MALAWI'S

MINI INTEGRATED RESOURCE PLAN

2016-2020

STRATEGIC ROADMAP OF MALAWI'S POWER SECTOR

DECEMBER 2015

Table of Contents

List of Figures and Tables

Figures

Tables

Acknowledgements

The development of this IRP has been a success because of the collaborative efforts of teams from the Ministry of Natural Resources, Energy and Mining (MNREM), the Department of Energy (DoE) and Electricity Supply Corporation of Malawi (ESCOM). Special credit should also go to the Malawi Energy Regulatory Authority (MERA) and Malawi Investment and Trade Centre (MITC) for providing the necessary data for the production of this report.

Acronyms

CSP	: Concentrated Solar Power
DSM	: Demand Side Management
EDM	: Electricidade de Mocambique
EPC	: Engineering, Procurement and Construction
ESCOM	: Electricity Supply Corporation of Malawi
ESSP	: Energy Sector Support Program
FS	: Feasibility Study
GoM	: Government of Malawi
GWh	: GigaWatt hour
IAEA	: International Atomic Energy Agency
IPP	: Independent Power Producer
IRP	: Integrated Resource Plan
Km	: Kilometer
kV	: Kilovolt
MCC	: Millennium Challenge Corporation
MERA	: Malawi Energy Regulatory Authority
MNREM	: Ministry of Natural Resources, Energy and Mining
MoU	: Memorandum of Understanding
MW	: MegaWatt
PV	: Photovoltaic
SAPP	: Southern African Power Pool

1. Introduction and Background

In the last few years, there has been attempts to examine Malawi's energy demands and portfolio to guide long-term energy planning for the Country. These include the Integrated Resource Plan (IRP) under the auspices of the Millennium Challenge Corporation-Malawi Compact (ICF/CORE International, 2011) and the energy demand forecast under the guidance of the International Atomic Energy Agency (IAEA, 2011). These efforts however did not receive the necessary endorsement and buy-in from key energy stakeholders particularly the Government of Malawi (GoM). This left Malawi without an officially accepted IRP or a strategic road map with which to secure reliable and cost-effective energy resources. Apropos of this, in October 2015, the Ministry of Natural Resources, Energy and Mining (MNREM), the Department of Energy (DoE) and Electricity Supply Corporation of Malawi (ESCOM) initiated a process to develop a Mini IRP for the period 2016 – 2020.

The Mini IRP is expected to become the basis for planning and mobilizing resources for requisite additional power sector investments over the period 2016 – 2020. This entails: modeling energy demands; adjustment for technology efficiencies like Demand Side Management (DSM) and loss reduction, procurement of energy supplies from ESCOM, Independent Power Producers (IPPs,) and imports; and expansion as well as reinforcement of the transmission and distribution networks.

Teams from the MNREM, the DoE and ESCOM kick started the task of preparing the Mini IRP in October 2015. The output of the work was presented to key stakeholders including the Malawi Energy Regulatory Authority (MERA) for validation in December 2015. This document therefore presents a stakeholder- validated Mini IRP as a brief, research-based plan of future energy needs and supply profile for Malawi. It will be a guide which will be updated when input assumptions significantly change especially due to current feasibility studies for energy projects as they are completed and also with the necessity for a full IRP developed over a full period of time.

2. Why a Mini IRP

A sophisticated IRP process considers a full range of power sector investments to meet new demand for electricity, not only in new generation sources, but also in transmission, distribution, and importantly demand side measures and energy efficiencies on an equal basis. These IRPs typically use a twenty to thirty year planning horizon on complex computer models that include risk assessment. In many jurisdictions, IRP integrates environmental and other external costs and benefits, and generally includes regulatory mechanisms to overcome utility and customer barriers to demand side efficiency.

Because many groups in society are affected by the development and operation of the power system, a wide range of stakeholders have legitimate basis for being part of the planning process. A best practice IRP process includes not only utility representatives, but also representatives of energy consuming sectors, community groups, advocacy groups, and government ministries (economic planning, environmental protection, and energy, etc.). Incorporating the views of a broad spectrum of those affected by planning decisions fosters consensus and helps avoid polarization as plans are implemented.

These views should be solicited and incorporated at multiple occasions in the development of the IRP. These objectives may conflict with one another to varying degrees. Therefore, preparing, deciding upon, and implementing a preferred resource plan requires both a series of objective analyses (based on solid facts, that explores consequences of different choices) and the use of processes (incorporating principles of transparency, accountability, and public participation) by which the values and judgments of stakeholders are applied in developing plans. This process is not done not in weeks but rather in a period of about 12 months or more and is usually led by an independent team of experts. This IRP, however, has been developed in a record time by focusing on selected critical issues over a five year planning horizon therefore termed a 'Mini IRP'. The developers employed their knowledge of the existing ESCOM network and a list of available long term projects under various stages of study and implementation. For a full IRP, there will be need for incorporating the findings of the various energy projects' feasibility studies underway as well as optimization studies. This mini IRP recognizes security of supply and least cost as a required outcome of the optimisation analysis.

3. Overall Approach to Developing the IRP

Figure 1 illustrates the steps that are usually taken in coming up with Integrated Resource Plan

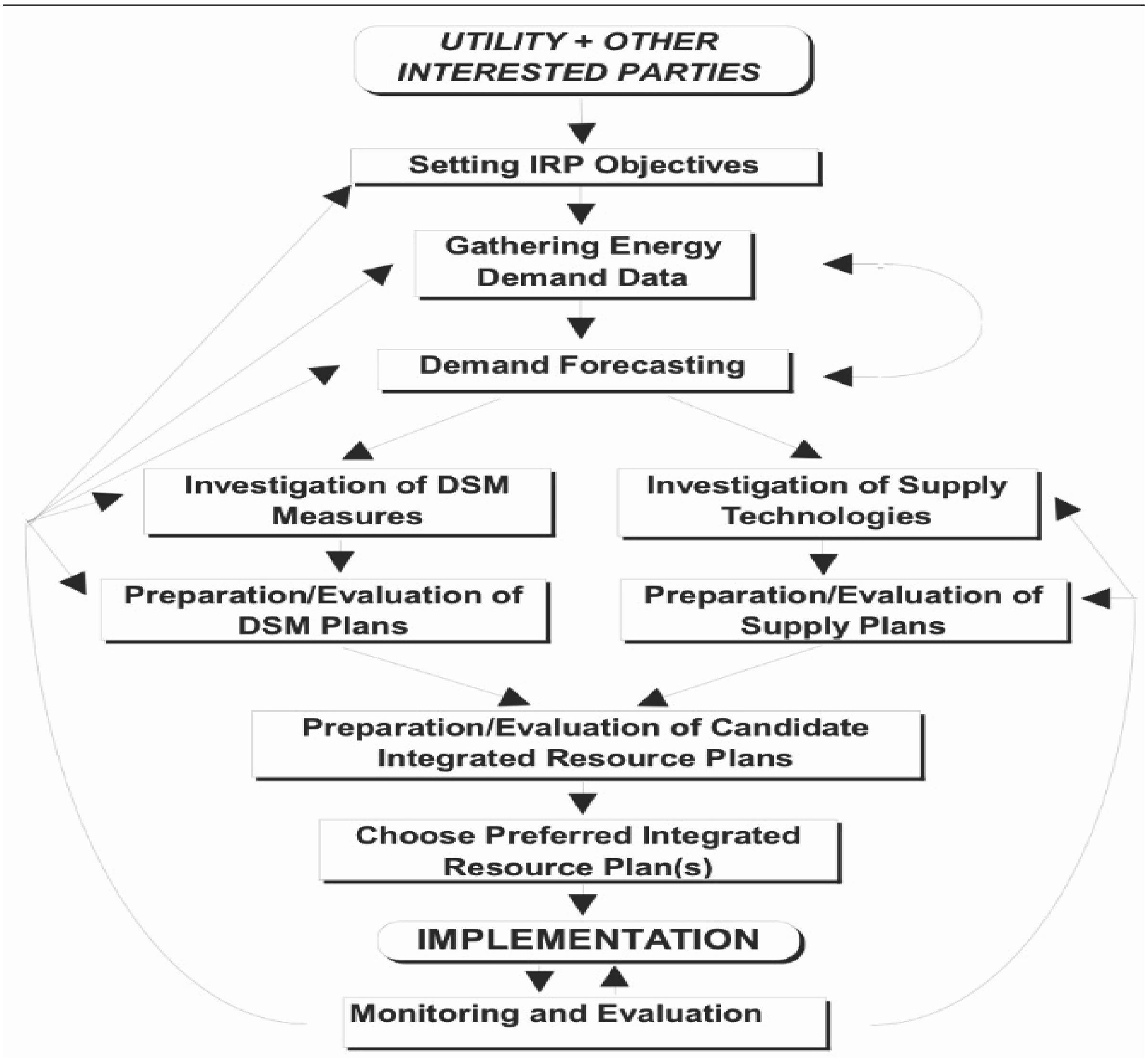


Figure 1: The Integrated Resource Planning Process (Adapted from von Hippel & Nichols, 2000).

To develop this IRP, the following steps were taken:

1. Establishment of scope and objectives;
2. Survey of energy use patterns and development of demand forecasts;
3. Investigation of electricity supply options;
4. Investigation of demand-side management measures;
5. Preparation and evaluation of supply plans;
6. Preparation and evaluation of demand-side management plans;
7. Integration of supply- and demand-side plans into candidate integrated resource plans;
8. Selection of the preferred plan; and
9. Implementation arrangement of the plan including monitoring, evaluation, and iteration.

4. IRP - Scope and Objectives

An IRP can be thought of as a process of planning to meet users' needs for electricity services in a way that satisfies multiple objectives for resource use. As such, it does not presume that the only objective to be optimized is cheap electricity that meets reliability standards. This mini IRP is intended to be a strategic guiding framework for Malawi for period 2016-2020. Its main objective is to serve as a strategic road map for Malawi to secure reliable and cost-effective energy resources in the stipulated period under different situations. Its broad objectives include:

1. Conform to national, Southern Africa Power Pool, and local development objectives.
2. Ensure that all households and businesses have access to electricity services from current access rate of about 10% to 30% by 20130.
3. Maintain reliability of supply with zero blackout and Loss of load expectation (LOLE) of less than 25hours per annum.
4. Minimize the short term or long term economic cost of delivering electricity services, including interconnection with Mozambique by 2018.

5. Minimize the environmental impacts of electricity supply and use during the life of the project.
6. Evolve renewables sources covering cogeneration, geothermal, solar including roof top PV.
7. Enhance energy security by minimizing the use of external resources and optimizing use of local resources.
8. Provide local economic benefits, by enabling industrial growth.
9. Minimize foreign exchange costs.
10. Intensify quick electrification projects
11. Participate in the SAPP power market through active power trading.

It is worth noting that these objectives, if not properly aligned, may conflict with one another to varying degrees. Therefore, preparing, deciding upon, and implementing a preferred resource plan requires both a series of objective analyses (based on solid facts to explore consequences of different choices) and the use of processes (incorporating principles of transparency, accountability, and public participation) by which the values and judgments of stakeholders are applied in developing the plan..

5. Demand Side Assessment

Demand side assessment is the first step in the lead-up to the development of this IRP. Its purpose is to provide an outlook of the future energy demands for the period 2016-2020.

5.1. The Demand Forecasting Method

Once objectives are determined, the next step is to understand current energy use patterns within the scope of the IRP and make projections about the future. An IRP process looks at energy and power requirements 5 to 30 years into the future. Solid data on energy usage patterns is the foundation to a strong IRP. Some of the types of information used in IRPs include:

A. **Energy end-use data:** This data includes the number of households using specific electric appliances, the number of commercial, institutional, or industrial consumers using different types of electric equipment, and the amount of electricity used per customer per end use. The significance of this is that it facilitates projection of demand. A typical local example is that of a housing estate which was initially designed without taking into account use of water gysers / heaters and cookers but at a later phase residents started installing these equipment. Effective power system planning should work to develop and maintain historical records for each customer class and major end use.

B. **Electricity sales records:** Sales records by geographical area and by customer class (for example, household, commercial and industrial classes) are needed, along with the number of customers by class and by area, for as many historical years as are available.

C. **Demand records:** Data on power demand that charts the MW load requirements over days, weeks, months, and years are needed to determine the relationship between electricity sales and the amount of generation capacity required. Disaggregated data (broken down by customer class) are useful. The shape of the load curve (the variation of peak loads over time, or the "load profile") helps to determine what types of generating capacity are needed.

D. **Economic and demographic historical data and projections:** Historical data on economic performance, and population or the number of households together with economic and demographic projections are useful for the portion of demand that is difficult to capture with end-use data.

For this IRP, given the constraint of time, teams from ESCOM, MNREM, and DoE conducted a quick but comprehensive review of available energy end-use data, electricity sales records, demographic data, and other demand forecast data. Particularly, the teams looked at the following documents:

1. The Malawi Energy Policy,
2. The ICF/CORE IRP,
3. The Draft IAEA Demand Forecast,
4. The Malawi 2015 Annual Economic Report,
5. ESCOM Customer Energy Consumption Records,
6. Records of potential miners from the Department of Mining, and
7. A broad-based literature on IRPs.

In addition, the IRP development team also visited the MERA and Malawi Investment and Trade Center (MITC) to collect records of energy consumers with self-generation and potential investors respectively.

The demand forecast process for this IRP comprised the following steps:

1. Modelling actual electricity use for 2015 (base year) by the following sectors: households, agriculture, mining, construction, manufacturing, and services. This was done using ESCOM customer energy consumption records.
2. Estimating future electricity use for the period 2016 – 2020.
3. Projecting peak loads for the years 2016 – 2020.

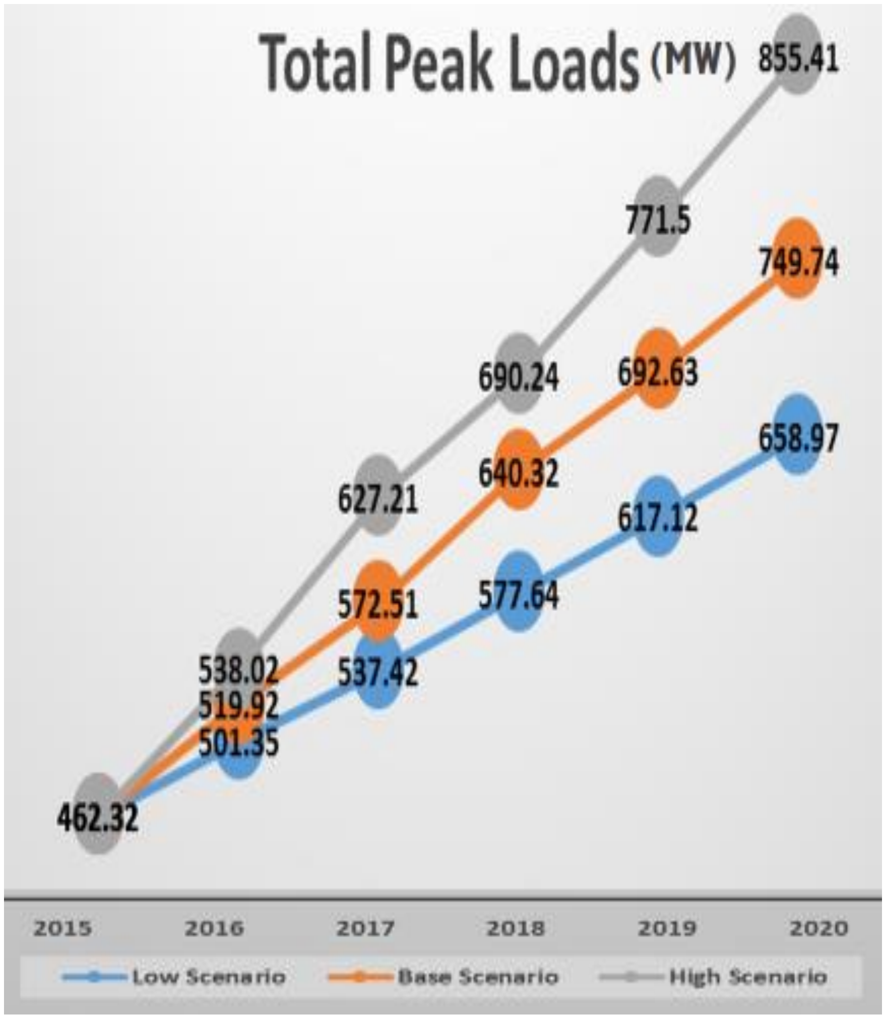
The projection is based on the economic performance as indicated by GDP growth estimates and also the electrification targets provided by the Government of Malawi. Detailed demand assessment steps are provided in Annex 6.

5.2. Forecasting Scenarios

With the above assumptions, the most likely scenario where there is concerted effort is called the base scenario. Two other scenarios, high and low scenario have also been projected. The high scenario is the case where the economy is performing extremely well while the low one is presents a case of business as usual. Thus, this demand forecast has three growth path scenarios for access to electricity access in Malawi:

1. A Low Scenario that follows the past trend in access to electricity.
2. A Base Scenario representing an optimal path that assumes the target of 30% in 2030 (the lower end of the GoM policy),
3. A High Scenario that assumes the target of 50% in 2030 (the higher end of the GoM policy).

Figures 2 and 3 show the peak and energy demands by all the three scenarios. The peak demand forecasts shown in figure 2 indicate that total peak loads increase from 462.32 in 2015 to 658.97 in 2020 for the Low Scenario, and 749.74 and 855.41 for the Base and High Scenarios respectively. These represent total peak load increase of 42.54% for the Low Scenario, 62.2% for the Base Scenario and 85% for the High Scenario.



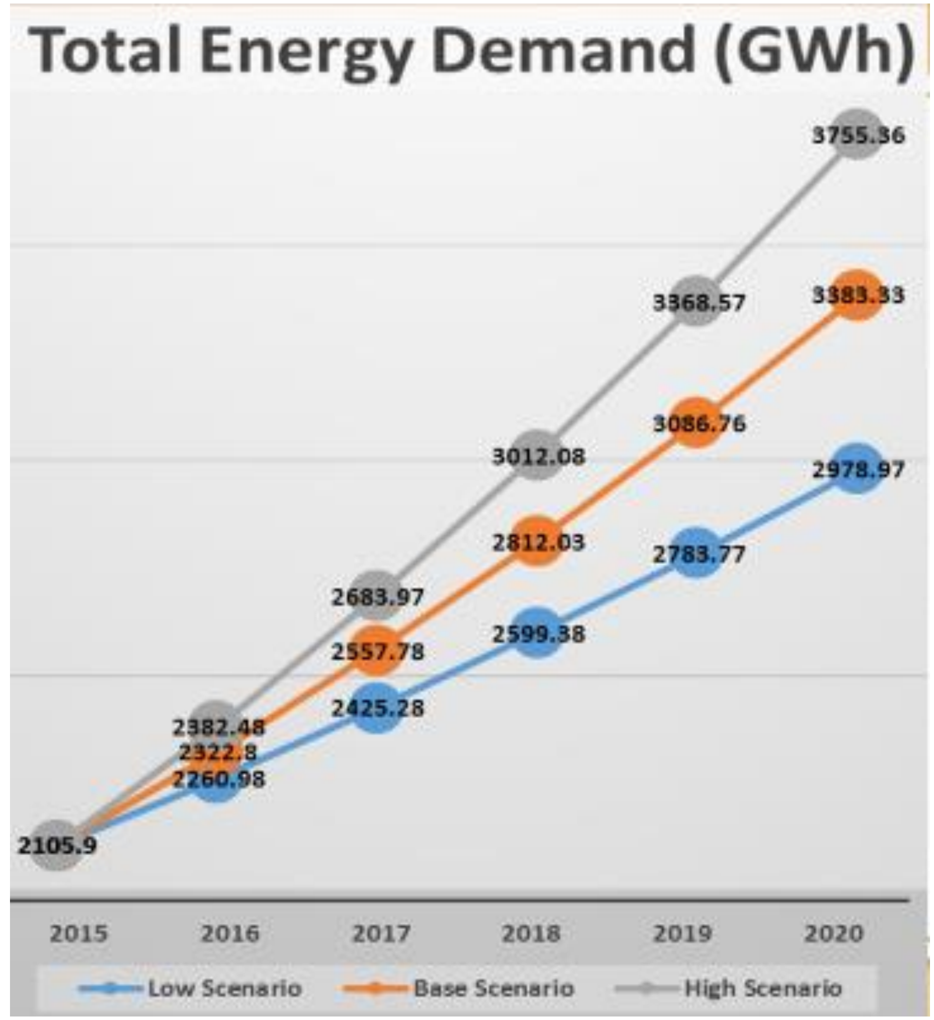


Figure 2. Peak loads

Figure 3. Energy demands by scenarios

From Figure 3, total electricity use increases from 2105.9 GWh in 2015 to 2978.97 GWh in 2020 for the Low Scenario and to 3383.33 GWh and 3755.36 GWh for the Base and High Scenarios respectively. These represent respective increases of 41.46%, 60.66% and 78.33% for the Low, Base and High Scenarios respectively over the period 2015 – 2020. The annual peak demand increase for the Low Scenario is 8% for year 1 and 7% thereafter while for the Base Scenario, the increment starts with 12% then 10% and 12% respectively before tapering to 8%. The High Scenario on the other hand starts off with a steep increase of 16% and 17% before tapering to 10%, 12% and 8% in that order. These initial increments are due to anticipated new step loads.

In terms of sectoral consumption in 2015, households account for 41.11% of the total electricity consumed in Malawi followed by Agriculture (25.07%), Services (17%), Manufacturing (12.14%), Mining (4.77%) and Construction (0.27%). Figure 4 shows the sectoral electricity use in 2015.

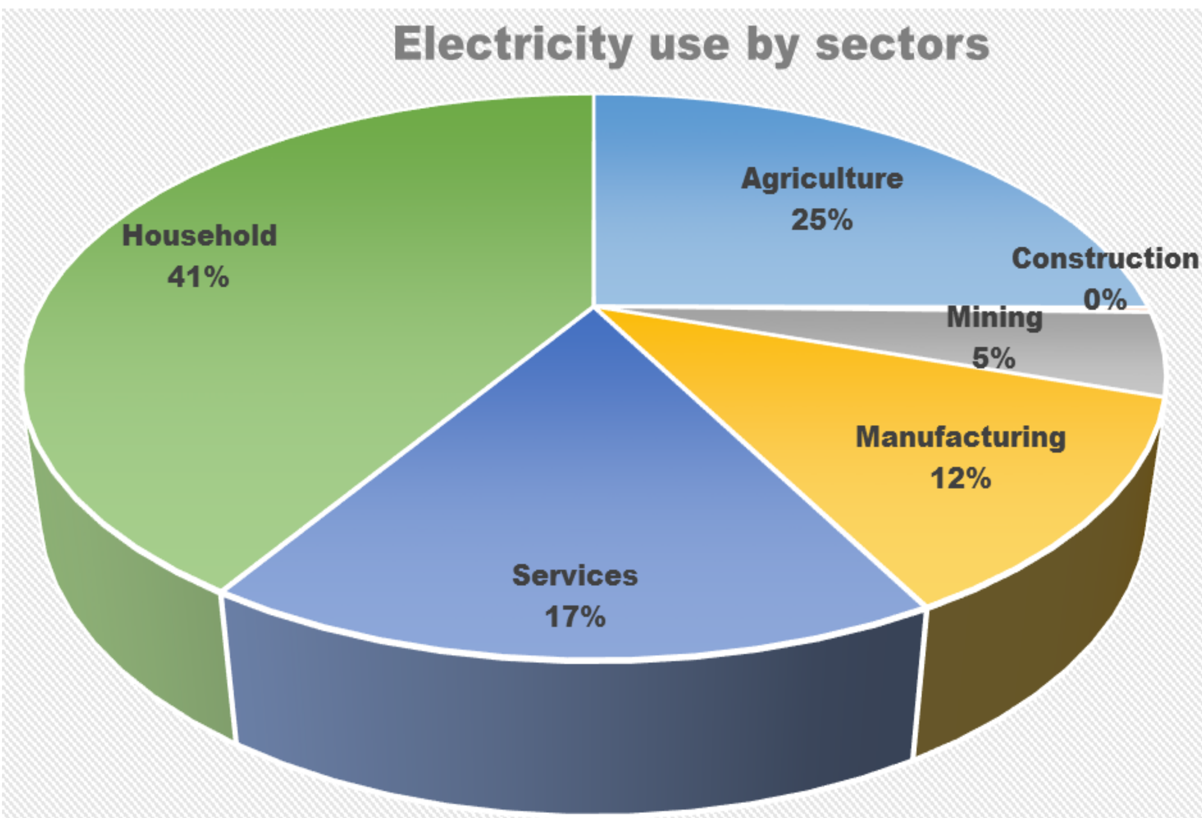


Figure 4. Sectoral electricity use in 2015

Under base scenarios, access to electric for domestic customers is expected to increase at least to absorb customers so that access to electricity will now be at least 30% and also that all the outstanding loads will be connected.

Over the 5 year period (2016-2020), the highest step loads are expected in the mining sector followed by agriculture, manufacturing, services and construction in that order. Table 1 shows the total electricity use for all sectors for the period 2015 – 2020 for all the three Scenarios.

Table 1. Total Electricity Use for All Sectors, 2015 – 2020, GWh

	Low Scenario			**Base Scenario**			**High Scenario**		
Year	Household Sector	Other Sectors	All Sectors	Household Sector	Other Sectors	All Sectors	Household Sector	Other Sectors	All Sectors
2015	865.75	1240.19	2105.9	865.75	1240.19	2105.9	865.75	1240.19	2105.9
2016	957.66	1303.32	2260.98	1006.87	1315.93	2322.8	1053.91	1328.57	2382.48
2017	1055.46	1369.82	2425.28	1161.23	1396.55	2557.78	1260.41	1423.56	2683.97
2018	1159.49	1439.89	2599.38	1329.67	1482.36	2812.03	1486.4	1525.68	3012.08
2019	1270.05	1513.72	2783.77	1513.08	1573.68	3086.76	1733.08	1635.49	3368.57
2020	1387.47	1591.5	2978.97	1712.43	1670.9	3383.33	2001.77	1753.59	3755.36

It should be noted however that 2015 was not a good representative year for estimating demand using ESCOM's customer consumption records. This was because of severe draught which affected the flow of Shire River resulting in much load shedding. Energy and power supplied is therefore not expected to exceed that of the previous year. Maximum demand in the year 2014 was 335MW (without load shedding) whilst in 2015 it was 328MW (with load shedding).

6. Demand Side Management Measures

6.1. The General Approach

Demand-side management (DSM) refers to programs or projects undertaken to manage the demand for electricity: reducing electric energy use, changing the timing of electricity use (and thereby the profile of peak power demand), or both. By reducing the demand for electric energy and power, demand-side management options reduce the need to generate electricity, and also reduce loads on transmission and distribution systems. In this stage of an IRP, demand side options are identified and their cost and performance is analyzed, and the most promising options are selected.

The list of potential DSM options for utility systems is longer than the list of supply options. DSM options can be roughly divided into four categories, as follows.

A. Information and/or Incentives to Encourage Efficiency in Electricity Use

One class of options is to provide information to electricity consumers on how to use energy wisely and efficiently, and to provide pricing structures that help spur customers to change the amount and timing of energy use.

One emerging example of information awareness is to print out on the electricity billing invoice showing what the amount due would be if the customer had implemented power factor correction. However recognizing recent trends of shifting customers to prepayment, an electronic or hard copy statement for a firm period can still be sent showing a summary of transactions. Banks do similar transactions with their internet customers who receive banking statement even though each transactions was previously communicated.

Pricing structures can provide a powerful incentive to save. Block rate tariffs charge higher rates for those customers that consume greater amounts of electricity.

B. Higher-Efficiency Technologies

Energy-efficiency measures reduce energy consumption (and peak loads) by substituting more efficient appliances and equipment for less efficient units or systems. Energy efficiency measures are available for virtually every end-use application. Such equipment include cathode ray tube (CRT) displays like computer screens and television screen being replace by flat screen displays or an old model fridge being replaced by an energy efficient one. Similarly incandescent lamps being replaced by efficient lighting like light emitting diode (led) or compact fluorescent lamps (cfl). Often the equipment being pulled out of circuit from high income residential areas often finds a way back into homes of low income areas hence defeating the purpose of this exercise.

Recently, Government of Malawi replaced several incandescent lamps with cfl but the impact was not accurately quantified due to lack of proper monitoring and/or measurement systems. After a duration of several months, the project will now resume with led lamps instead.

C. Fuel-Switching Technologies

In an IRP, the most common types of fuel-switching options are those that save electricity and reduce peak loads by substituting another fuel for electricity. Illustrative fuel choice alternatives include:

● Use of solar energy (instead of electricity) to provide space heat, water heat, or industrial process heat. Colleges, hospitals, homes, industries like tobacco and chicken rearing business could have all water heating and space heating needs provided by solar energy thus reducing their dependences on electricity for water or space heating.

● Solar-thermal absorption chillers (instead of electricity) for air conditioning or refrigeration.

D. Load Management

Load management measures reduce peak demand by shifting power use from times of high power demand (for example, during the day or early evening) to times of lower demand (during the night). Examples include:

i. **Water heater controllers for household applications.** These can be simple timers that turn off appliances during peak times, or electronic controls ("load control") activated by the utility system operator. With centrally activated load control systems, different groups of end-use equipment can be cycled off for a few minutes during peak loads.

ii. **Ice-storage or water chiller systems for cooling.** Chilled water or ice is made at night by refrigeration, and stored until cooling is needed (for example, in an office building or hospital) during the day. The ice is then melted in a heat exchanger and used to cool the building.

iii. **Special "interruptible" rates.** Large volume electricity users may be offered price discounts in exchange for allowing the utility to disconnect all or a portion of their electrical equipment when the utility system is short of generating capacity.

iv. **Off-peak water pumping.** This measure requires water boards/utilities to develop water storage facilities to pump and store water during off-peak hours.

Ultimately energy efficiency measures are adopted based on the attractiveness of their attributes to the entity with authority in making the facility's investment decisions. Attributes of energy efficiency that should be noted include:

- Applicability (market size, and identification of sectors and end-uses)
- Fuel type
- Reliability and lifetime (based on experience in previous applications)
- Efficiency (energy and power saved relative to standard equipment)
- Capital and operating costs
- Environmental impacts

- Foreign exchange requirements and local input (fraction of the materials and technology that can be provided locally).

With data for these attributes collected, measures are screened to select those with lower costs of saved energy (measured in kWh over the lifetime of the measure). One common conceptual tool is a "cost of saved energy curve." If the objective is to minimize the total cost of electricity services, a utility would work to implement DSM measures until the cost of saved energy reaches the cost of supplying and delivering electricity or goes slightly above.

There are several reasons to choose DSM measures:

1. From the utilities perspective, DSM measures almost always cut back on the peak load, which is almost always more expensive than the base load.
2. Adding DSM measures has to be compared with the costs of adding additional generation capacity together with the cost of any transmission investments that this new generation requires.
3. DSM measures, because of their distributed and often passive nature, often are less risky than supply measures.
4. DSM measures often have a significantly lower social or environmental cost (such as carbon emissions) over new supplies which, as we've pointed out before, are very hard to quantify and hence are not adequately included in the "costs" of the various measures.

6.2. DSM Monitoring and Evaluation

Since what gets measured gets done, it is important that necessary measurements be undertaken in order to access the impact of DSM measures. These DSM and efficiency measures should be implemented following measurement and verification guidelines as is the norm in other utilities.

7. Loss Reduction

The advantages of loss reduction efforts include: reduction of losses, lower voltage drop, higher power factor, and lower distribution transformer failure rate. Key loss reduction initiatives are:

A. High Voltage Distribution System

This entails running 33 and 11kV lines as near as the load possible and installing appropriate capacity transformers to feed small numbers of loads therefore limiting LV lines.

B. Distribution System Reconfiguration

This involves extending high voltage distribution systems to meet new loads or converting existing low voltage distribution systems to high voltage distribution systems.

8. Supply Side Assessment

8.1 The General Approach

The analysis of supply options comprises the following discussions points:

a. Existing power supply options in the Country
b. Hydro power options within and slightly outside the IRP planning horizon
c. Thermal power options within and slightly outside the IRP planning horizon
d. Transmission interconnection options with neighbouring countries
e. Renewable power options within and slightly outside the IRP planning horizon
f. DSM strategies within the IRP planning horizon
g. Compilation of all supply options falling within the planning horizon of the IRP
h. Analysis of Supply – Demand Balance within the planning horizon of the IRP

The analysis of the existing power supply options centered on their installed capacities, and their current and expected challenges and limitations. On the other hand, the hydro, thermal, interconnection and renewable power supply options were assessed and vetted based on the current status of the projects, their associated installed capacities (power and energy), costs and expected commissioning years.

8.2 Existing Supply Options

The existing interconnected power system has its source of supply hydro power stations on the Shire River and a 4.5MW mini-hydro on the Wovwe River. Embedded in the distribution network is also a MVA solar photovoltaic plant at Kamuzu International Airport run by the Airport authority. Table 2 gives details of ESCOM's hydro-generation plants. Nkula A is not in good condition and will be taken out in 2017 for rehabilitation. When recommissioned in the following year, it is expected to increase its capacity from 3x8MW to 3x12MW. The existing operating capacity of ESCOM is therefore 351.7MW. ESCOM carries a system operating reserve of 10MW.

Table 2: ESCOM current installed plants

Plant	**Nkula A**			**Nkula B**					**Tedzani I/II**				**Tedzani III**		**Kapichira**				**Wovwe**		
Unit No.	1	2	3	4	5	6	7	8	1	2	3	4	5	6	1	2	3	4	1	2	3
Power per unit (MW)	8			20					10				26		32				1.45		
Year Commissioning	66	66	67	80	81	85	86	92	72	72	76	77	96	96	00	00	13	13	95	95	95
Years in Service	49	49	48	35	34	30	29	23	43	43	39	34	19	19	15	15	2	2	20	20	20
Current Plant State	Poor			Fair					Good				Good		Excellent				Good		

8.3 Limitations of Existing Plants

The existing hydro power stations have often been affected by trash, silt and climatic changes. Silt and trash challenges are being addressed by:

a. Acquisition of a weed harvester at Kamuzu Barage, Liwonde as well as possibly at power stations.
b. Acquisition of dredgers for silt removal and
c. Establishment of a trust under MCC compact to manage upstream activities and
d. Rehabilitation of Kamuzu Barrage to control water flows at Liwonde under World Bank funding.

In the Masterplan Malawi Study by Lahmeyer International, 1998, two projects were identified for immediate implementation for security of supply in Malawi. These were the Mozambique – Malawi Interconnection and Mangochi Pumping Scheme. Both projects have not yet advanced to implementation although there is again renewed interest in the Interconnection. The Mangochi Pumping Scheme is a Government project but ESCOM may need to follow up with the Government as it has invested heavily on this River and it stands the most to lose. Issues of climatic changes are receiving wide international coverage and studies are being conducted by leading international institutions even at regional levels. International organisations and universities are carrying out regional simulations of the various hydrological systems. The possibilities of support from other river basins in times of distress is therefore highly recognized.

8.4 Committed Supply Options with Fundin

Committed supply options are those where there is a demonstrated commitment to the project implementation during the period 2016 – 2020. This covers technical feasibility and financing. ESCOM is currently implementing the following power supply projects:

1. 10MW diesel peaking plant in Lilongwe expected on line by 2016 and funded by ESCOM.
2. 6MW diesel peaking plant in Mzuzu currently under procurement and funded by ESCOM. It is expected on line by 2017.

3. 23MW Tedzani IV under procurement and funded by JICA. This is expected on line by 2018.
4. 300MW Kammwamba Coal Fired plant being championed by Government of Malawi. Plans are to bring 10% of output on line by 2019 and 90% by 2020 with the final 100% by 2021.

8.5 Committed Supply Options Under Feasibility and Design Study

Government is undertaking several feasibility and design studies of power sources which could be implemented, at least partly, within this short term of 2016 – 2020. Here is a brief summary of the projects:

A. Songwe River Basin Hydro Electric Project Phase I

This is a joint project by Governments of Malawi and Tanzania. In both countries Departments of water have taken the lead. African Development Bank funded the feasibility and design studies. The final Design Report was expected end of 2015. Funding and other administrative issues are expected to be finalized in 2016. This project will be commissioned in 2022 with 90MW reserved for each country. Although it is outside the current window of interest, it will have an impact on other project financing and implementation being undertaken within 2016 -2020. Power evacuation under this project will be at 132kV. This is necessary for electrification projects in Karonga and Chitipa which have been included under the Songwe River Hydro Electric Project.

B. Mpatamanga Hydro Electric Project

The ongoing studies up to detailed design are funded by the World Bank. The feasibility report is expected to be out in 2016. Mpatamanga is expected to be a peaking plant generating up to about 350MW. It will have a large reservoir expected to be of much benefit to investments downstream like Kapichira Power station, the future Hamilton Falls Hydro Electric Project and also the Lower Shire Irrigation Project. Current estimates are that the power station will be on line by 2021. Power is expected to be evacuated through the new Phembeya Substation.

C. Kholombidzo Hydro Electric Project

The feasibility and design studies are being funded by the African Development Bank. The choice will be either run off river which will generate about 100MW or with some storage sized according need to environmental and social impact demands. Kholombidzo is very close to the new Phombeya Substation through which power is expected to be evacuated. The feasibility report is expected to be delivered in 2016.

D. Lower Fufu Hydro Electric Project

The feasibility study and detailed design of this project is funded by the World Bank. The project will be on South Rukuru River with North Rumphi and Lower Fufu River transfer. The location is independent of the other power stations and also Phombeya Substation. For system stability, its location would greatly enhance security of the power system and also reduce losses. However system optimization would require the above feasibility studies due sometime in 2016.

The scope of works for Lower Fufu involve extensive tunneling and may cause delay in the completion of the project. A proposal from the consultant is to have phase 1 of the project commissioned with flows from one river and with other river flows being augmented.

E. Cogeneration (Renewable)

The proposal is to use bagasse from Illovo sugarcane mills at Dwangwa and Nchalo to generate power for the grid. This comes under renewable energy. The study is being funded by the World Bank and expected to be finalized in 2016. The project has a quick implementation period. At Dwangwa, a 5MW can be injected into the grid in one year and this can be followed by 20MW at Dwangwa and 35MW at Nchalo by 2018. Unlike other renewables, this type is dispatchable and does not cause system instability due to sudden changes in its output. It is proposed that its developments should be done by an IPP or PPP.

F. Geothermal

Government is recruiting a consultant to scan and identify potential sites for geothermal. This will be followed by drilling the likely site. While geothermals are a very attractive source of power, it is prudent to be conservative about the likelihood of a find at this phase. The project is part of World Bank funded package.

8.6 Transmission Interconnection with Neighbouring Countries

8.6.1 Interconnectors under feasibility

A. Mozambique – Malawi Interconnection

This is the first phase of interconnection between Malawi and Mozambique at 400kV and will connect Tete in Mozambique and Phombeya in Malawi. The initial design for this line was to construct a line with a transmission capacity of 280MW during drought conditions. The line is currently having its feasibility and design updated and is expected to be commissioned in 2018. EDM has committed to provide 50MW as part of the agreement. World Bank is funding this SAPP project.

B. Malawi – Tanzania Interconnection

A SAPP Regional Generation and Transmission Expansion Plan Study by Nexant and funded by the World Bank in 2009 recommended that "the planned projects to interconnect ESCOM and TANESCO be given high priority and accelerated to the extent possible". The World Bank is currently funding a feasibility study to interconnect Malawi and Tanzania with a 400kV line from Nkhoma in Malawi via Songwe to Tanzania. This project will also interconnect the SAPP with the Eastern African Power Pool making Malawi a key player in the power trade.

C. Zambia – Malawi Interconnection

The feasibility study for this interconnection is being funded by the World Bank. An MoU was signed between the Governments of Malawi and Zambia to facilitate project implementation. This line will be at 330kV connecting Chipata in Zambia to Nkhoma in Malawi.

8.6.2 Interconnectors at concept stage

A. Malawi – Mozambique Interconnector

The second phase of interconnection with Mozambique will involve the construction of a 400kV line from Phombeya in Malawi to Nampula (Nacala) Province. This will enable Malawi wheel power from the energy rich Tete Province (Both Hydro and Coal Power stations) to Nampula Province. This interconnection offers a great relief in power deficit through power imports and also sets open a door for exports to the regional market in times of excess power as well as an opportunity for railway electrification from Phombeya substation.

B. Zambia-Malawi Cross-border Connection

The Border town of Lundazi in Zambia is supplied by a 33kV line from Chikangawa, Malawi which is a terminal substation on a 66kV line from Chintheche. Malawi is short of power in the short term when there are projects like Shayona Cement and other mines which are expecting to receive power within the first quarter of 2017. Malawi can address its short term power shortage by upgrading the Lundazi – Chikangawa – Chintheche to 132kV which can deliver about 30MW. The line could be built on monopole making it faster to construct and vandal proof. The line would greatly improve voltage profiles from Salima northwards. Chikangawa is about 76km from Lundazi and 71km from Chintheche. It is quicker and cheaper to do this option compared to the other options.

8.7 Other Renewable Power Options

Apart from mini-hydro power and cogeneration potential plants, other renewable power generation options also exist in Malawi. These include concentrated solar power (CSP), solar photovoltaic (PV) and wind. Most of these options can be developed for either grid connection or off-grid use. With support from the World

Bank and also the University of Strathclyde, the GoM is looking at potential sites for these renewables. A thorough study however has to be undertaken to validate the development and application of these renewable energy sources in the Country. Annex 1 is a map of Malawi developed by the International Renewable Energy Agency (IRENA) showing the distribution of renewable energy potentials in Malawi.

It is also worth noting that the current ESCOM's grid can only absorb limited amount of power from variable renewable sources such as wind, solar PV and CSP. Some preliminary assessments have indicated that the grid can only take up to 20 MW of such variable power source on the existing network. Solar PV technology takes lots of land and for a country like Malawi with very high population density this needs to be handled with care. In situations like these, reclaimable land can be used.

In other countries, solar PV are installed on roof tops instead. This option should be pursued. This enables this generation of power not to be restricted to few power producers. However the utility (ESCOM) will still have to monitor the total available solar PV capacity to avoid too much generation by solar PV so that the network cannot be overwhelmed.

For this reason, it is suggested that Government institutions like colleges, hospitals, car parks etc. become part of the scheme either with Government direct investment or with the utility making such an investment by renting the roofs. The scheme can be extended to the private sector when appropriate framework have been formally developed and passed.

Besides the interconnected system, ESCOM also operates two isolated systems at Likoma and Chizumulu Islands which are supplied by diesel generators. At the moment generators only run for less than 8 hours a day and are switched off at 22:00. The maximum demand for each generating plant is below 150kW. Within the next five years, minigrid solar modules are planned to be installed starting with Likoma. These plants are designed to operate in conjunction with the existing diesel plants to reduce the fuel bill and the duration of blackouts.

8.8 Demand – Supply Balance (2016 – 2020)

Figure 5 is a profile of the Malawi power system for a week in 2014. The normal peak for ESCOM and most SAPP members is in the evening. It is apparent that there is abundant surplus power between 21:30 and 04:30 the following day.

It is critical to note from the demand profile shown in Figure 5 that the minimum load is about 150MW which is met adequately from existing hydro power stations which are run off river with no storage capacity. From one angle, this implies that a coal fired power plant with individual units of capacity higher than 50MW would create a challenge locally during the off peak period. The solution would be to engage the mining investors so that they are able to consume this power during the off-peak period. This should be confirmed with the individual potential investors as some have not yet developed their proposals to a point where they enter into negotiations with ESCOM concerning their power requirements during construction of the mine or its operation.

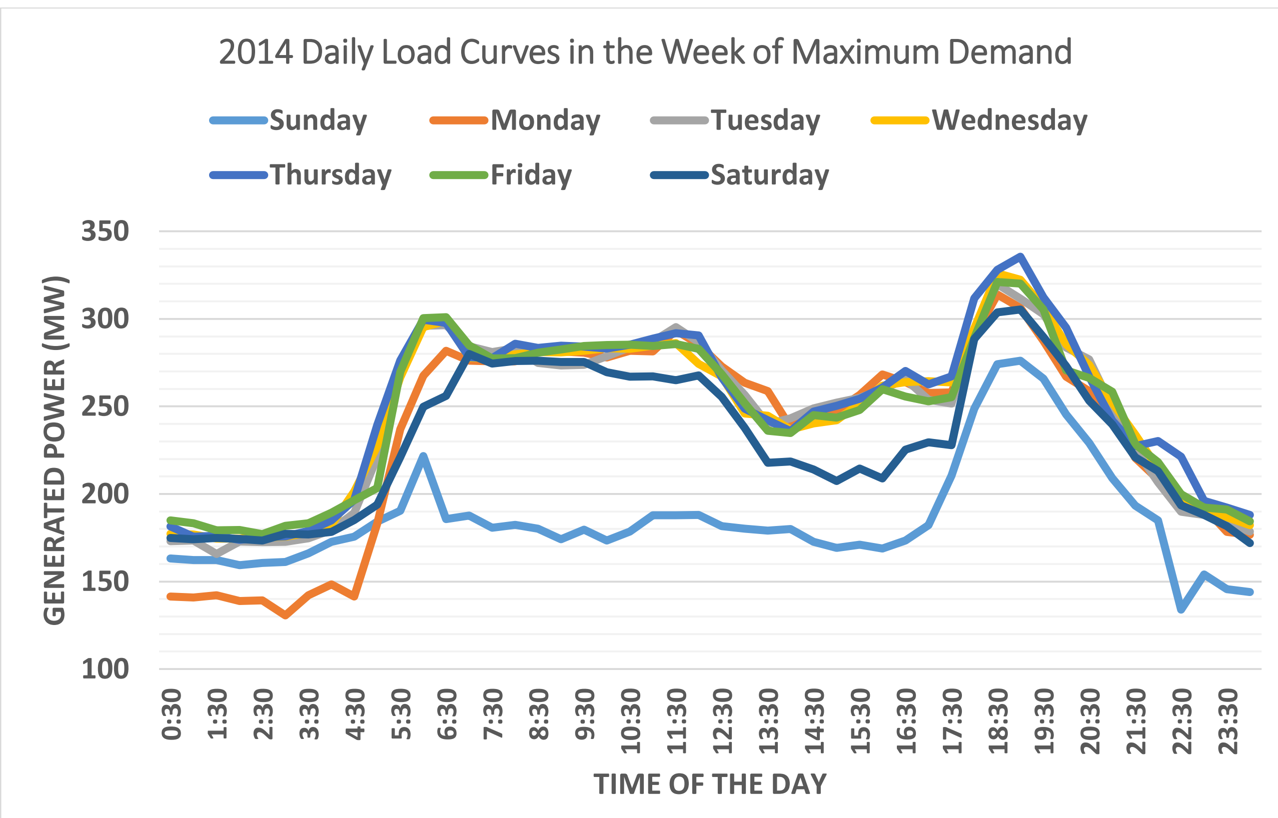


Figure 5. Load profile of ESCOM system

Comparing the demand forecast and supply options that are expected to be commissioned within the time frame of this IRP gives a clear indication of the energy situation in Malawi and, ultimately, an impetus to accelerate some supply projects where possible.

It should be noted that the demand forecast presented earlier on does not include transmission and distribution system technical loses which stand at 13% (FINOP Losses study, 2015) and a provision for a spinning reserve (7.5%). These (loses and spinning reserve) need to be factored in to accurate gauge the power generation requirements. Table 3 thus displays the total Malawi energy supply needs taking into account the losses and spinning reserve over and above the forecasted demand.

Table 3: The 2016 - 2020 energy supply requirements

Scenario	2016	2017	2018	2019	2020
Low Scenario	602.94	646.76	693.18	742.36	794.41
Base Scenario	619.43	682.09	749.89	823.15	902.24
High Scenario	635.34	715.74	803.24	898.31	1001.5

Note: Figures capture demand forecast plus technical losses and spinning reserve

On the supply side, considering the current state of the projects, most of the major power stations will come on line in or beyond 2020. This has led to lack of significant change in the total installed capacity over the years until 2020. Table 4 shows the growth of Malawi's installed capacity as new (likely) power projects come on the grid.

Table 4: Likely power supply sources to be commissioned (2016 – 2020)

Power Plants	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Existing Plants (ESCOM & self-generation)	386*	386	362**	386	386	386
Diesel (Kanengo)		10	10	10	10	10
Bagasse Illovo Phase I			11	11	11	11
Zambia - Malawi 132kV Cross Border Connection			30	30	30	30
Diesel (Mzuzu)			6	6	6	6
Nkula A HPP Upgrade				12	12	12
Bagasse Illovo Phase II				40	40	40
Diesel (Kanengo)				10	10	10
Diesel (Mapanga)				20	20	20
Lweya HPP					15	15
Tedzani IV HPP					22	22
Mbongozi HPP					41	41
Chizuma HPP					50	50
Mozambique - Malawi 400kV Interconnector					50	50
Kammwamba - Coal					50	250
Kholombidzo HPP						200
Total Installed Capacity	**386**	**396**	**419**	**525**	**753**	**1153**

Note: * Self generation (not to be confused with back-up) includes Kayerekera, Lujeri Tea estate, Dwangwa and Nchalo.
**The capacity goes down because Nkula A power station will be out for rehabilitation in 2017 under the MCC-Malawi Compact.

The list in Table 4 omits the commissioning of any solar PV plant within the planning horizon. This is because, though it is highly likely that such a plant will be commissioned in the IRP period, it will not have any effect on the peak demand which is usually an evening peak for Malawi. The impact will however be on the non dispatchable energy generated (GWh) which currently cannot be stored or banked due to absence of those facilities such as batteries.

Plotting the demand forecast (plus technical losses and spinning reserve) and total installed capacity across the years on the same graph shows significant power deficits. Figure 6 shows the demand supply balance whilst Figure 7 shows the overall power deficits expected in the country over the 2016-2020 period.

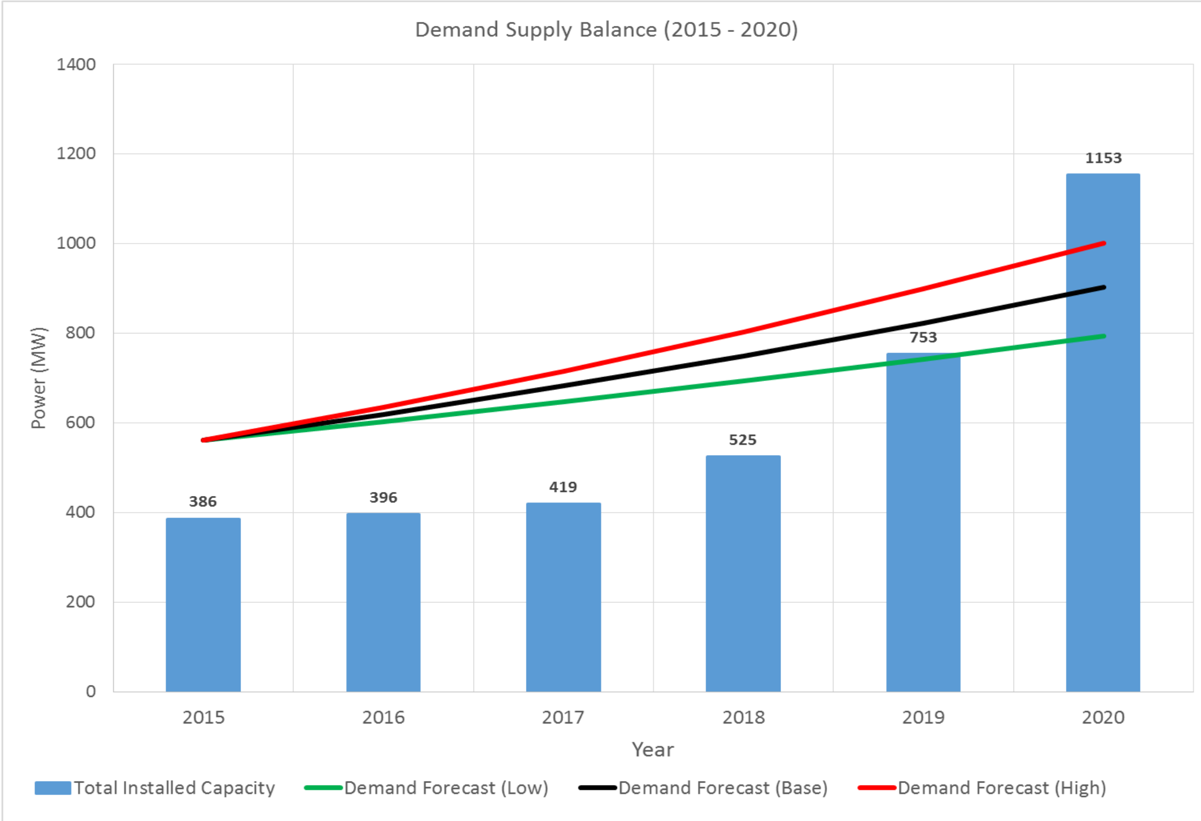


Figure 6: Demand – Supply Balance (2015 – 2020)

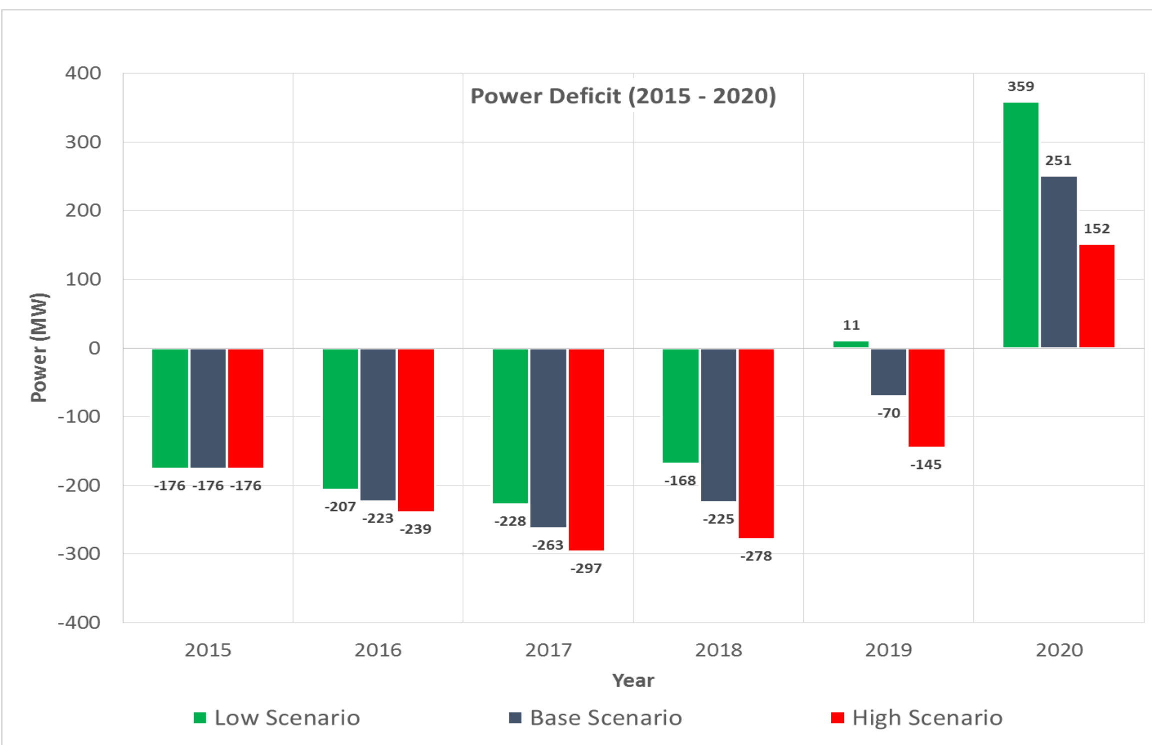


Figure 7: Peak Power Deficit (2015 – 2020)

A comparison of the available and likely supply options to be implemented within the time frame of the IRP shows that the peak power deficit will keep worsening until the year 2019 when some few power generation options will be on line. It is only in the year 2020 when the country is expected to have excess power. Therefore, there is need to optimize the power supply options available as well as make efforts to meet current and future power demands.

9 Transmission Adequacy Study

9.1 General Approach

Following the projected demand up to 2020, a disaggregation of demand has to be made so that the transmission network services the load centres. Major step loads are known where there will be likely provided. ESCOM also provided likely loads at the remaining nodes based on their knowledge of the system. Table 5 lists the likely step loads of at least 5 MW expected to come before 2020.

Table 5. Step loads, 2016 - 2020

#	Project	MW	Year on line
1	Heavy Mineral Sand, Makanjira	Above 50	Not known
2	Heavy Mineral Sand, Tengani	15	Not known
3	Kayelekera Mine	13	2017
4	Shayona Cement	8	2017
5	Kanyika Mine	20	2018
6	Mkango Mine	7	2018
7	Graphite Mine, Lilongwe	5	Not known
8	Bwanje Cement	15	2017
9	Greenbelt, Salima	5	2016
10	Blantyre Water Board	15	2018/19
11	Lilongwe Water Board	10	2016
12	Irrigation, Golomoti	7	2017

In order to serve the existing demand better and also cater for expected increase in demand, ESCOM has embarked on some transmission expansion projects co-funded by Millennium Challenge Corporation and the World Bank. These are expected on line by 2018. Annex 2 lists the MCC-Malawi Compact transmission projects and World Bank funded power projects.

ESCOM is also undertaking several feasibility studies on transmission projects using own resources and some assistance from the World Bank. Table 6 lists the projects being funded by the World Bank (except for the Malawi-Mozambique extension). However, it is expected that the World Bank will fund the implementation of the Malawi – Mozambique line. As listed in Table 6, the 400kV Malawi – Tanzania interconnection is required by 2022 in order to evacuate power from the Songwe River Power Station on the Malawi – Tanzania Border River. Phase I of the project (Songwe) is due for commissioning in 2022.

Table 6. The 400kV Transmission Interconnection Studies underway.

#	Project	Status	Year on line
1	400kV Mozambique – Malawi Interconnection	Firms procured for Feasibility study	2018/19
2	400kV Malawi – Mozambique (extension)	Feasibility start 2016	Not known
3	400kV Malawi - Tanzania	Feasibility 2016	By 2022
4	400kV Malawi - Zambia	Feasibility 2016	Not known

From the energy supply side assessment, it is clear that most of the proposed supply options are going to be online in 2020. Because of this, a transmission system adequacy study was conducted particularly for the year 2020. The adequacy study took into account the projected demand and the supply options that will be connected to the grid in the mini IRP period. A load flow simulation was done using Digsilent Power Factory software. This was done to gauge the capacity of existing infrastructure to supply current and forecasted load. The output of the system studies thus provide the most effective transmission Infrastructure projects that have to be implemented by year 2020 to allow for sustainable evacuation of power to critical loads. These include:

1. New Double Circuit 132kV Nkhoma to Nanjoka Substation (Salima including transformer upgrade) – Nkhotakota – Dwangwa –Chintheche at an estimated cost of US$ 50 Million.
2. New 132kV Dwangwa – Chatoloma transmission line at an estimated cost of US$ 9.7 Million.
3. New 132/33kV Substation in Blantyre at an estimated cost of US$ 6 Million.
4. New 132kV Single Circuit Phombeya – Kangankude – Machinga – Zomba – New Blantyre at an estimated cost of US$ 13.6 Million.
5. Upgrade 66kV Single Circuit Golomoti to Monkey bay Overhead line to 132kV Transmission Line at an estimated cost of US$ 5.4 Million.
6. 132kV Nchalo – Nsanje
7. 132kV Karonga – Kayerekera (energised at 66kV up to 2022)
8. 400kV Nkhoma – Bwengu
9. 132kV Blantyre West – Fundi's X – Mkango
10. 400kV Phombeya - Makanjira

The Malawi network has Shire River in the Southern Region as its major source of generation. This power has to be transmitted over a long distance to loads in Central and Northern Regions. The distances are too long for these type of loads at this voltage. One of the recommendations is a high voltage network. Possible voltage levels are 220kV, 330kV and 400kV. The 400kV was selected because it is the obvious choice after 132kV as the rule of thumb on the optimum separation between transmission voltage levels being at least a factor of three, i.e. 3x132kV. For this reason, the 66kV will be dropped preferring 132kV, 33kV and 11kV. Secondly, the Moz-Mal and Mal-Moz Interconnectors have already been specified at 400kV. The Phombeya – Nkhoma transmission line is specified at 400kV. Since the life of a transmission line on steel or concrete structures is fifty years, a higher voltage than 132kV is recommended for new lines as they will likely reach their optimum loading during their lifespan. For voltage stability reasons, at least a major station is required in the North. Songwe or Lower Fufu Hydroelectric Power station are this category.

10 Distribution and Electrification

This IRP aims at increasing access to electricity from a current value of about 10% to 30% for a base case and 50% for high scenario. These are high rates which will require special strategies in order to meet the targets. Current methods would not be adequate. The current practice is that MAREP (Malawi Rural Electrification Program) is under Government while ESCOM is free to do Peri-Urban electrification.

In order to boost electrification, ESCOM is running a pilot project using ready board for rural connections. The customer may not even have to make advance payment as payment is recovered from prepayment energy purchases. It should be borne in mind that the prepayment meter is not cheap. A rural connection has a very low consumption mostly from less than 6 led lights. This makes this method unsustainable. Further steps will need to be undertaken to move the project towards sustainability including promoting use of hot plates. Normally, low income households use solely charcoal or firewood which use charcoal burner or 3 bricks. These are all made of local materials with no duty, tax or levies whatsoever unlike cookers or hotplates which are so loaded with various taxes. Secondly, quality hot plates and cookers are not cheap. But with Government drive towards massive electrification, the private sector should be engaged to bring these to local market cheaply and reliably with application of tax incentives. Such an investment would make the electrification exercise worthwhile with intention of redressing the deforestation.

Other benefits would include better health as user will no longer have to be exposed to smoke and it will be easier for families to prepare meals.

A robust distribution network is required in order to support the electrification drive. While there are some distribution networks in urban centres, these may require some reinforcements. The distribution system may have been built when specific demand was very low with power being used mostly for lighting. With residents and other customers acquiring more equipment, loading of the circuits has increased despite some implementation of DSM leading to higher network losses, transformer overloads, frequent broken jumpers and fuse blow outs among other challenges. For centres where distribution networks have been in operation for a long time like in Blantyre, it will be necessary to undertake some reinforcements in order to support peri-urban electrification.

11 The Recommended Integrated Expansion Package

11.1 Assessment of Available Expansion Plans

Based on the investment requirements necessary to develop energy infrastructure projects, there was a need to identify the key projects that can kick start Malawi's sustainable energy program for economic growth within and beyond the Mini IRP timeframe.

The following assessment criteria was used to determine priority projects for investment:

- Sustainable energy output,
- Expected benefits of the project,
- Current stage in development,
- Estimated time to commissioning,
- Security of supply,
- No major negative environmental impact,

Tables in Annex 3, 4 and 5 show all the supply options with the energy fuel source, capacity factor, expected energy output and costs. Through a scan of the various documentation available on the displayed supply options (refer to Table 4 and annexes 3, 4 and 5), an analysis of the supply options showed Mpatamanga Hydro Power Project with 2199 GWh; Kammwamba Coal Fired Power Station with 1650 GWh, and Kholombidzo with 1262 GWh as projects which offer the highest energy output, and can be commissioned by the year 2020.

Of the three power stations, Mpatamanga and Kholombidzo are currently undergoing feasibility studies to be completed in the second half of 2016. The Kammwamba Coal fired power station project has already secured financing from the Chinese Government with detailed design work and mobilization expected to commence in 2016.

On further analysis of the pre-feasibility study for Kholombidzo power station, it was noted that the hydrological flows were assumed to be $400m^3/s$ as run of river yet the average recorded flow on the Shire River has been around $200m^3/s$. It is expected that during the feasibility study, an option of damming the river will be considered and there will also be a revision of the flow rate to more realistic figures which will ultimately affect the magnitude of energy output as well as the MW.

Although Mpatamanga offers the highest energy potential and can be dammed to regulate water for positive impacts on power stations downstream (Kapichira), it is, like Kholombidzo and other existing power stations, situated on the Shire River. This offers no diversification to the current source of energy.

An analysis of the three highest ranked base options indicates that Kammwamba Power Station offers diversification and security of supply from Shire River hydro energy followed by Mpatamanga Hydro Power station because of its capacity to regulate the water flow on Shire River (given a damming option) and then Kholombidzo Hydro Power Station.

Load Flow analysis of the various supply options indicated that energizing more supply options in the southern part of the Country with the various transmission infrastructure projects switched in limited the capacity to transfer energy to some of the other key sector consumers located in the Central and Northern Regions of the Country. It is therefore strongly recommended that to fully utilize existing infrastructure and minimize transmission infrastructure investments, another power station has to be commissioned North of the major load centre of Lilongwe City (following the commissioning of a power station in the Southern Region).

From Annex 3, 4 and 5, there are six energy sources located North of Lilongwe City, of which four have details of the potential power and energy output. Of these four, Lower Fufu ranks highest with a potential output of 140 MW (834 GWh) followed by Songwe Hydro Power Site with an output of 90 MW (349.5 GWh); Chizuma with an output of 50 MW (240.96 GWh) and Dwangwa Co-generation with an output of 11 MW (31.40 GWh) in that order.

System Studies show that the construction of either Songwe or Lower Fufu provide better system stability, improved system losses and high quality supply to key economic sectors in the Central and Northern Regions of the Country. Looking at the current stages of the projects, Songwe is one phase ahead of the Lower Fufu Project (Refer to Annex 3). For this reason, it is recommendable at a fast glance that the implementation of Songwe River Project be fast tracked. Nevertheless, considering that Songwe is a cross-border project with a significant number of stakeholders that could affect its implementation speed, it is advised that the Lower Fufu project should be developed in parallel. At the moment, Lower Fufu Power Station is at feasibility and design study level using funding from the World Bank. Unlike other major substations, Lower Fufu is based on a different waterway, hence it will bring in some independence and reliability to the power system. One river will be diverted into another to augment the flows for increased capacity and energy. To speed up its implementation, Phase 1 of the works may focus on building main tunnels and power station and works.

Although the 11 MW Dwangwa Co-generation project (Refer to Annex 4) has low energy output, it offers the quickest implementable solution with a local energy source which can be regulated. Switching in this energy source also improves system stability and reduces losses. It is therefore suggested that financing arrangements be developed to manage capital expenditure for these smaller projects. This will allow the Nation to free up capital for implementation of the high energy options with lower levelized costs.

As Malawi starts to diversify into variable renewable energy sources, the Country is recommended to develop up to 20 MW of solar energy for grid connection at one of the potential sites identified in the IRENA proposal for Malawi. These projects should however only be effected based on an assessment of the energy output for the proposed site and the levelized cost for the energy on offer. If financially viable, the other potential sites can be used for the development of off grid energy supply which can be considered for connection to the grid after 2020. To ensure system stability given the integration of the non dispatchable solar energy source, there is a need to also include, in the supply package, some standby heavy fuel oil, gas turbines or a diesel energy source to peak on loss of output from the solar farm. It is recommended that an assessment of feasibility studies from potential developers be done by mid-2016 for commencement of implementation at the end of the 2016.

The transmission adequacy studies showed that for high reliability and sustainable energy supply, there is a need to develop the transmission system between the South and Northern Regions of the Country. Switching in the 400 kV Transmission Line from Phombeya to Nkhoma and the 66kV Transmission Line Ring in Lilongwe have significant impacts on improving the reliability and quality of supply to most of the irrigation, manufacturing and service loads and it will also serve as a backbone to supplying most of the mining loads.

Two transmission line backbone projects are also being proposed for investment in this IRP. The first line being a 700 km single circuit transmission line running from Nkhoma through Chatoloma, Bwengu to Songwe (Western Corridor Backbone). The second transmission line runs from Nkhoma through Salima, Nkhotakota, Dwangwa to Chithenche (Eastern Corridor Backbone). An assessment of the transmission options indicate that, despite having a lower energy transfer capacity, the Eastern Corridor Backbone allows for higher connection with new and existing energy sources to current and potential energy consumers while the Western Corridor Backbone Transmission Line (with its higher transfer capacity) offers Malawi the capacity to interconnect and trade power with Zambia, Mozambique and Tanzania.

Taking into consideration 1) the results of the system adequacy study, 2) the proposed sequencing of energy supply options, and 3) the impact of the line in delivering energy from supply to consumers, the Eastern Corridor Transmission line ranks highest for investment within the 2016 to 2020 period. It should be noted however, that within the same period, there is a need to finalize the feasibility study and identify funding for developing the Western Corridor for higher energy transfer, system redundancy and regional power trading.

It was further noted that despite having an adequate transmission backbone and supply sources, there are still large scale infrastructure projects that need to be implemented for effectual power transfer to key energy demand sectors. A financing framework, thus, needs to be established and made available to individuals interested in developing potential sites to ensure timely provision of sustainable energy.

To reduce the current gap between energy supply and demand, it is recommended that throughout the 2016–2020 period, a program on DSM, loss reduction and energy efficiency be made operational to fully utilize the existing energy sources. These targeted initiatives are currently underway but there is a need to develop a country wide structured campaign across Malawi which should be monitored and evaluated to ascertain its effectiveness.

11.2 Recommended Supply and Expansion Package

The analysis above (Section 11.1) shows that the development of supply options should proceed with Kammwamba Power Station. By 2016, an assessment should be finalized and funding should be allocated for the construction of either Songwe or Lower Fufu Power station. It is also recommended that discussions be held among key players of the Illovo Sugar Co-generation project (i.e. with ESCOM and potential funders) to aid its development as well as mobilize resources to commence the project within the first quarter of 2016. Additionally, proper DSM and energy efficiency measures should also be rolled out concurrently with the recommended supply options.

For transmission projects, tender documents for the Eastern Corridor Backbone line should be ready by mid-2016 for contract award towards the end of the same year. In the same vain, there is need to closely track the projects that are connected to the development of this project financed under the ESSP and the MCC-Malawi Compact.

Following the signing of the Interconnector MoU with Zambia and the progress in the feasibility studies for interconnection with Mozambique and Zambia, a decision has to be made by mid-2016 on which of the two interconnectors should receive priority funding. This decision should be based on both technical and financial benefits offered by each interconnector. In the case of the interconnection projects, there is also a need to set up strong teams to track and ensure the quick completion of the Nkhoma and Phombeya Substations funded under the MCC-Malawi Compact.

It is also advised that all IPP's should submit feasibility studies of their projects by the first quarter of 2016 to be evaluated for possible development within the second quarter of 2016. These should be done for all proposed options in both non dispatchable and standby dispatchable energy supplies. Table 7 displays the recommended supply and expansion plan.

Table 7. The recommended supply and expansion plan

Project Name	Capacity (MW)	Capacity (GWh)	CAPEX (m$)	Current Project Status	Expected Commissioning year
Kamwamba Coal	300	1,650	667	Implementation MoU signed between Malawi Government and China-Guezuba	2019–10% 2020–90% 2021–100%
Lower Fufu	140	834	-	Feasibility and Design in Progress	2024
Songwe 1	90	349.5	237	Detailed designing	2022
Illovo Cogeneration – Bagasse Phase I	11	31.40	6.01	Engineering studies	2017
Mozambique – Malawi (400kV)	300	416	140	FS in Progress	2019
Zambia (Chipata) – Malawi (Nkhoma) 330kV	-	-	41.9	MOU Signed. Feasibility Study in progress	-
DSM, Loss reduction, and energy efficiency	40			LED and power factor correction under way; other options being assessed.	
Non dispatchable energy supplies (solar)	20			Unsolicited bids received by ESCOM; vetting process being developed.	2016
New Double Circuit 132kV Nkhoma to Nanjoka Substation (Salima including transformer upgrade) – Nkhotakota – Dwangwa – Chintheche			50	Pre-feasibility	2018/19

12. The IRP Implementation Arrangement

The first milestone in the lead-up to implementing this Mini IRP is its adoption. This entails getting support and formal endorsement of the Mini IRP as Malawi's main energy sector plan by the GoM, MERA, ESCOM, IPPs and other key stakeholders for the period 2015-2020. Once adopted, the GoM should take full responsibility to ensure that all power sector development initiatives comply with the plan.

For successful implementation of the electricity supply options, there is a need to either execute contracts for the purchase and evacuation of power or construct utility-owned facilities. In this regard, a basket resource mobilization approach is pivotal to the mini IRP implementation process. Particularly, the IRP has to be marketed to potential investors in the power sector within and outside the Country. It is also recommended that an IRP implementation team involving key stakeholders be set up to constantly examine and track the financial, technical, legal, social and environmental issues affecting each power project lined up for implementation in the mini IRP implementation period.

During implementation, monitoring and evaluation should be part and parcel of the process to help assess the progress and effectiveness of the IRP. This will provide critical information for the mid-term review as well as the iteration of the integrated resource planning process. It is thus expected that this IRP will be a living document that will be amended with availability of new information or as major key economic and social conditions change over the time span of this IRP.

13. Limitations of the IRP

1. Due to the urgency of this IRP, the development team did not have enough time to exhaustively consult all the key energy stakeholders particularly the potential investors and potential IPPs.
2. The process of vetting potential power supply options was based on available data and feasibility study reports. This approach had its own limitations due to unavailability of actual data and feasibility reports for some of the potential power plants.

14. Conclusion

In order to meet the existing and future energy demand in the period 2015 - 2016, Malawi should take the necessary steps to implement the energy supply options recommended in this mini IRP. Particularly, efforts should be made to accelerate implementation of the recommended supply and expansion package to minimize the period of energy deficit as forecasted in this mini IRP. The development of the transmission infrastructure projects with the right energy supply options will ensure reliable and secure transfer of energy to all electricity consumers in Malawi.

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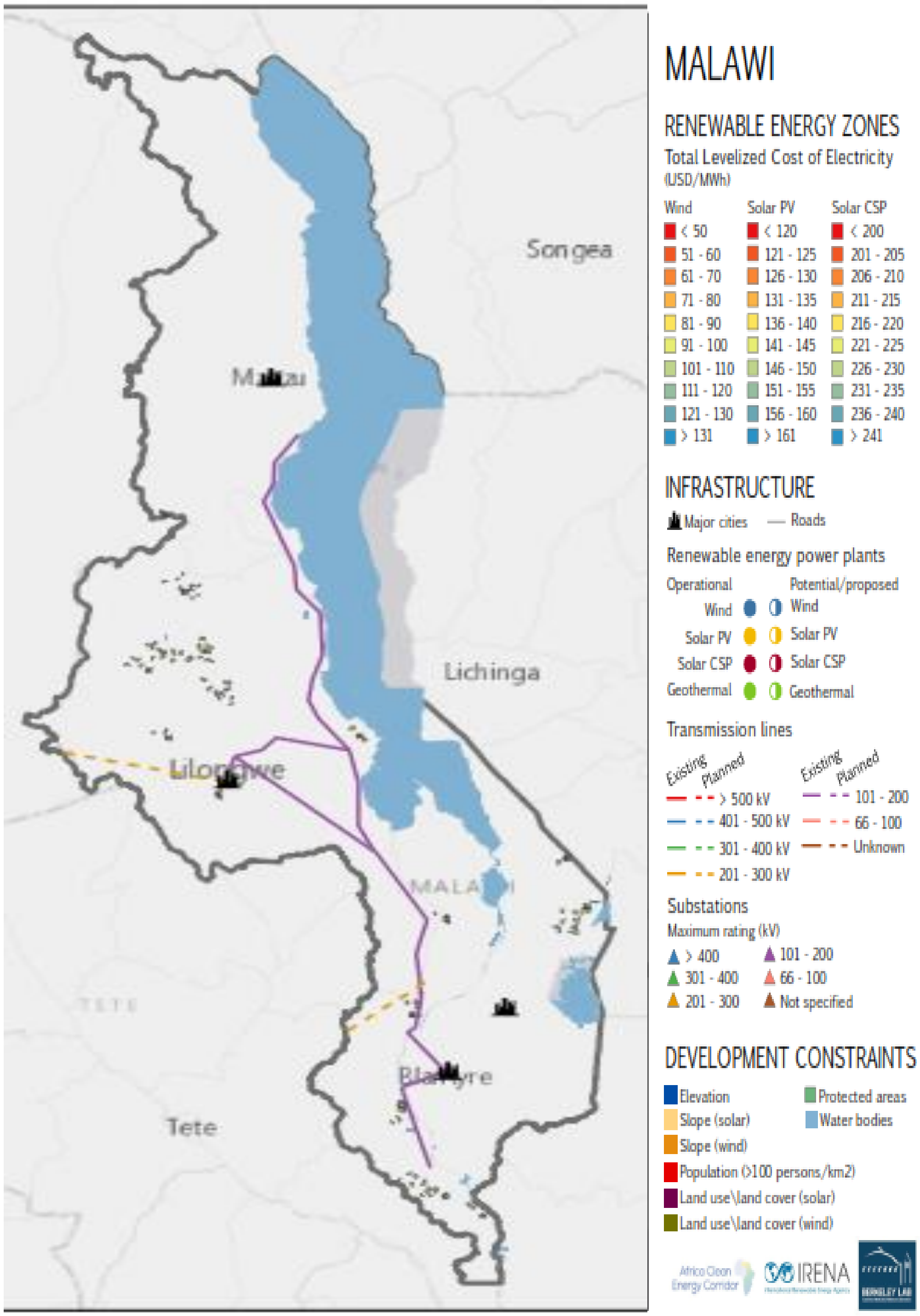
Annexes

1. Map showing distribution of solar energy potentials in Malawi



2. MCC and World Bank funded projects

MCC PROJECTS

1) Construction of a New 400kV Line from Phombeya to Nkhoma
2) Upgrade of 66kV Lilongwe Ring with 3 new 66/11kV Substations
3) Construction of a New 132kV Line from Chintheche to Bwengu
4) Construction of 200 MVA 400/132 kV Phombeya substation
5) Construction of 200 MVA 400/132 kV Nkhoma substation
6) Construction of 132 kV line from Nkhoma to Bunda Turn off
7) 50 MVA 132/66 Bunda Turnoff substation
8) Kang'ombe 66/11 7.5 MVA
9) 25 MVA 132/33 kV Luwinga substation
10) 25 MVA 132/33 kV new Bwengu
11) Upration of 66 kV line from Kanengo to Area 48
12) Upration of 66 kV line from Area 48 to Lilongwe A
13) Upration of 66 kV line from Kanengo to Barracks

World Bank Projects

1) Construction of 132/33/11 kV 25/30MVA Substation at Dwangwa, 66/11kV 15/20MVA at Kauma and 33/11kV 10/15 MVA at Katoto Substation.
2) Construction of 132/33 kV 25/30MVA Substation at Nkhotakota, 132/33/11 kV 25/30MVA Substation at Golomoti, 66/33 kV 15/20MVA Substation at Chingeni, and 33/11kV 10/15 MVA at Balaka.
3) Construction of 66/33 kV 25//30MVA Substation at Nkula, 66/33kV 15/20MVA at Fundis Cross and 33/11kV 10/15 MVA at Bangwe Substation.

3. Potential hydro power options and their statuses

Project Name	Capacity (MW)	Capacity (GWh)	CAPEX (m$)	Current Project Status	Expected Commissioning year
Mpatamanga	350	2,199	639	Feasibility + Design study in progress	2021
Kholombidzo	200	1,242	524	Feasibility study (FS) in Progress	2020
Lower Fufu	140	834	-	Feasibility and Design in Progress	2024
Hamilton Falls	50	240	180	Conceptual level	Not Known
Songwe 1	90	349.5	237	Detailed designing	2022
Chizuma	50	240.90	167	Awaiting financing	2019
Mbongozi	41	197.50	100	Off-taker agreement signed between IPP and Utility	2019
RUO	23	110.8	115	Malawi/Mozambique Border Project. Sourcing financing for FS	2023
Tedzani IV	22	170	75	Procuring EPC contractor	2019
Lweya	15	72.3	45	Pre-FS in progress	2019
Nkula A Upgrade	12	57.8	-	EPC contract award	2018
Tedzani III Upgrade	10	48.2	-	EPC contract award	2022

Note: This list is not exhaustive. Also note that the figures that have been used for projects that have not passed the feasibility study are only indicative of the potential scale of the projects and not confirmed.

4. Potential thermal power plant projects

Project Name	Capacity (MW)	Capacity (GWh)	CAPEX (m$)	Current Project Status	Expected Commissioning year
Kammwamba – Coal	300	1,650	667	Implementation MoU signed between Malawi Government and China-Guezuba	2019–10% 2020–90% 2021–100%
Karonga – Coal	200	1,100	-	FS in progress	2021
Illovo Cogeneration – Bagasse Phase II	40	267	35	FS in progress	2020
Illovo Cogeneration – Bagasse Phase I	11	31.40	6.01	Engineering studies	2017
Chipoka – Coal	-	-	-	Pre – FS in progress	2024
Diesel – Kanengo Phase I	10	17.5	-	Under implementation by ESCOM	2016
Diesel – Mzuzu	6	10.5	-	Procurement of EPC Contractor	2017
Diesel - Kanengo Phase II	10	17.5	-	Awaiting MERA approval in 2017	2018
Diesel – Mapanga	20	35	-	Awaiting MERA approval in 2017	2018

Note: This list is not exhaustive. Also note that the figures that have been used for projects that have not passed the feasibility study are only indicative of the potential scale of the projects and not confirmed.

5. Interconnection and cross-border projects

Project Name	Capacity (MW)	Capacity (GWh)	CAPEX (m$)	Current Project Status	Expected Commissioning year
Mozambique – Malawi (400kV)	300	416	140	FS in Progress	2019
Zambia (Chipata) – Malawi (Nkhoma) 330kV	-	-	41.9	MOU Signed. Feasibility Study in progress	-
Tanzania – Malawi	-	-	-	Feasibility Study in progress	2022
Zambia (Lundazi) – Malawi (Chikangawa) 132kV Crossborder Connection	30	-	-	Conceptual phase.	2017

Note. Among the interconnection projects displayed, the 132kV cross-border connection between Malawi and Zambia is seen as a quick option to relieve the Country of its power deficit. A preliminary value of 30MW is expected to be transferred to Malawi through this line by year 2017.

6. Demand forecast

REVISED METHODOLOGY FOR MODELLING

ELECTRICITY DEMAND IN MALAWI: 2015 – 2020

BY

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REVISED BY ESCOM'S PLANNING DEPARTMENT

25 NOVEMBER 2015

1. Introduction

The Ministry of Natural Resources, Energy and Mining (MNREM) and ESCOM have initiated a process to prepare a mini Integrated Resource Plan (IRP) for the period 2015 – 2020. It is expected that the IRP will become the basis for planning the procurement of electricity generation from the various sources (IPPs, ESCOM and others).

The first step in preparing such a Plan is the preparation of demand forecasts for the period 2015 – 2020. At the present time, there are no accepted official generation forecasts for the period 2015 – 2020. Several electricity demand models and the associated forecasts were prepared in the last few years. These include the ICF/CORE International report of August 2011 and the International Atomic Energy Agency (IAEA) report of January 2011. However, none of these demand models or forecasts has received an approval or endorsement by the Government of Malawi (GoM). Accordingly, the MNREM and ESCOM initiated a new approach to develop a demand modelling methodology and the associated demand forecasts.

The objective of this report is to present the newly developed demand modelling methodology and the associated electricity demand forecasts for the period 2015 – 2020.

In preparing this methodology, the following guiding principles have been used.

- The methodology should support the primary GoM goals of reducing poverty by enhancing economic growth. In this regard, the methodology should take into account the GoM target for access to electricity of 30% to 50% by 2030.

- The methodology should result in a practical modelling and forecasting approach which can assist in preparing demand forecasts for the period 2015 – 2020 with the use of data that are readily available.

- The methodology should assist in preparing electricity demand forecasts disaggregated by key sectors of the economy.

The proposed methodology, and the associated approach to operationalize it, are based on utilizing some of the existing work by the ICF/CORE International and the IAEA. However, the foundation of the methodology is significantly different from the approaches used by ICF/CORE International and the IAEA.

A key assumption employed in the model is that the technological structure of energy demand, including end-use efficiency, in Malawi will remain constant over the period under discussion.

2. Overall Process for Demand Modelling of Electricity Use And Peak Loads

The overall process for demand modelling of electricity use and peak loads is shown in Figure 1:

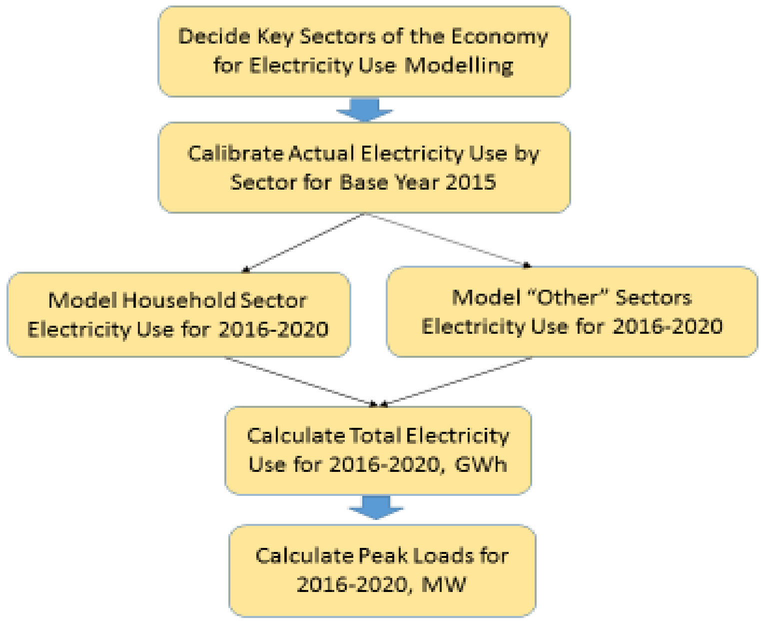

Figure 1. Overall Process for Modelling Electricity Use and Peak Loads.

The process comprises the following parts.

- Decide key sectors of the economy for modelling of electricity use (discussed in Section 3).
- Calibrate actual electricity use by sector for Base Year 15 (discussed in Section 3).
- Model Household sector electricity use for 2015 – 2020 (discussed in Section 4).
- Model "Other" sectors electricity use for 2015 -2020 (discussed in Section 5).
- Calculate total electricity use for 2015 – 2020 (discussed in Section 6).
- Calculate peak loads for 2015 – 2020 (discussed in Section 7).

Following the development of a demand model and the formulation of demand forecasts, further steps are required to prepare the IRP for the period 2016 – 2020. They are discussed in Section 8.

3. Calibration of Base Year (2014/15) Electricity Use Data

3.1 Actual electricity use

For the 2014/15 financial year, the total amount of electricity used as captured at consumption point is estimated to be 2105.93 GWh. This figure includes the following:

- Total consumption by ESCOM customers,
- Estimates of load shedding,
- Estimates of consumption from those who generate their own power.

3.2 Economic Sectors

This electricity demand forecast uses the household sector and five other sectors of the economy as categorized in the Malawi national accounts data. These are:

- Household
- Agriculture
- Construction
- Mining
- Manufacturing
- Services

3.3 Calibration of Electricity Use for Base Year 2014/15

The objective of this part of the methodology is to calibrate "actual" electricity use data disaggregated by the six sectors.

This is achieved by examining the actual electricity consumption by ESCOM customers and those who generate their own power. Figure 2 is a pie chart showing the sectorial electricity consumption.

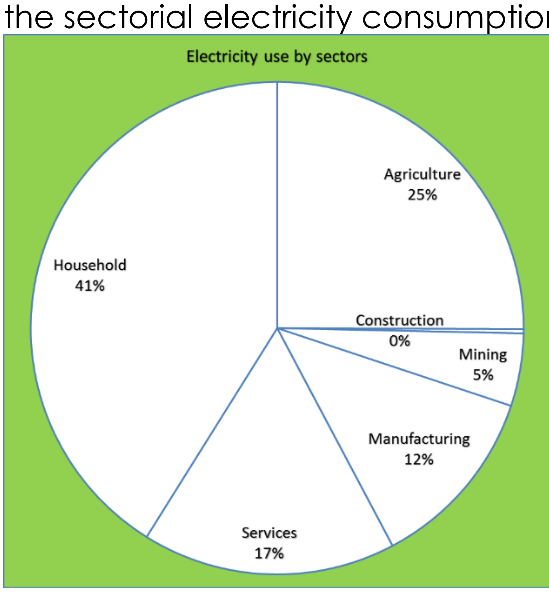

Figure 2

The actual electricity consumed as disaggregated by the six sectors is displayed in Table 1.

Table 1: "Actual" Electricity Use by Six Sectors for 2014/15

Sector	"Actual" Electricity Use from ESCOM, GWh
Household	865.75
Agriculture	527.96
Construction	5.69
Mining	100.45
Manufacturing	255.66
Services	350.43
Total	2105.93

4. Electricity Use for the Household Sector

The objective of Section 4 is to prepare forecasts of electricity use for the Household sector for each financial year of the period 2015 – 2020.

This is achieved in two stages.

- Stage 1, which is described in Section 4.1, is concerned with arriving at values of key parameters for the year 2020.
- Stage 2, which is presented in Section 4.2, is focused on arriving at values of the key parameters, including electricity use for the Household sector, for each financial year in the period 2015 – 2020.

4.1 Data for 2020 for Access to Electricity and Household Numbers Disaggregated by Urban and Rural Households

In this stage (Stage 1) several numerical analyses were undertaken to arrive for 2020 the values of the following parameters:

- Access to electricity for all households;
- Number of urban and rural households; and
- Access to electricity for urban and rural households.

i) Access to Electricity for 2020 for All Households

At present, access to electricity in Malawi is estimated to be at 10%. But the GoM's policy goals require achieving access to electricity for 2030 to a level between 30% and 50%. Therefore three scenarios for access to electricity are created. A Low Scenario that follows the past trend in access to electricity; A Base Scenario representing an optimal path that assumes the target of 30% in 2030 (the lower end of the GoM policy), and a High Scenario that assumes the target of 50% in 2030 (the higher end of the GoM policy).

Given that the present level of access to electricity is10.0%, the access data for 2030 the Low Scenario are estimated by a linear extrapolation of the past trends in electricity access. Data from the World Bank as well as ESCOM's database shows that the level of access to electricity in Malawi has grown from approximately 5% in the year 2000 to 10% in 2015. If the trend in economic performance remain unchanged, the level of access in 2030 is estimated to be at 15% in 2030, which in this study is being considered a Low case scenario. Mere linear interpolation is then used to calculate the values for 2020 and 2025.

For the Base and High Scenarios, the data for access to electricity for 2020 and 2025 are calculated by a linear interpolation between 10.0% in 2015 and 30.0% in 2030 for the Low Scenario and 50% for the High Scenarios in 2030.

All these data are shown in Table 2.

Table 2: Data for Access to Electricity for All Households

	Low Scenario	Base Scenario	High Scenario
2015	10.0	10.0	10.0
2020	11.7	16.6	23.3
2025	13.3	23.3	36.7
2030	15.0	30.0	50.0

(ii) Data for Access to Electricity for Urban and Rural Households

The National Statistical Organization (NSO) used the data from the 2008 Census to prepare projections of numbers of urban and rural households for the period 2010 - 2030. The NSO data for the numbers and percentages for 2010 and 2030 for the urban and rural households are reproduced in Table 4 from ICF/CORE International report (Exhibit 3-3).

These data, shown in Table 3, form the basis for estimating the numbers and percentages of urban and rural households for 2020. The data for 2020 were derived by linear interpretations of data for 2010 and 2030.

To illustrate the process, urban household numbers are chosen. As can be seen from Table 3, urban household numbers are 411,047 and 1,168,788 for 2010 and 2030 respectively.

The urban household numbers for 2015 and 2020 are calculated by linear interpolation of the two numbers 411,047 and 1,168,788. Hence the number for urban households for 2020 in Table 3 is 789,917.

The method for calculating the numbers and the percentages for the urban and rural households is once again the linear interpolation.

Table 3: Urban and Rural Households, Numbers and Percentages for the Period 2010 – 2030.

Year	Urban Household Number	Urban Household %	Rural Household Number	Rural Household %	Total Household Number	Total Household %
2010	411,047	14.0	2,537,309	86.0	2,948,356	100.0
2015	600,482	15.5	3,081,723	84.5	3,682,253	100.0
2020	789,918	17.0	3,626,237	83.0	4,416,150	100.0
2030	1,168,788	20.0	4,715,167	80.0	5,883,945	100.0

(iii) Data for Access to Electricity for Urban and Rural Households

The data for access to electricity for urban and rural households are constructed in the following way.

The data for 2010 for access to electricity for the urban and rural households are derived from the work of ICF/CORE International. ICF/CORE International established that access to electricity for 2010 for urban and rural household were 52.5% and 0.5% respectively (see section 3.4.2. of ICF/CORE International report).

From these data and using the urban and rural household percentages from Table 3; simple arithmetic gives the value for access to electricity in 2010 for all households as 7.8%.

As noted earlier, the data for access to electricity in 2030 for all households are 15%, 30.0% and 50.0% for the Low, Base and High Scenarios respectively. The values for 2015 and 2020 for the Low, Base and High Scenarios are derived from simple interpolation between the 2010 and the 2030 figures. The resulting values for 2015 and 2020 are shown in Table 4.

To arrive at the values for access to electricity for the urban and rural households, the process starts in 2030. For the Low case Scenario, the access to electricity in the urban areas is expected to grow to a level not higher than 70% in 2030. This is based on the historical trend of electricity access in Malawi. The figure of access to electricity in the rural areas is derived by the following equation.

0.70 * PUH + Z * PRH = 0.15 PTH **(3)**

Where:

Z = percentage of rural households having access to electricity in 2030.
PUH = Percentage of urban households for 2030.
PRH = Percentage of rural households for 2030.
PTH = Percentage of total (urban + rural) households for 2030. This equals 100.0 by definition.

By substituting the values of PUH and PRH for 2030 from Table 3, the value of Z is calculated as 1.3% for 2030.

The percentages of access for the urban and rural areas in 2015 and 2020 are derived by interpolation of the 2010 and 2030 respective values. The resulting figures are displayed in Table 4.

A similar process is followed for arriving at rural and urban access levels for the Base and High case Scenarios. The only difference however is; the 2030 urban access level for the Base and High Scenarios has been fixed at 90%. This is what is assumed to be ambitiously high as per GoM aspirations but realistically achievable given the low percentage of urban households in Malawi.

Once the 2030 urban access level is set at 90% for 2030, the process for calculating Base and High Scenario access figures using equation 3 is identical to that used for the Low case Scenario. Table 4 shows the results.

Table 4: Data for Access to Electricity for Urban and Rural Households

	Low Scenario			**Base Scenario**			**High Scenario**		
Year	*Urban Household %*	*Rural Household %*	*Total Household %*	*Urban Household %*	*Rural Household %*	*Total Household %*	*Urban Household %*	*Rural Household %*	*Total Household %*
2010	52.5	0.5	7.8	52.5	0.5	7.8	52.5	0.5	7.8
2015	56.9	0.7	9.6	62.0	4.1	13.4	62.0	10.4	18.4
2020	61.3	1.1	11.4	71.3	7.8	18.9	71.3	20.3	28.9
2030	70	1.3	15	90.0	15.0	30.0	90	40	50.0

(iv) Normalized Data for Access to Electricity for Urban and Rural Households

From Table 4, it is apparent that there is a miss-match between estimated data for 2015 and the ground reality, particularly the Base and High Scenarios.

The estimated data in Table 4 for access to electricity for all households in 2015 are 13.4% and 18.4% for the Base and High Scenarios respectively. However it is known that the percentage of all households having access to electricity in 2015 is 10%. This is similar to the Low case Scenario which has an access level of 9.6% (approximately 10.0%). So to suit the situation on the ground and also match the Low Scenario, total access values for 2015 for the Base and High Scenarios aare set at 10%. For the Low Scenario, the value for access to electricity in the rural areas is assumed to have grown from 0.5 in 2010 to 0.7% in 2015 as shown in Table 4. This is practicable and not far from reality considering the progress made by the rural electrification project in enhancing electricity access in the rural areas over the same period. Therefore it is essential that, for 2015, actual data for access to electricity for all households is set at 10.0% whilst the level of access in rural areas is fixed at 0.7% for all Scenarios.

With 10% total access to electricity and 0.7% access to electricity in the rural areas, values for access to electricity in the urban areas in 2015 are reworked using the following equation:

$$m \times PUH_{2015} + 0.07 \times PRH_{2015} = 0.10 \times PTH_{2015} \qquad \textbf{(4)}$$

Where:

m = percentage of urban households having access to electricity in 2015.

PUH_{2015} = percentage of urban households in 2015.

PRH_{2015} = percentage of rural households in 2015.

PTH_{2015} = percentage of all (urban plus rural) households in 2015. This by definition is 100.0.

The data for percentages of urban and rural households for 2015 are taken from Table 3.

Thus m is calculated as 0.607(60.7%). This is valid for all Scenarios. The data for access to electricity for 2020, for all Scenarios are calculated by a linear interpolation of the corresponding data between 2015 and 2030. The resulting data are shown in Table 5.

Table 5: Normalized Data for Access to Electricity for Urban and Rural Households, Percentages

	Base Scenario			**Low Scenario**			**High Scenario**		
Year	*Urban House hold %*	*Rural Hous ehold %*	*Total House hold %*	*Urban House hold %*	*Rural House hold %*	*Total House hold %*	*Urban House hold %*	*Rural House hold %*	*Total House hold %*
2010	52.5	0.5	7.8	52.5	0.5	7.8	52.5	0.5	7.8
2015	60.7	0.7	10	60.7	0.7	10.0	60.7	0.7	10.0
2020	63.8	0.9	11.7	70.5	5.5	16.7	70.5	13.8	23.3
2030	70	1.3	15	90.0	15.0	30.0	90.0	40	50.0

4.2 Electricity Use for the Household Sector for the Period 2016 – 2020

In this stage (Stage 2), several numerical analyses were undertaken.

Firstly, a numerical analysis was undertaken to arrive at values of average electricity use for the Base Year 2015 for the Urban and Rural Households.

Subsequently, a number of numerical analyses were undertaken to arrive at, for each year of the period 2016 – 2020, values of the following parameters:

- Numbers and percentages of urban and rural households;
- Access to electricity in percentages for the urban and rural households; and
- Total electricity use for the Household sector.

These are now discussed.

(i) Average Electricity Use for the Urban and Rural Household for the Base Year 2015

The fundamental equation used for calculating average electricity use for urban and rural households is:

$$AAEUUH_{2015} * NUH_{2015} * PUHAE_{2015}/100 + AAEURH_{2015} * NRH_{2015} * PRHAE_{2015}/100 = TEUAH_{2015} * 10^6 \quad (5)$$

Where:

$AAEUUH_{2015}$ = Average electricity use for urban households for 2015, kWh.

NUH_{2015} = Number of urban households in 2015.

$PUHAE_{2015}$ = Percentage of urban households having access to electricity in 2015.

$AAEURH_{2015}$ = Average electricity use for rural households for 2015, kWh.

NRH_{2015} = Number of rural households in 2015.

$PRHAE_{2015}$ = Percentage of rural households having access to electricity in 2015.

$TEUAH_{2015}$ = Total electricity use for all households in 2015, GWh.

It is further assumed that: AAEUUH = 3.0 * AAEURH ***(6)***

In other words, an average urban household in Malawi, in 2015, uses three times as much electricity as an average rural household. This is a typical consumption pattern for most developing countries. Additionally, this aligns well with the NSO's Individual Housing Survey 3 finding that poverty incidence in the urban areas is three times less than in the rural areas.

The values of NUH and NRH for 2015 are obtained from Table 3.

The values of PUHAE and PRHAE for 2015 are obtained from Table 5.

The value of TEUAH for 2015 is obtained from Table 1.

By substituting these values into equation (5), the values of AAEUUH and AAEURH for 2015 are calculated as 2329.26 KWh and 776.42 KWh respectively.

This is shown in Table 6.

Table 6: Average Electricity Use for Urban and Rural Households for 2015

Average Electricity Use, Urban Household, kWh	Average Electricity Use, Rural Household, kWh
2329.26	776.42

(ii) Urban and Rural Households for Each Year in the Period 2016 – 2020: Numbers and Percentages

Table 7: Urban and Rural Households: Numbers and Percentages

The numbers and percentages of the urban and rural households for each year in the period 2015 – 2020 is shown in Table 7.

Year	Urban Household Number	Urban Household %	Rural Household Number	Rural Household %	Total Household Number	Total Household %
2015	600,482	16.3	3,081,723	83.7	3,682,253	100.0
2016	638,369	16.6	3,190,626	83.4	3,829,032	100.0
2017	676,256	16.9	3,299,529	83.1	3,975,811	100.0
2018	714,143	17.3	3,408,432	82.7	4,122,590	100.0
2019	752,030	17.6	3,517,355	82.4	4,269,369	100.0
2020	789,917	17.9	3,626,237	82.1	4,416,150	100.0

The numbers and percentages for 2015 and 2020 are obtained from Table 3.
The values for years 2016, 2017, 2018 and 2019 are obtained from linear interpolations.

(iii) Access to Electricity for Urban and Rural Households for Each Year in the Period 2015 – 2020

The urban and rural households having access to electricity, in each year in the period 2015 – 2020, are shown in Table 8.

Table 8: Access to Electricity for Urban and Rural Households Percentages; 2015 – 2020

	Low Scenario			**Base Scenario**			**High Scenario**		
Year	Urban House hold %	Rural House hold %	Total House hold %	Urban House hold %	Rural House hold %	Total House hold %	Urban House hold %	Rural House hold %	Total House hold %
2015	60.7	0.7	10	60.7	0.7	10	60.7	0.7	10
2016	61.32	0.74	10.34	62.66	1.66	11.34	62.66	3.32	12.66
2017	61.94	0.78	10.68	64.62	2.62	12.68	64.62	5.94	15.32
2018	62.56	0.82	11.02	66.58	3.58	14.02	66.58	8.56	17.98
2019	63.18	0.86	11.36	68.54	4.54	15.36	68.54	11.18	20.64
2020	63.8	0.9	11.7	70.5	5.5	16.7	70.5	13.8	23.3

The values for 2015 and 2020 are obtained from Table 5. The values for years 2016, 2017, 2018 and 2019 are obtained by linear interpolations.

(iv) Total Electricity Use for the Household Sector for Each Year in the Period 2016 – 2020

For calculating total Household electricity use for 2016, 2017, 2018, 2019 and 2020, Base Year 2015 is used as the starting point.

The following equation is used for calculating the electricity use for the Household sector.

$$THEUU_n = AAEUUH_{2015} * (1+GDPG*0.6/100.0)^n \frac{*NUHn*PUHAE_n}{100} + AAEURH_{2015} *(1+GDPG*0.2/100.0)^n \frac{*NRHn*PRHAE_n}{100} \quad \textbf{(7)}$$

Where:

THEUU =	Total Household electricity use.
$AAEUUH_{2015}$ =	Average annual electricity use for urban households for 2015.
GDPG =	Annual growth rate for GDP for the period 2016 – 2020, percentage.
NUH =	Number of urban households.
PUHAE =	percentage of urban households having access to electricity.
$AAEURH_{2015}$=	Average annual electricity use for rural households for 2015.
NRH =	Number of rural households.
PRHAE =	Percentage of rural households having access to electricity.

And

Where *n* = 1for year 2016
2 for year 2017
3 for year 2018
4 for year 2019
5 for year 2020

Equation 7 embodies the following assumptions.

- Average annual electricity use per urban household increases, during the period 2016 – 2020, at 60% of the GDP growth rate.

- Average annual electricity use per rural household during the period 2016 – 2020 increases at 20% of the GDP growth rate.

These assumptions are based on the fact that the average annual growth in total household electricity use over the past 5 years (since 2009) was at 80% of the average annual GDP growth rate during the same period. The apportionment of 60% growth for urban households and 20% for rural households was made to maintain the 3-to-1 urban-rural electricity use ratio 1 as expressed in equation 6.

The following annual GDP growth rates are assumed during the period 2016 – 2020:

- 5% for the Low Scenario
- 6% for the Base Scenario
- 7% for the High Scenario

The annual GDP growth for the Low Scenario is fixed at 5% because the average annual GDP growth rate for Malawi since 2009 was approximately 5%. Applying a 20% and 40% mark-up on the 5% rate in the Low Scenario gives us annual GDP growth rates of 6% and 7% for the Base and High Scenarios respectively.

The calculated values for the electricity use for the urban and rural households and for the Household Sector are sown in Table 9.

Table 9: Total Electricity Use for the Household Sector; 2015 – 2020

	Low Scenario			**Base Scenario**			**High Scenario**		
Year	Total Urban Household Electricity Use, GWh	Total Rural Household Electricity Use, GWh	Total Household Electricity Use, GWh	Total Urban Household Electricity Use, GWh	Total Rural Household Electricity Use, GWh	Total Household Electricity Use, GWh	Total Urban Household Electricity Use, GWh	Total Rural Household Electricity Use, GWh	Total Household Electricity Use, GWh
2015	849	16.75	865.75	849	16.75	865.75	849	16.75	865.75
2016	939.14	18.52	957.66	965.25	41.62	1006.87	970.84	83.07	1053.91
2017	1035.08	20.38	1055.46	1092.49	68.74	1161.23	1105.18	155.23	1260.41
2018	1137.13	22.36	1159.49	1231.48	98.19	1329.67	1253	233.4	1486.4
2019	1245.61	24.44	1270.05	1383.04	130.04	1513.08	1415.36	317.72	1733.08
2020	1360.84	26.63	1387.47	1548.06	164.37	1712.43	1593.41	408.36	2001.77

5. Electricity Use for Other Sectors

The equations used to arrive at electricity uses, for other sectors for each year in the period 2016 – 2020, are given below.

$$AGTEU_n = AGTEU_{2015} * (1 + GDPG*1.2/100)^n \quad \textbf{(6)}$$

$$CONTEU_n = CONTEU_{2015} * (1 + GDPG*0.8/100)^n \quad \textbf{(7)}$$

$$MNTEU_n = MNTEU_{2015} * (1 + GDPG*1.2/100)^n \quad \textbf{(8)}$$

$$MNFTEU_n = MNFTEU_{2015} * (1 + GDPG*0.6/100)^n \quad \textbf{(9)}$$

$$SERTEU_n = SERTEU_{2015} * (1 + GDPG/100)^n \quad \textbf{(10)}$$

Where:

AGTEU = Total electricity use in the Agriculture sector

CONTEU = Total electricity use in the Construction sector

MNTEU = Total electricity use in the Mining sector

MNFTEU = Total electricity use in the Manufacturing sector

SERTEU = Total electricity use in the Services sector

n = 1 for year 2016
2 for year 2017
3 for year 2018
4 for year 2019
5 for year 2020

And suffix 2015 denotes year 2015.

The basic assumptions made in equations 6 to 10 are based on the trend analysis of the average annual growth rate registered by the individual sectors over the past years (since 2009) relative to average annual GDP growth. On that basis,

- Electricity use in the Agriculture and Mining sectors increases at 120% of the GDP rate of growth.
- Electricity uses in the Manufacturing and Construction sectors respectively increase at 60% and 80% of the annual GDP growth rate.
- Electricity use in the Services sector increases at the rate of GDP growth.

As earlier assumed, GDP growth will be at 5%, 6% and 7% for the Low, Base and High Scenarios respectively.

The total electricity use data for each of the "Other" sectors for 2015 are obtained from Table 1.

The calculated electricity use for the "Other" sectors for the period 2016 – 2020 are shown in Tables 9, 10 and 11 for the Low, Base and High Scenarios in that order.

Table 9. Total Electricity Use for Other Sectors, 2015- 2020, Low Scenario, GWh

Year	Agriculture	Construction	Mining	Manufacturing	Services	Total Other Sectors
2015	527.96	5.69	100.45	255.66	350.43	1240.19
2016	559.64	5.92	106.48	263.33	367.95	1303.32
2017	593.22	6.15	112.87	271.23	386.35	1369.82
2018	628.81	6.40	119.64	279.37	405.67	1439.89
2019	666.54	6.66	126.82	287.75	425.95	1513.72
2020	706.53	6.92	134.42	296.38	447.25	1591.5

Table 10. Total Electricity Use for Other Sectors, 2015 – 2020, Base Scenario, GWh

Year	Agriculture	Construction	Mining	Manufacturing	Services	Total Other Sectors
2015	527.96	5.69	100.45	255.66	350.43	1240.19
2016	565.97	5.96	107.68	264.86	371.46	1315.93
2017	606.72	6.25	115.44	274.40	393.74	1396.55
2018	650.41	6.55	123.75	284.28	417.37	1482.36
2019	697.24	6.86	132.66	294.51	442.41	1573.68
2020	747.44	7.19	142.21	305.11	468.95	1670.9

Table 11. Total Electricity Use for Other Sectors, 2015 – 2020, High Scenario, GWh

Year	Agriculture	Construction	Mining	Manufacturing	Services	Total Other Sectors
2015	527.96	5.69	100.45	255.66	350.43	1240.19
2016	572.31	6.01	108.89	266.40	374.96	1328.57
2017	620.38	6.35	118.03	277.59	401.21	1423.56
2018	672.49	6.70	127.95	289.25	429.29	1525.68
2019	728.98	7.08	138.70	301.39	459.34	1635.49
2020	790.22	7.47	150.35	314.05	491.50	1753.59

6. Total Electricity Use for All Sectors

Table 11 shows the total electricity use for all sectors for the period 2015 – 2020.

Table 11: Total Electricity Use for All Sectors, 2015 – 2020, all Scenarios, GWh

	Low Scenario			**Base Scenario**			**High Scenario**		
Year	Household Sector	Other Sectors	All Sectors	Household Sector	Other Sectors	All Sectors	Household Sector	Other Sectors	All Sectors
2015	865.75	1240.19	2105.9	865.75	1240.19	2105.9	865.75	1240.19	2105.9
2016	957.66	1303.32	2260.98	1006.87	1315.93	2322.8	1053.91	1328.57	2382.48
2017	1055.46	1369.82	2425.28	1161.23	1396.55	2557.78	1260.41	1423.56	2683.97
2018	1159.49	1439.89	2599.38	1329.67	1482.36	2812.03	1486.4	1525.68	3012.08
2019	1270.05	1513.72	2783.77	1513.08	1573.68	3086.76	1733.08	1635.49	3368.57
2020	1387.47	1591.5	2978.97	1712.43	1670.9	3383.33	2001.77	1753.59	3755.36

The total electricity use increases from 2105.9 GWh in 2015 to 2978.97 GWh in 2020 for the Low Scenario and to 3383.33 GWh and 3755.36 GWh for the Base and High Scenarios respectively.

These represent respective increases of 41.46%, 60.66% and 78.33% for the Low, Base and High Scenarios over the period 2015 – 2020.

7. Total Peak Loads

Total peak loads for each year of the period 2016 – 2020 are calculated by adding the various components. The key components are:

- Peak loads resulting from electricity generated by the power system.
- Peak loads that would result if the load shedding was not resorted to by ESCOM.
- Self-generation by a number of large customers.
- Step loads likely to arise from the industrial projects in the mining and other sectors.

As noted in Section 2, the total electricity use of 2105.9 GWh in 2015 includes the following:

- Total consumption by ESCOM customers,
- Estimates of load shedding,
- Estimates of consumption from those who generate their own power.

Hence the forecast electricity use data shown in Table 11 includes the three components (generation from the power system, load shedding and self-generation).

7.1 Peak Loads from Electricity Use including Load Shedding and Self-Generation

The peak loads for each year in the period 2016 – 2020 are estimated by converting the total electricity use data in Table 11. A system wide load factor of 0.52 has been used. This is based on the work of ICF/CORE International (see Exhibits 3 –10, 3 –11 and 3 –12). The resulting peak loads for all Scenarios are shown in Table 12.

Table 12: Total Peak Loads for All Sectors, All Scenarios, MW

Year	Base Scenario	Low Scenario	High Scenario
2015	462.32	462.32	462.32
2016	496.35	509.92	523.02
2017	532.42	561.51	589.21
2018	570.64	617.32	661.24
2019	611.12	677.63	739.50
2020	653.97	742.74	824.41

7.2 Step Loads

ESCOM maintains a schedule of enquiries from the prospective investors in the mining and other sectors of the economy in regard to step loads in the next few years. However, the available information is far from satisfactory. There is a need for a more systematic and on-going interaction with potential investors and a more in-depth catalogue of the likely projects, load requirements, probability and timing for the projects.

From the information available, it is estimated that if all projects, that are currently on the table do eventuate, the additional peak loads by 2020 would be approximately 150 MW. However, it is unlikely that all projects (currently being deliberated on) will eventuate.

Accordingly, step loads resulting from the projects have been estimated by assigning probabilities to the various energy demanding projects expected between 2015 and 2020.

Basically, there are three step load cases. The first step load case embodies all projects that are very likely to materialize and is called the "very likely" situation. This is tied to the Low Scenario. The second step load case is a "likely" situation and comprises projects in the "very likely" case plus those that may occur. This is linked to the Base Scenario. The last step load case covers the "likely" situation projects plus those that are least likely to eventuate and is called a "least likely" case.

The three step load cases are presented in the Table 13.

Table 13: Step Loads from the Various Sources, MW

Year	Very likely step loads	Likely step loads	Least likely step loads
2015	0	0	0
2016	5	10	15
2017	5	11	38
2018	7	23	29
2019	6	15	32
2020	5	7	31

7.3 Total Peak Loads

The peak loads resulting from the three step load cases are shown linked with the respective Low, Base and High Scenarios in Table 14.

Table 14: Total Peak Load, MW

Year	**Low Scenario**	**Base Scenario**	**High Scenario**
	(Very likely)	***(Likely)***	***(Least likely)***
2015	462.32	462.32	462.32
2016	501.35	519.92	538.02
2017	537.42	572.51	627.21
2018	577.64	640.32	690.24
2019	617.12	692.63	771.50
2020	658.97	749.74	855.41

From Table 14, total peak loads increase from 462.32 in 2015 to 658.97 in 2020 for the Low Scenario, and to 749.74 and 855.41 for the Base and High Scenarios respectively. These represent total peak load increases of 42.54% for the Low Scenario, 62.2% for the Base Scenario and 85% for the High Scenario.