution**
2021	5.49%	16.71%	5.49%	16.71%	5.49%	16.71%
2022	5.49%	16.71%	5.49%	16.71%	5.49%	16.71%
2023	5.49%	16.71%	5.49%	16.71%	5.49%	16.71%
2024	5.11%	15.54%	5.04%	15.35%	4.98%	14.16%
2025	4.79%	14.59%	4.68%	14.24%	4.56%	11.60%
2026	4.58%	13.95%	4.43%	13.49%	4.28%	11.61%
2027	4.44%	13.51%	4.26%	12.97%	4.09%	11.62%
2028	4.38%	13.32%	4.19%	12.76%	4.01%	11.64%
2029	4.35%	13.13%	4.17%	12.61%	3.93%	11.65%
2030	4.32%	12.93%	4.16%	12.47%	3.84%	11.66%
2031	4.29%	12.74%	4.14%	12.32%	3.76%	11.39%
2032	4.25%	12.55%	4.13%	12.17%	3.67%	11.13%
2033	4.22%	12.35%	4.11%	12.03%	3.59%	10.86%
2034	4.19%	12.16%	4.10%	11.88%	3.51%	10.60%
2035	4.16%	11.97%	4.08%	11.73%	3.42%	10.33%
2036	4.13%	11.77%	4.06%	11.59%	3.34%	10.06%
2037	4.10%	11.58%	4.05%	11.44%	3.25%	9.80%
2038	4.06%	11.39%	4.03%	11.29%	3.17%	9.53%
2039	4.03%	11.19%	4.02%	11.15%	3.08%	9.27%
2040	4.00%	11.00%	4.00%	11.00%	3.00%	9.00%
2041	4.00%	11.00%	4.00%	11.00%	3.00%	9.00%
2042	4.00%	11.00%	4.00%	11.00%	3.00%	9.00%

Source: Loss Reduction Road Map

A4 Statistical results from the regression analysis

A4.1 Commercial sales econometric equation

The statistical results of the econometric analysis for the chosen equations for commercial sales together with a comparison of a historical forecast using the econometric equation against actual sales is shown in the table below.

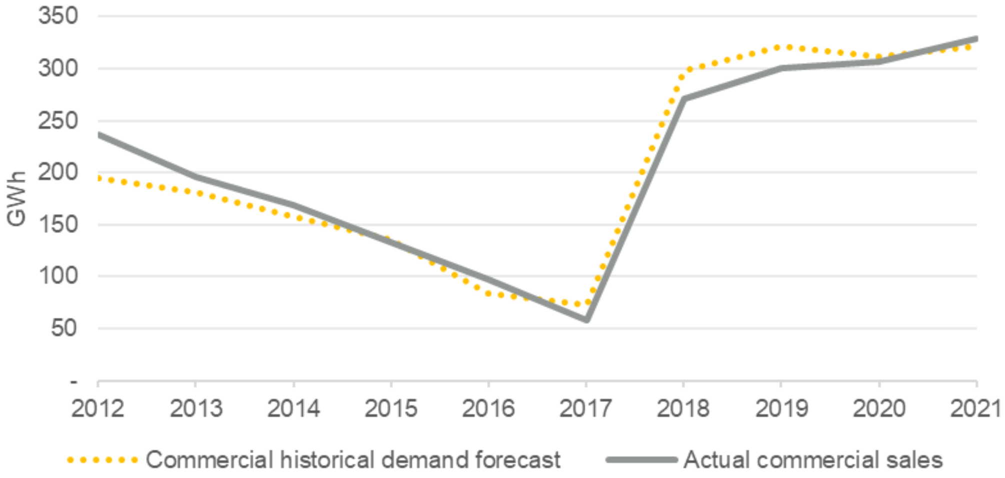
Table 56 Statistical results for the commercial sales econometric equation

Regression Statistics	
Multiple R	0.973937
R Square	0.948554
Adjusted R Square	0.936682
Standard Error	0.111135
Observations	17

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	2.960407	0.986802	79.89705	1.25E-08
Residual	13	0.160562	0.012351		
Total	16	3.120969			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-0.04651	7.832987	-0.00594	0.995352
LN(Real GDP per capita)	1.045044	0.638795	1.635962	0.125816
LN(Comm Connections)	0.633373	0.043497	14.56141	1.99E-09
LN(Commercial Tariff)	-0.21057	0.069718	-3.02034	0.009846



Source: ECA analysis using ESCOM data

A4.2 LV Industrial sales econometric equation

The statistical results of the econometric analysis for the chosen equations for LV Industrial sales together with a comparison of a historical forecast using the econometric equation against actual sales is shown in the table below.

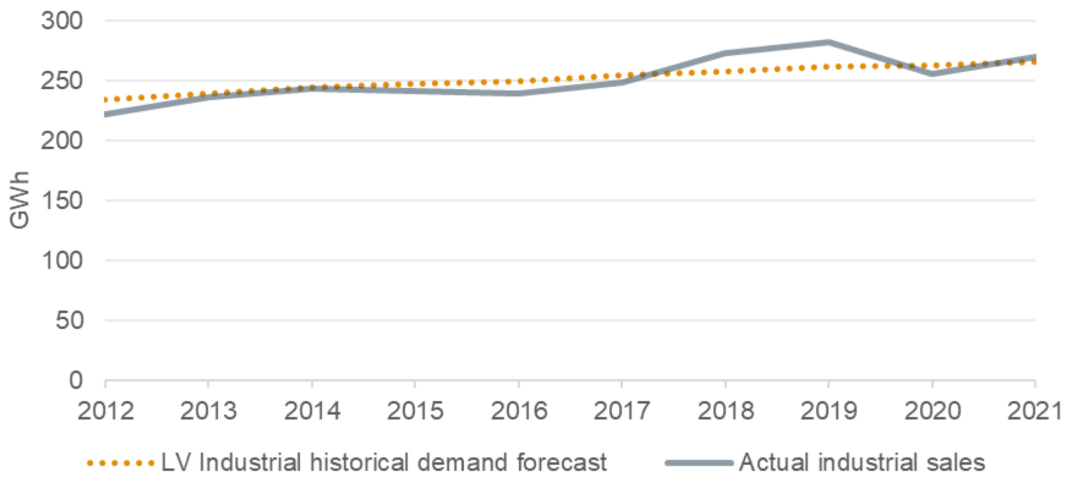
Table 57 Statistical results for the LV Industrial sales econometric equation

Regression Statistics	
Multiple R	0.863506
R Square	0.745642
Adjusted R Square	0.728685
Standard Error	0.05229
Observations	17

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.120232	0.120232	43.97201	8E-06
Residual	15	0.041014	0.002734		
Total	16	0.161247			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	9.078276	1.539073	5.898535	2.92E-05
LN(Real GDP)	0.348131	0.052499	6.631139	8E-06



Source: ECA analysis using ESCOM data

A4.3 MV Industrial sales econometric equation

The statistical results of the econometric analysis for the chosen equations for MV Industrial sales together with a comparison of a historical forecast using the econometric equation against actual sales is shown in the table below.

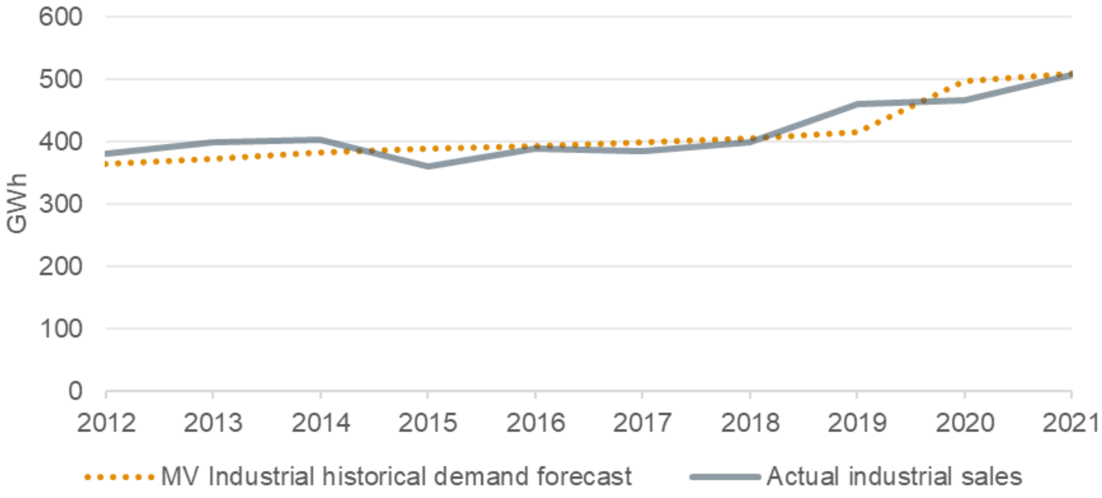
Table 58 Statistical results for the MV Industrial sales econometric equation

Regression Statistics	
Multiple R	0.924297
R Square	0.854326
Adjusted R Square	0.844614
Standard Error	0.061564
Observations	17

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.33342	0.33342	87.96944	1.15E-07
Residual	15	0.056853	0.00379		
Total	16	0.390273			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*
Intercept	5.074143	1.564504	3.243293	0.005458	1.739482
LN(Industrial GDP)	0.534582	0.056996	9.379202	1.15E-07	0.413096



Source: ECA analysis using ESCOM data

A4.4 Unsuccessful models considered in the analysis

Table 31 compiles the econometric model specifications tested for residential, commercial, and industrial users. In most cases, the specifications proved to have too little statistical significance (ie p-value above 10% for all variables in the equation). For others, highlighted in grey, the equation was deemed to be unreliable due to the inclusion of residential connection data.

Table 59 Unsuccessful models considered in the analysis

Dependent Variable	GDP	Sector GDP (Commercial, Agricultural or Industrial)	GDP per capita	Tariff (Residential, Commercial, or Industrial)	CPI	Lagged dependent variable	Connections (Residential, Commercial or Industrial)	Oil Price
Average consumption per household per year (kWh/year)	x							
			x					
				x				
					x			
						x		
							x	
	x			x				
	x				x			
	x					x		
	x						x	
			x	x				
			x		x			
			x			x		
			x				x	
			x	x		x		
			x	x			x	
			x		x	x		
			x		x		x	
			x			x	x	
				x		x		
				x			x	
				x		x	x	
Commercial sales (kWh)	x							
		x						
			x					
				x				
					x			

Dependent Variable	GDP	Sector GDP (Commercial, Agricultral or Industrial)	GDP per capita	Tariff (Residential, Commercial, or Industrial)	CPI	Lagged dependent variable	Connections (Residential, Commercial or Industrial)	Oil Price
						x		
							x	
	x			x				
	x				x			
	x						x	
		x		x				
		x			x			
		x				x		
		x					x	
		x		x		x		
			x	x				
			x		x			
			x			x		
			x	x		x		
			x		x		x	
				x	x	x		
				x		x	x	
Industrial LV sales (kWh)		x						
			x					
				x				
					x			
						x		
							x	
	x			x				
	x				x			
	x					x		
	x						x	
		x		x				
		x			x			

Dependent Variable	GDP	Sector GDP (Commercial, Agricultral or Industrial)	GDP per capita	Tariff (Residential, Commercial, or Industrial)	CPI	Lagged dependent variable	Connections (Residential, Commercial or Industrial)	Oil Price
		x				x		
		x					x	
		x		x		x		
			x	x				
			x		x			
			x			x		
		x		x		x		
		x			x	x		
		x			x		x	
Industrial MV sales (kWh)	x							
			x					
				x				
					x			
						x		
							x	
	x			x				
	x				x			
	x							x
		x		x				
		x			x			
		x				x		
		x					x	
		x		x		x		
			x	x				
			x		x			
		x		x		x		x
		x			x	x		
		x			x		x	

Source: ECA analysis. Note: The lagged explanatory variables described in the table were also considered in all specifications, nominal and real tariffs were also considered

A5 Demand forecast 2022-2042

Table 60 Sent-out energy and peak demand forecasts

	Low scenario		Base scenario		High scenario	
Year	Sent-out Energy (GWh)	Peak demand (MW)	Sent-out Energy (GWh)	Peak demand (MW)	Sent-out Energy (GWh)	Peak demand (MW)
2022	2,367	371	2,378	373	2,379	373
2023	2,447	383	2,587	405	2,610	409
2024	2,538	394	2,891	449	2,985	462
2025	2,679	409	3,351	508	3,524	535
2026	2,931	440	3,897	582	4,437	661
2027	2,985	449	4,111	617	5,199	781
2028	3,090	464	4,412	663	6,460	975
2029	3,219	481	4,847	725	7,495	1,129
2030	3,334	498	5,166	774	8,539	1,291
2031	3,462	518	5,551	834	9,101	1,378
2032	3,599	539	5,982	900	9,740	1,475
2033	3,771	565	6,485	976	10,458	1,583
2034	3,909	587	6,939	1,048	11,068	1,680
2035	4,077	612	7,468	1,130	11,772	1,790
2036	4,229	636	8,007	1,214	12,485	1,903
2037	4,389	662	8,593	1,307	13,258	2,025
2038	4,558	688	9,230	1,407	14,095	2,157
2039	4,736	716	9,927	1,516	15,004	2,301
2040	4,924	746	10,684	1,636	15,991	2,457
2041	5,137	779	11,531	1,768	17,129	2,635
2042	5,362	815	12,458	1,914	18,371	2,830

Source: ECA analysis

Table 61 North region - Sent-out energy and peak demand forecasts

	Low scenario		Base scenario		High scenario	
Year	**Sent-out Energy (GWh)**	**Peak demand (MW)**	**Sent-out Energy (GWh)**	**Peak demand (MW)**	**Sent-out Energy (GWh)**	**Peak demand (MW)**
2022	227	62	228	62	228	62
2023	236	64	252	68	254	69
2024	238	65	272	74	278	76
2025	252	68	326	89	343	93
2026	340	93	496	135	581	158
2027	345	94	514	140	674	183
2028	355	97	545	148	815	222
2029	392	107	614	167	961	261
2030	407	111	649	177	1,084	295
2031	422	115	693	189	1,146	312
2032	438	119	740	201	1,212	330
2033	454	124	792	216	1,285	350
2034	472	128	849	231	1,363	371
2035	514	140	945	257	1,493	406
2036	533	145	1,013	276	1,585	431
2037	553	151	1,086	296	1,685	458
2038	575	156	1,167	317	1,793	488
2039	597	163	1,254	341	1,910	520
2040	621	169	1,350	367	2,037	554
2041	648	176	1,457	397	2,184	594
2042	676	184	1,575	429	2,345	638

Source: ECA analysis

Table 62 Central region - Sent-out energy and peak demand forecasts

	Low scenario		Base scenario		High scenario	
Year	Sent-out Energy (GWh)	Peak demand (MW)	Sent-out Energy (GWh)	Peak demand (MW)	Sent-out Energy (GWh)	Peak demand (MW)
2022	975	159	979	160	979	160
2023	1,009	165	1,070	174	1,078	176
2024	1,066	174	1,249	204	1,305	213
2025	1,105	180	1,377	224	1,452	237
2026	1,147	187	1,509	246	1,747	285
2027	1,177	192	1,611	263	2,088	340
2028	1,223	199	1,726	281	2,602	424
2029	1,272	207	1,850	302	2,965	483
2030	1,323	216	1,983	323	3,418	557
2031	1,378	225	2,143	349	3,643	594
2032	1,435	234	2,317	378	3,885	633
2033	1,496	244	2,507	409	4,147	676
2034	1,559	254	2,714	442	4,431	722
2035	1,625	265	2,939	479	4,736	772
2036	1,695	276	3,185	519	5,067	826
2037	1,768	288	3,452	563	5,426	885
2038	1,845	301	3,743	610	5,815	948
2039	1,926	314	4,061	662	6,236	1,017
2040	2,012	328	4,407	718	6,694	1,091
2041	2,108	344	4,793	781	7,218	1,177
2042	2,209	360	5,215	850	7,789	1,270

Source: ECA analysis

Table 63 South region - Sent-out energy and peak demand forecasts

	Low scenario		Base scenario		High scenario	
Year	Sent-out Energy (GWh)	Peak demand (MW)	Sent-out Energy (GWh)	Peak demand (MW)	Sent-out Energy (GWh)	Peak demand (MW)
2022	1,165	275	1,171	277	1,171	277
2023	1,201	284	1,266	299	1,278	302
2024	1,235	292	1,370	324	1,402	331
2025	1,321	312	1,649	390	1,729	408
2026	1,442	341	1,891	447	2,109	498
2027	1,461	345	1,986	469	2,437	576
2028	1,511	357	2,142	506	3,043	719
2029	1,553	367	2,383	563	3,569	843
2030	1,602	379	2,534	599	4,036	954
2031	1,660	392	2,715	642	4,313	1,019
2032	1,724	407	2,925	691	4,642	1,097
2033	1,819	430	3,185	753	5,026	1,188
2034	1,877	443	3,377	798	5,275	1,246
2035	1,937	458	3,584	847	5,543	1,310
2036	2,000	473	3,810	900	5,833	1,378
2037	2,067	488	4,055	958	6,147	1,453
2038	2,137	505	4,321	1,021	6,488	1,533
2039	2,212	523	4,611	1,090	6,858	1,620
2040	2,291	541	4,927	1,164	7,260	1,716
2041	2,381	563	5,281	1,248	7,727	1,826
2042	2,477	585	5,668	1,339	8,237	1,946

Source: ECA analysis

Table 64 Sales forecast by economic activity

GWh	Residential			Commercial			Industrial		
Year	Low case	Base case	High case	Low case	Base case	High case	Low case	Base case	High case
2022	763	763	763	322	330	332	778	778	778
2023	803	891	899	329	346	351	794	800	804
2024	848	1,027	1,084	341	368	378	844	929	972
2025	895	1,177	1,288	358	399	412	926	1,164	1,274
2026	942	1,339	1,682	376	436	452	1,088	1,447	1,620
2027	984	1,493	2,275	394	478	498	1,089	1,454	1,634
2028	1,039	1,655	3,177	420	525	552	1,102	1,508	1,750
2029	1,097	1,826	3,783	447	577	613	1,131	1,656	1,965
2030	1,155	2,005	4,536	477	636	681	1,144	1,693	2,036
2031	1,216	2,229	4,882	510	701	759	1,165	1,736	2,121
2032	1,279	2,471	5,254	546	775	846	1,188	1,792	2,238
2033	1,343	2,734	5,653	585	857	945	1,237	1,879	2,389
2034	1,410	3,019	6,083	628	949	1,056	1,251	1,897	2,409
2035	1,479	3,328	6,544	675	1,052	1,182	1,286	1,944	2,469
2036	1,550	3,662	7,040	726	1,168	1,325	1,301	1,961	2,489
2037	1,623	4,023	7,572	783	1,299	1,488	1,316	1,979	2,510
2038	1,699	4,414	8,144	844	1,446	1,672	1,331	1,998	2,532
2039	1,777	4,837	8,759	912	1,612	1,881	1,347	2,017	2,554
2040	1,858	5,294	9,419	986	1,799	2,120	1,363	2,036	2,576
2041	1,942	5,787	10,129	1,068	2,010	2,391	1,379	2,055	2,599
2042	2,028	6,319	10,892	1,158	2,249	2,701	1,395	2,075	2,623

Source: ECA analysis