Zambia Electricity Cost of Service Study

Inception Report

Prepared for

Energy Regulatory Board

With the support of African Development Bank

Submitted by

Energy Market and Regulatory Consultants Limited (part of the MRC Group)

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Suite 3.03, 83 Princes Street, Edinburgh EH2 2ER United Kingdom (edit as appropriate)

tom.jardine@energy-mrc.com alice.waltham@energy-mrc.com

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Acronyms

Acronym	Description
AfDB	African Development Bank
BSA	Bulk Supply Agreement
CAPEX	Capital Expenditure
CAPM	Capital Asset Pricing Model
CEC	Copperbelt Energy Corporation
COSS	Cost of Service Study
DDP	Dual Dynamic Programming
DoE	Department of Energy
DP	Dynamic Programming
ECA	Economic Consulting Associates
FCF	Future Cost Function
GDP	Gross Domestic Product
GRZ	Government of the Republic of Zambia
Hm3	Cubic Hectometre
IAEA	International Atomic Energy Agency
IBRD	International Bank for Reconstruction and Development
IBR	Incentive Based Regulation
ICF	Immediate Cost Function
IG&T	Integrated Generation & Transmission
JICA	Japan International Cooperation Agency
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
EoI	Expression of Interest
EPB	Environmental Project Brief
ERB	Energy Regulation Board

Acronym	Description
ESAP	Electricity Services Access Project
IBR	Incentive Based Regulation
IMF	International Monetary Fund
IPP	Independent Power Producers
IT	Information Technology
LV	Low Voltage
MAED	Model for Analysis of Energy Demand
MoE	Ministry of Energy
MP	Member of Parliament
MTF	Multi-Tier Framework
MV	Medium Voltage
NEP	National Energy Policy
NWEC	North Western Energy Corporation
OPEX	Operating Expenditure
OPPPI	Office for Promoting Private Power Investment
PCM	Parametric CAPEX Model
PPA	Power Purchase Agreement
REA	Rural Electrification Authority
REMP	Rural Electrification Master Plan
RES	Renewable Energy Sources
RfP	Request for Proposals
ROR	Rate of Return
RU	Reference Utility
SAPP	Southern African Power Pool
SDDP	Stochastic Dual Dynamic Programming
SMT	Study Management Team

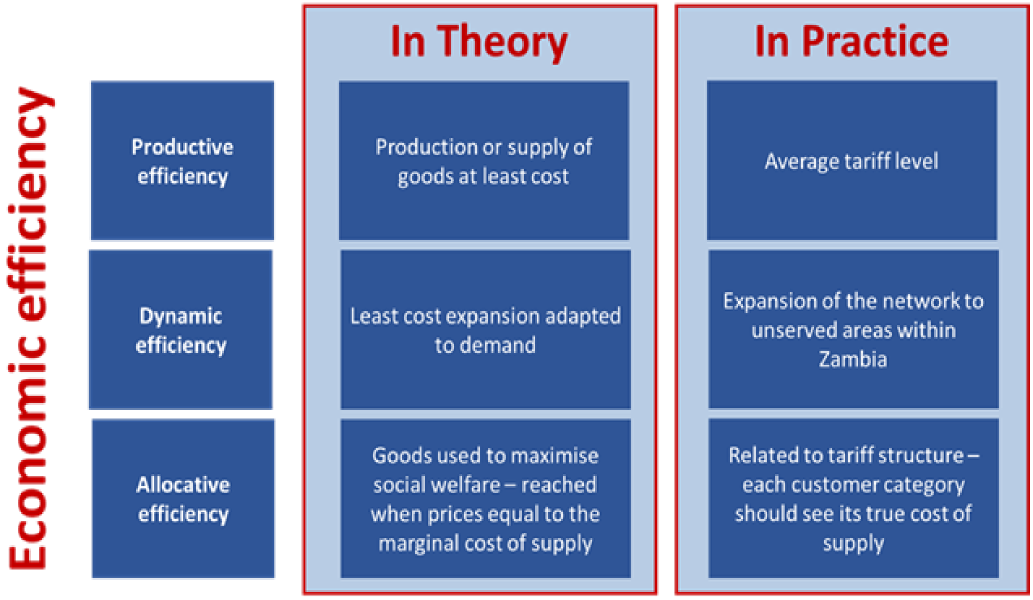
Acronym	Description
SRMC	Short Run Marginal Cost
SSC	Study Steering Committee
STC	Study Technical Committee
WARMA	Water Resources Management Authority
WICS	Water Industry Commission Scotland
ZACCI	Zambian Chamber of Commerce and Industry
ZAM	Zambian Association of Manufacturers
ZEMA	Zambia Environmental Management Agency
ZMW	Zambian Kwacha
ZNFU	Zambian National Farmers Union
ZPPA	Zambia Public Procurement Authority

1 Introduction

1.1 Background

With financial support from the African Development Bank, ERB has commissioned a study to determine the true cost of grid-connected electricity supply in Zambia. The resulting Cost of Service Study will form a vital tool in improving the efficiency of the industry and thereby reducing costs to the benefit of customers. Figure 1 illustrates how efficiencies can be achieved.

Table 1 - Promoting Efficiency in Electricity Supply [1]



In 2006 the ERB conducted a Cost of Service Study which focussed primarily on ZESCO which was then the producer and supplier of about 96% of the electricity consumed in the country. Since then significant changes have taken place in the sector. As a result, the cost of electricity production and supply is no longer known with certainty. A new COSS is therefore required.

[1] in practice, "the average price" is a composite of capacity charge and energy charge in economic terms to assure productive efficiency. The expansion of the network to unserved areas must be based on economic viability of the extension. For the allocative efficiency, the tariff structure should reflect the structure of economic costs to each consumer category

1.2 Contracting process

The contracting process commenced in 2018 with the issuance of a call to Express Interest and the resultant pre-qualified bidders were then issued with a Request for Proposals (RfP). EMRC delivered its proposal based on the RfP in January 2019. Following confirmation that it had been selected as preferred bidder EMRC attended contract negotiations in August 2019 and the contract was signed on 31st October 2019.

1.3 Inception visit

An Inception Visit took place over a two-week period from 2nd to 13th December, 2019. EMRC team in attendance were as follows:

First week	Tom Jardine, Thomas Miti, Keith Burwell and Alejo Loira
Second week	Tom Jardine, Thomas Miti, Keith Burwell, Carlos Migues, Daniel Serrano and Andrea Marroni

Informal and introductory meetings took place at ERB on Monday 2nd December with ERB. The team moved into the office allocated by ERB for the COSS and gained access to the ERB IT network.

The official launch of the COSS took place in the ERB auditorium on the morning of Tuesday 3rd December, 2019 attended by a significant number of stakeholders including the Minister of Energy, Honourable Matthew Nkhuwa, MP. In the afternoon EMRC presented the project to the Steering Committee, which was followed by a wide-ranging discussion. On Wednesday 4th December EMRC made a more detailed presentation to, and discussion with, the Technical Committee for the project.

On Thursday 5th December the team held an introductory meeting at ZESCO to plan the data gathering to take place over the remainder of the Inception Visit. Additional meetings were arranged with ZESCO and took place as follows:

Thematic Area	Date
Planning - generation, transmission and distribution	Monday 9th December
Finance and accounts	Monday 9th and Thursday 12th December
Billing and IT (customer services)	Tuesday 10th December

System Operations and Power Trading	Wednesday 11th December
Business Development	Wednesday 11th December
Management Corporate Strategy	Wednesday 11th December
Water Management for Hydro Generation	Thursday 12th December

Meetings with other stakeholders also took place and these are summarised below:

Institution	Date
Ministry of Energy	Thursday 5th December
Maamba Collieries Limited	Friday 6th December
AfDB	Friday 6th December
CEC	Friday 6th December
OPPPI	Monday 9th December
ERB	Tuesday 10th and Friday 13th December
REA	Thursday 12th December

Notes of most[2] meetings are included in Annex B.

1.4 Content of this Inception Report

This Inception Report is a statement of what we found during the inception visit and an analysis of whether the terms of reference will achieve the objectives. This inception report provides a confirmation of the basis on which the project has commenced identifying any elements that may have changed since the proposal was submitted.

I. The composition of the steering committee and technical committee are confirmed in section 2.
II. A Project communications protocol is proposed in section 3.
III. Section 4 provides a sector review based on the information collected during the inception visit.
IV. Section 5 confirms the proposed approach and methodology for the twelve tasks of the project taking into account the findings of the Inception Visit.

[2] Excluding Maamba Collieries and CEC

v. Section 6 is a discussion of important issues identified during the Inception Visit that may affect the COSS.
vi. The proposed programme is presented in section 7
vii. The proposed Inception Workshop content is provided in section 8.
viii. Finally, the data requirements for the COSS are presented in section 9.

2 Composition and formation of teams

The EMRC team members (Key Experts) each confirmed their availability on separate letters submitted to ERB on 2nd December.

The Inception Visit confirmed the management and committee arrangements for the project to be in line with the Request for Proposals as follows in Figure 2:

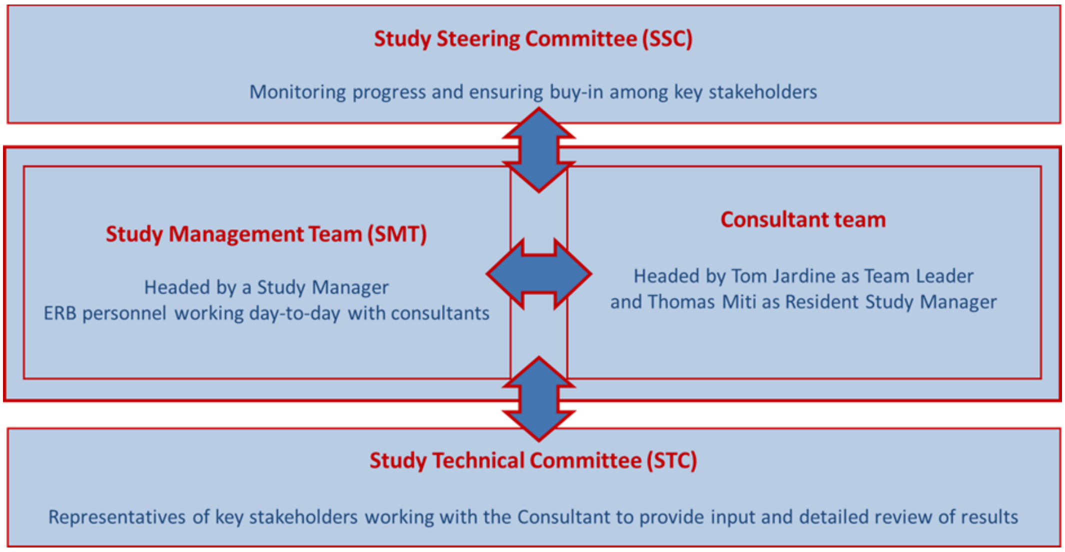


Figure 1 - Management and Committee Arrangements

The Study Management Team is headed by the Executive Director of the ERB supported by the Executive Committee and a dedicated Study Manager.

The Study Technical Committee is headed by the Director of Economic Regulation of the ERB and comprises:

- ERB
- ZESCO
- CEC
- DoE

The Study Steering Committee is headed by the Permanent Secretaries of the Ministry of Energy and Ministry of Finance. It comprises senior representatives from:

- Ministry of Energy
- Ministry of Finance
- ERB
- ZESCO
- Industrial Development Corporation (IDC)
- Chamber of Mines

- Consumer Unit Trust Society (CUTS)
- Zambia Private Sector Alliance (ZAM, ZACCI, ZNFU)
- Policy Monitoring and Research Centre (PMRC)
- CEC

3 Communications

The point of contact at EMRC is the Team Leader, Tom Jardine, and the Resident Manager, Thomas Miti, by email on tom.jardine@energy-mrc.com and thomas.miti@energy-mrc.com respectively. For administrative purposes and as a back-up all emails should be copied to alice.waltham@energy-mrc.com.

The point of contact at ERB is the Study Manager, Besa Chimbaka, by email on bchimbaka@erb.org.zm and copied to mphiri@erb.org.zm.

All communications with the technical and steering committees will be through ERB.

EMRC has developed a contact list for the COSS project which will be updated regularly throughout the project. The contact list as it was at the end of the Inception Visit is included as Annex C.

4 Preliminary review of power sector

4.1 Paving the way for the Task 2 Report: our approach

The Task 2 Report will undertake an appraisal of the structure and performance of the power sector including the existing legal and regulatory framework. The review of the legal and regulatory framework will focus on the institutional, legal and regulatory arrangements which might either pose constraints to, or opportunities for the determination and setting of cost-reflective electricity tariffs.

There are few common steps in electricity sector reform internationally. Introducing competition for generation is generally the first step. However, as indicated by the recently released World Bank report «*Rethinking Power Sector Reform in the Developing World*» the design of power sector reforms should be gradual and informed by the enabling conditions of the particular country and oriented primarily toward achieving better sector outcomes. The design of power sector reform needs to be thoroughly grounded in the political realities. For instance, an unbundling reform conducted in isolation simply creates several smaller state-owned companies that, in the absence of other measures, may suffer from similar performance problems as the original parent company. A good legal and regulatory framework that is charged with regulating an incoherent or contradictory industry or market structure is likely to achieve little in improved sector performance and investment.

Our approach emphasises regulation as a means to an end, not an end in itself ("*Handbook for Evaluating Infrastructure Regulatory Systems*", IBRD, World Bank, 2006). Laws and regulations may appear well-designed and consistent, but the evaluation may show that other elements are preventing the sector from achieving good results, e.g. economic conditions, market structures, or the reliability of institutions. The legal and regulatory framework needs to be clearly defined and understood. Here we refer to government-imposed controls on business activity, defined as the "combination of institutions, laws, and processes" that, taken together, enable a government to exercise formal and informal influence over the operating and investment decisions of enterprises that supply the services to ensure that the overall government policy objectives are met.

Our evaluation has two different levels.

1. Regulatory governance: the institutional and legal design of the system and the framework within which decisions are made. It is the "how" of regulation including the process, both formal and informal, by which decisions are made; the transparency and predictability of decision-making; and the organisational structure of the relevant entities.

2. Regulatory substance: the content of regulation. This is the actual decision-making, whether explicit or implicit, made by the regulator or other entities, along with their rationale. It is the “what” of regulation. It typically involves concrete specific decisions (for instance about tariff levels and structures, obligations and reviews, accounting systems, or network access conditions for new and existing customers)

4.2 Main Features of the electricity supply industry

4.2.1 Overview

During the inception visit, ERB has introduced the Consultant to the key stakeholders in the Electricity Supply Industry (ESI) and the various agencies and Institutions. The Consultant worked closely with the ERB and the Governmental institutions.

We present here a preliminary review of the structure and performance of the power sector:

I. The electricity supply industry in Zambia is dominated by the vertically integrated ZESCO Limited (ZESCO). The utility is wholly state-owned through the Industrial Development Corporation, the holding company for the majority of state-owned enterprises in Zambia.

II. ZESCO operates within the Southern Africa Power Pool (SAPP), connecting to it with interconnectors to both Zimbabwe and DRC and with a planned connection to Tanzania. The relative generation capacities of Zambia and other SAPP countries are shown in Table 2. ZESCO has reported its supply and consumption balance with other countries as shown in Table 3.

Table 2 – Zambia generation compared to other SAPP countries (Source SAPP website)

Country	Installed Capacity (MW)	Operating Capacity (MW)	Current Peak Demand (MW)
Angola	3,129	2,500	1,869
Botswana	927	459	610
BRC	2,457	1,076	1,376
Lesotho	74	70	150
Malawi	352	351	326
Mozambique	2,724	2,279	1,850
Namibia	614	389	695

South Africa	50,774	48,463	38,897
Swaziland	70	55	232
Tanzania	1,366	823	1,051
Zambia	2,734	2,734	2,194
Zambia % of Total SAPP	4.1%	4.5%	4.3%
Zimbabwe	2,045	1,555	1,615
	67,266	**60,754**	**50,865**

Table 3 – Zambia net energy imports 2012 to 2016 (Source ZESCO power balance statistics)

	2012	2013	2014	2015	2016
Imports GWh	148	960	1286	1172	768
Total Supply GWh	12989	12841	13466	13327	12089
% of Total supply	1.1%	7.5%	9.5%	8.8%	6.4%

III. ZESCO owns and operates the majority of the generation, transmission, and distribution assets in the country and supplies electricity to all grid-connected consumers, with the exception of some of mining consumers in the Copperbelt Province. The latter are served by Copperbelt Energy Corporation, a private company that purchases bulk power from ZESCO for onward supply to the mines and is a conduit for ZESCO to deliver power to towns in the Copperbelt Province. The mining industry is the largest consumer category, accounting for over 50% of the national electricity consumption.

IV. ZESCO is currently focused on on-grid electrification. The sector is opening up to new IPPs for on-grid and off-grid transactions. The industry operates on the basis of a single buyer model in which ZESCO is the off-taker for power generated by the IPPs. This implies that most of the investment opportunities in electricity power generation require a Power Purchase Agreement (PPA) with ZESCO as the off-taker of electricity.

V. Zambia has 2,981MW of installed electricity generation capacity, of which about 80% is hydro based – see Table 4 below. A severe drought in 2014/15 led to a drop in output at the major hydropower plants, resulting in power rationing. Uncertainty over the impact of climate change on the region's hydrology underlines the need to build up a diverse power mix and enhance regional connections. In 2019, Zambia was again experiencing outages as a result of another drought.

VI. ZESCO operates the electricity grid and is responsible for much of the country's power generation from four large hydro power plants, five small and mini hydro plants and two diesel power plants.

VII. The operational IPPs are:

   I. Lunsemfwa Hydro Power Company Ltd which supplies power to ZESCO under a PPA;
   II. Ndola Energy Company Limited a thermal plant supplying power to ZESCO under a PPA;
   III. Zengamina Power Limited, an off-grid mini hydro power plant licensed to generate, distribute and supply a rural area.
   IV. Itezhi Tezhi Hydro Power Company Limited
   V. Maamba Collieries Limited
   VI. Bangweulu Power Company
   VII. Ngonye Power Company

I. Copperbelt Energy Corporation Plc (CEC) is an independent power company listed on the Lusaka Stock Exchange that purchases power from ZESCO and supplies the mines, smelters and refineries in the Copper Belt region via its own transmission and distribution lines under a bulk supply agreement. It also exports power to the Democratic Republic of Congo.

II. North Western Energy Corporation Limited (NWEC) is also a licensed electricity distributor in the North Western Province of Zambia who is supplied by ZESCO under a PPA.

III. Although Zambia is endowed with significant resources for power generation, no new plants have been commissioned between 1977 and 2014. This was due to a period of excess capacity that lasted until the early 2000s.

IV. The weakened financial position of the electricity sector, lack of an adequate planning and procurement framework, and an overall high-risk[3] environment make new investments in generation difficult. New generation plants have been brought on stream recently and more are planned (see Annex D).

Table 4 - INSTALLED GENERATION (KW) [Source ZESCO, 2019]

MAIN HYDROS

1. [3] As defined by the INTERNATIONAL DEVELOPMENT ASSOCIATION PAD 2303 - ELECTRICITY SERVICE ACCESS PROJECT - JUNE 6, 2017. Examples of factors contributing to the high risk are regulatory and legal uncertainties with reforms in process, and payment uncertainty related to the financial losses of ZESCO

	MACHINE	INSTALLED	AVAILABLE
STATION	TYPE	CAPACITY	CAPACITY
		(kW)	(kW)
KAFUE GORGE	HYDRO	990,000	960,000
KARIBA NORTH	HYDRO	720,000	705,000
VICTORIA FALLS	HYDRO	108,000	105,000
SUB – TOTAL		**1,818,000**	**1,770,000**
MINI HYDROS			
LUSIWASI	HYDRO	12,000	7,500
MUSONDA FALLS	HYDRO	10,000	9,600
CHISHIMBA FALLS	HYDRO	6,000	4,300
LUNZUA RIVER	HYDRO	14,800	14,800
SHIWANG'ANDU	HYDRO	1,000	1,000
SUB – TOTAL		**43,800**	**37,200**
ISOLATED SYSTEM (DIESEL STATIONS)			
LUANGWA	DIESEL	2,600	732
SHANGO'MBO	DIESEL	1000	1,000
SUB - TOTAL	**DIESEL**	**3,600**	**1,732**
GRAND TOTAL		**1,865,400**	**1,808,932**

Generating Stations for Copperbelt Energy Corporation and Private Owners

STATION	TYPE	INSTALLED CAPACITY (kW)	AVAILABLE CAPACITY (kW)	OWNER
BANCROFT	GAS TURBINE	20,000	20,000	C E C
LUANO	GAS TURBINE	40,000	40,000	C E C
LUANSHYA	GAS TURBINE	10,000	10,000	C E C
MUFULIRA	GAS TURBINE	10,000	10,000	C E C
LUNSEMFWA	HYDRO	23,200	23,200	LUNSEMFWA
MULUNGUSHI	HYDRO	30,800	30,800	LUNSEMFWA
KNBE	HYDRO	360,000	360,000	KNBE
MCL	THERMAL	300,000	267,000	MAAMBA COLLIERIES
ITPC	HYDRO	120,000	120,000	TATA/ZESCO

STATION	TYPE	INSTALLED CAPACITY (kW)	AVAILABLE CAPACITY (kW)	OWNER
NDOLA ENERGY	THERMAL	105,000	105,000	NDOLA ENERGY
BANGWEULU POWER COMPANY	SOLAR	54.3	54.3	IDC & NEOEN S.A.S
NGONYE POWER COMPANY	SOLAR	34	34	IDC & ENEL GREEN POWER S.p.A
TOTAL		**1,019,0880.3**	**986,0880.3**	

4.2.2 Access to Electricity[4]

As part of the national strategy ("Vision 2030"), the GRZ has set electrification targets at 90% for urban and 51% for rural areas to be reached by 2030.

The recently released "*Access Diagnostic Report Based on the Multi-Tier Framework*"[5] (MTF) provides up-to date statistics on access. Figure 2 extracted from this report summarises the access levels across Zambia. It demonstrates that significant progress in increasing access for urban households has been achieved with more than one-third (37.7%) of households in Zambia now connected to the national grid. It also shows that access in Rural areas has stagnated, indicating that - as of 2017 - 1.4 million Zambian households (42.4%) have access to electricity through either national grid or off-grid sources, while the remaining 1.9 million households (57.6%) have no access to electricity. Out of the 42.4% with electricity, 4.7% primarily use off-grid solutions. The difference in access to electricity between urban and rural areas is substantial: most urban households (74.8%) access electricity through the national grid, yet the majority of rural households (88.1%) have no access to any kind of electricity source.

[4] A WB definition of Access for Zambia states "Electricity access is defined in the national living conditions survey as access to the national grid. Central Statistics Office,

Living Condition Monitoring Survey 2015"

[5] Luzi, Lucia; Lin, Yunhui; Koo, Bonsuk; Rysankova, Dana; Portale, Elisa. 2019. Zambia – Beyond Connections : Energy Access Diagnostic Report Based on the Multi-Tier Framework (English). Energy Sector Management Assistance Programme (ESMAP). Washington, D.C. : World Bank Group. http://documents.worldbank.org/curated/en/477041572269756712/Zambia-Beyond-Connections-Energy-Access-Diagnostic-Report-Based-on-the-Multi-Tier-Framework .

The MTF was developed to monitor and evaluate energy access under the Sustainable Energy for All (SE4ALL) initiative launched by the United Nations in 2011 to achieve universal access to modern energy services by 2030. The MTF approach goes beyond binary measurement of energy access as 'having or not having an electricity connection' or 'relying or not relying on solid fuels for cooking' by considering

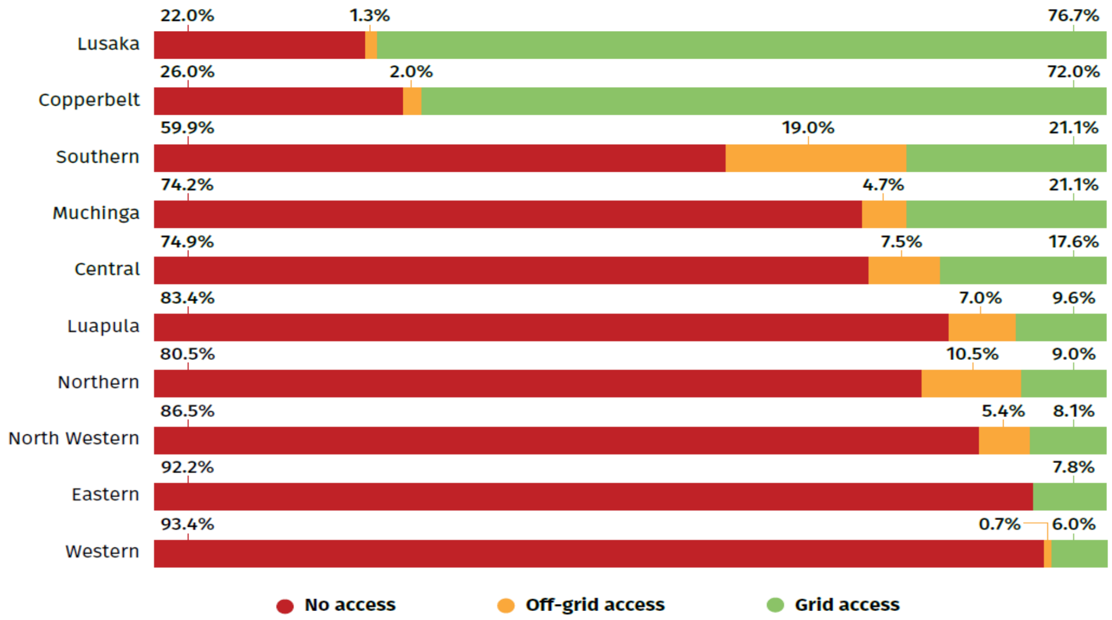


Figure 2 - Access to electricity by technology, by province [SOURCE MTF, 2019]

In rural areas, Zambia has one of the lowest population densities in Southern Africa; scattered households make providing access particularly challenging. In addition, affordability of the connection fees for grid access remains a major barrier for this population (almost 77%[6] of the rural population in Zambia living below the poverty line): consequently the current grid connection fee and the requirement that it is to be paid up front presents a significant barrier to access even in areas where the grid exists.

4.2.3 Planning Process

Scaling up access requires a comprehensive Expansion Plan that would provide a planning framework, remove possible regulatory impediments, provide a policy framework for sustainable financial support, and improve institutional coordination, covering electrification of both urban and rural areas.

various service levels and attributes, such as availability, quality, reliability, health/safety, convenience, and affordability, and multiple technology options (for example, grid and off-grid electricity). The MTF measures access on a tiered-spectrum, from Tier 0 (no access) to Tier 5 (the highest level of access). Tier 1, for instance, includes basic applications such as task lighting, radio, and phone charging.

[6] source MTF 2019

The COSS will help to define roles and responsibilities for REA, ZESCO, and the private sector, in achieving optimised implementation of access programmes throughout the country. A conducive environment, capable institutions, and efficient and well-targeted government financial support can successfully mobilise the private sector.

The work will be developed through extensive consultation with all relevant stakeholders, including local government, communities, and the private sector.

4.2.4 Policy, Institutional and Legal Setup

The energy policy formally adopted by the Zambian Government is dictated by the National Energy Policy (NEP) approved in 2008. The NEP mentions the need for cost-reflective tariffs but does not go further into detail regarding other elements of tariffs such as social (lifeline) electricity tariffs. There is a reference to cost-reflective tariffs for isolated grids. A new National Energy Policy has been recently approved.

The NEP 2019 will be reviewed in detail within Task 2. It contains ambitious policy objectives and responds to emerging market dynamics in the sector. It explicitly promotes cost reflective tariffs in the pricing of energy services and provides indications with regards to: open access transmission regime including net metering; determination of tariffs for bulk supply customers; design of a Multi-Year Tariff Framework that will ensure implementation of a pre-determined tariff migration path to cost-reflectivity; and a mechanism to protect vulnerable groups in society.

The activities of the Policy will be practically achieved with the strengthening of the two Bills currently being promulgated as described below.

In terms of the Institutional set up that stems from the current regulation of the sector, the Task 2 Report will summarise the roles of the key entities.

- The electricity sector is overseen by the **Ministry of Energy** which has policy making responsibility for the electricity sector (and other energy sectors). It is responsible for formulation and implementation of national energy policy, coordination of stakeholders, development of national energy strategy and plan, monitoring and evaluation of current policies, and development of new energy plans.
- The independent **Energy Regulation Board (ERB)** is responsible for licensing, tariff setting, and quality of supply and service standards for all segments of the energy sector (including fossil fuel, Renewable Energy and electricity) in accordance with the provisions of the 1995 Energy Regulation Act as amended in 2003. The ERB sets electricity tariffs for all consumers, with the exception of the mining industry and other large consumers, which are set through long-term power purchase agreements (PPAs).

- The **Rural Electrification Authority (REA)** is responsible for electrification in rural areas and manages the Rural Electrification Fund (REF). The mandate to promote rural access lies with REA, established by the Rural Electrification Act of 2003. REA's functions include administering the REF, developing and implementing rural electrification plans, tendering electrification projects, and providing subsidies to developers. Currently the REA is positioned as the entity implementing projects.
- The two main statutory instruments are:
  - the Energy Regulation Act, Cap 436 as amended by the Energy Regulation Act No. 23 of 2003, the Law establishing and giving mandate to the Energy Regulation Board
  - the Electricity Act, Cap 433 as amended by the Electricity Act No. 21 of 2003, which relates to the electricity sector more generally including the organisation of the sector, duties and powers and, importantly, tariffs and tariff approvals.
- The new Electricity Bill and Energy Regulatory Bill would replace the Electricity Act, Cap 433, and the Energy Regulation Act, Cap 436.
- In the Legislation there are two specific elements which are reconsidered carefully by the new Bills:
  - The legislation does not confer on the regulator explicit power to set tariffs. The ERB is not specifically mandated to set Tariffs. ERB's powers to intervene on tariffs are only derived from interpretation of certain provisions.
  - There is not a clear legal framework for transparency of the regulator's performance and predictability of its decisions.

Currently, opportunity exists to improve stability and enforceability of laws and contracts, removing lacunas in the laws which may erode investor confidence and are likely to deter investments in Zambia's electricity industry. The legal and regulatory provisions of the new Bills address ownership and control of the transmission and distribution systems which are critical to ensuring open and non-discriminatory access to the grids. The new legislation gives legal support to the ERB; allows it to set parameters for contracts and monitor their implementation and gives the discretion to respond to rapidly changing market conditions.

The new bills are aligned with the new NEP 2019 which contains ambitious policy objectives and responds to emerging market dynamics in the sector. The NEP promotes diversification of energy sources at cost reflective pricing which will promote new investment in the sector including scaling up access to energy services in rural areas.

The Third and Fourth Chapters of the NEP (outlining the Vision, rationale and underlying guiding principles, strategic objectives) focus on "creation of a market environment promoting increased private sector participation", with a strong emphasis on "encouraging the multiplicity of players in the energy market through appropriate institutional and legal frameworks".

During the course of this Study, there is a need to reflect on the provisions of the new Bills and to evaluate their pertinence in respect of the policy goals. We have had the opportunity to peruse the draft Bills and we have concluded that the new legal framework (which derives from the NEP) supports market restructuring more completely than the current framework and is therefore a significant step forward.

The liberalization of Zambia's ESI in 1995 had limited success in stimulating private sector participation and competition over the proceeding years. Zambia has a monopoly dominated by one large vertically integrated state-owned utility responsible for the generation, transmission, distribution and supply of electricity.

The new legal framework supports multi-year and automatic cost pass-through tariff adjustments; market restructuring which provides for the establishment of an independent system operator.

The Regulator will guarantee cost-reflective tariffs that ensure financial viability and a sustainable, reliable and quality electricity supply. Legal support is given towards autonomy from political and market influences, including the setting of parameters for contracts.

The Task 2 Report will address several key questions including the following: is the new legislation really conducive to reducing ZESCO's market dominance, encouraging private sector participation and introducing competition? Is the general architecture of the new legislation well-aligned? Are the two Acts orchestrated in coordination? Do they provide for third party access to the transmission grid? Which level of unbundling must be considered for tariff design?

Do the Bills grant a clear demarcation between Policy Regulation & Implementation, with regulations to be issued by the independent regulator and the Minister to deal with purely policy matters? Is there any trace of influence of politics on the operations of the ESI? Are there prescriptions which could be improved?

4.3 Tariffs not cost-reflective and lack of efficient price signals

The preliminary assessment of the data so far indicates that the power sector of Zambia is not financially sustainable at the present time and the current tariff levels in Zambia do not guarantee future financial sustainability of the sector.

The relevant provisions of the Electricity Act, together with some sections of the Energy Regulation Act:

- Do not provide a solid argument to clearly state that ERB has a legal mandate to set tariffs
- Do not mention the cost reflectivity principle.

ERB's ideal function to guarantee cost-reflective tariffs that ensure financial viability and sustainable, reliable and quality electricity supply has been hampered by the lack of legal backing required to effect tariff adjustments.

Electricity tariffs in Zambia are relatively low[7]. The historical low tariffs have made it difficult to service financing loans, to recover operations and maintenance costs and to attract investments for new generation capacity.

There is a uniform tariff for each customer category regardless of location. Therefore, there is an implicit (and to-date accepted) cross subsidy within the power sector between clients where supply is more expensive and clients where supply is cheaper.

At present, ZESCO purchases power from Independent Power Producers (IPP) and sells at below the price paid.

There is thus a need for a legal framework that is more comprehensive than it is at the moment to support multi-year and automatic cost pass-through tariff adjustments. We expect the new bills, the drafts of which we have seen, is likely to achieve some or all of the changes required.

Nevertheless, the more comprehensive tariff regulation needs to include provisions on:

- The type of tariff regime to be applied (cost plus, incentive based, price cap, revenue cap)
- The way to guarantee financial sustainability of the sector in the future
- Approach for the definition of allowed revenues, enhancing productive efficiency and optimal tariff levels

[7] However significant tariff increases were announced after the inception visit which came into effect on 1st January 2020

- Approach to be applied for tariff design and charges structure, enhancing allocative efficiency through efficient price signals
- How reliability and service quality will be addressed and guaranteed
- In the absence of more precise definitions under the current regulation, we will discuss and define with ERB during the assignment, suitable criteria for carrying out the cost of service estimation and the final tariff design for ZESCO.

4.4 Tariff review

There is no regular process for tariff review: ERB does not have the explicit power to carry out periodical tariff reviews and adjustments.

Under the ERB Tariff Review Guidelines, ZESCO may present a request for a tariff adjustment to the ERB: under section 8 sub-section 2 of the Electricity Act CAP 433 of laws of Zambia:

1. ZESCO makes an application to the ERB for a tariff increase;
2. ERB grants approval to ZESCO to publish the intended increase;
3. Public notices begin running in the public media;
4. Public Hearing is held; and
5. ERB makes a determination and announces the decision.

For example, in December 2018, the main factors that have necessitated the ZESCO application included: "the prevailing adverse economic conditions, the need for system and customer base expansion, the need to attract private investment in the sector aimed at increasing generation capacity in market, rising cost of electricity purchases from new ZESCO Generation plants as well as Purchases from Independent power producers, and the need for ZESCO to financially support its backlog of investments in generation, transmission, distribution and supply to meet the rising cost of supplying electricity to its customers and meet the needs of the growing consumer demand". [QUOTED FROM THE ZESCO DOC TO THE IMF]

In 2015 and 2016, due to the significant drop in hydro reservoir water levels, ZESCO was forced to start importing costly emergency power. There was a repeat of this scenario in 2019.

4.5 Renewable energy (RE) projects developed by IPPs

4.5.1 Current legal framework

There are various uncertainties in the current national legal framework applicable to the energy sector and specifically related to RE projects developed by IPPs.

The GRZ intends to scale up its solar, wind, and geothermal power generation capacity. The Government has allocated directly to ZESCO a certain amount of MW for this purpose[8]. A Study[9] says that up to 929 MW RE-based power can be absorbed. This absorption capacity of the grid is currently under review. Further clarification is needed regarding the responsibilities of each actor involved (i.e. the off-taker and the Project Company) in the IPP procurement process.

It is necessary to evolve from ad-hoc IPP procurement processes to a more standardised, transparent one with equal treatment of all parties. While the existing PPAs are based on a standard template, the finer details of power purchase costs are not yet benchmarked and are largely analysed on a case-by-case basis.

Transparent and competitive procurement framework (auction based bidding process) for private sector investments would be key in ensuring a viable development of energy sources.

[8] The first solar plant financed and tendered under the Scaling Solar programme will provide 54 MW. The Bangweulu project was awarded to NEOEN S.A. / First Solar Inc in May 2016 as part of the first round.

In numbers:

- 6.02: tariff in US¢/kWh achieved for the project.

- 25: Number of years the tariff will remain fixed for.

- 39: Million US$ of financing provided by IFC, OPIC, and the IFC-Climate Change Program. This is roughly 2/3 of the total project cost (excluding financing costs) of 56 million US$. 27,000: Homes supplied with electricity thanks to Bangweulu, based on average power consumption per capita.

The second project (34MW Ngonye solar PV facility) is located in Lusaka South Multi-Facility Economic Zone. 25-year PPA, partly funded through a financing agreement signed with Zambia's Industrial Development Corporation (IDC) by the developer Enel Green Power ("EGP"). It is the second round of the World Bank Group's programme. The Ngonye solar plant is owned by a special purpose vehicle 80% held by EGP and 20% by IDC, expected to produce around 70 GWh per year. In June 2018, Enel signed a financing agreement with IDC of around 34 million US dollars for the construction of the PV plant, involving senior loans of up to 10 million US dollars from the IFC, up to 12 million US dollars from the IFC-Canada Climate Change Programme and up to 11.75 million US dollars from the EIB.

At the same time, Zambia's Government launched another tender for an additional 100 MW of PV to be awarded under the GET FiT solar framework.

[9] Noted during the meeting with ZESCO Business Development on 11th December 2019 – see Annex B6

4.5.2 Procurement Process Solicited and Unsolicited

OPPPI with assistance from the EU Technical Assistance Facility IAREP is developing a guidance manual for private companies and investors wishing to develop and finance power generation projects in Zambia including renewable energy technologies. The framework will guide developers through the process of licensing by describing a series of orderly and timely steps and covers both the unsolicited proposals and the solicited framework, implemented under International Competitive Bidding procedures. The stages involved are shown in Figure 3 provided by OPPPI.

The Steps for Solicited projects include:

1. **Site identification by OPPPI** – Upon determination of the power generation and associated evacuation infrastructure project technology option to be developed in the country in line with the existing power sector expansion plans. Based on the expansion plans, the MoE will identify a potential project site or several sites depending on the power demand. The power project technology option is determined in collaboration with ZESCO and other stakeholders, in line with Government objectives and grid related technical aspects as per categorisation criteria. During this process the MoE identifies the site/sites and undertakes reconnaissance studies to determine the project power generation/transmission/distribution capacity, a power demand analysis of the area and a preliminary environmental assessment.
2. **Packaged pre-feasibility study** – Power project sites with positive reconnaissance study results will proceed to pre-feasibility study stage. The reconnaissance and pre-feasibility study will be undertaken by a consultant who will be procured by the MoE and supervised by the OPPPI. The pre-feasibility study is undertaken to confirm the project parameters such as the resource availability, accessibility of the project location, project generation/transmission/distribution capacity and the environmental and social aspect of the project. Upon completion of the pre-feasibility study, the consultant will give a recommendation based on the results of the study on whether to proceed the project site to a full feasibility study or abandon the site.
3. **Preparation of a Bankable Feasibility Study**
4. **Procurement of a developer –** through a two-stage competitive bidding process
5. **Bidder Optimisation Study**
6. **Negotiate Implementation Agreement with Government**

7. **Commercial Agreements and Permits –** including environmental, water use, lad title, national heritage permits, PPA with preferred power off-taker, connection agreement with transmission or distribution provider, investment license, generation endorsement license from ERB
8. **Project Inspection and Monitoring**

For Unsolicited Projects a private developer will be expected to identify a viable power project for development and submit a detailed project proposal to the MoE. Acceptable site location and detailed project proposals submitted will form the basis for the issuance of a permission letter/ memorandum of understanding by the MoE to undertake a feasibility study. The steps involved in an unsolicited procurement would then be as follows – again as shown in Figure 3:

1. **Letter of Intent/Interest to MoE -** the project developer presents a pre-identified project site with location and coordinates, the project type i.e. generation/transmission/distribution, the technology type (e.g. hydro, solar, wind, biomass, bagasse, geothermal), estimated project size and the proposed project objectives. The company also presents the company profile or consortium members, experience in power projects development and financial capacity of undertaking the proposed project feasibility study. The project developer is expected to conduct preliminary investigations and evaluations on the proposed project site in order to build an initial project case and to raise the interest of local stakeholders. At this stage, the proposed developer expresses interest and willingness to undertake the feasibility study at their own cost and risk for the proposed project.
2. **Due Diligence –** by the MoE through the OPPPI
3. **Grant of Feasibility Study Rights**
4. **Bankable Feasibility Study –** carried out by the developer and including local community engagement, and environmental studies and off-taker discussions.
5. **Review and Approval of the Bankable Feasibility Study**
6. **Implementation Agreement with Government**
7. **Permits and Commercial Agreements**
8. **Project Construction**

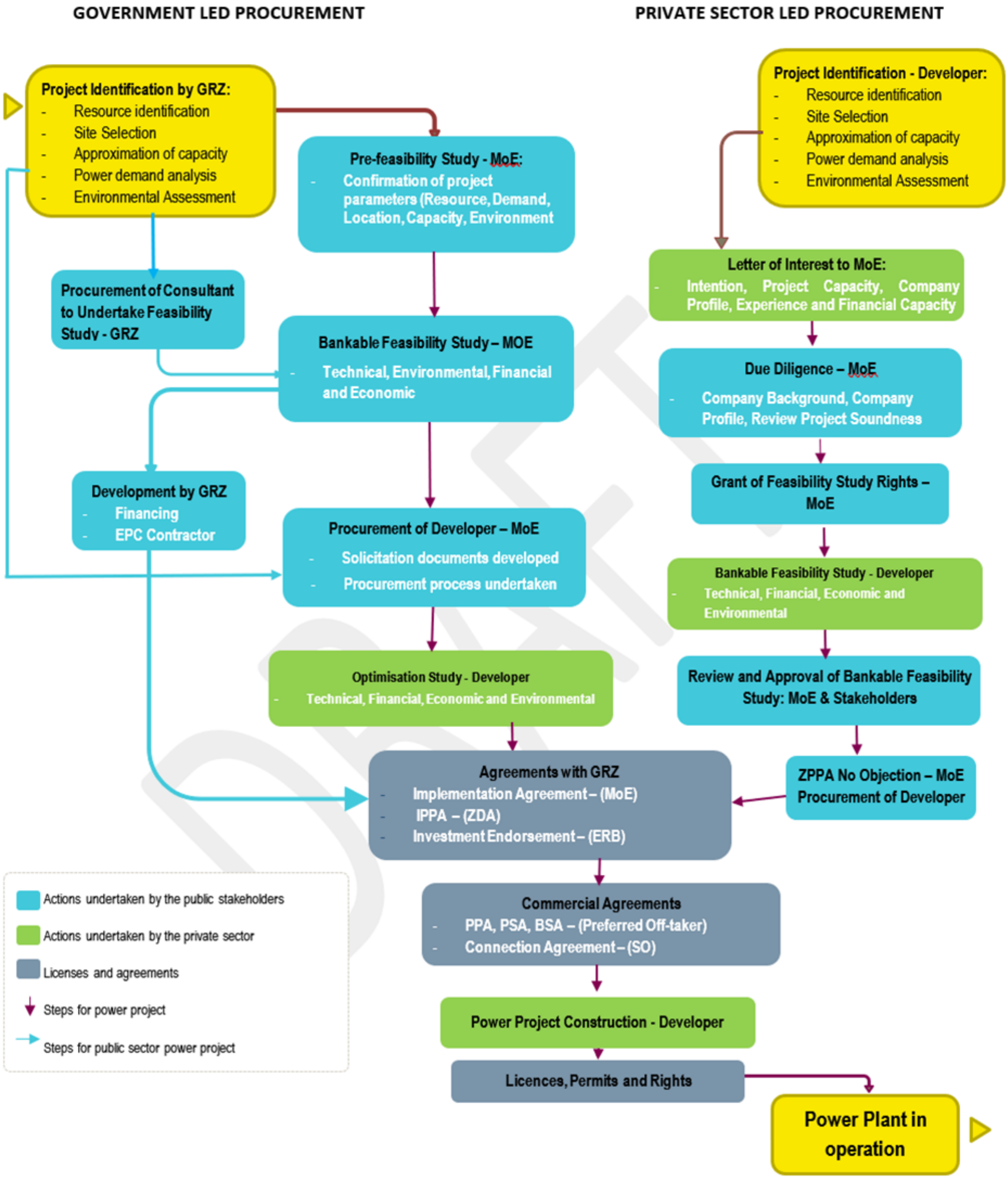


Figure 3 – Flow Chart on Procurement of Generation and Associated Evacuation Infrastructure Power Projects (Source OPPPI)

5 Delivery of Tasks

5.1 Inception Report

This Inception Report is the first deliverable of the COSS. Given the evident high profile and importance of the COSS in Zambia, the Inception Visit team envisaged in both the TOR and our technical proposal, was increased significantly. As a result, we believe the Inception Visit has been able to complete particularly thorough and detailed investigations and that as a result provides an excellent basis for taking the project forward. It has identified important issues that will inform our work throughout the project programme (detailed in this section and section 6).

5.2 Appreciation of the power sector

This task will elaborate on the inception visit findings described in section 4.

5.3 Load forecast

The primary goal of the load forecast is the forecast of maximum demand for the determination of the least-cost expansion programs for generation, transmission, and distribution as basis for the determination of the incremental cost of unit of capacity addition at the time of system peak demand.

The Inception visit raised several issues related to the load forecast that may suggest a potential change in approach.

In our proposal, we outlined an approach to load forecasting based on:

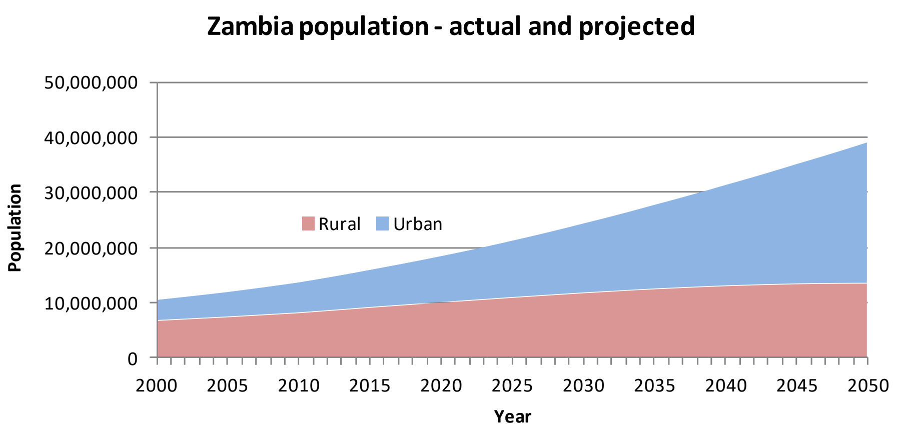
- Reviewing ZESCO's forecasts;
- Close linkage to expansion plans developed in task 4; and
- Econometric analysis of electricity demand based on key drivers (e.g. GDP and population).

The issues we have understood from ERB and other stakeholders, which may change our approach, are:

- **Previous econometric approaches:** Previous load forecasts have been based on econometric approaches with the significant load from mining operations forecast separately.
- **Mining is a critical sector:** Mining demand represents a very significant proportion of load (about 50%) and will be critical to the accuracy of the forecasts. Previous forecasts have treated mining separately and developed independent forecasts. A techno-economic rather than econometric approach

would allow consistent scenarios for mining and other sectors to be developed within a single model. EMRC will work closely with CEC and the Chamber of Mines to ensure that mining demand forecasts are as accurate as possible.

- Population growth in urban and rural areas: The population growth of Zambia as a whole is currently about 3% per annum. This growth rate is projected to decline to about 2.5% by 2040[10]. The growth rate is significantly skewed towards urban growth, currently 4.3%, with rural growth slower at 1.8%. This disparity in growth rates is projected to widen over time and by 2050 the urban population will have grown from its current level of 45% of the overall population to more than 65% (see Figure 4). The demand projection will need to ensure this is reflected in the chosen model.



Source: raw data extracted from: https://www.worldometers.info/world-population/zambia-population/

Figure 4 – Zambia population projection

- **Uncertainty over grid expansion:** There is uncertainty about the extent to which the grid will be expanded to meet potential demand from those areas not currently served or whether it should focus on expanding connectivity in those areas served by (or close to) the existing network. The shift towards urbanisation suggests that one option may be to concentrate grid connectivity growth to the urban areas with only limited network investment, and as the urban areas grow so will connectivity. EMRC are already planning to closely link the load forecasts to expansion plans that will be developed in task 4, and this emphasises the need for that interrelationship.
- **Preliminary income and affordability analysis**: A preliminary analysis of income distribution, discussed in more detail in Section 5.6, reveals a high

[10] Source: https://www.worldometers.info/world-population/zambia-population/

degree of income inequality in Zambia. Based on the current tariff structure, the poorest 20% could not currently afford a service (regardless of the cost of a connection) and the next 20% could only afford a minimal level of supply of less than 30 kWh per month, and only at the current subsidised lifeline tariff. It will be important to consider the price-elasticity of demand, and whether changes in the tariff structure (e.g. removing fixed charges and/or reducing the level of supply that qualifies for the subsidised lifeline tariff) may affect the demand for electricity in different income groups.

With detailed consumption and billing data we should be able to examine the distributional effects of demand in more detail to determine better the potential for increased sales and revenues from service expansion.

5.3.1 Choice of demand modelling approach

There are two main modelling families used for load forecasting:

1. **"Econometric"** also called "top-down" models, which are pure economic models based on historical data;
2. **"Techno-economic"** or "bottom-up" models, which model demand based on exogenous assumptions about demand drivers (also called "end-use" models or "engineering" models).

The strengths and weaknesses of each are summarised in Table 5 and Table 6.

Table 5: Strengths and weaknesses of econometric models

Strengths	Weaknesses
▪ Robust provided there are only minor changes in policies and economic structures. ▪ Very well equipped to assess price related issues. ▪ Can differentiate between rural and urban demand, provided sufficient parameters are included in the model.	▪ Very dependent on historical trends. ▪ Difficult to assess the impact of policy measures, technological changes or changes in lifestyles and economic structures. ▪ Different modelling approaches used for different sectors (e.g. mines).

Table 6: Strengths and weaknesses of techno-economic models

Strengths	Weaknesses

Strengths	Weaknesses
■ They are well adapted to simulate the impact of alternative energy efficiency policies. ■ Can differentiate between rural and urban demand. ■ Allows a consistent approach to modelling different sectors (e.g. mines).	■ Very data intensive. ■ Essential to have internal consistency of the assumptions driving social, economic and technological evolution for a given scenario. The expected future trends for each determining factor are exogenously introduced by the modeller, so heavily dependent on the modeller's understanding. ■ May not include price elasticities, depending on the model chosen.

The task of collecting and bringing together statistical data, calculating numerous input parameters and reconstructing the base year (i.e. calibrating the model) is much more time-consuming for a technoeconomic model than an econometric model and would require much greater input from ERB and other stakeholders.

An example of a techno-economic model is the Model for Analysis of Energy Demand (MAED) developed by the International Atomic Energy Agency (IAEA), who makes it freely available on request to member countries (which includes Zambia). It is Excel-based, allowing it to be used without obtaining bespoke software. EMRC used a similar approach in Lesotho in 2017.

MAED evaluates future energy demand based on a set of consistent assumptions on medium to long term socioeconomic, technological and demographic developments. Energy demand is computed for end use activities in three main "demand sectors": household, services, and industry and transport. Future energy needs are linked to the production and consumption of goods and services, technology and infrastructure innovation and lifestyle changes caused by increasing personal incomes. A critical element in MAED is the internal consistency of the assumptions around two sets of determining factors: (i) **socio-economic factors** (economic growth, population, lifestyle); and (ii) **technological factors** (efficiency, energy intensity, market penetration) which underpin each scenario. The expected future trends for each determining factor are exogenously introduced by the modeller. Therefore, the consistency of the model outcomes depends heavily on the information that is available on the interrelation and dynamics of various determining factors in the country. It is very data intensive.

In general, the reliability of econometric models decreases as the time-horizon increases because structural changes not accounted for in the model could lead to systematic errors. Techno-economic models can be valuable for long-term forecasts but are significantly more data intensive. If data is not available assumptions must be made by the modeller that may risk greater systematic errors.

In our technical proposal, EMRC proposed to use an econometric model for load forecasting. In our view, the data requirements of a comprehensive techno-economic model mean that it is not a practical choice for this assignment. It would require a long-term cross-institutional effort that is not practical in the timeframe.

The previous econometric studies demonstrate that adequate data is available for an econometric approach. We intend to learn from all the previous studies to improve the performance of the demand forecast and ensure it provides a robust basis for the cost of service study. We will supplement the econometric analysis with a bottom-up techno economic approach for the mining and large industrial sectors and other types of customer if the information needed can be obtained. The detailed approach we intend to take is summarised in the following section.

5.3.2 Proposed econometric approach

Approach to categorising demand

Previous econometric demand studies in Zambia have separated demand into three broad categories:

- Residential and commercial demand;
- Industrial demand excluding mines – the JICA 2010 study grouped all industrial demand; and
- Mining demand.

The mining demand was forecast based on planned development of new mining projects, rather than any econometric basis.

We therefore intend to treat both mining and the large industrial demand (tariff categories MD3, MD4 and other PPA-based customers) separately from the econometric approach. We intend to work with key stakeholders, including CEC, the Chamber of Mines, and Federation of Zambian Industries[11] to identify an exogenous prediction for these large industrial and mining customers. However, we will also review the impact of specific external factors to the mining demand: for example, the country policy environment, the impacts of unreliability of electricity supply, and international price trends (as discussed later in this section).**Demand shape**

Whilst previous studies appear to have focussed on overall annual consumption, it will also be important to consider peak demand where possible. Peak demand and average consumption will both influence the costs that different customer classes impose on the system.

To better understand the influences on demand, we will request data from ZESCO and other distributers at a greater level of granularity (e.g. monthly) and for both peak demand and overall energy consumption.

Voltage levels

For later stages in the cost of service study, it will be important to have information on the demand at each voltage level. We will investigate the demand data to see if we can separate the customers into voltage levels for the regression analysis. Previous demand studies have not incorporated voltage level, so it is not clear whether data will be available.

Explanatory variables

Previous studies have drawn on the following explanatory variables for residential and commercial demand:

- GDP per capita (real);
- Customer numbers; and
- Electrification rate.

The incorporation of the electrification rate into the regression analysis presents an interesting challenge. Newly electrified customers are often only able to afford a very small electricity demand. As a result, JICA 2010 reported a coefficient below 1 for customer numbers. These results imply that as electrification increases, demand per customer decreases.

[11] As referenced in the TOR and listed as member of the Steering committee. Other representatives of Zambian Industry may also be applicable such as Zambia Association of Manufacturers (ZAM) and the Zambia Chamber of Commerce and Industry (ZACCI).

We intend to explore several ways of reflecting this electrification effect in the econometric analysis, to see which offers the best performance, including:

- Separating rural and urban demand in the regression (data permitting) and ensuring that electrification is also separated into new rural and urban customers. This may capture the fact that electrification is largely in rural areas with lower income levels. It may also allow us to capture urbanisation effects. However, it is not clear whether data will be available.
- Treating electrification rate as an explanatory variable. This seems to have substantially increased the explanatory power (R^2) relative to JICA 2010.
- Using the number of customers as an explanatory variable (as JICA 2010) and recognising that the elasticity below one reflects decreasing demand with electrification. This approach may be more rigid as it effectively is based on past electrification levels. If electrification rates are higher or lower in the future, there might be a change in the coefficient.

Previous studies have drawn on the following explanatory variables for industrial customers:

- Industrial GDP (real) or overall GDP (real).

As mentioned above, GDP has a reasonable explanatory power for smaller industrial loads, and larger industrial and mining loads have previously been treated as an exogenous calculation based on external forecasts. We will explore whether the addition of other explanatory variables, such as those listed below under exogenous factors, could allow us to forecast these sectors more accurately.

Additional exogenous factors

There are additional factors that will potentially have an influence on the demand forecast. Based on the amount of data available, we will review to what extent these could be incorporated in the model or used as exogenous adjustment. These include:

- Electrification plans – electrification plans are set out in the Rural Electrification Master Plan (REMP) 2008-2030.We will seek information from the Ministry of Energy and Rural Electrification Authority (REA) to understand and sense-check the current position and the trajectory expected to 2040. It is worth noting that we understand preparation is underway for a GIS least cost electrification roll-out plan by World Bank, REA and MoE. Our current understanding is that Government may adopt this plan over the next 6 months. If sufficient findings are made available arrive before this project is complete, they can be incorporated in the load forecast. Otherwise, our training for ERB (see section 5.3.3) will enable them to incorporate the plans themselves.

- Load shedding – JICA 2010 used load shedding to adjust the peak demand forecast, but not the overall demand. We will seek information from ZESCO and CEC on load shedding. If sufficient data is available, we can explore whether adding load shedding to the econometric analysis could capture the impacts of unreliability of electricity supply on average demand.
- Changes in price – changes in tariff levels (and experienced tariffs including taxes or levies) can have an impact on demand. We will seek to incorporate this in our analysis.
- Demand side management and energy efficiency – these can cause a structural change in demand and should be factored in. We will discuss the latest status and plans for demand side management and energy efficiency with ERB and Ministry of Energy and adjust the forecast to account for these measures. The impact on average consumption and peak demand may be different depending on the measures considered.
- Climate – if data is available, we may also wish to consider climate factors (e.g. rainfall and temperature) and whether they can have any impact on demand, particularly if we are using demand data at a sub-annual level. The results may be complicated if generation is supressing demand (e.g. load shedding in years with low rainfall).
- Demographic change – including growth in population over time, changes in household size and rural-urban shift.
- Commercial losses – measures to reduce commercial losses will potentially have two impacts, both to reduce demand (consumers will use less when they must pay for it) and to increase billed energy. We will discuss with ERB and ZESCO whether there are plans in place for significant commercial loss reduction strategies that might cause a structural change in the demand.
- Wider macroeconomic factors – beyond GDP, we may wish to consider any other factors that might influence industrial demand, for example number of industrial customer sites, international price trends or exchange rates.
- Wider impacts of the country policy environment on industrial and mining demand, and potential structural changes in demand as a result of policy changes.

Testing the model

The previous studies did not report any results of testing the demand models.

We intend to "hold out" data for model validation purposes. This means that we will only use part of the data for the initial regression analysis to specify the model, and the rest we will set aside to test the model performance. Depending on the quantity of data available we will aim to hold out up to 20% of the data set for model validation. The model derived from the 80% data will be used to forecast the remaining 20% and compared to the real data. This will provide the best indication of the accuracy that can be expected for forecasting demand over a longer time horizon.

For the final model we will use all the available data for estimation, so that the model benefits from the most recent data.

Confidence intervals

We will report the confidence intervals of the forecast in the results.

5.3.3 Training in using the demand forecast

It will be important to ensure that stakeholders understand how to use the underlying demand model to update the forecasts.

As part of the training (section 5.11), we will demonstrate how the forecasts can be updated when new data is available, including new forecasts for GDP, electrification plans and any other explanatory variables used in the forecast.

5.4 Long term development programme

5.4.1 Overview

As a first step for the long-term development programme estimation, we will examine all existing expansion plans for generation, transmission and distribution, ideally covering a 10-year or longer timeframe. This will include procurement agreements with ZESCO, IPPs and neighbouring countries.

During the inception visit, we have identified the following documents as the basis for the initial analysis:

- The Power System Master Plan (JICA – 2010) covering Generation, Transmission and Distribution
- From the Government of Zambia (Ministry of Energy):
  - Energy Policy 2019 – approved draft
  - Vision 2030 Report (Department of Energy)
  - 7th National Development Plan, which addresses rural electrification topics

At the Distribution level, two Divisions of ZESCO have prepared updated plans, namely, Southern Division (year 2015) and Lusaka Division (year 2012).

The results and projections of the documents above will be reviewed to check their consistency/alignment. These will form important inputs to the expansion plan along with the results of the base case demand projection from Task 3.

We will also gather input data for modelling the optimal path for system expansion at generation, transmission and distribution level. We will collate and refine the primary data and Base Case Demand scenario, and enter this data into a set of models to produce a least cost expansion plan for generation, transmission and distribution. With the results of the expansion plan, the future costs to supply the demand of Zambia will be computed.

Before running the model, all inputs will be passed to the Study Technical Committee (STC) for review and validation. These inputs will be in the form of an MS-Excel "data workbook". The data workbooks will be developed to distinguish between data for generation, transmission and distribution. This workbook will be formatted clearly to allow for any updates by the SMT for future studies.

5.4.2 Potential Developments

The Department of Energy within the Ministry is responsible for macro energy planning (matching long-term supply and demand) whereas ZESCO develops its own project at a micro level. ZESCO has no plans to develop thermal-fuelled projects. Renewable Energy Source (RES) project development (wind, solar, small hydro, geothermal) is the responsibility of a separate division of ZESCO. Under the GeTFiT programme development[12], RES plants are being assessed and include approximately 120 MW of solar + 100 MW of small hydro projects-. These are to be developed in the northern region of the country and no relevant congestion issues are expected.

[12] A programme supported by KfW which in addition to diversifying Zambia's power mix, GET FiT Zambia aims to strengthen the Zambian power market by encouraging private sector participation from a wider range of developers, construction firms and financial institutions.

Our model will consider new potential generation within Zambia, the network expansion due to the electrification program, and projections for the Southern African Power Pool (SAPP). We will consider thermal power plants that could be developed by the private sector using latest technologies for pollution abatement, and minimization of climate change impacts. We will also consider the potential impact of the Zambia-Mozambique interconnection to provide opportunities for long-term bilateral contracts for supply from Coal/gas-based generation from Mozambique; as well as the ZTK interconnection providing opportunities for long-term bilateral agreements for hydro-based imports from the Eastern Africa Power Pool.

In planning terms, the current pipeline looks like[13]:

- Kafue Gorge Lower (750 MW) – end of 2020 – GRZ financed with a Chinese loan.
- Chishimba Falls (15 MW) – KfW.
- Lusiwasi Lower (86 MW) – to be contracted for development (2022), financed by ZESCO.
- Batoka Gorge. Bi-national dam developed by the governments of Zambia and Zimbabwe (1200 + 1200 MW). Contracted to Power China and GE (2025).
- Kalungwhisi 163 MW. Feasibility studies on-going (2026).
- Solar potential is being studied by the RE division of ZESCO.
- Aside from current and future hydro schemes there are no plans to develop energy storage schemes (pumps, batteries).

SAPP is operating a day ahead market for electricity. Although this is modest at the moment it is increasing in terms of volume and number of active participants. The model will consider the opportunities in the long term supply of power from SAPP.

ZESCO is responsible for transmission planning insofar as it relates to its own network. In parallel, CEC plans its own network. SAPP network development plans are aligned with those of ZESCO and CEC since both entities provided input to the SAPP data base in the preparation of the regional plan. ZESCO and CEC work together in this regard.

The Rural Electrification Authority (REA) undertakes development of rural electrification in accordance with the latest Rural Electrification Master Plan (REMP) developed by JICA in 2009.

[13] ZESCO staff confirmed that the feasibility studies of the plants in the pipeline can be shared subject to receiving the data request

REMP was launched in 2008 and ratified by an Act of Parliament as described in section 4. To allow for changes in circumstances the REA has adopted a flexible five-year rolling plan. In some cases, the prioritisation of projects has changed e.g. some places have been upgraded to Districts and which in turn affects their ranking. The Ministry of Energy has been engaged to commence a review of the REMP, that accommodates such changes resulting in a refreshed technological approach.

The Department of Energy has formulated the Electricity Services Access Project (ESAP) whose objective is to evaluate how rural electrification can be rolled out. JICA has shown interest in offering support to review REMP.

We will assess all the available generation expansion candidates, including bilateral import options and REMP options, for their technical and commercial feasibility such that inputs to the model-based analyses are soundly based.

5.4.3 EDM and SDDP Models

We will use a suite of modelling tools for the project. We will use the models to determine the "optimal" investment schedule (generation and transmission and the major distribution lines) required to supply the forecasted load in Zambia for the Base Case scenario.

The models apply a dynamic programming approach to evaluate the least cost options for the operational variables over the planning period. The main operational variable in the system that needs to be optimised is the generation from hydro stations that have reservoirs with significant storage. Dynamic programming enables the calculation of the total cost of system operation taking into account all variable operating costs which are mainly thermal fuel costs. The dynamic programming technique optimises hydro station generation in each of the specific time periods over a year – potentially in time-increments as small as one hour. It therefore models the optimum operation of all generators on the system including hydro power stations with reservoirs and run-of-river, IPPs and supplies through interconnectors.

Over the planning horizon selected (in this case 20 years to 2040) the new plant required to meet increasing demand will be added to the generation capacity so that demand can be met in each year of the plan. And the dynamic programming will capture the optimised and therefore least-cost capital and operating expenditures needed in each year of the plan. These optimised capex and opex costs are critical inputs to the cost allocation to tariffs.

Existing and plant under construction will be modelled as available. Identified candidate plants will be added to the model as their capacity becomes necessary to meet increasing demand.

Model outputs will include a schedule of the generation facilities assumed over the life of the plan showing any modelled changes to generation capacities and the coming online of the new plant. It will also include the critical elements of optimised opex and capex in each year of the plan. These latter outputs will be the critical inputs to the cost allocation modelling to follow. The model will also be used to determine and provide as output the long run marginal cost of generation over the planning period.

The data requirements for the least cost expansion modelling are set out in Annex F, which describes the detailed information required for the whole least-cost expansion planning process including details on: existing thermal plants (Table 1 of Annex F), detailed information for candidate thermal plants (Table 2), existing large hydro plants with reservoirs including storage information (Table 3), run-of-river hydro plants (Table 4), candidate hydro plants (Table 5), RE plants, and detailed transmission line characteristics.

For Generation and Transmission planning, we will use MRC Group's proprietary EDM expansion model. It is designed to minimise investment cost and expected operation cost by considering fuel cost plus costs associated with supply reliability constraints and the cost of non-served load. The model will consider the existing generation fleet and its age and production capabilities. Supply options include large and small-scale hydro generation, small-scale renewables, contracts and interconnections with SAPP. Candidates for new generation can be defined by zones, taking into consideration resource availability and the costs of each. Interconnections (such as those with South Africa and Mozambique) will also be modelled.

The model allows planning with long horizon frameworks that are defined by the user. In this case the planning horizon is expected to align with the base case demand projection for the next 20 years to 2040. By considering the transmission network and generation in a single model we are able to define consistent scenarios for expansion. Demand can then be met with existing and new generation.

At the time that EDM proposes and compares total costs for different investment paths (for example over 20 years), it can be complemented by a module that optimises operational costs of the given generation system in a more detailed manner. In other words, EDM compares total costs of investment strategies to supply the forecasted demand, considering the CAPEX associated to each investment plan, and the detailed OPEX structure is estimated by the complementary module.

In the Zambian case, the complementary module we are going to use is SDDP. The SDDP Model was developed by PSR (Brazil) and has been extensively used by private investors, government agencies and multilateral institutions in more than twenty countries worldwide. SDDP is a transmission-constrained production simulation model that calculates the optimal stochastic hydrothermal dispatch on a monthly or weekly basis, and performs a detailed modelling of all system components: transmission network (linearised power flow model), hydro (variation of production coefficient with storage, spillage, filtration etc.), thermal (unit commitment, multiple fuels, limitations on gas supply, etc.) and contracts. It also has the functionality to model the stochastic inputs from other renewable energy projects such as wind power and solar power and solar power generation will be part of the plan. The basic objective of hydrothermal system operation is to determine generation targets for each plant, at each stage, so as to minimise the expected operation cost along the planning period. This cost comprises the fuel costs for thermal plants, purchase costs from neighbouring systems, and penalties for interruption of load supply.

The SDDP model will be used on a stand-alone basis to evaluate in more detail an expansion plan produced by EDM.

Figure 5 represents the way both models interact:

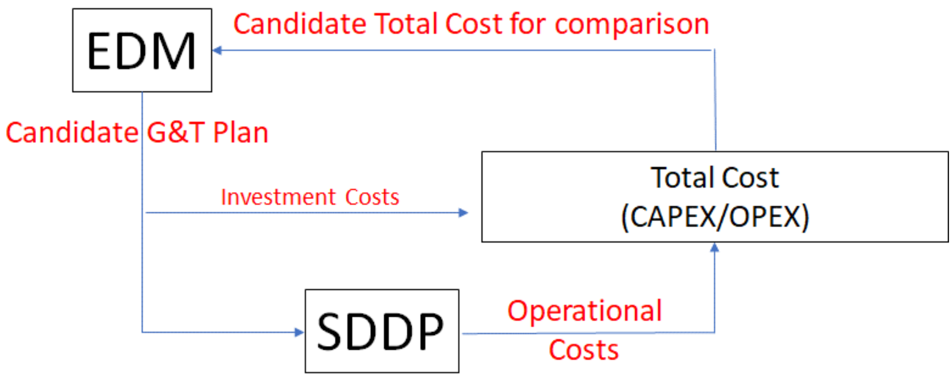


Figure 5 - EDM – SDDP interaction

Our modelling work will also address the following:

- A separate modelling of the generation and transmission systems to achieve the long-term least cost generation expansion programme based on a dynamic optimisation programming technique.
- Ensure that all relevant system and related costs would be captured in the analyses.
- Dynamic optimisation to take place either through EDM or the SDDP model to arrive at a single solution objective function for the long-term least-cost

generation expansion program. The full definition of the objective function in terms of its composition is stated.

- Computation of the value of water under various hydro conditions mentioned in determining the variable production cost from the SDDP model.
- Use of the generation expansion programme to estimate the marginal cost of meeting an increment of a MW of demand at the system peak over the long-term.
- Consideration of the principle of "peak responsibility" to provide an estimation of the SRMC.
- Those points are specifically considered and elaborated in Section 6.2.

5.4.4 PCM Model for distribution expansion

The model to be used for distribution CAPEX forecasting is MRC Group's proprietary parametric planning model (Parametric CAPEX Model – PCM). Experience shows that the development (expansion and reinforcement, together with replacements and rehabilitation) of power distribution networks, despite not being totally predictable, tends to follow paths where key ratios remain constant or with an overall slow evolution. These ratios or parameters are related to the intrinsic structure of a distribution system: distributing energy to end-consumers requires step-down transformers, that are necessarily linked by medium voltage conductors and that supply energy to consumers through MV/LV transformers and LV conductors[14]. They tend to be quite stable over time, due to the low impact that the small percentage of the grid that is installed/modified represents compared to the total network's structure already in place.

PCM is based on the identification and quantification of these stable network characteristic parameters from the historical data on the distribution grid and their use to predict future performance. Figure 6Figure 6 illustrates the structure of the PCM model. The PCM model provides a projection of revenue requirements for tariff setting purposes and includes the following:

- The historical performance of the distribution network (loading levels, loss levels, SAIDI/SAIFI) will be analysed to identify needs.
- The demand forecast will be used to evaluate if the distribution network carrying capacity is enough to supply future demand. To this end, we would need the company to supply us the energy balances with enough level of detail to allocate loads to substations and distribution transformers and feeders.

[14] As provided in Zambian Standard (ZS 387-Power Quality and Reliability Standards)

- The loading statistics of transformers and feeders, coupled with the demand forecast, will serve to detect existing and potential future overloading issues. In this way we will obtain indications on the need for capacity increases, either through refurbishment or greenfield expansion at the MV level (11kV – 33 kV).
- The parametric model will be applied both to MV network, LV network and transformers to provide: a) a basis for comparison of MV network needs and b) the projection of LV network needs. LV network expansion needs will not be carried out on an individual project basis because it is unnecessary and impractical. In the case of the MV network, it will depend on the type of data that is available.
- The electrification expansion plan should be an input to the distribution expansion projection. We will need to obtain indication on what electrification actions are already planned, and which need to be transferred to distribution tariffs.

The application of the parametric model provides a base reference investment programme, that then is fine-tuned where necessary based on specific issues. For example, investment in loss reductions plans, modernization of ICT, extraordinary expansions or electrification interventions, etc.

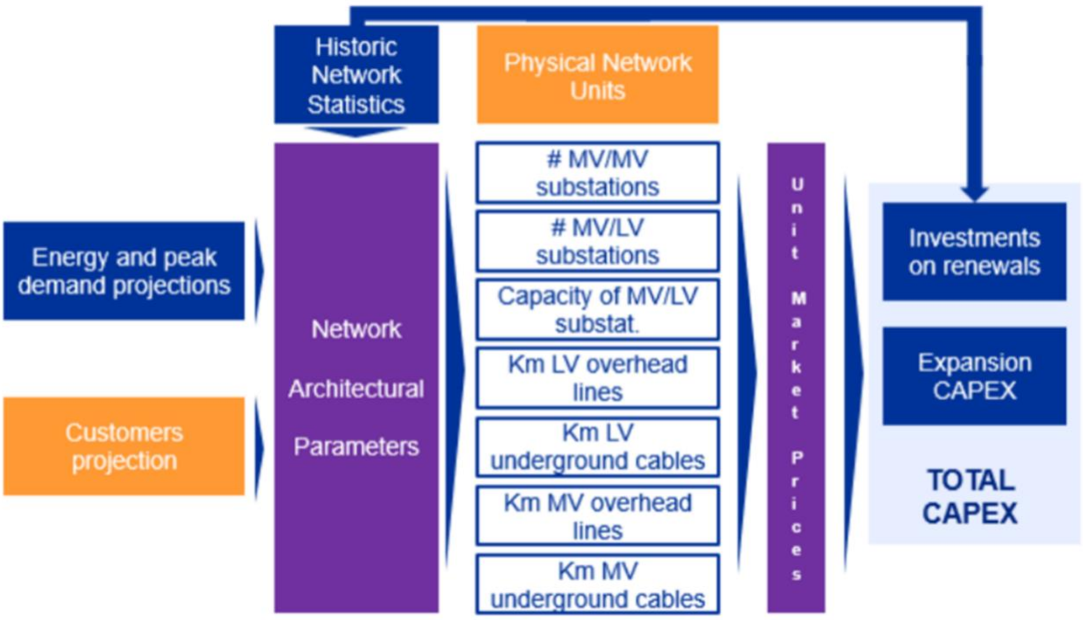


Figure 6 - PCM Model Structure

Since the investment in asset replacement in the parametric model is based on average asset useful life and condition, the actual replacement of assets may vary depending on the actual state of each specific asset. Therefore, in the long-term investment plans of the company, it should project actual replacements based on the feedback obtained from the field operators and the asset surveys that should be periodically carried out.

Annual CAPEX requirements will be estimated using a base year (probably 2019) constant prices for the main distribution network assets (which include equipment and installation costs).

The Basic CAPEX will include the investments in distribution transformers (also called secondary substations), lines, cables and primary substations that constitute the basic network infrastructure required to address the future demand. Total CAPEX will include, in addition to Basic CAPEX, investments that will be required for asset replacement, maintaining, and eventually improving, the state of the network.

Within the parametric model, estimation for the physical assets installed per year is obtained by type of major asset, which will be multiplied by the asset unit prices to transform physical units into economic investments required.

- The unit price selected for distribution transformers is based on reference prices for an average transformer to be selected based on ZESCO's statistics for secondary substations.
- Overhead lines and underground cables unit prices will include the cost for poles/towers and trenching and coupling respectively; they refer to circuit kilometres.
- MV underground cables and overhead lines are assumed to be of average type to be determined from analysis of ZESCO data.
- LV overhead lines and primary substations will also be based on ZESCO norms.

The selection of the value of each parameter of the model will be done by comparing historic data on the distribution network with our experience in international projects where the same parametric model was applied.

Aspects such as the average length of low voltage lines required per new customer and the undergrounding ratio in the low voltage network follow a low-slope glide path towards lower meters per customer and higher shares of underground cable respectively to account for the typical evolution of town networks over time.

Because of the low-slope assumed (to take into account that the main objective of distribution companies in the short to medium term will be focused in electrification and not in redesigning the network), the effect of this glide path is usually quite small.

Assuming an average useful life for power distribution assets of 35 years and that the installation of new assets in the network increases year on year, the age-distribution of assets installed would follow an exponential trend. Applying this probabilistic reasoning, the share of the total number of currently existing assets that will have to be replaced in a period of 35 years will be determined.

The existing asset base of the distribution company will be valued at current market prices for new equipment. Replacement costs will then be equally distributed over the years of the study period.

The advantage of using a parametric model is twofold:

- The utilisation of simple parameters allows for a fast and easy identification of the structure of the current network by establishing direct relations between networks assets, and between those assets, demand levels and customer numbers.
- As parameters can be calculated with relatively simple data, comparison between distribution companies is possible and assumptions can be made on the evolution of those parameters over time.
- Asset replacement in the PCM is based on average asset useful life and condition by type of asset. The actual replacement may vary depending on the actual state of each specific asset.

(Physical Units)	2014	2015	2016	2017	2018	2019	2020
# MV/LV transf.	141	134	158	162	167	154	164
MVA MV/LV transf.	51	49	57	59	61	56	60
km MV OHL	349	329	386	394	404	370	392
km MV UGC	35	36	44	47	51	49	55
km LV OHL	835	3,682	5,711	5,373	5,151	3,568	4,111
km LV UGC	2	11	23	27	31	25	33
MV Meters	15	12	13	11	11	11	11
LV Meters	99,725	81,913	84,498	85,175	87,820	90,546	93,355
# Primary substations	1	2	2	2	1	2	2

(2013 Real prices - USD)	2014	2015	2016	2017	2018	2019	2020
MV/LV transformers	5,466,779	5,196,294	6,131,632	6,258,922	6,470,573	5,950,066	6,350,123
MV conductors	11,719,173	11,266,756	13,437,241	13,933,846	14,525,152	13,543,148	14,580,926
LV conductors	17,834,486	78,922,005	122,935,964	116,159,870	111,834,516	77,779,520	90,004,262
Primary substations	1,373,846	2,747,692	2,747,692	2,747,692	1,373,846	2,747,692	2,747,692
Meters	5,413,587	4,446,543	4,587,092	4,623,083	4,766,523	4,914,356	5,066,690
Expansion CAPEX	**41,807,872**	**102,579,290**	**149,839,622**	**143,723,413**	**138,970,609**	**104,934,783**	**118,749,694**
Renewal	46,655,169	48,091,775	50,190,253	52,203,075	54,149,334	55,618,928	57,281,997
Total CAPEX	**88,463,041**	**150,671,065**	**200,029,875**	**195,926,488**	**193,119,944**	**160,553,711**	**176,031,691**

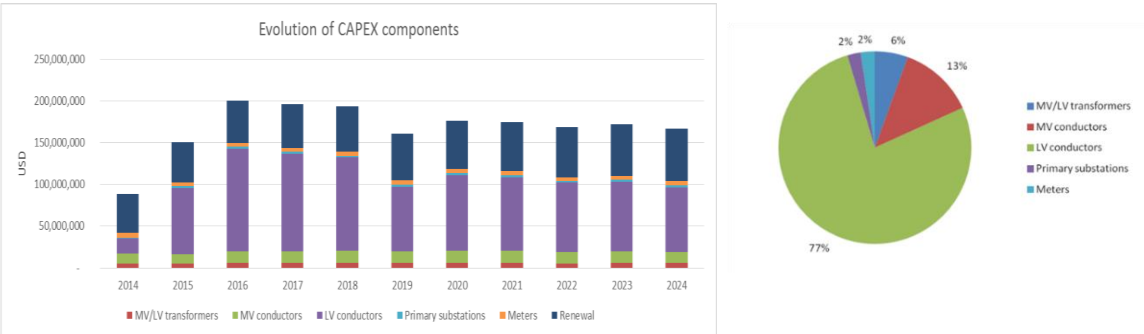


Figure 7 - Example of typical outputs of the PCM

5.4.5 Electric studies. DigSilent

We will assess the technical feasibility of the Least Cost Expansion Plan through electrical studies executed using DigSilent software, checking in particular for transient instability that could result in particular from solar power generation on the network. As agreed with ERB during the kick-off mission we will carry out static studies for the transmission network that will check its behaviour in terms of voltage regulation and eventual congestion effects.

DigSilent cases of the transmission network were requested from ZESCO who confirmed that they were available. These details are required for the current and foreseeable future and only for the transmission network; the distribution network will be modelled in a parametric manner.

5.4.6 Results

The previous models will be used to prepare three reports:

- The Long-Term Least Cost Generation Expansion Plan
- The Long-Term Least Cost Transmission Expansion Plan
- The Medium-Term Distribution and Supply Expansion Plan

These reports will be developed in collaboration with the Study Management Team (SMT) and subsequently passed to the Study Technical Committee (STC) for review and validation. The models and the reports can readily provide results for different scenarios – for example generation that is largely Zambian-based compared with a significant level of imported generation. We will review with the Study Management Team which scenarios to include once the optimum options become clear. Validation of the demand forecast is a critical component for the computation of economic tariffs and the design of the roll-out strategy.

5.5 Economic tariffs

The discussions and data collection undertaken during the Inception visit have reconfirmed that the detailed approach we set out in the technical proposal is still the optimum for the determination of economic tariffs. In general terms the methodological approach is summarised below:

5.5.1 The electricity supply chain

Our tariff methodology will consider the costs of the whole electricity chain, including:

- Authorised costs of energy and power procurement in the wholesale market.
- Allowed revenues for the regulated transmission business.
- Allowed revenues for the System Operator and for providing ancillary services.
- Allowed revenues of the regulated distribution business.
- A justifiable retail margin which, if there is sufficient competition, can be determined by the market rather than regulated[15]. We understand that the bulk of the electricity retail market in Zambia as administered by ZESCO is unlikely to be opened up to free competition in the foreseeable future and as a result the margin for retail shall largely be based on ZESCO's allowable return on capital.

[1515] Even in a competitive retail market for electricity regulators do maintain a degree of oversight to ensure that market participants adhere to market rules designed to ensure fair competition and that vulnerable consumers are adequately protected.

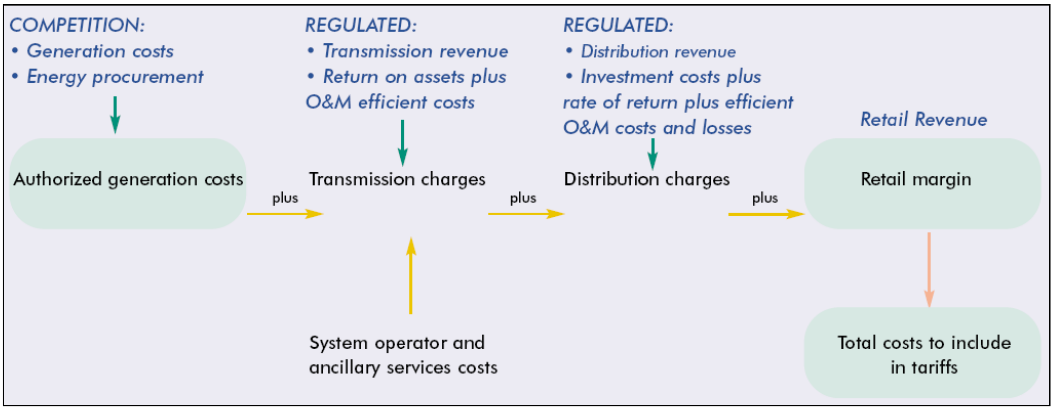


Figure 8 - The costs that make up the electricity chain

Figure 8 illustrates the costs that make up the electricity chain

In line with the envisaged electricity structure market and in accordance with the draft Energy Operations Regulation, we shall prepare the tariff guidelines methodology on the basis of determining tariffs for each segment of the electricity supply market namely: generation, transmission, distribution and retail.

Our methodology will allocate the allowed revenues amongst the various customer groups or tariff categories based on sound economic principles.

5.5.2 Tariff design

Figure 9summarises the methodology through which our final tariff model will address all relevant variables:

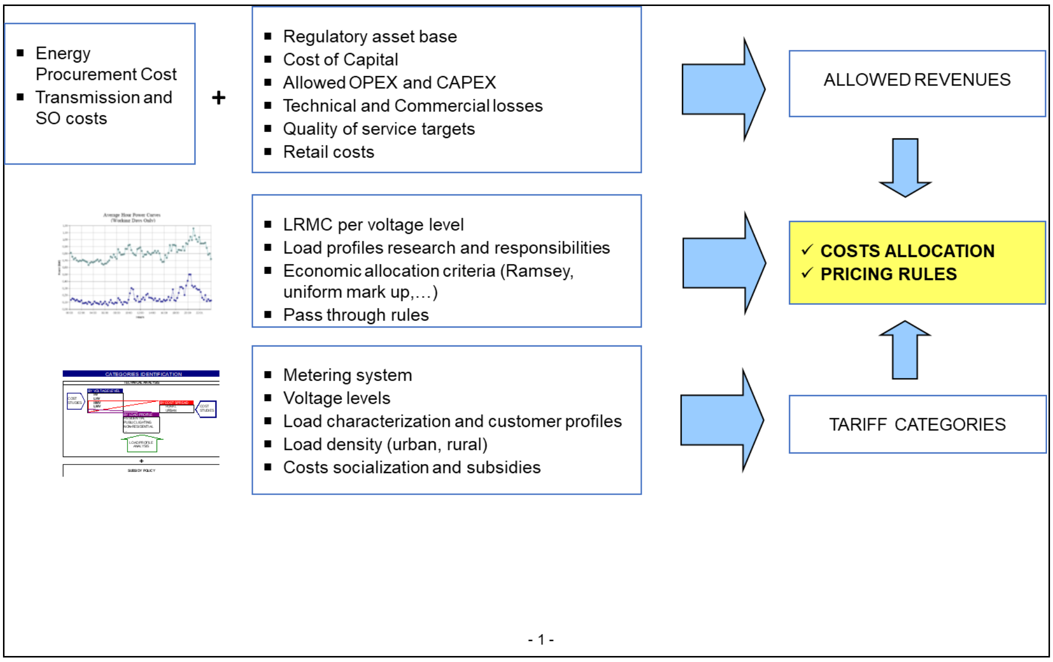


Figure 9 - Tariff Design Process

5.5.3 Generation costs

The bulk energy supply costs to produce energy from the power plants will depend on the wholesale market and bilateral contracts. Our unbundled tariff methodology will provide for the bulk costs of energy to be transferred to end users (pass-through) with formulae to insulate utilities from rises or falls in bulk energy costs.

5.5.4 Transmission charges

Transmission charges will have the following components:

- **Connection charges** related to the assets used to connect users to the grid. The charge is usually in US$/KVA connected. Consumers pay according to the maximum contracted demand, and generators according to their installed capacity. The connection charge is computed yearly, and includes costs related to capital cost of connection assets (transformers, substation equipment, etc.), O&M expenses associated to these assets, and indirect costs.
- **Use of common network charges, or transmission network use of system (TNUOS).** These are payments associated with lines and transformers, as well as equipment for operation and compensation of lines. Difficulties to define those charges arise from the impossibility to trace the energy within a

transmission system. This is the major problem in transmission pricing, because it is not possible to identify the assets used for parties in a particular transaction. In any case, we will analyse the various approaches currently used in other jurisdictions.

- **Postage stamp**. Allowed transmission revenue is allocated among users either in proportion to their peak demands and installed capacities, or in proportion to their energy production and consumption.
- **Long run marginal cost**. Allocation is proportional to the marginal contribution of each user to the cost of an ideal transmission network constructed to match supply and demand.
- **Extent of use (consistent with the AIC methodology)**. Allocation is proportional to the "utilisation" of each transmission line which is attributed to each user.
- **Contract Path Method**. The transmission service charges are based on a contract path method. This method assumes a reasonable (hypothetical) path between the receipt and delivery points.

- **System Operator** expenses and ancillary services costs

International experience shows that there is not a method that can be considered as the standard solution for transmission pricing. Those approaches will be reviewed with ERB both at the inception phase and the start of Task 4 to ensure that we choose the most appropriate mechanism.

5.5.5 Distribution Service Charges

Drawing upon tried and tested methods adopted by regulators elsewhere in the world the efficient allocation of distribution costs are determined by:

- Functional allocation, associating costs to specific functions and facilities;
- Classifying costs in terms of the driver of their growth (energy consumption, power demand, customer basis); and
- Costs allocation, into specific tariff charges. The rationale we will apply for this allocation is summarised in the following table:

Specific Costs	These costs are directly related to each customer. They are easy to allocate and primarily depend on cost estimations. Specific costs are directly allocated to each customer (simple cost analysis).
Shared Costs	These costs are those not specifically related to one client but that can be fairly allocated to a service or customer group based on cost studies (i.e., marginal cost) and cost responsibility based on load profiles. Shared costs are often forced to be referred to capacity demand and are allocated based on cost studies and load profile allocation.
Indirect costs	These costs are those not specifically related to one client and cannot be fairly (neither efficiently) allocated to a service or customer group. Common costs are often distributed to groups of customers based on case specific rules, not necessarily efficient. More sophisticated and efficient rules (i.e., Ramsey) can be applied.

Figure 10 illustrates the different types of cost, their functions and classification.

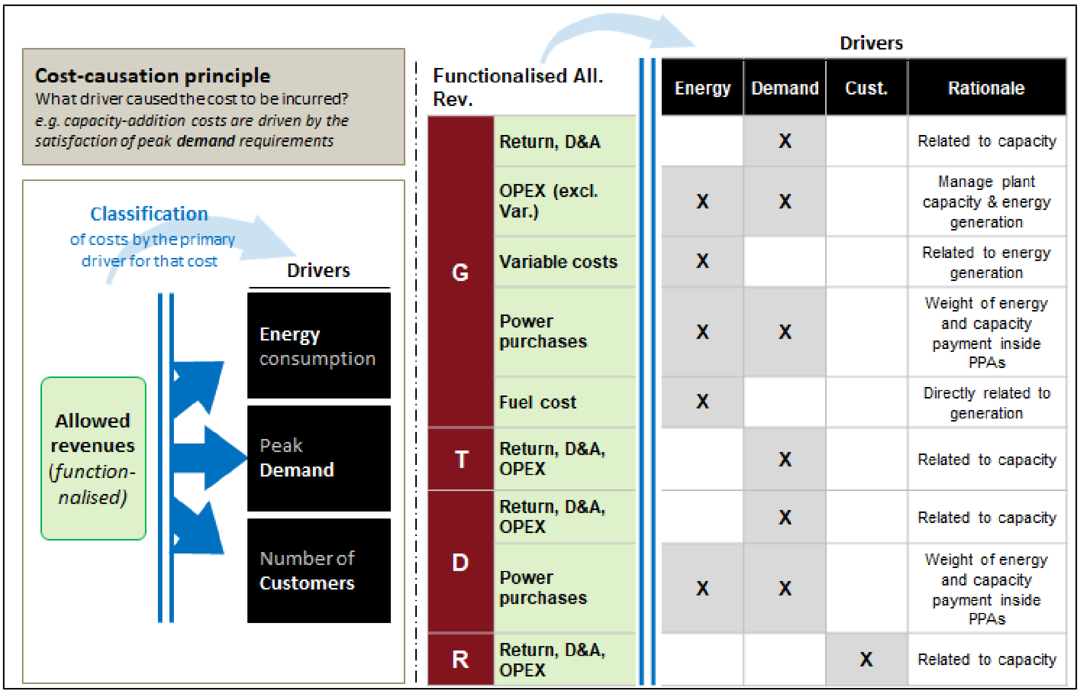


Figure 10 – Cost functions and classification

5.5.6 Exchange rates and inflation

We have examined the relationship between USD ZMW exchange rates and relative inflation between USA and Zambia (see Figure 11). Although there may be short term divergences the longer run correlation is strong (97%). The last few years has seen a divergence with the exchange rate moving out at a faster pace than inflation. The impact of this may be that future years (in the short run) inflation may move faster than the exchange rate although many other macro-economic factors may distort this outcome. For the purposes of our analysis we assume that there are no fundamental reasons to suggest any long run divergence, i.e. movements in the exchange rate reasonably reflect relative movements in prices between the USA and Zambia.

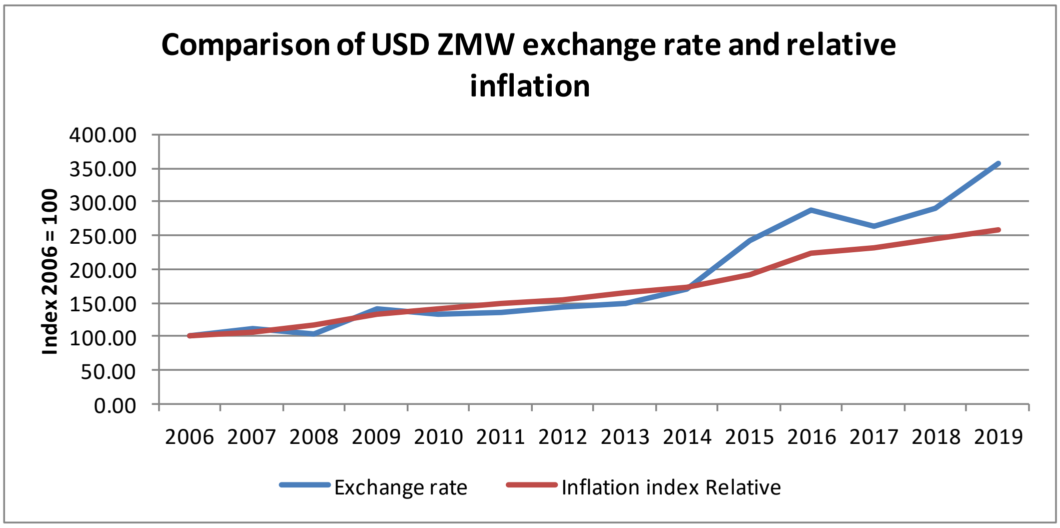


Figure 11 – Exchange rate and inflation analysis (source EMRC analysis of data in public domain)

5.5.7 Cost of capital

The ERB currently use a real cost of capital of 6%. This figure has not been derived from any detailed economic analysis using the Capital Asset Pricing Model (CAPM) or similar. It has been adopted by the ERB as a yardstick measure drawing on the cost of capital applied in other environments. In the course of our work we shall examine various options to determine this measure and present our findings for ERB consideration. A particular aspect of this is that ZESCO is state-owned and therefore measures that rely on comparisons with private sector models (e.g. CAPM) may not necessarily be a true reflection of the most relevant cost of capital. The Water Industry Commission Scotland (WICS) faced a similar dilemma when trying to determine a cost of capital for state-owned Scottish Water. It took the approach of setting financial targets necessary for Scottish Water to maintain investment grade status as set by the ratings agencies and then reverse engineered the outcomes to determine the cost of capital which was slightly lower than Scottish Water's privately owned counterparts in England and Wales. We have undertaken a simple preliminary analysis using the WICS criteria and applying it to the 2018 ZESCO accounts. This revealed a cost of capital of just over 5% would be sufficient, although to achieve this outcome the required increase in net revenue would need to be nearly 50%.

Although the Government of Zambia is the shareholder of ZESCO it has not taken dividends as ZESCO has not declared profits. However, if ZESCO returned to profitability then it would expect to be rewarded for its investment. Consequently, an assumption of zero return on government equity, an approach sometimes adopted in other environments, will not apply. We shall examine the implications of the return on government equity bearing in mind existing government policies in this regard.

5.5.8 Regulatory asset base

The determination of the regulatory asset base shall draw on the asset register that has been recently re-valued. We propose to make an indexation adjustment to a base year regulatory asset value.

A proportion of the assets have been financed by grants and customer contributions for which the accounts hold a reserve value of un-amortised grants and customer contributions. This reserve, however, has not been re-valued in parallel with the asset revaluation and therefore the net regulatory asset value (asset values less grant reserve) is possibly over-stated. We shall examine the value of the grant reserve to determine, based on the best information available, a reasonable estimate of a re-valued grant reserve to arrive at a more cost reflective value of the net regulatory asset value.

We understand that part of the rural electrification programme includes a process where rural network assets financed by others are adopted by ZESCO. It is unclear at this inception stage if such assets appear on the ZESCO asset register and whether or not there is provision for it in the grant and customer contributions reserve. We shall examine this aspect and, where necessary, make adjustments to the regulatory asset values accordingly.

5.6 Life-Line Tariff

A preliminary analysis of income distribution reveals a high degree of income inequality in Zambia with the wealthiest 30% of the population earning over 75% of the income. Our analysis shows that at current tariff levels the poorest 20% could not afford a service (regardless of the cost of a connection) as the fixed charge alone would be beyond acceptable levels of affordability. The next 20% could only afford a minimal level of supply of less than 30 kWh per month, and only at the current subsidised lifeline tariff.

Although the 5th, 6th and 7th decile population groups could potentially afford electricity at rates in excess of 100 kWh per month the bulk of the consumption will fall into the lifeline rate and as such, rather than add to profitability it may be loss making (see Figure 12 and Figure 13). Detailed data on income distribution separated by rural and urban populations is necessary to determine the degree of correlation between the longer-term projection of 65% urbanisation and the 60% of population by income. A reasonable degree of correlation may support an approach which targets grid expansion to the urban areas as a first priority.

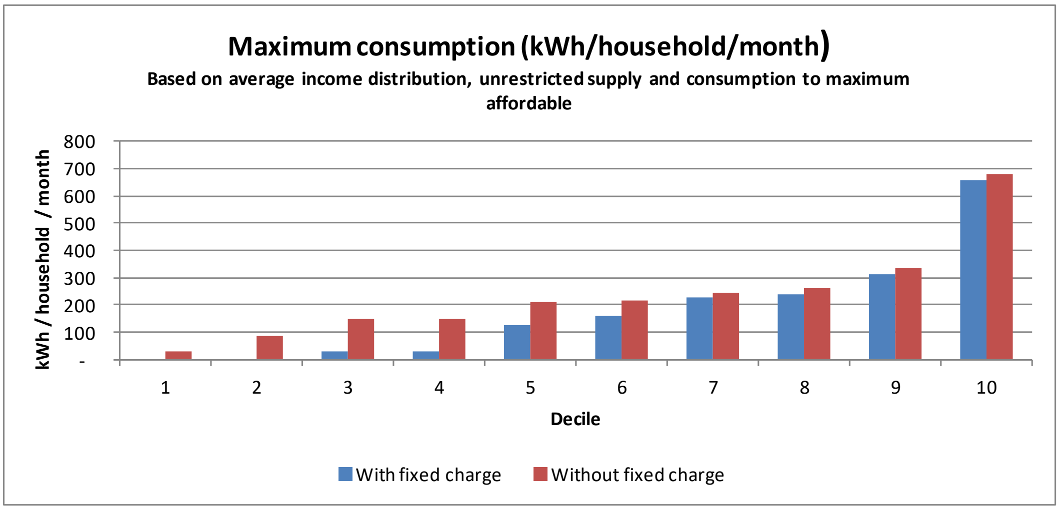


Figure 12 - Maximum consumption (kWh/household/month)

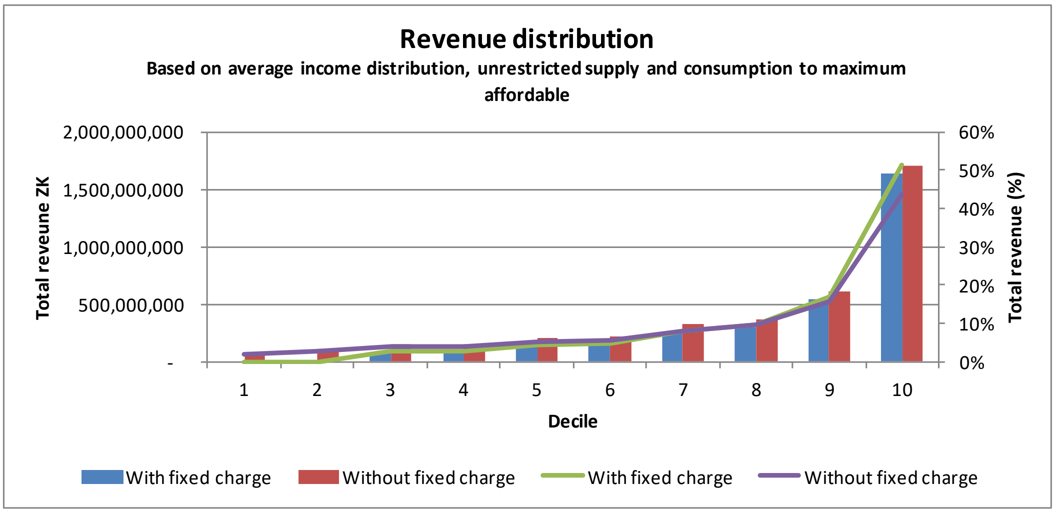


Figure 13 - Revenue distribution

The current proposal to remove the fixed charge[16] from the tariff schedule may improve levels of consumption but this would need to be balanced by a corresponding increase in the tariff to compensate for the lost income from foregoing the fixed charge. This, in turn, will dampen the effect of increased demand with limited net improvement in revenue even though the increase in energy generation may add to the overall cost of service.

With detailed consumption and billing data we shall be able to examine the distributional effects of demand in more detail to determine better the potential for increased sales and revenues from service expansion.

A preliminary analysis of income distribution in Zambia reveals a high degree of income inequality with a Gini coefficient of 0.69 nationally[17]. Data from two sources[18] reveal this inequality (see Figure 14).

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[16] Meetings with ZESCO reveal that the fixed charge has resulted in self-disconnection by many consumers. This occurs when a consumer has not purchased power for some time and when an attempt is made the bulk of the payment is to meet fixed charges arrears thereby rendering the purchase unfeasible.

[17] CSO, 2015 Living Conditions Monitoring Survey - Key Findings, 2015

[18] (1) https://www.indexmundi.com/facts/zambia/income-distribution and (2) *CSO, 2015 Living Conditions Monitoring Survey - Key Findings, 2015*

The concept of a lifeline tariff is to subsidise the service to allow for the poorest in society to benefit from the service. By its nature this approach is a progressive charging structure and relies on the subsidised element to be financed from consumption from the non-poor, assumed to be the higher consuming consumers. This does not avoid the dilemma that low consuming wealthy consumers will enjoy the benefit of the lifeline tariff. In Zambia, with a connection rate of 30% the lifeline tariff is effectively a redistribution of charges between the top three deciles of the population, the lowest of which has an income level that is over twice the median for the whole country. Furthermore, the considerably lower value of the lifeline tariffs relative to economically efficient cost reflective tariffs dilutes the incentive for energy efficiency. Consequently, consumers will tend to consume more energy than is economically efficient, i.e. consuming up to the threshold because it is low cost. At the other end of the scale the higher consumers (and non-domestic consumers) who are paying extra to subsidise the lifeline tariff are possibly consuming less than they would like to if tariffs were cost reflective tending to dampen economic activity, e.g. reduced consumption in other sectors and for non-domestic consumers higher prices for their goods and reduced economic output.

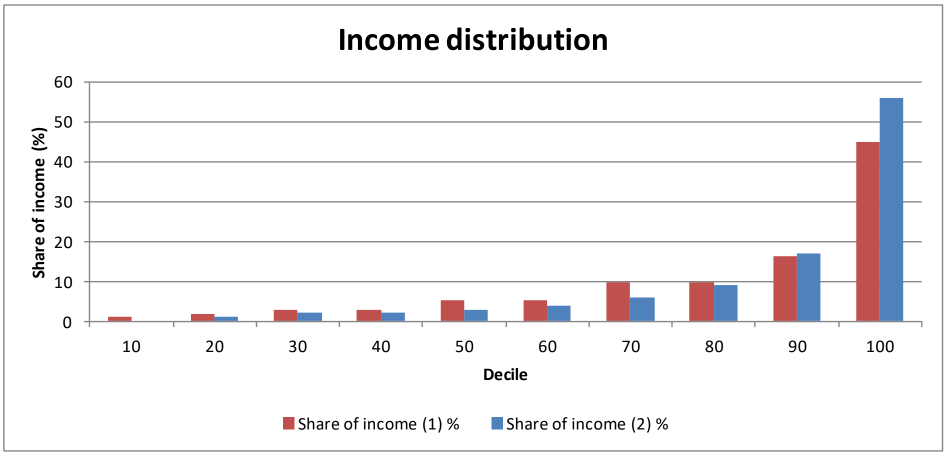

Figure 14 – Income Distribution in Zambia[19]

[19] Source: consultant's analysis based on CSO, 2015 Living Conditions Monitoring Survey - Key Findings, 2015

Preliminary analyses show (refer discussion in Task 2 – Load forecast) that a large sector of the population may be unable to afford electricity (or only afford a minimal level of consumption). This is exacerbated by the disproportionate value of the regressive fixed charge that runs counter to the progressive lifeline tariff. This mismatch of lifeline tariffs and fixed charges is recognised as being counter-productive and the latest ZESCO tariff submission to ERB is calling for the fixed charge to be removed.

The December 2019 threshold for the lifeline tariff was 200[20] kWh per month. We consider this value to be extraordinarily high if it is intended for basic needs use only. To put this into perspective the median level of consumption in the UK is estimated as 258 kWh per month (3,100 kWh per year). A recent EMRC project in Lesotho recommended a lifeline threshold of 30 kWh per month.

We have undertaken a preliminary analysis to examine the effects of reducing the threshold to 30 kWh per month. This reveals that if consumers consumed to their maximum affordability revenue would not change but overall consumption could fall by as much as 30%. This assumes that the fixed charge will also disappear. This phenomenon will require more detailed analysis to consider the effects of price and income elasticity on demand.

With respect to service expansion our analysis indicates that virtually all new consumers (assumed to be in the next lowest income deciles) are unlikely to consume enough electricity to exceed the current lifeline threshold. Consequently, the financial benefits to ZESCO are unlikely to be sufficient to cover costs and will probably contribute to increased financial losses. The wealthier households who are able to exceed this threshold will enjoy the full benefit of the lifeline tariff whereas the poorer households who do not exceed it enjoy a smaller benefit.

5.7 Performance review

The Performance Review comprises 4 distinct sub-tasks:

- Benchmarking the operational efficiency of ZESCO against other comparable utilities around the world.
- A financial review of ZESCO's historical performance
- The modelling of ZESCO's projected financial performance with inputs from the analysis carried out in the earlier tasks (demand, expansion plans, economic tariffs and a lifeline tariff)
- Performance review of the non-ZESCO players in the Zambia power sector.

[20] Has been reduced to 100 as part of tariff changes from 1st January 2020

5.7.1 Benchmarking

As described in the technical proposal we will undertake a conventional benchmarking of ZESCO with comparable utilities elsewhere in the world. From several meetings with ZESCO during the Inception visit we have collected and will continue to collect data relating to the performance of the business. We will submit further data requests which are necessary to establish the reference utility (RU) benchmarking process.

The “bottom–up” benchmarking methodology has been developed for setting prices of services provided by companies under Incentive Based Regulation (IBR) approaches, applied in many regions, e.g. Latin American and throughout Europe. The methodology consists of a “company specific” design creating an ideal efficient (frontier) utility that provides the regulated services under the same conditions existing for the actual utility under examination, i.e. economically adapted to the local conditions of the area where services are provided.

The RU approach is company specific. It overcomes the limitations of traditional benchmarking and the effects of information asymmetry. It is widely adopted in Latin America and Western Europe. It is based on engineering cost estimates considering specific conditions of service provision, rather than econometric comparators. This approach can be applied to both network and generation activities.

Every process and activity necessary for efficient service provision meeting predefined requirements on availability and quality is identified and precisely described. International experience and references and conditions on availability and quality defined by the competent authorities are considered to define frequency of execution of those processes and activities and required human and material resources. For every process and activity, the required human and material resources for its efficient execution are defined in physical terms and then valued considering prices of representative supply markets. This means that a “benchmark” is built at the level of each process and activity and the overall benchmark, representative of efficient performance, is obtained by adding the individual values in a “bottom-up” process.

This approach allows us to properly consider every specific condition of the service, in particular relevant aspects of the assets’ starting condition, local conditions for execution of certain processes and activities, and prices of representative supply markets.

The efficiency parameters have been collected from the best practices of more than 100 companies in Latin America and Europe. We have researched for the best solution provided by the companies for every activity regardless of the environmental conditions.

We have noted from the Inception visit that the number of staff in ZESCO appears quite high at close to 7000 for a customer base of just 1 million, i.e. only about 140 customers per employee. This was remarked on by others during the visit both within ZESCO and external to it. Some in ZESCO believe it is justified by the dispersed low consuming rural population. The RU approach described above is ideally suited to identify if that is the case and if there are inherent inefficiencies that can be identified.

5.7.2 ZESCO Historical financial performance

The Terms of Reference call for the review of past performance to consider the last 15 years. We consider a backward-looking review going back so far to be of limited benefit. Our analysis shall concentrate our efforts on the last three to five years (where accurate data is available and taking into account the impact on financial performance of years with severe droughts). We shall undertake a lighter touch high level review of the earlier 12 years to identify any key issues or trends.

In this review we shall concentrate on identifying the key areas of concern, notably factors such as movements in accounts receivable / payable, operating costs, impact of PPAs, debt service and any other principal issues identified in the course of the analysis.

The financial performance parameters that investors and creditors require toward assessing risk and expected returns are well established. There is trade-off between the level of detail in the indicator and the availability of information to calculate it. We will consider ratios that are relatively simple to estimate.

Ratios or Key Performance Indicators will provide quantitative measures of the impact each scenario would have on the company's liquidity and solvency. Examples we may consider include: working ratio, net operating margin, current ratio, capital work in progress as percent of long-term liabilities, accounts receivable as a percent of revenue, inventory as percent of total operating expenses, accounts payable as percent of total operating expenses, return on equity, return on net fixed assets, debt-equity ratio, debt-service coverage ratio and self-financing ratio.

Where necessary, the findings of the review shall inform other aspects of the study, notably areas such as the development of cost of service, cost reflective tariffs, lifeline tariffs, and roll-out strategies.

We have made an initial examination of the audited financial accounts for 2018 and during the Inception visit we engaged in discussions with senior financial officers of ZESCO. Our resulting key preliminary findings are:

- ZESCO is continually loss making. This is not just at the expense of not earning enough to meet non-cash requirements (depreciation and return on equity) but has reached the point where it is unable to meet its cash needs. As a result ZESCO is in default to its creditors to the tune of more than ZK 10 billion at the end of 2018 and we understand this has now increased to ZK 16 billion by the end of November 2019.
- This situation is exacerbated by a high level of trade receivables of over ZK 6 billion (although ZK 5 billion has been set aside for bad / doubtful debts). For residential consumers on pre-paid meters arrears are gradually being collected as a component of the pre-payment charge. For post-paid consumers the recovery of arrears is difficult, e.g. some major customers (mines) threaten significant job losses if ZESCO was to take enforcement measures such as disconnection and as a result ZESCO has been instructed to continue the supply even if payment is not forthcoming.
- Financial officers of ZESCO confirmed that the current financial status places the organisation in default of its loan covenants. Lenders are awaiting the outcome of discussions related to PPAs and tariff adjustment proposals before considering what actions, if any, they propose to take.
- Cash flow is adversely affected by the requirement to pay VAT and other taxes (based on billings) even though the tax amount has not been received from customers.
- ZESCO is seeking to refinance some of its debt to secure better terms but at this stage it is unable to share the details with the consultants for commercial confidentiality reasons. We expect to discuss this further with ZESCO during the execution of the COSS.
- ZESCO's current adverse financial situation and the means to redress it will have significant implications for the cost of service study. Principal issues include:

  - Although the COSS shall determine cost-reflective tariffs on the basis of a clean canvas with no legacy issues, the resulting tariffs may not be sufficient to repair the financial well-being of ZESCO and the situation may deteriorate further if the glide path period from current tariffs to cost reflective tariffs is prolonged. Our analysis will quantify the impact of the legacy debt on the financial viability of ZESCO during the transition to a cost-reflective tariff. We will review such results and, if necessary, seek guidance from ERB, ZESCO and Government on potential solutions or interventions to ensure the financial viability of ZESCO.
  - Cost-reflective tariffs may be insufficient to provide the cash returns necessary for ZESCO to meet its financial obligations to its creditors. An

option for the analysis would be to consider an additional revenue requirement to meet such obligations. This would, in effect, require a higher return on equity in the short term but could be compensated by a reduced return in later years. If such a solution appears necessary and beneficial, we would include it in any review of the way forward with ERB, ZESCO and Government.

5.7.3 ZESCO projected performance model

The forward-looking financial analysis will follow the development of costs of service and cost reflective tariffs. Principal input data for the financial analysis will originate in the earlier Tasks 3, 4, 5 and 6, such as tariffs, demands and allowed revenues. For optimum efficiency we plan to link the tools developed for each task, i.e. a single model comprised of several interlinked modules.

The financial analysis may identify additional costs to be considered in the cost of service analysis that may otherwise be missed, e.g. commitments to meet pension deficit repair obligations; adjustments to the regulatory asset base to take into account grants, adopted assets and customer contributions; and specific requirements as set out in loan covenants and other commitments.

From our Inception visit we have identified several key areas to be considered in the development of the modules:

- In accordance with conventional cost of service analysis the base analysis shall be undertaken in base year price levels, i.e. a 'real' terms model. The financial analysis may need to convert this to a nominal model to cater for those revenues and costs that do not track inflation. These include:
  - Recovery of legacy accounts receivable and payment of accounts payable
  - Taxation where costs and revenues are recognised at their actual values rather than their inflation adjusted values. This includes legacy brought forward tax shields, and future tax credits (capital allowances etc.) based on historic (actual) procurement cost.
  - Debt service (interest and repayment of principal) which although partially tracks inflation it is limited to inflation differentials between the country of the currency of the loan and Zambia.

We therefore propose that the financial analysis component will need to take a forward-looking approach to inflation to derive a more meaningful outcome. Not doing so could effectively understate or overstate some costs and revenues. Future inflation is uncertain and the further ahead the analysis goes the probability of forecasting error increases.

- We understand that ZESCO has a high level of brought forward tax losses that can be used to offset future profits, but such losses are time limited. We will seek advice from local taxation specialists including those within the ZESCO finance team to accurately model the future taxation applicable to ZESCO.
- The financial analysis shall build in options for accommodating legacy issues (accounts payable/ receivable etc.) as applicable and taking into account any feedback from ZESCO and ERB once our model has quantified the impact.
- The accounts report a potential defined benefit pension deficit, but further investigation is required to determine the scale and nature of the deficit. We shall examine the legal status of any obligations for ZESCO to be responsible for the repairing of any pension deficits, e.g. do the obligations rest with ZESCO, Government of Zambia or some other agency[21]. If we discover it is a ZESCO obligation, we may need to incorporate a pension deficit repair programme in the allowed revenues and reflect the contributions in the financial analysis.
- We shall conclude the forward-looking financial analysis with projected financial statements (income, balance sheet and cash flow) and financial indicators. These will be in nominal values in the first instance, but a simple indexation exercise can convert the outputs to their real values to allow comparisons with the cost of service outputs.

5.7.4 Performance of non-ZESCO players

We shall review the operational efficiency performance of existing Independent Power Producers (IPPs), Independent Transmission and/or Distribution Companies (IDTC), and wholesale distributors. The review will compare their performance with comparable private utilities and internationally accepted norms, taking into account generation technologies to identify areas of operational inefficiencies and their impacts on wholesale prices to off-takers.

[21] There is regulatory precedent for allowing pension deficit repair programmes as a pass through to the allowed revenue. Ofgem, the GB energy regulator, makes a provision for deficit repair costs (limited to legacy deficits prior to privatisation) to be passed through and subject to regular (tri-annual) reviews in line with statutory pension reviews even though the price control review period is considerably longer (currently eight years).

The operational performance review will cover Copperbelt Energy Corporation Plc (CEC), North Western Energy Corporation Limited (NWEC), Maamba Collieries Limited (MCL), Ndola Energy Company Limited (NECL), Itezhi-Tezhi Power Corporation Limited (ITPC), Kariba North Bank Extension Power Corporation Limited (KNBEPL), and Lunsemfwa Hydro-Power Company Limited). (LHPC). We will indicate areas of improvements in line with realistic expectations of improved efficiency.

We held discussions with CEC and Maamba Collieries during the Inception visit and we understand ERB has already passed on our initial data requirements to the other sector participants. More detailed data requirements are included here in section 9.

5.8 Wheeling charges

In Task 4 we will have reviewed and selected the method of allocation: postage stamp, long run marginal cost, extent of use or contract path. In this task 8, we will consider more specifically what this means for third party transmission access. There are two circumstances where wheeling charges are relevant:

1. Where participants in SAPP wheel power from SAPP to the Zambia network and vice versa.
2. To allow further investment in power or network feeding into the Zambia transmission system, for example by new generators wishing to connect and supply SAPP as reinforced in the recently updated Energy policy.

Open and non-discriminatory third-party access to the networks by those who do not own the physical network infrastructure is an important part of facilitating competition and making cross border energy markets like SAPP work effectively. The principle is that owners and operators of the electricity networks should provide non-discriminatory access to their lines to third parties.

Wheeling is one of the potential future challenges in the successful operation of SAPP. Wheeling charges are currently based on whose systems the current flows through. This works reasonably well as most of the international part of the system is radial rather than a meshed network and identification of individual flows is not a challenge. Once the system develops and becomes more interlinked, it will become considerably more complex and arguably meaningless to try to identify individual current flows.

We will explore mechanisms for third party access that will be suitable in the immediate trading arrangements and assess their robustness for future development of arrangements in SAPP.

The mechanism for third party access can also set a framework in which third party or independent investment in expansion of the network is possible, for example from new generators wishing to connect.

We will assess the particular conditions in Zambia to design the most appropriate methodology for estimating cost-reflective tariffs that will enable appropriate third-party access.

5.9 Review of tariff adjustment methodology

We are aware of the proposed changes to the regulatory regime that are being currently promulgated in two bills before Parliament (see also discussion on these bills in section 4). They appear to be providing a more flexible regime giving ERB clearer and more structured powers to regulate the sector more effectively and in particular to set cost-reflective tariffs. We will evaluate the degree to which these changes will result in expected outcomes for the sector and consider what, if any, additional changes may be required to further improve the tariff-setting processes for Zambia Electricity Supply.

5.10 Roll-out strategy

During the Inception visit we learned that the current tariffs in Zambia are likely to be significantly less than cost reflective. The average tariff is one of the lowest in Africa and a number of independent generators sell to ZESCO at tariffs that are higher than the retail tariff. The gap between current tariffs and cost-reflective tariffs would, at first impressions, be considerable and to avoid socially and economically disruptive price shocks the transition to cost-reflective tariffs may need to be phased over several years. We will work closely with ERB in the development of suitable implementation ("Roll Out") strategy including:

- Developing a path for the gradual transition of the tariffs, indexation and performance incentives from the current ones to the ones included in the Tariff Plan.
- Preparing a programme of mitigation measures to help the vulnerable have access to electricity at affordable prices, as identified by the studies carried out in Task 6.
- The strong layers of review built into the project structure by the interaction with the Study Technical Committee and Study Steering Committee will be an important element in ensuring stakeholder buy-in and will have a critical role in communicating widely the findings of the project.

- The Workshops in Task 12 will also be used to discuss points of view on the impact that implementing the tariff plan would have from a socio-economic perspective and a technical perspective, as well as strategies on the implementation of the tariff plan and any required impact mitigation strategy. This latter point shall specifically address the lifeline tariff subsidy or support scheme to facilitate the access to electricity of low-income households, but at the same time avoid subsidisation of consumer categories or subcategories (energy consumption bands) which do not require it because they can afford the economic tariff.

As a result, we will propose scenarios for tariff adjustment that provide a gradual process of adjustment for customers but within the boundaries as required by current and future commitments. We will also provide recommendations on the adjustment and administration of life-line tariff and draft regulations for enforcement of life-line tariff.

5.11 Training

We will work with the STC to optimise the capacity building opportunities that arise during the project. Workshops form a major part of those opportunities and we will seek STC guidance to select the attendees to the workshops and to provide a broad skills audit of the participants so that the workshops are designed at an appropriate level.

5.12 Workshops

We expect to deliver the workshop programme as required by the TOR and as set out in the proposal. The project programme presented in Annex A shows when the workshops are expected to take place.

6 Commentary on critical issues

6.1 Adequacy of planning information

Planning Information required for the elaboration of expansion plans is detailed in Section 9.

Partial information has been provided by Generation Support Services of ZESCO related to Victoria Falls and Kariba Basin (lake level, inflows, outflows, spillage). This information is still under assessment, and a precise conclusion on their suitability or required adjustments will be obtained in advance of the Inception Report Mission.

6.2 Least cost expansion model

We address the specific comments raised by AfDB during the contract negotiation stage, and elaborate on them based on the methodology and model characteristics described in Section 5.4.

From AfDB: A separate modelling of the generation system to achieve the long-term least generation expansion programme based on a dynamic optimisation programming technique should be provided, with a clear definition of the objective function, and its composition. Consultant should clarify the modifications to its EDM model to achieve this. This implies that transmission would be modelled separately for the optimised long-term least cost expansion program.

Consultant response: The objective function of the model is reproduced at the end of the document in Annex E. Our modelling technique is an advance on basic dynamic programming (DP) which has well-publicised limitations when optimising real-size power systems. It uses a combination of integer programming with advanced decomposition techniques applied to the classical DP algorithms.

No modifications to EDM are required to model separately the generation system from the associated network. It is as simple as defining a single-node power system in the interface. As this is already a contract requirement we are obliged to comply.

In addition to this requirement our long experience in the fields of planning and system operations leads us to recommend that the analysis considers the influence of network expansion in combination with generation expansion. This process is known as Integrated Generation and Transmission Planning (IG&T). In Zambia, with dispersed demand centres as well as numerous feasible generation candidates also widely dispersed across the country, and not necessarily close to the load, the combined influence of the associated investments could be underestimated if planning is undertaken as two distinct processes.

From AfDB: A detailed list of input data must be provided on: (i) the existing generation system, including committed plants and retirements; (ii) the generation expansion plant candidates, separately for thermal and separately hydro plants, and renewable energy plant candidates; (iii) economic parameters; (iv) system characteristics; and (v) others. The purpose is mainly to judge the cost elements of the objective function of optimised long-term generation expansion programme to ensure that all relevant system and related costs would be captured in the analyses.

Consultant response: The objective function of the model is reproduced at the end of the document in Annex E. Additionally, we confirm that all the input data will be reproduced in the relevant report (and/or its annexes) to grant full transparency on the key variables used to run the models.

Detailed data requests have been sent to the relevant contact points to collect as much data as possible to populate the model. Any assumptions produced by the consultant will be explicitly shown in the reports and, if possible, previously agreed with the counterpart.

From AfDB: The above is being raised because it is unclear where the dynamic optimisation takes place either through EDM model or the SDDP model to arrive at a single solution objective function for the long-term least-cost generation expansion program. The full definition of the objective function in terms of its composition should be stated. The statement about "salvage value" as was provided in the Minutes of Negotiations appeared confused and needs further clarification.

Consultant response: Dynamic optimisation (actually stochastic dual dynamic optimisation) takes place in both models. The only difference is the level of detail each of the models uses. EDM operates hydro assets in a simplified manner considering only storage capabilities and historical energy generation time series. Its use is recommended in situations in which detailed data collection was not possible for hydro power plants and the benefits provided by the use of the SDDP model (super detailed hydro power plants and water allocation modelling) cannot be captured.

Under both situations, EDM standalone and EDM+SDDP, the objective function remains the same, being this the minimisation of the net present value of the sum of the operation and expansion costs of an electric system. This is subject to a set of constraints that guarantee that both system operations and the expansion plan result in a secure, adequate power system that complies with any technical, environmental and policy limitation set out by the technical/regulatory/policy agents in place. This means that from a high-level overview, using mathematical decomposition techniques, there is only one objective function to be satisfied namely the least-cost expansion one (which considers the least-cost operations).

The objective function is reproduced at the end of this document in Annex E. It does not explicitly consider the salvage value of the investments since this is implicitly embedded in the investment module for each candidate power plant. All investments are decomposed into annuities (taking into consideration their CAPEX, amortisation period and time needed for construction). The model will then optimise the objective function in a way that minimises the net present value of the operations and expansion costs, taking into consideration the annualised costs, thus, internalising the salvage value of such investments when selected at a point in time in which the remaining simulation horizon is shorter than the useful life of the asset.

From AfDB: Clarity needs to be provided on the determination of the value of water under the various hydro conditions mentioned in determining the variable production cost from the SDDP model.

Consultant response: Water value is defined as the opportunity cost of using an additional Hm3 (or MWh if converted to energy figures) of water. It can be regarded as the "fuel cost" of hydro power plants with storage capability. SDDP tool guarantees that the combined use of all generation resources (thermal, hydro, RES) minimises the net present value of the dispatch costs, thus it is able to optimally allocate water resources at the moments of time (limited to the storage size of each individual plant) that they provide the most value to the system.

Water value is calculated, plant by plant (for all hydro plants with reservoir capability), for every time step used in the model. In mathematical terms the water value is the equilibrium point between the use of water now, the immediate cost function (ICF) and its future value (FCF). SDDP calculates the water value the same way Dynamic Programming (DP) does but improving the algorithm to avoid the great disadvantage of such a technique (curse of dimensionality). It does this by approximating the FCF, *dual dynamic programming (DDP,)* and in addition to that, capturing the uncertain nature of the hydro plants' "fuel", hydro streams, represented by historical time series which can be converted into probability distribution functions to perform a stochastic dispatch, *stochastic dual dynamic programming (SDDP).*

As a consequence, the dispatch results are optimal from a least-cost point of view, with the benefit of embedding the risks associated with the uncertainty created by the hydrological inflows. Water values, which are calculated in the solution process, are then available to the user as a result of the optimisation process.

From AfDB: The essence of the generation expansion programme is to be used to estimate the marginal cost of meeting an increment of a MW of demand at the system peak over the long-term. It is therefore based on the difference in the discounted present-worth cost of the objective function for the increased load long-term least cost expansion programme and the base case expansion programme per unit increment in MW demand. The proposed approach by the Consultant is unclear and needs further clarification to be provided in the Inception Report for discussion to ensure that it meets the requirement of Task 5.

Consultant response: The consultant's approach revolves around the use of a least-cost generation (and transmission) expansion tool. This tool minimises the net present value of the sum of the operation and expansion costs of an electric system subject to a set of constraints that guarantee that both system operations and the expansion plan result in a secure, adequate power system that complies with any technical, environmental and policy limitation set out by the technical/regulatory/policy agents in place.

This means that the methodology guarantees that the expansion plan obtained (under different assumptions for the relevant input variables, e.g. demand forecast, candidate generation portfolio, environmental policy, etc., is optimal, both from a centralised and a decentralised point of view[22]. This methodology is the state-of-the-art approach for any planning entity, regardless of whether the plans to be issued are binding (centralised planning) or indicative (decentralised approach).

While the marginality reference made in AfDB's comment is theoretically true and can be applied by EDM model, it would only produce realistic results in a scenario that allows continuous variables for expansion candidates. In a real-life scenario, especially for the Zambian situation, it will most probably not apply due to the lumpy nature of the investments involved, e.g. large hydro plants that cannot be assumed to be partially built. The most probable outcome of the plant will result in investments that do not only supply the additional MW, but rather over-invest since there is no better alternative option. This replicates the actual cyclic investment profiles of real-life power systems.

The addition of other constraints such as environmental constraints or policy related inputs, e.g. minimum investment on RES based generation, will only build up on the previously described effect.

Regardless of the circumstances, we will apply and analyse the results obtained through the approach suggested by AfDB.

From AfDB: A reference plant is alluded to as the basis of estimating Short-Run Marginal Cost of generation. A system-wide approach that considers the principle of

[22] Under a perfect competition assumption.

"peak responsibility" is likely to provide more reliable estimation of the SRMC. Descriptions of these two approaches should be provided in the Inception Report.

Consultant response: As far as we are aware, there is no mention to a "reference plant" as the basis of the estimating of Short-Run Marginal Cost (SRMC) of generation in our documents. The SRMC is calculated as an output of the least-cost dispatch optimisation, which considers, on a plant-by-plant basis[23] the available supply to meet the forecast demand taking into consideration all the necessary operational, network, security and policy constraints. This is similar to the actions of any System Operator to dispatch the generation plants.

Under this scenario, the SRMC is, from a theoretical stand, the cost of the additional MWh to be supplied under the assumption of a marginal increase of the (energy) demand. From a modelling point of view, this is computed as the dual variable (or shadow cost) of the supply/demand balance equation.

Our methodology and our tools guarantee the computation of the SRMC. It considers the optimal stacking of the generation resources (not only on a cost basis, but also from an operational, security, adequacy and policy point of view) at every computational time step considered in the modelling exercise. These figures can then be aggregated into monthly and/or annual results.

6.3 Treatment of CEC/ZESCO Bulk Supply Agreement

The Bulk Supply Agreement (BSA) between ZESCO and CEC is scheduled to terminate in March 2020. The agreement, outlined in section 4, sets out the terms for ZESCO's supply of power to CEC for onward supply to its 10 mining customers. The BSA defines the terms for the transfer of power back to ZESCO for onward distribution to commercial and domestic customers near the CEC mines.

The COSS will provide important inputs to the renegotiation of the BSA. In particular it will establish a reasonable level for transmission wheeling charges in Zambia. We understand one of the options being considered for the future relationship between ZESCO and CEC is a purely wheeling arrangement in which ZESCO would take over CEC's mining customers and pay CEC a wheeling tariff for the transmission part of their supply. The COSS will not deliver the cost-reflective wheeling tariff in time for its inclusion in negotiations prior to March 2020. It may therefore be worth considering

[23] Being all plants constrained by their operational characteristics: max/min capacity, availability, fuel constraints, resource availability (including time series) for RES/hydro resource, hydro power plants operational characteristics including reservoir modelling, etc.

an extension to the BSA or some other temporary arrangement pending the outcome of the COSS.

6.4 Mining customers engagement

The TOR and our proposal have already noted the need for engagement of all stakeholders. Of particular note is the need for an effective engagement with the mining customers of ZESCO. During the Inception visit we learned that the mining customers believe ZESCO to be inefficient and that as a result tariffs are actually higher than they should be. This has resulted in some customers resisting payment of electricity charges. We have noted already in section 5.10 that we believe it is unlikely that cost reflective tariffs will be lower than current tariffs. It is therefore essential from the start of the project to involve the mines in the COSS processes so that they develop an understanding and believe our results when they are delivered.

6.5 Rural electrification

Section 5.3 describes how we propose to develop the projected demand and comments on the rural electrification impact on future demand. We believe the preliminary indications are that the low levels of income of the majority of the rural population in Zambia would suggest that rural electrification is more likely to follow the solar home and mini-grid route rather than any significant rolling out of the grid in the near to medium term. In the longer term as the economy grows the income levels amongst the rural population are likely to increase to levels that make grid connected electricity viable but we see this as possibly only likely beyond the timescale horizon of this project, i.e. beyond 2040.

The demand projection and the lifeline tariff studies will seek data on income levels and affordability to confirm these assumptions.

6.6 Metering System and Tariff Categories

Tariff categories to be defined are very much influenced by the installed and available metering system. It is currently based on two broad metering groups:

- Pre-paid customers:
  - Contracted capacity 15 kVA and below.
  - Comprise 99% of all customers but approximately 40% of billings.
  - Billed on basis of energy and fixed charge only. The latest tariff application proposes the fixed charge to be suppressed because it is not compatible with a lifeline tariff and results in effective self-disconnection.

- Post-paid customers:
  - Contracted capacity above 15 kVA.
  - Comprise 1% of all customers but about 60% of billings.
  - Billed on the basis of energy consumption and actual peak demand (not contracted demand), on two time periods (peak and off peak) and four demand ranges (16-300kVA, 301-2MVA, 201-7,5MVA, 7,5-25MVA).
  - No reactive power charges.
  - The category is assigned according to contracted capacity but monitored, and if peak demand crosses threshold then charged at higher band.
  - Above 25 MVA, charges are based on PPAs. The 25MVA threshold is expected to be decreased to 5 MVA.
  - Charges to generators are included in PPA agreements.

Tariff categories to be defined must consider the previous metering structure.

A particular finding on the tariff structure that must be addressed as well, is that current tariff categories do not depend on the voltage at which the customer is connected. This fact will be discussed and assessed with ZESCO and ERB, to reach a joint conclusion of the suitability of keeping this approach or evolving to a tariff structure dependant on the voltage level of connection.

6.7 Adequacy of database download

Task 5 (Economic tariffs design) and Task 6 (Life line tariff definition) require a precise representation of the current ZESCO commercial database, including geographical location, type of customer, voltage level of supply and all billing variables for a recent normal year (with no load shedding, as for example 2018). The information required from ZESCO during the Inception Mission include, for each customer:

- Customer details (excluding name, therefore anonymous)
- Location (town)
- Transformer or substation served by (if transformer data can be linked to operational data it may be possible to identify substation)
- Voltage level
- Enrolment date
- Monthly energy charges (including fixed charges) purchased (also maximum demand charges for post-paid)
- Arrears included in pre-paid charges (we understand that if arrears were accrued on the switch to pre-paid the payments include a payment plan to pay back arrears, albeit at a very slow rate in many cases).

ZESCO confirmed that this information could be delivered, and three samples have been submitted for the assessment of the Consultant:

- Post-paid clients – 2018 monthly billing variables
- Pre-paid clients – 2018 monthly billing variables
- Clients under Power Supply Agreements (ex. Copperbelt)

Those samples are still under assessment, and a precise conclusion on their suitability or required adjustments will be obtained in advance of the Inception Report Mission.

6.8 Financial policies

The outcome of the forward-looking financial analysis will depend significantly on ZESCO’s decisions with respect to legacy issues, notably how it intends to address factors such as accounts payable and accounts receivable. Although provisions are made in the accounts neither has been written off. We will make suitable recommendations based on the outcome of our analysis, but we are likely to require guidance from ZESCO, ERB and Government where applicable as to their expectations and strategies, e.g. write-off strategies, timeline for debt recovery etc. We shall follow up these issues with the responsible institutions in the course of the study.

Similarly, we may also need guidance from the responsible institutions with respect to strategies designed to satisfy concerns of creditors, notably development agencies where it appears ZESCO may already be contravening its loan covenants.

7 Project Programme

In the Inception visit we identified no reasons to alter the project programme provided in the EMRC proposal which is included here as Annex A.

8 Inception Workshop

An Inception Workshop is required to present the Inception Report to the Technical Committee. We propose this take place during the next visit to Zambia and take the form of a day or half-day workshop with presentations by EMRC and discussions. We propose the following topics for the workshop sessions and presentations

- Cost of Service Introduction - Theory and Practice
- Zambia electricity sector overview (based on section 4 of this report)
- Overview of the EMRC COSS Project (based on section 5 of this report)
- Issues identified for the COSS – including specific response to the AfDB comments in its letter of “No Objection”

9 Data Requirements

A data requirements list was delivered in advance of the Inception visit.

During the Inception visit the data requirements were elaborated considerably and the expanded, more detailed list, is provided below in Table 7. This table is an extract (first two columns) from the data requirements spreadsheet which will be shared with ERB. The spreadsheet includes columns to record the date the data was requested, the date it was received and any comments. Significant parts of the data listed were received during the Inception visit and some further data has been received since. This list will be reviewed with ERB during the Inception Workshop to verify the information already received and hence identify what is still outstanding.

Table 7 Data Requirements – List copied from Data Requirements spreadsheet

Zambia Cost of Service Study (COSS) - Data Requirements	
ERB	
1	Legal framework related to tariff setting and tariff regulation including details of any pass-through of cost fluctuations (e.g. foreign exchange, fuel price) to tariffs
2	Benchmarking data and models currently available in ERB
3	Recent estimations of Regulated Rate of Return (e.g. WACC)
4	ERB tariff reviews 2010 to date
5	ERB tariff review model
6	SAPP expansion plans
7	Other Tariff Reports 2016
	ZESCO
8	Annual accounts and reports and financial ratios since 2000 (in tabulated form)
9	Historic records as far back as possible (please identify any structural changes in the data e.g. change in basis of measurement)
a	Statistics for overall ZESCO energy consumption per voltage level (as great a granularity as possible e.g. daily or monthly, as far back as possible)
b	Statistics for overall ZESCO system peak demand per voltage level (as great a granularity as possible e.g. daily or monthly, as far back as possible)

c	Historic **energy consumption** broken down by tariff class and voltage level (same level of granularity as electricity demand e.g. daily or monthly and same duration - as far back as possible)
d	Historic **number of customers** (same level of granularity as electricity demand e.g. daily or monthly and same duration - as far back as possible) broken down by:
e	I) tariff class and whether or not they are mining demand
f	II) voltage level
g	III) whether they are urban or rural
h	Projected customer numbers (to 2040 if available)
i	Projected roll-out of rural electrification (to 2040)
j	Energy billed/ZMW invoiced per tariff category
k	Technical losses - broken down between transmission and distribution and by voltage level
l	Any plans or initiatives for technical loss reduction, their extent and expected impact
m	Commercial losses
n	Any plans or initiatives for commercial loss reduction, their extent and expected impact
o	Collection losses by customer category including details of any write-offs in last three years
p	Any plans or initiatives for collection loss reduction, their extent and expected impact
q	Tariff charges (energy, demand, connection charges), levies and taxes
r	Records of planned and unplanned system outages and amount of load shedding and duration (as great a granularity as possible e.g. daily or monthly, as far back as possible)
s	Opinion on which climatic/weather conditions are likely to influence demand (e.g. temperature, rainfall etc.)
t	Historic and projected electrification rate (%)

u	Existing or planned changes in demand management or energy efficiency policy, with dates of introduction (potential structural change in demand).
10	Typical annual load profiles per voltage level and tariff category
11	Customer database during a normal year (ex. 2018): client ID, tariff category, location, metering equipment, billing variables
12	Service quality records
13	Ancillary service requirements and records
14	Description of billing and collection procedures
15	Previous tariff and financial models
16	Connection process description and rates
17	Organisational structure and numbers of employees by type
18	Details of labour costs
19	Demand studies and projections broken down by tariff category and type of consumption
20	Market studies or analysis
21	Asset valuation reports
22	Operational costs of ZESCO including unit prices for main operational and maintenance materials
23	Capital investment costs of ZESCO including unit prices for main investment components
24	Details of work in progress
25	Details of outstanding loans and grants both commercial and donor supported
26	Details of capital contributions by third parties (REA and others)
27	ZESCO Generating Plants
a	Effective capacity MW
b	Historic generation figures MWh
c	Fuel and specific fuel consumption figures
d	Variable and fixed OPEX by plant

28	ZESCO Procurement and Supply agreements
a	Copperbelt Energy Corporation
b	IPPs
c	SAPP
d	Utilities in DRC, Botswana, Namibia, South Africa, Zimbabwe, Mozambique
e	Others
29	System overview for both transmission and distribution systems (line diagrams including voltage levels, system performance, equipment summaries, topology and characteristics of lines and substations, capacity of lines, network constraints)
30	Fully disaggregated monthly figures for generation, imports and exports of power, energy and where applicable ancillary services
31	Power System Master Plan 2010
Include as much excel data as possible to support:	
a	Generation modelling
b	Demand modelling
c	Transmission and distribution planning
32	Any update available to the master plans, including generation, transmission and distribution studies
a	Southern Division
b	Lusaka Division
c	Others
33	Generation development pipeline (all projects: under development, not contracted and not selected)
a	Full feasibility studies including:
b	Operational design parameters of the generation units (operation curves)
c	Reservoir design parameters
d	Historical hydrological records
e	Network connection point

	f	Location within river/basin
	g	Costs of developing the project
	h	Costs to connect the project to the network
34		Hydrological Information - Generation Support Services
	a	Hydrological stations topology. Locations in rivers and relation with power generation. For all rivers in the country subject to power generation.
	b	Historical inflow metering (monthly steps) for the last 40 years
	c	List of hydrological constraints associated to reservoirs/power stations (minimum/maximum discharge, ecological flows, navigation limits, evaporations, etc etc)
	d	Historical data of inflows provided to NCC for generation
35		PSS-E transmission network cases
	a	Current network
	b	Future network (and generation assets)
	c	Peak, off-peak cases
	d	Wet, average, dry cases
36		Five years evolution of Network Assets (see attached Workbook)
37		SAPP latest generation/network development plans
38		Projections of future MD3 and MD4 industrial demand (to 2040 if available)
39		Projections of future mining demand (to 2040 if available)
Ministry of Energy		
40		Sector overviews and reports
41		Any separate Government agreements in the Energy Sector
42		Details of agreements with multilateral aid agencies that may be available to support the sector
43		Rural and off-grid electrification:
	a	Current organisation and funding
	b	Plans for Rural Electrification to 2040, including any updates to the 2008-2030 plans

c	Historic and projected electrification rate (%)
44	Updated National Energy Balance
45	Revised Energy Policy (draft / approved)
46	Vision 2030 report
47	7th National Development Plan
48	Projections of future mining demand (to 2040 if available)
Central Statistical Office	
49	Surveys on household income and electricity consumption
50	Data on living standards from census and other sources
51	Data on poor household uses of electricity
52	Historic records of Gross Domestic Product (GDP) (real, monthly if available, annual if not)
53	Historic records of value added by the industrial sector (GDP of industry) (real, monthly if available, annual if not)
54	Official projections of GDP to 2040
55	Official projections of value added by the industrial sector to 2040
56	Historic records of population for Zambia
57	Official projections of population to 2040
58	Population split between rural and urban locations (historic and projected)
59	Average urban household size (number of people) (historic and projected)
60	Average rural household size (number of people) (historic and projected)
61	Historic data on number of households in rural and urban areas (if available)
Zambia Meteorological Department under the Ministry of Transport and Communications	
62	Historic temperature and rainfall data (granularity to match demand)
Bank of Zambia	

63		Macro-economic data (inflation, exchange rate, GDP growth) in Zambia and South Africa
64		Financial data (interest rates for credit, overdraft, local & foreign loans)
Rural Electrification Authority (REA)		
65		2009 Rural Electrification Masterplan
66		Plans for Rural Electrification to 2040, including any updates to the 2008-2030 plans
67		Historic and projected electrification rate (%)
68		For each year since its establishment:
	a	How many projects has it developed?
	b	Type of each project (mini-grid, grid-extension, etc.)
	c	Who operates each infrastructure (REA, ZESCO, other)
	d	CAPEX of each project
	e	O&M of each project
	f	Number of connections for each project
	g	Revenue being received for each project
	h	Any other costs for each project (ZESCO payments, etc.)
Copperbelt Energy Corporation Plc (CEC)		
69		Operational data
70		Historic records as far back as possible (please identify any structural changes in the data e.g. change in basis of measurement)
	a	Statistics for overall CEC energy consumption per voltage level (as great a granularity as possible e.g. daily or monthly, as far back as possible)
	b	Statistics for overall CEC system peak demand per voltage level (as great a granularity as possible e.g. daily or monthly, as far back as possible)
	c	Historic **energy consumption** broken down by tariff class and voltage level (same level of granularity as electricity demand e.g. daily or monthly and same duration - as far back as possible)
	d	Historic **number of customers** (same level of granularity as electricity demand e.g. daily or monthly and same duration - as far back as possible)

	broken down by:
	I) tariff class and whether or not they are mining demand
	II) voltage level
	III) whether they are urban or rural
e	Projected customer numbers (to 2040 if available)
f	Projected roll-out of rural electrification (to 2040)
g	Energy billed/ZMW invoiced per tariff category
h	Technical losses - broken down between transmission and distribution and by voltage level
i	Any plans or initiatives for technical loss reduction, their extent and expected impact
j	Commercial losses
k	Any plans or initiatives for commercial loss reduction, their extent and expected impact
l	Collection losses by customer category including details of any write-offs in last three years
m	Any plans or initiatives for collection loss reduction, their extent and expected impact
n	Tariff charges (energy, demand, connection charges), levies and taxes
o	Records of planned and unplanned system outages and amount of load shedding and duration (as great a granularity as possible e.g. daily or monthly, as far back as possible)
p	Opinion on which climatic/weather conditions are likely to influence demand (e.g. temperature, rainfall etc.)
q	Historic and projected electrification rate (%)
r	Effective demand W
71	Historic own generation figures MWh
72	Variable and fixed OPEX
73	Annual Reports in tabular form since commissioning

74		Any reports on performance and efficiency
75		Reports on future plans
76		Records of planned and unplanned system outages and amount of load shedding and duration (as great a granularity as possible e.g. daily or monthly, as far back as possible)
77		Opinion on which key factors are likely to influence demand
78		Any plans or initiatives for commercial loss reduction, their extent and expected impact
79		Projections of future MD3 and MD4 industrial demand (to 2040 if available)
80		Projections of future mining demand (to 2040 if available)
Maamba Collieries Limited (MCL)		
81		Operational data
	a	Effective capacity MW
	b	Historic generation figures MWh
	c	Fuel and specific fuel consumption figures
	d	Variable and fixed OPEX
82		Annual Reports in tabular form since commissioning
83		Any reports on performance and efficiency
84		Reports on future plans
85		Projections of future grid demand (to 2040 if available)
Ndola Energy Company Limited (NECL)		
86		Operational data
	a	Effective capacity MW
	b	Historic generation figures MWh
	c	Fuel and specific fuel consumption figures
	d	Variable and fixed OPEX
87		Annual Reports in tabular form since commissioning
88		Any reports on performance and efficiency

89	Reports on future plans
Itezhi-Tezhi Power Corporation Limited (ITPC)	
90	Operational data
a	Effective capacity MW
b	Historic generation figures MWh
c	Variable and fixed OPEX
91	Annual Reports in tabular form since commissioning
92	Any reports on performance and efficiency
93	Reports on future plans
Kariba North Bank Extension Power Corporation Limited (KNBEPL)	
94	Operational data
a	Effective capacity MW
b	Historic generation figures MWh
c	Variable and fixed OPEX
95	Annual Reports in tabular form since commissioning
96	Any reports on performance and efficiency
97	Reports on future plans
Lunsemfwa Hydro-Power Company Limited) (LHPC)	
98	Operational data
a	Effective capacity MW
b	Historic generation figures MWh
c	Variable and fixed OPEX
99	Annual Reports in tabular form since commissioning
100	Any reports on performance and efficiency
101	Reports on future plans
North Western Energy Corporation Limited (NWEC)	
102	Operational data

a	Effective demand MW
b	Historic generation figures MWh
c	Variable and fixed OPEX
103	Annual Reports in tabular form since commissioning
104	Any reports on performance and efficiency
105	Reports on future plans
Chamber of Mines	
106	Forecasts of new mining projects and resulting changes in peak demand
107	Forecasts of closure or decrease in mining projects and resulting changes in peak demand
108	Indications of macroeconomic and other factors that influence the level of mining operations
109	Projections of future grid demand (to 2040 if available)
Federation of Zambian Industries	
110	Forecasts of expected changes to large industrial demand (tariff classes MD3 and MD4) (to 2040 if available)
111	Indications of macroeconomic and other factors that influence the level of large industrial demand (tariff classes MD3 and MD4)

A Annex A - Programme

Overall Summary followed by the Detailed programme provided in the Proposal

Deliverable	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
1. **Inception**		•										
2. **Sector Review**				•								
3. **Demand**				•								
4. **Development**								•				
5. **Cost & Tariffs**								•				
6. **Life-line**								•				
7. **Performance of Sector**											•	
8. **Transmission**											•	
9. **ERB Tariff**											•	
10. **Roll Out**											•	
11. **Training**	•								•		•	•
12. **Workshops**		•							•		•	•
13. **Final Report**												•

#	Task / Activity	Week 0	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Week 15	Week 16	Week 17	Week 18	Week 19	Week 20	Week 21	Week 22	Week 23
	Contract Signature	◆																							
T1	**First Field Visit for Study Launch and Data Collection**																								
M1/TS1	Mission 1 / Training Seminar 1																								
D1	Inception Report						◆																		
W1	Workshop 1 - Presentation of the Inception Report																								
T2	**Appreciation of Power Market and Legal and Regulatory Framework**																								
D2	Task 2 Report																◆								
	ERB Review																								
T3	**Electricity Load Forecasts**																								
D3	Task 3 Report																		◆						
	ERB Review																								
T4	**Medium to Long Terms System Development Plans**																								
	Generation and Transmission																								
	Distribution																								
T5	**Determination of Economic Cost of Supply, and Structure and Level of Tariffs**																								
D4	Task 4/5 Report																								
	ERB Review																								
T6	**Life Line Tariff Mechanism**																								
D5	Task 6 Report																								
	ERB Review																								
T7	**Review of Financial and Technical Performance of ZESCO and other Electricity Companies and Preparation of Projections**																								
T8	**Transmission and Wheeling Charges**																								
W2/TS2	Intermediate Workshop/Training Seminar 2																								
T9	**Review of ERB Tariff Adjustment Methodology**																								
T10	**Tariff Adjustment Roll-Out Strategies**																								
D6	Tasks 7/8/9/10 Report																								
TS3	Training Seminar 3																								
D7	Draft Study Report																								
W3	Final Workshop																								
W4	Stakeholders Workshop																								
D8	Tasks 11/12 Report																								
	ERB Review																								
D9	Final Report																								
T11	**Training**		TS1																						
T12	**Workshops**									W1															

#	Task / Activity	Week 24	Week 25	Week 26	Week 27	Week 28	Week 29	Week 30	Week 31	Week 32	Week 33	Week 34	Week 35	Week 36	Week 37	Week 38	Week 39	Week 40	Week 41	Week 42	Week 43	Week 44	Week 45	Week 46	Week 47	Week 48	Week 49	Week 50	Week 51	Week 52
	Contract Signature																													
T1	**First Field Visit for Study Launch and Data Collection**																													
M1/TS1	Mission 1 / Training Seminar 1																													
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	ERB Review																													
D9	Final Report																													
T11	**Training**																TS2									TS3				
T12	**Workshops**																W2									W3	W4			

Office Work

EEA and WB review

Task execution period

Mission

B Annex B - Notes of Meetings

Planning - generation, transmission and distribution	Monday 9th
Finance and accounts	Monday 9th and Thursday 12th
Billing and IT (Customer Service)	Tuesday 10th
Operations	Wednesday 11th
Business Development	Wednesday 11th
Management re Corporate Strategy	Wednesday 11th
Water Management for Hydro Generation (Generation Support)	Thursday 12th

Ministry Department of Energy	Thursday 5th
AfDB	Friday 6th
OPPPI	Monday 9th
ERB	Tuesday 10th and Friday 13th
REA	Thursday 12th

B.1 Note of Meeting – ZESCO Planning (Generation, Transmission and Distribution), 9 December 2019 09.30 to 11.30

Company	Attendee
ZESCO	George Muyunda Victor Shamende Victor Lukwesa Maliwa Mukelabai Abeauty Sikombe John Lungu
EMRC	Tom Jardine Thomas Miti Carlos Migues Daniel Serrano

B.1.1 Purpose of the Meeting

Data collection and discussions

B.1.2 General Discussion

- TJ provided a summary of the project objectives and approach.

- Discussions started focusing on the demand forecast, transmission and distribution planning since the generation planning staff from ZESCO was not readily available.
- Demand forecast:
  - Last demand forecast study was done in year 2010 (JICA). Although on regional basis there are some updates (Southern division, Lusaka Division).
  - ZESCO requests the demand forecast to be at 11 KV customer level.
  - ZESCO will provide most recent updates.

Transmission planning:

- Transmission planning is performed by ZESCO to the extent of the networks they own. CEC plans their own networks. There's a fair amount of communication between both companies under the umbrella of SAPP network planning.
- The last master plan is part of the Power System Master Plan (JICA – 2010). Although ZESCO has done several studies that update this plan. Rural electrification is considered as part of the transmission plan (and subsequent studies).
- Also, GET FiT program development (RES plants) are being assessed -120 MW solar + 100 MW approx. of small hydro projects-. These are to be developed in the northern region of the country and no relevant congestion issues are to be expected.
- Currently a set of ToRs are being developed in order to tender a mid-term grid development plan (5 years).
- In terms of policy, there is an Energy Policy draft from the government and a Vision 2030 document (from the government as well). Also, as part of the latter the 7th National Development plan has been issued, which addresses the rural electrification topics. All plans are supposedly aligned.
- In terms of international planning, SAPP network development plans are aligned with those of ZESCO and CEC since both entities feed SAPP team in order to prepare the regional plan. There is a program to interconnect to the EAPP via Tanzania.
- PSS-E cases were requested, and it was confirmed that they were available (both on PSS-E and DigSilent). It was clarified that these were needed for the current and foreseeable future and only for the transmission network, not the distribution network (since the latter will be modelled in a parametric manner).
- Hourly system wide demand records for 2 complete years (reference years, 2019 cannot be consider due to load shed).

Distribution Planning:

- The last master plan available is JICA's one (already mentioned, from year 2010) although ZESCO informs that two regional divisions have prepared updated plans, namely, Southern Division (year 2015) and Lusaka's division (year 2012).

- The VISION 2030 plan (DoE) goes on a parallel way and should be consistent with ZESCO studies. We must cross-check.

Generation Planning:

- ZESCO planning staff joined the meeting.
- From the conversation it was made clear that ZESCO only takes care of developing their own projects, but it's not the entity in charge of planning per se (matching supply and demand in the long term), we were referred to energy division at the Ministry for this.
- We also learnt that ZESCO is not developing any thermal fuelled project (and does not plan on doing so) and that RES project development (RES potential and projects; RES = Wind, Solar, Small Hydro, Geothermal) is in the hands of a different division at ZESCO.
- In planning terms, ZESCO staff confirmed that the feasibility studies of the plants in the pipeline can be shared subject to the data request proposal, the current pipeline looks like:
  - Kafue Gorge Lower (750 MW) – End of 2020 – Government financed with a Chinese loan
  - Chishimba Falls (15 MW) – Almost finished (Feb 2020) – KfW
  - Lusiwasi Lower (86 MW) – To be contracted for development (2022), financed within ZESCO
  - Batoka Gorge. Bi-national damn developed by the governments of Zambia and Zimbabwe (1200 + 1200 MW). Contracted to Power China + GE (2025).
  - Kalungwishi 163 MW. Feasibility studies on-going (2026)
  - Solar potential is being studied by the previously referred to division
  - In terms of energy storage (pumps, batteries), nothing is being explored besides the current/future reservoirs.

B.2 Note of Meeting – ZESCO – Financial Reporting Team, Lusaka, 09 December 2019 09:00 to 11.30

Company	Attendee	Attendee
ZESCO	Fitzpatrick Kapepe Mwelwa Chibesakunda	Venasio Phiri
EMRC	Keith Burwell	Andrea Marroni

B.2.1 Purpose of the Meeting

Data collection and discussions

B.2.2 General Discussion

Summary of discussion follows:

EMRC: Financial data handed over: 5 years full financial reports in excel.

EMRC: Asset register (post revaluation) to be provided together with chart of accounts schedule / codes to aid allocation of assets (Action ZESCO).

ZESCO: Wish to have a meeting with wider team to meet with ZESCO senior financial team (Action EMRC to arrange with ZESCO).

EMRC: Questions related to cursory review of latest financial statements follow:

EMRC: Very large tax credit which turns loss into profit. Cannot understand how a tax credit can be used this way, i.e. would expect credits to be limited to operating profit.

ZESCO: Not clear, will investigate and come back to us. (Action ZESCO).

EMRC: Require details of grant reserve account and if it has been re-valued in parallel with the asset register, i.e. depreciation of grant funded assets is balanced by amortisation of grant but if grant not re-valued then result is distorted.

ZESCO: Unsure if grant reserves have been re-valued. Will investigate and come back to us. (Action ZESCO).

EMRC: largest cost item is 'local purchases' – what is it, suspect it is power purchases in the main.

ZESCO: Correct, will provide a breakdown. (Action ZESCO).

EMRC: Does ZESCO hedge currency risk?

ZESCO: No, but many transactions are in USD anyway and do not therefore require hedging. The tariff adjustment formula allows for currency movements to pass through to tariffs and therefore consumers are indirectly bearing exchange rate risk.

EMRC: Describe bad debts policy.

ZESCO: Provision is based on expected loss (time driven, e.g. long overdue debts are provided at 100% whereas shorter debts less so (refer accounts). Much of the debt is due to resistance to payment from the mines. Some government agencies also not paying. Although residential consumers on prepayment there is a legacy of bad debts but these are being recovered (albeit slowly) through an attachment to the pre-payment bills, e.g. 10% of the pre-payment goes towards repayment of past debts. At the moment debts are not written off. VAT is charged on billings and passed to treasury even though VAT is not collected on arrears and bad / doubtful debts. Considered to be a major cash flow burden. ZESCO awaiting outcome of assessment of PPA charges to see if they have an impact on receivables (?).

EMRC: Did auditors have any concerns when conducting the audit?

ZESCO: Two main concerns: a) the status of ZESCO as a 'going concern' and b) rate of trade payables.

ZESCO: Trade payables rising rapidly. 2018 accounts show ZMK 10 billion but at present in the order of ZMK 16 billion. Most of this is to the PPAs. A concern is whether this should be classified as current or non-current liabilities. ZESCO is trying to renegotiate the PPAs (a consultant – Fichtner - is appointed for this).

The current status now puts ZESCO in default of its loan covenants but lenders are waiting on discussions around PPA tariffs and ZESCO's consumer tariffs.

ZESCO: also looking to refinance loans as finance costs appear high). Potential further debt equity swaps on the radar.

Government equity is 100% but ZESCO has not paid dividends.

EMRC: What is tax status of asset revaluation (most tax regimes limit allowable depreciation / capital allowances to historic (original) asset purchase values. This means that an apparent operating loss (with no tax liability) can, for tax purposes, be a profit and subject to tax.

ZESCO Unclear of tax status of re-valuation. Will come back to us. (Action ZESCO).

EMRC: What actions are ZESCO taking / planning to turn around ZESCO?

ZESCO: Looking to improve cost efficiency in areas ZESCO has control over but believes that there is no fat in the structure to cut out. The cost of sales is 32% of revenue so that is limited options to reduce costs.

ZESCO: Not comfortable with status of CEC. One issue id KCM (Vedanta) not paying and CEC withholding payment to ZESCO.

ZESCO: Government does not lean on ZESCO but does lean on ERB.

ZESCO: Submits annual returns to IMF and World Bank – will pass on submissions to EMRC (Action ZESCO).

B.3 Note of Meeting – ZESCO – Senior Finance Team, Lusaka, 12 December 2019 10:30 to 11.30

Company	Attendee	Attendee
ZESCO	Fitzpatrick Kapepe Mwelwa Chibesakunda Matthew Lungu	Venasio Phiri Brown Zimba Raymond Sikazwe
EMRC	Keith Burwell Carlos Migues Tom Jardine	Andrea Marroni Thomas Miti

B.3.1 Purpose of the Meeting

Update of previous meeting to answer previous questions and discuss subsequent identified issues.

B.3.2 General Discussion

Summary of discussion follows:

EMRC: Revaluation of assets and tax status: Are depreciation provisions allowed for tax allowances based on historical (actual) purchase costs or on re-valued asset values?

ZESCO: Not 100% sure but fairly confident it is in line with general worldwide practice of being based on historic costs. [Subsequent email with details of the tax calculation has confirmed this]

EMRC: Grant reserve and re-valuation: When the asset register was re-valued was there a parallel exercise to revalue the grant reserve account? EMRC explained that in theory this should be done for the purposes of determining a regulatory asset base (which should be the net asset value less that component financed by grants or customer contributions). Without revaluing the grant reserve account the regulatory value of assets may be over-stated.

ZESCO: The grant reserve has not been re-valued and it may not be possible to undertake such an exercise.

EMRC: It may be possible for the revaluation of the grant to be re-valued by a pro-rata adjustment relative to the asset revaluation. This will not be accurate but because the size of the grant element is small any inaccuracies are unlikely to have a material impact.

EMRC: Tax statements: It is unclear to us how the tax credit is derived.

ZESCO: They will send a detailed tax computation [Now received in pdf format]

EMRC: Tax projections: Shall we consider tax in the analysis or shall it be ignored on the basis that there is sufficient carry forward of losses to eliminate the need for tax?

ZESCO: The carry forward of losses is time limited and on the basis that the cost reflective tariffs are expected to turn the organisation into profit then we must consider tax.

EMRC: We shall look into this but we anticipate some problems – we shall examine the implications of this [Action: KB to discuss with RY and CH]

EMRC: Dividends: Will government expect to receive dividends from ZESCO and if so what will government expect?

ZESCO: Certainly if ZESCO was operating profitably. Understand that they will take 35% of profits. The expectations are set out in the Investment Development Corporation (IDC) policy [subsequently forwarded to us].

B.4 Note of Meeting – ZESCO – Customer Services Team, Lusaka, 10 December 2019 09:00 to 11.00

Company	Attendee	Attendee
ZESCO	Mwelwa Chibesakunda Matthew Lungu	Mary Chibwana Chitembo Chabi Namposya
EMRC	Keith Burwell Tom Jardine	Carlos Migues

B.4.1 Purpose of the Meeting

To set out in detail the information requirements with respect to customer details.

B.4.2 General Discussion

General discussion with respect to customers etc.

- Pre-paid customers

- – 15 kVA and below
- – Comprise 99% of all customers but approx 40% of billings
- – Billed on basis of energy and fixed charge only (and the latest proposal is for the fixed charge to go as it is not compatible with a lifeline tariff and results in effective self disconnection [This is customers who do not buy for a month or so and when they prepay the backlog of fixed charges which has to be settled is too high and discourages paying for the service]. The proposal is in the latest tariff application.
- – Post-paid customers

- Above 15 kVA
- 1% of all customers but about 60% of billings
- Billed on basis of energy and actual peak demand (not contracted demand)
- No reactive power charge
- Charges based on three categories of peak demand (not voltage levels).
- Category assigned according to contract capacity but monitored and if peak demand crosses threshold then charged at higher band
- Above 25 MVA charges based on PPAs but seeking to lower threshold to 5 MVA
- No charges to generators – assumed to be included in PPA agreements.

- – Database requirements

- Require database download. Data to include (for each customer):

- – Customer details (excluding name, therefore anonymous)
- – Location (town)
- – Transformer or substation served by (if transformer data can be linked to operational data it may be possible to identify substation)
- – Voltage level (subsequent issue of sample data suggests voltage level not provided but it may be possible to work it out from the transformer data provided – [Action - TM to investigate]
- – Enrolment date
- – Monthly energy, charges (including fixed charges) purchased (also maximum demand charges for post-paid)
- – Arrears included in pre-paid charges (we understand that if arrears were accrued on the switch to pre-paid the payments include a payment plan to pay back arrears, albeit at a very slow rate in many cases).

- Suggest sample of database output be sent to us to confirm that we can open files [Action – ZESCO to send [post-paid sample sent but pre-paid sample outstanding]
- Details of new connections and connection charges over time [Action – ZESCO to provide data]
- Suggest sample (anonymous) bills (several for each category, to be provided to us [Action –ZEXCO to provide]

B.5 Note of meeting – ZESCO System Operations, 11 December 2019 09.15 to 11.00

Company	Attendee	Attendee
ZESCO	Morris Njobvu Mwelwa Chibesakunda Collins Mumba	Davidson Musonda Mpaisha Phiri Victor Musenga
EMRC	Daniel Serrano Carlos Migues	Thomas Miti

B.5.1 Purpose of the Meeting

Data collection and discussions about system operations, SAPP trading and water management.

B.5.2 General Discussion

CM provided a summary of the project objectives and approach, followed by DS with an introduction to the work expected to be carried away as part of the generation and transmission planning activities.

Data requirements:

The discussion on this end did not go very far. The consultant was requested to prepare a data request document and NCC will review and provide the data. In principle, data should be available, although reference to hydrological information was made, it will probably be available with ZESCO's Generation Support Services (GSS), in charge of managing water resources at ZESCO.

A meeting with GSS was requested and it was allocated for the next morning (Thursday 12).

System Operations:

ZESCO NCCs has direct control over 3 large hydro PPs (Victoria Falls, Kariba and Kafue and an approximate 20 MW total of small hydro PPs and two thermal units.

Dispatch is performed on a self-nomination basis in which ZESCO receives everyday (expect for the weekends in which the whole process takes place on Fridays), the day-ahead nominations of all IPPs and uses its own resources in order to supply the net demand. There is no economic dispatch implemented, although the company is in the processes (or at least wishes) of implementing such a mechanism. Currently, if deviations occur, the system is balanced manually based on operators' experience trying to internalize the PPA tariffs as a proxy to variable costs.

Reservoir management is not in the hands of NCC, they just receive (at different timeframes, usually weekly updates) the allowed water schedules to be used at the hydro stations plus instructions to release, store, spill water from the GSS team. Also, they refer to the Zambezi River Authority as the one that decides on water management for Kariba, informing on a year-ahead basis. IPPs also decide independently on their generation schedules when use of water is concerned.

With this information, NCC prepares a yearly operations plan, coordinating results with other units, and in terms of operations, they prepare the day-ahead schedules.

Reserves:

Reserve requirements are calculated following SAPP requirements. Zambia is in this regard a single control area (that extends to some parts of the DRC). Based on the largest generator fault and SAPP countries contribution, a MW quantity of spinning reserves is calculated. There is a requirement to maintain the ACE to zero s as to maintain regional balance.

Currently, due to the lack of power, reserves are basically not being provided. If the situation happened to be better, supposedly reserves' provision (at least spinning) would be distributed.

Currently only Kafue is connected to the AGC, although it's being extended to Kariba North power plant.

The grid code details the reserve requirements and instructs NCC to go into agreements with power plants for the provision of AS. This can be done via PPA or via separate agreements. Currently PPAs were signed prior to these requirements and no separate agreements have been signed yet.

SAPP interconnections and operations:

Currently there are 3 international interconnections (Zimbabwe, Namibia and DRC), although there are several other under constructions and in planning that would end-up interconnecting Zambia with 9 different countries if the EAPP interconnection is achieved.

SAPP trading includes bilateral and spot trading, on a day-ahead basis spot trade is received from the pool, which is combined with the bilateral nominations in order to set the day-ahead international cross-border schedules. It was informed that during some parts of the year the national grid cannot accept all international flows (since there is wheeling from Malawi to Zimbabwe via Zambia) and curtailments are needed.

There was a comment that referred to the lack of payments for AS under the current scheme, since SAPP puts penalties for not complying to reserves' requirements on the regional pool, but no one locally wants to respond to these (due to the non-remuneration issue).

B.6 Note of Meeting – ZESCO Business Development 11th December 2019 9.30

Company	Attendee	Attendee
ZESCO	Sarah Muyuni	Mutinta Lunda
EMRC	Tom Jardine Keith Burwell	Andrea Marroni

Attendees:

The Dept is dealing with:

- Strategy
- Business Planning
- Investment
- Economic analysis
- Regulatory analysis - (incl. pricing of PPAs)

The current draft Bills include those elements

- Open access regime and -> ISO
- Multiyear tariff design and approval . With the new Laws, ERB has been conferred the explicit power to carry out periodical tariff reviews and adjustments.
- A more dynamic / flexible corrective review (intra-year) would be desirable however not easy to adopt (Provision of automatic adjustment?)
- Small number of categories is desired
- DSM measures and dynamic price signals to be strengthened
- Discipline of non-retail customers PPA
- Self-consumption allowed
- Mini-grids regulation (draft exists)

With regards to RE, the Government has allocated directly to ZESCO a certain amount of MW

A Study says that up to 929 MW RE-based power can be absorbed.

This absorption capacity of the grid is currently under scrutiny. A Grid access to electricity division of ZESCO is involved

Scaling solar program

- The first solar plant financed and tendered under the Scaling Solar program will provide 54 MW. The Bangweulu project was awarded to NEOEN S.A. / First Solar Inc in May 2016 as part of the first round
- Bangweulu in numbers: 6.02: tariff in US¢/kWh achieved for the project. 25: Number of years the tariff will remain fixed for. 39: Million US$ of financing provided by IFC, OPIC, and the IFC-Climate Change Program. This is roughly 2/3 of the total project cost (excluding financing costs) of 56 million US$. 27,000: Homes supplied with electricity thanks to Bangweulu, based on average power consumption per capita in
- The second (34MW Ngonye solar PV facility) is located in southern Zambia. 25-year PPA partly funded through a financing agreement signed with Zambia's Industrial Development Corporation (IDC) by the developer Enel Green Power ("EGP"). It is the second round of the World Bank Group's program. The Ngonye solar plant is owned by a special purpose vehicle 80% held by EGP and 20% by IDC, expected to produce around 70 GWh per year. In June 2018, Enel signed a financing agreement with IDC of around 34 million US dollars for the construction of the PV plant, involving senior loans of up to 10 million US dollars from the IFC, up to 12 million US dollars from the IFC-Canada Climate Change Program and up to 11.75 million US dollars from the EIB.
- At the same time, Zambia's Government launched another tender for an additional 100 MW of PV to be awarded under the GET FiT solar framework.

B.7 Note of Meeting – ZESCO Senior Management

Company	Attendee	Attendee
ZESCO	Patrick Mwila Sarah Muyuni	Cynthia Kunda Mwelwa Chibesakunda
EMRC	Tom Jardine Carlos Migues Keith Burwell	Andrea Marroni Daniel Serrano Thomas Miti

B.7.1 Purpose of the Meeting

High level engagement with ZESCO Management and discussions.

B.7.2 General Discussion

The ZESCO delegation was led by the Director, Corporate Affairs and Strategy, Patrick Mwila who stated that he was a member of the Study Steering Committee and that he had attended the maiden meeting that was held on 3rd December 2019.

EMRC thanked the ZESCO delegation for allowing them to meet ZESCO at high level. TJ stated that EMRC had held a lot of fruitful meetings with ZESCO in the past two weeks.

TJ mentioned that EMRC had a lot of questions for ZESCO and that there was need to model the future shape of the power sector in Zambia to buy into ZESCO's future plans.

EMRC would like to know where ZESCO stands on the Bulk Supply Agreement (BSA) with CEC.

PM: There are a lot of issues that surround the BSA between ZESCO and CEC but will give a brief on what is currently on the ground. BSA was initially meant to facilitate and help in the Operations of the Copper Mines and NOT the electricity supply. There are a lot of other matters that do not sit well with the Government and ZESCO.

LEAST COST EXPANSION MODEL: Diversification has to be taken into consideration and has to be optional. A lot of commitments have been made to bring in new generation onto the grid. Emphasis and interest from ZESCO is to come up with an optimal model that looks at an energy mix. The longer the period under consideration the better. ZESCO will support model that looks at all aspects and levels of the sector. Energy demand changes in Zambia occur in very large quantum (either up or down). The country can be in excess energy capacity in one instance and suddenly change to an extreme deficit; an example was in 1999/2000 and the first load shedding of 2008.

TJ: There are a lot of options to consider on models but EMRC will look at models that are in line with Policy requirements.

ZESCO: There are a lot of factors that are to be taken into consideration. One issue that has been emotive has been on the numbers. We need to have a focussed approach as we do the benchmarking.

Carlos: Situations differ from country to country and these have to be considered in benchmarking using the bottom-up approach.

ZESCO: Zambia has a land area of 750, 000 km2 with a population of approximately 17 million people with generally sparsely distributed people settlements.

TJ: Bottom-up approach will perfectly address the above scenario.

ZESCO: A Cost of Service Study (COSS) was carried out in 2006 and there will be no harm in referring to it although a lot of changes have occurred since it was done.

ZESCO looks forward to expediting the process so that the COSS Report can be presented before November 2020.

Andrea: EMRC would like to have a clear understanding of Legal Requirements in the electricity supply sector and Regulations especially that this is a particular task of the COSS.

B.8 Note of Meeting – Generation Support Services, 12 December 2019 9.00 to 10.30

Company	Attendee	Attendee

ZESCO	Bornwell Sinkala Mwelwa Chibesakunda	Andrew Mabula Kelvin Kabwe
EMRC	Tom Jardine Carlos Migues	Thomas Miti Andrea Marroni Keith Burwell

B.8.1 Purpose of the Meeting

- Understand the way GSS manages the water resource and how it is reflected in system operations.
- Require necessary information for SDDP setting.

B.8.2 General Discussion

TJ provided a summary of the project objectives and approach. There are two main river basins: Zambezi and Kafue

Zambezi Basin

- Shared basin with Zimbabwe, managed by Zambezi River Authority (ZRA)
- Kariba North (Zambia): 1.080MW. The power station is property of ZESCO.
- Kariba South (Zimbabwe): 1.050MW
- There is a shared reservoir: Lake Kariba. The dam is property of ZRA.
- Downstream Kariba plants, there is Cahora Basa in Mozambique
- There is a Water Purchase Agreement (WPA) between ZRA and ZESCO
- Each year (January) ZRA makes a total water allocation for the two PSs (North/South), based on the projection of annual inflows into Kariba. Based on the total allocation, ZESCO estimates a monthly profile
- Annual allocation can be updated along the year
- In January 2019, ZESCO allocation was 19 bill.m3, what means an average capacity of 500MW. In April 2019 it was updated to 17 bill.m3 for the whole year (375MW average). Monthly allocation was updated by ZESCO on a pro-rata basis.
- For 2020, it is expected that total ZESCO allocation will be reduced even more, to 11 bill.m3 (275MW average).
- Rules of the WPA:
  - 5% consumption over annual allocation: no additional cost
  - Between 5 and 20%: tariff increases in 50%
  - Above 20%: tariff increases 100%
- Water tariff doesn't depend on the head at Kariba reservoir:
  - Minimum level: 475.5mts
  - Maximum level: 488.5mts
  - There is a minimum inflow due to environmental restrictions from Mozambique

Kafue Basin

- Three cascade PSs (three reservoirs):
  - Itezhi Tezhi Power Corporation (ITPC):120MW (peaking plant)
  - Kafue Gorge Upper: (600+300+90)MW
  - Kafue Gorge Lower: 750MW, to be commissioned in 2020
- Each plant has a reservoir:
  - GSS defines the amounts (m3) NCC is allowed to generate, keeping reservoirs between their minimum and maximum level
  - GSS issues weekly reports to NCC, communicating the updated allowed generation 12 months ahead (monthly targets)
  - There is an environmental restriction of minimum 25m3/seg
  - There are extractions between ITPC and Kafue (see JICA 2010 MP)
  - Kafue serves Kafue Gorge PS and Lusaka Water Company

B.8.3 Information Requirements

- WPA agreement between ZRA and ZESCO. Prices past evolution and adjustment rules
- Example of weekly report from GSS to NCC
- GSS can provide 40-year inflow statistics as required, as well as a topology diagram of the metering stations

B.9 Note of Meeting – Ministry of Energy (Department of Energy) - 5 December 2019 11.00 to 12.30

B.9.1 Attendees

Company	Attendee	Attendee
MMEWD	Michael Mulasikwanda Lawrence Musalila David Wamulume Khuzyawo Mhlanga	Isaac Soko Saul Jere Mundia Sitali Aggrey Siuluta
ERB	Besa Chimbaka	
EMRC	Tom Jardine Alejo Loira	Thomas Miti Keith Burwell

B.9.2 Purpose of the Meeting

Data collection and discussions

B.9.3 General Discussion

TJ gave a brief background on EMRC and highlighted that the major areas on which EMRC provided consultancy services were in energy and gas. EMRC is global and able to draw personnel from around the world. He stated that EMRC had recently undertaken COSS in Lesotho, Ghana, Tanzania, Ethiopia, Thailand and Jamaica.

TJ: Part of COSS objectives is to review the power sector and emphasized that EMRC would need support from the Department of Energy (DoE). He then provided a summary of the project objectives and approach.

Mr. Michael Mulasikwanda (MM) pledged that the DoE will do everything possible to ensure that all required data and documentation would be made available to the COSS Team

Question	Answer
(Min) When will project be complete?	EMRC) By Nov 2020 but has been requested to finish earlier. Can be done but depends on timely receipt of data (particularly ZESCO). Require the full customer database. Need to model most probable scenario (not numerous scenarios). Many tasks are inter-dependant.
(Min) Is 1 year standard?	(EMRC) There is no standard but 10 – 18 months is typical (Lesotho took 12 months) (ERB) There is no standard time but what determines the duration is the scope of the study.
(Min) Will the mines be represented in the study and how?	(EMRC) Yes, will work with them (and consult them) and workshops will invite representation from the mines.
(Min) Public concern over tariffs and whether pass-through from PPA are efficient.	(EMRC) Will assess all segments of value chain. Recognised that there are concerns that such agreements are too costly but also recognise that full cost reflective tariffs may still be higher yet due to inefficiencies and shortcomings elsewhere in the value chain.
(Min) Main challenge is the tariff and this is what needs fixing	EMRC) Will consider all aspects (legal, markets etc.) to arrive at our findings. Also understand concerns over IPP procurement and tariffs should be cost-reflective for efficient utilities.
(Min) Tariff increases under appeal as some stakeholders are reluctant	(EMRC) We will examine / compare ZESCO with CEC. Efficiency improvements will take

to finance ZESCO inefficiency.	time and the 5 yr tariff review can provide for expected efficiency improvements.
(Min) Do you need information from ECA?	(EMRC) Not essential but if available we shall look at it.
(Min) What is most important data for Inc Rep?	(EMRC) All is important and we need as much as possible now
(EMRC) Can you give a brief overview of role of Min?	Min) Min responsible for oversight of sector. Min responsible for policy development and steering legislative process. Although independent regulator in place and ZESCO established they are still subject to a degree of government direction.
(EMRC) Who invests in rural electrification?	(Min) REA invests but assets adopted by ZESCO. There is a Rural Electricity Fund (REF) that is financed by a 3% levy on bills but is passed on to Government Treasury (effectively it is a tax). Although REA builds infrastructure there is a low take-up of connections. Consequently, ZESCO is reluctant to pay for the infrastructure (considers it to be a liability rather than an asset).
(EMRC) Why the low take-up? Connection cost or energy cost?	(Min) Poverty, Not only is cost of connection prohibitive but households will have the added expense of household wiring. In some cases World Bank have subsidised connections which has had better results.
(EMRC) What is the rural electrification policy with respect to REA vs private sector	(Min) Considers private sector not viable without subsidies. Electrification expected to pick up with anticipated income growth. MM notified the meeting that the Contact person for data collection at the DoE would be Mr. Isaac Soko and Mr. Lawrence Musalila. In turn Isaac Soko stated that he was going to avail some data on the study at the end of the meeting.
KB: What is the brief overview of the DoE?	MM: Gave a brief structure of the Ministry/ERB/REA and that ZESCO Limited was a Parastatal under the Industrial Development Corporation (IDC). There are

	two Independent Power Distribution Companies (North Western Energy Corporation (NWEC)) and a Chinese Company in Chambishi town on the Copperbelt Province.

B.10 Note of Meeting – AfDB, 6th December 2019 11.30 to 12.30

Company	Attendee
AfDB	Liezl Harmse Elizabeth Muguti (on skype from Joburg)
EMRC	Tom Jardine Thomas Miti Keith Burwell

B.10.1 Purpose of the Meeting

Introductory and to discuss the conditions EMRC need to meet in the Inception Phase in response to AfDB's comments in the "No Objection" letter to ERB accepting the appointment of EMRC.

B.10.2 Discussions

General

AfDB see that effective engagement with stakeholders is a critical requirement for the COSS. In particular to engage with the mining sector and individual mining companies.
AfDB suggested that efficiency of ZESCO Limited was a major concern and that the Mines in particular were reluctant to finance inefficiency at ZESCO.

AfDB stressed the importance of the delivery of a high-quality product at each stage of the project. They noted that our proposal was the only proposal received that described a QA system and that this influenced them in selecting us for the project. In this regard they suggested we complete all QA checks before delivering the Inception Report.
AfDB also remarked on the importance of a permanent local presence for the study team which was not available in the ECA project. It was noted that Thomas would need to be fully conversant with the COSS progress throughout its execution.

AfDB suggested that because the COSS is a vital input to the development of all parts of the electricity sector progress should be regularly reported to the other donors. AfDB suggested EMRC might therefore make presentations to meetings of the donors – the Co-operating Partners (CPs) working group.

EMRC stated that the Lesotho COSS was delivered in fourteen months and AfDB confirmed that some delay in completing the study was due to late engagement between the Bank and Consultant.

EMRC pointed out that we were being pressured to move quickly and complete the COSS earlier than one year but to do that we seek support from AfDB, e.g. timely approvals.
AfDB asked whether we intended to use ECA data and EMRC responded that ECA data was already two years old and as a result would have limited benefit to this COSS. However, we gave assurance that there was no harm giving it a once over.

AfDB noted that if we identify that ZESCO needs to improve its operational efficiency (Task 7) it has funds earmarked to support the improvement process.

AfDB wanted to find out when the Inception Report would be submitted to ERB; EMRC gave assurance that the Inception Report would be submitted before Christmas this year. AfDB insisted that there should be no rush in submitting the IR and that they would be comfortable if a good quality IR were submitted early in January 2020 than a poor quality IR in December 2019.

Liz Muguti visits Lusaka regularly and may attend the Inception workshop.

Conditions in "no objection" letter

AfDB need to be sure that:

- The methodology (model) we intend to apply for Tasks 4 and 5 is adequate for the results required, and
- The technical resource in our team is competent to use the selected model.
- AfDB noted their concern is based on:
- The experience in the Lesotho COSS where they consider the methodology applied would be inadequate for the Zambia situation,
- Insufficient detail in our response to ERB comments during the negotiation phase of the EMRC proposal,
- The need for a project-by-project optimisation modelling and not an averages approach as described in the technical proposal.

EMRC stated that we intend to use a bespoke GT&D expansion model, one that is geared towards hydro schemes.

EMRC explained that it has specifically mobilised the modelling team to come to Lusaka next week to address these issues. AfDB undertook to attempt to arrange a conference call with

Liz Muguti in Joburg and the AfDB COSS consultant, Sam O'Brien in the USA – Wednesday 11th afternoon would be proposed.

B.11 Note of Office Private Power Projects Investment – 9th December 2019 [15.00 – 16.15]

Company	Attendee	Attendee
OPPPI	Clement Saasa	Clement Chiwele
EMRC	Tom Jardine Daniel Serrano	Thomas Miti Andrea Marroni

B.11.1 Purpose of the Meeting

Introduction of the Project and Team Members
LC Expansion Plan is main subject of the meeting

B.11.2 Discussions

General

- OPPPI is not acting as one-stop-shop for private sector; it takes the lead in coordination and in facilitating the process.
- Having said that, if mandated to do so it may promote projects for public sector development as well.
- As a result of the description of the solicited process, the regulatory framework seems weak with a three-phases stage which could possibly leave room for controversy.
- Pre investment studies are the basis for procuring a private developer who undertakes the feasibility study.
- The project is openly procured on this basis: the developer takes the risk that he doesn't get the project.
- Project documentation is not "pre-packed". After the award, the winning bidder gets the concession agreement, that should cover the possible controversy about the permitting cycle. To be confirmed: this looks like a disincentive
- From the ppt delivered by the OPPPI, we understand that a programme to procure utility-scale solar PV (50 MW) in Zambia attracted several applicants and brought low prices of $4/cWh (first round and less than $4/kWh (second round), under the GET FiT program.
- They allow private entities to develop feasibility studies and propose new projects at their own cost and risk.

- The project identification is mostly based on the JICA report, but priority lists for project development factor a wide variety of variables (policy, environment, costs, diversification, etc.)
- They are technology neutral in terms of project identification, from hydro to nuclear, all technologies, all fuels.
- A long list of projects from various technologies were identified and shown, at different status of development (construction, PPA negotiations, feasibility, pre-feasibilty). We will review and assess which ones we want to ask for the detailed feasibility studies. Project include international development (shared hydro projects with neighbouring countries).
- Bilaterally negotiated PPAs (unsolicited bids) are still allowed. Power plants of the (outdated) Plan are all advertised. Resource map is still incomplete (medium-small plants) hence unsolicited bids bringing feasibility studies are welcome.
- Least-cost expansion path/model for Zambia should focus not only in Grid Extensions (not economically viable but in off-Grid Solutions as well. A lot of consideration to international interconnections in order to become a hub is also considered.
- Rather sceptical about mini-grids -> population is very scattered and low demand.

B.12 Note of Meeting – ERB 10th December 2019 14.30 to 16.30

Company	Attendee	Attendee
ERB	Alfred Mwila Besa Chimbaka	Boyd Chilembo
EMRC	Tom Jardine Carlos Migues Andrea Marroni (notes)	Thomas Miti Keith Burwell Daniel Serrano

Carlos

- The current tariff regime is oriented to actual cost of the system.
- We understand the direction is towards a more incentive-based regime in which some items (operation and expenditures) are judged as efficient costs , resulting from different criteria/models to be applied
- In case of operational costs, room for optimization is remarkable.

Alfred

- Paradigm shift -> where we wish to be
- Tariff structure needs to recognize the cost of structure / Difficult to recognize the allocation of true costs along the supply chain of the ESI. Prudently, we shall introduce efficiency with incentive for good performance
- Efficiency debate

Carlos

- KPI system has a sort of parallel regime
- KPI are designed as an ex post mechanism to induce performance at the end of the computation; not applied to the cost of service estimation. Strictly speaking, our specific work will not be influenced by the KPI regime

Keith

- An alternative regime identifies ex ante the financial indicators that are necessary to achieve investment grade credit rating
- First the criteria, then the calculation of the revenue stream (necessary to satisfy it) is done.
- You may find numbers are quite scary!

Tom/Alfred

- With regards to the TASK 2 and the ECA reports, an indication is necessary on how to refer to these reports, manipulate the content and handle the source (already leaked somewhere)
- In order to avoid any controversy, ERB will discuss internally first
- The Team will use the source "tactfully", anyway and not quote from it.

Andrea

- With the new Laws, ERB has been conferred the explicit power to carry out periodical tariff reviews and adjustments.
- There are not many gaps in the legislation. What is questionable is the general macropolicy and the architecture of the legislation. Some wonders and concerns about the process / who is orchestrating the two Acts in coordination?
- At first sight, the influence of politics on the operations of the ESI is less strong. However, in some cases there are several prescriptions which seem a bit "intrusive".
- Policy and Legislation should be dealt with by the Government (Legislation and secondary Legislation; while Regulation should go under the Authority (Regulatory or statutory instruments + orders)
- INCEPTION PHASE and TASK 2: Analysis of regulatory governance (looking forward) and power sector model
- Reg substance of the two energy Bills (currently under scrutiny of the Parliament). Major highlights of comments from other consultants will be possibly made available
- A possible set of recommendations on Institutional setup
- ERB has jurisdiction over licensing and enforcement of license conditions. In addition, the ERB is competent authority for the industry codes including amendments to the codes

Daniel

- OPPPI might be an indirect source of info -> A long list of projects from various technologies were identified and shown, at different status of development.
- We should get (via formal request of the ERB) the feasibility studies.

B.13 Note of Meeting – ERB, 13 December 2019 09:30 to 11.15

Company	Attendee
ERB	Besa Chimbaka
EMRC	Keith Burwell

B.13.1 Purpose of the Meeting

Informal chat to discuss areas where ERB needs support and possible training options.

B.13.2 General Discussion

Areas where training is sought:

- Load forecasting (for benefit of the technical committee). Need to understand how to work with raw data through to outputs.
- Determination of generational marginal costs and incremental costs of transmission and distribution. Considers this the most critical aspect of their needs.
- New model(s) and training in their use. Would prefer models not to have macros unless limited to simple macros that can be edited.
- True-up processes in a multi-year framework.
- Regulatory process in general, e.g. best practice approaches to regulatory decision making, processes for amending instruments such as licence conditions, tariff methodology rules, derogations etc.

B.14 Note of Meeting – Rural Electrification Authority, 12 December 2019 14.59 to 16.25

Company	Attendee	Attendee
REA	Jacqueline H. Musonda	Patrick Mubanga
ERB	Besa Chimbaka	
EMRC	Tom Jardine Carlos Migues	Keith Burwell Thomas Miti Andrea Marroni

B.14.1 Purpose of the Meeting

Introduction to the Rural Electrification Authority (REA).

B.14.2 General Discussion

JHM welcomed all to the meeting and that REA was looking forward to the success of the COSS. She is the Director for Strategy and Planning.

Tom Jardine stated that EMRC really appreciated the time that REA had given to meet the team and that this was important because REA was a key stakeholder on the COSS. He proceeded and gave a brief introduction of COSS and its' objectives. TJ gave a summary of the 12 Tasks of the COSS.

JHM thanked TJ for the brief but thorough summary of the tasks. She gave a background of REA: set up through an Act of Parliament in 2003; mandated to increase access to rural electrification and improve the quality of supply; The guiding principal for implementation of rural electrification is based on the Rural Electrification Master Plan (REMP) that was commissioned by the Japanese International Co-operative Agency (JICA). The target for REA is to take electricity to Rural Load Centres (RLC) to schools, clinics and households by supplying to catchment areas of RLC. Supply to RLC is not economically viable but IRR for RLCs are very favourable.

JHM: REA is also mandated to implement Grid Extension Projects (GEP), Solar PV Systems, Solar Mini Grids and Mini Hydros. REA is currently operating a 600kW mini solar project in Northern Province of Zambia in accordance with Legal and Regulation requirements. They applied and obtained a Generating Licence from ERB. REA has also completed a 640kW mini hydro power plant in Mwinilunga District of North-Western Province of Zambia, the plant is awaiting technical commissioning. REA has also installed remote solar systems to a number of Chief's Palaces around the country. Grid connected installations are handed over to ZESCO Limited for O&M but for grid isolated installations; SPVs are set up to manage them through Public Private Partnerships (PPPs).

JHM: There is currently a 300kW Solar mini grid under construction in Lunga that is based on PPP model; 200kW Solar mini grid in Chunga that is located in a Game Management Area (GMA). The Act of Parliament that set up REA also included the establishment of the Rural Electrification Fund (REF).

Carlos: What is the tariff regime used?

JHM: The Rural electrification Act has provisions for smart subsidies which are applied on the initial capital cost of a project and not on O&M. The objective of applying the smart subsidies is to make the projects sustainable.

Carlos: To whom is the subsidy paid?

JHM: REA procures all rural electrification project materials and only contracts for labour through turnkey projects. The subsidies are paid via agreed milestones with the turnkey contractors.

Keith: For grid connected customers, are tariffs uniform to what ZESCO charges?

JHM: Yes

Keith: Who collects payments?

JHM: REA projects are community based and the community-based model has been adopted for mini-grids. The community collects payments and oversees O&M for that mini-grid. Any tariff adjustment can only be done by ERB.

Patrick: Licence holder for all off grid installations is REA.

JHM raised a concern that GEP has provisions for Life-Line Tariffs but that this was not correctly being implemented because it benefits even very rich households.

Carlos: EMRC will request for Expansion Plans from REA (specifically JICA REMP).

JHM: REMP was launched in 2008 and that a lot of things had changed on the ground over time. REA has adopted a five-year Roll-Out Plan so as to keep abreast with changes. Priority ranking of projects has changed e.g. some places have been upgraded to Districts and this facilitates change in priority ranking. The Ministry of Energy and Water Development has been engaged to commence REMP review.

Patrick: REMP is out of age. New Districts have popped up; technological approach has to be taken into consideration. The Department of Energy has formulated the Electricity Services Aspect Project (ESAP) whose objective is to evaluate how rural electrification can be rolled out. REMP went through a lot of processes and had to be ratified by an Act of Parliament. JICA has shown interest in offering support to review REMP.

Carlos made a request for the latest Roll -Out Plan and REA affirmed that they would share it.

Tom: Are there statistics that show changes after electrifying a rural establishment? There has been a lot of technological advancements in solar installations and this in turn has brought solar connection prices low. REA should consider taking this advantage into consideration.

Patrick: REA has observed that there have been numerous cases where newly connected rural customers had defaulted in paying for the usage of electricity. REA were aware of the dropping costs for solar installations.

Tom requested for specific Project Plans for rural electrification to which REA said that EMRC should formally request for all relevant data required.

Keith: What are typical differences between Feasibility Study price estimates and actual costs?

Patrick: Feasibility Study estimates tend to be lower than actual costs in most cases and that the gap between the two was usually large.

JHM: Is the COSS going to look at net metering? When off-grid networks get connected to the grid there will be need for consideration and regulation.

Besa: There is currently an EU funded project that is currently looking at this.
REA will share the National Electrification Policy.

Keith: Does the financing of rural electrification projects go through REA accounts or does it go directly to Projects:

JHM: REA will share Annual Reports (may be available on the REA website) and this should answer the question above from Keith.

Keith requested for plus five years Annual Reports and Carlos requested for the CAPEX breakdown to which REA affirmed to make available.

C Annex C - Contact List

C.1 Electricity Cost of Service Study Contacts List

C.1.1 EMRC

No.	Names	Position	Email	Mobile -Main	Mobile - Alt	Skype	WhatsApp
1.	Tom Jardine	Team Leader	tom.jardine@energy-mrc.com	+44 7731975923	+260 963 046589	tomalfrick	+44 7731 975923
2.	Keith Burwell	Financial Analyst	keith.burwell@edecon.co.uk	+44 7734152802		keithpurwell	+44 7734152802
3.	Alejo Loira						
4.	Carlos Migues	Electricity Pricing Specialist					
5.	Daniel Serrano	Power Planning, Data and Modelling Analyst					
6.	Andrea Marroni	Regulatory Lawyer					
7.	Louise Thomson						
8.	Alice Watham						
9.	Jorge Colomer						
10.	Thomas Miti	Resident Manager/ Transmission and Distribution Engineer	thomit2012@gmail.com	+260 977 844617	+260 955 844617	Thomasmiti2014	+260 977 844617
11.	Alfonso Santos	Power Engineer					
12.	Jorge Bircher	Power System Planning Specialist					
13.	Robert Yates	Utility Accountant					
14.	Agnes Inthasane	Office Manager	ainthasane@mrc-consultants.com	+34 608 321 082		Ainthasane_3	+34 608 321 082

C.1.2 ERB

No.	Names	Position	Email	Mobile -Main	Mobile - Alt	Skype	WhatsApp
1.	Langiwe H. Lungu	Executive Director	llungu@erb.org.zm	+260 955 776 847	+260 977 718856		
2.	Edna Mutalama Mwansa	Board Secretary/ Director Legal and Secretarial Services	emwansa@erb.org.zm	+260 977 688 657	+260 211 258 844 - 9		
3.	Alfred M. Mwila	Director Economic Regulation	amwila@erb.org.zm alfredmmwila@gmail.com	+260 977 826525	+260 211 258844 -9		+260 977 826525
4.	Besa Chimbaka	Economic Analyst Electricity	bchimbaka@erb.org.zm	+260 977 865912	+260 211 258844 - 9		+260 977 865912
5.	Kwali Mfuni	Public Relations Manager	kmfuni@erb.org.zm	+260 966 826 590	+260 211 258844 - 9		

C.1.3 REA

No.	Names	Position	Email	Mobile -Main	Mobile - Alt	Skype	WhatsApp
1.	Clement Silavwe	Chief Executive Officer	csilavwe@rea.org.zm	+260 977 827 046			+260 977 827 046
2.	Jacqueline H. Musonda	Director – Strategy and Planning	jhmusonda@rea.org.zm	+260 976 550 888	+260 977 640 740		
3.	Patrick Mubanga	Director – Engineering Services	pmubanga@rea.org.zm	+260 977 640 740	+260 211 241 296 - 8		

C.1.4 Ministry of Energy– Department of Energy (DOE)

No.	Names	Position	Email	Mobile -Main	Mobile - Alt	Skype	WhatsApp
1.	Arnold Simwaba	Acting Director					

2.	Michael Mulasikwanda	Principal Power Development Officer					
3.	Isaac Soko	Energy Economist	soko.isaac@moe.gov.zm	+260 975 067 768			
4.	Lawrence Musalila	Senior Electrification Officer	lawrence.musalila@moe.gov.zm				

C.1.5 ZESCO

No.	Names	Position	Email	Mobile -Main	Mobile - Alt	Skype	WhatsApp
1.	Patrick Mwila	Director – Strategy and Corporate Affairs	pmwila@zesco.co.zm	+260 966 432 465	+260 211 362510		
2.	Cynthia M. Kunda	Senior Manager – Business Development	ckunda@zesco.co.zm	+260 966 953 535	+260 211 362556		
3.	Sarah Muyuni	Chief Financial Analyst	smuyuni@zesco.co.zm muyunisarah@gmail.com	+260 965 859 521	+260 211 362 562		
4.	Mwelwa Chibesakunda	Financial Analyst	mchibesa@zesco.co.zm	+260 966 440 369	+260 362 577		+260 966 440 369

C.1.6 Copperbelt Energy Corporation (CEC) PLC

No.	Names	Position	Email	Mobile -Main	Mobile - Alt	Skype	WhatsApp
1.	Titus Chongo Mwandemena	Chief Commercial Officer	mwandemenat@cec.com.zm	+260 979 431 427	+260 212 244 064		
2.	Sylvester Hibajene	Head – Government and Investor Relations	hibajenes@cec.com.zm	+260 966 771 162	+260 212 244 900		
3.	Mulenga Mubanga Bwalya	Senior Manager – Account Management	mulengab@cec.com.zm mulebwa@yahoo.com	+260 977 705 944	+260 212 244 063		

C.1.7 Lunsemfwa Hydro Power Corporation (LHPC)

No.	Names	Position	Email	Mobile -Main	Mobile - Alt	Skype	WhatsApp
1.	Matthew M. Lindunda	Chief Executive Officer	Matthew.lindunda@lunsemfwahydro.com.zm	0977771025	0960993361	nil	0977771025
2.	Justin Loongo	Chief Technical Officer	Justin.loongo@lunsemfwahydro.com.zm	0977777158	Nil	Shichabwe1	0977777158

C.1.8 NEOEN

No.	Names	Email	Mobile - Main	Mobile - Alt	Skype	WhatsApp
1.	Christophe Desplats-Redier	Christophe.desplats-redier@neoen.com	+33 6 13 46 49 40			
2.	Ines Duclairoir	Ines.duclairoir@neoen.com	+260 963 075 397			

C.1.9 DT Global

No.	Names	Email	Mobile -Main	Mobile - Alt	Skype	WhatsApp
1.	Alexander Filippov	directfilippov@gmail.com	+260 977 609 706	+260 211 258 844		+260 977 609 706

C.1.10 Maamba Collieries Limited

No.	Names	Email	Mobile -Main	Mobile - Alt	Skype	WhatsApp
1.	Ravi Ahuja	ahujar@maambacoal.com	+260 962 565 974	+260 211 258 381		

C.1.11 African Development Bank Group

No.	Names	Email	Mobile -Main	Mobile - Alt	Skype	WhatsApp
1.	Liezl Cecilia Harmse	l.harmse@afdb.org	+260 960 704 916	+260 211 257 868 - 9		

C.1.12 Policy Monitoring and Research Centre (PMRC)

No.	Names	Email	Mobile -Main	Mobile - Alt	Skype	WhatsApp

1.	Akabondo Kabechani	akabondo.kabechani@pmrczambia.net akabondo@gmail.com	+260 977 773 067	+260 979 015 660 +260 211 269 717		

C.1.13 Zambia Chamber of Mines

No.	Names	Position	Email	Mobile -Main	Mobile - Alt	Skype	WhatsApp
1.	Goodwell Mateyo	President	Goodwell.mateyo@mopani.com.zm	+260 962 555 746	+260 212 247 030		

D Annex D – Generation Projects

D.1 Generation Projects coming on stream in 2019-2026 [Source ZESCO, 2019]

PROJECTS	CONTRACT SUM (US$m)	DATE/ YEAR STARTED	DATE/YEAR END	PROJECT STATUS	PAYMENT TO DATE (US$m)	AMOUNT CERTIFIED OUSTANDING (US$m)	BALANCE (US$m)	% OF WORK DONE	REMARKS
Kafue Gorge Lower 750MW Hydro Project	2,400 (Total Project Sum)	January 2016	August 2020	Implementation	873.187	125.793	1,526.813	74%	• Financial closure for HPP reached. Second drawdown made in November 2018. • Negotiations for financing transmission line in progress. • Delays by senior lenders in accommodating the subordinate debt is creating undue pressure on the sponsor to fund financing costs that should be made from the sub-debt.
Lusiwasi Lower 86MW Hydro Scheme	196.863	February 2018 (Contract signing date)	TBA	Implementation	1.00	0.00	195.863	0%	• Financial close not reached • Ministry of Finance completed the drafting of the concessional loan facility amounting to USD183 million and has

PROJECTS	CONTRACT SUM (US$m)	DATE/ YEAR STARTED	DATE/YEAR END	PROJECT STATUS	PAYMENT TO DATE (US$m)	AMOUNT CERTIFIED OUSTANDING (US$m)	BALANCE (US$m)	% OF WORK DONE	REMARKS
									submitted the same to the Attorney General's Chambers for legal review. • Speedy conclusion of CEB concessional loan required. • Contractor mobilised to site for additional site soil investigations and topographic studies.
Lusiwasi Upper 15MW Hydro Scheme	48.666	February 2016	October 2019 (Revised)	Implementation	38.773	1.454	9.893	94%	• 85% of the project is financed by ZESCO equity. • 15% of the project is financed by Standard Chartered Bank. Financial Closure reached and funds fully disbursed. • Project activities currently being financed by loan from the contractor. • EOT for achieving Operational Acceptance from 28 February 2019 to 18 October 2019 approved.

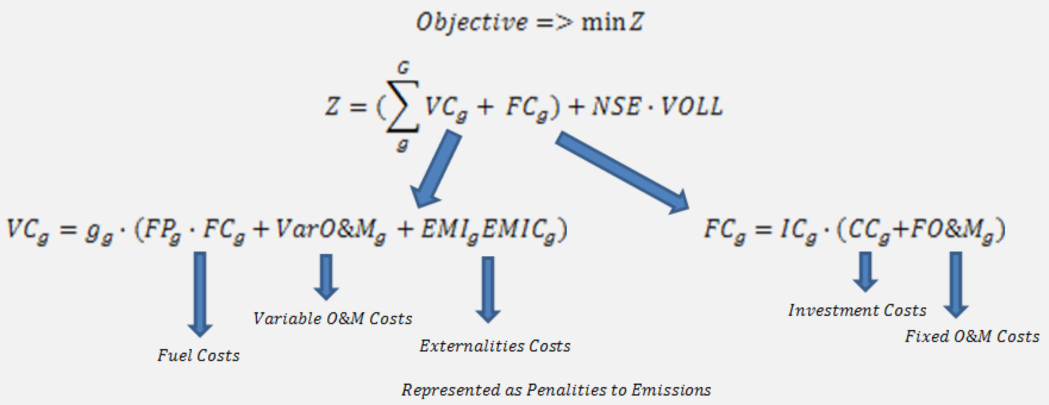
PROJECTS	CONTRACT SUM (US$m)	DATE/ YEAR STARTED	DATE/YEAR END	PROJECT STATUS	PAYMENT TO DATE (US$m)	AMOUNT CERTIFIED OUSTANDING (US$m)	BALANCE (US$m)	% OF WORK DONE	REMARKS
									• There is need to secure alternative financing arrangement as ICBC decided against providing a loan to ZESCO.
Musonda Falls 10MW Hydro Scheme	42.087	June 2014	November 2017	Completed	36.407	5.305	5.68	100%	• Project completed, the station is operational and in defect liability period. • Project was funded by ICBC at 85% and Standard Chartered Bank at 15%. • Financial Closure reached for both financiers. • Funds from Standard Chartered Bank have been fully disbursed. • Completion certificate was issued.
Luapula River Hydro Scheme, 600MW	1,500	TBA	TBA	Feasibility	0	0	1,500	0%	• DBSA approved Project Preparation Development Fund (PPDF) allocation of US$3.5million. • Project Preparation grant facility agreement was extended and will be available until 31st October 2020. • The ESIA and Engineering

PROJECTS	CONTRACT SUM (US$m)	DATE/ YEAR STARTED	DATE/YEAR END	PROJECT STATUS	PAYMENT TO DATE (US$m)	AMOUNT CERTIFIED OUSTANDING (US$m)	BALANCE (US$m)	% OF WORK DONE	REMARKS
									consultant schedule were aligned to minimise delays. • Preparations for detailed feasibility study have commenced and draft ToR for a full feasibility was submitted to SAPP for review.
Batoka Gorge Hydropower Project, 1200MW	4,000	TBA	TBA	Feasibility	0	0	4,000	0%	• The studies were funded through a grant under CIWA which expired on 31st December 2018. • The project preparation status is currently behind schedule due to financial challenges. The Developer has indicated that they shall bridge the financing gap for the remaining studies • Price Water Coopers was selected as the new TA but the contract is yet to be signed with ZRA. • The Developer submitted a proposal in

PROJECTS	CONTRACT SUM (US$m)	DATE/ YEAR STARTED	DATE/YEAR END	PROJECT STATUS	PAYMENT TO DATE (US$m)	AMOUNT CERTIFIED OUSTANDING (US$m)	BALANCE (US$m)	% OF WORK DONE	REMARKS
									September 2019 but it was rejected as it was non-responsive. The Developer was requested to resubmit a revised proposal.
GET FiT Solar Projects									
GETFIT SMALL HYDRO POWER PROJECTS									

E Annex E – EDM Objective Function

On a mathematical basis, EDM model determines the optimal generation schedule investments (generation and transmission) required to supply the forecasted load in a nodal (or multi-region / multi-country system). The objective is to minimise investment cost plus expected operation cost, composed of fuel cost and variable O&M, plus the cost of lost energy (VOLL) associated with supply reliability constraints, plus or minus the effects of externalities (a simplified representation for illustrative purpose can be seen next).



Being:

g..G: Index representing all generators in the system (Thermal, Hydro, RES)

Z: Objective Function (USD)

VC_g: Total variable costs per generator (USD)

FC_g: Total Fixed costs per generator (USD)

g_g: Energy output of generator g (MWh)

FP_g: Fuel Price of generator g (USD/MCal)

FC_g: Fuel Consumption of generator g (MCal/MWh)

$VarO\&M_g$: Variable operational and maintenance costs per generator (USD/MWh)

EMI_g: Quantity of pollutants emitted by generator g (ton)

$EMIC_g$: Penalty price for the emissions per generator (USD/ton)

IC_g: Installed Capacity of generator g (MW)

CC_g: Capital Cost Expenditures per generator (USD/MW)

$FO\&M_g$: Fixed operation and maintenance costs per generator (USD/MW)

NSE: Non-supplied Energy (MWh)

VOLL: Value of Lost Load (USD/MWh)

Exhibit 1 – Objective Function Illustrative Representation

The real objective function expands the summation to all time steps and to all stochastic scenarios, thus adding more indexes to the above representation. Additionally, it considers several penalty factors to make sure that the model always finds a feasible solution being able to balance all the constraints present in the model.

Some items of the illustrative objective function presented are much more detailed in the real model, such as:

- Fuel consumption, which is represented as a linearised function of the plants output rather than a single parameter
- Non-supplied Energy, which is represented as a step-wise function that can consider different costs depending on the amount of energy shed.
- Capital Cost Expenditures, represented as the annuity of each and every plant for each and every timestep

For this particular case, externalities will not be considered (no direct cost associated to CO_2 emissions is present in Zambia)

F Annex F – Detailed Data Request for Least Cost Expansion

Request for information

1. Information Needs

IMPORTANT NOTE: The following paragraphs detail the data required to carry out the study, but, regardless of these, which are generic for this type of work, we note that, in case available, the consultant can make use of system DBs in any format in order to extract the data from it. The consultant has licenses of several commercial modelling tools (DigSilent, SDDP, OptGEn, etc.), so sharing available databases can accelerate and make more efficient the data transfer compared to sharing separate files containing each piece of information requested.

It is expected that most of the information requested below is already included in the simulation models currently used by ZESCO or other operators.

In the particular case of DigSilent models of the power system, receiving the latest model version that correctly converges, configured for real operation situations in Zambia would be the most efficient method to receive the detailed information.

Information needs are divided into four main groups: demand, generation system and transmission systems, additional information necessary and relevant to energy and electrical studies.

Finally, note that the information requirements relate to systems in its current state, i.e. at the end of 2019 (or the beginning of 2020), and its development for the next 20 years. In the context of electrical studies, this information is required for all operating scenarios.

1.1. Demand

1.1.1. Information required for Generation planning

In order to model demand the following information will be required:

1. annual, monthly or weekly data (the more disaggregated, the better) for energy and peak demand in the country for years required (this will be an outcome of the demand forecast study);
2. Load curves. At least two full years (possibly 2017 and 2018[24]) with 8760 hourly demand values.

[24] The years must be representative years in which load shedding has not occurred, or it's minimal.

Finally, if any export (import) to (from) third countries other than those already interconnected is forecast, these shall be reported both in quantity and location in the network, with the same granularity as the already specified information. They will be considered as demand (generation) assets to be modelled.

1.1.1. Required information for Electrical Studies

The information as required for electrical studies is:

- Location: grid node and identifier (if several loads are connected to the same node)
- Dispatchable / non-dispatchable
- If any, adjustments of load shedding relays including settings and frequency triggers (e.g. for ROCOF, rate-of-change-of-frequency relays)

1.2. Generation System

1.2.1. Information required for Generation Planning

For all plants it will be required to indicate their connection node to the grid.

Thermal plants

The following table summarizes the information needs for all thermal plants of the system (ZESCO, IPP and CEC), both existing and future[25]. Note that consumption units (MCal, MWh ...) can be replaced by those most commonly used in the country.

Table 8 – Thermal plants information needs

Item	Description
1	Plant name
2	Number of units
3	Installed capacity – Nameplate Capacity (MW)
4	Minimum Output (Technical Minimum – MW or %)
5	Maximum Available generation (MW or %)
6	Historical average availability [spare time / total time] (%)
7	Variable O&M costs[26] (USD / MWh)

[25] Units in the table are indicative, if data are available in other units, please specify.

[26] O&M: Operation and Maintenance

Item	Description
8	Fixed O&M costs (USD / KW)
9	Fuel(s) used (number and type)
10	Fuel(s) Heat Rate (Mcal / MWh)[27]
11	Cost of fuel(s) (USD / Mcal)
12	Fuel(s) Transportation Cost (USD / MCal)
13	Type of plant (Technology: steam turbine, gas turbine, ...)
14	Plant status (commissioned, planned + expected commissioning date-, candidate, to be withdrawn + expected withdrawal year-)

In the case of fuel, any limitations affecting the availability of the (current or future) primary resource is required.

Information for future projects to be part of the candidate portfolio for expansion purposes should also be included:

Table 9 – Candidate Thermal plants information needs

Item	Description
1	Capital costs (USD/KW), not including interest during construction
2	Construction time
3	First year available
4	Linkage to other projects

The candidate project information can be received in the form of feasibility studies or due diligence reports, whatever is available from the relevant institutions in Zambia.

Fuel availability

As for fuels, two needs are identified:

1. National resources: For each type of fuel (if applicable) => Price and heating value, availability (annual) and seasonality (monthly) and identification of plants using the resource.

[27] This can be provided as consumption curve, historical average consumption, consumption at maximum load ....

2. Imports: For each type of fuel => Plants consuming this resource (existing and future) purchase prices (fuel + transport costs and others) and availability (restrictions on imports, physical or financial) current and future.

Hydropower plants

There are two important elements for the proper modeling of a hydro generation: river basins' characterization and representation of each of the power plants responsible for power generation.

Hydro basins

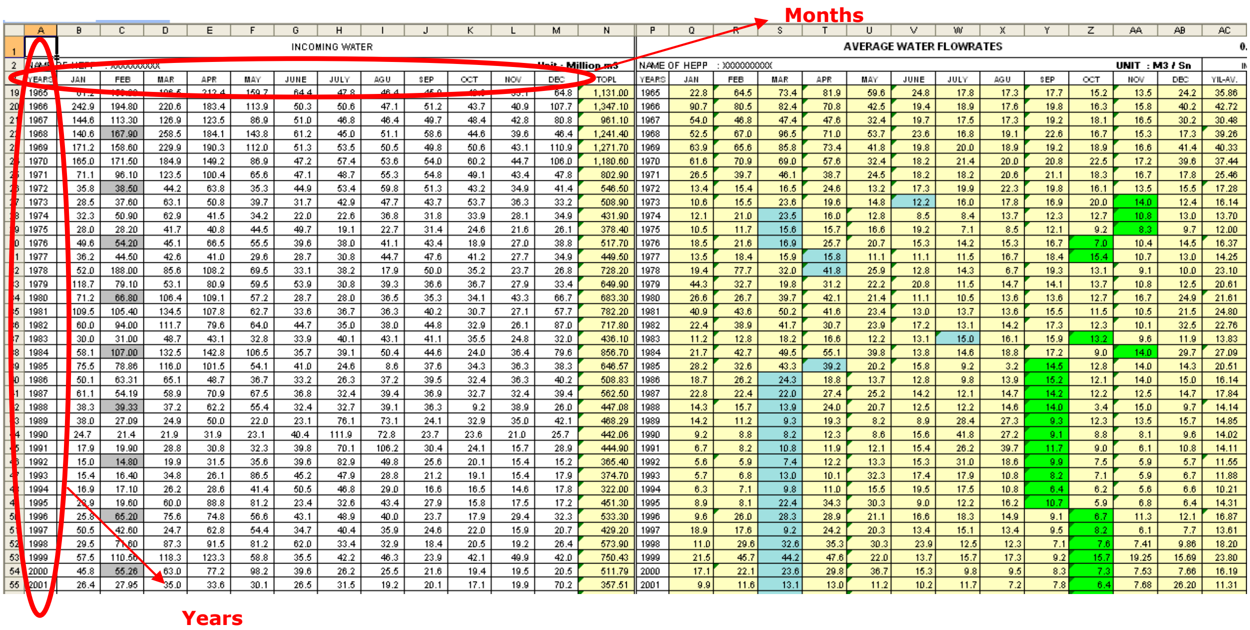
In order to correctly model the use of water of hydraulic plants we need to have the following information on the historical behavior of the flows fed to each of the relevant basins, in order to project its future availability:

a. Maps showing the physical condition of the plants watershed basin.

b. Maps of water uses in basins (map flow) if necessary to simulate load tap reservoirs or not associated with power generation.

c. For each plant / reservoir, a table with historical information flow (see example in the figure below).

Figure 15 - Example of hydrological data



Large hydro plants

The following table shows the information needed for each plant.

Table 10 - Hydro plants information needs (Large hydro with reservoir)

Item	Description
1	Plant name
2	Plant name (if any) for discharging / spilling / filtrations
3	Number of generating units
4	Installed capacity – Nameplate capacity (MW)
5	Net head (masl)
6	Average production factor (MW/m3/s)
7	Minimum turbining rate (m3/s)
8	Minimum storage (Hm3)
9	Maximum storage (Hm3)
10	Initial level of the reservoir. Generally, it is the level of the reservoir on January 1st, it is often given as a percentage of the maximum storage or other units (height, volume)
11	Storage Capacity: Daily, weekly, seasonal, multi-year ...
12	Minimum discharge => Minimum turbining + spilling (m3 / s)
13	Average historical availability [spare time / total time] (%)
14	Variable O&M costs (USD / MWh)
15	Fixed O&M costs (USD / KW)
16	Plant status (commissioned, planned + expected commissioning date-, candidate, to be withdrawn + expected withdrawal year-)

Any operational constraint that might affect the operation of these units (environmental flows, irrigation or human consumption needs, etc.) is required. Also, if detailed operation tables are available (production factor vs. volume, etc.) they will help to better model the actual operation of the plant and will replace the use of average production factors.

RoR Plants

Plants without reservoir (or with very limited regulation capacity) data requirements are very similar to those of the above table, with some simplifications as in the following table.

Table 11 - Hydro plants information needs (RoR)

Item	Description
1	Plant name
2	Plant name (if any) for discharging / spilling / filtrations

Item	Description
3	Number of generating units
4	Installed capacity – Nameplate capacity (MW)
5	Net head (masl)
6	Average production factor (MW/m3/s)
7	Minimum turbining rate (m3/s)
8	Net Volume (Hm3)
9	Peaking factor (0 - 1) [Plant capacity to regulate the net volume]
10	historical average availability [spare time / total time] (%)
11	Average historical availability [spare time / total time] (%)
12	Variable O&M costs (USD / MWh)
13	Plant status (commissioned, planned + expected commissioning date-, candidate, to be withdrawn + expected withdrawal year-)

The same comments regarding water usage (human needs, irrigation, etc) apply to these plants.

Mini or Micro central

For small plants (<10 MW without storage) the need for information is not as critical. The above tables can serve as a reference, but with a detail of hydrology, location (connecting node), plant status, availability, installed capacity and average production factor would suffice.

Candidate projects

Information for future projects to be part of the candidate portfolio for expansion purposes should also be included (apart from the information described in the previous tables):

Table 12 – Candidate Thermal plants information needs

Item	Description
1	Capital costs (USD/KW), not including interest during construction
2	Construction time
3	First year available
4	Linkage to other projects

The candidate project information can be received in the form of feasibility studies or due diligence reports, whatever is available from the relevant institutions in Zambia.

Renewable power plants

Plants using renewable resources (except hydro) may have a strong influence in the operation of the system given their intermittent nature (wind, sun), seasonal (biomass) or uncertainty (geothermal). For proper modeling of these resources, any available information will increase the quality of the study, in this regard, it is required:

a. Maps with the availability and energy potential of each resource.

b. Time records of each resource (e.g. wind speed or sun irradiation) in each candidate region. Or better, if available, the converted figures of the primary resource to series of gross electricity generation (GWh) to use directly in the simulation model. These records should be hourly for a full year (if possible) or for the typical months / days

c. General specifications (installed capacity, historical availability, development status -existing, planned, candidate-, production factor[28], O&M costs (fixed and variable), etc.)

Candidate projects

Information for future projects to be part of the candidate portfolio for expansion purposes should also be included (apart from the information described in the previous tables):

Table 13 – Candidate Thermal plants information needs

Item	Description
1	Capital costs (USD/KW), not including interest during construction
2	Construction time
3	First year available
4	Linkage to other projects

The candidate project information can be received in the form of feasibility studies or due diligence reports, whatever is available from the relevant institutions in Zambia.

1.2.2. Required information for Electrical Studies

For electrical studies, the necessary information to be provided is listed below:

- Location: grid node and identifier (if there are several power plants connected to the same node)
- Generation technology
- Nominal characteristics: rated power, voltage level

[28] In case of not having the series of historical (or probable) generation the formula that converts the series of the primary resource to electricity are needed.

- Operating margins: active and reactive power, voltage level

1.3. Transmission system

1.3.1. Required information for Electrical Studies

For electrical studies, the necessary information required is divided by type of network elements, as follows:

Power transmission nodes

For each node, the reference voltage level and its unique identifier code is required.

Lines

The information on each line element should include:

- ID: unique identifier
- Type: underground cables or overhead lines
- Situation: start and end nodes of the grid and identifier (if multiple circuits)
- Parameters: line reactance, line resistance, line charging susceptance
- Capacity (current rating or ampacity), or more detail in case you have several capacity levels (summer / winter, etc.)
- Surge Impedance Loading (SIL, in MW)

Transformers

Information on transformers should include:

- Situation: start and end nodes of the grid and identifier (if multiple circuits)
- nominal characteristics: rated power, high voltage / low voltage
- Parameters: Short-circuit impedance
- Voltage range of tap changers (in the case of transformers with regulation)
- Phase range (in case of phase-shifting transformer)

Shunts

Information on shunts should include:

- ID: unique identifier
- Type: capacitor or reactor
- Location: grid node and identifier (if there are several circuits)
- Range production / absorption of reactive power (rated capacity)

HVDC links

Information on HVDC links, if any, should include:

- Situation: start and end nodes of the grid and identifier (if multiple circuits)
- Identification technology: LCC, VSC, ...
- Nominal characteristics: Power, AC voltages and DC, power factor
- Operating margins: active and reactive power, voltage
- DC line parameters: pu resistance based system (100 MVA) or in Ohms

1.4. Other information necessary for Generation and Transmission Planning

1.4.1. Information required for Generation Planning

The following is required:

- Documentation relating to the expansion plans of generation systems and transmission for the next 25 years, where future assets are stated to be put into operation with its characteristics and expected date of entry into operation as well as the assumptions used for development.
- System topology maps, including:
  - physical maps for the location of the various generation and transmission assets in the country.
  - electrical maps (single-line diagrams) to facilitate the identification of potential energy corridors, connection points, etc.
- Operating reserve requirements. Criteria to meet the operational reserve needs (both primary and secondary) in the economic dispatch which will affect the dispatch of the units, for example:
  - Volume of reserves to be satisfied and plants that can provide these
  - Limitation in terms of energy outputs for some plants / corridors as to assure system stability
- Economic parameters: penalties, discount rate, non-supplied energy costs, etc.

1.4.2. Required information for Electrical Studies

This information is divided into information on the system topology related to the scenarios to be considered, and information related to network codes.

Information to be provided for each scenario to consider

Topology information system

For each load flow scenario, specify which elements of the power system are connected ("ON") and disconnected ("OFF").

System status configuration

Then the necessary information for each load flow scenarios that are identified as scenarios to be addressed needs to be detailed.

- Information on reference demand (load) and generation (power output) values in different system demand levels in the network:
  - Demand (load): current active and reactive power demand values at each grid node;
  - Generation: production value of each generator's active power;
- Position of grid control elements: voltage generators, shunts, take and / or phase transformers, voltage / power factor converters, etc.
- Exchanges: volume of power flows through cross-border interconnector or interconnections with neighboring power system (other transmission companies, or distribution companies), indicating the sense (incoming/outgoing).

Information concerning network codes

Information on technical specifications or requirements that must be respected in system operation:

- Permissible overloads lines and transformers in operation, situation N and N-1;
- Voltage limits network transport situation N and N-1;
- Critic faults maximum clearance times specified in the network code;
- Frequency bands for generators by technology, conventional i.e., wind turbines, solar photovoltaic, etc. including description of whether or not they must participate in ancillary services and how; and
- Protection Settings sub-frequency / over-frequency and sub-voltage / over-voltage.