Integrated Resource Plan

Ministry of Energy

Integrated Resource Plan for the Power Sector in Zambia

Inception Report (January – March 2021)

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ACKNOWLEDGEMENTS

The provision of energy services is an essential ingredient of socio-economic development worldwide. Energy is required in meeting basic human needs, such as food, shelter, health, transport, and education.

The development of an Integrated Resource Plan (IRP) for Zambia's energy sector is the result of an intensive and extensive consultative process, involving a variety of stakeholders in the country. While it is not possible to mention everyone who contributed to the development of the IRP, we would like to acknowledge the contributions from the following institutions:

1. Ministry of Finance
2. Ministry of Mines
3. ERB
4. ZESCO
5. CEC
6. REA
7. EIZ
8. WWF
9. OPPPI
10. UNZA
11. IDC
12. Zambezi River Authority
13. Chamber of Mines
14. NWEC
15. ZNFU

The development of the IRP would not have been possible without the generous financial and technical assistance provided by UK Aid provided through the Cities and Infrastructure for Growth Zambia (CIGZambia) programme. The Ministry of Energy is therefore greatly indebted to UK Aid for their vital assistance.

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GLOSSARY

7NDP	7th National Development Plan
AfDB	African Development Bank
CAIDI	Customer Average Interruption Duration Index
CAGR	Compound Annual Growth Rate
CAPEX	Capital Expenditure
CEC	Copperbelt Energy Corporation
COP	Conference of Parties
COSS	Cost of Service Study
Covid-19	Coronavirus disease
CSA	Climate Smart Agriculture
CSIR	Council for Scientific and Industrial Research
CSO	Civil Society Organisation
DER	Distributed Energy Resource
DFI	Development Finance Institutions
DNSP	Distribution Network Service Provider
DRC	Democratic Republic of Congo
DSM	Demand-side management
EAPP	East African Power Pool
EE	Energy Efficiency
ERB	Energy Regulation Board
ESMAP	Energy Sector Management Assistance Program
EU	European Union
FAO	Food and Agriculture Organisation
FCDO	Foreign, Commonwealth & Development Office
FCEH	Final Consumption Expenditure of Households
GCF	Green Climate Fund
G&I	Gender & Inclusion
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GHI	Global Horizontal Irradiation
GIS	Geographic Information System
GRZ	Government of the Republic of Zambia
GW	Gigawatt
HFO	Heavy Fuel Oil
IAEREP	Increased Access to Electricity and Renewable Energy Production
IAPRI	Indaba Agricultural Policy Research Institute
IBRD	International Bank for Reconstruction and Development
IDC	Industrial Development Corporation
IEA	International Energy Agency
IFC	International Finance Corporation
IPP	Independent Power Producer
IRP	Integrated Resource Plan
JICA	Japan International Cooperation Agency
KPI	Key Performance Indicators
KV	Kilovolt
KW	Kilowatt
LCEP	Least-Cost Geospatial Electrification Plan

LRE	Load-Related Expenditure
LWR	Least-Worst Regrets
M&E	Monitoring & Evaluation
MACP	Market Clearing Prices
MEL	Monitoring, Evaluation & Learning
MS	Microsoft
MNDP	Ministry of National Development Planning
MT	Metric Tonne
MVA	Mega Volt Amperes
MW	Megawatt
NDC	National Determined Contributions
NGO	Non-Governmental Organisation
NDP	National Development Plan
NEP	National Energy Policy
NHCC	National Heritage Conservation Commission
NLRE	Non-Load-Related Expenditure
NPV	Net Present Value
NWEC	Northwestern Energy Corporation
OPPPI	Office for Promoting Private Power Investment
PI	Profitability Index
PPA	Power Purchasing Agreement
PPCR	Pilot Program for Climate Resilience
PPT	PowerPoint
PUE	Productive Use of Energy
PV	Photo-Voltaic
RE	Renewable Energy
REA	Rural Electrification Authority
SADC	Southern African Development Community
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SAPP	Southern African Power Pool
SDG	Sustainable Development Goal
SMART	Specific, Measurable, Achievable, Realistic, and Timely
SSA	Sub-Saharan Africa
TAZAMA	Tanzania Zambia Mafuta pipelines Limited
ToR	Terms of Reference
TNSP	Transmission Network Service Provider
UNFCCC	United Nations Framework Convention on Climate Change
UNZA	University of Zambia
VRE	Variable Renewable Energy Sources
WARMA	Water Resource Management Authority
WWF	World Wildlife Fund
ZABS	Zambian Bureau of Standards
ZDA	Zambia Development Agency
ZRA	Zambia Revenue Authority
ZEMA	Zambia Environmental Management Agency
ZESCO	Zambia Limited

EXECUTIVE SUMMARY

About the Inception Report

This inception report presents the objectives, scope, overall approach, workstreams, and project plan for the development of the first Integrated Resource Plan (IRP) for Zambia's energy sector. The primary objective of the IRP is:

> "To develop a thirty-year (30) IRP for a sustainable electricity investment strategy for generation and transmission infrastructure that will ensure universal access to clean, reliable and affordable electricity at the lowest total environmental, social, economic and financial cost consistent with local, national and regional development goals. The IRP will also include implications arising from demand-side management (DSM) and pricing."[1]

The report is the first deliverable of the IRP project. It was prepared by the Ministry of Energy, with inputs and participation from the Energy Regulation Board and ZESCO, and facilitated through the technical assistance provided by the Cities and Infrastructure for Growth Zambia programme (CIGZambia).

The inception phase of the IRP project ran from January – March 2021, while the next phase will run for 12 months from April 2021 to March 2022, and will see the completion of the Final IRP Report.

Overall approach to the IRP

The Ministry of Energy will steer and coordinate the IRP project. IRP development will be a highly consultative and inclusive process, which will co-opt representatives from key stakeholders across the energy sector. Inclusion and active participation of key stakeholders throughout the project is critical to the success of the IRP development. Stakeholder participation in the Steering and Technical Committees that will guide the IRP project will ensure their stewardship, and high-level buy-in.

A strong emphasis on capacity building will be incorporated in all project activities, ensuring that stakeholder understanding and capabilities are built through active participation. This will ensure that capacity building is fully integrated in the work of developing the IRP and characterised by 'learning by doing' rather than based on one-off training events. The majority of the team working on the IRP will be national consultants and staff from key stakeholder organisations. This will ensure the long-term sustainability of the IRP.

Strong communications and stakeholder engagement will also be a key feature of the IRP project. A dedicated website has been developed and will shortly be launched – hosted on the Ministry of Energy's own website – to raise awareness and to share information, including relevant publications and reports.

While this report focuses on the main grid (i.e., grid connected demand and generation as well as required transmission and distribution infrastructure), reflecting the scope of the technical assistance being provided by CIGZambia, the IRP as a whole will also include off-grid sector development. This component is expected to be supported by other cooperating partners, most notably the World Bank, with which the project team will collaborate and coordinate closely to ensure a cohesive and comprehensive plan is developing embracing the full scope of the energy sector.

Key workstreams of the IRP

The report presents a situational assessment of the Zambia's energy sector pertaining to each workstream, followed by a proposed approach to develop the IRP and summary of key activities per deliverables.

[1] 2019 IRP Terms of reference. See Annex 1: Terms of Reference for the IRP Project

The five main technical workstreams presented are:

1. Demand Assessment and Forecasting
2. Generation Resource Assessment and Planning
3. Transmission Infrastructure Planning
4. Distribution Infrastructure Planning
5. Power Procurement, Financial Mobilisation, and Market Structure

Supporting and mainstreamed across the above are five cross-cutting workstreams:

1. Climate Resilience
2. Environmental Impacts
3. Gender, Social Inclusion, and Safeguarding
4. Communications and Stakeholder Engagement
5. Monitoring, Evaluation & Learning

The cross-cutting workstreams will ensure the IRP is developed sustainably; responsive to broader climate, environmental, and societal considerations; consultative and communicates clearly; and achieves its intended objectives.

Impact

The capability of Zambia's energy sector to deliver electricity reliably and efficiently to the nation's businesses, institutions and households is critical to successful economic and social development and has a vital bearing on resilience to the threats emanating from climate change. The IRP will play a critical role in enabling the power sector to develop and grow to meet this challenge, and thereby in promoting the achievement of the country's local, national, and regional development goals.

1 INTRODUCTION

1.1 Background

This project is concerned with development of the first ever Integrated Resource Plan (IRP) for the Zambian electricity sector. The idea to develop this plan was mooted in 2019 when the initial Terms of Reference (ToR) (see Annex 1: Terms of Reference for the IRP Project) were developed with the support of World Wildlife Fund (WWF). Presently, infrastructure development in the electricity sector is guided by, and based on, the Power Systems Development Master Plan of 2010, which was developed by Chubu Electric Power Company of Japan, as well as the Rural Electrification Master Plan covering of 2008[2]. According to the 2019 ToR, the primary motivation for developing a 30-year IRP is as follows:

> "Over the past years, electricity resource planning focused on supply side projects only – i.e., construction of generation and transmission facilities without coupling them to demand side management options to increase the productivity with which electricity is used by consumers. In addition, the assessment of supply side options was limited to a few major technologies without considering technologies such as Nuclear, Solar and Wind…
>
> There is need to approach electricity resource planning in a holistic, integrated manner that considers a full range of feasible supply side and demand side options. Therefore, it has become imperative to develop an Integrated Resource Plan for Electricity in Zambia."[3]

The development of the 2019 ToR involved key stakeholders, including the Ministry of Energy (MoE), ZESCO and the Energy Regulation Board (ERB). The primary objectives of the IRP were stated as follows:

> "To develop a thirty-year (30) IRP for a sustainable electricity investment strategy for generation and transmission infrastructure that will ensure universal access to clean, reliable and affordable electricity at the lowest total environmental, social, economic and financial cost consistent with local, national and regional development goals. The IRP will also include implications arising from demand-side management (DSM) and pricing."[4]

It is important to note that the development of this IRP is well-aligned and critical to the realisation of the Government of Zambia's (GRZ) national goals. Zambia's Vision 2030 is to become:

> "A Prosperous Middle-Income Nation by 2030... By 2030, Zambians, aspire to live in a strong and dynamic middle-income industrial nation that provides opportunities for improving the wellbeing of all, embodying values of socioeconomic justice, underpinned by the principles of: (i) gender responsive sustainable development; (ii) democracy; (iii) respect for human rights; (iv) good traditional and family values; (v) positive attitude towards work; (vi) peaceful coexistence and; (vii) private-public partnerships"[5].

The development of a resilient and sustainable electricity supply system that enables access for all is a necessary precognition to achieving Zambia's Vision 2030. Indeed, one of the aims of the 7th National

[2] Both plans were funded by the Japan International Cooperation Agency (JICA).
[3] See Annex 1 – 2019 IRP ToR
[4] Ibid.
[5] Ministry of National Development Planning (December 2006): Vision 2030, p.6, https://www.mndp.gov.zm/wp-content/uploads/filebase/vision_2030/Vision-2030.pdf

Development Plan (7NDP), which operationalises the Vision 2030, is to: "improve energy production and distribution for sustainable development."[6]

Since the ToR for IRP were first developed in 2019, there have been notable major developments, such as Zambia's National Energy Policy and, crucially, the enactment of the Electricity Act, 2019, and Energy Regulation Act, 2019 (see more in Section 2.1), which have paved the way for open access to the Zambian grid, thus enabling bilateral contracts between willing sellers and buyers using the national transmission and distribution networks.

The main drivers for the development of the IRP are discussed below.

1.1.1 Main drivers of the IRP

The energy sector globally is in a state of transition and Zambia is no exception. There are many developments that a forcing change driven largely by the realisation that climate change has been caused primarily by the use of fossil fuels for electricity generation. There is consensus amongst the majority of the scientific community and the world's governments that climate change poses an existential threat to humanity and every nation must play its role to stem further global warming beyond the tipping point of 1.5 degrees Celsius. This matter has had the attention of the world community who have been meeting annually for the last two and half decades under COP (Conference of the Parties) series. The next is COP26 which will be held in Glasgow later this year. While Zambia's contribution to CO2 emissions is very low in common with most African countries, there are climate related drivers that are creating an imperative to review the structure of the energy sector in Zambia to ensure climate resilience of the sector, through for example diversification of energy sources.

The primary drivers for developing an IRP can be further elaborated as follows:

- Ensuring **energy security** through the diversification of energy sources by exploiting potential resources (hydro, coal, geothermal, solar and wind).
- The **emergence of new technologies**, particularly the rise in the adoption of wind and solar PV (both distributed and large scale) as viable energy sources whose prices continue to fall and "increasingly beat even the cheapest coal competitors on cost"[7].
- The need to **attract greater investment** into the energy sector, which will further require the development of a robust and transparent framework for energy procurement and market operation.
- Ensuring **cost reflective tariffs,** while at the same time providing affordable tariffs for vulnerable segments of the Zambian society.
- Ensuring the energy sector is developed in a way that is compatible with **national climate commitments** and contributes to **decarbonisation**.
- The need to account for the **evolution of fuel prices** (local and international) and **changes in electricity demand,** requiring the review of existing national energy plans, including the 2010 Power System Development Master Plan and the 2008 Rural Electrification Master Plan.

Legislation of the Electricity Act, 2019, and Energy Regulation Act, 2019 has already laid the necessary groundwork for the transformation of the energy sector. These new Acts enable open access to the

[6] Ministry of National Development Planning (2017), 7 National Development Plan 2017 – 2021, p.72, https://www.mndp.gov.zm/wp-content/uploads/2018/05/7NDP.pdf

[7] Renewables Increasingly Beat Even Cheapest Coal Competitors on Cost, IRENA, 02 June 2020 https://www.irena.org/newsroom/pressreleases/2020/Jun/Renewables-Increasingly-Beat-Even-Cheapest-Coal-Competitors-on-Cost

grid[8]. As this is the first IRP being developed for Zambia, it will also provide a road map for the implementation of the IRP. It will thus be necessary to ensure that the IRP is reflective of these recent changes in the regulatory landscape, including the forthcoming Least Cost Electrification Plan, National Electrification Strategy, and Cost of Service Study.

1.2 Scope and Assumptions

The **scope** of the IRP can be summarised as follows:

- The IRP will address both grid and off-grid sectors. CIGZambia will focus on providing technical assistance on grid connected generation and demand. It is expected that the off-grid sector will be funded by other cooperating partners, some of whom have already signalled interest to support the IRP development. The form of support and modality of working together will be clarified following this inception phase.
- It will have a planning horizon of 30 years, starting in 2022.
- It will include climate and environmental impacts as well as mainstream gender and social inclusion considerations. It will further explore ways of to enhance local participation in the energy sector.
- Major technological developments, such as smart grids and distributed generation (e.g., roof top solar PV and local storage, solar water heating, electrification of transport, etc.) will be taken into account in the development of the IRP scenarios.

The main **assumptions** for this IRP include the following:

- Open access of the Zambia electricity grid will take full effect.
- The necessary market structure will be developed and implemented to enable open access and development of an ancillary services market.
- The Zambia Grid Code and Distribution Grid Code will be revised to provide requirements for connection of asynchronous generation.

1.3 Aims and Objectives

The objective of this project is to implement a robust energy planning system and develop a 30-year IRP that will address the constraints in Zambia's energy sector and include a sustainable electricity investment strategy for generation, transmission, and distribution infrastructure. The IRP will also include implications arising from tariff demand-side management (DSM), Energy Efficiency (EE) programmes, technology developments, and energy pricing. This will result in an energy sector that provides a high quality, clean, reliable, and affordable level of service to its customers (commercial and non-commercial), and is climate resilient, financially stable, and responsive to the needs of all members of society as customers, employees, and stakeholders.

Some of the specific objectives of the IRP include to:

- Provide a plan that will enable effective decision-making in the diversification and increase of energy security, in line with GRZ national policies, including the 7NDP;
- Provide a structure for ensuring the sustainable use of national resources with careful consideration of the environment and climate resilience as well as minimise the effect on the environment and society;

[8] The Acts have already been operationalised through Statutory Instrument no. 15 of 2020 (for the Electricity Act) and Statutory Instrument no. 16 of 2020 (for the Energy Regulation Act), both dated 6 February 2020. What may be required are Open Access Regulations to provide detailed rules and guidelines.

- Provide a framework that will enable meeting policy targets, such as those relating to the affordability of electricity or wider integration of renewables;
- Provide a framework that will enable meeting Zambia's climate commitments, including decarbonisation targets and Nationally Determined Contributions (NDCs);
- Provide a reference plan for effectively decreasing electricity tariffs by considering regional trade options, while ensuring supply security criteria are met;
- Consider climate change mitigation options to limit the environmental impact as a result of the power sector's expansion;
- Wider deployment of DSM to match electricity supply and demand patterns; and
- Provide local employment benefits and drive innovation in the power sector.

Critically, the IRP is a wide-based long-term holistic planning process that will mainstream gender and social inclusion as well as climate and environment factors into plans and strategies that will determine the impacts and choices of all Zambian residents with respect to energy use in future decades. The IRP consultation process will ensure that marginalised groups – including women and people living with disabilities – are involved in consultative processes with regards to access to energy, and in turn create opportunities for these groups to take part in economic activities improving their standards of living.

The overall intended aim is that all power consumers, including currently unserved communities, will benefit from access to reliable, cost-competitive power supplies. These will be delivered by power suppliers operating with sustainable business models, supported by a balanced regulatory framework that protects both consumers and investors, and that takes appropriate account of social and climate priorities. The targets for access to electricity in Zambia are reflected in the 7NDP to "improve energy production and distribution for sustainable development"[9] and in Sustainable Development Goal 7 (SDG7), which aims to "ensure access to affordable, reliable, sustainable and modern energy for all"[10].

The project outputs, outcomes and impacts are presented in the Theory of Change in Section 6.2.

1.3.1 Project deliverables

The core deliverables (and associated timelines) expected to be produced by this IRP project are shown in the table below:

Table 1: Key project deliverables

ID	Deliverable	Details	Estimated timelines
Phase 1 – Inception phase (December 2020 – March 2021)			
D1	Inception Report	*As detailed in this Inception Report*	31st March 2021
Phase 2 – Implementation phase (April 2021 – March 2022)			
D2	Consolidated IRP Implementation Report	With various component Reports covering: • Component 1: Least Cost Generation Options including Resource Assessment • Component 2: Transmission and Regional Connectivity Report • Component 3: Demand Report • Component 4: Distribution, DSM and EE Report	30th September 2021

[9] Ministry of National Development Planning (2017), 7 National Development Plan 2017 – 2021, p.72, https://www.mndp.gov.zm/wp-content/uploads/2018/05/7NDP.pdf

[10] https://sdgs.un.org/goals/goal7

		• Component 5: Climate and G&I Report • Components 6-8: Financial Sustainability and Sources Report; Market Structures and Regulation Report; Power Procurement Report	
D3	Scenario Analysis Report	Results of models of various scenarios (using Multi-Criteria Assessment) for future generation, transmission and distribution investments matching supply with demand and appropriate reserve margins, considering imports/exports, extent of investment required, impact on energy access (amongst other factors), and cross-cutting factors (gender and inclusion, and climate)	15th December 2021
D4	Draft IRP Report	First draft of final IRP Report	15th February 2022
D5	Final IRP Report and Implementation Plan	Final report issued with implementation plan to support recommendations	31st March 2022
D6	Completion Report	The report will document the transfer of skills, systems and capacity to MoE. Specifically, the Completion Report will include records of systems, models, regulations, policies, capacity building undertaken, and procedures required to take the IRP planning process forward	31st March 2022

1.4 IRP Project Team Structure

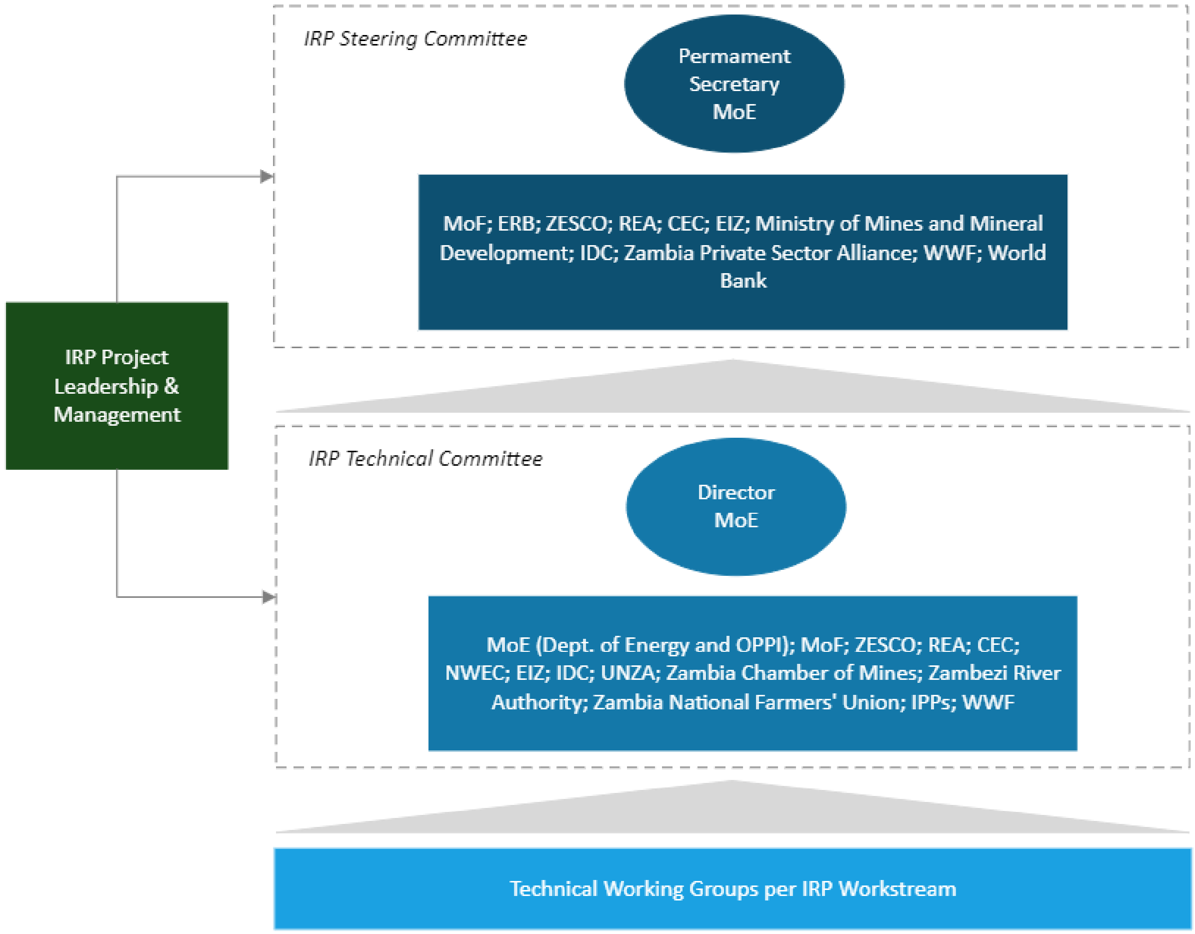
The IRP project will be governed by Steering and Technical Committees comprised of the key stakeholders of the energy sector, who will meet on a quarterly basis.

The Steering Committee shall be in charge of the overall governing of the IRP development process, while the Technical Committee shall ensure the delivery of the IRP project is to a high technical standard. Monthly Technical Working Groups will oversee the technical work per IRP workstreams, and will report into the Technical Committee.

The figure below outlines the proposed Governance Committees of the IRP[11].

[11] Please note that the finalised Terms of Reference for the Technical and the Steering Committees will be sent to the Governance Committee members.

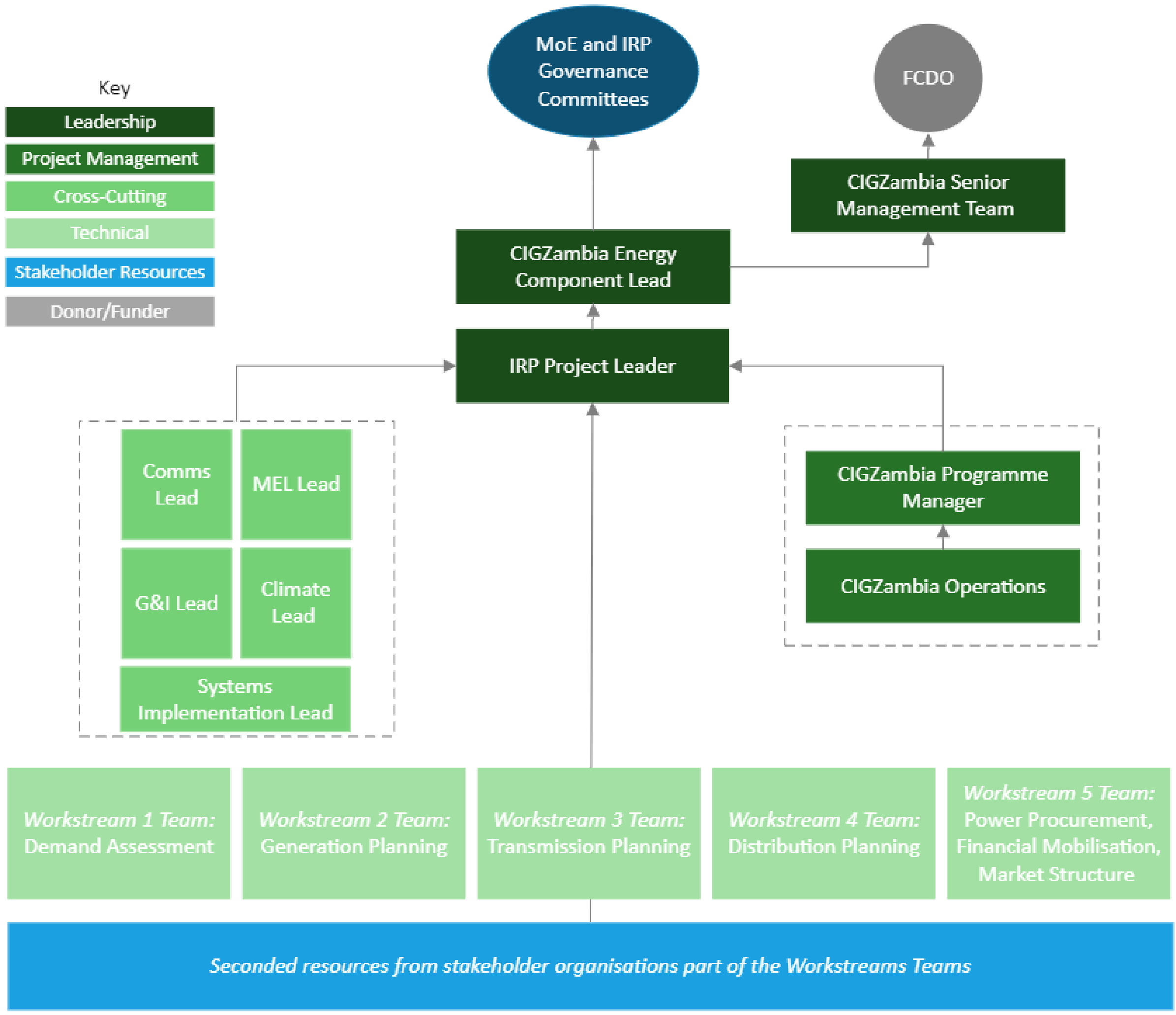
Figure 1: Governance structure of the IRP project



Structure of CIGZambia's support to the IRP project

The figure below shows more specifically the structure of CIGZambia's technical assistance to the IRP project, which includes resources from key stakeholder organisations (including, but not limited to, the MoE, ZESCO, and the ERB) who will work on the various project workstreams.

Figure 2: Structure of CIGZambia technical assistance to the IRP project



1.5 Outline of the Report

Following Section 1, which introduces and sets the context for the IRP project, this inception report is outlined as follows:

- Section 2 presents the governance and stakeholders of the energy sector;
- Section 3 outlines the overall approach taken in the IRP;
- Section 4 details the core workstreams of the IRP;
- Section 5 discusses cross-cutting issues pertinent to the IRP, such as climate resilience, the environment, gender and social inclusion, safeguarding, and communications;
- Section 6 examines the monitoring, evaluation, and learning plan for the IRP; and
- Section 7 concludes the inception report.

Note that a series of Annexes are also appended to the report, including the IRP project workplan (see Annex 2: High-Level Implementation Workplan).

2 Governance and Stakeholders of the Energy Sector

2.1 Institutional Framework

According to Gazette Notice No. 6526 of 2016, the MoE is responsible for the development and management of the energy sector. However, several Government Ministries also play a major role in the sector, as follows:

1. *Ministry of Finance* is responsible for mobilisation and allocation of financial resources for energy projects;
2. *Ministries of Water Development, Sanitation and Environmental Protection, Lands and Natural Resources* are responsible for allocation of water permits for hydropower and environmental impact assessments, provision of land rights for energy projects, wood fuel regulations and development of policies to ensure that climate change is mainstreamed in energy programmes;
3. *Ministry of Local Government* is responsible for the management of waste;
4. *Ministry of Mines and Mineral Development* is responsible for the exploration and extraction of hydrocarbons and geothermal energy;
5. *Ministry of Agriculture* is responsible for crop production which is used for biofuels and bioenergy;
6. *Ministry of Transport and Communication* is responsible for providing Metrological data which is used in the development of energy projects especially wind and solar projects. In addition, the Ministry also regulates the transportation of petroleum products and energy equipment;
7. *Ministry of Higher Education* is responsible for scientific research;
8. *Ministry of Commerce, Trade and Industry* is responsible for facilitating investment and incentives through the Zambia Development Agency and standards setting; and
9. *Ministry of Housing and Infrastructure Development* is responsible for building codes and the construction of energy infrastructure such as fuel depots and oil pipelines.

The Energy sector comprises both public and private actors. The MoE supervises the following statutory bodies: ERB, Zambezi River Authority, and Rural Electrification Authority (REA). The Ministry also provides guidance to the following state-owned enterprises: Indeni Petroleum Refinery Company Limited; Tanzania Zambia Mafuta pipelines Limited (TAZAMA); and ZESCO. Of these, Indeni and ZESCO fall under the Industrial Development Corporation (IDC), a share-holding arm of the Government. This arrangement has resulted in overlapping mandates between the MoE and IDC in supervision of Indeni and ZESCO. Apart from this supervisory role, the MoE coordinates all other actors in the sector.

2.1.1 Office for Promoting Private Power Investment

The Office for Promoting Private Power Investment (OPPPI) was established by the Government in 1998 under the MoE to promote private sector participation in the development of power. Its mandate is to coordinate the development and implementation of projects undertaken by the private sector[12].

[12] Under the leadership of the MoE, OPPPI coordinated the implementation agreements of projects, including the 300 MW Maamba Coal Fired Power Plant, 120 MW Itezhi-Tezhi Hydroelectric Power plant, 750 MW Kafue Gorge Lower Hydroelectric Power Project and the Zambia-Tanzania-Kenya Power Interconnector Project. Currently, OPPPI is coordinating feasibility studies for a combined capacity in excess of 2000 MW, with some of the projects currently at the stage of Power Purchase Agreement negotiations. (Source: Ministry of Energy (2019): National Energy Policy 2019, https://www.moe.gov.zm/?wpfb_dl=51)

2.1.2 Energy Regulation Board

The ERB was established through the Energy Regulation Act CAP 436 of the Laws of Zambia as amended in 2003, and subsequently repealed and replaced by the Energy Regulation Act No.12 of 2019. The ERB's mandate is to regulate the energy sector through: issuance of licenses to undertakings; monitoring the efficiency and performance of undertakings; receiving and investigating complaints; approval of location and construction of energy infrastructure; price adjustments of energy services and products; and development of standards codes, guidelines and other regulatory interventions.

The ERB licensing functions significantly depend on prior regulatory approvals from other statutory bodies and agencies, such as Water Resource Management Authority (WARMA), National Heritage Conservation Commission (NHCC), Zambia Environmental Management Agency (ZEMA), Zambia Development Agency (ZDA) and Department of Lands. Steps have been taken by MoE and ERB to improve coordination between these agencies with a view to streamlining the project development process.

2.1.3 ZESCO

ZESCO is a vertically integrated power utility and is responsible for generation, transmission, distribution, and supply of electricity. The company is the dominant participant in the electricity market in Zambia. Its current own generation capacity is in excess of 2,250 MW, with a further 750 MW expected to be commissioned during 2021, and it has a customer base of around 1 million consumers.

ZESCO has entered into power purchase agreements with several Independent Power Producers (IPPs) over recent years. However, the recently passed legislation (see following section) permits open access for the Zambian power network, and the Government is in the process of developing a framework of use of system and ancillary services charges that will support bi-lateral contracts between buyers and sellers who wish to use ZESCO's network.

2.2 Supporting Legislation

The energy sector is currently governed by four major statutes, namely:

1. the Energy Regulation Act No. 12 of 2019;
2. the Electricity Act No. 11 of 2019;
3. the Petroleum Act Cap.435; and
4. the Rural Electrification Act No. 20 of 2003.

The Energy Regulation Act has established the ERB as a body corporate, whose primary role is to license enterprises in the energy sector. The Electricity Act provides for the regulation of generation, transmission, distribution and supply of electricity.

Prior to the legislation passed in 2019, the legal framework for the energy sector was considered to have inherent deficiencies, including:

- there was no provision for a multi-year tariff regime, which can provide a cost reflective and yet predictable and consistent tariff framework to provide certainty and attract investment into the sector; and
- ERB was not expressly mandated to set, determine, approve and review non-retail tariffs, including tariffs in Power Supply Agreements with large customers.

Therefore, new legislation was passed, namely the Electricity Act No. 11 of 2019 and the Energy Regulation Act No. 12 of 2019, which are considered to have enhanced Government's oversight of the sector and have provided explicit mandate to ERB to regulate tariffs, and more clearly defined tariff determination principles, creating provision for multi-year tariff arrangements and providing for open access to transmission and distribution networks to enable large users to contract directly with IPPs.

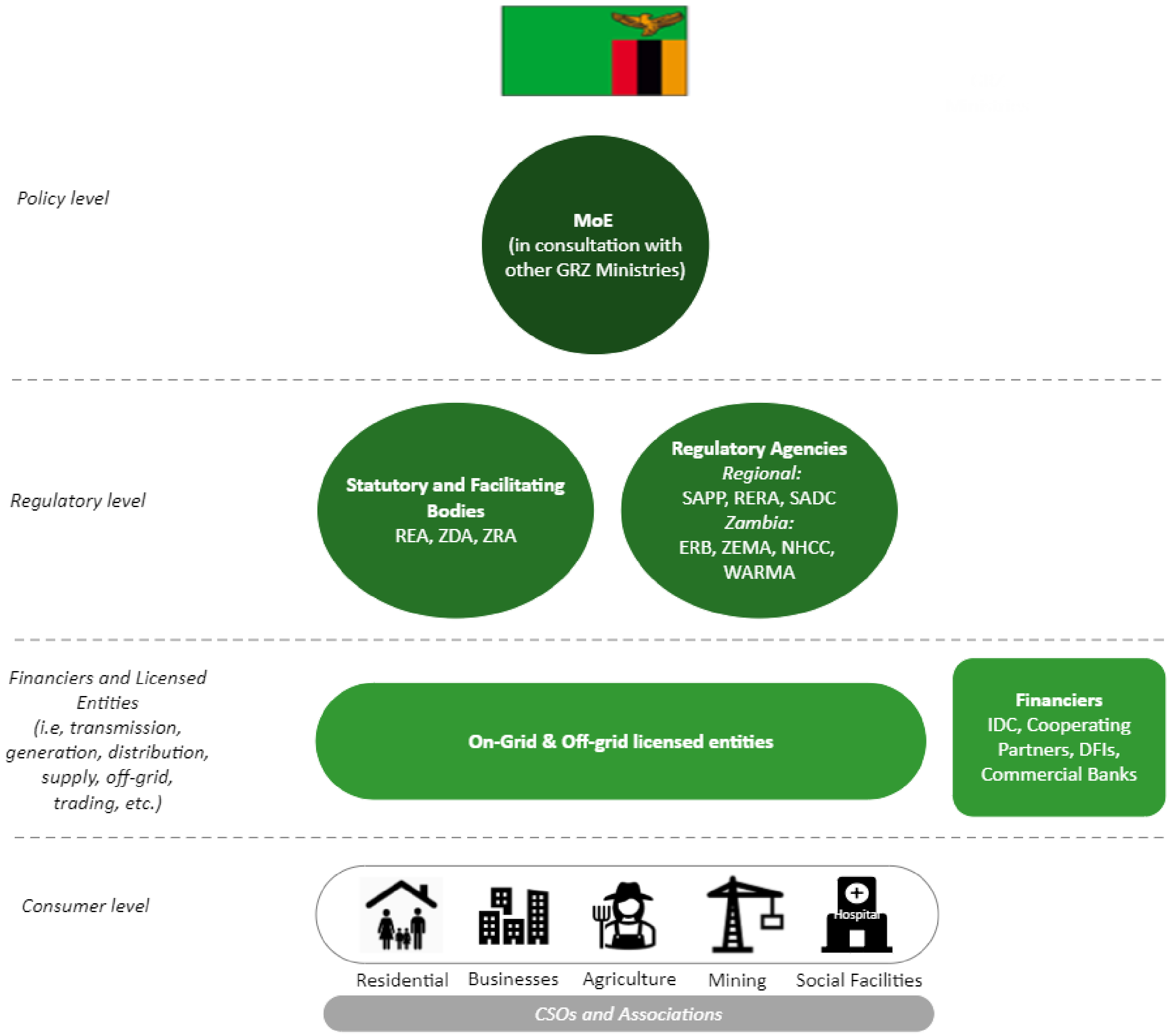
2.3 Interrelationships of Energy Sector Stakeholders

The success of the IRP is dependent upon creating alignment between key stakeholders in the sector starting at policy level, feeding through to regulators, facilitating agencies, licensed operators and financiers, and ultimately providing enhanced planning and transparency and decision-making in for the sector to meet the needs of power consumers over the long-term.

It is important to give appropriate weighting both to Zambia's cities, mines and industries, and to rural and unelectrified areas in which the level of service is currently inadequate. The IRP will align planning across all segments of the power delivery value chain, and seek to prioritise investments and interventions that are in the best interests of the country in line with the existing and future national development plans.

A high-level stakeholder diagram showing the interrelationships from policy formulation all the way to the consumers is shown in Figure 3 below.

Figure 3: Interrelationships of energy sector stakeholders



2.4 IRP Governance Principles

Figure 4 below shows a framework for *good governance*, adapted from the Guiding Principles of the GRZ's 2016 amended Constitution[13].

This framework has been adopted as the IRP Governance Framework, and will be used to guide the deliberations of the teams undertaking the various workstreams, as well as the IRP Steering and Technical Committees referenced in Section 1.4.

Throughout the IRP development process, the framework will further be used to guide the Scenario Analysis, and the process of creating transparency and seeking consensus around the recommendations of the IRP.

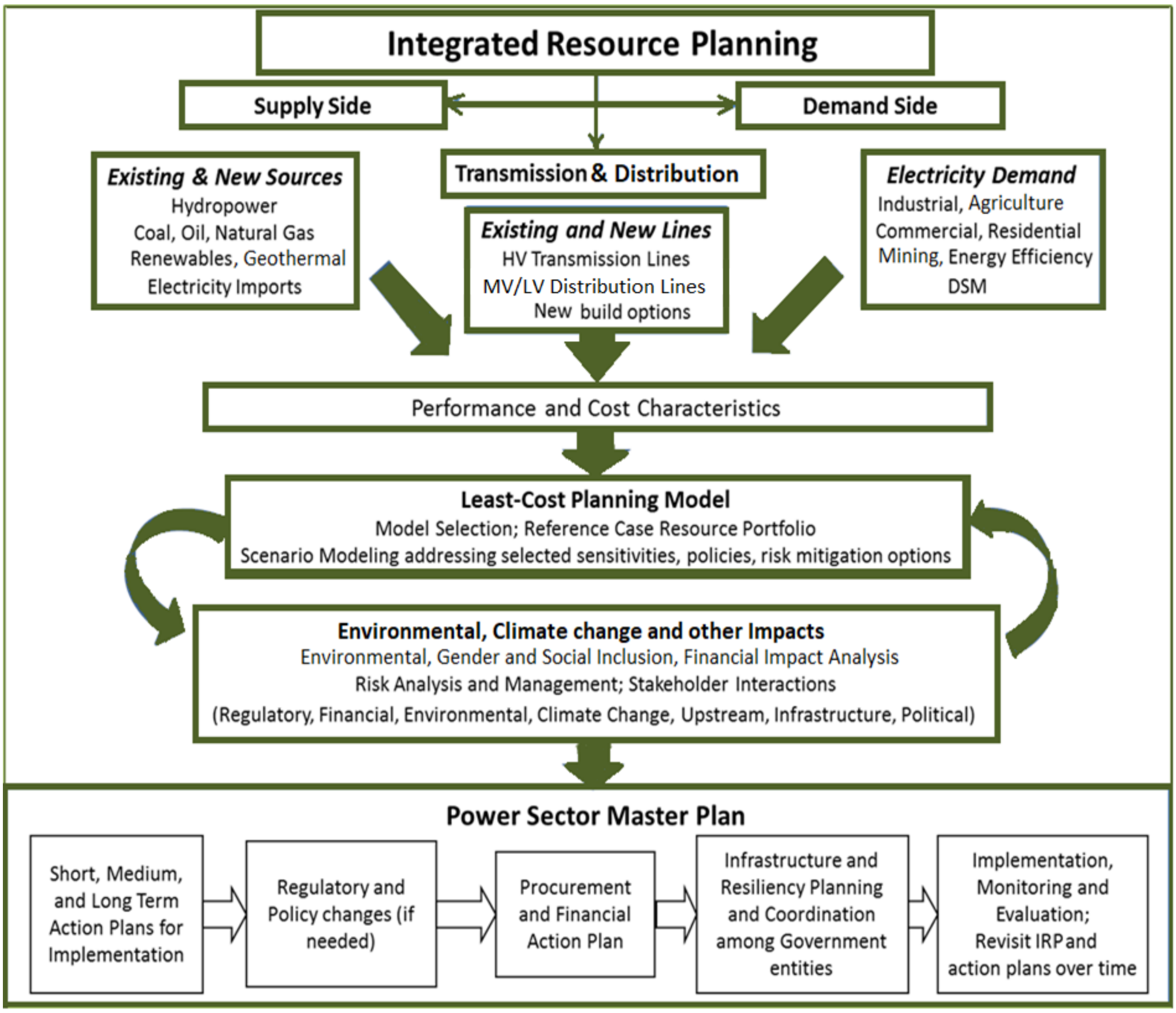
Figure 4: Good governance framework[14]

[13] Ministry of Energy (2019), National Energy Policy 2019, https://www.moe.gov.zm/?wpfb_dl=51

3 Overall Approach

A general framework for the **on-grid integrated energy planning**, with consideration of environmental, climate-change, and gender and inclusion impacts, is shown in the figure below. Note that a general framework that includes **off-grid** will be developed in consultation with the project teams working on this component.

Figure 5: Generalised on-grid framework for Integrated Resource Planning



3.1 Scenario Development

Energy scenarios are a popular tool for exploring possible future developments or states of energy systems.

Scenarios have a long history in business and politics as well as other areas, as a tool for strategic planning to inform consensus-based decision making in the face of uncertain futures. In recent years, there has been a growth in use of scenarios for assessing the implications of low carbon futures, for example in the UK.

A review will be undertaken of the methodologies commonly applied in scenario development with the view to selecting a suitable methodology for application in the development of the Zambian IRP.

In developing the scenarios for this IRP, demographics and human behaviour will be fully considered alongside technological changes. In addition, development of the energy pathways will consider environmental impacts to ensure that they are achievable, given that all projects of significance are required by law to secure express clearance by ZEMA. It will also be very important to ensure transparency in the assumptions underlying energy scenario modelling for this IRP. This will be achieved through the inclusive and consultative approach that is central to the development of this IRP.

The scenarios will include the following:

1. **Base case** – The assumptions on which the base case will be based will be clearly specified.
2. **High/Low demand case** – Least cost expansion option subject to the high/low scenario of the demand forecast.
3. **High renewables / Nationally Determined Contributions (NDC) case** – This scenario will assume a higher proportion of renewables and/or energy efficiency and demand side management measures to meet the Zambia's NDC commitments.
4. **Emissions reduction case** – A more extreme variant of the previous scenario with significantly reduce or even eliminate emissions from the electricity sector. This might include assumptions on emissions caps and incorporate national climate commitments (e.g., Zambia's NDC).
5. **Self-sufficiency case** – Require local generation to supplant imported energy or reliance on imported capacity (or some reduced proportion of imports).
6. **Wholesale market case** – Analysis of the changes to the national utility's generation investment sequence as the national electricity market is increasing opened up to competition.

The final scenarios will be reviewed for coherence and internal consistency.

3.1.1 Sensitivity Analysis

There are many variables that the IRP analysis will be sensitive to. While the core IRP scenarios will be designed to explore broad policy pathways, as described above, the sensitivity analysis will test the impact of changing individual input assumptions, such as demand. The table below highlights some of the input levers that the sensitivity analysis could consider. This analysis will provide insights on how resilient different IRP pathways are to alternative sets of assumptions. The choice of specific operational, financial or policy measures will be discussed with the Zambian authorities and stakeholders before undertaking the sensitivity analysis. Indeed, the sensitivity analysis will not explore all of the variables listed in the table; rather, we will agree to a number (e.g., 3-5) of key variables that we want to test for.

This will be based on specific risk factors that will be identified in defining the scenarios, which warrant additional analysis. Where the need for sensitivity testing is identified, these additional analyses will normally be modelled deterministically. However, depending on the risk factors being modelled, it might be appropriate to consider alternative approaches, such as probabilistic / stochastic approaches. The 'Least-Worst Regret' approach will be applied in project selection and ranking in the event of multiple solutions from the sensitive analysis results.

The IRP is envisaged to provide a long-term generation expansion plan with associated transmission infrastructure, which would identify the year-wise total capacity by technology-type (existing and new additions) to meet the demand projections at the lowest cost. The primary decision variable would thus be the total generation capacity (in MW) comprising of new and existing plants covering large hydro with reservoir, run-of-river, mini- and micro-hydro, thermal generators, nuclear, solar PV, wind technologies. Capital and operating costs, as well as emission level associated with generation operations, would be duly incorporated in the IRP. Based on the merit-order dispatch, it would also provide the unit commitment and plant dispatch under a number of operating and policy conditions.

Table 2: Illustrative list of sensitive variables

Sensitive operating variables	Financial incentives	Policy variables
• Quality of supply • Reliability and distribution upgrades • Off-grid networks and access • Water inflows/reservoir level • Liquid fuel and coal prices • Fuel availability • Renewable integration costs • Demand forecast and growth • Transmission pricing /availability • Technology cost and performance • Capital and O&M / financing costs	• Availability and cost of finance • Zambia concessional financing (IFI) • G-2-G access to long-term finance • Carbon finance • Financial incentives (construction – new, repowering, life extension) • Early retirement of ageing plants	• RE Portfolio Standards and targets • Emissions target (unit specific/average) • Expansion of access policy / target • Cap on coal-based plant, if any • Generation Performance Standards (e.g., heat rate, emissions, etc.) • Generation-mix diversification • National or regional targets

3.1.2 Risk and Resilience Assessment

The IRP will conduct a vulnerability assessment of Zambia's power system through the specification of climate-change events scenarios (drought or abnormal rainfall, urban flooding, temperature rise, etc). These scenarios would be defined in close consultation with the relevant Zambian authorities and the impacts would be measured in terms of electricity demand, supply and/or mitigation costs. The critical factors associated with Zambia's climate change scenarios that put power systems at risk will be identified, and risk-mitigation scenarios will be proposed.

The results of this assessment will be analysed to determine specific cost implications for various risks, which will be factored into the least cost expansion analysis. The results from the climate vulnerability analyses and the scenario outputs will be presented in a series of validation sessions to develop 'risk-managed' power sector development plan.

3.2 Inclusive Stakeholder Engagement

Although the IRP will be coordinated by MoE, the IRP development process will be highly consultative and will co-opt representatives from ZESCO, ERB, REA, private sector, institutions of higher education, cooperating partners, financiers, civil society organisations (CSOs) and non-government organisations (NGOs) to contribute to the different workstreams.

The active participation of key stakeholders throughout the project lifecycle is critical to the success of the IRP development. This approach will be guaranteed through, *inter alia:*

- The secondment of staff from the MoE, ZESCO and ERB to be part of the IRP project team and work across all workstreams to foster collaboration, buy-in, and ownership;
- The establishment of the IRP Steering and Technical Committees to guarantee ongoing senior-level commitment from key stakeholders;
- Making capacity building of the IRP's key stakeholders a core feature of all project activities – ensuring capacity building is not one-off events, but rather integrated into the modality of

technical assistance provided by the IRP project consultants (see Section 3.3 for the Capacity Development Approach and Plan); and

- Implementing an IRP Communications Strategy, underpinned by a carefully crafted Strategic Engagement Plan (see Section 5.4), to ensure the success of the IRP development process.

3.3 Capacity Development Approach and Plan

Capacity building is an important outcome of CIGZambia's technical assistance to MoE and other stakeholders that will be impacted by the IRP, including ZESCO, ERB, REA, and others. Indeed, capacity building activities will contribute to the long-term sustainability and institutionalisation of the IRP in Zambia's energy sector – hence to the success of the project itself.

3.3.1 On-the-job capacity building

The approach taken to the technical assistance being delivered for the IRP project is centred around capacity building. Capacity building is not just about one-off workshops and training sessions, but rather also about continuous, on-the-job training and mentorship being provided by the IRP project consultants to the key stakeholders.

As noted in Section 3.2, the IRP development process has been designed in an inclusive and consultative manner to ensure participation of key stakeholders throughout the workstreams' activities. In particular, the secondments of staff from various stakeholders (including, but not limited to the MoE, ZESCO, and ERB) to the IRP project's workstreams will foster close collaboration, buy-in, and – crucially – skills and knowledge transfer.

As such, the IRP project consultants will actively involve seconded staff in their workstreams and include them in, *inter alia:* data collection and analysis; provision of technical inputs under the relevant workstreams; undertaking model-runs and validating results; defining and reviewing scenarios in keeping with the Government's priorities and plans; and participating in meetings and working sessions with the Workstream Leads as well as the monthly Technical Working Groups.

3.3.2 Formal trainings

In terms of more traditional capacity building activities (e.g., formal trainings, workshops, etc.) for the various IRP workstreams, thematic training workshops are proposed.

In the context of long-term integrated resource planning, a number of tailor-made training workshops will be delivered during the implementation of IRP[15]. The choice of face-to-face and/or virtual setting will be dictated by the Covid-19 situation in Zambia.

These training workshops may, *inter alia,* cover the following:

- Demand forecast – initial base case demand projections and final projections for the IRP scenarios;
- Resource assessment and generation expansion planning and scenario analysis;
- Transmission network modelling and financial network modelling;
- Distribution systems development distributed solar PV, off-grid systems, and DSM; and
- Mainstreaming of gender and social inclusion, and climate resilience.

In addition, each workstream will end with training and handover workshops of the key tools before the February/March 2022.

The aforementioned training plan can be found outlined in the 'Summary of activities' tables in the each workstream section (Section 4) as well as in Annex 3: Capacity Building Workplan.

Based on previous experience, particularly from the CIGZambia *Scaled Renewable Energy* project with ZESCO, it is recommended that capacity building be done before the actual commencement of the scenario assessment where possible, so that staff from the key project stakeholders can be effectively

[15] Note that the exact number will be based on the budget available and may be funded by other donors/projects.

engaged in the work and complete most of the work themselves with supervision and support from the CIGZambia team. This has proven to be an effective way for ensuring knowledge transfer.

The content and objectives of the training workshops will be informed by a capacity needs-assessment to ascertain the capacity baseline and the gaps.

Note that several global institutions, notably the Pacific Northwest National Laboratory, International Atomic Energy Agency, International Renewable Energy Agency, and National Renewable Energy Laboratory, have substantial training material in the public domain, which may be used to tailor such training workshops.

4 TECHNICAL WORKSTREAMS

The section below details the technical workstreams of the IRP project. Note that a high-level project workplan is provided in Annex 2: High-Level Implementation Workplan. Cross-cutting workstreams, including climate resilience, the environment, gender and inclusion, safeguarding, and communications, are detailed in Section 5.

4.1 System Selection

4.1.1 Purpose and output

The development and implementation of the IRP will require appropriate tools to be used for simulation and modelling for the generation, transmission, and distribution expansion plans. For energy planning, the time horizon could span from short to long-term, as follows:

- Long-term generation expansion planning (typically spanning a period of 20-40 years);
- Geo-spatial planning for transmission (typically spanning a period of 5-20 years);
- Technical network studies (typically spanning up to 5 years); and
- Dispatch simulation (typically spanning a period of weeks to several years).

The DIgSilent PowerFactory software package is already in use by ZESCO for geo-spatial planning for transmission, dispatch simulation, and technical network studies.

Therefore, the main focus of the IRP system selection workstream is to identify a software that can be used primarily for the long-term generation expansion planning as part of the IRP, taking into account demand forecast as input data. The outputs of the IRP software will be used for more detailed transmission and distribution planning being used for geo-spatial planning for transmission, dispatch simulation and technical network studies.

There are hundreds of tools on the market that serve various purpose. Each of those tools have different strengths and weaknesses. There was thus a need to narrow down and assess the appropriate tools to determine the right tool for the IRP.

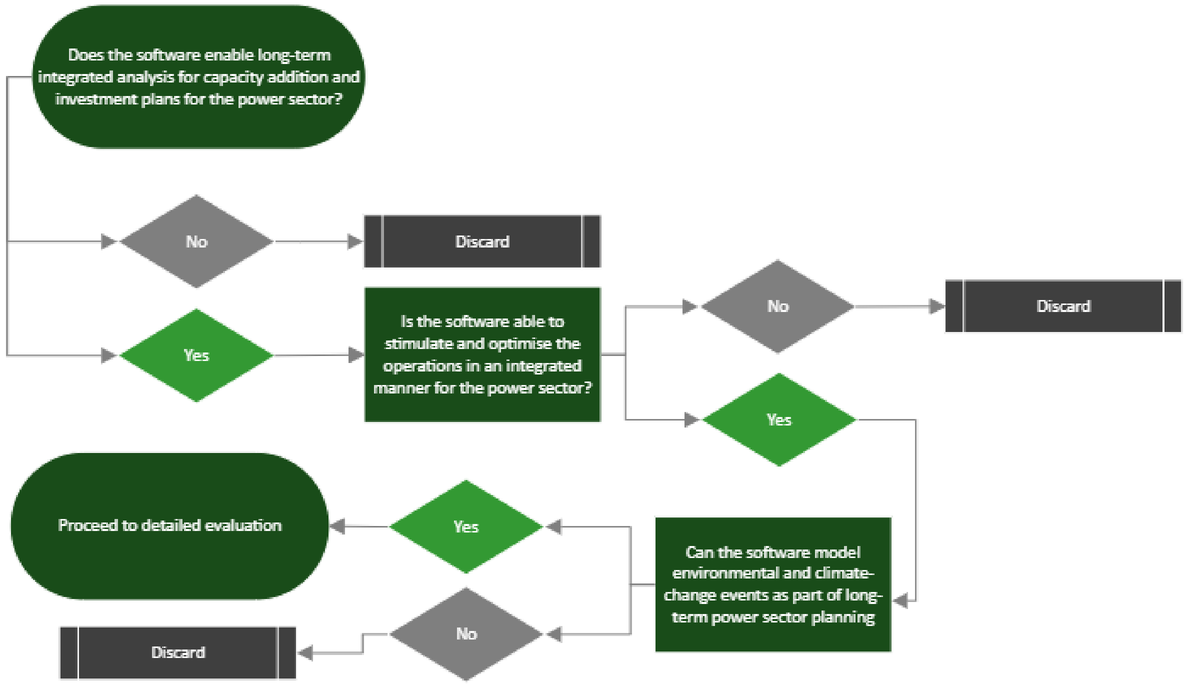
During the inception phase, the purpose of the system selection workstream was thus to assist in the selection of a software tool that will provide the usability as established by the main users of the software, best practices, and overall best 'fit for purpose' criteria. The output of this process is a software tool which provides the best functionality.

4.1.2 Approach and method to software selection

Development of the software selection tool

A two-stage process was used for the evaluation and selection of the IRP software. For the first-step assessment, a Pass/Fail criterion was used to decide which software could be considered relevant for detailed evaluation (see the figure below).

Figure 6: Pass/Fail for initial technical capabilities assessment of software



The second step involved a more detailed assessment of the software packages through a software selection tool that was developed by the IRP systems selection workstream team specifically for this purpose. In this evaluation, the cost, usability, compatibility, data input requirements and licensing requirements were considered among other criteria (see Annex 4: Software Selection Criteria and Results). As this selection tool was used one-time only to select the software, Microsoft Excel was used to build this tool, which is a good fit for this application as it is easy to set up and requires no cost.

The Excel software selection tool that was developed shows the evaluation criteria (Excel 'rows') by package or vendor (Excel 'columns'). There is one row for each evaluation criteria, which are grouped into categories ('outputs'). Each criterion was ranked by **importance** and **weight**, where:

- **Importance** = how important it is to have that feature.
- **Weight** = the relative importance of the feature.

The importance and weight were scored 1 through 5, where:

5 = critical
4 = important
3 = highly desirable
2 = nice to have
1 = not important

For each criterion, the software selection tool enables the drop-down selection of either 'yes' (if the software meets the requirement of the criterion) or 'no' (if the software does not meet the requirement of the criterion).

The software selection tool then automatically calculates a summary total value for each output as per the weights and importance for each criterion under the outputs and, ultimately, an overall score per software package. The highest score indicates which software package best fits the given requirements.

The picture below shows a section of the software selection tool from Excel, with one of the outputs ('Usability/Supportability/Compatibility'), the corresponding criteria and weights, and one of the software packages evaluated ('FINPLAN') with the associated total scores per output (i.e., '123') and overall (i.e., '270'). Note that the tool has a lot more outputs and software packages than shown below (see Annex 4: Software Selection Criteria and Results).

Figure 7: Sample screenshot of system software selection tool

Software / Outputs and Indicators	Importance 5=high 1=low	Weight 5=high 1=low	FINPLAN Model for Financial Analysis of Electric Sector Expansion Plans
Total Score			***270***
Usability / Supportability / Compatibility			***123***
Dashboards	2	2	Yes
Can integrate with existing s/w platforms	3	3	Yes
Can export to data warehouse	3	1	Yes
Can support 'x' number of concurrent users	2	2	Yes
Supportability	5	5	Yes
Online training	5	4	Yes
Online help	2	1	Yes
Support	4	2	Yes
Simulation	5	5	Yes
Operation optimisation	5	4	Yes
Investment optimisation	3	1	Yes

The scoring methodology employed ensured evaluation integrity and a common method to evaluate and score the software products. It was important to follow guidelines to ensure that:

- there is no ambiguity;
- each criterion is standalone and will be further refined if there are more than one criterion;
- each evaluation item contains only one theme; and
- there are no vague terms or wishful thinking, such as runs on all platforms or user friendly.

Key technical requirements for the selection of the software

The key requirements for the selection of the software models depends on the software to offer the following features:

a) *Ability to incorporate planning for long and short-term firm capacity (Generation adequacy):* The variability of Variable Renewable Energy Sources (VRE) makes the concept of 'capacity credit' – or the fraction of VRE capacity that is guaranteed to meet demand (known generally as 'firm capacity') – crucial to reflect in plans for the long-term expansion of electricity generation. This is essential if future power systems are to have sufficient supplies to cover periods when low amounts of VRE are available.

b) *Ability to enable planning for flexibility:*

As VRE generation increases and contributes to greater variability and uncertainly of supply, the flexibility of a system becomes more important. While smart planning of VRE deployment can limit the challenge of balancing supply and demand, high shares of VRE are likely to require more investment in flexibility measures to maintain balance at all times.

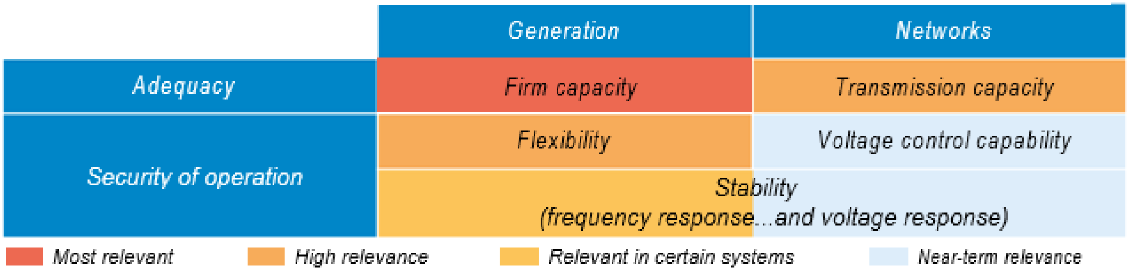
c) *Planning for transmission capacity:*
The availability of VRE resources depends on their location, and new capacity may need to be planned to transmit power from VRE resources that are far from centres of demand. Long-distance transmission lines also may need enhanced ways of controlling voltage.

d) *Planning for stability:*
Improved operational practices, and other technical solutions to maintain the capability to respond to contingency events and control voltage, should be available at relatively modest cost.

e) *Ability to quantify the minimisation of system costs in the generation, transmission, and distribution of electricity to the intended customers:*
Cost minimisation should also include the cost of operations and maintenance.

The summary guidelines to the selection of the software are outlined in the figure below.

Figure 8: Guidelines for software selection



Source: IRENA Planning for the Renewable future

Intended outcomes of the selected software

The software to be selected should be able to answer the following questions:

Table 3: Outcomes of the selected software

Feature considerations	Questions to be answered by the model
Data and Resource Assessment	• Available water for power generation • Available wind and solar sources • Cost of served and unserved energy consumption • Available fuel for thermal power generation • Available raw materials for nuclear power generation
Generation investment portfolio	• Current installed capacity of Zambia • Short to long term expansion capacity plan • Expected generation mix • Firm capacity requirements and generation adequacy • Need for grid extension investments • Impacts on system emissions, e.g., GHG emissions. • Impact on the existing energy policies and cost reduction for operations and maintenance
System operation requirements	• Least cost operation plan • Extent and impact of system reliability and flexibility • Impact on the decommissioned plants and cost implications • System requirements after loss of major load, e.g., loss of mining loads • Impact on system performance due to sudden weather change, climate change and droughts • Impact on huge penetration of VRES • Ability of the system and major power plants to safe island after a major load loss • Environmental requirements for safe disposal of waste and decommissioned plants

Approach and key inception phase steps

In addition to creating the software selection tool in Excel, the IRP Systems Selection team took and completed the key steps listed below during the inception phase. Note that the approach and method to the software selection was iterative, and not necessarily always sequential as listed hereunder. The approach taken was consultative in nature.

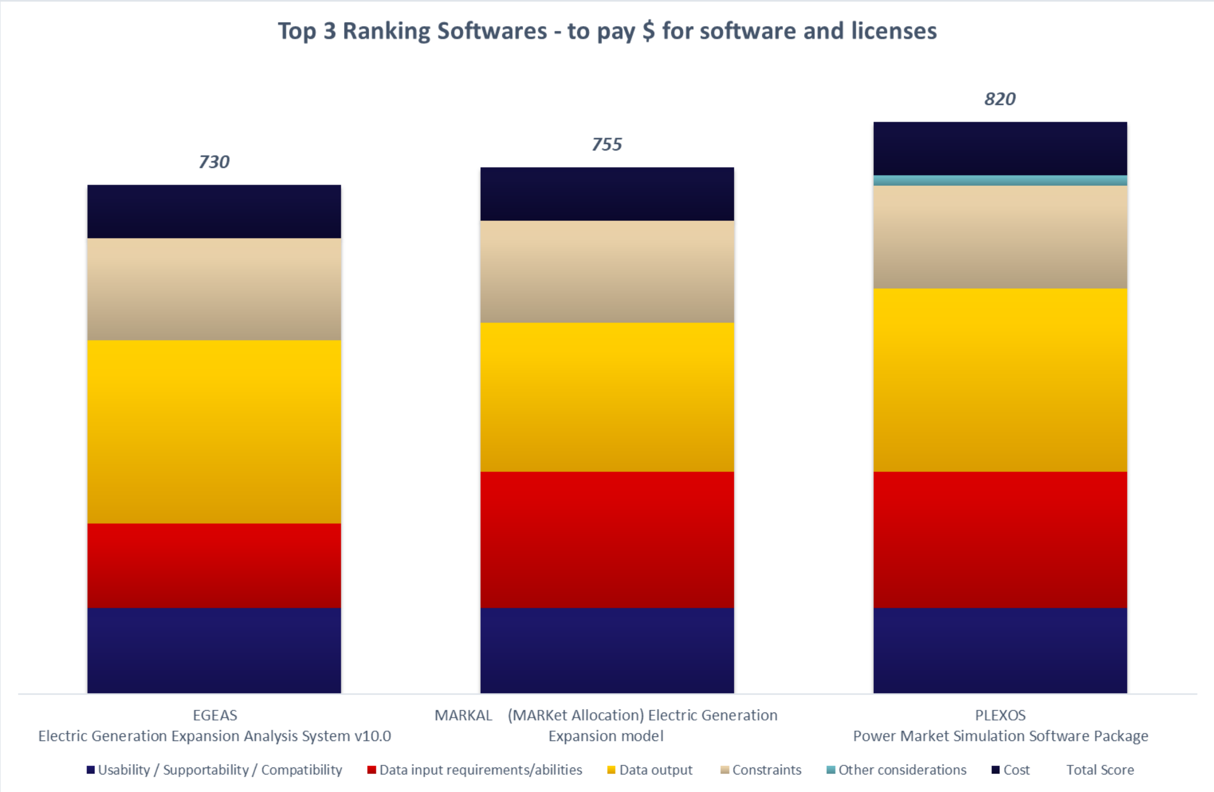
1. Reviewed industry best practices, to define the requirements of the software and initial criteria list. This included investigating available software packages and including them in the software tool.
2. Reviewed other similar initiatives (including in Malawi, Ghana, South Africa, and USA); and integrated the information gathered into the software selection tool.
3. Met with the end-users and subject matter experts who had used software of this nature through a series of workshops:
    - The end users included: Technical and IT teams within MoE and ZESCO, as well as IRP project technical consultants.
    - There were a total of 6 workshops held.
    - The objectives of the workshops were to: establish and agree on the criteria, including importance/weight; further understand and refine user requirements; solicit feedback on the software packages.
4. Inputted the data gathered from the workshops into the software selection tool and ranked the software packages.
5. The top three software packages that are *free* and the top three software packages that have *costs associated to them* were further assessed with end-users against initial costs (if applicable), total cost of ownership, and maintainability as well as to ensure that the top software packages met the intended requirements. A total of 6 software packages were thus evaluated at this stage. The decision to evaluate software packages that are free and that are not-for-free was taken to guarantee a suitable comparator in the final evaluation.
6. The highest scoring software package(s) was selected for trials before procurement.

A total of 15 software packages were identified and ranked (see Annex 4: Software Selection Criteria and Results for more information).

4.1.3 Software selection recommendation

The figures below show the top three ranking software packages that are *not-for-free*, as well as the top three ranking software packages that are for *free.*

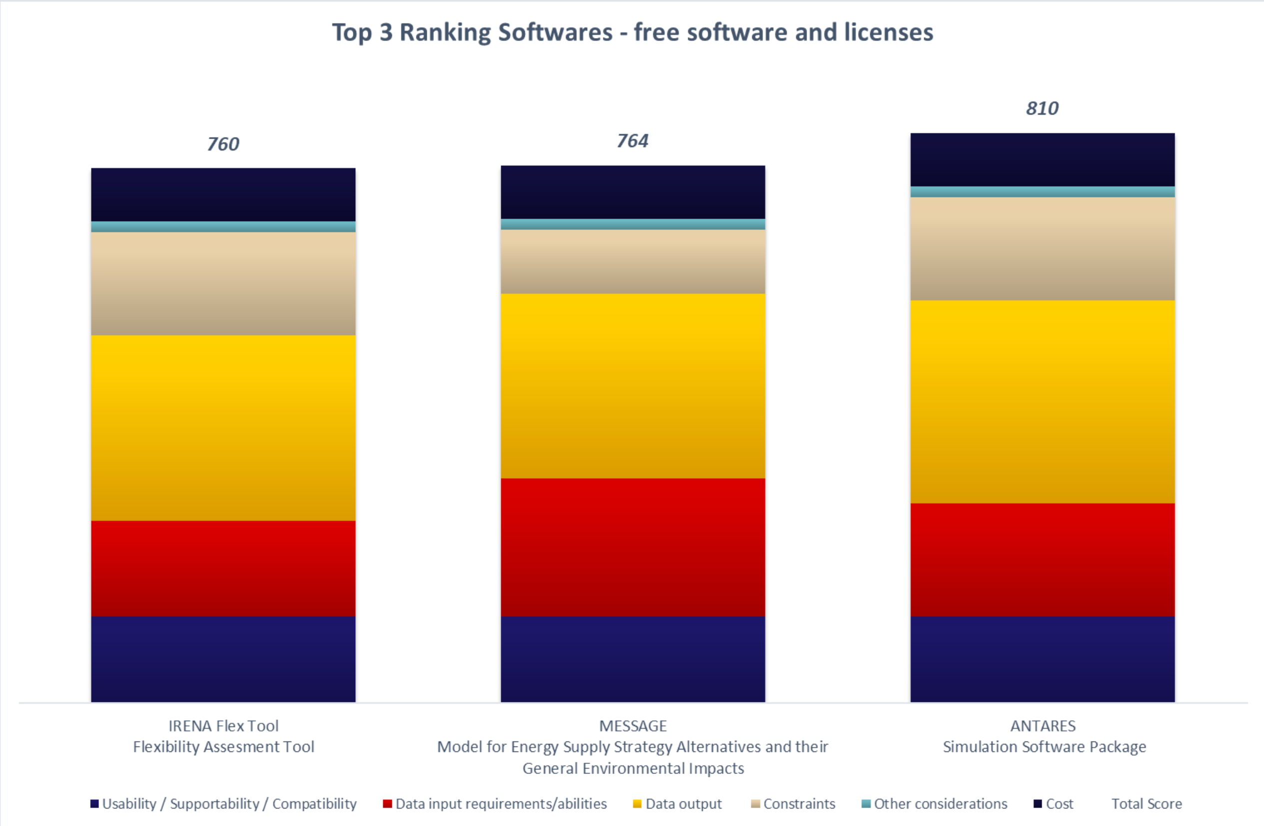
Figure 9: Top 3 software packages - not-for-free



Note that UPLAN (with a score of 795) was not considered in final top 3 ranking above because it is more applicable for network power modelling rather than for long-term generation planning[16].

[16] As a network power model, UPLAN is suitable for modelling and simulation of grid systems, which includes Optimal Power Flow and dispatch simulations to ensure that all transmission constraints, line contingencies, outages and physical constraints for power delivery are obeyed. This work is covered in the transmission planning process, for which a software already exists within ZESCO – the DIgSilent PowerFactory software.

Figure 10: Top 3 software packages - free



Besides the fact that there are no up-front capital investments, the **advantages of a free software** are that it brings:

- Wider utilisation of the software;
- Greater flexibility to trial and test – and thus to make a more informed decision if/when buying a software in future; and
- Overall longer-term potential for sustainability of the system and its every-day use.

Following workshops during the inception phase, there was consensus among the stakeholders that the top two free software packages – **Antares** and **MESSAGE** – would be **trialled** with end-users to assess and decide which one is more **fit-for-purpose**. The training capabilities and support of the two software providers will also be further explored during this trial period.

4.1.4 High-level summary of next phase activities

The table below summarises the next activities for this workstream.

Table 4: Systems selection – Summary of activities

#	Main activity	Expected completion date
1	Trial of top 2 free softwares	End April 2021
2	Procurement of the selected software	End May 2021
3	Installation and configuration	End June 2021
5	Training	End June 2021
6	Development of the IRP model	End September 2021

7	Handover (and write-up of capacity building activities to feed into the IRP Completion Report)	End March 2022

The structure on the selected software should have been completed by the end of June 2021 (data collection and compilation from assessment is expected to be completed by then). The IRP model should be developed by the start of July 2021. From July to September 2021, the following activities need to be performed with the IRP software: run with the baseline case, validate the model structure, refine inputs, and run alternate scenarios. The handover process should lead to institutionalisation of the software tool, which may thus entail more training activities for the wider teams in the MoE and ZESCO to whom the IRP software tool will be handed over for implementation; as such, this step will be ongoing to be finalised by end March 2022.

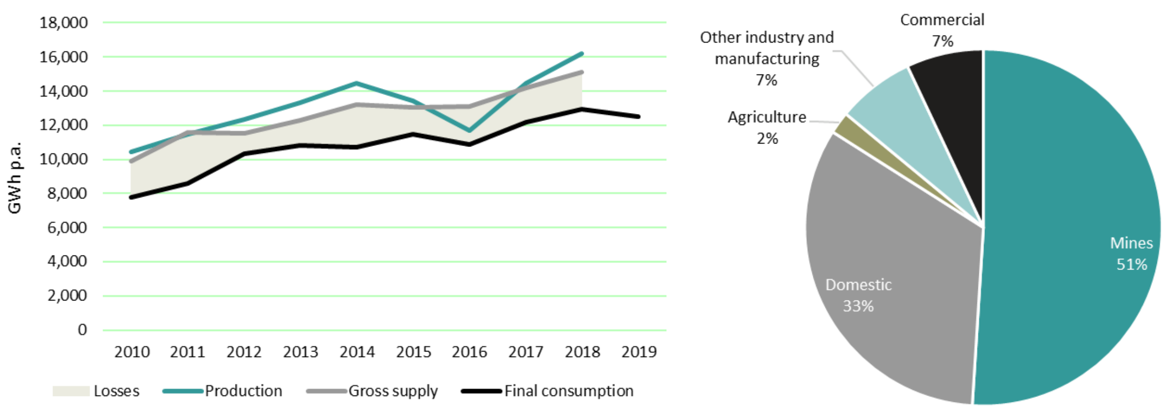
4.2 Demand Assessment and Forecasting

4.2.1 Situational assessment

Electricity demand in Zambia

Data availability relating to the existing demand for electricity in Zambia is generally good. The figure below presents a summary of electricity demand evolution in recent years. The panel on the left presents data from the International Energy Agency's (IEA) database. The black line shows final consumption, a breakdown of which is presented in the pie chart in the right panel. This illustrates the dominance of mining as a source of electricity demand in the country. The breakdown is taken from data presented in the ERB's annual "Energy Sector Report" for 2019[17]. Supply needs to meet more than the ~13 TWh of final consumption shown in the figure; losses of ~2 TWh also have to be covered. This figure covers station parasitic/auxiliary loads, as well as transmission and distribution losses.

Figure 11: Electricity demand in Zambia (left), and composition of final consumption, 2019 (right)



Source: *International Energy Agency, Energy Regulation Board*

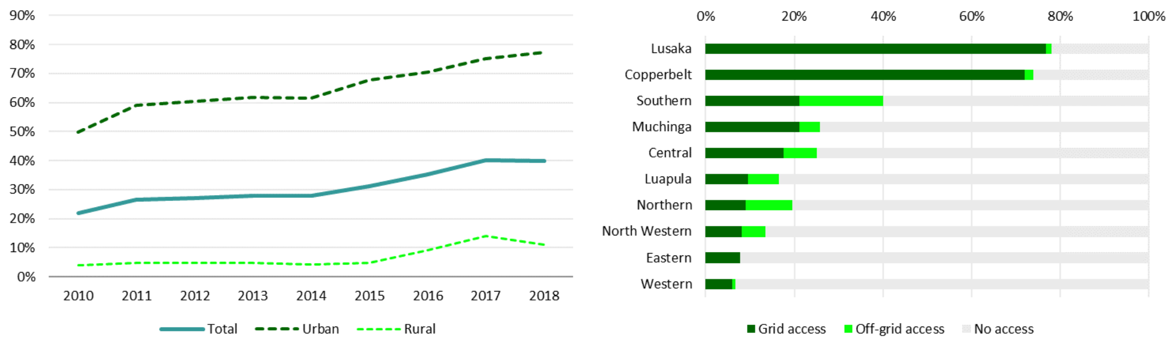
The figure above shows how demand for electricity has grown substantially in recent years in Zambia. Final consumption of electricity grew at a compound annual growth rate (CAGR) of 5.4% per annum over the period 2010-2019.

Electricity access has been gradually improving as shown in the figure below, although ~60% of the population still does not have access to electricity, with this share increasing to 89% in rural areas. In

[17] Energy Regulation Board (2019): Energy Sector Report 2019 http://www.erb.org.zm/reports/esr2019.pdf

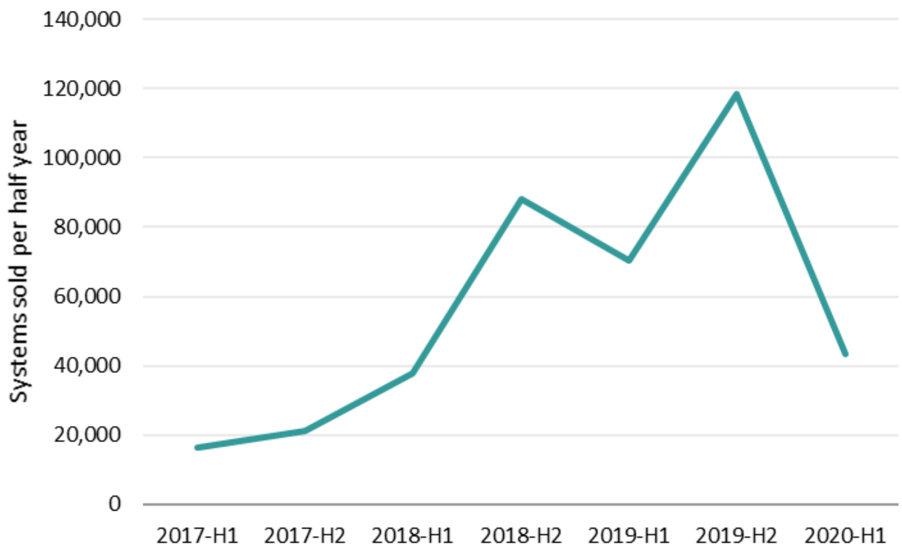
the addition to data from the annual tracking SDG7 report[18], the figure shows more granular analysis from a multi-tier framework survey[19] carried out by the World Bank in 2017/8. The right panel shows the role of off-grid system in addressing energy access, as well as the role of the traditional grid-based system. Sales of off-grid systems have grown rapidly in Zambia in recent years, as shown in Figure 13 (the dip in H1-2020 is attributable to restrictions brought in to control the spread of Covid-19), and the growing impact of off-grid on energy access (see figure below).

Figure 12: Electricity access over time (left), and grid and off-grid access by province, 2017/8 (right)



Source: *IEA et. al. (2020), Luzi et al. (2019)*

Figure 13: Half-yearly sales of off-grid solar home systems in Zambia



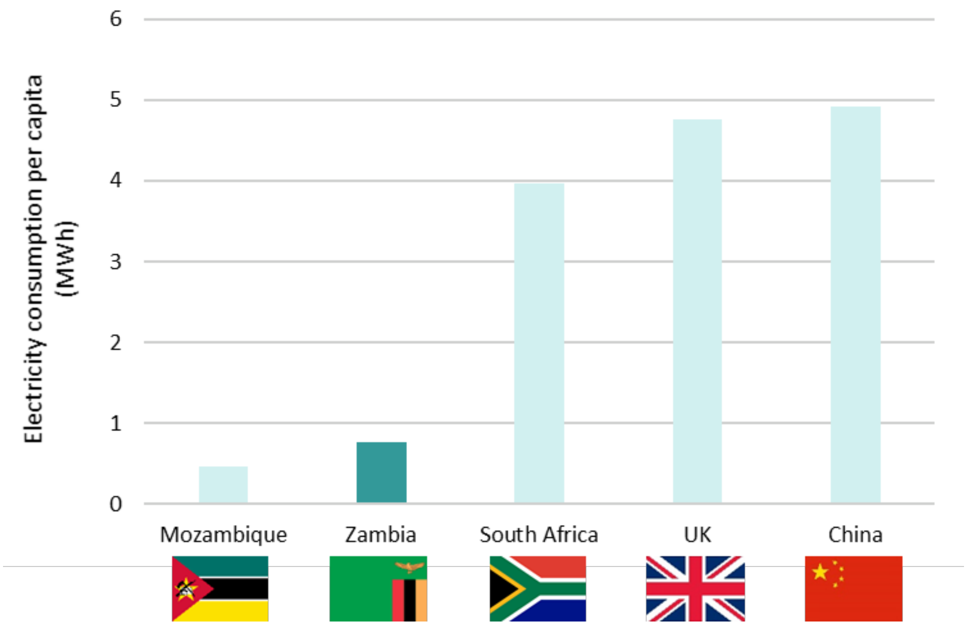
Source: *CIGZambia analysis of GOGLA half-year sales and impact reports*

Despite the growth in demand shown in Figure 11, Zambia's electricity demand remains very low on a per capita basis. The figure below shows Zambia's per capita electricity demand (0.77 MWh per capita in 2018, according to the IEA) compared against a range of other countries. While some other countries in the Southern Africa region, such as Mozambique, have lower demand per capita, Zambia's demand is far lower than South Africa's (3.96 MWh per capita).

[18] International Energy Agency; International Renewable Energy Agency; United Nations Statistics Division; World Bank; World Health Organization (2020): Tracking SDG 7: The Energy Progress Report 2020 https://openknowledge.worldbank.org/handle/10986/33822

[19] Luzi, Lucia; Lin, Yunhui; Koo, Brian Bonsuk; Rysankova, Dana; Portale, Elisa (2019): Zambia – Beyond Connections: Energy Access Diagnostic Report Based on the Multi-Tier Framework https://openknowledge.worldbank.org/handle/10986/32750

Figure 14: Comparison of electricity consumption per capita with other countries



Source: *International Energy Agency*

The data shown in Figure 11 show energy that was actually generated and supplied. Outages and reliability are likely to have an impact on measured demand as connected demand will not always be able to consume electricity. ERB's Energy Sector Report 2019[20] shows improved compliance with power quality standards stipulated by the Zambian Bureau of Standards (ZABS) in its Power Quality Reliability Standard (ZS 387) over the period 2015-2019. Compliance with the standard for interruptions is reported as having improved from 54.0% to 82.4% over this period. However, this figure indicates that interruptions remain a substantial challenge.

The impact of drought and correspondingly low hydro generation can be seen in Figure 11, pointing towards a more substantial impact of outages in some years. Demand is recorded as being lower in both 2015/16 and in 2018/19. We can refer to this connected, but unmet, demand as 'supressed' demand. Real demand is therefore somewhat higher than shown in the data, although it is difficult to quantify this gap precisely in practice.

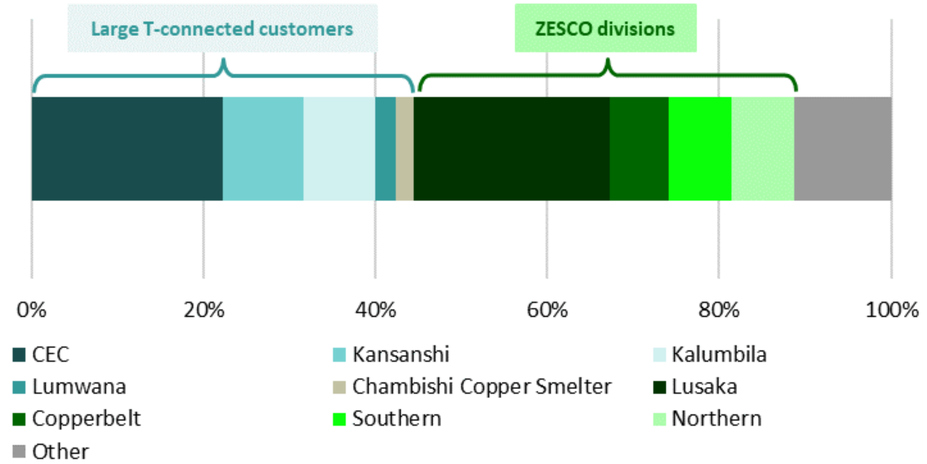
The figure below[21] presents analysis of electricity demand that provides an indication of the location of the demand that is currently connected to the network. Large customers are shown in different shades of teal; demand across each of ZESCO's main distribution networks/divisions is shown in different shades of green. This analysis shows two clear concentrations of demand:

[20] Ibid.

[21] Note that this data is not strictly complete. Five days of data are missing at the start and end of the year, and CIGZambia has patched small gaps in the data based on monthly average profiles during the periods in which data is available.

- Mining loads, many of which are connected to the (Copperbelt Energy Corporation (CEC) network. Some mines are also connected directly to the ZESCO network in North Western province. This includes the Kansanshi and Kalumbila mines in the Solwezi area.
- Beyond these loads, demand is concentrated in and around the Lusaka area. Lusaka accounts for about half of all distribution-connected demand.

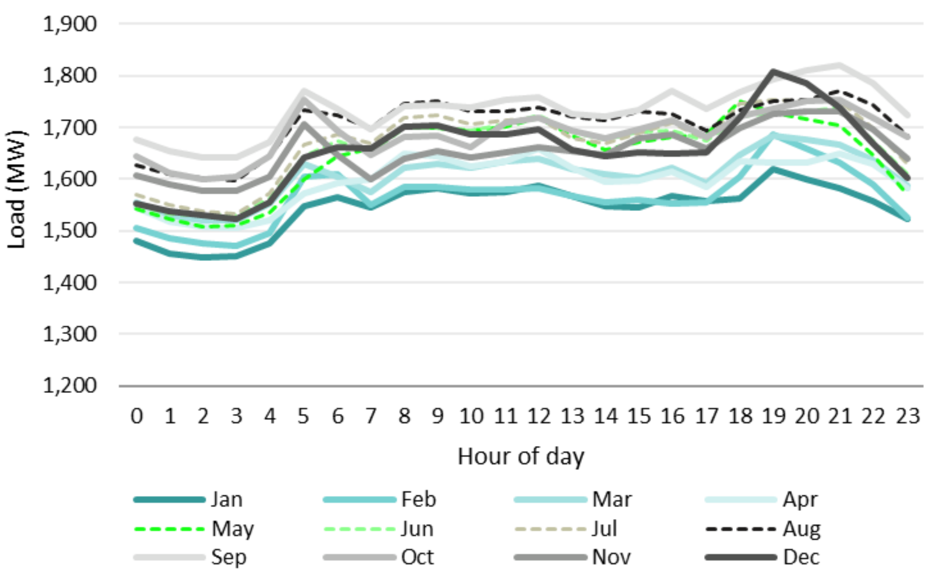
Figure 15: Breakdown of electricity demand, by large customers and ZESCO divisions, 2020



Source: ZESCO data, analysed by CIGZambia

ZESCO has provided hourly transmission level data for 2020. Average weekday load curves for the total system are shown in the figure below. This again shows the residual impact of load shedding during the first part of 2020. The average system load in January 2020 (shown by the teal line) is on average 100-200 MW lower than the load in December 2020 (shown by the dark grey line). Given that a gradual recovery in load can be seen through the year, this is likely to mostly be attributable to load shedding during the early part of the year. The absolute peak load in 2020 was 1,943 MW, during 7-8pm on 23rd December.

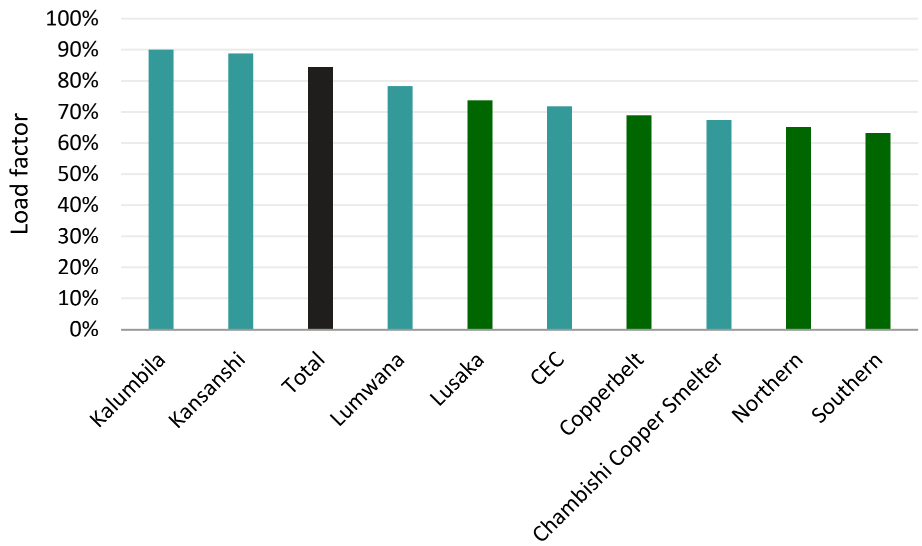
Figure 16: Monthly average weekday load curves for Zambia's transmission system, 2020



Source: ZESCO data, analysed by CIGZambia

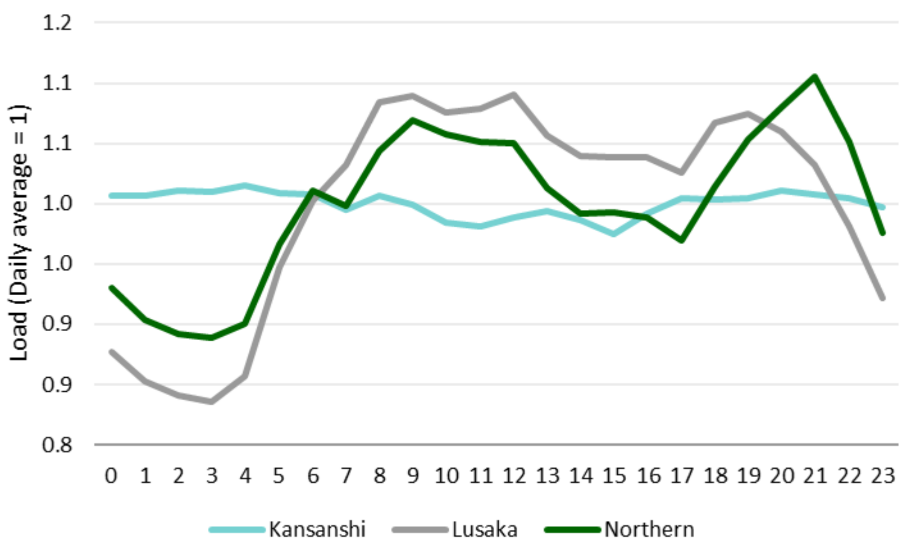
The above figure shows average load profiles across Zambia as a whole, but the load shape varies across the system. The figure below illustrates this point by showing average load factors across major customers (in teal) and ZESCO divisions (in green). Unsurprisingly this shows very high load factors (baseload-like profiles) for large mining customers, but lower load factors (peaky load profiles) in distribution networks with a greater share of residential demand. The load factor across Lusaka is slightly higher than across other ZESCO divisions, reflecting a greater prevalence of commercial and industrial loads. Interestingly, the total system load factor is much higher than the median of load factors shown. This indicates the impact of diversity of profiles across the regions, with daytime peaks in Lusaka complementing evening peaks in other regions. This is illustrated further by the example annual average profiles shown in Figure 18.

Figure 17: Load factors[22] across Zambia, 2020



Source: *ZESCO data, analysed by CIGZambia*

Figure 18: Annual average load profiles for Kansanshi, Lusaka, Northern, 2020



[22] These load factors should be treated with some caution as substantial data cleaning was required to calculate these estimates.

Source: *ZESCO data, analysed by CIGZambia*

Other demand assessment work underway

There are two main recent or ongoing projects that analyse demand for electricity in Zambia as part of their scope:

- The Cost of Service Study (COSS), which is being performed by EMRC for ERB, and is funded by the African Development Bank (AfDB).
- A Least-Cost Geospatial Electrification Plan (LCEP) for grid and off-grid rollout in Zambia, which has been prepared by Tractebel for the World Bank.

The COSS is still ongoing, although it is understood from MoE that it is expected the study will be completed by the end of March 2021. The objective of the COSS is to build a consensus view of the cost of service in Zambia so that this can inform a number of key sector decision making processes, most obviously tariff setting. In preparing this inception report, CIGZambia has been able to review the inception report prepared by EMRC, but no interim deliverables have been provided.

The COSS includes a demand assessment so that sector costs can be assessed on a per unit basis. EMRC's inception report details the demand assessment methodology that they intend to use. While the report evaluates the merits of both top-down econometric models and bottom-up techno-economic models, it is determined that a top-down approach should be used for the COSS. The main reasons provided for this approach is that *"the data requirements of a comprehensive techno-economic model mean that it is not a practical choice for this assignment."* However, it is proposed that the top-down analysis is supplemented with a bottom-up approach for the mining and large industrial sectors.

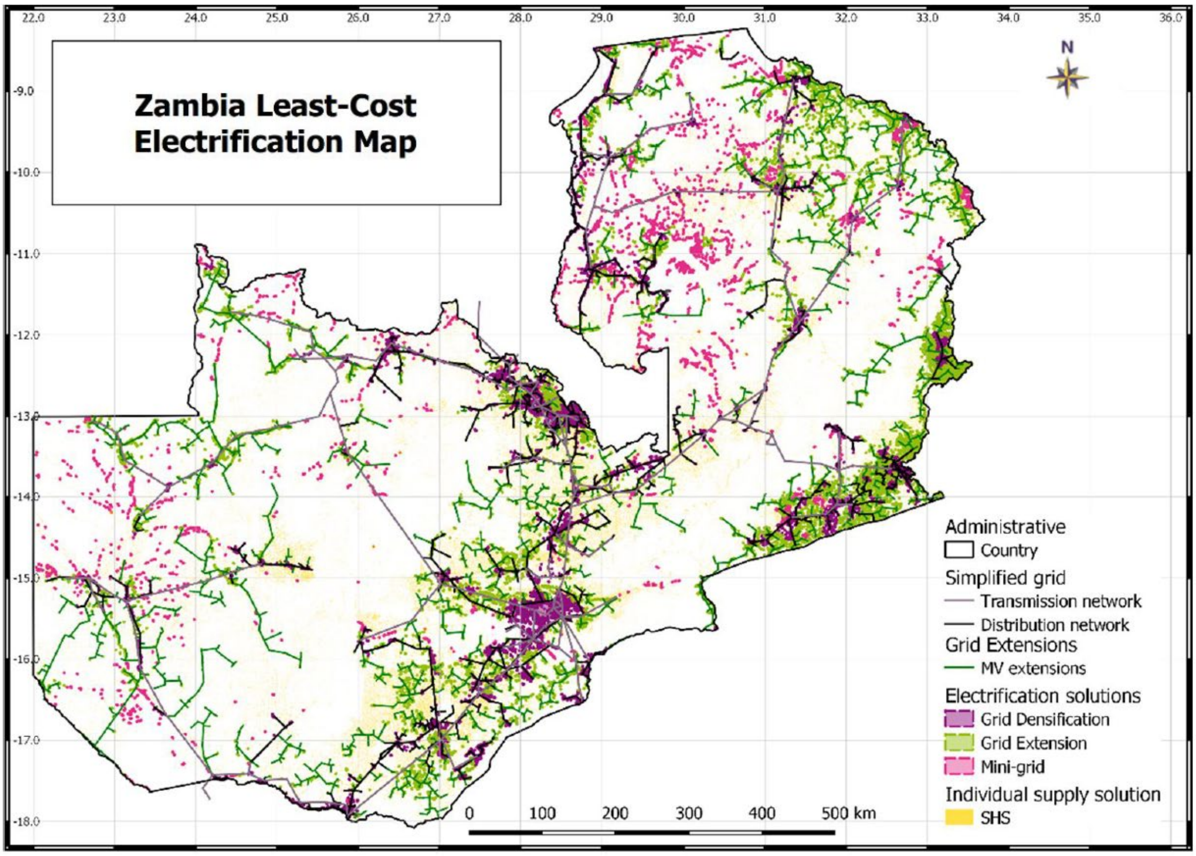
The COSS inception report proposes taking the following approach to forecasting different tranches of demand:

- For residential and commercial demand, an econometric approach is taken with consideration of three explanatory variables: GDP per capita, customer numbers, and/or the electrification rate.
- For smaller industrial loads, a straight link with GDP, or the industrial component of GDP, is proposed.
- For mining and large industrial loads, it is proposed that these are modelled exogenously, using a bottom-up approach, informed by engagement with industry stakeholders such as Chamber of Mines and the Federation of Zambian Industries.

The inception report notes that the forecasting methodology will also attempt to analyse electricity demand by voltage level, but it is not thought that the COSS will include a detailed locational analysis of demand. However, in each case, because we only have visibility of the inception report, the precise details of the forecasting methodology that has actually been used in the COSS analysis are not clear.

The World Bank funded LCEP, by contrast, is now complete. The LCEP report is intended to provide a plan outlining the least-cost approach to achieving universal access to electricity by 2030, in line with GRZ's Vision 2030, and indeed with SDG7. The LCEP considers four main modes of delivering new 'connections': grid densification, grid extensions, mini-grids, and stand-alone solar home systems (SHS). The first and second of these directly impact the IRP, but the off-grid technologies are also relevant as this analysis indicates areas where it is unlikely to make sense to extend the main electricity grid, at least on 2030 timescales. The figure below summarises the output from the LCEP, showing the locations where each solution is likely to be least-cost. The LCEP's Base Case suggests that 23.5% of households will be connected via grid densification, 18.2% by grid extension, 5.4% using mini-grids, and 28.9% using SHS.

Figure 19: Zambia least-cost electrification map



Source: *Tractebel LCEP (2020)*

The LCEP analysis required analysis of demand as an input to the least-cost optimisation, and importantly the geospatial characteristics of that demand. The LCEP analysed two components of demand:

- Agricultural demand, which mostly relates to irrigation requirements and is estimated using crop production data. It is unclear exactly what relationship between crop production and electricity is assumed.
- What the LCEP refers to as population demand includes residential, administrative, commercial, and industrial loads. This assumes a fixed composition of demand sources (residential, administrative, commercial, and industrial customers) per unit population, with a related fixed cross-section of demand. These cross-sections vary for urban versus rural locations. Baseline demand is scaled down to account for the current electrification rate in a location. Demand evolution is then directly linked to assumptions on population growth and urbanisation. Our understanding is that the demand composition assumptions are based on generic African data based on Tractebel's experience, rather than being specific to Zambia. Electricity demand for mining is not mentioned and is not modelled separately.

These two components are then added together to derive the total electricity demand. The analysis points towards some inputs that might be useful in the demand assessment for the IRP. However, it seems unlikely that the outputs from the analysis can be used directly, because the demand scenario shows total demand that is not aligned with actual electricity demand in Zambia today, as described earlier in the section. The LCEP assumes total demand in 2019 of 2,427 GWh, growing to 8,933 GWh by 2030 (still lower than actual electricity demand today).

4.2.2 Proposed approach and methodology

Approach to demand assessment in similar IRPs

A range of approaches has been used in developing demand forecasts for IRPs in other countries. The different approaches used reflect the varying quality and quantity of data available for establishing a dependable demand baseline in different countries. A recent review of power sector planning methodologies[23] by the Asian Development Bank identifies three key principles for demand forecasting:

- A clear set of underlying assumption;
- A relevant and scientifically-based methodology; and
- Dependable data.

The same review identifies three types of approach to demand forecasting, the first two of which are 'top-down', the third of which is 'bottom-up':

- **Trend forecasting**, which simply assumes that future rates of change are similar to those seen in the past. Electricity sectors that are at an early stage of development, such as Zambia, can experience periods of rapid change, meaning that such an approach is likely to be inappropriate.
- **Econometric forecasting**, which considered links between electricity demand and other economic and/or demographic factors. Ideally, such analysis is based on a long and internally consistent historical dataset.
- **End-use forecasting**, which involves detailed bottom-up modelling considering the end-use purpose of the electricity. Demand is disaggregated, with demand from individual sectors of the economy modelled separately.

As with most economic forecasting, the reality is that any demand forecast will be wrong. However, if the demand assessment is to provide a robust basis for other components of the IRP, the objective should be for the assessment to identify the key factors that drive electricity demand in a country, so that these factors can reflected in the design of scenarios incorporated to the IRP. The inherent uncertainty in a demand forecast means that it is common for IRPs to consider a range of demand forecasting methodologies, based on the approaches listed above.

In Sub-Saharan Africa (SSA), availability of data is often a limiting factor. Partly as a result, most IRPs prepared across SSA have used top-down demand forecasting methodologies. In South Africa, the demand forecasts used in developing the IRP are prepared by the Council for Scientific and Industrial Research (CSIR)[24]. The CSIR uses a multiple regression methodology that identifies sector-specific 'predictor' variables for electricity demand, which are incorporated to the forecasting model. The latest Integrated Power System Master Plan for Ghana[25] was developed using a simple econometric approach that projected demand at a national level, based on GDP growth only.

In a recent Africa-wide analysis to estimate energy sector investment needs to 2025, a long-term sector plan for the continent was modelled using a demand analysis that was modelled as a function of GDP growth. GDP elasticity of demand was assumed to be between 0.85 and 1.35, depending on the country. In most cases, GDP elasticity of demand was assumed to be lower for countries with higher income levels. Academic studies and ex post analyses also consider the price elasticity of demand. IRPs do not typically consider this impact; partly because there is greater uncertainty

[23] Asian Development Bank (2020): Transforming Power Development Planning in Greater Mekong Subregion: A Strategic and Integrated Approach (DOI: http://dx.doi.org/10.22617/TCS200375

[24] Centre for Scientific and Industrial Research (2017): Forecasts for Electricity Demand in South Africa (2017-2050) using the CSIR Sectoral Regression Model for the Integrated Resource Plan of South Africa http://www.energy.gov.za/IRP/irp-update-draft-report2018/CSIR-annual-elec-demand-forecasts-IRP-2015.pdf

[25] Energy Commission (2019): Integrated Power System Master Plan for Ghana, Volume #2, Main Report (2019 Update) http://energycom.gov.gh/files/Integrated%20Power%20System%20Master%20Plan%20Vol.%202.pdf

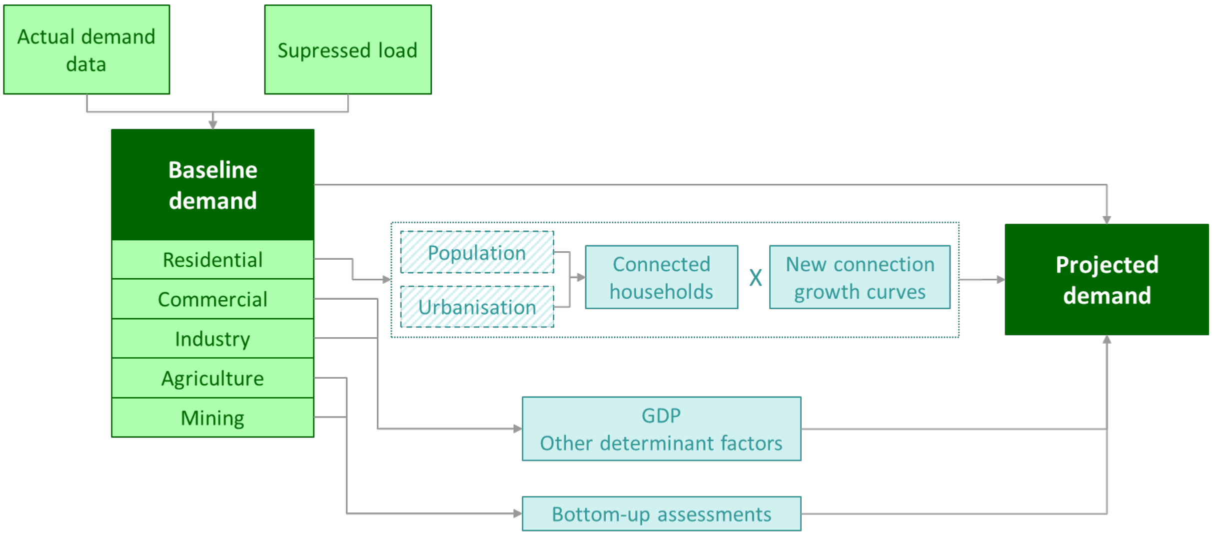
regarding the price elasticity of demand, and partly because it would introduce a circularity into the analysis that in most cases is assumed to be second order.

Overview of proposed approach

The figure below presents a high-level schematic overview of the approach proposed for the IRP demand assessment. In summary:

- The baseline demand will be defined using demand on actual data. Where possible, this baseline will be corrected to account for suppressed demand; i.e., connected demand that is not met because of outages.
- This baseline will be subdivided into different customer types. The figure indicates the customer types that it is expected will be most important to consider separately for the IRP: residential, commercial, industry, agriculture, and mining.
- Growth models will then be applied to this baseline to project future demand for electricity. As shown in the figure, the growth model is likely to vary for the different components of demand. This is described further below.

Figure 20: Schematic overview of demand assessment approach



The sub-sections below describe in more detail the approach proposed both for establishing a robust demand baseline and for projecting demand growth in each sector. Further detail is also presented on:

- The approach proposed for load shape and peak demand; and
- The approach proposed for allocating load to different locations, which will feed into the approach for the distribution planning component of the IRP, as outlined in Section 4.5.

Demand baseline and data availability

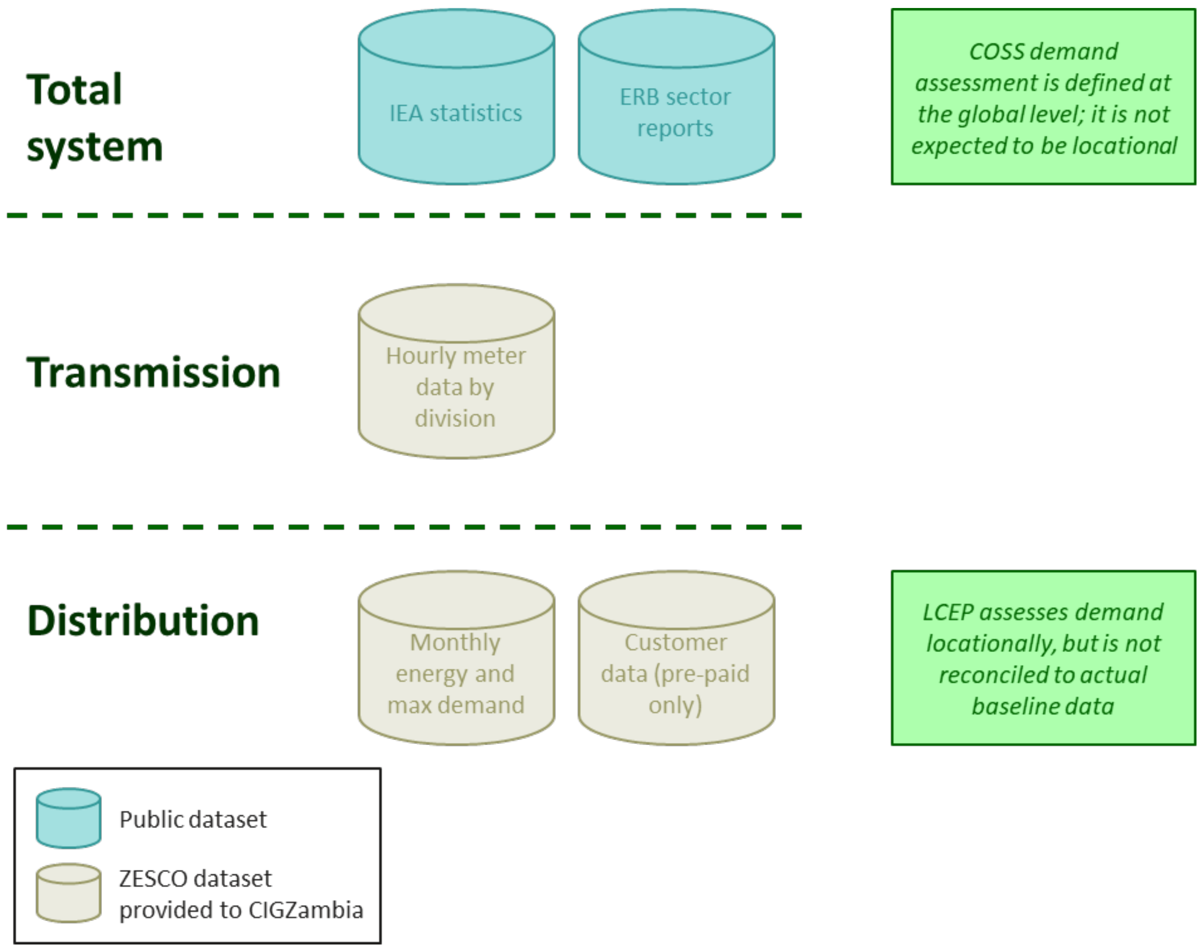
During the inception phase, CIGZambia has discussed in detail with ZESCO staff the availability of data describing the current demand for electricity on the Zambian grid. Overall, the data available is good and will greatly enhance the quality of analysis that can be completed in preparation of the IRP. Figure 21 provides a high-level summary of the some of the data made available during the inception phase. The figure distinguishes between aggregated total system demand data, and disaggregated data describing the impact of demand at different locations on both the transmission and distribution networks which, as noted above, will be required to feed into the network planning components of the IRP. Initial analysis of these datasets feeds into the situation assessment presented in Section 4.2.1.

In addition to the datasets shown in Figure 21, it has been noted that MoE and ERB have been working on a household survey to assess demand for energy at a more granular level. The IRP team is engaging with the Ministry to access emerging outputs from this study to evaluate whether this analysis also provides useful data for input to the demand assessment.

ZESCO has also noted that it has been developing its own demand forecasting methodologies, precisely for this purpose: to feed into network planning. ZESCO is keen for CIGZambia to develop its own approach to demand forecasting for the IRP, albeit leveraging some common datasets. The rationale for this is two-fold:

- The IRP will initially focus on top-down system-wide demand forecasting, as described below, whereas CIGZambia understands that ZESCO's existing demand forecasting is primarily bottom-up. ZESCO's modelling will be more relevant as locational detail is added to the demand forecast to feed into the distribution planning component of the IRP.
- As the IRP demand forecast is developed, existing ZESCO analysis can be compared against the emerging demand forecast, providing robust challenge with the aim of refining both the IRP and ZESCO approaches.

Figure 21: Summary of key datasets available for demand assessment

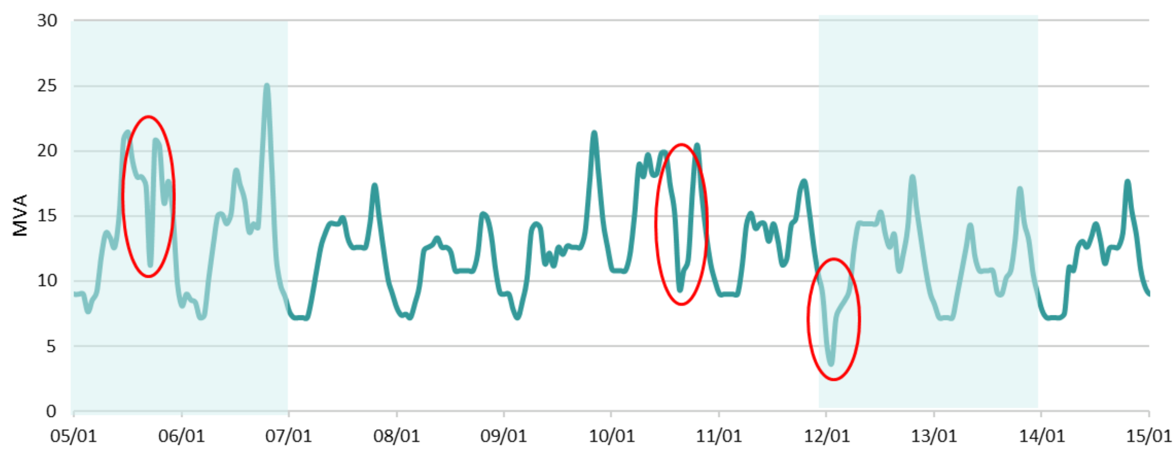


The baseline for the demand assessment will be defined by the available data describing actual demand. This baseline is described by the analysis in Section 4.2.1. There are some data challenges in defining the baseline, but solutions exist to addressing these challenges, as summarised in the table below.

Table 5: Data challenges in defining the demand baseline and proposed solutions

Data challenge	Proposed solution
Some of the 'total system' datasets presented in Section 4.2.1 currently extend to only 2018 or 2019. Ideally, the baseline data for the IRP will leverage the latest data; i.e., at least until the end of 2020.	Some more granular datasets seen during engagement with ZESCO do include 2020, so it should be possible to use 2020 data in establishing the demand assessment baseline.
During the inception phase it has not been possible to reconcile the distribution level demand data with the total system data.	Reconciling the data will require a more detailed understanding of the distribution network, the direction of flows across the network, and interconnections between different parts of the network. As work starts on the IRP, close co-ordination between the demand assessment and distribution planning workstreams will be required to address these challenges.
As is the case in many countries across Sub-Saharan Africa, load shedding will sometimes have a material impact on measured demand. In Zambia, it is clear that drought conditions have had a substantial impact on measured demand in some years – see for example 2016 and 2019 in Figure 11. Actual demand connected to the grid is likely to in fact be somewhat higher than measured demand. We refer to this as 'supressed demand', and the baseline should consider the impact of this demand that is not currently met. ZESCO has not been able to provide any detailed analysis of outages across the electricity system so supressed load can be estimated.	Supressed demand can only ever be estimated. While defining the baseline for the demand assessment, the team will continue to work with ZESCO to identify data that might help assess supressed load. Depending on the data made available, heuristic approaches could be applied to estimate the impact. For example, Figure 22 presents hourly meter data for a transmission line near Chipata. Possible load shedding events are identified; if we were able to cross-reference these events with a load shedding schedule it might be possible to analytically estimate supressed demand.
Hourly data is only available across the transmission network. Data on the distribution network is limited to monthly granularity.	Hourly data should not be required at the distribution level. This level of geographical granularity will only be required for the distribution planning workstream. Distribution planning will be driven primarily by maximum demand projections; the underlying shape will be less important.

Figure 22: Example data for a transmission line in Chipata indicating possible load shedding events, January 2019 (shading indicates weekends)



Source: *ZESCO data*

Load growth projections

As indicated in Figure 20, load growth projections will build from the baseline, with the approach used to estimate load growth varying by type of demand. A blend of top-down **econometric** and bottom-up **end use** modelling techniques is proposed.

Approach for residential, commercial, and industrial demand

For **residential**, **commercial**, and **industrial** (not including mining) electricity demand, the emphasis will primarily be on econometric approaches, which is consistent with the approach used for the South African IRP[26]. The table below lists the predictor variables used in the final regression models for each component of demand in South Africa. The regression models will be selected based on analysis of recent historical demand data and adopting the same principles as in South Africa: *"to be as simple as possible (i.e., having as few drivers as possible), and to satisfy a logical understanding of the sector being forecasted".* It is expected that GDP (or an equivalent measure) is likely to be a key predictor variable, along with demographic considerations such as population growth and urbanisation. The final choice of predictor variables will be confirmed along with other key scenario assumptions during the first few months of our work, as indicated in Table 7.

Table 6: Predictor variables used for econometric modelling of demand in South Africa's IRP

Demand component	Predictor variables included in regression model
Agriculture	Final Consumption Expenditure of Households (FCEH)
Transport	Mining index excluding gold
Domestic	FCEH
Commerce and manufacturing	Population, manufacturing index
Mining	Platinum index, gold ore treated

Source: Council for Scientific and Industrial Research (2017)

It is expected that the econometric analysis will implicitly include the impact of gradual improvements in energy efficiency and the gradual adoption of new appliances. However, any step-changes in the adoption of new technologies of energy efficiency measures many need to be considered outside of this econometric analysis (although we do not expect this to be relevant for the Base Case).

Demographic factors will be a particularly important factor in projecting domestic electricity demand, which accounts for roughly a third of total demand, making it the largest component of demand after mining. Scenario assumptions on whether policy objectives on electricity access are met or not will also be key. Vision 2030 sets the goal of achieving universal access to clean, reliable, and affordable energy by 2030, in line with SDG7; 7NDP also reiterates a commitment to improving access to electricity, in particular in rural and peri-urban areas.

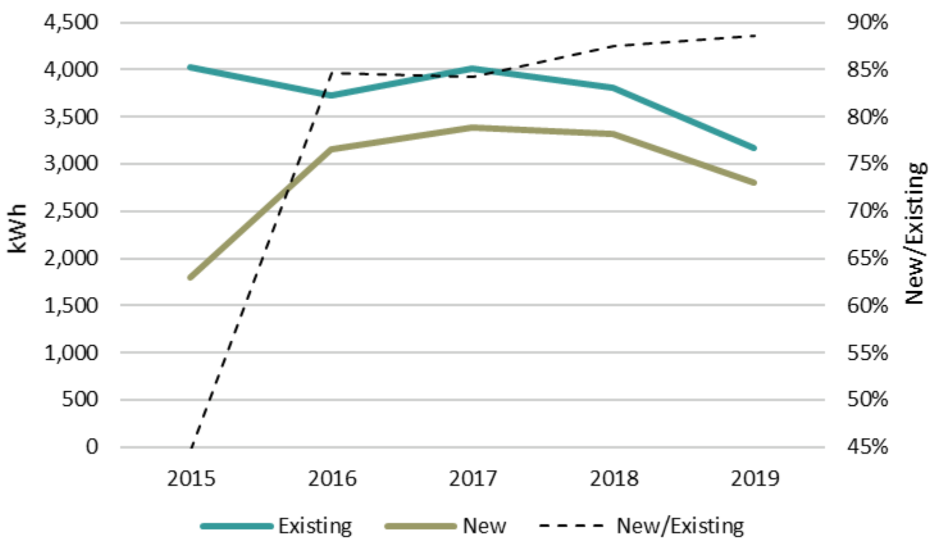
Neither the Vision 2030 document or 7NDP is prescriptive in setting the energy access modes by which these objectives are met; whether electricity is delivered via the grid or using off-grid technologies. The LCEP, discussed in Section 4.2.1 provides an overview of which technologies provide a least cost option for electrification in each location. As noted in Section 4.2.1, it is unlikely that the assessment of demand used in the LCEP can be used directly in preparing the IRP, because actual baseline demand is far higher than that assessed in preparing the LCEP. However, it might be possible to use select outputs from the LCEP, such outputs identifying households that are expected to be connected to the grid in meeting the universal access policy objective. In the absence of this data, the number of households to be connected to the grid will be estimated using high-level outputs

[26] Centre for Scientific and Industrial Research (2017): Forecasts for Electricity Demand in South Africa (2017-2050) using the CSIR Sectoral Regression Model for the Integrated Resource Plan of South Africa http://www.energy.gov.za/IRP/irp-update-draft-report2018/CSIR-annual-elec-demand-forecasts-IRP-2015.pdf

from the LCEP report combined with demographic analysis of population growth and urbanisation trends.

Projections of residential demand for electricity will also consider the ramp up of demand associated with newly connected households. The objective of this analysis will be to ensure demand from newly connected households is not over-estimated, which has sometimes been a challenge in other countries. Figure 23 shows a simple analysis of demand from households in Kitwe. The analysis differentiates between households connected in 2015[27] and those connected prior to 2015. This shows that electricity demand for newly connected households remains below that of existing households for many years. However, at least in the case of Kitwe, demand for these newly connected households is ~85% of that for existing households from an early stage. These findings could of course vary by location, especially if work to extend the grid is accelerated to meet GRZ's policy objectives for 2030. In preparing the demand assessment for the IRP, further analysis of electricity demand from newly connected households will be performed so that an appropriate assumption can be adopted.

Figure 23: Comparison of demand for existing and new households (connected in 2015), Kitwe



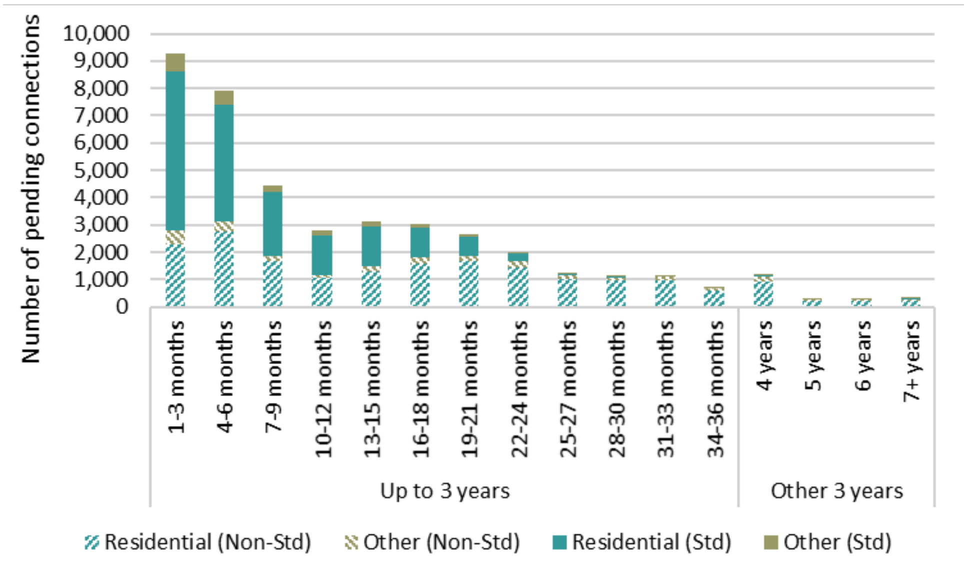
Source: *ZESCO data, CIGZambia analysis*

During the inception phase it has been suggested that pending connections might also need to be accounted for in preparing the demand assessment. ZESCO currently has a backlog of connections, which are delayed because of funding constraints. The tariff for connections is not cost reflective and ZESCO does not have the funds to cover this deficit. Data regarding the pending connections has been obtained from ZESCO and is summarised in Figure 24. According to this data, there are ~37,000 pending residential connections and ~5,000 non-residential connections.

While there are some connections that have been pending for many years, the majority have been waiting for less than a year. Even if all the residential customers awaiting connections are high demand customers (e.g., with 4 MWh of demand per year) this backlog would only account for ~150 GWh of demand, which is less than the average annual increase in residential demand for electricity in Zambia over the last 10 years. Therefore, it is proposed that the impact of these pending connections on total electricity demand is unlikely to be material when compared against other factors.

[27] These households are currently identified using a heuristic. Further analysis to refine this approach may be required in preparing the demand assessment. Note that this analysis only covers connections on pre-payment meters.

Figure 24: Pending demand connections, aged by payment date



Source: *ZESCO data, CIGZambia analysis*

Approach for mining demand

For **mining** and **agricultural** demand for electricity, while top-down econometric approaches will still be considered, the emphasis will be on bottom-up end use methodologies. As noted in Section 4.2.1, mining accounts for roughly half of all electricity demand in Zambia. This demand is highly dependent on dynamics in the global market for the extracted resources, primarily copper. Demand for copper is currently pushing prices to high levels, but a risk for Zambia is that these prices encourage investment in mining in other locations, potentially unlocking competitive threats to Zambia's mines over the medium to long-term. Due to the critical role that mining still plays in Zambia's political economy, there have been several interventions in the market to support the sector. Bottom-up analysis of mining demand will consider the demand resulting from different mining activities in the value chain; for example, smelting and refining.

While it is beyond the scope of the demand assessment to carry out a detailed evaluation of the global copper market, the IRP team will engage with key stakeholders in the mining sector, such as the Ministry of Mines, the Chamber of Mines. The IRP team is engaging with MoE to identify the relevant personnel to speak to in these institutions and to set up initial meetings. Semi-structured interviews with stakeholders will aim to identify the most important drivers of economic activity in Zambia's mining sector, as well as understanding stakeholder expectations for future electricity demand from the sector. It is expected that uncertainty around future demand for electricity from the mining sector will be one of the most important levers in defining alternative scenarios for the IRP.

Approach for agricultural demand

Agriculture currently only accounts for 2% of total electricity demand. However, it is proposed that demand from agriculture is split out for separate consideration in the IRP demand assessment for two main reasons:

- It is understood that establishing 'farm blocks' has been a major pillar of GRZ's agriculture policy since 2002. While this policy remains at an early stage in implementation terms, it has

the potential to accelerate the commercialisation of agriculture and to result in more substantial loads; for example, in the processing of agricultural outputs.
- The geospatial characteristics of agricultural loads (i.e., their rural location) could have an outsized impact on the development of network infrastructure in rural areas.

It is proposed that the IRP demand assessment will draw on two potential sources in analysing future growth in demand for electricity from the agriculture sector:

- The World Bank-funded LCEP also considered agriculture demand separately; indeed, agriculture is the only sector that was split out in the demand analysis underpinning the LCEP. The LCEP identified two main sources of demand from agriculture: irrigation and post-processing. The LCEP team analysed demand using Food and Agriculture Organisation (FAO) data on crop production and processing in Zambia. The IRP team is establishing contact with the LCEP team with the aim of further evaluating this dataset and analysis (which also assesses which loads should be met by the national electricity grid, and which by off-grid electricity infrastructure) so that it can be leveraged for the IRP.
- An alternative and/or complementary approach to assessing demand for electricity in the sector, is commissioning analysis from the Indaba Agricultural Policy Research Institute (IAPRI), which is a Zambia-based policy and research institute dedicated to analysis of the agriculture sector. This analysis could also build on bottom-up analysis performed by CIGZambia, evaluating the potential for 3.5 MW of load at the Luswishi farm block in Copperbelt province.

Treatment of losses in modelling demand

The objective of the demand assessment is to quantify the total demand that needs to be met by supply. The assessment will therefore need to consider gross demand, including the impact of losses. Loss reduction interventions could have the impact of reducing gross demand. Projections for loss reduction will be considered in close co-ordination with the transmission and distribution workstreams. The extent of loss reduction, especially reduction in technical losses, will largely be a function of investments made in the transmission and distribution networks.

Technical loss reduction has the impact of reducing the gross demand to be met. Conversely, a portion of non-technical losses may convert to 'real' demand, i.e., shifting from the gross to net demand lines. Estimates vary for the portion of non-technical losses that convert to 'real' demand, but assumptions of 30-70% are typical.

Impact of new technologies

Technology changes could have an impact on the composition of electricity demand over time. Examples of such technology changes include:

- Introduction of more efficient appliances, including lighting. Substantial improvements in the efficiency of appliances have been made in recent years; indeed, this has been one of the primary drivers of the growth in off-grid energy access technologies. In many developed countries, efficiency improvements have resulted in total electricity demand declining in recent years. In the first instance, it is proposed that the impact of improved efficiency will be incorporated in the econometric analysis that will drive much of the demand assessment, especially for residential loads. This analysis will, for example, consider the income elasticity of demand growth, which will reflect the impact of improved efficiency in the recent past. The impact of alternative elasticity assumptions could be considered in the definition of alternative IRP scenarios.
- Growth in the use of goods or new demand-side technologies that change the composition of demand. This might include growth in the use of electricity for cooking, or growth in use of electricity for transport. These types of technology change could have an impact on both the

level of demand and the shape of demand. It is proposed that technology change is considered in demand assessment in two different ways:

  - In the base case analysis, it is proposed that technology change is incorporated through the top-down econometric analysis. Analysis of historical demand trends will incorporate a certain amount of technology change, and if the analysis suggests this is appropriate key econometric parameters could evolve over time to reflect the impact of new technologies.
  - Separately, we will consider the impact that a material increase in the uptake of key technologies might have on the shape of load profiles. This analysis could, for example, consider the impact of a technology on the load profile for a typical household and combine with assumptions on uptake to derive the impact on system demand.

- Growth in the role of **distributed generation**, such as behind-the-meter solar PV or battery storage installations. In line with international best practice, the demand assessment for the IRP will in the first instance consider the evolution of gross demand. Distributed generation will therefore fundamentally be treated as a supply-side consideration. It is proposed that exogenous assumptions for the growth in distributed generation will be made, and these will be consistent with the overall assumptions (for example, the future evolution of technology costs) made for each scenario.

Regional demand for electricity

Zambia's central location in the Southern African Power Pool (SAPP) and the important role of interconnection with neighbouring countries means that the IRP will need to consider interactions with those markets, and the potential evolution of energy imports and exports. The exact scope of the modelling and analysis in those regional markets will partly be limited by the choice of modelling software, as outlined in Section 4.1. The demand assessment for Zambia itself will be prepared first; before demand is analysed in any detail in neighbouring countries[28].

Demand analysis for other SAPP countries will be less detailed and will primarily adopt the top-down econometric models developed for Zambia. There might be some exceptions to this top-down approach for components of demand that are either particularly important to Zambia's electricity sector, or for which there is an especially high degree of uncertainty. One example of this would be demand from the mining sector in DRC, which partly relies on electricity supply from Zambia. In this case a more focused bottom-up approach is likely; mirroring, for example, the approach taken to modelling demand from the mining sector in Zambia.

Load shape and peak demand

Detailed hourly load data has been made available by ZESCO, although this level of granularity is only available on the transmission system. Analysis using this data was presented earlier in Figure 16 and Figure 18. The data analysed for 2020 showed a gradual increase in load on the system during the calendar year. It is expected that this is largely the result of load shedding, which was worse at the start of 2020 because of drought conditions. In finalising the demand baseline for the demand assessment, a longer time series will be considered to correct for the impact of the drought-related load-shedding.

Load shape will not be explicitly modelled at the distribution level, but the maximum demand projections for distribution network planning will partly be informed by the load shape analysis for different parts of the transmission network.

[28] The analysis might also need to consider larger markets that are not strictly neighbouring markets; for example, South Africa.

Geographical granularity

For many aspects of the IRP – in particular the generation planning – the focus will be on analysis of national demand for electricity. The location of the demand will be of limited importance. However, a more granular analysis of demand will be needed for the distribution planning component of the IRP. The distribution analysis will drill down to 11 kV substations. It may not be possible or practical to drill down to this level for all aspects of the demand assessment, but wherever granular inputs are available they will be used to add geographical granularity to the demand assessment. For example, if geospatial data regarding households to be connected to the grid is obtained from the team that prepared the LCEP, these households can be mapped to different parts of the distribution network. Similarly, for commercial and industrial demand, it should be possible to add granularity to the baseline data using ZESCO's customer data; the econometric models used to grow this demand over time will then be applied to this granular baseline.

As noted in Section 4.2.1, it has not been possible to fully reconcile the distribution level demand data to the total system demand during the inception phase. However, it is understood that the differences can be explained with a comprehensive understanding of the layout of the distribution network. The demand assessment and distribution planning workstreams will work to resolve these reconciliation issues.

The demand assessment will model a fully diversified demand profile. For the network planning (distribution planning especially) a suitable diversity factor will need to be applied to ensure network capacity is adequate when local peaks occur.

4.2.3 High-level summary of next phase activities

The table below presents an overview of the main activities that will be completed in preparing the demand assessment, as well as the outputs associated with each task and the date by which it is expected the task will be completed. The table also shows how each task and output relate to the overall IRP project deliverables.

Note that most of the analytical work associated with the demand assessment will be completed by September 2021 as this analysis will be required to drive other parts of the IRP analysis.

Table 7: Demand assessment – Summary of activities

Deliverable	Main activity	Output	Expected completion date
D2 – Consolidated IRP Implementation Report (Component 3: Demand Report)	Collect and compile demand data to finalise baseline	• PPT presentation of demand baseline	End April 2021
	Analysis of data (e.g., econometric analysis) to feed into projections	• Working PPT presentations as required	End July 2021
	Propose assumptions for demand projections	• PPT presentation on scenario assumptions • Internal working sessions with technical stakeholders to confirm assumptions	End May 2021
	Initial base case demand projections, including training workshops	• PPT presentation of base case projections • Workshop to present base case to wider stakeholder group	End July 2021
	Finalise distribution-level projections	• Granular outputs for distribution planning workstream	End September 2021
	Analysis of demand projections for neighbouring markets	• Working PPT presentations as required	End September 2021
	Prepare inputs to implementation report related to demand assessment	• Relevant sections of implementation report	End September 2021
D3 – Scenario Analysis Report	Demand inputs to scenario analysis	• Working PPT presentations as required	End September 2021
	Finalise demand scenarios, including training workshops	• PPT presentation of demand scenarios • Demand assessment report • Workshop to present final scenarios to wider stakeholder group	End September 2021
	Prepare inputs to scenario analysis report related to demand assessment	• Relevant sections of scenario analysis report	Mid-December 2021
D4 – Draft IRP Report	Prepare inputs to draft IRP report related to demand assessment	• Relevant sections of draft IRP report	Mid-February 2022
D5 – Final IRP Report	Finalise inputs to the IRP report	• Updated relevant sections of draft IRP report	End March 2022
D6 – Completion Report (including capacity-building activities)	Handover demand assessment tools to key stakeholders	• 'Clean' version of demand assessment tools and models • Training and workshops to handover tools to stakeholders	End October 2021

Deliverable	Main activity	Output	Expected completion date
	Prepare inputs to completion report related to demand assessment	• Write-up of capacity building activities	End March 2022

4.3 Generation Resource Assessment and Planning

4.3.1 Situational assessment

In the following section, an overview of the operation of the generation sub-sector, and the energy resource base in Zambia is presented based on public documents. The data from the COSS, currently being undertaken, will be appropriately incorporated as it gets finalised.

Installed generation capacity, energy generated, and plant factors

Zambia's electricity generation capacity as of December 2019 was 2981 MW, predominantly hydro (80.5%), coal (10.1%), Heavy Fuel Oil (3.7%), diesel (2.8%) and solar (3.0%)[29]. ZESCO in the public sector is the major owner of the generation assets while a number of other power companies own and operate the remaining plants. The installed generation capacity has increased by 2.9% from 2,898.23 MW in December 2018 due to the commissioning of two solar PV power plants (i.e., Bangweulu Power of 54.3 MW and Ngonye Power of 34 MW). Total energy generated (exclusive of smaller units) during year 2019 was 15,040 GWh, which was about 7.6% lower than what was generated during year 2018. Plant factor for the base-load hydro power plants varied between 43-76%, showing large variability on account of hydrological conditions.

Hydrological situation

Zambia is hydrologically divided into six catchments, namely Zambezi, Kafue, Luangwa, Chambeshi, Luapula and Tanganyika, and the mean annual precipitation ranges between 1,400 mm in the northern region and 700 mm in the southern region of the country, with an average run-off of 135 mm. Most of the hydro-generation plants are located in the southern region of Zambia, which has lately experienced relatively below-normal rainfall in recent years, resulting in reduced water-inflows in the reservoir and consequent impact on hydro-generation. The table below provides the water level in the major reservoirs on December 30, 2018 and compares it with the water level recorded on December 30, 2019, just to provide a snapshot. It may, however, also be remembered that there are major seasonal fluctuations in water inflows during the months of November-April compared to the remaining six months (May-October) each year, causing the seasonality of hydropower generation.

Table 8: Hydropower reservoir level, design and actual levels

Main water Reservoir	Dam Design Operational levels (m)		Actual Dam Level (m)	
	Min Dam Level	Max Dam Level	December 30, 2019	December30, 2018
Kafue Gorge	974	977	974.45	976.12
Kariba North Bank	475.5	488.5	476.69	483.32
Victoria Falls	881.5	883.2	881.85	881.9
Itezhi-Tezhi	1,006.00	1,030.50	1,014.66	1,025.20

Source: Energy Sector Report, 2019

Electricity shortfalls and broadening the generation-mix

[29] Energy Regulation Board (2019), Energy Sector Report 2019 http://www.erb.org.zm/reports/esr2019.pdf

While Zambia has historically relied almost exclusively on hydropower generation to meet its domestic requirements, an unprecedented power shortfall in years 2016 and 2017 forced the Government to diversify the generation-mix. The Government, therefore embarked on the commissioning of a coal-fired plant, and added thermal generation capacity based on the use of Heavy Fuel Oil (HFO), in addition to several diesel generating sets. At the same time, great emphasis was placed on the development of renewable energy sources for electricity generation (principally solar), both under public and private sector. The table below presents a summary of installed capacity by technology, ownership, actual energy generated during the past three years, and plant factor for year 2019[30].

Table 9: Summary of electricity generation-mix and historical performance of the sub-sector

Licensee's Name	Station	Technology	Installed Capacity (MW)	Energy Generated (GWh)			Plant Factor 2019 (%)
				2017	2018	2019	
ZESCO Limited	Kafue Gorge	Hydro	990.00	7363.00	6527.00	6165.00	71.1%
	Kariba North	Hydro	720.00	2689.00	3597.00	3021.00	47.9%
	Kariba North Ext	Hydro	360.00	599.00	1611.00	1363.00	43.2%
	Victoria Falls	Hydro	108.00	684.00	723.00	725.00	76.6%
	Lunzua River	Hydro	14.80	40.40	69.30	69.70	53.8%
	Lusiwasi	Hydro	12.00	46.20	66.00	26.20	24.9%
	Chishimba Falls	Hydro	6.00	15.80	15.70	18.40	35.0%
	Musonda Falls	Hydro	10.00	6.10	54.00	51.00	58.2%
	Shiwang'andu	Hydro	1.00	2.10	2.70	3.30	37.7%
Itezhi-tezhi Power Corp.	Itezhi-tezhi	Hydro	120.00	735.40	709.21	715.80	68.1%
Zengamina Ltd.	Ikelengi	Hydro	0.70				0.0%
Lunsemfwa Hydro Power Co.	Mulungushi	Hydro	32.00				0.0%
	Lunsemfwa	Hydro	24.00	292.60	318.56	174.01	82.8%
	Total Hydro	80.5%	2398.50	12473.60	13693.47	12332.41	58.7%
Maamba Collieries Ltd.	Maamba Power Plant	Coal	300.00	1279.40	2040.47	1886.93	71.8%
	Total Coal	10.1%	300.00	1279.40	2040.47	1886.93	71.8%
Copperbelt Energy Corp. Generation Plants*	Luano	Diesel	40.00				0.0%
	Bancroft	Diesel	20.00				0.0%
	Kankoyo	Diesel	10.00				0.0%
	Maclaren	Diesel	10.00				0.0%
ZESCO Limited Generation Plants	Luangwa	Diesel	2.60	3.30	3.40	4.00	17.6%
	Shang'ombo	Diesel	1.00	1.00	1.10	1.10	12.6%
	Total Diesel	2.8%	83.60	4.30	4.50	5.10	0.7%

[30] MRC Group (2020): Cost of Service Study Inception Report

Ndola Energy Generation Plants	Ndola	Heavy Fuel Oil	110.00	698.80	451.02	698.74	72.5%
	Total HFO	3.7%	110.00	698.80	451.02	698.74	72.5%
REA Generation Plants	Samfya	Solar	0.06				0.0%
Copperbelt Energy Corp.	Kitwe	Solar	1.00				0.0%
Muhanya Solar Ltd.	Sinda Village	Solar	0.03				0.0%
Ngonye Power Ltd.	LSMFEZ	Solar	34.00			40.50	13.6%
Bangweulu Power Co.	LSMFEZ	Solar	54.00			77.06	16.3%
Solera Power	Luangwa Bridge	Solar	0.01				0.0%
Standard Micro grid	Kafue	Solar	0.02				0.0%
Mugurameno	Chirundu	Solar	0.01				0.0%
	Total Solar	3.0%	89.13	0.00	0.00	117.56	15.1%
Grand Total			**2981.23**	**14456.10**	**16189.46**	**15040.74**	**57.6%**

Source: Energy Sector Report, 2019 and FAO Inception Report - Cost of Service Study, 2020

* Under IRP, only such generation assets of ZESCO and private sector would be considered, which are available to the national grid on a continuing basis. Standby generation capacity maintained by CEC or other large customers (mining) would not be accounted for.

Fuel consumption for power generation

HFO are consumed for power generation, in addition to coal at the Maamba Power Plant. HFO consumption witnessed a significant increase from 97,881 metric ton (MT) in year 2016 to 173,485 MT in year 2019. During 2019, there was increased demand for HFO for power production necessitated by low water levels and reduced hydro power generation.

Regional power trading

ZESCO is a member of the SAPP, a regional power trading block comprising member states' power utilities in the SADC region. The aim of SAPP is to optimise the use of available energy resources in the region, support one another during emergencies, and facilitate power trading among the member utilities through both bilateral and competitive markets. In this regard, it established the Short-Term Energy Market in April 2001 and then the day-ahead market in December 2009. The SAPP trading Platform was upgraded with Forward Physical Markets and the Intra Day Market in 2015. Trade on the SAPP market generally reduced from 2,132 GWh in the year 2018 to 2,005 GWh in 2019 representing a 5% decrease. The day-ahead market continued to dominate the SAPP market trade. Peak trade was recorded in October 2019, when total traded volumes rose to 256 GWh at an average Market Clearing Prices (MACP) of US cent 6.2/kWh. Meanwhile the average MACP reached its highest in July 2019 at US cent 10.3/kWh. For the rest of the year, traded volumes averaged 160 GWh at an average MACP of US cent 7.05/kWh. The SAPP recorded an increase in the number of total system disturbances in 2019 to 78 from 60 recorded in 2018. Major disturbances were recorded in January, February, July, and October 2019. Most of the system disturbances were due to power oscillations especially in the central corridor (Botswana, Zimbabwe and Zambia). These disturbances interrupted energy interchange among SAPP members but also endangered performance of power equipment.

ZESCO electricity exports and imports

As a member of the SAPP, ZESCO was involved in cross border trading with other regional utilities through bilateral agreements and or the spot market. During 2019, ZESCO recorded a 22% reduction in exports from 1,250.4 GWh in 2018 to 975.6 GWh in 2019 due to the reduced electricity generation from most of its hydro power plants. Meanwhile, ZESCO's imports increased by 30% in 2019 from 152.2 GWh in 2018 to 198.2 GWh.

Electricity consumption

During year 2019, total electricity consumed was 12,526 GWh which was a 4% reduction from the 13,080 GWh consumed in 2018. The reduction in total electricity consumption over this period was attributed to the decrease in generation occasioned by low water levels in the main reservoirs. The mining sector accounted for the highest consumption of national electricity of 51% (6,359 GWh). The second energy intensive sector was the domestic sector which consumed 33% (4,023 GWh) of electricity. Meanwhile, the other sectors accounted for 16% (2,144 GWh) of the total national electricity consumption. Generally, consumption from all the sub sectors reduced marginally consistent with the reduction in generation between 2018 and 2019. However, in order to minimise the adverse economic impact of the electricity shortage, the reduction in power supply to economic sectors was marginal and the burden was borne by residential customers resulting in longer hours of load shedding.

Strategic considerations related to electricity generation

The GRZ has defined its strategic objectives under the National Energy Policy (NEP) 2019, which is to "achieve universal access by year 2030 through an optimal energy resource utilisation to meet the country's domestic and non-domestic needs at the lowest total economic, financial, social, environmental and opportunity cost and establish it as a net exporter of energy"[31]. In order to achieve these objectives, the Government has identified ten specific strategic considerations and policy measures (see the Box below). The provisions of NEP 2019 have important implications for the development of the generation sub-sector.

Box 1: Strategic consideration and Policy Measures

1. Strengthen institutional arrangements.
2. Strengthen regulatory frameworks.
3. Promote efficient use of energy.
4. Promote sustainable exploitation of biomass resources.
5. Increase exploitation of renewable energy (RE) to diversify the energy mix.
6. Increase access to electricity by expanding generation, transmission and distribution capacity.
7. Ensure adequate, reliable and affordable supply of petroleum products and natural gas.
8. Promote private sector participation in the sector.
9. Promote innovation, and research and development.
10. Mainstream gender, climate change, and health and safety in the energy sector.

Source: Zambia National Energy Policy 2019

Exploitation of indigenous energy resources

A quick review of the strategic direction and imperatives of NEP 2019 make the following abundantly clear:

[31] Ministry of Energy (2019): National Energy Policy 2019, https://www.moe.gov.zm/?wpfb_dl=51

a) generation, which is usually two-thirds of the delivered cost of electricity to the end-consumers, can go a long way in achieving optimal lowest costs;
b) exploitation of renewable energy based on national endowment can broaden generation-mix and energy security, and also reduce the fiscal burden due to imported fuel supplies;
c) greater reliance on distributed generation can potentially lead to off-grid supplies and enhanced access to electricity in remote rural areas; and
d) increase in the proportion of renewable energy could help the GRZ protect the environment and meet its obligations under the Paris Agreement (COP21).

Hydro generation potential and planned projects

According to the estimate of studies undertaken in the past, Zambia has a potential of hydropower generation of more than 6,000 MW and only 2,398MW out of that has been developed so far.

On-grid large hydro generation potential: Cognisant of this potential, the Government has planned to develop several large on-grid hydro-power projects in the coming years[32].

Table 10: Generation projects (all types) with completed feasibility studies

Project Title	Site	Capacity (MW)	Developer
Pensulo Wind Power Project	Serenje, Central Province	130	Access Infra Africa
Consolidated Farming Baggas Powered Project	Kafue, Lusaka	24	Consolidated Farming Ltd
Kabompo Gorge Hydroelectric	Mwinilunga, North Western	40	Copperbelt Energy Corporation (CEC)
EMCO Coal Fired Power	Sinazongwe, Southern	300	EMCO Energy Zambia Ltd
Bulemu West, Solar PV	Kabwe, Central Province	20	GET-FIT Program
Bulemu East, Solar PV	Kabwe, Central Province	20	GET-FIT Program
Aurora Solar 1, Solar PV	Kafue, Lusaka Province	20	GET-FIT Program
Aurora Solar 2, Solar PV	Kafue, Lusaka Province	20	GET-FIT Program
Garnaton North, Solar PV	Kitwe, Copperbelt Province	20	GET-FIT Program
Garnaton South, Solar PV	Kitwe, Copperbelt Province	20	GET-FIT Program
Leopards Hill Solar Project	Leopards Hill, Lusaka	100	Globeleq
Luakela Hydroelectric Project	Mwinilunga, North Western	0.3	Hydro Electric Power Ltd
Kushijika Kesi Hydroelectric Project	Mwinilunga, North Western	0.5	Hydro Electric Power Ltd
Chiyesu (Zengamina II) Hydroelectric	Ikelenge, North Western	1.3	Hydro Electric Power Ltd
Lufubu Hydroelectric Power	Lufubu, Northern Province	163	Lufubu Power Company
Muchinga Hydroelectric	Mkushi, Central province	230	Lunsemfwa Hydropower Limited
MGC Solar Power Project	Mumbwa, Central Province	100	MGC Power Corporation
Chunga Solar Mini-grid Project, Solar PV	Luapula	0.2	Rural Electrification Authority
Kasanjiku Mini Hydropower Project	Kasanjiku River,Mwinilunga District	0.64	Rural Electrification Authority

[32] Ministry of Energy and JICA (2009): Rural Electrification Master Plan for Zambia 2008-20030

Lunga Mini-grid Project, Solar PV	Mumbwa, Central Province	0.3	Rural Electrification Authority
Chavuma Hydroelectric Project	Chavuma, North Western	30	Sinohydro Zambia Ltd
Chipota Falls Hydroelectric Project	Mulembo River, Serenje,Central Province	0.2	UNDP/Ministry of Energy
Ngonye Falls Hydroelectric	Sioma, Western	180	Western Power Company
Ndeke Solar PV Power Plant	Mufulira, Copperbelt Province	53	ZESCO
Chipata West Solar PV power plant	Chipata, Eatern Province	100	ZESCO
kafue Gorge Lower solar power plant	Kafue Gorge, Chikankata District	200	ZESCO
Kabwe solar power plant	Chisamba, Kabwe Step Down	200	ZESCO
siavonga solar PV power Plant	Siavonga, Southern Province	200	ZESCO
Chambish east solar PV power plant	Chambishi, Copperbelt Province	241	ZESCO
Kalungwishi Hydroelectric	Kalungwishi, Northern Province	247	ZESCO/GRZ
Kafue Gorge Lower	Kafue, Lusaka	750	ZESCO/KGLHC
	Total	**3,411.4**	

Source: *Ministry of Energy and ZESCO*

Off-grid micro-hydro power potential and projects: Zambia also has a significant potential for off-grid micro hydro-power projects, and six specific projects with a total capacity of 23.65 MW at a cost of $49 million were identified under the Rural Electrification Master Plan in 2008.

Micro-hydro generation potential: Based on hydro potential surveys conducted under the Rural Electrification Master Plan developed in 2008, several feasible sites have been identified for micro-hydro projects to provide off-grid electricity to the nearby communities. A total capacity of 4.70 MW was considered feasible at a cost of US$ 36.79 based on the 2008 survey (see the table before). The feasibility criteria during the survey comprised of:

a) water-head measurement;
b) water discharge estimation;
c) hydropower potential estimation;
d) proximity to the consumption centre, construction cost and cost of associated infrastructure; and
e) potential beneficiary communities, delivered cost of electricity, and return on investment.

There were several other promising sites which did not meet the feasibility criteria at that time but could be reviewed to identify additional micro-hydro potential in Zambia.

Solar generation potential and projects

The World Bank, under a project covering biomass, solar and wind mapping, developed a solar resource model for Zambia that was refined by integrating fields measurements performed on six selected sites over a period of two years. The model results show a generally high solar resource, especially for the south-western apart of Zambia, where average value of global horizontal irradiation (GHI) exceeds 2,000 kWh/m^2/year. The collected data showed the performance that could be reached by fixed tilted PV systems with standard modules and demonstrated that electricity generation is very similar in all six sites with capacity factors between 19% and 20%. The highest levels of solar generation are expected during the months from July to September, while the lowest solar production levels are likely to occur in January and December due to the combined effect of GHI and air temperature on PV power generation. The peak season for solar generation occurs during the dry season when reservoir levels and hydro generation are at their lowest values, and hence there is a complementarity between solar and hydro generation that can help the system during the dry season. The table below provides an overview of the solar power potential in Zambia in terms of existing and committed/candidate projects[33].

Wind generation potential and projects

Zambia is still in the early stages of exploring the resource potential for wind power: to date there are no utility scale wind turbines operating in the country. The Consultant (DNV GL) commissioned by the World Bank to develop a mesoscale wind atlas for Zambia, to be validated with wind speed measurements taken at eight met masts over a period of two years. The 80-metre-high masts were set up at Choma, Mwinilunga, Lusaka, Mpika, Chanka, Petauke, Mansa, and Malawi, and data collected during November 2016 – January 2018, indicated mean wind speed of 5.7 – 6.5 meter per second (m/s). DNV GL executed long-term adjustment of wind speed and estimates the wind speed from the measurement height to the 130 m hub height, which ranges between 7.0 – 8.2 m/s. Capacity factor for potential wind farms near the location of these eight masts ranges between 29.8% to 40.4%, indicating promising wind power potential in Zambia; however, there is currently only one candidate project, and the table below details of this wind generation project.

The energy potential available in Zambia from pre-feasibility studies conducted and ongoing feasibility studies is shown in Table 11 below.

Table 11: Portfolio of potential projects with completed pre-feasibility studies and ongoing feasibility studies

Energy source	Available potential (MW)
Hydropower	5,853 of which: • 5,488 large hydro power plants • 365 small hydro power plants
Thermal power	1,600 of which: • 1,300 coal fired power plants • 300 heavy fuel oil (HFO) power plants
Solar power	1,310
Wind power	920
Geothermal	320
Waste to Energy (Biomass)	240

Source: *Ministry of Energy Zambia*

The hydropower potential projects (amounting to a total of about 5,853 MW) are currently undergoing feasibility studies. For the wind sites assessed, there is a potential of about 920 MW. The solar power resource that has been assessed – where over 80% of the potential projects have undergone prefeasibility studies and are pending full feasibility studies – has revealed a potential of about 1,310 MW. Zambia has potential for thermal power of about 1,600 MW, comprising of coal fired and heavy fuel oil power plants; around 90% of these potential projects have been assessed and are located in Sinazongwe district in the Southern province of the country. Zambia also has the potential for geothermal power generation, however, only 320 MW has been assessed. Lastly, the

[33] CESI (2020): Integration of Variable Renewable Energy Sources in the National Electric System of Zambia

total capacity assessed to produce electricity using biomass is 240 MW, and most of the projects are in the infancy stages of pre-feasibility.

Biomass (wood-fuel) resources and consumption

According to 2014 remote sensing data, Zambia has approximately 46 million hectares (ha) of forests, covering about 61% of the country's total land area[34]. There are 490 official Forest Reserves (FRs) covering 4.2 million ha: 184 of these are national FRs to protect and conserve water catchments, and 306 are local FRs. Zambia has only around 59,000 ha of timber plantations, of which 50,000 ha (85%) are managed by the state-owned enterprise ZAFFICO. Due to unsustainable consumption of wood-fuel, the deforestation rate has been estimated at between 250,000 and 300,000 ha per year. The main drivers of deforestation and land degradation are agricultural expansion, mining, and wood extraction for wood-fuel and charcoal. Wood-fuel and charcoal account for up to 80% of Zambia's energy consumption. The table below presents the estimated wood-fuel consumption as household fuel, as well as for charcoal production.

Table 12: Wood-fuel for charcoal and household fuel, 2019

Forest Resource Use	Households	Exports	Total Use	% Use
Charcoal licensed (M3)	196,294	26,767	223,061	3.3%
Charcoal unlicensed (M3)	4,845,057	1,567,518	6,412,575	93.6%
Firewood licensed (M3)	749	-	749	0.0%
Firewood unlicensed (M3)	211,732	-	211,732	3.1%
Total Wood Products (M3)	**5,253,832**	**1,594,285**	**6,848,117**	**100.0%**

Source: *Zambia Forest Note, World Bank Publication, December 2019*

Geothermal resources and planned project

The GRZ's quest for geothermal resources are at an early stage, and it has commissioned Kalahari GeoEnergy to conduct exploration work in central Zambia which has drilled eight geothermal wells around the Bweengwa River, west of Lusaka[35]. The initial results have indicated the characteristics of a viable geothermal resource for electricity generation, and the company has identified six areas that could provide steam for power generation. The surface manifestations of the Bweengwa River Geothermal Resource Area include three groups of geothermal springs that extend over 9 km and are located on the southern fault of the Kafue Pit. Once the exploration results are confirmed, full technical and commercial feasibility study for a 10 MW power plant would be commissioned.

Coal resources, supply, and consumption

Zambia holds 50 million tonnes of proven coal reserves as of 2016, ranking 64th in the world[36]. These reserves are equivalent to 270 times the current annual consumption meaning the reserves could last for about 270 years if the existing consumption continues at this level and no additional reserves are added. In 2016, Zambia produced 138,946 tonnes of coal and imported 44,384 tonnes, while consuming 183,693 tonnes in different economic sectors. Mamba Collieries Limited is a major coal producer and operates a 300 MW mine-mouth coal-fired power plant. The table below provides an overview of the coal sector in Zambia.

[34] The World Bank (2019): Zambia – Country Forest Note, Towards a Sustainable Way of Managing Forests
[35] Afrik21 (2019): Zambia - Kalahari GeoEnergy conducts research for geothermal project
[36] The Global Economy (2021): Zambia Coal Resources and Utilization Zambia economic indicators | TheGlobalEconomy.com

Table 13: Coal reserves and consumption

	2016 Consumption (Tonnes)	Global Rank
Coal Reserves	49,603,950	64th in the world
Coal Production	138,946	59th in the world
Coal Consumption	183,693	94th in the world
Yearly Deficit	(-44,747)	
Coal Imports	46,205	
Coal Exports	1,821	
Net Imports	44,384	
Zambia's population (No.)	16,363,458	
Per Capita Consumption (kg/year)	11.23	

Source: www.theglobaleconomy.como › coal › Zambia-coal

Nuclear energy programme

Zambia's nuclear energy development is in its early stage and is planned to be implemented in two phases. During the first stage to be implemented over the next 5-6 years, a Centre for Nuclear Science and Technology is planned to be constructed primarily to produce medical isotopes. In the second stage, construction of a 2400 MW nuclear power plant is planned to diversify and broaden the generation-mix in Zambia[37]. Nuclear energy can, therefore, be a long-term energy option for the country considering the long lead time for constructing and operating the nuclear plants.

Different approaches for power sector planning

Past planning approach in Zambia and consequential risks

The absence of an integrated planning approach has led to an uneven development and growth of the electricity sector in the past many years in Zambia. Sector planning has been historically undertaken for the generation, transmission and distribution operations separately, but the linkages with the development of the fuel supply infrastructure or implications of climate change and environmental factors on the operations of the electricity sector have not been studied to come up with least-cost and resilient generation expansion plan. While traditional power sector master plans have been developed at the national and regional levels in the past, implementation of the proposed actions and projects under these plans has lagged behind and created capacity shortfalls.

While the load shedding of the last 5 years forced the Government to broaden the generation-base, it is unclear if adequate investments were made to develop the fuel supply systems, be it security of liquid fuel supplies or exploitation of indigenous coal resources. Similarly, commensurate investments in the transmission and distribution infrastructure were not forthcoming resulting in serious shortcomings in delivering electricity to end-consumers. The non-integrated approach and inadequate implementation of development projects has created major risk factors as follows:

- Major reliance on hydro-generation (82%) with its seasonal fluctuations, even though Zambia is reasonably well-endowed with indigenous energy resources and a systematic and integrated approach could have reduced this over-reliance and could have established a better balance between on-grid and off-grid supply systems.
- Climate risk and resource competition vis-à-vis electricity security from hydro-generation plants are significant, as these are multi-purpose projects with river-flows meeting the farming needs of the agriculture sector as a priority on the one hand, and drinking water

[37] Ministerial Statement (2018): The Minister of Higher Education, Nuclear Science and Technology Programme in Zambia http://www.parliament.gov.zm/sites/default/files/images/publication_docs/MINISTERIAL%20STATEMENT%20BY%20THE%20%20MINISTER%20OF%20HIGHER%20EDUCATION.pdf

needs for urban and rural communities on the other. Climate change has adversely affected water inflows and the resulting electricity generation.

- Lack of cost-reflective tariffs and financial sustainability of the electricity sector means that not enough revenues are available to pay for the higher-priced supplies from the private producers, nor are there any resources available to invest in cost-effective generation, transmission, distribution and fuel supply systems in Zambia.
- Grid readiness in Zambia is highly inadequate barring connectivity to the capital city of Lusaka and the mining towns in the Copperbelt and North Western Province, Grid readiness in Zambia is inadequate and evacuation and delivery of electricity to the markets is a challenge, especially to the provinces being under-served with restricted and unstable grid Absence of an integrated approach means that the country has significant untapped renewable energy resource which is not utilised because of the absence of transmission and distribution infrastructure, both on-grid and off-grid.

Planning approach and experience in other countries and regions

Zambia is not the only country that has suffered because of an uncoordinated approach towards long-term energy planning, and lack of implementation of actions spelled out in the master plans developed in the past. Power sector planning in contemporary times has been undertaken in different African countries and regions as follows:

Nigeria

Nigeria is a significant producer of crude oil and associated natural gas and has the seventh-largest hydrocarbon resources in the world. Its proven gas reserves stood at 180 trillion cubic feet, and it was producing almost 5.5 billion cubic feet per day. Paradoxically, Nigeria was flaring over 1.2 bcf/day after accounting for use in the Liquefied Natural Gas trains, re-injection in the reservoir, and limited domestic consumption. Conscious of this situation, the Government of Nigeria embarked on an ambitious plan of developing the power generation dependable capacity in the country which stood at a little over 3500 MW for a country of over 150 million people. It obliged international oil companies to put up new capacity, which was done without adequate capacity and investment in the fuel-supply infrastructure or the transmission capacity, resulting in stranded generation assets for a long period.

Ghana

The country struck the first offshore oil discovery in 2008, and quickly embarked on the development of crude oil and associated gas resources for the benefit of major customers in Ghana. It had experienced major electricity supply disruptions earlier as the country relied pre-dominantly upon the hydro-generation plants which were seriously impacted by climate change events. The Government of Ghana implemented a number of thermal plants using imported light crude oil, which placed a heavy financial burden on account of volatility of global prices. The offshore oil discovery for Ghana was very welcome but it was in the western part of the country, while the major power plants were in the eastern region near Accra. While the Government of Ghana desired to substitute the imported liquid fuel supplies with indigenous natural gas, it did not consider adequately the investments in the gas transmission infrastructure resulting in stranded gas.

Sub-Saharan Africa

Several Sub-Sahara African countries have relied upon a narrow generation-mix, which has been seriously impacted by hydrological conditions and climate-change event. In addition, investments in transmission and distribution infrastructure have been uncoordinated with generation expansion, resulting in sub-optimal evacuation of power to the markets and distribution to the end-customers.

Most of the problems have arisen because of power sector planning in silos with generation attracting the maximum attention of the decision-makers.

4.3.2 Proposed approach and methodology

The methodology and approach for the IRP development in Zambia is proposed to be integrated taking into account the complete value chain of electricity from fuel supply, generation, transmission and dispatch, and distribution and sale to the final customers. The integrated approach would highlight the weakest link in the supply-chain, and hence would enable decision-makers to take corrective actions. Another advantage of the integrated approach would be the consideration of technical, financial, commercial, and environmental parameters all at the same time. Use of optimisation routines would ensure that best-feasible financial solutions would be provided through the IRP. Scenario-building and sensitivity analysis allows decision-makers to test the consequences of different policy interventions. Another feature of the proposed approach of IRP implementation is that it would be highly participative and consultations-based.

Integrated approach

The IRP process will adopt an integrated approach, which is expected to result in a long-term power sector resource plan that will serve the expected electricity peak demand (MW) and energy requirements (GWh) over the long-term horizon (30 years). The long-term projections to be developed by the demand workstream (see Section 4.2) would inherently take into account considerations relating to energy efficiency due to the technological innovation or implementation of demand-side management plans. Over such a planning timeframe, the IRP would incorporate the following:

a) resource base, supply side assets (hydro, thermal and renewable), demand side interventions (efficiency, demand side management), and transmission capabilities;
b) incorporate unit capital and operating costs for new and rehabilitation projects, as well as overall system costs;
c) include emissions from the operations of electricity-sector assets;
d) include unit commitments and merit-order dispatch and consider the Variable RE in the grid; and
e) consider and evaluate uncertainties such as climate change, hydrology, fuel prices, regulatory changes and policy goals through scenario analysis. Two kinds of analysis would be undertaken: (i) scenario analysis estimating the impact of government policies on the operation of the power system; and (ii) sensitivity analysis whereby impact of events outside the control of the government (e.g., climate change) on sector operations would be assessed.

The output of this integrated approach and inter-play of different competing factors would be a least-cost resource expansion plan, including investment requirements, system costs, expected dispatch, CO2 emissions, and electricity prices.

Optimisation of sector costs

IRP is envisaged to be a production cost simulation model designed to project competitive market prices of electrical energy in Zambia's electricity sector. The model would also project plant generation levels, new power plant construction, fuel consumption, and inter-regional transmission flows using a linear programming optimization routine with dynamic effects – i.e., the IRP would look to future years and simultaneously evaluate decisions over an entire forecast horizon.

The optimisation process under the IRP would be undertaken in two steps: first, the least cost generation plan would be developed to reflect the situation for the base-year (proposed to by year 2020) as closely as possible. In the second step, scenarios/cases for over-riding factors (e.g., energy security, social and environmental protection) would be run to evaluate the impact of achieving these additional objectives. Linear programme methodology is used to define the overall objectives and the binding constraints for formulating and addressing the multiplicity of objectives.

All major factors affecting wholesale electricity prices are accounted for in IRP and include a detailed representation of existing and planned units, with careful consideration given to fuel prices, environmental allowance and compliance costs, and operating constraints. The IRP would project short-term price of electricity, annual capacity charges, and estimates of the marginal cost of emission reductions for the electricity generation sub-sector. IRP would also enable the determination of the least-cost means of meeting the environmental regulatory requirements, such as CO2 emissions caps, and would forecast prices for each cap market and compliance costs, unit dispatch, and retrofit decisions for each thermal generator.

The generic formulation of the optimisation question would be as follows:
Total Costs = (Gen Costs + New Cap Costs + Tran Costs + Emis Allowance Costs + Un-served Engy Costs) subject to:

- Capacity constraints
- Energy constraints (supply to meet demand)
- Operational constraints (turn down, capacity factor, pump storage, etc)
- Fuel use constraints
- Emissions constraints
- Transmission constraints

Least Worst Regret methodology

The Least-Worst Regrets (LWR) resource planning is used in the electricity sector when one is dealing with uncertainty where probabilities cannot be associated with the occurrence of future outcomes.

In such situations, the 'regret' is the difference in cost between the decision made and the optimal decision, given the actual realisation of a scenario e.g., a case where we could have saved $100 million on transmission capacity had we known the population would not grow. The National Grid of the UK has used this methodology for network capacity planning; capacity auction procurement, and supplemental balancing reserve.

The advantage of using LWR is that it is independent of the probabilities of the various potential future outcomes and generates risk averse (robust) solutions to protect from the worst-case outcomes. It provides the highest performance under the selected metrics in Zambia, which could be one or more of the following:

- net present value of revenue requirements;
- wholesale power prices;
- residential load served;
- un-served energy;
- build-plan volatility; and/or
- Greenhouse gas (GHG) emissions.

The metrics are appropriately weighted, statistically analysed, and combined to determine a score for each strategy, which fulfil specific objective(s), and all the strategies are ranked based on their scores. In general, the resource plan of a highly ranked strategy is more resilient under different scenarios, and IRP shall identify policies and strategies, which lead to a high score for a resource plan for Zambia.

The LWR solution for capacity expansion for Zambia's power sector shall be determined by evaluating how different policies and strategies for the future development of the power sector will react under varying sensitivities. In essence, a LWR strategy has the overall best characteristics in terms of cost, resilience, reliability, and environmental concerns, even under a broad range of potential techno-economic futures.

Input data requirements

In order to develop a planning structure and populate it with the necessary inputs, the following data would need to be collected:

Table 14: Illustrative IRP reference scenario data requirements and challenges

Description of Inputs	Potential Source of data	Data Challenge	Proposed Solution
Historical hydrological data, and projections	Ministry of Water Development, Sanitation and Environmental Protection; Zambia Meteorological Department	Historical data may be for insufficient number of past years and incomplete, and projections may not be available	Use data from international agencies, if necessary.
Electricity generation (plant-wise installed and firm capacity; technology; year of installation; economic life; plant factor; historical plant availability and forced outage rate; duality of fuels; fuel consumption; units generated; BTU/kWh; auxiliary consumption; capital cost; operating cost breakdown; system reserve margin; etc.)	ZESCO; ERB; OPPPI; IPPs	No major challenges anticipated; data for some legacy plants may pose challenges.	Suitable assumptions may be made.
Fuel supply for power generation (coal, liquid fuels)	MoE	Disaggregated data by plant/unit may pose challenges	Estimation may be made by energy generation
Off-grid / stand-alone electricity systems	ERB	Reliable off-grid / stand-alone generation data may not be available	Sample surveys may be undertaken
List of projects already committed and to be included in IRP (including more long-term projects)	MoE; OPPI; ZESCO	No major challenges anticipated; plants with financial close or already under implementation may be considered.	Seek agreed list from MoE
List of must-run generation plants	ZESCO	Views may differ on such plants.	Seek consensus at the MoE level
National resource base and energy potential	MoE; ZESCO; ERB	Resource data estimates may be outdated	Use available data as place-holder in the IRP model
Typical unit capital and operating costs, phasing of costs, average implementation period	MoE; ZESCO; ERB	Reliable unit cost data may not be available or may be highly divergent	Industry data-bases (adjustments to be done for Zambian conditions)

Empirical emissions for generation units, Zambia EPA specs/data, CC occurrences	Zambia EPA	Emissions data for thermal plants may not be available, given that few plants exist in Zambia	industry data-bases (for baseline emission levels)

Generation sub-sector indicative outputs

The IRP is envisaged to provide a long-term generation expansion plan that will, *inter alia,* provide the following key outputs:

- Generation capacity (MW) year-wise, existing and new (with broad plant location). Separate outputs would be available for on-grid and off-grid/distributed energy resources.
- Timing of capacity additions and retirements.
- Energy generation (GWh), reliability statistics, and dispatch of available capacity.
- Electricity delivered for transmission to the markets.
- Capacity and energy costs from each plant – considerations of societal benefits, i.e., cleaner environment due to waste-to-energy project would be outside the scope of this work.
- Overall power generation costs (capital, variable O&M, fixed O&M and fuel costs). This overall plan would not include analysis relating to the alignment of macro-economic framework; absence or otherwise of cost-reflective tariffs; financing of investments; and/or private sector participation. Such analysis would be separately done under the IRP Power Procurement, Financial Mobilisation, and Market Structure workstream.
- Fuel supply, consumption and prices.
- Emissions (NOx, SO_2, CO_2) and mitigation cost.

4.3.3 High-level summary of next phase activities

The table below presents an overview of the main activities for the generation planning workstream, as well as the outputs associated with each task and the date by which it is expected the task will be completed. The table also shows how each task and output relate to the overall IRP project deliverables.

It must be noted that there will be close collaboration with other workstreams, as the generation planning workstreams will require inputs on long-term demand, transmission and distribution infrastructure, and environmental and climate-change considerations for developing different scenarios.

Table 15: Generation planning – Summary of activities

Deliverable	Main activity	Output	Expected completion date
D2 – Consolidated IRP Implementation Report (Component 1: Least-cost Generation Options and Resource Assessment - Model and Report)	Collect and compile: (a) generation resource assessment data, e.g., hydro, solar, wind, geothermal, biomass, coal, nuclear; (b) capital and operating cost, completion time; and (c) emissions, environmental and resettlement mitigation costs	• Resource Assessment Data • Historical Data Book for the electricity Sector • Write-up on the basis and assumptions and use of the Data Book	End April 2021
	Develop an initial IRP structure to represent the Zambia generation sector and feeding of input data	• Working papers/PPT presentations for seeking confirmation of the initial structure and inputs	End June 2021
	Define and develop: (a) Reference Scenario; (b) comparison of the Reference Scenario predicted results with 2019 Actual for generation	• Working papers documenting scenario definitions • RP model computer outputs • Working papers documenting major variances and model	Mid-July 2021

	module calibration; and (c) validate the IRP model	refinements done	
	Undertake Reference Scenario computer-runs	• Computer outputs for Reference Scenario generation expansion plan (year wise capacity addition by technology, location, costs, and emission-levels)	End July 2021
	Finalise the initial Reference Scenario generation expansion plan	• IRP model computer outputs • PPT presentation describing model structure, key inputs, basis and assumptions for future expansion, and major outputs	Mid-August 2021
	Consult with stakeholders to: (a) share the initial Reference Scenario generation expansion plan; and (b) develop a set of alternative scenarios	• Workshop to present Reference Scenario results to the stakeholders	End August 2021
	Refine the generation expansion planning model with updated data, and with revisions to the model structure; and undertake model runs for Alternate Scenarios	• Working papers / computer outputs	Mid-October 2021
	Prepare and deliver capacity-development training on resource assessment and generation expansion planning	• PPT presentations and training workshops	Mid-December 2021
	Prepare inputs to implementation report related to generation planning	• Relevant sections of implementation report	End September 2021
D3 – Scenario Analysis Report	Finalise draft generation expansion model, and compilation of results for different scenarios	• Draft document / working PPT presentations for dissemination to stakeholders and for capacity-building, as appropriate	End October 2021
	Finalise inputs to the scenario analysis report relating to generation planning	• Relevant sections (Generation) of scenario analysis report	Mid-December 2021
	Prepare and delivery capacity-development training on scenario analysis	• PPT presentations and training workshops	Mid-February 2022
D4 – Draft IRP Report	Prepare inputs to draft IRP report related to generation planning	• Relevant sections of draft IRP Report	Mid-February 2022
D5 – Final IRP Report	Finalise inputs to the IRP Report related to generation planning	• Updated relevant sections of draft IRP Report	End March 2022
D6 – Completion Report (including capacity-building activities)	Prepare inputs to completion report related to generation planning	• Write-up of capacity building activities	Mid-February 2022
	Handover of the IRP model and documentation to the designated entity, and performance of project close-out activities	• Models and software on magnetic-medium • User manual/capacity-building materials • Project documents/reports	End March 2022

4.4 Transmission Infrastructure Planning

At its core, transmission planning aims to provide optimal transmission capacities to enable transportation of power from generation sources to load centres securely and economically. The transmission-planning problem is traditionally formulated as an optimisation problem, whose objective function is to minimise the sum of annual generator operating costs and annuitised transmission investments costs subject to physical laws that govern power flows in a power system, generator and transmission capacity constraints as well as network security constraints.

The annual demand is modelled as a load duration curve usually simplified into several demand levels.

Transmission network planning as part of the overall IRP project will is split into the following three phases:

1. *Situational assessment* – this includes a review of the similar work completed in Zambia up to this point. This is to avoid duplicating with the previous or current energy programme activities.
2. *Review of transmission planning practices* – this includes a review of experiences and processes used for the transmission network planning.
3. *Transmission planning methodology* – development of the appropriate technical and financial transmission planning methodology based on the collected and reviewed information.

A number of energy related programmes have already been completed in Zambia or are still in progress. The transmission workstream has reviewed processes and outcomes of the following activities.

4.4.1 Situational assessment

Overview of related energy programmes

A summary of the key energy programmes that are being undertaken in Zambia is provided in the table below.

Table 16: Summary of the key energy programmes done in Zambia

Programme	Key objectives	Latest activities
GET FiT programme	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. The initial phase of the GET FiT Zambia program was a tender for up to 100 MW of Solar PV capacity, which was launched in February 2018. The REFiT Strategy also allocated 100 MW of capacity to hydro projects. The Grid Integration Component of the GET FiT Program consists of three different elements: 1. The provision of advisory support to ZESCO regarding grid integration of solar PV into Zambia's national grid. 2. The provision of technical assistance for improved grid management; and The provision of financing for grid integration for select technologies, such as PV and hydro.	The GET FiT Zambia Secretariat continues to share lessons learned following the record setting results achieved in the Solar PV Tender while working with awarded consortia on achieving their project milestones.
RES4Africa	RES4Africa Foundation and Enel Foundation in collaboration with CESI, the MoE of Zambia, ZESCO, the ERB and the SAPP, have carried out the study Integration of Variable Renewable Energy Sources (VREs) in the National Electric System of Zambia. A study was done to assess the maximum amount of variable renewable energy that can be integrated into the grid while maintaining its stability. It is worth underlining that the aim of this VREs integration study was the optimal VREs integration in the Zambian electric power system given the existing and committed hydro and fossil fuel generation fleet. The study was not a least costs generation expansion plan; therefore, no candidates from non-VREs technologies (e.g., hydropower candidates) were analysed. The system reliability impact study shows that the transmission network expansion plan outlined by ZESCO will allow the development of big amount of VREs generation both in the mid- and in the long-term.	

Programme	Key objectives	Latest activities
	Nevertheless, the study suggests that additional transmission network studies are done.	
CIGZambia *Scaled Renewable Energy* project with ZESCO	The CIGZambia project objective is to support ZESCO and ERB to implement set of technical, financial and regulatory changes by adopting the latest practices for VRE integration, transmission network planning expansion and financially sustainable operation of the power sector.	• Transmission and Distribution Grid Code activities This component brought expert knowledge to support ZESCO, the ERB, and the Renewable Energy Grid Code Review Working Group. The provided support included developing amendments to the existing transmission and distribution grid codes to ensure they are suitable for the connection of grid scale intermittent or variable renewables (in particular wind and solar). Technical assistance was provided through facilitated workshops and mentoring. Technical inputs were provided through the drafting, stakeholder consultation and publishing phases. • VRE connection standards, Grid Code Compliance and Certification This component aimed to support a team within ZESCO to define the processes and procedures that intermittent renewable energy generators connecting to the network will need to follow to ensure compliance with the relevant codes and standards. It provided high-level training aimed at a range of ZESCO staff interested in the impact of renewable energy on the network and it provided an overview of the key aspects that need to be considered when connecting these generators to the system (such as control, fault levels, inertia, reactive power requirements, and harmonics). Capacity building activities included undertaking some elements of the actual static and dynamic DIgSILENT studies and understanding the details of the required commissioning tests. • Renewable Energy Penetration Studies This component brought expert knowledge to support and facilitate ZESCO's review of renewables penetration studies previously undertaken by other actors. It also aimed to build capacity with a carefully selected group of ZESCO engineers to ensure that they have the understanding

Programme	Key objectives	Latest activities
		and capability to plan and undertake these types of studies themselves for a range of scenarios. The initial objective of the required renewable energy penetration study was to inform the drafting of the renewable energy grid code (above) but also to form the basis long term network planning, renewable energy policy and network charging work. The process involved detailed basic and advanced DIgSILENT software trainings, which were facilitated through a series of workshops. These included building and verifications of the software models, completion of static, dynamic and power quality studies. Following support and capacity building with the REPS team, ZESCO has produced a final studies report and the presentation of that report.

It is worth highlighting here some **key lessons learned** from the CIGZambia *Scaled Renewable Energy* project.

1. **Geographic Information System (GIS) database**
    - Activities completed as part of the *Scaled Renewable Energy* project showed that a GIS is not currently available. Even though this may not be at the core of the transmission workstream planning activities, this exercise will be completed as part of the ongoing activities since such resources will be useful to Transmission Network Service Provider (TNSPs) for the purpose of the transmission system development.
2. **Software modelling and system studies**
    - Activities completed as part of the *Scaled Renewable Energy* project showed that ZESCO already uses DIgSILENT PowerFactory software for planning the transmission network. ZESCO already has in place steady state and dynamic models for the year 2020 and these models were used as a basis for the development of the models for the year 2025 and year 2030, as part of the *Scaled Renewable Energy* project. Capacity building activities delivered by CIGZambia included instructions on how to update models and perform system studies. This increased capacity will translate to transmission workstream planning activities. As such, since the software tool and models are already available, the transmission workstream activities will not involve any new software tools.

Review of recent studies

A number of previously completed studies were reviewed as part of the overall literature review activities. The most important studies and some brief observations are as follows, organised by publication year:

Table 17: Review of recent studies related to transmission planning

Study	Brief observations
Zambia Cost of Service Study[38] (2020)	Based on the inception report, this study briefly discusses transmission network inputs and relies on review of the existing ZESCO practices. It is mentioned that transmission network studies will be performed but the inception report does not include the methodology that will be used for the transmission network planning. The transmission planning workstream will monitor the status and the results of the COSS and account for recommendations and suggestions by this study, as soon as the final report is finalised and approved.
Reduction of Losses (GFA) Report[39] (2020)	This Report discusses reduction of losses in transmission and distribution system across group of countries including Zambia. The primary means of losses reduction include reactive power compensation and adjustment of tariffs. Nevertheless, there is no information that can be used for long-term transmission network expansion and planning.
RES4Africa Study[40] (2019)	The Study was done to assess the maximum amount of variable renewable energy that can be integrated into the grid while maintaining its stability. Even though the reliability of the transmission network is assessed at the high level, this study does not provide a detailed description of the transmission network plans. Completed work suggests that additional transmission network studies are done, and this has been completed as part of the *Scaled Renewable Energy* project done by CIGZambia.
Power System Development Master Pan[41] (2011)	The Master Plan was completed in 2010 and is used as a basis for long-term system planning. A detailed technical assessment of the transmission projects is included, however basic costing for the project is provided and there is no clear methodology how to prioritise transmission projects.
Feasibility Study and Conceptual Design of Tanzania-Zambia Power Interconnector Study[42] (2017)	In terms of transmission network analyses, steady state and dynamic analyses are performed for the Tanzania-Zambia interconnector for year 2020 and 2025. Network analyses were performed for the localised area in the electrical vicinity of the interconnector. Insulation levels for the interconnector were also studied.

[38] Energy Market and Regulatory Consultants Limited (10th January 2020): Zambia Cost of Service Study, Inception Report
[39] GFA Consulting Group (May 2020): Reduction of Technical Losses in the Transmission and Distribution System of Mozambique, Uganda, Zambia and Zimbabwe
[40] Enel Foundation (4th February 2019): Integration of Variable Renewable Energy Sources in the National Electric System of Zambia
[41] Power System Development Master Plan, June 2011
[42] AECOM (October 2017): Feasibility Study and Conceptual Design of Tanzania-Zambia Power Interconnector Study

Complementary Study on Power Trade Volumes, Wheeling Arrangements and Impact on the Interconnected Networks for the Zambia-Tanzania-Kenya (ZTK) Interconnector Project[43] (2016)	The report discusses possible trade volumes between the SAPP and the East African Power Pool (EAPP) via the ZTK interconnector which links Zambia, Tanzania and Kenya covering the period from 2016 to 2023. Regulatory and institutional aspects, including wheeling charges, are presented as well as technical impact on the existing system.

Approach to transmission planning in similar IRPs, existing ZESCO practices and GAP analysis

Considering the review of the existing polices, studies and international experiences, it can be noted that master plans that were done in Zambia in the past need to be revised and harmonised with the latest developments in the energy sector. This particularly refers to the technical studies that need to be conducted as well as the criteria against which results need to be compared. In addition, it has been noted that previously used financial assessment of the transmission system relied mainly on CAPEX estimation without trying to minimise system costs or decide on the proper timing for the project implementation.

There is no universal approach when it comes to transmission planning since it is highly affected by the market structure and participants, as well as the technical particularities of each system, etc. However, it can be said that any transmission system needs to comply with technical constrains set by relevant standards and regulations and to minimise investment and operation costs. Moreover, the proposed transmission development concept needs to take into consideration all of the changes that already happened or are about to happen, such as large scale VRE connection, such as solar PV and wind generation.

The transmission workstream of the IRP project will closely coordinate with other workstreams, in particular the demand forecast and generation, and use their inputs to for the development of the optimal transmission network capacities. The overall objective will be to determine the optimal transmission investments that will ensure economic system operation and while satisfying prescribed security and reliability standards. The proposed technical and financial evaluation methodology for the transmission projects is discussed in the following section.

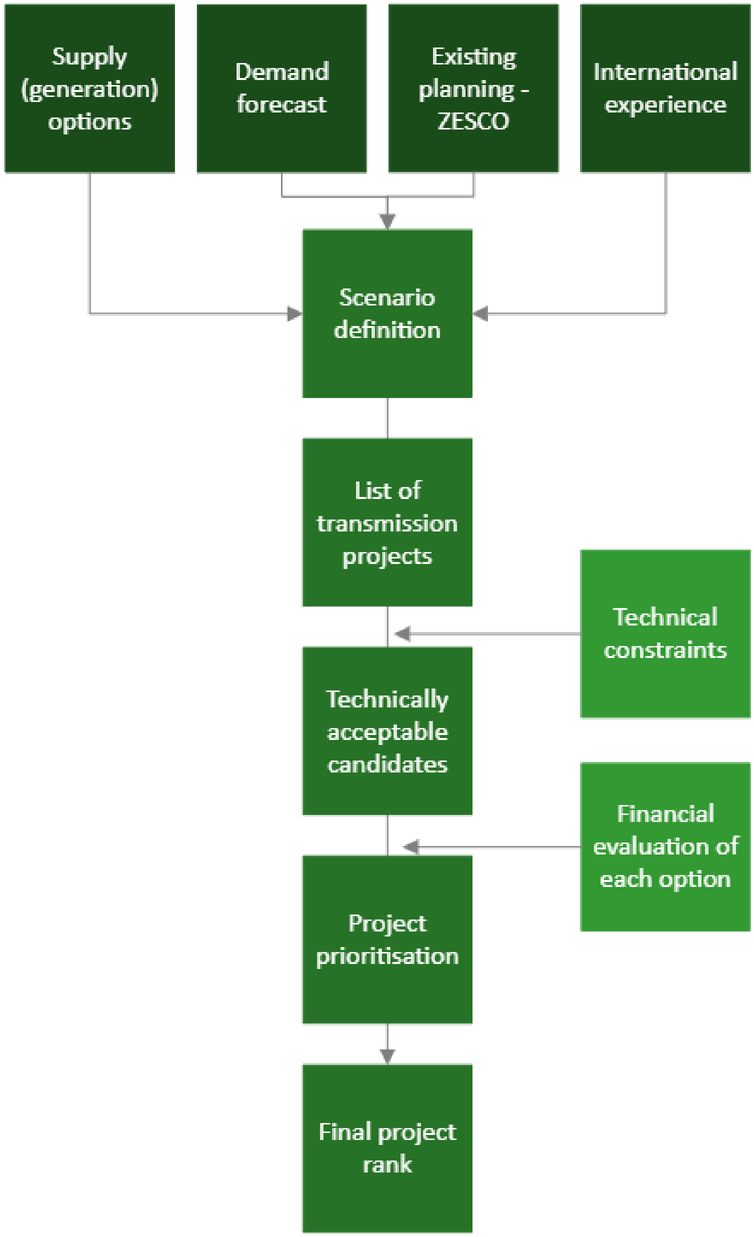
4.4.2 Proposed approach and methodology

This section describes the technical and financial methodology that is proposed for long-term transmission network planning in Zambia. It has been derived based on the situational assessment, the gap analysis, and a review of international practices. Transmission infrastructure development will be in line with SAPP's latest plans and standards and may involve the upgrade of the existing high voltage network to higher voltage level (e.g., 500 kV) if shown as necessary. Even though transmission planning will be harmonised with SAPP plans, the primary focus will be on addressing the Zambian system so that energy security is met. The transmission planning workstream will closely coordinate with other workstreams, particularly generation and demand forecast to develop a set of credible scenarios that will be used for required analyses of transmission network.

[43] Ricardo (2016): Complementary Study on Power Trade Volumes, Wheeling Arrangements and Impact on the Interconnected Networks for the Zambia-Tanzania-Kenya (ZTK) Interconnector Project

A summary of the transmission network planning philosophy is shown in the figure below.

Figure 25: Proposed transmission network planning methodology

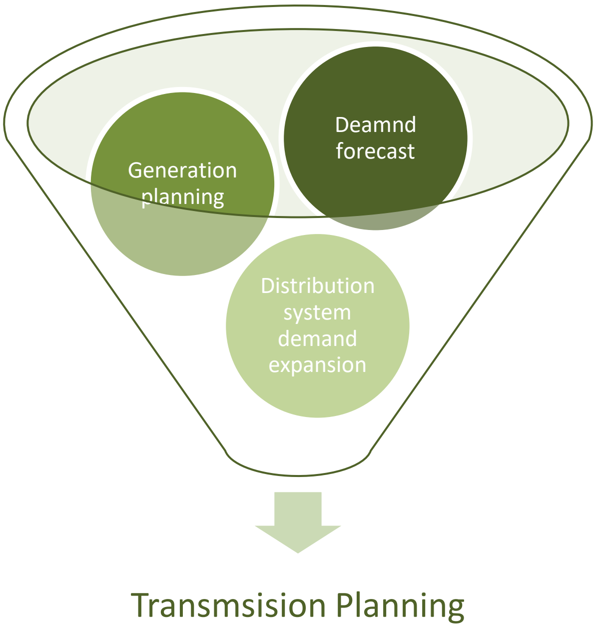


Once scenarios are defined between all involved stakeholders, the transmission workstream will use the methodology and tools described in the following sections to complete a 30-year transmission development plan, following transmission network technical *and* financial criteria. The primary focus will be on infrastructure development to meet projected demand, rather than to discuss system operation patterns that may not be predicted in a 30-year development timeframe.

Coordination with other workstreams

While overall coordination with the IRP project workstreams is crucial, the transmission workstream will rely most heavily on coordination with the demand forecast and generation planning workstreams. The relationship between demand forecast, generation planning, and transmission planning is summarised in Figure 26.

Figure 26: Relationship between the workstreams



Regarding the demand forecast workstream, it is expected that this workstream will provide demand information (in terms of the connected power) for residential, commercial and industrial sector and how these figures will change during a 30-year time horizon. The transmission workstream will thus seek for the maximum expected demand primarily because there is no major difference in consumption levels throughout the seasons in Zambia. The obtained demand figures on a yearly resolution will be used for update of the network models, which will be further assessed by completing a set of power system studies.

Regarding the generation planning workstream, the transmission workstream will require the generation plans for the 30-year planning horizon. These will include the type of the used technology (wind, solar, hydro, etc.), rating (MVA) and locations of these plants. Based on the provided inputs from this workstream, which will correlate with demand forecast, the transmission workstream will decide on the least cost transmission expansion solutions that will be used to connect generation to the consumers. The transmission workstream will consider developing high voltage overhead transmission circuits, substations, and underground cable lines considering the technical and financial considerations outlined in the subsequent paragraphs.

Influence of regulatory structure on transmission expansion planning

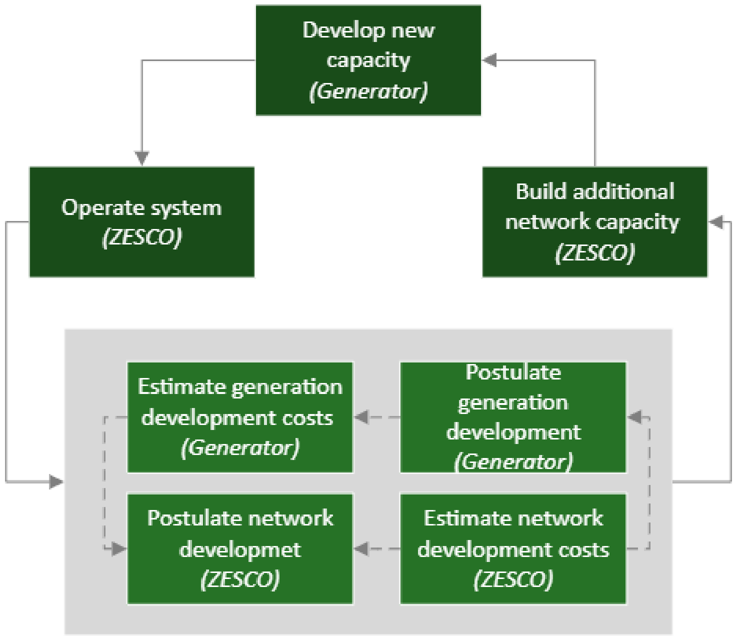
There are three possible approaches to transmission planning[44]:

- one approach typical of vertical integrated utilities; and
- two approaches reflecting a deregulated context where the transmission planner (ZESCO) cannot control generation investments.

The vertically integrated approach, shown in the figure below, is characterised by decisions on transmission investments coordinated within the vertically integrated entity via an iterative process. The iterative process successively refines generation and transmission development plans to deliver optimised or at least highly coordinated system development plan. This is often referred to as *centralised system planning*.

[44] CIGRE Working Group C1.24 (April 2014): Tools for Economically Optimal Transmission Development Plans

Figure 27: Vertically Integrated Planning Approach[45]



The second approach presents arrangement that might exist with a bilateral electrical energy market. In this decentralised arrangement the majority electrical energy is traded via bilateral arrangements between generators and retailers and the balancing mechanism is managed by the system operator. While the transmission planning authority has no direct control over generation development or future generation behaviour as a minimum the transmission planning authority would be expected to take into account available market signals such as balancing costs, congestion costs and transmission charges. In this arrangement individual market participants are making their own generation investment decisions. The transmission planning authority might or might not attempt to explicitly model a generator's investments. An example of such a structure can be found in Great Britain.

The third approach illustrates a pool-based electricity market in which the market determined prices provide a locational signal to generators. There may well be a financial market that overlays the physical energy market facilitating bilateral contracts between retailers and generators. Here, the immediate economic consequences of a transmission capacity enhancement can be seen in terms of locational market prices and the location.

It is assumed that ZESCO will remain the main custodian of the transmission network in Zambia in years to come, and that will be in charge to optimise existing generation and transmission operation.

Annex 5: Additional information for Transmission Planning Workstream sets out in detail the **proposed methodology for transmission project prioritisation** including:

- transmission network technical criteria;
- transmission network financial criteria; and
- transmission project prioritisation method.

Annex 5: Additional information for Transmission Planning Workstream also includes a **list of the existing and already planned transmission projects**. Please note that it is not a definite list of the planned transmission projects, as this will be fine-tuned as part of the transmission workstream planning activities.

[45] CIGRE Working Group C1.24 (April 2014): Tools for Economically Optimal Transmission Development Plans

Other transmission workstream activities – development of the GIS map

The transmission planning exercise will be complemented with the development of a GIS map, which will enable simplified geographical referencing of the existing and future transmission assets. The map will be developed in any of the freely available tools and imported to transmission software planning software so that analyses can be done. Geographic coordinates of the existing facilities will be provided by TNSPs, while the approximate location of the future network facilities will be determined based on the land availability, proximity to nearby roads, etc. It is allowable that accuracy of this information varies considering the long-term planning horizon.

4.4.3 High-level summary of next phase activities

The table below presents an overview of the main activities that will be completed for the transmission planning workstream, as well as the outputs associated with each task and the date by which it is expected the task will be completed. The table also shows how each task and output relate to the overall IRP project deliverables.

Table 18: Transmission infrastructure planning – Summary of activities

Deliverable	Main activity	Output	Expected completion date
D2 – Consolidated IRP Implementation Report (Component 2: Transmission and Regional Connectivity Report)	Prepare and deliver capacity building training on transmission network modelling up to 2040	• PPT presentations and training material	End April 2021
	Financial network modelling and considerations	• PPT presentations and training material	End May 2021
	Technical and financial assessment of the proposed transmission plans	• Inputs to the Consolidated IRP Implementation Report – Component 2	End September 2021
D3 – Scenario Analysis Report	Provide inputs for scenarios development	• Consolidated list of scenarios	Mid-December 2021
D4 – Draft IRP report	Provide inputs for the draft IRP report related to transmission planning	• Inputs for the Draft IRP Report	Mid-February 2022
D5 – Final IRP report	Provide inputs for the final IRP report and implementation plan	• Inputs for the Final IRP Report and Implementation Plan	End March 2022
D6 – Completion Report (including capacity-building activities)	Prepare inputs to completion report related to transmission planning	• Write-up of capacity building activities	End March 2022
	Handover tools to key stakeholders	• Training and workshops to handover tools to stakeholders	Mid-February 2021

4.5 Distribution Infrastructure Planning

4.5.1 Situational assessment

Overview of electricity distribution in Zambia

The power distribution system in Zambia is owned and operated by three Distribution Network Service Providers (DNSPs), namely the CEC, Northwestern Energy Company (NWEC) and ZESCO. ZESCO is the largest DNSP and its system is divided into four divisions – namely Copperbelt, Lusaka, Northern and Southern Divisions, which cover all the 10 provinces of Zambia. The distribution system is operated at high voltage (above 33kV up to 66kV), medium voltage (from 1kV up to 33kV) and low voltage (400/230V).

The distribution system in Zambia faces typical challenges prevalent in most developing countries. Some of the challenges include lack of distribution system capacity to meet growing demand, poor quality and reliability of supply, a financially constrained utility, and absence of an enabling environment to attract private investment in the sector.

As a result, the current distribution system is inadequate and inefficient, with asset maintenance well below international standards, especially in divisions outside Lusaka. In its Energy Sector Report 2019, the ERB indicated that the overall average compliance level for distribution substations (<33kV) for the period 2016 – 2019 was 73% against a target of 93% compliance to technical standards for electricity infrastructure as set by the regulator[46]. The compliance level measures factors related to health and safety, environmental, system maintenance, protection, and security of supply.

Distribution network investment plan

Currently, there is no national Distribution Master Plan to guide investment in distribution network assets in Zambia. The last comprehensive network development plan was the Power System Development Master Plan[47] developed in 2010. The Plan identified distribution investment plans amounting to USD $180 million by 2030. Subsequently, two further studies were carried out for Lusaka City[48] (20 years to 2032) and the Southern Division[49] (up to 2030), and some of the identified investment plans are being implemented within the Lusaka Transmission and Distribution Rehabilitation Project and the Sustainable Electricity Supply Southern Division project.

There are still outstanding distribution investment plans amounting to USD $297 million which have no funding secured. Due to a variety of factors, most of which beyond ZESCO's control, implementation of the identified investment plans may not all materialise, or the plans could be delayed significantly. Through the distribution planning workstream of the IRP, it is expected that a comprehensive distribution investment plan will be developed covering all distribution divisions and with a robust funding mechanism identified for timely implementation of investment plans.

Electricity access

According to the World Bank-sponsored Geospatial Least-Cost Rollout Report released in December 2020, approximately 32% of the Zambian population has access to electricity[50]. The Government of Zambia is targeting universal access by 2030 in its Vision 2030. In order to achieve the universal access, the electrification pace would have to increase from 70,000 annual customer connections to 341,000. The approximately five-fold increase in annual customer connections requires significant investments in grid densification and extension, including rehabilitation and reinforcement of the existing distribution system.

Quality and reliability of supply

The annual key performance indicators (KPIs) summary for ZESCO in 2019 as reported by the ERB's Energy Sector Report 2019 shows that ZESCO did not achieve its targets in three of four KPIs[51]. ZESCO recorded a System Average Interruption Duration Index (SAIDI) of 70.4 hours against a target of 27 hours, over 2.5 times worse than the expectation. A System Average Interruption Frequency Index (SAIFI) of 13.7 times was reported against a target of 5 times or less, almost 3 times worse than the

[46] Energy Regulation Board (2019): Energy Sector Report 2019 http://www.erb.org.zm/reports/esr2019.pdf
[47] Power System Development Master Plan for Zambia https://www.moe.gov.zm/?wpfb_dl=46
[48] Lusaka City Master Plan 2012 (Source: ZESCO Distribution Planning Team)
[49] Feasibility Study for the Project Sustainable Electricity Supply Southern Division 2016 (Source: ZESCO Distribution Planning Team)
[50] Final Geospatial Least-Cost Rollout Report, December 2020 (Source: ZESCO Distribution Planning Team)
[51] Energy Regulation Board (2019): Energy Sector Report 2019 http://www.erb.org.zm/reports/esr2019.pdf

expectation. The Customer Average Interruption Duration Index (CAIDI) was reported as 7.3 hours against a target of 6 hours[52].

The performance indicators reflect a distribution system in dire need of significant investments in order to meet growing demand and provide quality and reliability of supply as per licence obligations.

Distribution planning processes

Traditional distribution planning process

The traditional distribution planning process as defined by CIGRE[53] uses demand forecast methods that include historical load data, economic models, weather data and spatial load forecasting but exclude distributed generation and demand side options. The process also uses one or two snapshots at peak and minimum demand for deterministic network analyses to identify system needs. The analyses are usually basic load flow and fault level calculations to ensure compliance to planning criteria. This traditional approach that focuses primarily on peak demand analysis is no longer effective due to the variability of system conditions across the seasons from distributed VRE generation and other distributed energy resources (DERs), which are becoming a significant feature in developed electricity markets. System peak demand, as seen by the transmission system, is therefore impacted by the amount of DERs supplying power at the time of peak demand. In the United Kingdom for instance, DERs are in the order of thousands of megawatts (MWs) cumulatively and deployed at a much faster rate than equivalent capacity of individual large-scale generation stations which are connected directly to the transmission system. As per the National Grid's connection registers dated 9th March 2021, Scotland has 2,380MW of distributed generation connected to the distribution system (Embedded Register[54]) and 11,652MW of transmission connected generation (Transmission Entry Capacity Register[55]). DERs are now becoming a credible consideration in distribution planning analysis.

The deployment of DERs, smart grid technologies and electric vehicle charging infrastructure into the power distribution system in recent years has brought challenges in how distribution systems are planned and operated. These challenges include voltage rise, reduced network headroom, network asset loss of life and bidirectional power flows in radial circuits. The distribution system now requires further analyses than the traditional load flow and short circuit analysis. Detailed protection analyses are now required due to reverse power flows introduced by DERs. Most DERs are inverter-based and therefore introduce harmonics to the distribution system. The new approach to distribution planning also requires harmonic analysis to assess impact of DERs on the distribution system.

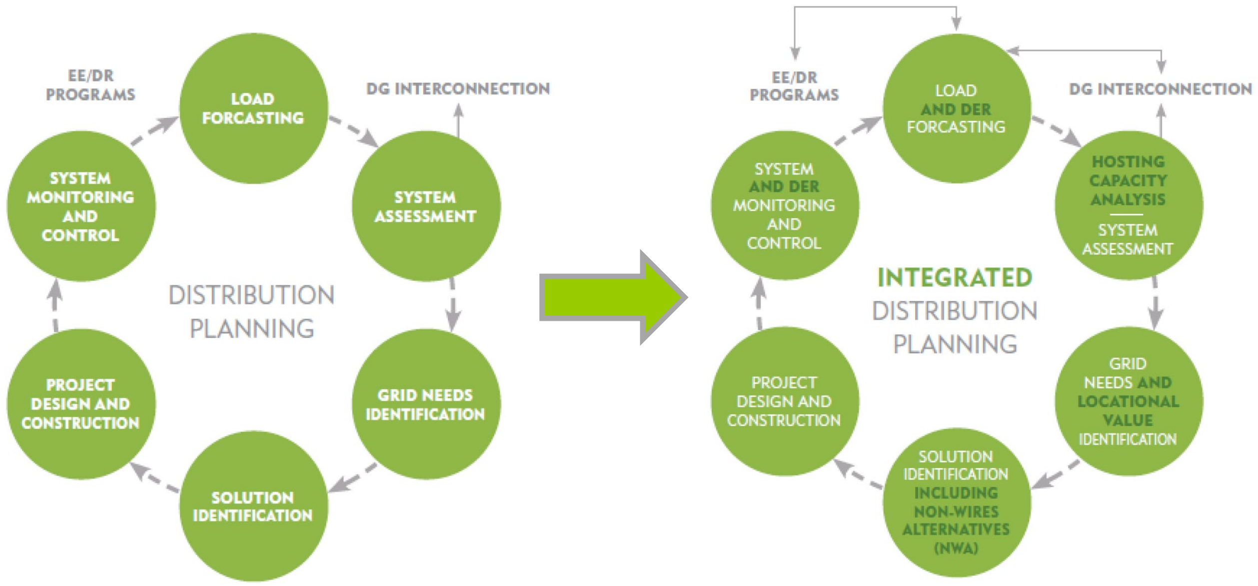
Integrated distribution planning process

Integrated distribution planning process differs with the traditional process in that it considers DERs in demand forecasting which results in net demand seen by the distribution system, where gross demand is the true demand from system users. The integrated distribution planning process also considers a wide range of solutions beyond just distribution infrastructure options (non-network solutions). These solutions may be provided by other players than the distribution utility as is the case with traditional distribution planning process.

[52] Ibid.
[53] https://e-cigre.org/publication/591-planning-and-optimization-methods-for-distribution-systems
[54] https://data.nationalgrideso.com/connection-registers/embedded-register
[55] https://data.nationalgrideso.com/connection-registers/transmission-entry-capacity-tec-register

The key differences between the two planning processes are shown in the figure below[56].

Figure 28: Traditional vs Integrated Distribution Planning Process



ZESCO distribution planning methodologies and tools

Planning methodology

ZESCO uses the traditional distribution planning process to determine its distribution investment plans. As indicated earlier, this approach will not be fit for purpose in the planning horizon of the IRP due to increased deployment of DERs, including distributed VRE generation.

Design manual

ZESCO's Distribution Directorate has a Design Manual[57] that provides basic guidelines for distribution network planning. The Manual covers network and load dimensioning, design of low and medium voltage networks and selection of transformer sizes. The Manual also provides specifications for overhead lines and cables, including standard sizes and parameters.

The Manual, however, does not cover the connection of distributed generation or energy storage systems which inject power into the distribution system. It also does not provide guidelines for the protection of the distribution system.

Planning tools

DIgSILENT PowerFactory software is currently used for distribution network modelling and analysis in ZESCO. The current version for the software license in ZESCO is PowerFactory 2020. ZESCO also uses Aurecon's PowerGLF for demand forecasting, the output of which is used for substation load forecasting.

[56] https://www.madrionline.org/wp-content/uploads/2019/10/MADRI_IDP_Final.pdf
[57] ZESCO, Network Information and Planning System (NIPS) Design Manual, revised 17.3.99 (Source: ZESCO Distribution Planning Team)

Figure 29: DIgSILENT PowerFactory[58]

In addition, Microsoft Excel is used to process data and carry out trend analysis for historical substation loading.

4.5.2 Proposed approach and methodology

Our approach to distribution infrastructure planning

The objective of the distribution planning workstream is to identify least-cost solutions to meet future demand and maintain distribution asset health in a manner that will reduce system risks and enhance system security, flexibility, and resilience.

The changing landscape of the electricity sector has seen an increase in DER deployment and customer involvement through demand side management and captive generation to reduce energy costs. This has resulted in an increased role for the distribution system in the whole system supply and demand balance. The distribution system now has a key role in the sector planning process – hence the inclusion of distribution infrastructure planning workstream in this IRP.

The existing Zambian distribution system has inadequate capacity to meet current and future demands without the need for significant investments. New disruptive technologies in the energy sector like DERs, electrical vehicles, and energy storage will see a significant growth in African electricity markets including Zambia. The International Renewable Energy Agency (IRENA)[59] estimates that around 33GW of distributed renewable energy will be deployed in Southern Africa by 2030, most of which will be rooftop solar PV (c. 23GW). There is therefore a need to adopt to new distribution planning approach in order to establish a distribution system that is fit for purpose to meet present and future requirements.

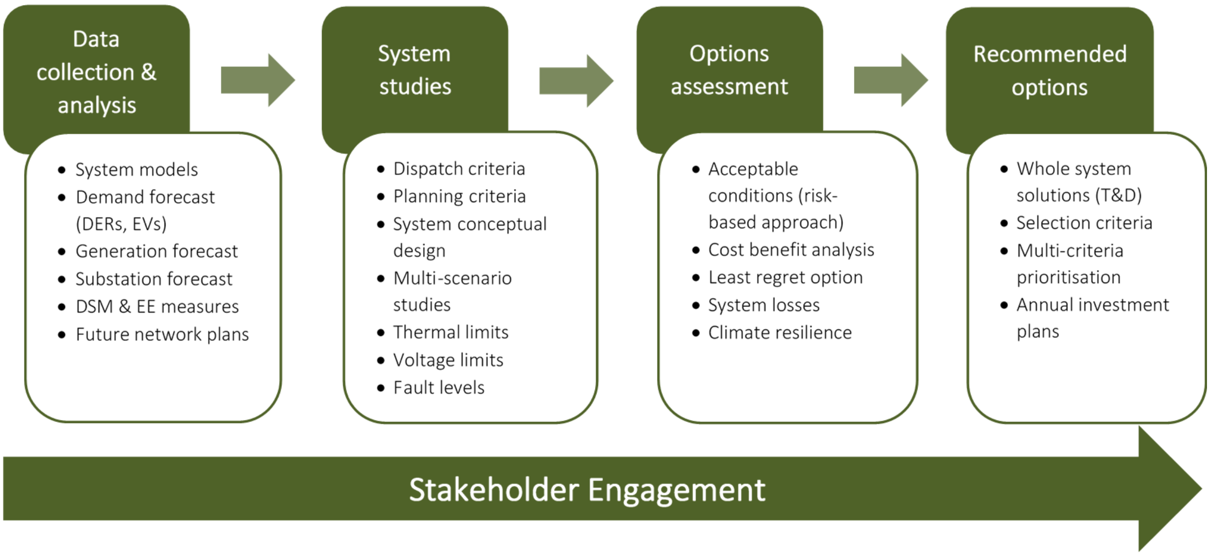
Our approach to distribution infrastructure planning will follow the integrated distribution planning process in Figure 28 above to the solution identification stage. The approach will therefore assess a matrix of network solutions and demand side options (non-network solutions) against planning objectives and criteria, including cost, risk, and environmental impact. Our approach will also consider

[58] https://www.digsilent.de/en/power-distribution.html
[59] https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2015/IRENA_Africa_2030_REmap_2015_low-res.pdf

the factors that will enhance the distribution system resilience to climate change. These factors include design of distribution circuits through meshed network topologies, sectionalization of networks and use of automated switching as identified in the study by the Energy Sector Management Assistance Program (ESMAP) of the World Bank titled *Enhancing Power Sector Resilience*[60]. The following are the key tasks in the distribution infrastructure planning process.

- Task 1: Data collection and analysis
- Task 2: System modelling and studies
- Task 3: Options assessment
- Task 4: Least-cost investment plan

Figure 30: Distribution planning process



To facilitate an efficient and effective distribution planning process, each task in the process will have its own work instruction and swim-lane diagram that will highlight key steps in the task, stakeholders, data requirements and tools. Stakeholder engagement will be the underpinning principle in the distribution planning process. The work instructions will therefore facilitate stakeholder buy-in at every step of the process and enable consistency in the planning process across distribution planning staff in all of ZESCO's distribution divisions. The key features of the work instructions include:

- Data sources (e.g., billing system, planning models, SCADA);
- Data providers – responsible officer's name and title;
- Tools (e.g., DIgSilent PowerFactory, PowerGLF, Excel);
- Responsibilities and approvals – RACI matrix

Task 1: Data collection and analysis

The first step in the distribution planning process is collection of data and its subsequent analysis and modelling. The data supports the modelling of the power distribution system for analysis of existing and future scenarios in short, medium, and long-term timescales of the IRP. There are considerable amounts of data to be collected as part of the planning process.

The review of collected data is ongoing. The review includes evaluating the quality of data against commonly accepted industry benchmarks, timeliness, and accessibility of the data. The integrity and

[60] https://openknowledge.worldbank.org/bitstream/handle/10986/26382/113894-ESMAP-PUBLIC-FINALEnhancingPowerSectorResilienceMar.pdf?sequence=1&isAllowed=y

quality checks will be carried out in consultation with ZESCO counterparts. Suitable assumptions will be agreed upon in cases of missing data, ensuring balance between data collection efforts and value of data integrity.

The following data will be required by the distribution planning workstream for the implementation phase of the IRP project:

- Existing distribution system models – PowerFactory models for all divisions up to 11kV level of a primary substation;
- Demand forecast, including distributed energy resources and electric vehicles deployment from the Demand Workstream and substation demand forecast from the GIS software;
- Generation forecast – *to be obtained from the generation planning workstream;*
- Future network plans – *to be obtained from the transmission planning workstream* and ZESCO's plans;
- Demand side management options.

The main sources of data will be ZESCO's internal systems, outputs from other IRP Workstreams and publicly available data. Data collection will also include getting industry updates that may affect assumptions and inputs for Distribution Planning Workstream. These industry updates will cover results from ongoing interventions and studies, including the COSS.

Demand Side Management (DSM) and Energy Efficiency (EE) options

A listing of current DSM and EE practices and potential DSM and EE options will be collected for analysis and consideration for non-network solutions. The assessment will also include global and regional industry trends in DSM and EE measures that will be relevant to Zambia in short, medium and long-term. Within the context of smart grids, DSM includes demand response. Demand response schemes are often automatic and rely on smart appliances.

DSM and EE measures may be classified into two categories namely energy reduction and load management. These are mostly implemented by distribution utilities and end users. Energy reduction measures involve the reduction in demand through efficient processes, equipment and buildings. These measures include efficient lighting systems, efficient industrial systems (e.g., boilers, steam plants and motors), and domestic appliances (e.g., refrigerators, air conditioners and water heaters). For utilities, energy reduction measures include energy loss reduction through use of low-loss conductors and transformers. The measures also include grid automation to manage power flows by reducing current flows from high impedance circuits.

Load management measures include peak clipping, where demand is reduced at peak times and demand shifting, where loads are moved away from the peak demand period, thereby reducing the peak demand. Load management measures also include load control where appliances are switched on or off remotely by the utility or automatically through either frequency or voltage controlled smart appliances.

System constraints

Data collected on existing system models will be used to review distribution system status. Existing system constraints will be identified in each division and these constraints may include overloaded transformers and distribution lines, and areas of low voltages below voltage criteria. The review of system constraints will also include review of data used for regulatory reporting on SAIDI, SAIFI and CAIDI KPIs.

Task 2: System modelling and studies

The objective of Task 2 is to assess the impact of forecasted demand on the distribution system and identify system constraints that are non-compliant to planning criteria and security standards. The outputs from Task 2 will be results for each study year, highlighting the constraints identified and the level of non-compliance to determine acceptable and non-acceptable conditions of the distribution network.

Modelling and study tool

New technologies like distributed generation, battery energy storage systems, and electric vehicles present new challenges in the planning and operation of distribution networks. These technologies introduce reverse power flows and voltage rise in the distribution networks, leading to increased complexity in power system analysis. The power distribution module for PowerFactory software package provides base functions including load flow, short circuit analysis, contingency analysis and models for solar photovoltaic (PV) systems based on solar radiation, electric vehicles, battery storage.

Therefore, DIgSILENT PowerFactory will be used in the Distribution Planning workstream of the IRP for efficiency and enhanced capacity building, taking advantage of existing skills and competency within ZESCO's Distribution Planning team. The existing PowerGLF geographical information system (GIS) software will be used for substation load forecasting, providing input to PowerFactory models.

For distribution planning studies, existing PowerFactory cases will be used. These cases will be reviewed and agreed upon with ZESCO before creating a base model for the IRP studies. Base models will be created for each study year at specific intervals in the IRP horizon period as agreed. Each study will assess the capability of the distribution network to accommodate the forecasted demand within the planning criteria and standards.

Steady-state analysis

Steady-state analysis will include basic load flow and short circuit analysis to derive system performance parameters. Load flow studies will assess the distribution system performance against thermal and voltage limits while short circuit studies will determine fault levels for the system and assessed against equipment ratings.

Results of load flow studies will show overloaded system components or areas with higher or lower voltage than the planning criteria (if any). Short circuit studies will show parts of the network where faults levels will likely exceed the existing equipment rating and support equipment short-circuit rating selection during system design.

Contingency analysis

Utilities use N-1 contingency criteria for their interconnected and radial systems. This reliability criteria tests the ability of the distribution system to maintain quality and reliability of supply under planned or unplanned outage conditions of a single system component.

The results of the contingency analysis will highlight parts of the system where reliability falls below expected standards.

Hosting capacity analysis

Hosting capacity analysis will be used to determine the maximum amount of DERs and energy storage the existing distribution system can accommodate without the need for system upgrades in a safe and reliable manner. The analysis will test the distribution system capability within thermal, voltage and protection limits at a feeder level. The results of the hosting capacity analysis will provide an indication, through heat maps, of the distribution system capability to accommodate DERs.

Multi-scenario analysis

Given the uncertainty of the power system landscape in future years and the uncertainty from embedded variable renewable generation, a multi-scenario approach will be used in the system studies. This will help to minimise the risk of study results being out of sync if one or more study variables change. Scenario assessment is useful to test the robustness of the solutions identified during the studies given uncertainty in the driving assumptions. Key assumptions that can change include generation and demand background, project costing, and financial evaluation parameters.

Task 3: Options assessment

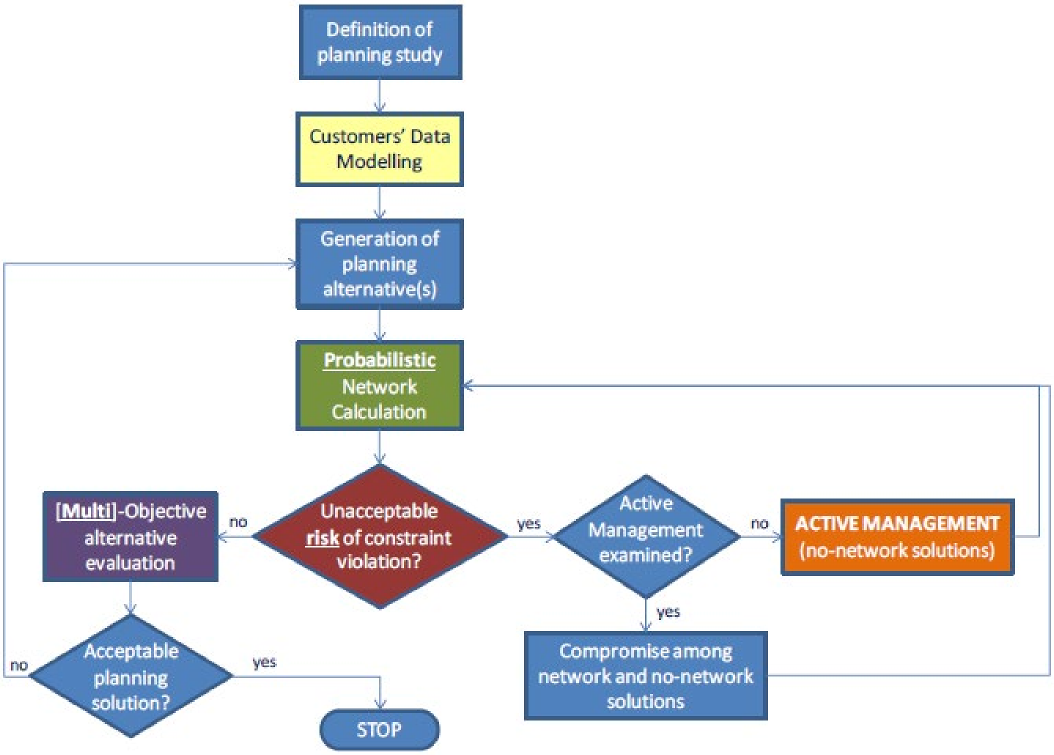
The objective of Task 3 is to identify a range of options that will satisfy the needs of the distribution system as highlighted in Task 2. The options are in three broad categories namely creation of new assets, upgrade of existing assets and non-network solutions, including DSM measures. Creation of new asset includes development of new distribution circuits, construction of new substations and installation of new switchgear and voltage regulators. New assets solutions will also include deployment of DERs including behind-the-meter energy storage to defer system reinforcements. Solutions to upgrade existing assets include replacement of transformers with higher rated units at a substation, reconductoring of existing circuits with higher rated conductors and voltage upgrades of existing distribution circuits from 11kV to 33kV. Non-network solutions will include load shifting where consumption moves away from peak demand periods through time-of-use tariffs, EE measures through use of efficient lighting and appliances and use of alternative sources of energy through solar heating and refrigeration.

The assessment of network solutions will consider options that not only provide additional capacity but also contribute significantly to energy loss and GHG emissions reduction. The assessment of overall potential DSM measures will include the impact of various technological, financial, and economic factors on the measure that could be realistically achieved. The options assessment will also consider lifetime costs for each option when evaluating the costs and benefits against other options. The options for consideration shall be developed in collaboration with key stakeholders to ensure that the measures ultimately proposed can viably be implemented.

The scenario analysis will determine the degree of implementation of DSM measures and the energy supply strategy. The scenarios for deployment of DSM measures will consider EE measures by each end-use sector, taking into consideration the EE cost curves.

The flow chart below shows the steps to be taken to assess the proposed option in addressing the identified constraint.

Figure 31: Flowchart for Option Assessment[61]



The results of this assessment will be presented in a detailed report setting out the recommended least-cost options that provide the necessary changes to meet future requirements. The Options Assessment report will describe the capabilities and costs of each option category considered, including its functional specifications.

Task 4: Least-cost investment plan

The objective of this task is to develop a least-cost distribution investment plan covering the entire IRP period. The plan will identify and prioritize necessary investments in the Zambian distribution network over the short, medium, and long-term scenarios, including DSM measures.

There are two main drivers of capital investment in the distribution system namely load related expenditure (LRE) and non-load related expenditure (NLRE). LRE covers investments to connect new customers and associated system reinforcements to increase system capacity for the customer connections. NLRE covers investments to replace distribution assets on the basis of increased maintenance costs, safety risks or end of asset life. NLRE also covers investments for grid modernisation and system reliability requirements, e.g., installation of auto-reclosers or sectionalisers.

[61] https://e-cigre.org/publication/591-planning-and-optimization-methods-for-distribution-systems

The selection criteria for inclusion into the least-cost distribution investment plan will include:

- Least-Worst Regret solutions;
- Number of connections supported;
- Synergy with transmission and embedded generation projects;
- Energy loss reduction;
- Contribution to GHG emissions reduction.

The parameters to undertake the financial and economic evaluation of proposed distribution solutions are reflected in the overall approach for the IRP. The table below shows the key data needed for the proposed distribution solutions.

Table 19: Data for financial and economic evaluation of distribution solutions

Data Type	Description
Distribution system assets	• O&M costs (USD/kVAyr) • Planned capital expenditure (USD/kVA)
Distribution system constraints	• O&M costs (USD/kVAyr) • Planned capital expenditure (USD/kVA)
Demand Side Management Options	• Capital costs • Effective MW savings • O&M costs • Hourly or time-of-day profile • Payback period/discount rate

4.5.3 High-level summary of next phase activities

The table below presents an overview of the main activities that will be completed for the distribution workstream, as well as the outputs associated with each task and the date by which it is expected the task will be completed. The table also shows how each task and output relate to the overall IRP project deliverables.

Table 20: Distribution infrastructure planning – Summary of activities

Deliverable	Main activity	Output	Expected completion Date
D2 – Consolidated IRP Implementation Report (Component 4: Distribution, Demand Side Management and Energy Efficiency Report)	Collect and format demand, generation and substation forecast data for PowerFactory input	• Generation and substation input data for PowerFactory	End April 2021
	Collect and review existing PowerFactory models	• Baseline PowerFactory models	End April 2021
	Collect and compile existing distribution investment plans	• Variation file for each investment plan	End April 2021
	Create study case and carry out system studies for each study period	• Study case model and system constraints report for each study period	End July 2021
	Carry out options assessment for each study period	• Options assessment report for each study period	End August 2021
	Create project prioritisation criteria and template	• PPT presentation of prioritisation template	Mid-September 2021

	Training on distribution systems development distributed solar PV, off-grid systems, and DSM	• PPT presentations and training material	End September 2021
	Prepare inputs to implementation report related to distribution planning	• Relevant sections of implementation report	End September 2021
D3 – Scenario Analysis Report	Update study case and carry out system studies for each study period following final demand scenarios	• Revised study case model and updated system constraints report for each study period	End October 2021
	Update options assessment for each study period	• Updated options assessment report for each study period	End November 2021
	Prepare inputs to scenario analysis report related to distribution planning	• Relevant sections of scenario analysis report	Mid-December 2021
D4 – Draft IRP Report	Prepare inputs to draft IRP report related to distribution planning	• Relevant sections of draft IRP report	Mid-February 2021
D5 – Final IRP Report	Finalise inputs to the IRP report	• Updated relevant sections of draft IRP report	End March 2022
D6 – Completion Report (including capacity-building activities)	Handover PowerFactory models and planning tools to key stakeholders	• PowerFactory models and planning tools • Training and workshops to handover tools to stakeholders	End March 2022
	Prepare inputs to completion report related to distribution planning	• Write-up of capacity building activities	End March 2022

4.6 Power Procurement, Financial Mobilisation, and Market Structure

4.6.1 Procurement strategy

The current procurement process has some identified shortcomings, with some of the critical being:

- The processes have on occasions been perceived as opaque;
- The is no clear process for handling unsolicited bids, thus creating serious problems for the utility, as numerous developers seek access to the grid often seeking to sign PPAs with the utility;
- The de facto single buyer model with ZESCO as the off taker with IPPs seeking to sign PPAs often with sovereign guarantees, rather than considering alternative off-taker options.

Therefore, a new approach for energy procurement is required.

The IRP procurement process will be designed to support the recommendations for investment in generation, transmission, distribution, off-grid technology and infrastructure, and DSM / EE initiatives derived from the different IRP workstreams, with the overall objective of facilitating predictable and consistent power delivery to consumers at the lowest possible cost.

It is recognised that procurement for projects recommended through the IRP will be undertaken by both the public sector and the private sector, depending on nature of the project. In both cases, there will be need for transparency and accountability in relation to the procurement process, and the following principles should be adhered to:

1. Projects considered for support should have feasibility studies completed that can be submitted for approval or endorsement by the appropriate regulatory authorities. The MoE will develop and own this process, in liaison with ERB, WARMA, National Heritage Conservation Commission, ZEMA, and such other Ministries or Agencies as may be appropriate for the project under consideration.
2. Procurement processes should be based around the principle of competitive bidding. Depending on the size and nature of the project, international competitive bidding principles should be adhered to. For some projects (such as grid based generation projects), the competitive process will be linked to the tariff that is offered. For other projects (such as grid extension), the competitive process is more likely to be linked to the overall contract cost. In each case, it will be important to determine the most appropriate mechanism to ensure that there is competition and value for money achieved through project procurement, which will ultimately have the effect of minimising end user tariffs to consumers.
3. Procurement processes should fall within the technical and commercial parameters for projects as recommended under the IRP with respect to technology type, size, tariff as well as compliance with best practice in relation to environmental, climate and local content considerations as will be recommended through the IRP development process.
4. Procurements should be undertaken only where there is an identified source of financing for the project. In certain instances, the competitiveness of the source of financing may be assessed for reasonableness and also subjected to a competitive process.
5. Exceptions to the defined process should be accepted for well-defined and documented reasons, and subject to approval by a senior authority.
6. All projects will be subject to monitoring and evaluation by MoE through the implementation and post-implementation period. This process will verify that the project has been delivered within the desired technical, commercial, and environmental parameters, and record any variances or changes to the project scope. Where appropriate, learning points will be recorded and used to inform future procurement processes for similar projects.

Specific considerations to be observed in relation to the procurement of generation projects are detailed below:

Technical factors:

- Overall size of the plant in accordance with the incremental demand and reserve requirements identified;
- Whether the generation source is synchronous or asynchronous, and the extent to which asynchronous sources can be absorbed into the grid based on grid studies undertaken;
- Extent to which power sources is predictable (day vs. night, consistency between seasons, predictability during the day);
- Proximity of the generation source to the grid;
- Proximity of the generation source to load centres;
- Grid connection costs and associated losses;
- Ability of generation source identified to provide ancillary services that may provide additional value to the grid / system operator;
- Overall plant availability;
- Overall technical risk (size, complexity, extent to which technology is proven).

Financial factors:

- Tariff calculated on a Levelised Cost of Energy (LCOE) basis (i.e., factoring in the effect of contractual tariff escalation factors);
- Capacity / Energy Split of the tariff, with an appropriate weighting between sources considered to be non-variable vs variable;
- Financial value attributable to ancillary services that may be provided;
- Anticipated risk allocation under the power purchase agreement (with a view to minimising financial risk assigned to the Government) including financial guarantees required for credit support and termination compensation;
- Financial complexity and anticipated timing to financial close. The extent to which public sector or private sector finance debt or equity finance (as appropriate) is considered to be readily available, and the conditions for drawing down on such finance can be met within the anticipated timescales;
- Diversity – i.e., the extent to which overall risks should be mitigated by developing multiple smaller projects versus a fewer number of larger projects, where risk is concentrated around a single developer at a particular identified site.

Other factors:

- Environmental impacts of the proposed investment in generation plant, including both the impact on the natural environment and the impact on livelihoods of local people;
- The extent to which the generation investment facilitates resilience to climate change;
- The extent to which the generation investment minimises carbon emissions in accordance with Zambia's NDC;
- The extent to which the investment in generation plant results in job creation, both directly and indirectly, particularly for people living close to the generation plant;
- The extent to which the generation plant incorporates local content during development, construction, and operation.

For potential investments in DSM and EE, the characteristics of projects will be compared as far as possible on a like-for-like basis with potential generation projects or indeed transmission and distribution projects that would have the equivalent overall impact of making reliable and consistent power available on the grid. Quantitative methods will be suggested on how to perform the comparison.

The procurement of transmission projects will follow the recommendations of the transmission workstream of the IRP, with particular emphasis on aligning the assumptions around demand growth, implementation of the least cost generation plan and alleviating identified constraints in the distribution network, whilst maintaining a stable and resilient national grid. Transmission investments to be considered as part of the IRP review process will include grid stabilisation equipment, as well as high voltage lines and substations. The financial appraisal of investments will incorporate a detailed assessment of technical losses on the transmission network, and the extent to which losses can be minimised and power quality standards adhered to through (for example) locating generation sources as close as possible to demand centres; installing compensation equipment to stabilise voltage and frequency; or installing equipment to maintain power factors within the required grid standards. The financing of transmission projects will most likely be undertaken by the appropriate TNSP, but consideration may also be given to allocating concession rights for new transmission lines (e.g., international interconnectors) to special purpose vehicles owned by a consortium of investors.
The procurement of distribution projects is most likely to be undertaken by the relevant DNSP, and by their nature, projects are likely to be smaller but far greater in number. A system wide approach to the procurement of distribution infrastructure is recommended, with investments prioritised so as to facilitate the maximum impact of distribution investment in improving energy access overall, as well

as providing a higher quality of service to commercial, industrial, agricultural, mining and public service customers in locations across Zambia.

The procurement of off-grid projects will be informed by the Rural Electrification Plan of 2008 and the Least Cost Geospatial Electrification Plan and National Electrification Strategy (both currently under development). An important output of the IRP process will be a clear strategy and plan for extension of the grid by existing licenses operators over the next decade, so there is clarity as to where isolated grids, mini-grids and solar home systems (or stand-alone solar / other generation systems) are anticipated to provide services to meet customer demand.

4.6.2 Financing approach

Financial appraisal and project ranking

As the IRP by its nature takes an integrated approach to sector planning, this principle will be reflected in the financial appraisal framework for projects considered by the IRP. It is assumed that the ultimate objective of all investments made by licensed operators in the power sector, whether on-grid or off-grid, is to improve and widen service availability to customers at the lowest possible cost subject to adequate consideration of social, environmental, climate, and local content factors and evaluation of project risk.

A financial appraisal framework will capture capital and operational costs at project level, and derive a high-level tariff estimate based on the operational parameters of the proposed project (e.g., energy generated, energy transmitted, energy distributed, or energy saved) and generic financing assumptions, which may be varied depending on the nature of the investment (i.e., public sector vs. private sector, debt / equity split, project finance vs. corporate finance). The financing assumptions will be market based and will take account of market feedback from cooperating partners, investors, and lenders with capacity and a mandate to invest in the Zambian power sector.

The financial appraisal framework will also consider systemic risk factors linked to factors such as climate and currency depreciation, and will quantify the extent to which projects are resilient to such risks.

The framework will enable different potential projects to be compared and ranked based on different criteria to be defined through the IRP development process, but which may include, *inter alia:*

- Least cost, risk-weighted cost of energy generated factoring-in transmission costs, transmission losses and ancillary services provided;
- Impact of possible different investments in increasing energy access and/or enhancing customer service levels;
- Impact in developing a sustainable export market for power generated in Zambia;
- Impact in maintain quality of supply in years of draught.

The framework and scenario planning will take into account the overall leverage of the sector, and the practical limitations that will apply as a result of this. In the first 5 years of the IRP planning horizon, the availability of financing in the sector is likely to be limited, but as the sector recovers, it is anticipated that the availability of new funding from investors and lenders will gradually increase.

Due consideration will be accorded to policy issues that impact the financing of projects, such as the policies for the charging of connections to the transmission or distribution grid, the charging framework for use of system and ancillary services and policies and regulations supporting local content in power projects. In a number of instances, the IRP will reference parallel projects that are focusing on these areas, and which are expected to show tangible results within the agreed reporting timeframe for the IRP. Where policies have yet to be fully formulated, the IRP will recommend areas for further development of policy and regulations by MoE and ERB, and any planning assumptions made will be clearly stated.

Finance sources

The nature of ownership of licensed entities operating in the Zambian power sector impacts the sources of finance that are available for projects. ZESCO is wholly owned by the GRZ and has typically raised finance from the public sector investment arm of multilateral lenders, Development Finance Institutions (DFIs), Government-to-Government arrangements, as well as the GRZ itself, with some commercial bank participation for shorter-term facilities.

Privately-owned entities operating in the power sector are owned by a mixture of Zambian and international investors, such as Maamba Collieries (owned by Nava Bharat Ventures and ZCCM-IH) and CEC (listed on the Lusaka Securities Exchange). Private investors typically raise investment loans from DFIs for large infrastructure investments, commercial banks and existing shareholders.

The majority of financing for the Zambian power sector for investment in infrastructure is raised in US Dollars under long-term financing arrangements, and contracts between IPPs and utilities and inter-utility power trading contracts (including those within the SAPP) are denominated in US Dollars. Tariff requirements for investors are typically determined to a large extent by the need to cover capital and interest repayments to lenders in US Dollars (or other hard currencies) under long-term financing arrangements.

Power Supply Agreements with the mines, who consume over half of the power supplied in Zambia, are denominated in US Dollars. However, the remaining customer groups mainly consume power based on tariffs denominated in Kwacha and determined by the ERB. The rapid depreciation of the Kwacha over recent years has created a currency hedging risk that has proven challenging to mitigate despite a number of increases to Kwacha based tariffs having been approved by ERB.

The finance workstream for the IRP will investigate the appetite, quantum and conditionality for the following finance sources and instruments:

- Sources of investment capital across the different sectors of the power delivery value chain (generation, transmission, distribution, DSM and EE, off-grid and power trading) for both public sector and private sector;
- Structuring and risk mitigation strategies and instruments;
- Sources of finance that are specifically directed towards poverty alleviation, and which may be concessional in nature;
- Opportunities to widen the participation of local banks and investors in the Zambian energy sector at all levels;
- Risk mitigation instruments that can mitigate key perceived investment risks (e.g., credit risk, currency hedging risk, climate risk) to facilitate increased investment from both local investors and international investors.

Sector financial risks and risk management

The power sector has accrued financial arrears over the past 5 years due to a variety of factors, two of the main factors being that:

- tariffs that are significantly below cost reflective levels (due to a significant increase in the cost of generation from new capacity that has been added to Zambia's power system since 2014, and the sector currency hedging risks outlined in the previous section; Finance sourcesclimate change factors, which impacted the power system in 2016 and 2019, thus reducing energy available from low cost in-country hydro plants and resulting in increased load shedding, lower utility revenues and increased costs of imported power; and
- implementation challenges following tariff increases proposed by the ERB.

The GRZ has identified the key conditions related to the power sector in its Economic Recovery Programme 2020-2023[62], which include the completion of the COSS to facilitate cost reflective tariffs, the development of a multi-year tariff framework, and the development of the IRP. Furthermore, the programme articulates the need to enhance the coordination of climate change adaption and mitigation actions, to strengthen resource mobilisation for climate action, to build the adaptive capacity of the economy to climate change and to enhance community resilience to climate change. The programme also emphasises the importance of market reform through the implementation of the open access regime in line with the 2019 Electricity Act.

The successful completion of the IRP process will assist in building a framework for sector recovery, through which actions can be taken and mechanisms developed to address systemic sector financial risks.

It is recognised that different customer groups have varying capacities to pay for power, including the cost of connection for those who are being connected for the first time. The long-term financial stability of the sector is linked to attaining the correct balance between tariff affordability, protection of utilities and investors, cross cutting factors and alignment over the future strategy and plans for the power sector. The IRP will investigate and present different scenarios with a view to identifying this balanced view.

The analysis performed will be consistent with the Electricity Act of 2019, which summarises the principles that must be taken into account with regards to tariffs – i.e., a tariff must be fair and reasonable and reflect the cost of efficient business operation; a tariff must ensure quality of service; there is predictability of tariff adjustment and a reasonable rate of return on capital investment; a tariff must encourage competition, economic use of the sources of the electricity, good performance and optimum investments; a tariff will reward efficiency in performance; and a tariff will reflect enforceable standards for the quality and cost of the supply of electricity to retail consumers and non-retail consumers.

4.6.3 Market structure

Context

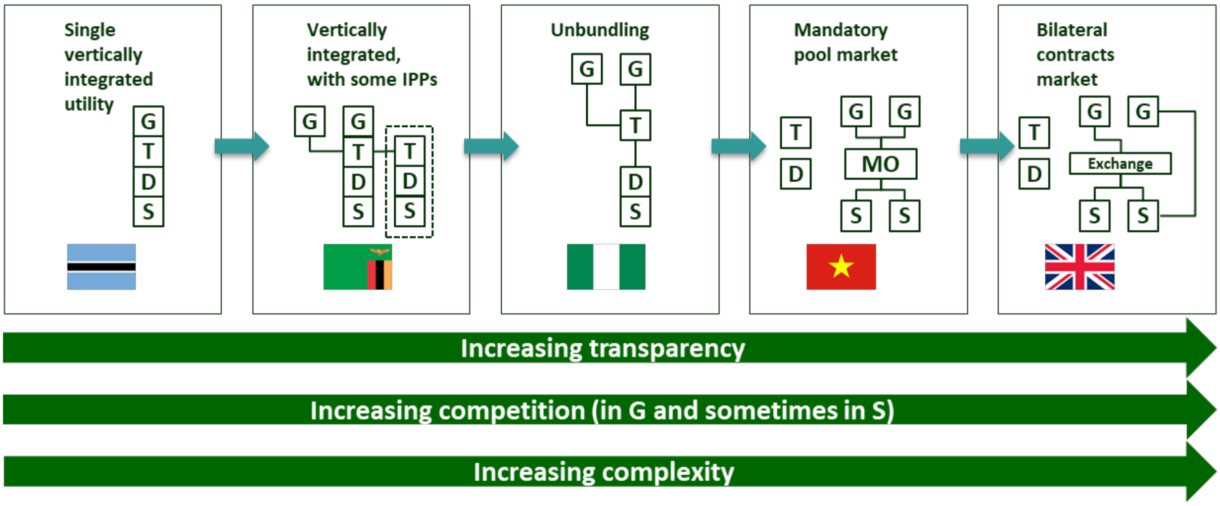
The focus of this project is to prepare an IRP. Implementation of the IRP will require an appropriate enabling environment, including a market structure that facilitates delivery of the projects identified by the IRP. This section identifies some of the key considerations that the IRP team will need to address to ensure that the final IRP document provides a plan than can, in fact, be implemented.

Market structure interacts closely with the other pillars required to mobilise capital, outlined in this section. In the case of Zambia, financial sustainability of the electricity is negatively impacted by end customer tariffs that do not allow for the full recovery of costs incurred.

The structure of Zambia's electricity market is similar to many other markets in Sub-Saharan Africa. The sector is dominated by a Vertically Integrated Utility, ZESCO, but with private sector investment allowed in IPP projects, which sign Power Purchase Agreements (PPAs) with ZESCO. A simplified representation of this model is shown in the figure below, compared against other market models, ranging from a fully vertically integrated sector, as in Botswana, to a fully unbundled and liberalised electricity sector, based on bilateral contracts, as in the United Kingdom and many other European markets. The market structure in Zambia also includes CEC, which also owns generation, transmission, and distribution assets, and whose primary role is supplying power to the country's mines on the Copperbelt. This is indicated by the additional transmission/distribution utility shown in the dashed box in the figure below.

[62] Ministry of Finance and Ministry of National Development Planning (2020): Zambia Economic Recovery Programme – 2020-2023 https://www.zambiaembassy.de/wp-content/uploads/2020/12/2020_Economic_Recovery_Report.pdf

Figure 32: Schematic representations of alternative electricity market models



Zambia has also recently taken steps to open up its electricity sector to new participants, through reforms in The Electricity Act, 2019. The Act provides the primary legislation allowing third parties access to the electricity network. This in theory allows for more participants in the market. However, the secondary legislation required to implement this reform has not yet been developed, so it is currently unclear both (a) how third-party access will be implemented in practice, and (b) how third parties will be charged for wheeling, or Use of System. The current projects being undertaken by ERB to prepare a COSS and to develop use of system charges for network operators are expected to reduce the level of uncertainty once completed.

Market structure considerations

Market reforms are often implemented to achieve some combination of the following results:

- Greater **competition**, which might be achieved by making changes to the procurement mechanisms used for power sector infrastructure, with the aim of driving down costs for consumers;
- Attracting **new capital** into the sector by creating new structures to facilitate private sector participation. There are lots of different models that can be adopted to achieve this;
- Financial restructuring and tariff reforms can be used to achieve **cost recovery**, which is critical to achieving long-term financial sustainability. Commercial arrangements in the sector can also be made more **cost reflective**, providing the price signals for more economically efficiency decision-making;
- **Transparency** can be improved by unbundling the sector and improving visibility of the commercial arrangements between different parties in the sector. This can help to create more of a level playing field for new entrants, and ultimately can encourage competitive behaviours that drive down costs for end users.

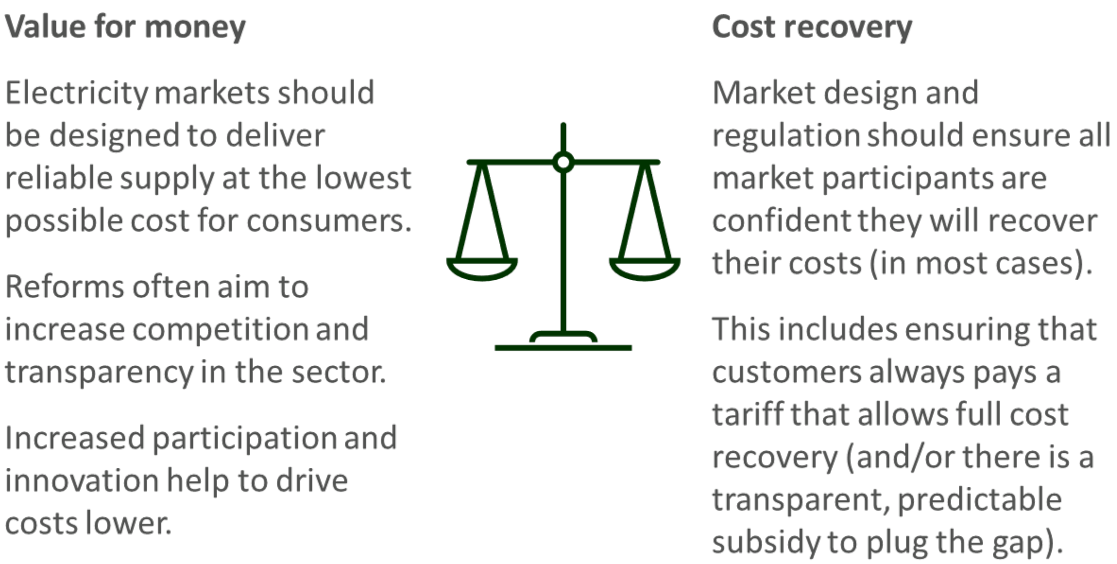
This wide range of possible objectives shows how the third-party access reforms proposed in Zambia are not a panacea; they do not, for example, tackle the sector's cost recovery challenges. There are many international examples of countries that have implemented reforms to their electricity market structure, which have not achieved the outcomes that were intended. This includes examples from other countries in Sub-Saharan Africa.

In Nigeria, unbundling was followed by privatisation of both generation and distribution assets. However, these transactions took place before regulatory practices to ensure tariffs remained cost reflective were properly embedded. In reality, tariffs have fallen well short of levels that would allow distribution companies to recover their costs. As a result, many distribution companies in Nigeria are in effect insolvent.

Ghana has also unbundled its electricity sector, and recently attempted to involve the private sector in its distribution sector through a concession arrangement similar to the (broadly successful) model adopted in Uganda. However, this concession was cancelled. In the end, the contract was cancelled for compliance reasons, but challenges had been mounting for a while. Fundamentally, the concession contract was pushed through before tariff reforms to ensure cost recovery had been properly implemented. This meant that there was limited interest in the concession, limiting the extent to which the reform would have delivered value-for-money.

These examples highlight the importance of reforms being tailored to the context in which they are implemented and clarity and focus on the outcomes that the reform aim to achieve. As suggested by the examples above, at the heart of many market reforms there can be a tension between the desire to deliver lower tariffs to end consumers of electricity and the need for the sector to be financially sustainable (illustrated in the figure below). It is normally important to ensure that robust governance and independent regulation are in place to achieve cost recovery before using other market reforms to increase competition and drive down costs.

Figure 33: The balance to be struck between value for money and cost recovery



There is also a balance to be struck in the complexity of market structures that are implemented. As illustrated by the arrows at the bottom of Figure 32, increasingly liberalised market structures can help to increase transparency and competition. This can lead to benefits for consumers. However, these reforms can also increase the level of complexity in the market. Rudnick and Velasquez (2018)[63] suggest that the costs of this additional complexity may outweigh the benefits of liberalisation for electricity markets smaller than ~3 GW, because the market is unable to absorb multiple buyers and sellers.

Approach to market structure in delivering the IRP

As noted at the start of this section, the focus of this project is preparation of an IRP, rather than providing advice on market design *per se*. Our work on market structure will therefore be **demand-led** and will focus on areas that are directly relevant to implementation of the IRP.

[63] Rudnick, H. and Velasquez, C (2018): Taking Stock of Wholesale Power Markets in Developing Countries, A Literature Review https://openknowledge.worldbank.org/bitstream/handle/10986/29992/WPS8519.pdf?sequence=5&isAllowed=y

Specifically, for the IRP to be a practical plan, it is important that the supply-side and demand-side projects proposed by the IRP are consistent with the current market structure. Some examples of where this interaction might be relevant include:

- **Demand-side participation** – Demand-side resources can sometimes be an attractive alternative or complement to investment in the supply-side, or indeed to investment in network infrastructure. However, bringing forward these resources to achieve an optimal outcome is likely to require new incentive structures, both for the customers expected to provide demand-side services and for network operators to ensure that they are incentivised to seek the least cost dispatchable resources.
- **Flexibility through interconnection** – The interconnection with other SAPP countries may sometimes provide a useful source of flexibility, which may be captured in the modelling performed in preparing the IRP. However, the extent to which interconnectors can in practice operate flexibly is likely to be constrained by the commercial arrangements in place between countries. If capacity is secured through long-term contracts, this might mean that capacity that is technically available might not be commercially available to provide short-term flexibility.
- **Optimised network investment** – Distributed energy resources – both on the supply-side and demand-side – can be used to defer, or as an alternative to, investment in reinforcing network infrastructure. However, these options are unlikely to be selected in practice without the right regulatory structures and incentives in place to support ZESCO in selecting these options.

Throughout the IRP process, we will check for consistency between the analysis being performed to prepare the IRP and the actual market structures in place in Zambia. Inconsistencies will be tackled in two ways:

- In some cases, iterative adjustment of the analysis may be required to better reflect the commercial reality on the ground.
- If the IRP analysis identifies areas where new market structures and reforms could unlock a lower cost plan, we will advise stakeholders of those options and, if appropriate, provide guidance on the reforms or new market frameworks that might be required.

4.6.4 High-level summary of next phase activities

The table below presents an overview of the main activities that will be completed for the power procurement, financial mobilisation, and market structure workstreams, as well as the outputs associated with each task and the date by which it is expected the task will be completed. The table also shows how each task and output relate to the overall IRP project deliverables.

Table 21: Power procurement, financial mobilisation, and market structure – Summary of activities

Deliverable	Main activity	Output	Expected completion Date
D2 – Consolidated IRP Implementation Report (Components 6-8: Financial Sustainability and Sources Report; Market Structures and Regulation Report; Power Procurement Report)	Provide data sets for the energy planning system	• Initial base case outputs for energy planning system	End September 2021
	Prepare inputs to implementation report related to procurement strategy, financial mobilisation, and market structure	• Relevant sections of implementation report	End September 2021

D3 – Scenario Analysis Report	Provide inputs for scenarios development	• Consolidated list of scenarios	Mid-December 2021
	Prepare and delivery training on e.g., methods for comparing alternative solutions to achieve a given performance (for financing/energy procurement)	• PPT and training materials	End December 2021
	Prepare inputs to scenario analysis report related procurement strategy, financial mobilisation, and market structure	• Relevant sections of scenario analysis report	Mid-December 2021
D4 – Draft IRP Report	Prepare inputs to draft IRP report related procurement strategy, financial mobilisation, and market structure	• Relevant sections of draft IRP report	Mid-February 2021
D5 – Final IRP Report	Finalise inputs to the IRP report	• Updated relevant sections of draft IRP report	End March 2022
D6 – Completion Report (including capacity-building activities)	Handover of models and planning tools to key stakeholders	• Training and workshops to handover tools to stakeholders	End March 2022
	Prepare inputs to completion report related to distribution planning	• Write-up of capacity building activities	End March 2022

5 Cross-Cutting Workstreams

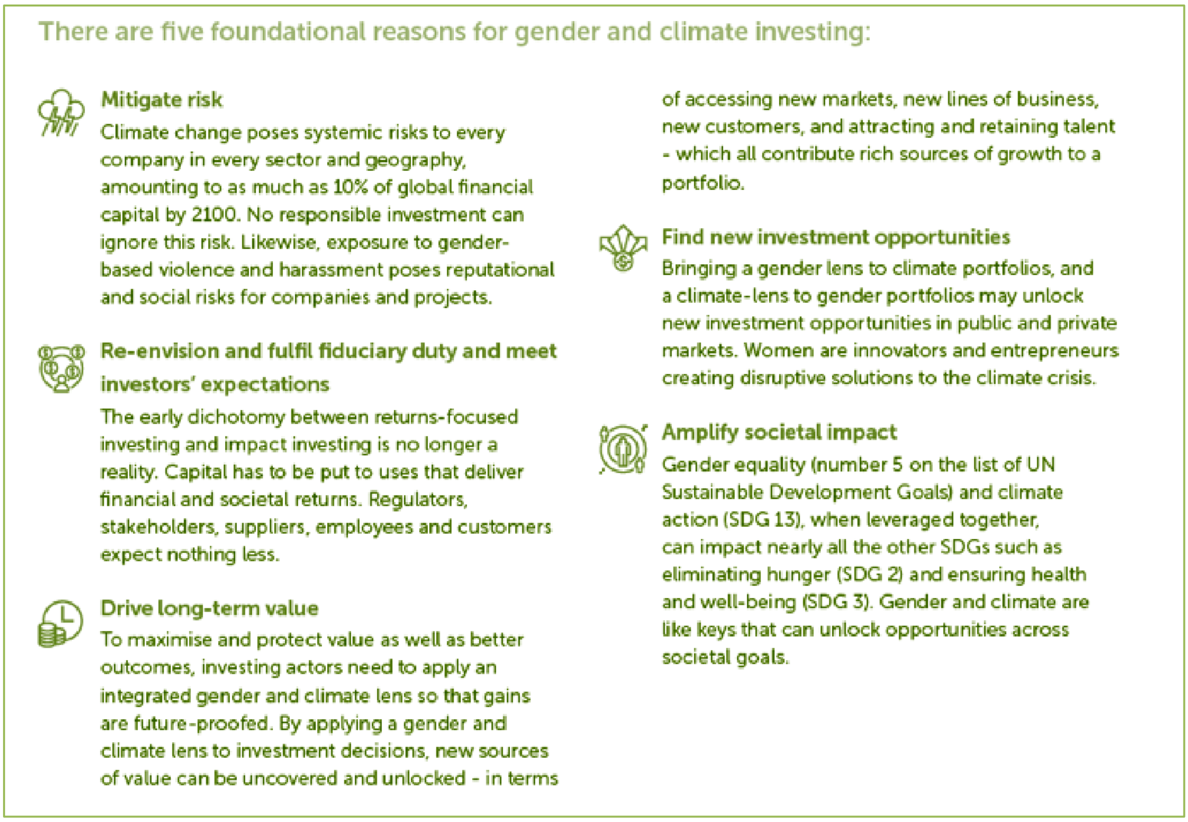
The cross-cutting workstreams of the IRP include **Climate Resilience**; the **Environment**; **Gender, Social Inclusion** (G&I), **and Safeguarding**; **Communications**; and well as **Monitoring, Evaluation and Learning** (see separate Section 6 for MEL).

Before discussing each in turn, it is important to recognise from the outset that there is clear link between G&I and climate change impact – hence the need for these interlinkages within the IRP for Zambia.

A 2021 GenderSmart & Partners publication emphasises that, in the energy sector, the opportunities with the most potential lie in expanding renewable energy access that responds to the gender differentiated needs of women, their households, businesses, and communities[64].

The report also makes the business case for financiers to invest in infrastructure projects that are gender transformative as outlined in the figure below. They argue that gender climate investment makes business sense, is good for the planet, supports a just transition to a green economy and is good for all people[65]. There is an increasing recognition that this is the way forward and that energy investments must capitalise on the gender and climate resilience synergies.

Figure 34: Reasons for gender and climate investing



There are five foundational reasons for gender and climate investing:

Mitigate risk
Climate change poses systemic risks to every company in every sector and geography, amounting to as much as 10% of global financial capital by 2100. No responsible investment can ignore this risk. Likewise, exposure to gender-based violence and harassment poses reputational and social risks for companies and projects.

Re-envision and fulfil fiduciary duty and meet investors' expectations
The early dichotomy between returns-focused investing and impact investing is no longer a reality. Capital has to be put to uses that deliver financial and societal returns. Regulators, stakeholders, suppliers, employees and customers expect nothing less.

Drive long-term value
To maximise and protect value as well as better outcomes, investing actors need to apply an integrated gender and climate lens so that gains are future-proofed. By applying a gender and climate lens to investment decisions, new sources of value can be uncovered and unlocked - in terms of accessing new markets, new lines of business, new customers, and attracting and retaining talent - which all contribute rich sources of growth to a portfolio.

Find new investment opportunities
Bringing a gender lens to climate portfolios, and a climate-lens to gender portfolios may unlock new investment opportunities in public and private markets. Women are innovators and entrepreneurs creating disruptive solutions to the climate crisis.

Amplify societal impact
Gender equality (number 5 on the list of UN Sustainable Development Goals) and climate action (SDG 13), when leveraged together, can impact nearly all the other SDGs such as eliminating hunger (SDG 2) and ensuring health and well-being (SDG 3). Gender and climate are like keys that can unlock opportunities across societal goals.

Below are some of the proposed areas of exploration for the IRP:

64 Suzanne Biegel and Sophie Lambin Gender & Climate Investment: A strategy for unlocking a sustainable future, February 2021 by GenderSmart and partners https://www.wocan.org/resources/gender-climate-investment-strategy-unlocking-sustainable-future#

65 Ibid.

Figure 35: G&I and climate resilience considerations for the IRP

5.1 Climate Resilience

Zambia is among the world's most vulnerable countries to climate change, ranking 26 out of 182 countries in the 2018 Global Climate Risk Index[66] and classified as having high to extreme risk in the 2018 Climate Change Vulnerability Index[67]. Climate variability is high, with frequent droughts, floods, extreme temperatures and dry spells. Climate records from 1960 to 2003 indicate that mean annual temperature has increased by 1.3 degrees Celsius, with an average rate of 0.34 degrees C per decade. Mean rainfall over the same period has decreased by an average of 1.9 mm/month (2.3%) per decade.

According to Zambia's National Communication report to the United Nations Framework Convention on Climate Change (UNFCCC), floods and droughts have increased in frequency over the past three decades, costing the nation 0.4% in annual economic growth, adversely impacting infrastructure, food and water security, energy and livelihoods of the people, especially in rural communities[68]. These trends are expected to intensify in the future.

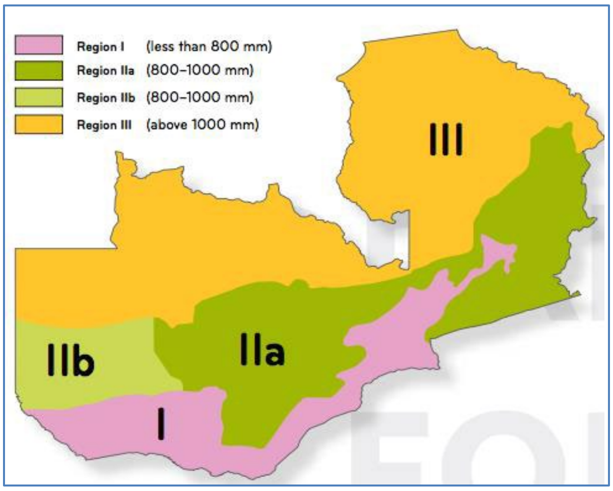
By 2100, projected temperatures are expected to increase by 3-5 degrees Celsius, with average precipitation declining during the early rainy season (October to December) and intensifying thereafter. An assessment of potential climate impacts by Zambia's Ministry of environment, shows that without adaptation, climate change hazards pose risks to economic growth and undermines efforts to improve livelihoods, adversely impacting key economic growth sectors including water, agriculture, forestry, wildlife, tourism, mining, energy, infrastructure, and health [69]. According to the

[66] https://germanwatch.org/en/download/20432.pdf
[67] Maplecroft (2018) https://www.maplecroft.com/risk-indices/climate-change-vulnerability-index/
[68] Zambia National Determined Contribution (2015) https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Zambia%20First/FINAL+ZAMBIA%27S+INDC_1.pdf
[69] Ministry of Tourism, Environment and Natural Resources (MTENR) (2007): Formulation of the National Adaptation Plan of Action (NAPA) on Climate Change. Final Report

World Bank, rainfall variability alone reduces annual GDP growth by 0.9%[70]. Inadequate economic opportunities and energy in rural areas contribute to wide-spread deforestation. Deforestation in Zambia accounts for 90% of carbon emissions.

The country is classified into three major agro-ecological zones[71]. Based on data from 1961-1990, zone I in southern part of the country is the most vulnerable, often impacted by droughts and floods. The region receives the least rainfall, less than 800mm followed by western and central parts of the country that receive an average of 800mm-1000mm (Zone II). The northern part of the country receives over 1200mm (Zone III). Zone III, IIa and IIb are also exposed to floods, around floodplains.

Figure 36: Zambia's ecological zones



The impacts of reduced rainfall have been felt across the country affecting GDP and employment. In 2016, Kariba Dam recorded the lowest water levels in history leading to record energy deficits across the country and loss of jobs in the mining and manufacturing sectors.

The poor are particularly vulnerable to climate change impacts due to their heavy reliance on agriculture. The rural population in the Zambezi Basin, particularly along the southern and western zones, are amongst the poorest and most vulnerable in Zambia, due to recurrent floods and droughts.

The elderly, female-headed households are the most vulnerable. Their food and income sources are heavily reliant on subsistence crops, sales of livestock and natural resources, and casual labour (mostly paid for in food), making them vulnerable to climate-induced crop failure.

5.1.1 Input to generation planning

A number of inputs are foreseen to generation planning. These will be aligned in accordance with 3 main themes; firstly, identifying and elucidating the climate change risks that will need to be considered for the generation types (identified in Section 4.3 above). An example of such a risk would be in hydroelectric generation – declining streamflow is expected to significantly reduce the hydroelectric generation capacity, while shifting rainfall patterns are expected to result in increased seasonal changes to generation potential and increases in both flooding and erosion; the latter two factors may increase the operational costs of hydroelectricity. Evaluating the risks of climate change impacts will also need to go beyond generation into distribution and transmission. Climate change impacts such as increased soil erosion, increased flood frequency and intensity and increases to extreme winds may affect exposed transmission infrastructure.

Secondly, identifying the potential opportunities for energy sector development and reform in strengthening climate resilience. While some forms of energy generation may be exposed to climate risks, well-planned and forward-looking development of energy resources may have significant potential for reducing the vulnerability of local communities and livelihoods. Clear examples where energy generation may contribute towards strengthened climate resilience (while also achieving other benefits) are through, for example, development of solar groundwater pumping schemes and improved access to refrigeration and cooling.

[70] World Bank (2013): Project Appraisal Document on a Proposed Strategic Climate Fund – PPCR 2013
[71] Meteorological Department (2004)

Lastly, opportunities presented by climate change for future generation will be investigated. This will include opportunities that are directly as a result of climate change impacts.

In addition to generation, climate change impacts on distribution and transmission should be explored with each of the leads of the other workstream.

5.1.2 Diversification of energy mix

Climate impacts will seriously undermine the Zambian energy sector. Increased frequency of droughts and low rainfall are already impacting the country's capacity to generate hydropower. In the recent past hydropower production has significantly reduced due to poor rainfall, resulting in low water availability and levels, which is attributed to the high climate variability and climate change being experienced. In 2016, Zambia faced power shortages due to low water levels in the Zambezi River that supplies Kariba Hydropower plant.

Energy generation in Zambia relies almost entirely on hydro power – around 80% of the total installed generation capacity of 2,981 MW[72]. Despite abundant potential for hydro-power generation at over 6,000 MW and high potential for solar and wind energy, only 31.4% of the population has access to electricity[73].

While climate change is impacting water reservoirs for hydropower, demand for electricity has grown very rapidly as new customers get connected to the grid. Demand has increased from around 1,600 MW in 2008 to 2,043 MW in 2020[74].

Energy reforms are underway to meet the growing demand and attract private sector investments. The MoE is responsible for the overall energy policy and strategy, while the ERB governs the energy sector regulations, licensing of IPPs, setting petrol prices and electricity tariffs. The OPPI is responsible for stimulating private investment in generation and transmission of electricity.

ZESCO dominates the electricity sector with 78.6% of installed capacity, while IPPs such CEC and Lunsemfwa Hydropower Company (LHPC), Itezhi-Tezhi and Renewable energy IPPs amount to only 176 MW (all hydro), equal to 6.22% of total installed capacity in Zambia. The REA leads implementation of the rural electrification, while IDC oversees the performance ZESCO, along with other parastatals.

With electrification rate as low as 28%, the largest energy source for majority of households in both rural and urban areas is firewood and charcoal from biomass or wood fuel. This accounts for 70% of country's energy supply. Consequently, Zambia's deforestation is one of the highest in the world at 300,000 ha/ year, causing carbon emissions.

Diversification of the energy mix will provide significant opportunities for reducing the national carbon emissions. In order to do promote such diversification, potential sources of climate finance (such as the Green Climate Fund (GCF)) should be explored for qualifying technologies that are identified.

5.1.3 Situational assessment

There are a number of climate initiatives being undertaken in Zambia that may have a relevance to the IRP. The GCF is funding a number of projects that are active in Zambia. In addition to these GCF projects, the World Bank's Pilot Programme for Climate Resilience (PPCR) will provide US$86 million in grants and near-zero interest credits for Zambia's PPCR strategic programme. The programme was

[72] Energy Regulation Board (2019): Energy Sector Report, p.53
http://www.erb.org.zm/reports/esr2019.pdf
[73] Ibid.
[74] MoE 2020 data accessed by the IRP project team

designed under the leadership of the GRZ in coordination with AfDB and the World Bank Group (IBRD, IFC).

Zambia's priorities with regards to climate change are outlined in the country's Nationally Determined Contributions. Of these, the identified priority adaptation programmes can be used to identify where energy projects are most likely to contribute to climate resilience (through *inter alia* providing energy for agricultural production).

Table 22: Adaptation programmes

Priority programmes	Key activities	Co-benefits
1. Guaranteed food security through diversification and promotion of Climate Smart Agriculture (CSA) for crop, livestock and fisheries production and conversation.	• Promote CSA practices through conversation agriculture, agroforestry, use of drought tolerant varieties, water use efficiency management and fertiliser use efficiency management. • Promote crop such as cassava, maize, sorghum, finger millet, beans, cowpea and their wild relatives. • Promote livestock CSA practices through improved feed management, improved animal health, improved rangeland management, and use of drought tolerant feeds. • Promote sustainable aquaculture practices through improved water management, improved feeding regimes and use of appropriate stocks. • Develop and implement policy incentives for farm diversification.	• Poverty reduction, increased food security due to improved agricultural production and diversification • Increased rural household incomes from diversified production systems. • Increased soil fertility and conservation leading to improved crop productivity. • Increased agro-biodiversity conversation, Improved health impacts as a result of food security. • Increased livestock productivity, reduced vulnerability, increased fisheries productivity.
2. Develop a National Wildlife Adaptation Strategy and ensure its implementation through supportive policies, local, community, civil society and private sector participation.	• Develop a National Wildlife Adaptation Strategy. • Map and protect wildlife corridors and refuges. • Promote community/private/public partnerships in the sustainable management of wildlife resources. • Enforce equitable benefit sharing arrangements among government, communities and the private sector in the management of wildlife resources.	• Improved governance of the wildlife estate. • Increased wildlife system resilience and reduced vulnerability. • Increased income from tourism-related activities.
3. Protection and conservation of water catchments, enhanced investment in water capture, storage and transfer (linked to agriculture, energy, ecological, industrial and domestic use.	• Promote the protection of catchment forests in the Zambezi, Kafue and Luangwa watersheds. • Promote rainwater harvesting, improve water storage through dams and weirs. • Develop and improve water transfer infrastructure through canals, piped systems and undertake restoration projects.	• Improved water security for ecological, domestic and industrial purposes. • Increased hydrological systems resilience and reduced vulnerability to climate change impacts. • Improved water quality.

Priority identified mitigation programmes, on the other hand, indicate strong opportunities for altering the energy mix to reduce Zambia's national carbon emissions:

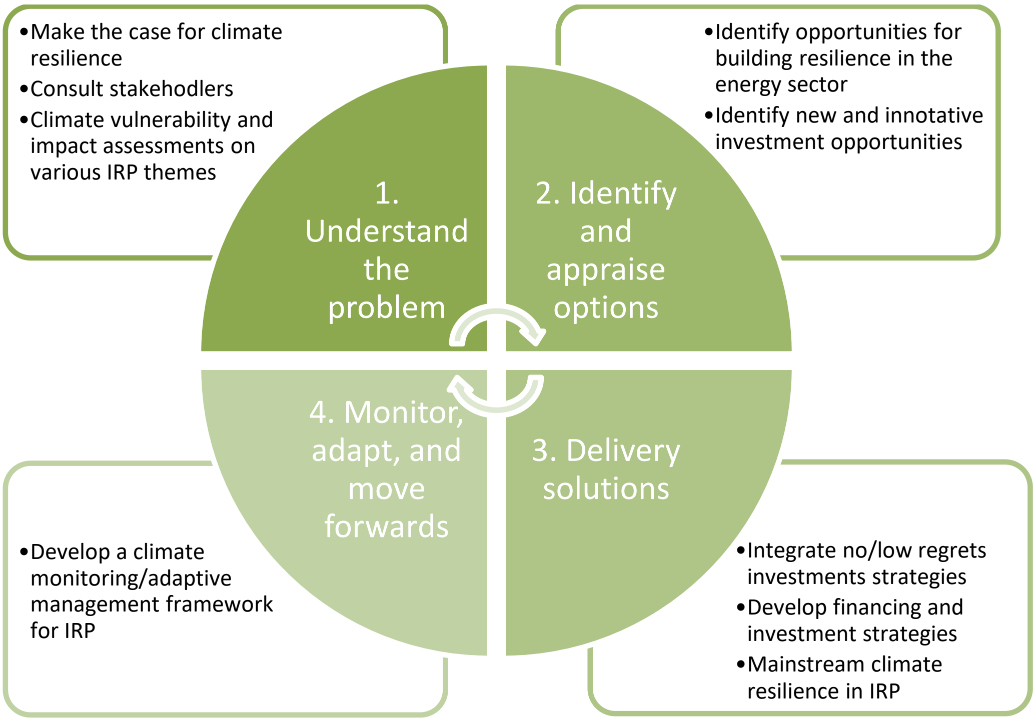
Table 23: Mitigation programmes

Priority programmes	Key activities
1. Sustainable forest management programme promotes natural regeneration, afforestation, reforestation, sustainable charcoal production and utilisation practices and generation of electricity from forest waste and residues.	• Forest enhancement including natural regeneration and afforestation/reforestation • Sustainable charcoal production to include improved kilns • Improved cooking devices to include biomass stoves, use of ethanol and LPG stoves and switch to electric stoves • Participatory forest management (CFM, JFM, PFM) • Forest fire management
2. Sustainable agriculture programme promotes conservation/ smart agriculture activities leading to adaptation benefits and enhancing climate resilience, especially in rural areas, and generation of electricity from agriculture waste.	• Conservation/Smart agriculture • Rural biogas plants • Rural biomass electricity generating facilities
3. Renewable energy and energy efficiency programme promotes switching from conventional and traditional energy sources to sustainable and renewable energy sources and practices, and use of off grid renewable energy technologies for rural electrification as decentralised systems.	• Fuel switch (diesel/HFO to biodiesel), coal to biomass) • Switch from existing isolated diesel to mini-hydro • Introduce and increase blending bio-fuels with fossil fuels and where possible substitution with bio fuels • Off grid to non-electrified rural PV and wind • On grid expansion programme to support economic growth and grid extension through inter-basin water transfer • Grid extension to non-electrified rural areas

5.1.4 Proposed approach and methodology

As demonstrated in this section, Zambia is highly vulnerable to the impacts of climate change. This vulnerability will be expressed in all sectors – including the energy sector. A cyclical, phased approach should be applied to the implementation of the IRP to ensure continued adaptive management that will build climate resilience.

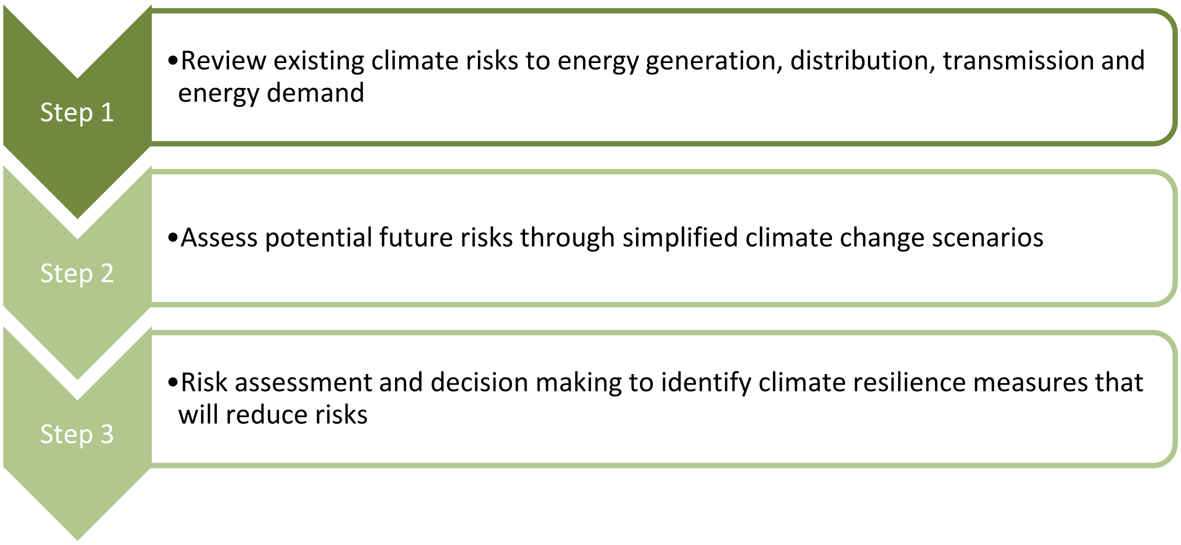
Figure 37: Climate resilience development



For the purposes of the IRP development, the first two phases will comprise the priority of the work under this workstream, as no implementation is expected during the development of the IRP. Indeed, steps three and four are for the MoE and various stakeholders to utilise during the IRP implementation.

Identifying and assessing the key climate risks to the sector will be crucial to ensure that activities under the IRP are: i) climate-proofed; ii) able to identify and make use of the opportunities of climate change; and iii) can contribute towards building climate resilience. The diagram below shows an outline of a basic three-step framework for screening the proposed initiatives under each of the major themes of the IRP.

Figure 38: Framework for climate screening



In order to screen for climate risks, the work of all the major themes will be analysed using this screening approach. It should be noted that, in many cases, appropriate solutions for handling uncertainty will need to be applied. This is because there is significant uncertainty around a number of climate change impacts in Zambia – particularly on precipitation. A qualitative planning approach may often be recommended for handling these.

5.1.5 High-level summary of implementation phase activities

Table 24: Climate resilience – Summary of activities

Deliverable	Task	Output	Expected completion Date
D2 – Consolidated IRP Implementation Report (Component 5: Climate and G&I Report)	Prepare inputs to implementation report related to climate	• Relevant inputs for report	End September 2021
D3 – Scenario Analysis Report D4 – Draft IRP Report D5 – Final IRP Report	Capacity building on: Mainstreaming climate resilience in energy sector programming	• PPT presentations and training material	End December 2021
	Ongoing coordination with and provision of cross-cutting advice to the core workstreams - Prepare inputs to these deliverables with the Workstream Leads	• Relevant inputs for the reports	Mid-December 2021 Mid-February 2021 End March 2022
D6 – Completion Report (including capacity-building activities)	Prepare inputs to the completion report related to climate	• Write-up of capacity building activities	End March 2022

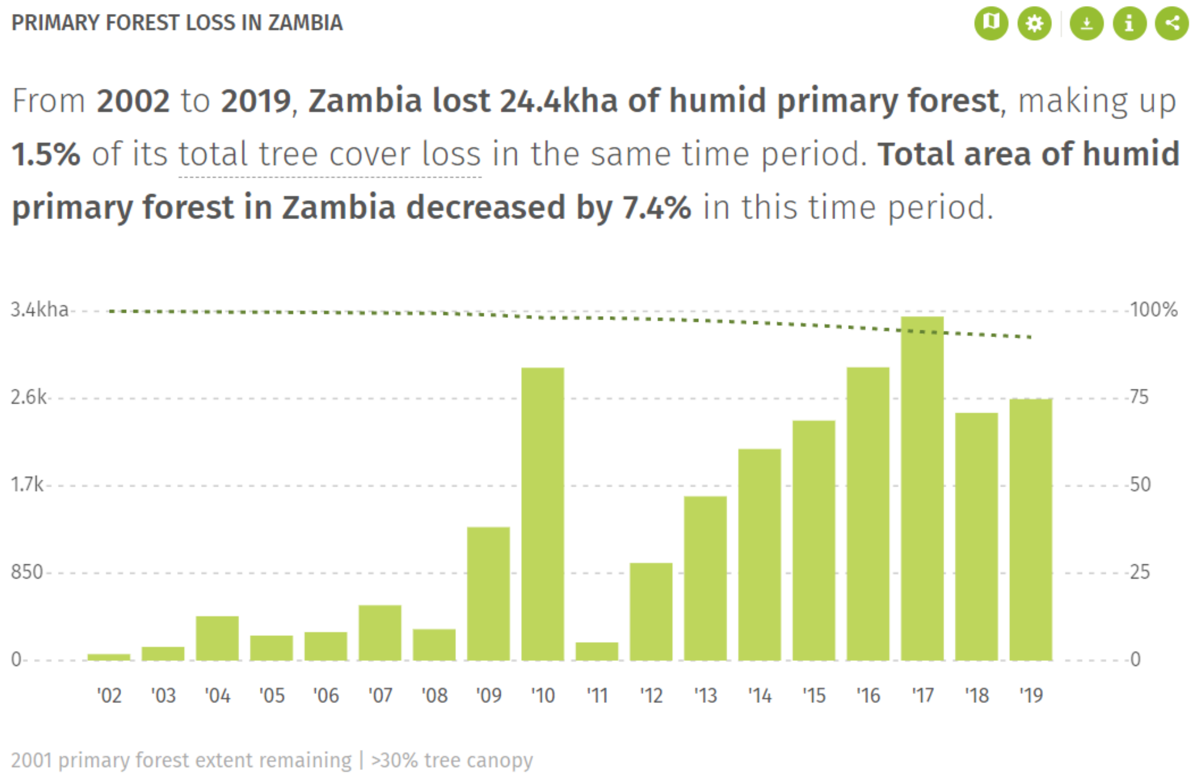
5.2 Environmental Impact

Safeguarding the environment is now central to the planning of most infrastructure projects worldwide, including in Zambia. Under the Zambia Environmental Management Act (2011) of the laws of Zambia, ZEMA is mandated to approve or reject projects based on the adequacy or otherwise of their environmental impacts. The feasibility and cost of energy projects are therefore critically dependent on their environmental impact. This is fully recognised and accepted; hence the environmental impact, and mitigation where necessary, of projects that will be part of the portfolio of the IRP will be fully considered.

The utilisation of forests for energy has an impact not only on the environment but also on climate. The rate of deforestation in Zambia is quite high, estimated to be at approximately 300,000 hectares of forest cover lost per year[75]. In 2019 alone Zambia lost 125 kilo hectare of tree cover, equivalent to 32.4Mt of CO2 emissions[76].

[75] Day, M. *et al.* (2014): Zambia Country Profile – Monitoring, reporting and verification for REDD+, Center for International Forestry Research (CIFOR) and USAID https://www.cifor.org/publications/pdf_files/OccPapers/OP-113.pdf
[76] Global Forest Watch (2020), Zambia Country Profile

Figure 39: Deforestation in Zambia - Global Forest Watch[77]



Indeed, according to the Ministry of Lands and Natural Resources, deforestation is a key contributor to greenhouse gas emissions in Zambia,

> "mainly due to: a) over-exploitation of forest resources and encroachment of the protected areas as well as uncontrolled forest fires; b) extensive crop production practices especially through slash-and-burn agriculture; c) increased forest conversion for energy especially charcoal and firewood; d) forest conversion for mining and infrastructural development; and e) unplanned land uses that compromise forest integrity and biodiversity conservation"[78].

The interplay between electrification and domestic energy use will therefore need to be explored in the development of the future energy scenarios for the IRP.

The other environmental impact that is relevant to IRP is the opportunity cost of lack of access to clean electrical energy for cooking, leading to over dependency on charcoal for cooking. In addition to this, especially in large towns and cities, there is also the need to consider the environmental impact related to air pollution from fossil fuels.

Timely adoption of electrification of transport will forestall future problems for Zambia. It is now common knowledge that other countries worldwide have made firm commitments to phase out fossil fuel cars in the next decade (the UK, for example, has made a policy commitment that by 2030, it will not be possible to purchase new petrol and diesel vehicles – all new cars will be electric). It would be a travesty if all fossil fuel cars that will become very cheap in developed countries as they transition to electric vehicles were to find their way into Zambia. In the development of this IRP, it will be

[77] Global Forest Watch (2020), Zambia Country Profile

[78] Ministry of Lands and Natural Resources (November 2017): National Investment Plan to Reduce Deforestation and Forest Degradation (2018-2022), p.vi https://climateinvestmentfunds.org/sites/default/files/meeting-documents/zambia_final_investment_plan_fip.pdf

important to frame the assumptions regarding the transport sector, as this will have a significant impact on the electricity infrastructure requirements to support the electrification of transport.

Given the projected growth in solar home systems with battery storage for both on-grid and off-grid electrification, another important environmental consideration is the need for safe end of life disposal of the waste from these systems, in particular batteries and solar panels. Safe disposal of lead acid batteries is particularly critical because poor disposal, through say landfill, can lead to poisoning of the environment as well as ground water systems since lead is known to be carcinogenic[79]. It will therefore be worth exploring the feasibility of either establishing battery recycling facilities in Zambia or export for safe disposal to avoid their unsafe disposal.

5.3 Gender, Social Inclusion and Safeguarding

It is essential that the IRP proactively approaches gender and social inclusion (G&I) during the development, implementation, and monitoring and evaluation phases of the IRP project, as the IRP has the potential to transform lives of many vulnerable Zambian populations, particularly women, children, and marginalised groups.

Global evidence demonstrates that a gender and inclusive energy sector is essential for the following reasons:

1. **More women in the labour force is good for the economy. It increases economic growth and provides new business opportunities.**

    - Increased economic opportunities for women has multiplier effects for households, communities and the economy as a whole. Closing the gap in women's participation in the labour force could add $12–28 trillion or up to 26% to global GDP in 2025[80].
    - Investments in energy infrastructure that target low-income women in urban areas can unlock new revenue streams for energy companies whilst reducing costs for the consumer and the economy[81].

2. **Energy access reduces women's time poverty and improves household health and wellbeing.**

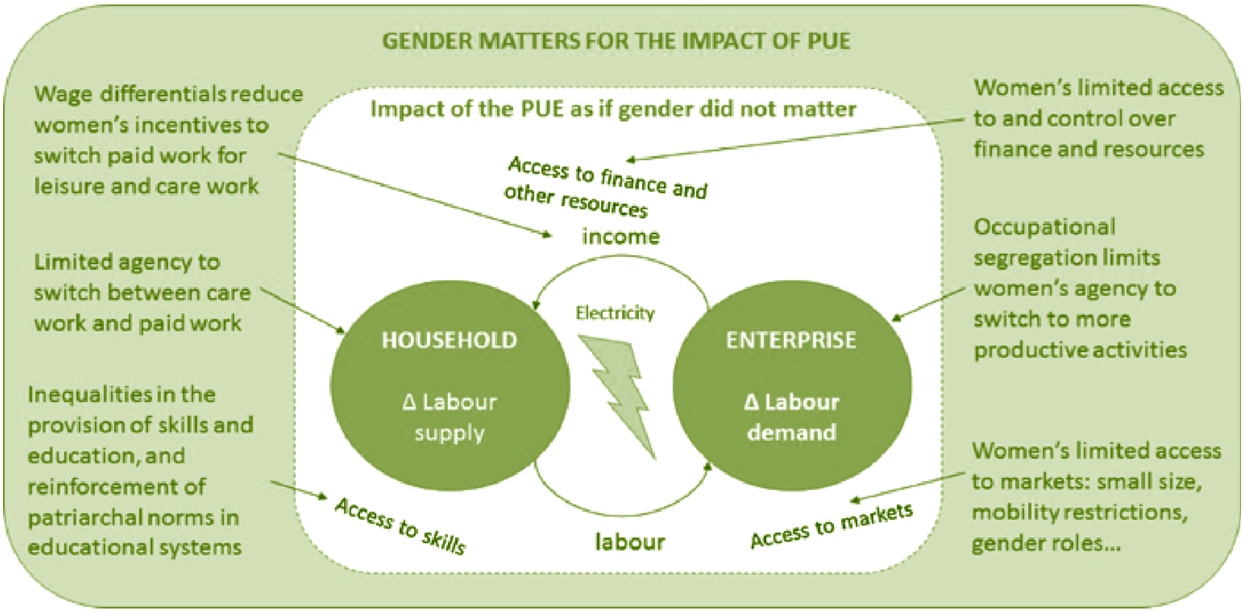
    - Access to energy and affordable clean, efficient, energy technologies have the potential to save time spent by women and girls on unpaid domestic work and improve health and safety[82].
    - Access to clean and efficient cookstoves improved women's and their families' health due to a reduction in air pollution from burning biomass as fuel[83].

3. **Energy access can improve women's productivity and foster entrepreneurship and support wealth creation for poor women and men**.

[79] https://www.who.int/news-room/fact-sheets/detail/lead-poisoning-and-health
[80] Woetzel, Jonathan et al. (September 2015): How advancing women's equality can add $12 trillion to global growth, McKinsey Global Institute, McKinsey & Company
https://www.mckinsey.com/featured-insights/employment-and-growth/how-advancing-womens-equality-can-add-12-trillion-to-global-growth#
[81] Colenbrander, Sarah (2016): Cities as engines of economic growth: the case for providing basic infrastructure and services in urban areas, Working Paper, IIED
https://pubs.iied.org/sites/default/files/pdfs/migrate/10801IIED.pdf
[82] O'Dell, Kathleen et al. (2014): Women, energy, and economic empowerment – Applying a gender lens to amplify the impact of energy access, Deloitte University Press
https://www2.deloitte.com/content/dam/insights/us/articles/women-empowerment-energy-access/DUP_950-Women-Energy-and-Economic-Empowerment_MASTER1.pdf
[83] Ibid.

- It enables women to start and grow home-based enterprises and small businesses and access modern appliances and technologies[84].
- Connecting households to the electric grid enables people to buy and use mobile phones, fridges and other time saving technologies that can increase the productivity of home-based work and create wider business opportunities[85].
- In South Africa, rural electrification increased female employment by 9%, largely in self-employment and microenterprises as electricity lowered the cost of new home-based products and services[86].
- In selected developing countries across Sub-Saharan Africa, the Middle East and North Africa, Asia, and Latin America, informal enterprises were found to contribute between 15-62% of national GDP[87].

Figure 40: Gender impact of productive use of energy



Source: Pueyo & Maestre (2019)

The green box highlights the gender specific barriers and social and cultural norms that shape and constrain the wider enabling environment and thus, women's access and decision-making to productive resources. These need to be taken into account in design and implementation to tap into the full potential and positive impact of energy interventions.

[84] United Nations High-Level Panel on Women's Economic Empowerment (2016), Leave No One Behind – A call to action for gender equality and women's economic empowerment, UNHLP https://www2.unwomen.org/-/media/hlp%20wee/attachments/reports-toolkits/hlp-wee-report-2016-09-call-to-action-en.pdf?la=en&vs=1028

[85] Ibid.

[86] Dinkelman, Taryn (August 2010): The Effects of Rural Electrification on Employment: New Evidence from South Africa, Princeton University https://rpds.princeton.edu/sites/rpds/files/media/dinkelman_electricity_0810.pdf

[87] World Cities Report (2016), Urbanisation and Development – Emerging Futures, UN Habitat https://unhabitat.org/world-cities-report

4. Gender and inclusion sensitive energy investments improve resilience and can support a just transition to a green economy.

- In 2012, the UNDP reported that several studies confirmed that women's empowerment is crucial for all-round social development, environmental sustainability and ensuring efficiency and sustainability of climate change responses (see Section 5.1 on climate resilience).
- Specifically, "incorporating the contributions and concerns of women and men can help inform programmes and increase access to grid and off-grid electricity access…failure to consider gendered interests and the different needs of men and women can limit the effectiveness of energy programmes and policies, as well as other development activities that involve energy use."[88]

5.3.1 Situational assessment: understanding G&I in the energy sector context

In 2018, the Green Climate Fund (GFC) noted that the participation of women in the energy sector value chain in Zambia is very limited, especially as entrepreneurs or business leaders in renewable energy[89]. In terms of energy access, the framework notes that "the majority rural population is especially energy poor over 90% of rural Zambians are without access to energy."[90] The Zambia National Energy Policy (2008)[91] and the National Gender Policy (2014)[92] recognise the intersection of gender, energy access, and energy systems development. However, an assessment by CIGZambia in 2018 revealed significant gaps in gender mainstreaming in the sector including that[93]:

- **there are numerous supportive national laws and plans** that address G&I in energy that may be leveraged on.
- **there is a lack of diverse representation across energy sector institutions** due to social norms that limit women's advancement in technical fields.
- **lack of sex- and socio-economic disaggregated energy sector data in Zambia** presents challenges to formulating quantifiable targets and sound policies.
- **poor access to credit and financial services is a significant barrier to access (renewable) energy and entrepreneurial opportunities**.
- **the solar small-scale and off-grid energy market in Zambia is under untapped,** with high opportunity for increased employment and entrepreneurship among women, youth, and people living with disabilities.

According to World Bank Group, "in the energy sector, gender dimensions of **access to services, access to benefits, and exposure to risks and benefits**, are being increasingly recognized as important elements to be considered for effective policy making and project design"[94]. In line with the SDGs,

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[88] Habtezion, Senay (2012): Gender and Climate Africa Policy Brief 3, Gender and Energy, United Nations Development Programme
https://www.undp.org/content/dam/undp/library/gender/Gender%20and%20Environment/PB3_Africa_Gender-and-Energy.pdf

[89] Green Climate Fund (March 2018): Zambia Renewable Energy Financing Framework, Africa Development Bank Group
https://www.greenclimate.fund/document/zambia-renewable-energy-financing-framework

[90] Green Climate Fund (March 2018: Zambia Renewable Energy Financing Framework, Africa Development Bank Group
https://www.greenclimate.fund/document/zambia-renewable-energy-financing-framework

[91] Ministry of Energy (2008): National Energy Policy 2008
https://www.moe.gov.zm/?wpfb_dl=42

[92] Ministry of Gender and Child Development (2014): National Gender Policy 2014
http://extwprlegs1.fao.org/docs/pdf/zam152916.pdf

[93] Cities and Infrastructure for Growth Zambia for FCDO (2018): CIGZambia Gender Equality and Social Inclusion (G&I) Assessment, August 2018

[94] Hughes, Wendy et al., (February 2013): Integrating Gender Considerations into Energy Operations, ESMAP, Report no. 76751, Knowledge Series 014/13, the World Bank
http://documents1.worldbank.org/curated/en/501071468177837535/pdf/765710ESM0P1230to0Energy0Operations.pdf

energy initiatives that **increase income-generating opportunities, employment and entrepreneurship** for women are critical for improving food security, reducing poverty, *and* supporting inclusive growth.

Therefore, the IRP will invest time and resources to understand the G&I dimensions – the constraints and opportunities with regards to the energy sector. This will cover the following areas of ambition and potential impact:

- **Ensure no harm is done** and that proper due diligence is built into and informs the IRP processes to manage risks in line with international standards on environmental, social and governance risk management (e.g., IFC performance standards and the World Bank Social & Environmental Governance Framework).
- Facilitate **equitable access to clean, reliable and affordable energy** to all that need it.
- Apply social and gender analysis and participatory processes for IRP to identify and promote **energy as catalyst for income earning, employment, entrepreneurship and leadership opportunities especially for poor and excluded women and men**.
- Identify opportunities for **long-term sustainable change in the energy sector to address systematic barriers and promote institutional and organisational change.**

Below are some of the proposed areas of exploration for the IRP.

Gender-energy interactions – institutional incentives for transformational change

A 2019 study commissioned by the European Union recommended that energy programmes should also seek to be more responsive by:

- **Prioritising energy for cooking-to address women's energy needs** for cooking, research and investments.
- **Increasing women's representation in the workforce in all public and private bodies** in the energy sector including putting in place measures for a conducive work environment (safeguarding) such as harassment policies (sexual harassment in particular) should be developed with clear reporting procedures and sanctions towards perpetrators.
- **Training in gender mainstreaming** and applying it through the development of gender action plans.
- Appointing **gender focal points** in each institution.
- **Supporting monitoring and evaluation units for gender-sensitive data collection.**
- Considering **gender certification procedures for programmes and projects** in the energy sector to ensure that gender is mainstreamed in the design and implementation of all energy programmes and projects.
- Increasing support to the **Zambia Gender and Energy Network (ZGEN).** [95]
- **Operationalising gender and inclusion transformative procurement procedures** that factor social and gender requirements in all tender documents to increase affordable access, and to support women's economic opportunities.

Energy access to improve health, safety and quality of life

Access to affordable clean energy can have health, safety, and quality of life benefits for women, girls, and vulnerable populations at the household level. Since women and girls tend to be responsible for most of the household cooking, they are at greater risk of the negative impacts of cooking with solid

[95] European Union (May 2019): Enhancement of the policy, legal and regulatory environment and capacity building for renewable energy and energy efficiency, Zambia: Gender Assessment of the Energy Sector in Zambia (Version 2), FED/2018/395-092
https://www.moe.gov.zm/?wpfb_dl=52

fuels in poorly ventilated stoves and kitchens, the World Health Organisation in 2018 published the following key facts[96]:

- Each year, close to 4 million people die prematurely from illness attributable to household air pollution from inefficient cooking practices using polluting stoves paired with solid fuels and kerosene.
- Household air pollution causes non-communicable diseases including stroke, ischaemic heart disease, chronic obstructive pulmonary disease and lung cancer.
- Close to half of deaths due to pneumonia among children under 5 years of age are caused by particulate matter (soot) inhaled from household air pollution.

Access to electricity in health centres facilitates improves healthcare outcomes for respective patients, including those diagnosed with Covid-19, while streets, markets and schools with lighting contributes to a safer environment after dark, potentially opening up opportunities for women and girls who otherwise may not have been able to undertake activities outside the house after dark[97].

Household expenditure and improved energy services

According to the World Bank, "energy sector interventions that impact household expenditure on energy services include reforms or other actions that raise electricity tariffs and activities aimed at improving energy efficiency, which has the potential to reduce household`s expenditures on energy for a given level of service"[98]. This can have a particularly negative impact on poor women and excluded groups.

The IRP should thus acknowledge and factor into its design and implementation that household energy expenditures will impact men and women differently due to their roles in household decision-making and use of disposable income after paying for energy services. This should be a particular concern for female, elderly, and child-headed households. This is therefore an opportunity to look at cross-subsidisation and mechanisms to help low-income households to connect to the grid with e.g., financing schemes that cover upfront connection costs for poor or female-headed households, micro and small enterprises including home-based enterprises.

Energy as a catalyst for income generation, employment, entrepreneurship, leadership and expanded market activity

Global evidence demonstrates that companies with more women in leadership positions perform better, are more profitable are more innovative and achieve higher environmental ratings (EY 2016)[99]. This is because these companies can tap into a wider talent pool, their retention rates for women in the workforce are better and they tend to invest in diversity and gender equality, which makes them more competitive and effective in the long run.

[96] WHO (2018): Factsheets-Household Air Pollution and Health https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health

[97] Hughes, Wendy et al., (February 2013): Integrating Gender Considerations into Energy Operations, ESMAP, Report no. 76751, Knowledge Series 014/13, the World Bank http://documents1.worldbank.org/curated/en/501071468177837535/pdf/765710ESM0P1230to0Energy0Operations.pdf

[98] Hughes, Wendy et al., (February 2013): Integrating Gender Considerations into Energy Operations, ESMAP, Report no. 76751, Knowledge Series 014/13, the World Bank http://documents1.worldbank.org/curated/en/501071468177837535/pdf/765710ESM0P1230to0Energy0Operations.pdf

[99] Ernst and Young Women in Power and Utilities Index 2016

- **Job creation opportunities –** the physical process of designing and constructing infrastructure increasingly involves women as contractors, semi-skilled and skilled workers and supervisory engineers.
- **Skills development and career progression** – helping women build skills and enhancing access to information, training, finance and technology can support women's retention and career progression within energy and engineering companies.
- **Women in leadership and decision-making positions** – encouraging greater representation of women in senior, decision-making and leadership. For example, PEG Ghana was able to increase female leadership by 14% in a 12-month period and at the same time achieve a 60% growth in revenue and earnings before taxes[100].
- **Accessing new markets and latent demand** – companies can design approaches and services that support female entrepreneurs and women and men in the informal sector with financing mechanisms that enable e.g., women customers to afford the initial operating costs and start-up costs of equipment.
- **Integrate 'complementary services' in order to amplify the impact of electrification** – "electrification projects should be accompanied by complementary services such as credit facilities, trainings on entrepreneurship, creation of savings groups and other initiatives[101].
- **Value chain opportunities –** Women's participation has been shown to increase value chain sustainability, enhance commercial activity and sales and has a positive impact at the community level. During product and service design as the primary energy household users can improve design, reach and innovation.
- **Women's engagement in marketing, sales and distribution** in, for example, clean cook stoves, has resulted in a much higher take up by women as they can use their networks and first had knowledge to raise awareness and build trust.
- There are also opportunities in **installation and maintenance** to train and employ women in higher-skilled jobs.
- **Women also could play a much greater role in front office services** – providing customer support, and in billings, collection and repayment.

Resettlement

The World Bank's 2019 toolkit on resettlements notes that impacts of development-induced resettlement can disproportionately affect women and they are likely to face more challenges than men while coping with disruption to their families[102].

Taking G&I differences into account during IRP consultation process, the design and implementation of compensation plans will be essential for a successful resettlement process if such a need arises – one that goes beyond risk mitigation to one that seeks to enhance livelihoods and capitalise on opportunities.

[100] USAID and Power Africa (2019): Power Africa Case Study Ghana – Advancing Gender equality in Africa's Off-grid Energy Sector
https://www.usaid.gov/sites/default/files/documents/1860/PA_Case_Study.2019.04.09.508.pdf

[101] European Union (May 2019): Enhancement of the policy, legal and regulatory environment and capacity building for renewable energy and energy efficiency, Zambia: Gender Assessment of the Energy Sector in Zambia (Version 2), FED/2018/395-092
https://www.moe.gov.zm/?wpfb_dl=52

[102] World Bank (2019): How to Ensure Better Outcomes for Women in Resettlement: A Toolkit, The World Bank Group
http://documents1.worldbank.org/curated/en/812241554967756481/pdf/How-to-Ensure-Better-Outcomes-for-Women-in-Resettlement-A-Toolkit.pdf

5.3.2 Proposed approach and methodology

The section below outlines the proposed approach for integrating G&I into the IRP.

Step 1: G&I assessment (stakeholder consultations)

Stakeholder consultations will not only seek to engage women and marginalised populations for the sake of participation but will aim to realise valuable insights about stakeholder expectations; “they need to be meaningfully involved and capable of exercising influence in decision-making processes, in ways that are defined by them, ensuring equal opportunity to contribute their knowledge and express their views”[103].

The consultations will employ a multi-method approach applying qualitative techniques with a bias in in-depth analyses of selected factors or underlying influences of economic, social and environmental development, inequalities, marginalisation, gaps and challenges as perceived by stakeholders selected from diverse groups of communities within selected communities. The process will also involve desk reviews, virtual and in-person consultations, which will be compliant with Government guidelines to prevent the transmission of Covid-19.

The key principles for the stakeholder engagement and consultations will include:

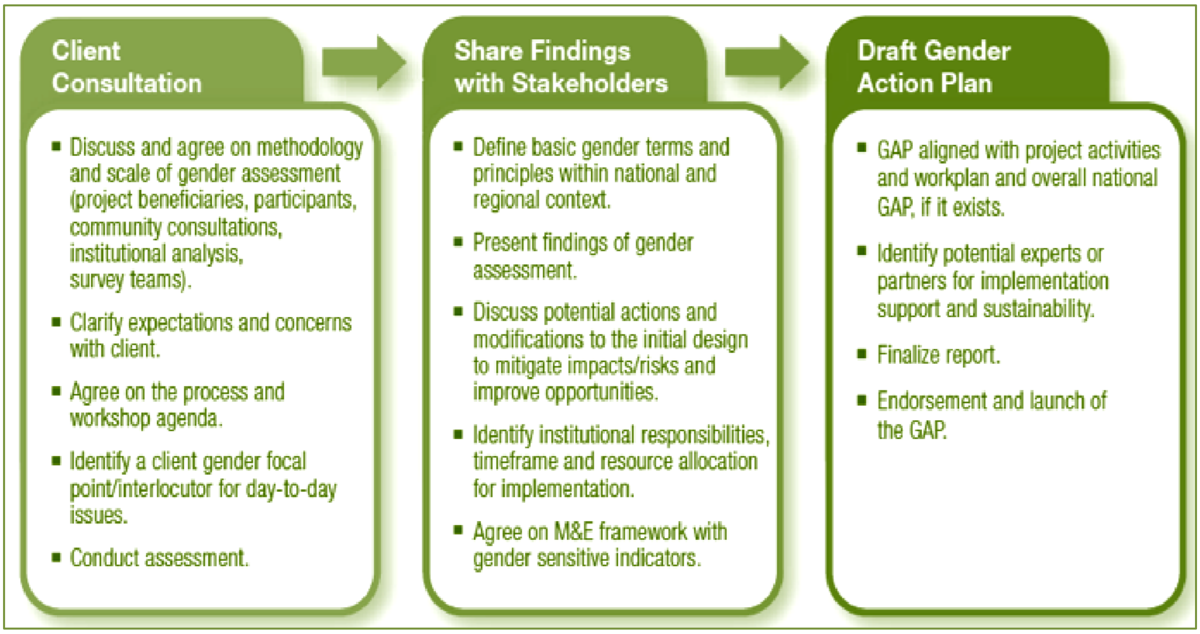
- Commitment to genuine and meaningful stakeholder engagement and consultation;
- Integrity of engagement by fostering mutual respect and trust;
- Respect and recognition of stakeholder’s rights, cultural beliefs and values;
- Transparency in taking-on community concerns as well as providing feedback in a timely, open and effective manner;
- Inclusiveness of the process through engagement of a representative stakeholder base;
- Trust achieved through open and meaningful dialogue that respects and upholds a community’s beliefs, values and opinions.

Step 2: G&I action plan development

The Plan will be developed and integrated within the IRP to demonstrate that this project is committed to meeting the stakeholder expectations on G&I. This will aid the sector in setting concrete targets, identifying special measures, and holding all staff accountable for its implementation. The Plan will also guide the stakeholders (especially MoE, ERB, and ZESCO) in tracking progress towards achieving its vision of an energy sector that is equally enabling for women and men. The figure below is an illustration of the proposed process that will be adopted for integrating the G&I plan into the IRP process.

[103] Global Water Partnership (August 2017), ISBN 978-91-87823-40-4

Figure 41: Proposed process for integrating the G&I plan into the IRP process



Step 3: Monitoring, evaluation and safeguarding

The stakeholders will be engaged to establish monitoring mechanisms, including the monitoring and evaluation indicators for the IRP to ensure they are gender-sensitive and that data is gender-disaggregated (see Section 6.2.2) to track progress along gender dimensions.

The IRP must ensure that social accountability mechanisms for quality public service delivery[104], including grievance and redress mechanisms for non-compliance with performance standards, are in place. A dedicated G&I expert may need to be assigned and trained for this particular purpose.

5.3.3 High-level summary of implementation phase activities

Table 25: G&I – Summary of activities

Deliverable	Task	Output	Expected completion Date
Stakeholder Consultation Report	Conduct stakeholder consultations with women, men, young people, marginalised communities and sector key stakeholders on the IRP – including, benefits of electricity for cooking and potential opportunities for community engagement	• Stakeholder Consultation Report	End June 2021
D2 – Consolidated IRP Implementation Report (Component 5: Climate and G&I Report)	Prepare inputs to implementation report related to G&I	• Relevant inputs for report	End September 2021

[104] Biswas, S. and Hassan, F. (2019): Strengthening Gender & Social Inclusion (with a focus on Women's Economic Empowerment) within the Global Infrastructure Programme, WOW Helpdesk Query No. 33

D3 – Scenario Analysis Report D4 – Draft IRP Report D5 – Final IRP Report	Capacity building to private and public energy sector actors on, *inter alia:* - Mainstreaming G&I in energy sector programming - Workplace safeguarding How to facilitate business opportunities in the energy sector for women and girls	• PPT presentations and training material	End December 2021
	Ongoing coordination with and inputs to the workstreams Prepare inputs to these deliverables with the Workstream Leads	• Relevant inputs for the reports	Mid-December 2021 Mid-February 2021 End March 2022
D6 – Completion Report	Prepare inputs to the completion report related to G&I	• Write-up of capacity building activities	End March 2022

5.4 Communications

5.4.1 Communications Strategy and Stakeholder Engagement Plan

The Communications Strategy and Stakeholder Engagement Plan (see Annex 6: Communications Strategy and Stakeholder Engagement Plan) sets out the approach to be taken by the IRP project in communicating the project's scope, objectives, and benefits to its intended stakeholders.

At a macro-level, the IRP process is designed to include a stakeholder consultation process that is as transparent and inclusive as possible. This is to both to share information (the 'push' element) and solicit and receive feedback (the 'pull' element). This two-pronged approach is reflected in the Communications Strategy and Stakeholder Engagement Plan document.

The Communications Strategy and Stakeholder Engagement Plan identify the following specific objectives:

Communications objective:

- Raising awareness among key stakeholders of their role(s) in the development of the IRP in the period from December 2020 to March 2022.

Engagement objectives:

- Providing effective platforms to enable stakeholder participation in IRP development process by conducting a series of workshops and meetings between December 2020 and March 2022.
- Securing the support and commitment of key stakeholders in achieving the objectives of the IRP project by March 2022 (and throughout its implementation period).

A brief analysis of the approach set out in the Communications Strategy and Stakeholder Engagement Plan is covered here.

Communications approach

Communication and stakeholder engagement efforts are led by the MoE team, with other actors working in support roles to the MoE's efforts. It is vital that ownership and execution of the strategy comes from the MoE, to deliver a process that is both legitimate and sustainable within the GRZ's structures. The roles and responsibilities to support this approach are set out in the Strategy to provide clear guidance on the process in the coming year.

It is important to note that, with guidance received from the MoE, the stakeholder engagement process has been defined as largely an intra-governmental one. In other words, the primary focus of the consultations is to build consensus, understanding and visibility for the IRP internally, with other GRZ Ministries, departments, and parastatal enterprises. Other audiences such as the private sector, academia, communities, and the media are indeed reflected in the Strategy and the Plan, but the emphasis is first and foremost on building alignment within GRZ structures.

To support this process, messages have been workshopped during the inception phase within the MoE and CIGZambia teams. This exercise brought greater clarity and focus to the key information each audience needs to understand about the IRP's ambitions and design. This workshopping process also helped to refine thinking about the priorities for communication and engagement, and to sharpen how the MoE sees each stakeholder group contributing to the IRP process. The agreed messages are listed in the Strategy and will be shared via the channels set out in the Strategy.

The MoE has determined that **a dedicated website** is an urgent priority for communicating the IRP to internal and external stakeholders. This website – hosted on the existing MoE website for continuity and sustainability – will serve as an online hub. The website will set out comprehensive information and background documents about the IRP, which interested stakeholders might wish to access, including its objectives, timelines, and process. The CIGZambia team supported the MoE in procuring, designing and populating this website during March 2021; the website will soon become live in April 2021 following user testing with target audiences.

Stakeholder engagement approach

The IRP, when finalised and delivered to the GRZ in March 2022, must be a robust document which has been strengthened and refined through consultation.

The SEP sets out the **stakeholders identified** in detail, categorising them as internal and external. It highlights legal considerations as well as the importance of engaging vulnerable stakeholders. Alignment with the cross-cutting **gender considerations** on stakeholder engagement outlined in Section 5.3 of this inception report have been incorporated into the SEP.

The broader societal context in which the stakeholder consultation for the IRP takes place is also taken into consideration. After years of power-cuts and uncertainty in the energy sector, **low trust levels** define the backdrop for engagement with different sectors of Zambian society. Clear messaging, risk identification, and clarity around feedback loops from stakeholders into the IRP are all discussed in the Strategy and Plan, in an effort to prepare for the pragmatic context for outreach.

One of the obvious outcomes of the stakeholder engagement process will be feedback into the IRP design process. This feedback will, in some cases, require consideration and may require adaptation or adjustment to the design of the final IRP in response. Ensuring that there are **robust feedback loops,** and a clear process to take critical feedback into consideration, is part of the SEP. The Plan sets out processes for incorporating critical input from stakeholders into the project management and IRP design process, to ensure it receives suitable consideration if and as required.

Please refer to Annex 6: Communications Strategy and Stakeholder Engagement Plan for the full document.

6 MONITORING, EVALUATION AND LEARNING

Monitoring, Evaluation and Learning (MEL) is an integral component for the success of the IRP. The table below explains the components of 'MEL'. Please note that this section as a whole refers to both monitoring and evaluation (M&E) and MEL interchangeably.

Table 26: Descriptions of MEL

Component	Description
Monitoring	• An ongoing activity through a project's lifecycle. • The collection and analysis of data/information to identify changes or progress within the project as compared with the project's intended objectives. • Key question: Are we (or not) on track?
Evaluation	• An activity that takes place at specific intervals depending on the length of the project (e.g., quarterly, semi-annual, or annual) during a project's lifecycle. • The use monitoring data and the collection and analysis of further data to review the effectiveness of the project's activities – i.e., to understand how and why an intervention has or has not worked. • Key question: Why are we (or not) on track?
Learning	• Ongoing and periodic internal sharing of lessons learned from the project's activities as well as monitoring and evaluation data for future adaptations/improvements. • External dissemination of lessons learned to external key stakeholders. • Key question: How can we adapt our interventions based on what we are learning? How can others learn from our project?

MEL is critical to a project because it helps to, *inter alia*:

- Assess the performance of projects;
- Determine whether you are on course to delivering desired results;
- Identify gaps/risks, and informs mitigation plans;
- Inform evidence-based decisions regarding project adaptations for current and future improvements.

Usually, a Theory of Change and an associated MEL Plan with SMART[105] performance indicators are developed. Moreover, a dedicated MEL team is usually responsible for MEL on a given project, although good MEL is practiced throughout the entire project team.

6.1 Situational assessment

6.1.1 Development of the Energy Sector M&E Plan

In 2020, the MoE, with the support of the European Union, published its *Energy Sector Monitoring & Evaluation Plan,* which provides a comprehensive, robust, and integrated framework for M&E across the energy sector in Zambia. The overall and specific objectives of the Plan are as follows:

1. *Overall objective:* Promote reliable efficient, sustainable and climate-smart production through an energy sector integrated M&E result framework;

[105] SMART = Specific, Measurable, Achievable, Realistic, and Timely

2. *Specific objective:* Provide a comprehensive integrated energy sector-wide M&E system[106].

To date, the energy sector as a whole has had limited integrated M&E systems; each stakeholder in the sector has their own internal data and reporting structures, and there has not been a centralised energy sector M&E system to harmonise data[107].

However, the importance of M&E has been recognised by the Government. As noted in the MoE's Energy Sector M&E Plan, energy sector interventions must be sustained by good M&E practices to drive results, evidence-based decision-making, accountability, and transparency[108]. Driving performance of the sector is further important given that the energy sector is critical to many other economic sectors in Zambia, particularly within industry (mining, transport, etc.).

At the broader level, the Government's 7NDP (2017-2021) has emphasised the need to better link the performance of the NDP with the outcomes of the Vision 2030 through a National Development Framework (NPF). The NPF was launched in 2018 (covering the period 2018-2030), which, accompanied by Sector performance Frameworks), shall better link the outputs and outcomes of sector plans and programmes to the NPD and Vision 2030. The Ministry of National Development Planning is responsible for, *inter alia,* the coordination and development of the NDPs, as well as the monitoring and evaluation of their implementation.

Underpinning this, the first National Monitoring and Evaluation Policy (2019-2023) – and Implementation Plan – was launched in 2019 to create "a results-oriented, evidence-based, well-coordinated, integrated and robust Government-Wide Monitoring and Evaluation System for improved development results."[109]

The development and objectives of the Energy Sector M&E Plan thus build on this National M&E Policy.

6.1.2 M&E capacity in the MoE and across other stakeholders

As a result of the above, a Monitoring, Evaluation and Research (M&E) unit was established in 2017 within the MoE's Department of Planning and Information (DPI). The unit is responsible for M&E of the MoE's programmes and projects, as well as coordinating research to guide policy formulation. Additionally, the M&E unit will be responsible for, *inter alia,* establishing the M&E system for the energy sector, overall coordination of M&E activities in the energy sector, and pulling relevant M&E data from implementing agencies, including ZESCO, ERB, REA, and others.

The unit is currently staffed with four full-time positions, as follows:

1. Principal M&E Officer
2. Senior M&E Officer
3. M&E Officer
4. Senior Research Officer

The MoE through the M&E unit reports its progress on a quarterly and annual basis to the Ministry of National Development Planning and the Secretariats of the 7NDP Cluster Advisory Groups for Pillar 1 (Economic Diversification and Job Creation) and Pillar 3 (Reducing Developmental Inequalities).

The MoE's M&E unit has strong relationships with the M&E units within various energy sector stakeholders, including ZESCO and the ERB, who are among the main stakeholders for the IRP project.

[106] Ministry of Energy, Energy Sector Monitoring & Evaluation Plan, 2020, p.11, https://www.moe.gov.zm/wp-content/uploads/2020/11/Energy-Sector-Monitoring-and-Evaluation-Plan.pdf
[107] Ibid., pp. 6-7
[108] Ibid., p.7
[109] Ibid., p.6

Both ZESCO and the ERB have respective M&E units. In ERB, M&E is split between two departments – the ERB's M&E unit is responsible for gathering organisational-level M&E data, while the Research and Economic Regulations Units are responsible for gathering more sector-level M&E data. There are five full-time M&E staff members who report to the Director-General's Office and are responsible for monitoring the implementation of the ERB's Strategic Business Plan. Within ZESCO, the day-to-day responsibility for data collection and management rests with their internal individual departments.

6.1.3 Steps towards an integrated M&E system for the energy sector

The Energy Sector M&E Plan outlines a Theory of Change and an Indicator Matrix, which has proposed list of indicators to report on by results-area and highlights which stakeholder shall be responsible for collecting the data.

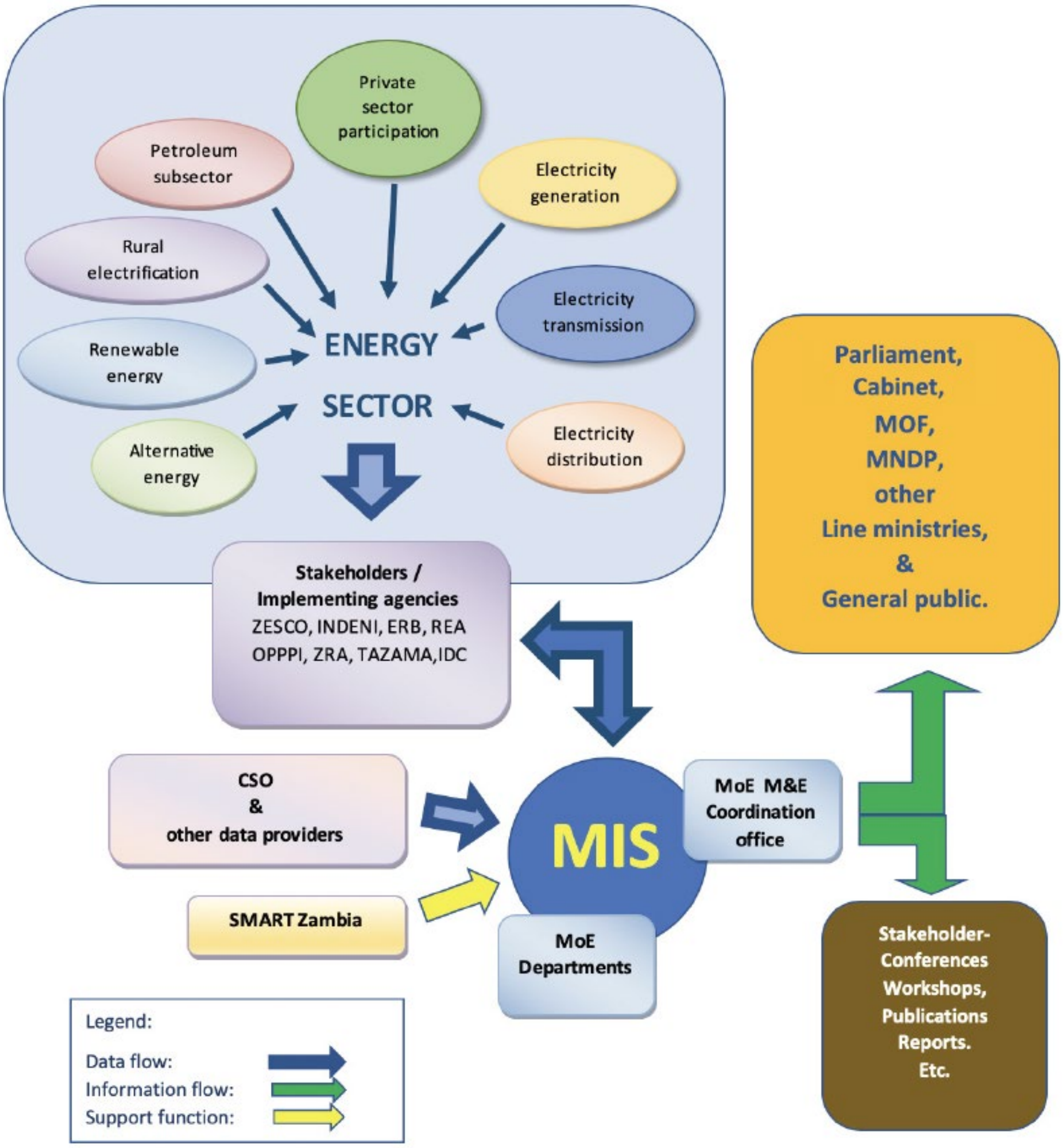
An MIS for the energy sector is currently under development[110]. The DPI will host and manage the integrated Energy Sector Management Information System (MIS), which is currently under development and is planned to be built by June 2021. Further fine-tuning and capacity-building of stakeholders will, however, likely entail that this roll-out will only be fully completed by the end of 2021.

Once the MIS has been established, the intention is for the indicators listed in the Indicator Matrix to be submitted for input into the MIS. The energy sector stakeholders will all have access to this MIS to track progress against targets and will be responsible for updating the MIS accordingly.

The figure below shows the intended integrated M&E system for Zambia's energy sector.

[110] The system will be procured under the EU-funded Increased Access to Electricity and Renewable Energy Production (IAEREP) TA-1 programme, in cooperation with the MoE and SMART Zambia Institute.

Figure 42: Integrated M&E for the energy sector[111]

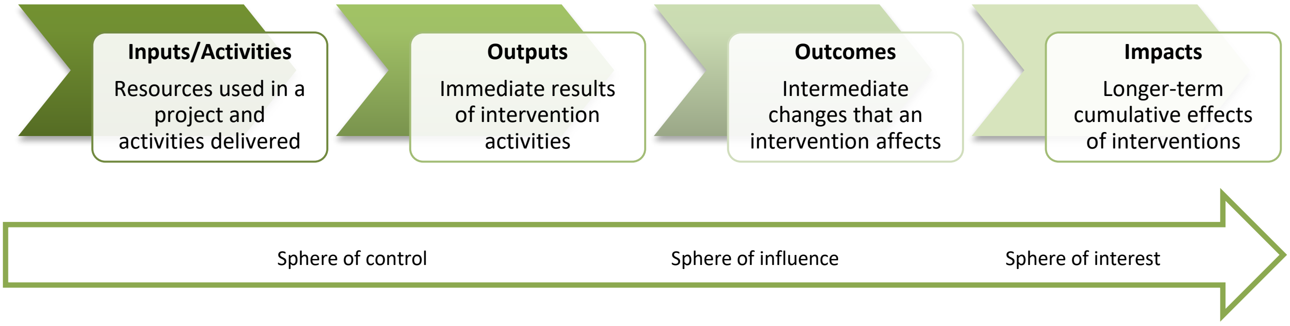


6.2 Theory of Change for the IRP

The Theory of Change is a diagram (usually a flow chart) that illustrates the intended results of a project – in other words, what it will achieve. The diagram shows causal relationships between a project's inputs, activities, outputs, as well as desired outcomes and impacts. As one moves from left to right along the results chain, there is a decrease in the project team's ability to directly control the results – that is, there is a general move away from a 'sphere of control' towards a 'sphere of interest'.

[111] Figure from: Ministry of Energy, Energy Sector Monitoring & Evaluation Plan, 2020, p.36
For more information on the role of each stakeholder in this diagram with regards to M&E, please refer to pp.22-31.

Figure 43: A sample Theory of Change Results Chain



A Theory of Change is a useful project tool to monitor and evaluate the project along the anticipated 'results chain' – from inputs to impact.

It is an adaptive and dynamic tool, which is expected and encouraged to be revisited and revised throughout the course of projects, particularly following periodic evaluations.

The diagrams below show the proposed Theory of Change for the IRP project, as well as, subsequently, the alignment with the MoE's Theory of Change for the energy sector.

Note that the Theory of Change presented here is for the IRP project as a whole, including its implementation – i.e., beyond March 2022.

Figure 44: Proposed Theory of Change for the IRP

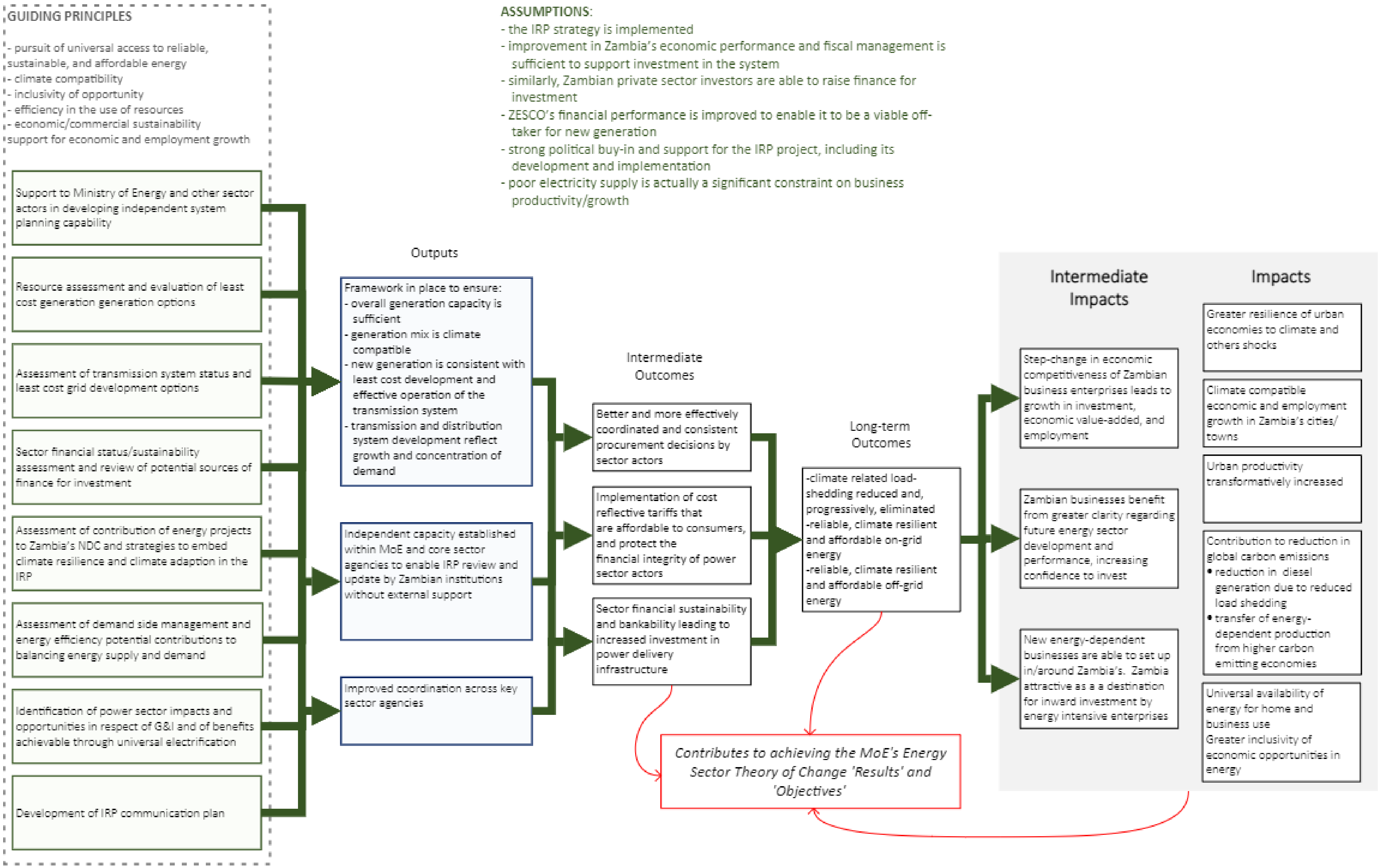
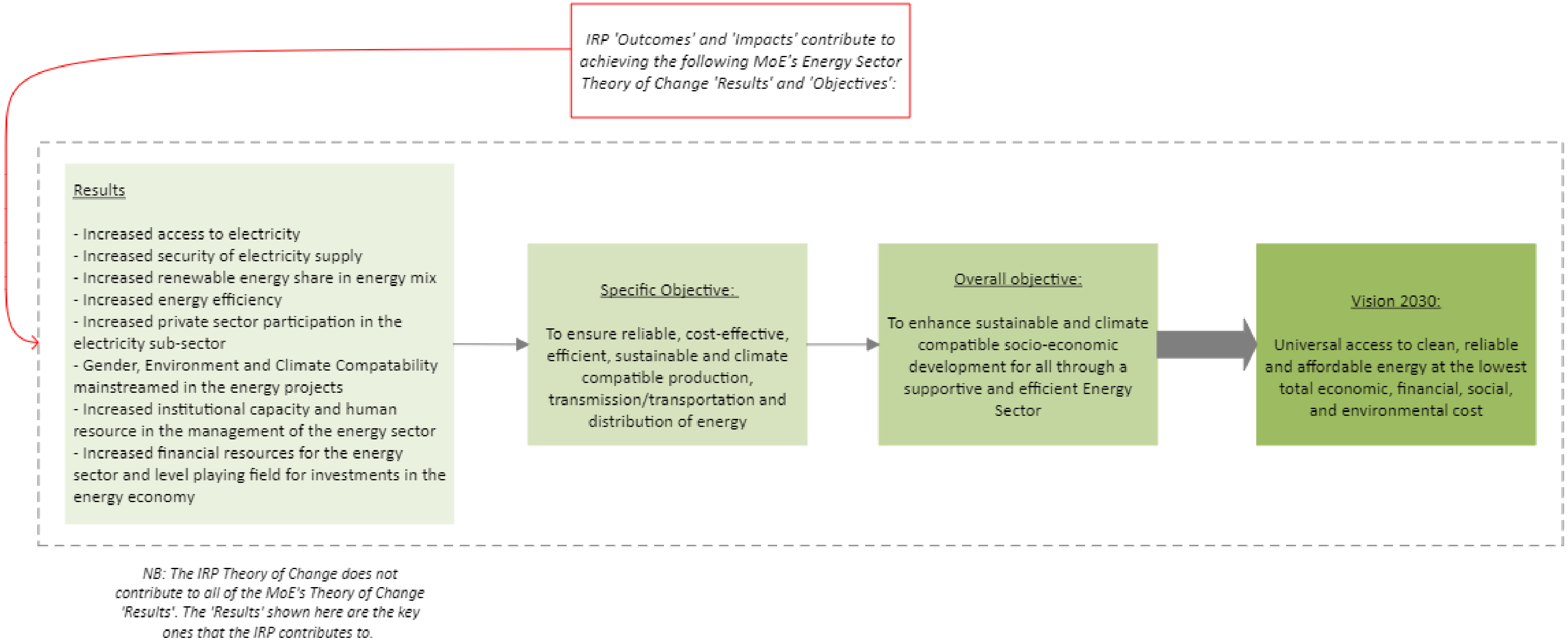

GUIDING PRINCIPLES
- pursuit of universal access to reliable, sustainable, and affordable energy
- climate compatibility
- inclusivity of opportunity
- efficiency in the use of resources
- economic/commercial sustainability
support for economic and employment growth
Support to Ministry of Energy and other sector actors in developing independent system planning capability
Resource assessment and evaluation of least cost generation generation options
Assessment of transmission system status and least cost grid development options
Sector financial status/sustainability assessment and review of potential sources of finance for investment
Assessment of contribution of energy projects to Zambia's NDC and strategies to embed climate resilience and climate adaption in the IRP
Assessment of demand side management and energy efficiency potential contributions to balancing energy supply and demand
Identification of power sector impacts and opportunities in respect of G&I and of benefits achievable through universal electrification
Development of IRP communication plan
ASSUMPTIONS:
- the IRP strategy is implemented
- improvement in Zambia's economic performance and fiscal management is sufficient to support investment in the system
- similarly, Zambian private sector investors are able to raise finance for investment
- ZESCO's financial performance is improved to enable it to be a viable off-taker for new generation
- strong political buy-in and support for the IRP project, including its development and implementation
- poor electricity supply is actually a significant constraint on business productivity/growth
Outputs
Framework in place to ensure:
- overall generation capacity is sufficient
- generation mix is climate compatible
- new generation is consistent with least cost development and effective operation of the transmission system
- transmission and distribution system development reflect growth and concentration of demand
Independent capacity established within MoE and core sector agencies to enable IRP review and update by Zambian institutions without external support
Improved coordination across key sector agencies
Intermediate Outcomes
Better and more effectively coordinated and consistent procurement decisions by sector actors
Implementation of cost reflective tariffs that are affordable to consumers, and protect the financial integrity of power sector actors
Sector financial sustainability and bankability leading to increased investment in power delivery infrastructure
Long-term Outcomes
-climate related load-shedding reduced and, progressively, eliminated
-reliable, climate resilient and affordable on-grid energy
-reliable, climate resilient and affordable off-grid energy
Contributes to achieving the MoE's Energy Sector Theory of Change 'Results' and 'Objectives'
Intermediate Impacts
Step-change in economic competitiveness of Zambian business enterprises leads to growth in investment, economic value-added, and employment
Zambian businesses benefit from greater clarity regarding future energy sector development and performance, increasing confidence to invest
New energy-dependent businesses are able to set up in/around Zambia's. Zambia attractive as a a destination for inward investment by energy intensive enterprises
Impacts
Greater resilience of urban economies to climate and others shocks
Climate compatible economic and employment growth in Zambia's cities/ towns
Urban productivity transformatively increased
Contribution to reduction in global carbon emissions
• reduction in diesel generation due to reduced load shedding
• transfer of energy-dependent production from higher carbon emitting economies
Universal availability of energy for home and business use
Greater inclusivity of economic opportunities in energy

Figure 45: Adapted MoE Energy Sector Theory of Change[112]



[112] Adapted from: Ministry of Energy, Energy Sector Monitoring & Evaluation Plan, 2020, Theory of Change, p.13

6.2.1 Alignment with the MoE's Energy Sector M&E Theory of Change and other national policies

The figure above shows how the IRP will contribute to the overarching MoE's Theory of Change for the energy sector. Note that the IRP Theory of Change is not expected to contribute to all of the MoE's anticipated 'Results' for the energy sector; the IRP project is only expected to contribute to the ones listed in the box above.

Through one of the IRP's intermediate outcomes (regarding sector financial sustainability), its longer-term outcomes, and expected impacts, the IRP project will contribute to the MoE's specific and overall objectives for the energy sector. These are to ensure "reliable, cost-effective, efficient, sustainable and climate compatible production, transmission/transportation and distribution of energy"[113] and enhance "sustainable and climate compatible socio-economic development for all"[114].

The IRP Theory of Change will further contribute – and is aligned with – the following national policies:

- *Vision 2030 for the energy sector*: providing "universal access to clean, reliable and affordable energy at the lowest total economic, financial, social, and environmental cost." This includes the following sector targets to achieve the Vision:
    - Abundant and reliable supply of affordable energy to both urban and rural areas;
    - Increased renewable and alternative sources of energy;
    - Export-led energy industry;
    - Reduce the share of wood fuel to 40% by 2030.

- *7NDP Development Outcome number 4*: "Improved energy production and distribution for sustainable development." This includes the following four strategies:
    - Enhance generation, transmission and distribution of electricity;
    - Enhance strategic reserves and supply of petroleum products;
    - Promote renewable and alternative energy;
    - Improve electricity access to rural and peri-urban areas[115].

6.2.2 MEL Plan for the IRP project

Once the IRP MEL team is in place, a MEL Plan that corresponds with the final Theory of Change will be developed for the IRP during the first month of project implementation. This will be aligned with the current MoE's Energy Sector M&E Plan, particularly the Indicator Matrix.

The development of the MEL Plan will take an inclusive stakeholder consultation approach, which will include key partners such as the private sector.

It is important to note that the indicators used will also be gender-sensitive for gender disaggregated data collection in order to ensure that it is possible to track the IRP project against gender dimensions.

The MEL Plan will also establish a reporting frequency and a schedule for interim reviews, which will be used for 'strategy-testing' and revising the Theory of Change, accordingly.

[113] Ministry of Energy, Energy Sector Monitoring & Evaluation Plan, 2020, Theory of Change, p.13
[114] Ibid.
[115] Ibid., p.3

6.3 Levels of MEL for the IRP

There are two levels of MEL data being captured for the IRP project for two separate purposes and audiences:

1. Monitoring and evaluating the *success of the IRP project itself*, for which the audiences are all the stakeholders of the project, including the general public;
2. Monitoring and evaluating the *success of CIGZambia's technical assistance to the IRP project*, for which the main audiences are the core stakeholders (e.g., MoE, ZESCO, ERB) and FCDO.

Both are discussed in turn in the sub-sections below.

6.3.1 IRP MEL Team

In order to monitor and evaluate the success of the IRP project, the project shall have a dedicated MEL team with clear responsibilities for the purpose of:

- Collecting and analysing data;
- Tracking progress and reporting performance on indicators;
- Informing evidence-based decisions among the IRP stakeholders and learning;
- Coordinating with GRZ Ministries, Agencies, Departments, and state-funded actors to avoid duplication in data collection and reporting; and
- Ensuring alignment with the Energy Sector M&E Plan.

To empower the key stakeholders of the IRP, guarantee sustainability of the MEL system for the IRP project, and ensure alignment with the Energy Sector M&E Plan, it is proposed that the responsibility for MEL rest with the M&E units from MoE's DPI, ZESCO, and ERB. The DPI M&E unit will have an overall oversight and coordination role.

The MEL team for the IRP project shall thus be composed of the following roles:

Table 27: IRP MEL Team - Roles & Responsibilities

Organisation	Number	Role	Responsibilities	Notes
DPI M&E Unit (MoE)	3	1x Principal MEL Officer Assisted by 2x DPI M&E unit staff	• Quality assurance of MEL Plan, data collection and data analysis • Performance tracking of targets against MEL Plan and Theory of Change, with the assistance of dashboard • Assist in developing M&E methodologies for data collection and analysis • Ensure coordination and manage stakeholder relationships • Ensure alignment with	*Works with:* IRP project team *Report to:* IRP Governance Committees

			Energy Sector M&E Plan • Inform lessons learned and decision-making • Monitor and escalate risks	
ZESCO and ERB M&E units	2	M&E Officers (1 from ZESCO and 1 from ERB	• Develop data collection and analysis methodologies • Data collection and analysis • Input into MEL Plan databases • Inform lessons learned and decision-making • Monitor and escalate risks	*Works with:* Principle MEL Officer, DPI M&E Unit
Other resources until end March 2022				
CIGZambia MEL unit	1	MEL Expert	Provides guidance and support to the IRP MEL team in the: • Development of MEL Plan • Establishment of data collection tools and systems • Data collection and analysis, as well as tracking progress	MEL support from CIGZambia for now is expected to be provided until the end of March 2022

Note that there may be the need to tap into the data collection capabilities of other stakeholders in the energy sector, depending on the type of indicators defined in the IRP MEL Plan. This will likely involve the private sector, particularly as this sector grows; moving forward, the IRP MEL team must ensure that there are mechanisms in place to involve the private sector in the monitoring and evaluation of the energy sector. It is envisaged that the IRP MEL team will be empowered to reach out to those stakeholders to get the required data.

6.3.2 CIGZambia MEL Team

In order to monitor and evaluate the success of CIGZambia's technical assistance being provided to the IRP project, the CIGZambia in-house MEL team will be employing several tools throughout the lifecycle of the project.

CIGZambia is required under its own terms of reference to monitor and report to FCDO the results achieved through its programme and the contribution that it has been able to make, for example in respect of capacity building. This involves the occasional collection of information from clients to confirm the contribution that has been made. CIGZambia will ensure that the processes involved in gathering this information place a minimal burden on MoE and other agencies involved in IRP project. Client support to MEL activity will, however, be greatly appreciated and will assist CIGZambia in providing the most effective possible programme of support.

Starting from project implementation in April 2021, the CIGZambia MEL team (with assistance from the CIGZambia project team) will administer with the MoE and various other stakeholders the following at the beginning and throughout the project:

- Capacity building scorecards (baseline) – to get a baseline of our client's and stakeholders' current capacity in key areas (disaggregated by sex).
- Workshop and training feedback forms – to learn and adapt the project (disaggregated by sex).

At the end of the project (around March 2022), we will administer with the client:

- Capacity building scorecard (endline) – to measure capacity building progress (disaggregated by sex).
- Project lifecycle scorecard (to check if the client is closer to bankability as a result of our support).
- Final project feedback form – to ascertain whether the objectives of the project have been reached, the client's satisfaction with CIGZambia's technical assistance, and capture any final lessons learned.

Note that the IRP project sits within a wider context of inter-related projects that CIGZambia is delivering in the energy sector. As such, some of the CIGZambia MEL tools may be administered with these other associated projects in mind.

Furthermore, the CIGZambia MEL team will also be a resource for the IRP MEL team to draw from for MEL-related advice and guidance.

6.4 Knowledge and Data Management

The IRP project will gather existing knowledge and data relevant to the IRP, as well as produce its own body of knowledge (including reports, studies, capacity building material, etc.) over the project lifetime. The knowledge and data gathered from other sources or produced by the project may have various formats[116].

Information will be available internally to project stakeholders (MoE, ZESCO, ERB, and others) through a dedicated Microsoft Office (MS) Teams project channel and externally to wider audiences through the IRP website (hosted on the MoE's own website), which will store information readily accessible by all external stakeholders, including the general public.

During the inception phase, it was agreed that having a MS Teams project channel would be the most effective and safe way of sharing knowledge between project stakeholders and storing data. This project channel was set-up by the CIGZambia project team during the inception phase.

A *Data Protection, Security and Confidentiality Policy* was agreed between the MoE and CIGZambia, and which every new user added onto the MS Teams project channel must adhere to, thus ensuring all IRP project data is stored and managed safely. Following the end of CIGZambia's technical assistance to the MoE on the IRP project, all data from the MS Teams project channel will be transferred to the MoE's server and the MoE's data archive and retention policy shall apply.

For the IRP project, knowledge and data management will be the responsibility of the MoE's Senior Informatics Officer and the IRP Project Management Unit.

[116] PDF, Word, Excel, PPT, JPEG, PNG, PPT, etc.

7 CONCLUSION

This inception report has outlined the genesis of the first ever 30-year Integrated Resource Plan (IRP) for Zambia's energy sector. It has further outlined the objectives, scope, overall approach, workstreams, and project plan for the development of the IRP. For each workstream, an exposition of the situational assessment and a proposed approach and methodology for the development of the workstream, suitable for the Zambian context, have been presented.

It is worth restating that the work that has been scoped in detail in this report is for grid-connected demand and generation, including the associated transmission and distribution infrastructure development. The approach to off-grid sector development will rely on support from other development partners, most notably the World Bank; the project team will collaborate and coordinate to ensure an integrated IRP.

To recap, the technical and cross-cutting workstreams that this inception report has proposed for the IRP project include:

Technical workstreams

1. Demand Assessment and Forecasting
2. Generation Resource Assessment and Planning
3. Transmission Infrastructure Planning
4. Distribution Infrastructure Planning
5. Power Procurement, Financial Mobilisation, and Market Structure

Cross-cutting workstreams

1. Climate Resilience
2. Environmental Impacts
3. Gender, Social Inclusion, and Safeguarding
4. Communications and Stakeholder Engagement
5. Monitoring, Evaluation & Learning

The cross-cutting workstreams will be mainstreamed across the IRP project to ensure it is developed sustainably; responsive to broader climate, environmental, and societal considerations; consultative and communicates clearly; and achieves its intended objectives.

The overall approach to the development of the IRP will be highly consultative and include wide stakeholder consultation and participation. At the heart of the IRP project is a capacity building strategy that will guarantee the transfer of skills to key stakeholder organisations and local staff, who will form the majority of the IRP project team. The inclusive and consultative approach is also reflected in the project's Communications Strategy and Stakeholder Engagement Plan, which recognises the importance of strong communications and incorporating the views of stakeholders through project feedback loops.

The IRP will be developed under the stewardship of the Ministry of Energy, who will coordinate the project; crucially, however, the process will include the active participation of key stakeholders across the energy sector to ensure a sustainable and successful IRP.

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Annex 1: Terms of Reference for the IRP Project

NOVEMBER 2019

TERMS OF REFERENCE (TOR)

FOR

Development of an Integrated Resource Plan for Electricity

DRAFT

2020

Table of Contents

1. Country & Sector Context: Zambia

Country Context

Zambia's electricity supply industry is dominated by the vertically integrated utility company ZESCO Ltd which owns and operates generation, transmission, and distribution assets. Another major player is the Copperbelt Energy Corporation (CEC), a private company that supplies power to the mining industry on the Copperbelt Province.

The Country's installed electricity generation capacity stands at about 2,976 MW as at end of 2019. The country relies mainly on hydropower contributing over 80 percent of the installed capacity. Of the total installed capacity, the mining sector accounts for over 50 percent of the country's electricity consumption, followed by the residential sector at 29 percent.

The overall national electricity access rate, defined as connection to the grid, is 31 percent and just 4 percent in rural areas. Under its Vision 2030, the Government has set a target of "universal access to clean, reliable, and affordable energy at the lowest total economic, financial, social, and environmental cost consistent with national development goals by 2030."

Government has recognized the need to promote the provision of reliable, and affordable energy in an environmentally and sustainable manner as a building block to reduce poverty and facilitate expansion of businesses, and alternative energy sources and technologies for increased provision of clean and efficient energy services.

Sector Context

Electricity plays an important role in the economic growth of any country.

In Zambia, the labour productivity index and per capita energy consumption has been increasing due to increased mining, agricultural, tourism activities and industrialization.

The current installed electricity generation capacity is about 2,976.3 MW with hydropower accounting for over 82.3%. The heavy reliance on hydro power has negatively affected the electricity sector's potential to contribute to economic growth due to the adverse effects of climate change.

Government has recognized the need to promote the provision of reliable, and affordable energy in an environmentally and sustainable manner as a building block to reduce poverty and facilitate expansion of businesses, and alternative energy sources and technologies for increased provision of clean and efficient energy services.

In this regard, it has become increasingly necessary to adopt smart development strategies for the development of a climate resilient energy sector through integrated resource planning.

2. Need for an Integrated Resource Plan

Over the past years, electricity resource planning focused on supply side projects only i.e., construction of generation and transmission facilities without coupling them to demand side management options to increase the productivity with which electricity is used by consumers. In addition, the assessment of supply side options was limited to a few major technologies without considering technologies such as Nuclear, Solar and Wind.

There is need to approach electricity resource planning in a holistic, integrated manner that considers a full range of feasible supply side and demand side options. Therefore, it has become imperative to develop an Integrated Resource Plan for Electricity in Zambia.

3. Objectives

3.1 Overall Objective

To develop an thirty year (30) IRP for a sustainable electricity investment strategy for generation and transmission infrastructure that will ensure universal access to clean, reliable and affordable electricity at the lowest total environmental, social, economic and financial cost consistent with local, national and regional development goals. The IRP will also include implications arising from demand-side management (DSM) and pricing.

The implementation of the IRP is also expected to contribute to the following outcomes:

1. Improve the long-term reliability, affordability[117], efficiency and security of electricity supply through meeting adequacy criteria over and above keeping pace with economic growth and development;

[117] Affordability

2. Minimise the short term and long-term economic costs of delivering electricity services;
3. Ascertain Zambia's capacity investment needs for the medium and long-term business planning environment;
4. Minimise environmental, climate change and other externality impacts of electricity supply and use.
5. Provide local economic and social benefits from electricity related projects, activities and programmes including power generation.
6. Increase Zambia's generation capacity through a diversified energy mix
7. Provide a framework for Ministerial determination of new generation and distribution capacity.

Task 1: Undertake a situation analysis of Zambia's electricity supply industry

1. Electricity Generation and Transmission

The consultant shall:

a. Review the 2010 Power Systems Development Master Plan;
b. Review the 2008 Rural Electrification Master Plan;
c. Review Integrated Resource Plans from the Region;
d. Review regional interconnector feasibility study reports available;
e. Review the current generation and transmission infrastructure, and the adequacy thereof;
f. Review current generation technologies in respect of cost of technology, fuel availability, impact on the existing electricity supply infrastructure and their impacts on the environment;
g. Review the impact of climate change on electricity generation and transmission infrastructure;
h. Review the current processes and procedures in responding to security of supply within the power sector.

2. Electricity Demand

a. ***Review the historical consumption patterns***

i. End-use Data by sector: historic sales by customer class, historic MW demand (days, weeks, months, years) impact on peak load over time, economic & demographic growth-based projections on above)

ii. Econometric Data: correlations by consumer classes between income levels, inflation, employment, productivity, GDP, fuel prices, etc. vs electricity consumption and demand

iii. Reconcile the two by both Stakeholder Participation as well as Base, High, Low Case sensitivity analyses

b. Develop key assumptions for the study

Task 2: Undertake an electricity demand forecast

1. Collect and analyse the following data:

a. Demand records: Disaggregated data by geographical area, province and district on power demand that shows the energy requirements on the interconnected grid as well as isolated grids over days, weeks, months, and years to determine the relationship between electricity sales and the amount of generation capacity required. This analysis should be reflected in appropriate load duration curves and load profiles, and that will be the basis of determining the generating capacity required.

b. Economic and demographic data: Collect and use historical data on economic performance, and population or the number of households.

c. Energy end-use data: Collect data on DSM measures/interventions that have been implemented and planned.

d. Collect data on pending power supply applications (backlog) disaggregated by customer class (i.e household, commercial, industrial etc.,) and by geographical area (province and district).

e. Reconcile the above through stakeholder consultation as well as Base, High, Low Case sensitivity analyses

2. The consultant shall derive the following projections and indicators:

a. Economic and demographic indicators for power development for both on-grid and off-grid solutions: With consultations with relevant stakeholders including but not limited to the Zambia Statistics Agency, highlight key demographic and economic indicators that shall stimulate power developments; in undertaking this assignment, the consultant shall review relevant National Development Documents such as the 7NDP.

b. Environmental indicators for Power Development; With consultations with relevant stakeholders (i.e., ZEMA, WWF, NHCC, etc.) highlight key climatic and environmental indicators that shall influence development of particular energy resources for given geographic locations; and

c. Future energy demand projection: this shall include the associated load profile. The energy demand shall further be disaggregated into province and district.

Task 3: Investigate electricity supply options

The consultant shall review supply options beginning with identification of all applicable options and related infrastructure, review of the attributes of the options, and selection of promising options for further study and analysis.

In addition, the consultant shall consider requirement for baseload, intermediate load, and peaking capacity. Further, the consultant shall assess and cost numerous technical choices for transmission systems including mini-grid/distributed generation.

The consultant shall also; assess the quantity of emissions and wastes per unit of electrical output by type of generating technology and fuel used, together with emissions control and waste disposal costs.

A major part of this process of reviewing the supply options shall involve a collection of the quantitative and qualitative information needed to sift among alternatives that will include but not limited to the following attributes:

> Plant capacity, Maximum and optimal capacity factors, Fuel type, Fuel costs, Fuel Supply Security, Reliability, Capital and operating costs, Lifetime, Decommissioning costs, Foreign Exchange requirements and Environmental impacts.

Data on supply options must be evaluated to select attractive options to include in candidate Supply (generation and transmission infrastructure) Plans with the goal of screening out options that are clearly inappropriate based on cost, resource, technical, or other grounds.

Task 4: Investigate DSM measures

The consultant shall review DSM options that shall include identification of all applicable options and their cost and performance characteristics. The more promising DSM options should be selected for further study and incorporation in draft DSM programs and plans. Potential DSM options for utility systems shall include but not limited to the following;

Information and/or Incentives to Encourage Efficiency in Electricity use
Higher Efficiency Technologies
Fuel Switching Technologies
Load Management

Data on DSM options shall be evaluated and compared with each other and with supply-side options to select attractive options to include in candidate DSM plans with the goal of screening out options that are clearly inappropriate based on cost, resource, technical, or other grounds. Attributes of DSM options that need to be considered are outlined as follows:

> Applicability, Fuel type, Reliability and lifetime, Efficiency, Capital and operating Costs, Environmental impacts, Foreign exchange requirements and local availability.

The consultant shall further investigate the amount of saved energy and its cost for each DSM option. Information about the cost of saved energy from specific DSM measures shall be combined with estimates of the amount of total energy that could be saved by implementing each measure to construct a cost of saved energy curve.

Task 5: Prepare and evaluate supply options

The consultant shall compile the options into supply plans that help to meet forecasted electricity demand and associated transmission infrastructure expansion plan.

Using appropriate software and other relevant tools/approaches, the consultant shall screen the list of supply options in consideration of the following elements;

> Location of power plant or other supply resources, timing relative to need, costs and financing, system integrity and reliability.

The consultant shall carry out dispatch modelling using appropriate software to decide which power plants will be used to provide energy to the electric grid and at which times so as to optimise supply plans. Each candidate plan must be assessed using such criteria as cost, technical reliability, environmental impacts and other quantitative and qualitative criteria as well as taking into account the following:

Direct cost curve comparisons, Capital Expenditure (CAPEX) avoidance, and Lower risk, couple Financial Analysis with Economic Analysis

Task 6: Prepare and evaluate supply options under regional power trade scenario

The consultant shall compile the options into supply plans that help to meet forecasted national electricity demand and plausible regional trading.

The consultant shall review the available regional Interconnector project plans with respect to the preferred IRP and evaluate the options and capacity of the existing or proposed internal transmission network

Using appropriate software and other relevant tools/approaches, the consultant shall screen the list of supply options in consideration of the following elements;

> Location of power plant or other supply resources, timing relative to need, costs and financing, system integrity and reliability.

The consultant shall carry out dispatch modelling using appropriate software to decide which power plants will be used to provide energy to the electric grid and at which times so as to optimise supply plans. Each candidate plan must be assessed using such criteria as cost, technical reliability, environmental impacts and other quantitative and qualitative criteria as well as taking into account the following:

Direct cost curve comparisons, Capital Expenditure (CAPEX) avoidance, and Lower risk, couple Financial Analysis with Economic Analysis

Task 7: Prepare and evaluate demand-side management plans

The consultant shall screen DSM measures to identify the most attractive options and candidate DSM measures shall be bundled into prototypical DSM programs that could be implemented to secure the reliability, cost, environmental, and other benefits of the DSM technologies. The DSM programs recommended should combine one or more DSM measures with a set of services or inducements to encourage energy users to adopt the program measures. Candidate programmes should be screened by considering; the anticipated costs of administration, advertising and marketing, and monitoring and evaluation activities related to the delivery of candidate programs.

The consultant must assemble candidate DSM plans from candidate DSM programs which should involve weighing a number of considerations including the following;

Technology availability, Program effectiveness, the timing and persistence of savings, Financing, Social and institutional issues and Environmental issues.

Under this assignment, the consultant shall ensure that the assessment criteria for DSM plans should overlap with those for supply plans, and include energy and peak power savings, costs, practicality and applicability, net environmental impacts, and other criteria.

Each DSM candidate plan must be assessed using such criteria as cost, technical reliability, environmental impacts and other quantitative and qualitative criteria as well as taking into account the following:

Direct cost curve comparisons, Benefits of Peak Demand reduction, Capital Expenditure (CAPEX) avoidance, reduced risk, Couple Financial Analysis with Economic Analysis.

Task 8: Integrate supply- and demand-side plans into an integrated resource plan

The consultant shall assemble candidate supply and demand-side plans into a set of supply and DSM combinations, evaluate these supply and DSM plans, and propose a preferred IRP for the coming years. The IRP shall combine plans for supply- and demand-side resources into a resource portfolio that meets forecasted electricity requirements based on security of supply criteria.

In consultation with stakeholders, a criteria to be applied in screening candidate supply and DSM plans should be formulated to inform the evaluation and ranking of the candidate plans, the results of the evaluation must be used to decide on the preferred or optimal plan to adopt for implementation or further study.

Task 9: Selection of Preferred Plan

Under this assignment, the consultant shall recommend the preferred plan with stakeholders input by taking into consideration the following attributes:

1. Financial and economic considerations to include an overall cost plan covering capital, fuel/resource, and other costs, preferably expressed in present value terms.
2. Performance Criteria with attention to customers served, Loss of load probability, Reserve margin, Efficiency of energy use on supply and/or demand-side.
3. Energy Security Criteria to Diversify supply taking into account percentage contribution of each fuel/resource used, use of domestic resources and use of renewable energy resources.
4. Environmental Criteria: This should have special considerations for; minimal impact on ecosystems, amount of carbon dioxide produced over the life of the plan, amounts of other air pollutants produced over the life of the plan, size of land used for energy facilities, liquid waste production, solid waste production and impact of the plan on biodiversity.
5. Social Safeguards Criteria: provide special consideration for the prevention and mitigation of undue harm to people and their environment. The consultant shall identify and design a project that assesses the potential social risks and impacts (positive and negatives) associated with the IRP. Further the consultant shall define measures and processes to effectively manage risks and enhance positive impacts.

Other Criteria:

6. Aesthetic issues; impact of plan on recreation and tourism
7. Employment impacts of plan
8. Impacts of plan on other economic sectors both positive and negative impacts
9. Political acceptability/feasibility of plan
10. Impacts of the plans on cultural important resources

The consultant shall spell out the decision process in a transparent, clear, and complete manner, so that stakeholders may review the decisions made during the IRP formulation process. The preferred plan should be accompanied by an implementation schedule that details when and how key plan activities such as building power generation, transmission and distribution infrastructure and/or starting a DSM program will be undertaken.

Contingency IRP plans should be developed for use in case; electricity demand grows faster or slower than expected, fuel prices trend differently from what was assumed, national environmental laws or regional and global agreements create restrictions on certain resources, or technological changes offer new opportunities.

Task 10: Reporting and Knowledge Transfer

The Ministry of Energy shall constitute a working group which shall be the main counterpart:

The Consultant shall report to the Working Group led by the Ministry of Energy.

The consultant shall be required to prepare a capacity building plan tailored around the Zambian case at the time of submitting the bid. The capacity building plan shall outline measures to ensure that the counterparts are fully trained to independently implement and update the plan in the future for planning purposes.

The Consultant shall be expected also to transfer any models and tools utilized to conduct this assignment to the counterpart(s). The consultant shall facilitate the training of counterpart staff during the duration of the assignment to familiarize them with the overall capabilities of such models and tools utilized, the methodology and analysis framework for formulation and subsequent updating of the integrated resource plan, and key variables.

The Consultant shall list and procure any licenses needed to ensure the functionality of the models/tools used.

Task 11: Stakeholder consultation process

The consultant shall engage the relevant agencies, Ministries or authorities/organisations to collect data sets for this assignment. Further, the Consultant shall convene workshop(s) with stakeholders to discuss key issues, assumptions and scenarios underpinning the analytical framework behind the Integrated Resource Plan.

Task 12: Draft Final Integrated Resource Plan and Organisational Arrangement

The Consultant shall prepare the draft final Integrated Resource Plan, documenting in appropriate detail, methodological framework and key assumptions, results of the analysis including a year by year investment plan as called for in the tasks delineated above, and recommendations.

The Consultant shall review global best practice and engage in stakeholder consultations to identify and recommend the appropriate institutional and organizational arrangements such that the Integrated Resource Plan is maintained and regularly updated and that the planning exercise can be replicated in the future.

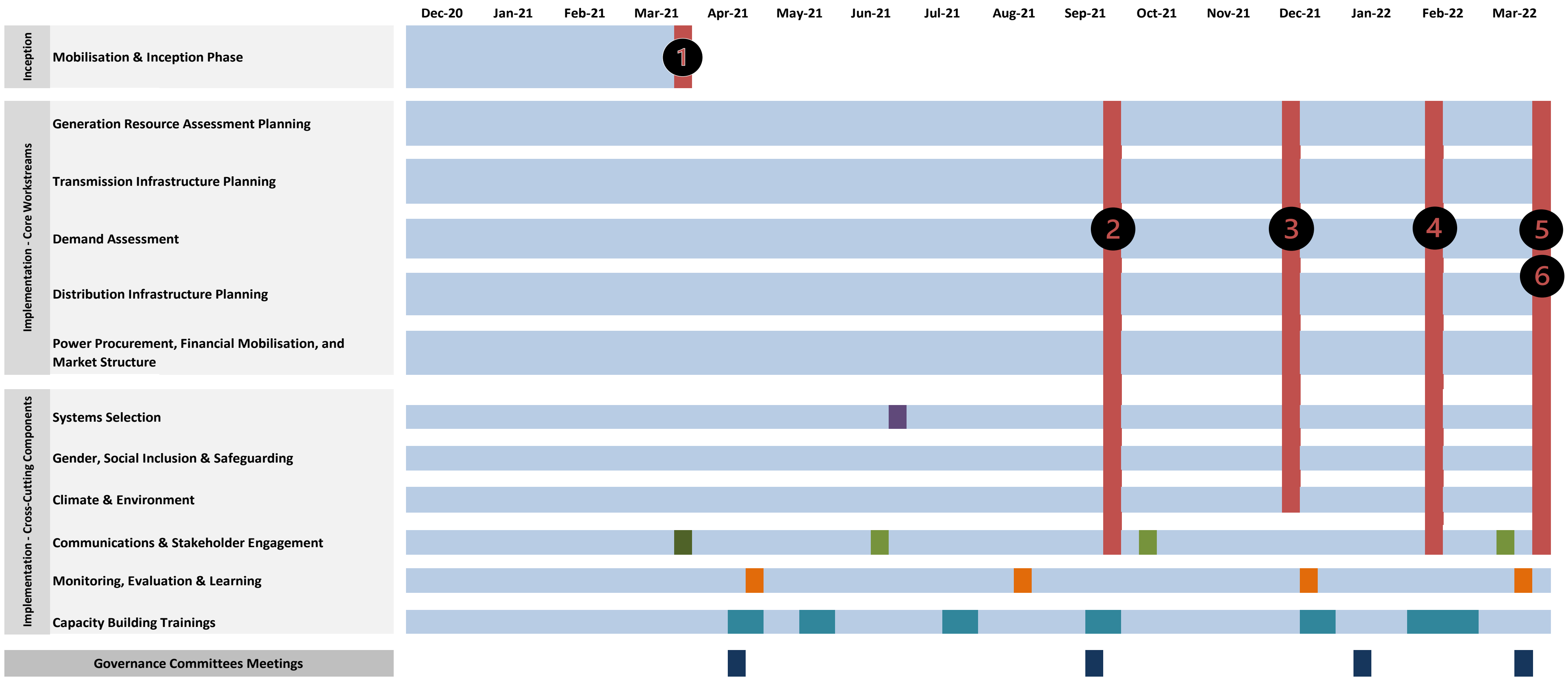
4. Schedule and deliverables

No.	Activity/Deliverable	Due Date
1.	Kick-off workshop	Week 2
2.	Inception Report	Week 6
3.	Inception review Workshop	Week 9
4.	Field Visits	Week 12 - 18
5.	Draft Report of the Integrated Resource Plan	Week 26
6.	Draft Report review Workshop	Week 30
7.	Final Draft of the Integrated Resource Plan	Week 36
8.	Validation and Adoption Workshop	Week 40

ANNEX 2: HIGH-LEVEL IMPLEMENTATION WORKPLAN

Following the inception phase, the IRP project will run for 12 months from April 2021 to March 2022.

The figure below presents a **high-level implementation workplan** for the IRP project, with an accompanying legend at the bottom. In order to ensure timely and successful implementation of the IRP, a **detailed workplan will be developed following the inception phase in consultation with stakeholders.**



- Ongoing activities
- Systems implementation completed
- Communications Strategy & launch of IRP website
- Thematic stakeholder events
- MEL reporting
- Capacity building trainings and handover
- Governance Committee meetings

1	Inception Report	4	Draft IRP Report
2	Consolidated IRP Implementation Report	5	Final IRP Report
3	Scenario Analysis Report	6	Final Project Completion Report

ANNEX 3: CAPACITY BUILDING WORKPLAN

The table below shows the consolidated tentative capacity building training plan per workstream, as outlined in Section 4. The table relates to **formal training** and does not include more informal capacity building across the project workstreams.

Note that the expected completion dates and the content of the trainings may be subject to change following futher consultations with key stakeholders after the inception phase. Furthermore, the exact number of trainings and days per workshop will be based on budget availability. Finally, the choice of face-to-face and/or virtual setting will be dictated by the Covid-19 situation in Zambia.

Table 28: Capacity building training workplan

Workstream (core and cross-cutting)	Formal capacity building training	Expected completion date
System Selection	Training on the new selected software	End April 2021
Demand Assessment	Training and workshops on base case demand projections	End July 2021
	Training and workshops on demand scenarios	End September 2021
Generation Resource Assessment and Planning	Training on resource assessment and generation expansion planning	Mid-December 2021
	Prepare and delivery capacity-development training on scenario analysis	Mid-February 2022
Transmission Infrastructure Planning	Training on transmission network modelling up to 2040 and financial network modelling	End April 2021
Distribution Infrastructure Planning	Training on distribution systems development distributed solar PV, off-grid systems, and DSM	End September 2021
Power Procurement, Financial Mobilisation, and Market Structure	Training may include, *inter alia,* methods for comparing alternative solutions to achieve a given performance (for financing/energy procurement)	End December 2021
Climate Resilience Gender and Social Inclusion	Capacity building to private and public energy sector actors on, *inter alia:* - Mainstreaming G&I in energy sector programming - Mainstreaming climate resilience in energy sector programming - Workplace safeguarding - How to facilitate business opportunities in the energy sector for women and girls	End December 2021
All workstreams	Handover trainings of models and tools for all workstreams	End March 2022

ANNEX 4: SOFTWARE SELECTION CRITERIA AND RESULTS

The table below shows the finalised outputs and criteria for the system selection tool, including their associated importance and weight, as validated by stakeholders.

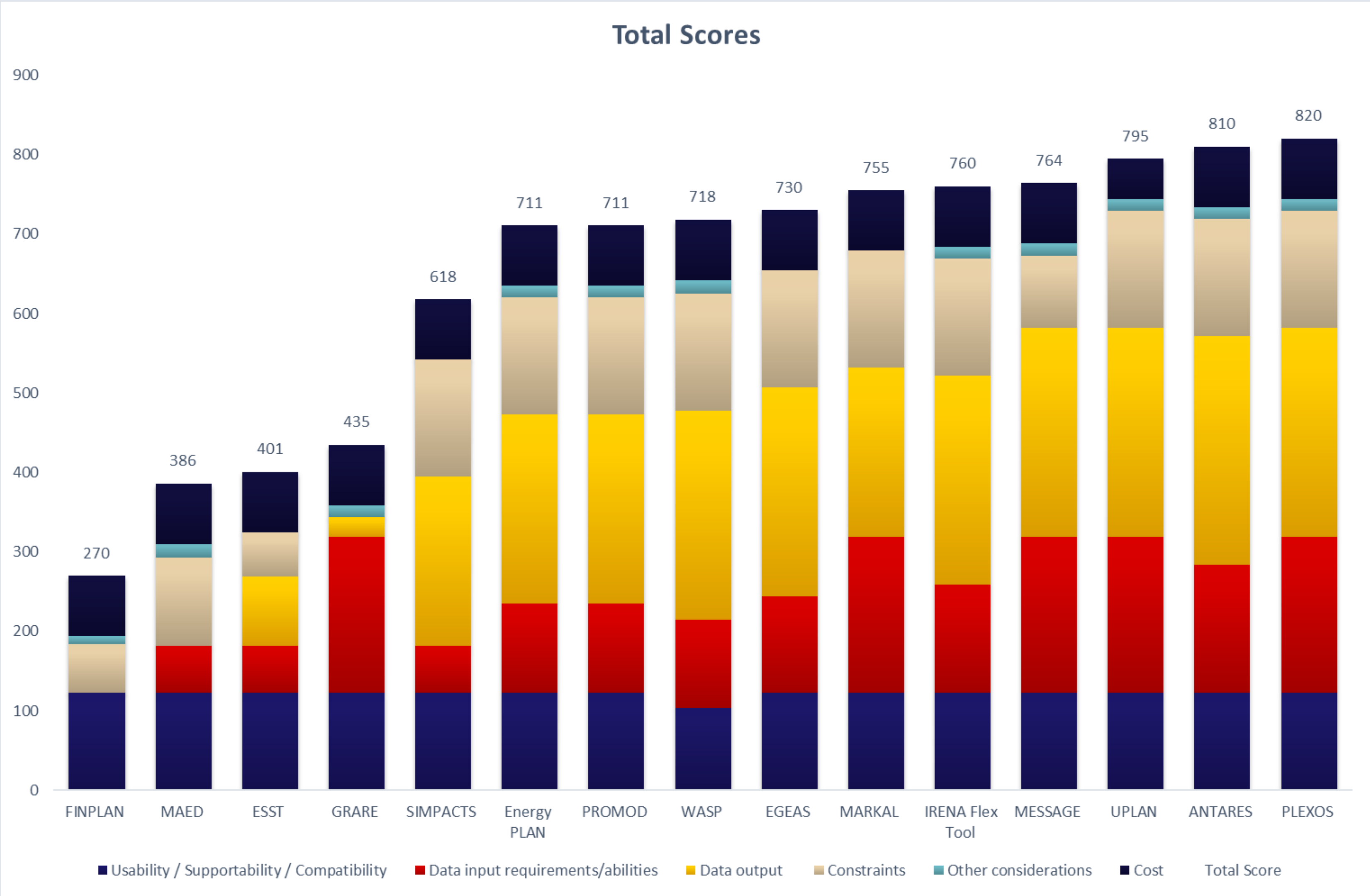
The figure following this table graphically represents the scores – and ranks – of the 14 software packages evaluated.

Table 29: System selection tool outputs and criteria

Software / Outputs and Criteria	Importance 5=high 1=low	Weight 5=high 1=low
Total Score		
Usability / Supportability / Compatibility		
Dashboards	2	2
Can integrate with existing s/w platforms	3	3
Can export to data warehouse	3	1
Can support 'x' number of concurrent users	2	2
Supportability	5	5
Online training	5	4
Online help	2	1
Support	4	2
Simulation	5	5
Operation optimisation	5	4
Investment optimisation	3	1
Future energy demands based on		
Medium to long-term scenarios	5	5
Socioeconomic development	5	4
Technological development	3	1
Demographic development	4	2
Data input requirements/abilities		
Firm capacity (Generation adequacy) Requirements	5	5
Total scheduled demand over a certain period of time	5	5
Planned maintenance activities	3	4
Total reserve capacity requirements (contingency reserves)	5	5
Unit set points (Frequency, voltage, reactive power etc)	5	5
Transmission lines operating limits (Line thermal limit - Loadings and transformer capacities)	5	5
Underfrequency loadshedding management	5	4
Reactive power compensation requirements & setpoints	5	3
Ancillary services co -optimisation	5	3
Power system tracking (capacity, generation, fuel prices, tariffs, energy efficiency savings, policies, etc)	3	3
Data output		

Transmission violations	5	5
Unit capacity factor	5	5
Unit mean time to repair (Downtime)	5	5
Available water for power generation (Lake /Forebay water level)	5	5
Units sent out (Total power generated)	5	5
Total production cost over a period of time	5	5
Unserved Energy	5	5
Total emission intensity	5	5
Available generation mix	4	3
Resolution in time and space	5	3
Unit start up time	3	4
Unit ramp rates	3	4
Partial load efficiency	3	4
Change in Dispatch	5	5
Constraints		
Financial	5	5
Water availability	5	4
Emission restrictions	3	1
Solar resource availability	5	3
Fuel availability (HFO, COAL, Feedstocks, Diesel etc)	5	4
Wind resource availability	5	4
System reliability & flexibility	4	2
Cost of unserved energy	4	3
Unplanned maintenance activities (Breakdowns, severe weather change)	4	3
Electricity tariff restructuring	4	3
Other considerations		
Climate modelling	3	3
Transmission capabilities	1	1
Distribution capabilities	1	1
Contract terms	2	2
Vendor history with organisation	2	1
Cost		
Within budget	5	5
Support & maintenance available	5	4
Yearly Standard Upgrades included	3	1
Customisation available	4	2
Licensing costs included in M&S costs	5	4

Figure 46: Final scores per software package



ANNEX 5: ADDITIONAL INFORMATION FOR TRANSMISSION PLANNING WORKSTREAM

Methodology for Transmission Project Prioritisation

This Annex sets out in detail the proposed methodology for transmission project prioritisation including:

- transmission network technical criteria;
- transmission network financial criteria; and
- transmission project prioritisation method.

Transmission network technical criteria

The proposed technical criteria for the Transmission Network Service Providers' (TNSPs) transmission system planning are used for the technical evaluation of the candidate projects for transmission network reinforcements. The technical criteria include the:

- (n-1) criterion;
- voltage and reactive power criterion;
- short-circuit criterion; and
- stability criterion.

These are each discussed in turn below.

The (n-1) criterion

The (n-1) criterion is satisfied if, after a single system element has failed (e.g., transmission line, transformer, generating unit, etc.), the following rules are satisfied:

1. No breach of the limiting values for network operation variables (operation voltage, frequency, etc.) that may endanger the security of the power system or lead to an unacceptable strain on equipment, damage, destruction or an inadmissible reduction in the life of equipment;
2. No inadmissible overloading of components may take place;
3. The voltages and frequency are satisfactory for consumers and generating units;
4. Interruptions of supply are avoided (with the use of redundancies temporarily available in lower voltage networks and in the installations of transmission system users);
5. Secondary tripping through activation of further protection devices on equipment not directly affected by the disturbance cannot involve the risk of spreading the disturbance;
6. There is no need to change or, if necessary, interrupt power transfers; and
7. The loss of generating unit stability is avoided.

The (n-1) criterion is related to the loss of:

- single-circuit overhead 330 kV, 220 kV or 132 kV line (interconnection or internal line);
- one circuit of double-circuit overhead 330 kV, 220 kV or 132 kV line (interconnection or internal line);
- cable 330 kV, 220 kV or 132 kV;
- transformer 330/132/11 kV,330/88/11 kV, 330/220/11 kV, 330/66/11 kV, 220/66/11 kV;
- the largest generator in a power plant connected to 380 kV, 220 kV or 132 kV transmission voltage level.

The loss of both circuits of double-circuit overhead lines, several cables inside the same cable route, and bus-bars are not observed as (n-1) contingency.

During the (n-1) security check only 330 kV, 220 kV, 132 kV and important parts of lower voltage networks (88 kV, 66 kV) should be monitored for overloads. Overloading in medium voltage networks are considered as a local problem.

The transmission system's ability to satisfy the (n-1) criterion is checked by conducting power flow calculations during maximum load conditions:

- Maximum permitted loadings of branches (lines and transformers) must not exceed 100% of the nominal rating;
- Maximum permitted line loadings should not be less than thermal ratings or overcurrent protection settings; and
- Maximum permitted transformers loading should not be less than transformers rated power. Permitted voltage ranges are defined by Zambian grid code.

Each candidate project which solves the problem related to the (n-1) security has to satisfy economic criteria to be included into future network configuration.

<u>The voltage and reactive power criterion</u>

Sufficient reactive resources, determined by thorough assessment of the reactive power balances, need to be available for use immediately after network operator request and have to be located throughout power system, with a balance between static and dynamic characteristics. Dimensioning of the installations for the compensation of the reactive power is made with the observance of the acceptable voltage ranges in all nodes, under all operation regimes in configuration with (n) and (n-1) elements in operation.

The network operator has to conduct assessments to ensure reactive power resources are available to meet projected customer demands. Power flow simulations, including P-V and V-Q curve analyses, could be used and verified by dynamic simulation when steady-state analyses indicate possible insufficient voltage stability margins.

The transmission system's ability to satisfy voltage and reactive power criterion is checked by power flow and eventually stability calculations during peak and minimum load conditions, for all scenarios related to the future transmission network development. Such analyses will be integral part of the transmission workstream planning process.

<u>The short-circuit criterion</u>

In order to check network facilities and related equipment parameters, short-circuit calculations have to be performed during short-term and mid-term planning for the transmission system. Short-circuit calculation must be done according to the IEC 60-909 publication, and it has to include complete TNSPs transmission network and influence of neighbouring power systems. Short-circuit calculations further have to be performed on planned network configuration, including calculations of:

- maximum three-phase ((Isc3'')
- single-phase sub-transient short-circuit currents (Isc1'')

for each network node between 330 kV and 88 kV.

The facilities and devices connected to the network must be designed to operate according to given current limits. TNSPs has to ensure that its system design guarantees that at any node on a power system:

- short circuit currents will not exceed the capacity of devices installed on that node; and
- a sufficient short-circuit power value is available for fault clearance by the protection system.

The replacement of devices connected to transmission facilities is planned when a maximum of short-circuit three-phase or single-phase current exceeds 90% of maximum limit for analysed device (facility). In order to satisfy the short-circuit criterion, network sectioning may be analysed, but that measure must not jeopardise the (n-1) criterion.

The stability criterion

Planned network configuration in the short-term and mid-term timeframe has to satisfy the stability criteria during small or large-scale system disturbances. We can denote the following stability types:

- angle stability (transient stability) –
  - to be performed occasionally by TNSPs when voltage and reactive power analyses show that voltage instability may potentially occur.
- voltage stability –
  - to be performed periodically in the short-term and mid-term network planning, assuming planned network topology according to technical and economic criteria, for the most dangerous system conditions (peak load, heavily loaded large generators, large power transits etc.).

The angle stability criterion is satisfied for large-scale disturbances if all generators continue to operate synchronously after the occurrence of large disturbances, such as short-circuits, removal by normal protection systems operations, etc. Stability calculations have to determine the limit time value of short-circuits duration (Critical Clearance Time – *Tc*) for which stability is kept, in order to estimate stability margin. Critical Clearance Time should be calculated for lines which are part of corridors of important power transits. Steady-state scenarios for stability calculations should be determined by TNSPs. The angle stability criterion is satisfied if Critical Clearance Time is larger than the short-circuit duration (with respect to protection activation time) for all analysed scenarios.

Planned network configuration should be examined according to the stability criterion, taking into account the following possible small and large-scale disturbances, such as:

- near to bus-bars three-phase short circuits on 330 kV lines, removed by normal protection system operation; and
- short duration transitory short circuits (up to 60 ms) on 330 kV lines close to large power plants.

Normal protection system operation assumes removal of short-circuits within time interval defined by TNSPs.

Transmission network financial criteria

The section below discusses the most important financial indices that will be used for the financial assessment of transmission projects.

Profitability index / Net Present Value

The profitability index (PI) is defined as the ratio between expected annual benefit from a candidate project and the annuity of its expected costs:

$$PI_i = \frac{EB_i}{EC_i}$$

where:

- is the profitability index in year *i*,
- is expected benefit from construction in year *i*,
- is the annuity of candidate project expected costs
- profitability indices for candidate projects have to be calculated for the whole planning horizon
- observed candidate project is economically profitable if:

$$PI_i > 1$$

for all studied years *i*.

A candidate project is economically profitable and should be included into network configuration for the first studied year in which its profitability index is larger than 1, assuming that it stays larger than 1 for other future studied years as well. Special cases may occur when the profitability index is larger than 1 in studied year but it falls below 1 for future studied years – such project candidates are considered as not economically profitable.

The most important transmission candidate project is the one with the highest value of the profitability index. Economically profitable transmission candidate projects should be included into planned network configuration according to declined profitability indices (from the highest profitability index of a candidate project to the lowest but greater than 1). Planned transmission network configuration should not contain any economically not profitable candidate project.

It is important to mention that the PI and Net Present Value (NPV) use identical inputs but differ in their calculation. The PI is a ratio and the NPV is a difference.

Transmission projects will be assessed against NPV and this will include optimisation of investment considering the following constraints:

- The cost of electrical losses;
- The economic impact of failure rates (reliability);
- Investment costs, including initial costs, initial value, scrap value, and expected life span; and
- Project timings.

<u>Expected benefit of transmission facility construction</u>

The types of benefits from the construction of candidate projects that may be estimated for the purpose of economic criterion evaluation are described below. The total expected annual benefit from the construction of candidate projects is the sum of benefits defined above.

- *Benefit due to reduction of expected annual undelivered electricity costs*

For given operating conditions (defined by generation and load pattern, network topology etc.), network overloading may be reduced or removed only by load reduction. This measure, whether caused by dispatcher decision or by automatic protection system operation, causes some expenses that cannot be easily defined. The construction of new transmission system object or facility may decrease undelivered electricity costs. The unit value of undelivered electricity costs ($/kWh) for Zambia, for the transmission system planning purposes, is suggested to be determined as the ratio between the GDP's (in $) in Zambia and the delivered electricity in Zambia for the observed planning year.
Each node of the TNSPs transmission network should have the same unit value of undelivered electricity costs. The unit value of undelivered electricity costs can be used for the profitability index (NPV) calculation, as shown above.

- *Benefit due to annual losses reduction*

The construction of every single new transmission object or facility (overhead line, cable, transformer etc.) generally decreases losses in a transmission system – although an increase of losses is also possible but rare. If we transform annual losses reduction into monetary value, a clear benefit is visible from the construction of observed transmission object or facility. The cost of power losses for a specific operational condition may be calculated as the marginal price of the most expensive dispatched generator. The unit value of annual losses reduction can be used for the profitability index (NPV) calculation, as shown above.

- *Benefit due to reduction of annual re-dispatching costs*

The transmission system planning methodology assumes that all generators are engaged according to the least-costs order (starting from the cheapest one to the most expensive one for a given system load). This may be possible only if there are no constraints in the transmission system. If some constraints occur in the transmission system, network overloading or perturbation of system variables (voltage, current) may be avoided by different generators engagement that will result in increased overall production costs. Annual re-dispatching costs will be taken into consideration over one planning year. This will be done to understand the difference in generation costs due to transmission network constraints. The construction of a new transmission system object or facility may help to avoid some transmission system constraints and thus to decrease re-dispatching costs.

This represents the problem of determining the best operating levels for electric power plants in order to meet demand given throughout a transmission network, usually with the objective of minimising operating costs; losses; and load shedding.

This analysis is subject to various constraints that include: thermal limit of the lines; active/reactive power limits of generators; and voltage limits.

Expected costs of transmission facility construction

The following types of costs from the construction of candidate projects may be estimated for the purpose of the economic criterion evaluation:

- investment costs; and
- operation and maintenance costs.

For planning purposes, investment costs may be estimated using unit equipment price values ($/km of overhead line or cable, $/transformer, $/bay etc.). The unit equipment price values that will be used for transmission planning purposes have to be determined by the TNSPs.

Operation and maintenance costs may be estimated as 2% of the overall network facility or object investment.

The annuity of expected costs (*ECi*) is calculated as follows, assuming that expected lifetime of 45 years is valid for all candidate projects:

$$EC_i = \frac{d \cdot (1.02 \cdot I)}{1 - \frac{1}{(1+d)^N}}$$

where:

- is the annuity of expected costs of a candidate project
- *I* is total investment in a candidate project
- *d* is discount rate
- *N* is expected lifetime of a candidate project (N=45)

For the purpose of planning, the assumption that all costs (investment, operational and maintenance) are divided into equal annual values during expected lifetime is made in order to allow comparison between expected annual benefits and annual costs. Experience shows that expected lifetime of transmission facility or project candidate is larger than its amortisation period. A lifetime of 45 years is estimated as relevant for overhead lines, cables and transformers. The discount rate that will be used for the transmission system planning should be determined by relevant institutions (ERB, MoE, ZESCO).

Transmission project prioritisation method

List of candidate projects

Transmission network development plans will include new facilities, planned primarily to satisfy energy demand requests, obligations, and criteria. The regional and market significance of these projects may be invisible or not estimated and taken into account. The unique list of candidate projects will be determined for Zambia but will take into consideration transmission network developments as ongoing and planned SAPP activities; this specifically refers to planned SAPP interconnections. This list will include technical and economic parameters of candidate projects, including at least the following:

1. *For new overhead lines:*
    - predicted year of construction;
    - voltage level;
    - line length;
    - connection nodes;
    - material and cross-section;
    - electrical parameters (resistance, reactance, susceptance);
    - maximum permitted current;
    - unit construction costs ($/km);
    - total costs ($).

2. *For new transformers and transformer stations*
    - predicted year of construction;
    - rated voltages;
    - connection nodes;
    - rated power;
    - electrical parameters (resistance, reactance, etc.);
    - type of control and range of control.

The list of candidate projects prepared will be divided into two parts:

1. candidate projects with local significance; and
2. candidate projects with possible regional significance.

Candidate projects with possible regional significance should be evaluated at the SAPP regional level and examined according to predefined technical and economic criteria. The SAPP planning group will be allowed to propose new candidate transmission projects, apart from the proposed list, based on the analyses and problems found during simulations at the regional level.

Transmission workstream activities will be predominantly focused on the projects with local significance within Zambia and coordinated with SAPP as necessary, during the IRP implementation activities.

The evaluation of transmission investments will be made on 30-year planning horizon, and studied years will be defined with 5 years interval between them (for example 2020, 2025, 2030, 2035 and so on). These activities will be coordinated with demand and generation IRP workstreams.
A separate application of technical and economic criteria in transmission system development evaluation will be employed for the prioritisation of projects.

Evaluation of candidate projects according to the technical criteria

This section suggests project prioritisation according to the technical criteria. The process can be summarised as follows:

1. Starting from the common list of candidate projects, nominated by TNSPs and conducted analyses of load flows and (n-1) security, candidate projects will be included into the network topology one by one.
2. New load flow and security analysis have to be performed for all analysed planning scenarios in a studied year.
3. A new list of network constraints has to be created, and constraints that are removed when new project is included into the network topology have to be highlighted.
4. A new list of candidate projects must be determined, which includes only those projects that lead to the satisfaction of the technical criteria in at least one planning scenario. In other words, only candidate projects which remove one or more network constraints (in monitored network 330 kV 220 kV and 132 kV) in one or more planning scenarios in a studied year are included in the reviewed list of candidate projects.
5. Candidate projects that do not remove any network constraints are excluded from the list of candidate projects and are considered as not significant in a studied year.
6. Candidate projects that are included in the reviewed list of candidate projects are technically prioritised according to network constraints that are removed by candidate projects:
   - The first importance group contains candidate projects that remove network constraints with (n) available branches (the highest level of technical prioritisation); and
   - The second importance group contains projects that remove network constraints with (n-1) available branches (lower level of technical prioritisation).

Inside these two groups of candidate projects, further technical prioritisation is made according to:

- The number of planning scenarios in which candidate project removes network constraints (more planning scenarios with network constraints that are removed by candidate project, more technically significant is a project);
- Voltage level of overloaded transmission lines (removal of overloading on 330 kV lines are more significant than on 220 kV or 132 kV lines); and
- The number of network constraints that are removed by a candidate project (more constraints are removed, more technically significant is a project).

<u>Evaluation of candidate projects according to the economic criteria</u>

Candidate projects that are included in the reviewed list of candidate projects and prioritised according to the technical criteria will be further evaluated and prioritised according to the economic criteria.

Evaluation and prioritisation of candidate projects according to the economic criteria is based on:

- the profitability indices (profitability index / net present value); or
- on the basis of the ratio between annual expected projects benefit and costs annuity for a studied year.

Candidate projects will be included one-by-one into the network topology of a model, and their benefits will be estimated. Costs should be estimated by using same unit equipment prices.

Profitability indices should be calculated for all planning scenarios and average profitability index as a ratio between total sum of profitability indices for planning scenarios and the number of analysed planning scenarios should be determined.

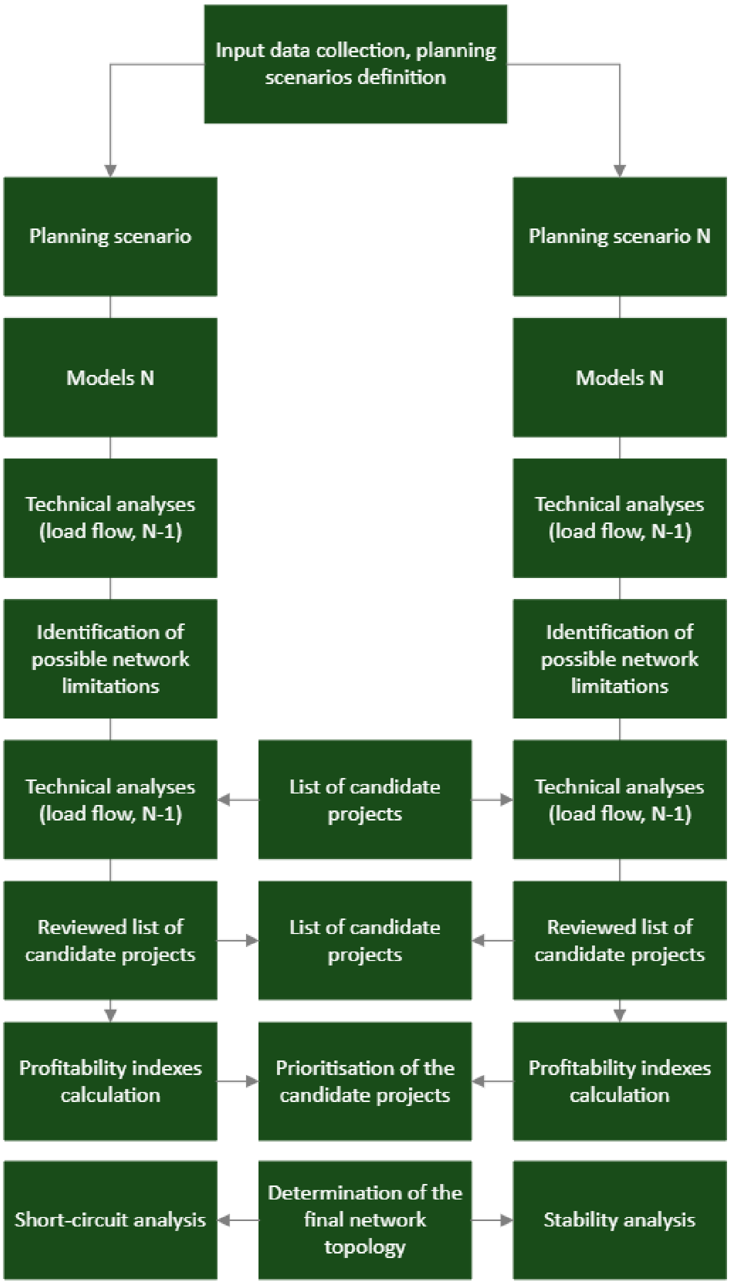
The prioritisation of the candidate projects should be made according to the maximum average profitability index. Transmission facility or object with maximum average profitability index should be included into network topology for a studied year, and all calculations have to be repeated in order to find out a candidate project with the second highest average profitability index. This procedure should be repeated until there are no other candidate projects with profitability index larger than 1 in any planning scenario.

It is worth noting that all projects (i.e., reinforcement of existing lines and new lines) will be assessed against both technical and financial criteria outlined above and ranked accordingly.

With regards to highest transmission voltage, it is noted that other than in South Africa, all SADC countries use 'in country' voltage levels up to 400 kV. Presently, there is no strong justification to step the Zambia transmission voltage up from 330 kV to 400 kV, as the transformation ratio is small, and it would be financially prohibitive. Nevertheless, should there be a requirement for bulk power transfer, analyses will have to be performed to confirm feasibility of and need for a higher voltage. If absolutely necessary, an upgrade of 330 kV voltage level to 500 kV for in country power transfer may be considered by, for example, installing 500/330 kV transformers in some transmission substations.

A summary of the prioritisation process for transmission project is shown in the figure below.

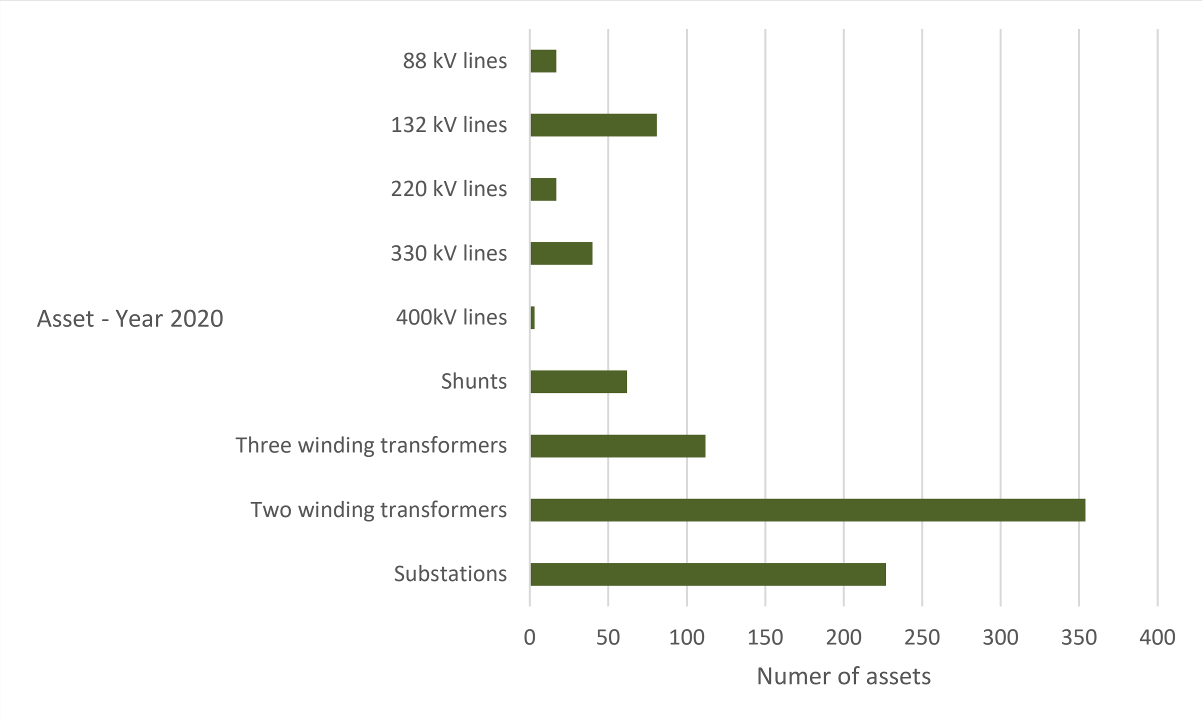
Figure 47: Proposed TNSPs transmission system planning procedure[118]



[118] Transmission Network Investment Criteria, Energy Institute Hrvoje Pozar, March 2007

High-level Summary of the Existing Transmission Assets

Figure 48: High-level summary of existing transmission assets



List of Planned Transmission Projects

Table 30: List of planned transmission projects

No.	Name	Project scope	Status	Comm. Year
1	330kV Mpika substation	• Mpika 330/66kV, 2x90MVA	Under construction	2019
		• 1x30MVAr Pensulo Line Reactor, Mpika		
		• 1x30MVAr 330kV Shunt Reactor,		
		Mpika		
2	Livingstone - Victoria - Hwange Interconnector (ZIZABONA Phase 1)	• 1x330kV Overhead line, 10km	Planned	2022
4	Lusiwasi Upper-Lusiwasi Evacuation Line	• 1x66kV Overhead line, 7km to Lusiwasi and 83km to Pensulo	Under construction	2018
5	Kasama Nakonde Transmission Project	• 1x330kV Overhead line, Kasama - Nakonde, 211km, with line reactors of 30MVAr at each end	Committed	2021
		• 1x132kv Overhead line, Kasama - Kayambi, 170km		

		• 330kV Overhead line, Kasama - Mporokoso, 159km, with line reactors of 30MVAr at each end		
		• Nakonde 330/66kV, 1x90MVA, 30MVAr bus reactor		
		• 330kV double ckt to Tunduma substation at 40km		
		• Tunduma 400/330kV, 3 x 315MVA. At 400kV bus create equivalent		
		• EAPP network referring to the EAPP/SAPP Case File issued		
		• 1x30MVAr 330kV Bus Reactor, Nakonde		
		• Mporokoso 330/66kV substation with 1 x 65MVA Transformer and 30MVAr bus reactor		
		• Reconfigure the 66kV Kawambwa-Mporokoso existing line to LILO at 10km from existing Mporokoso 66kV substation.		
6	Pensulo - Mansa Transmission Project	• 1x330kV Overhead line Pensulo- Mansa, 294km, with line reactors of 45MVAr at each end	Committed	2021
		• 1x132kV Overhead line Mansa- Samfya, 62km		
		• Samfya 66/33kV, 2 x 30MVA		
		• 66kV Mansa 330/66kV to LILO Musonda Falls-Mansa Town 66/33kV substation at 7km to Mansa Town substation		
		• Musonda T-Off 66/33kV substation, 2 x 16MVA transformers, 33kV side connecting to Musonda 10MW Power Station at 5km		
		• Mansa Town 66/11kV substation, 2 x 25MVA transformers		
		• Mansa 330/66kV, 2x90MVA,30MVAr bus reactor		
7	Kabwe - Pensulo 2nd Line	• 1x330kV Overhead line, 298km, with line reactors of 40MVAr at each end	Committed	2021
8	Chipata - Lundazi - Chama	• Chipata West-Mwasemphangwe 132kV line at 83km	Under construction	2019
		• Mwasemphangwe 132/33kV substation, 2 x 15 MVA transformers		
		• Mwasemphangwe-Lundazi 132kV line at 84km		
		• Lundazi 132/33kV substation, 2 x 25MVA transformers		
		• Lundazi-Egichikeni 132kV line at 47km		
		• Egichikeni 132/33kV substation, 2 x 15 MVA transformers		
		• Egichikeni-Chama 132kV line at 85km		
		• Chama 132/33kV substation, 2 x		

		25 MVA transformers		
9	Upgrade of transformers at Kitwe and Luano	• Luano 330/220kV, 4x315MVA (Installed capacity by 2021)	Construction	2021
		• Kitwe 330/220kV, 4x315MVA (Installed capacity by 2021)		
10	Livingstone - Muzuma - Kafue West 2nd Line	• 2x330kV Overhead line, 348km	Planned	2025
11	LTDRP 132kV	• Reinforcement of Lusaka 132kV Sub-Transmission Network	Committed	2021
		Leopards Hill 1 x 250MVA transformer, 330/132kV		
		• Leopards Hill-Roma-Lusaka West-Coventry - Leopards Hill 132kV ring uprated to 400MVA. • Halfway between Coventry and Lusaka West there shall be a 132/33/11kV Industrial substation with 2 x 90MVA @ 132/33kV and 3x 30MVA @ 132/11kV		
		• Water Works substation shall be uprated as follows;		
		2 x 90MVA @ 132/33kV and 3x 30MVA @ 132/11kV		
		• At Roma substation, 2 x 30MVA, 132/11kV additional capacity		
12	Muzuma - Choma	• 2x132kV Overhead line, 26km	Planned	2025
		• Choma 132/33kV, 2x20MVA		
13	Kafue Town -	• 1x132kV Overhead line, 55km	Planned	2025
	Mazabuka	• Choma 88/33kV, 1x45MVA		
14	Kafue Gorge	• 1x330kV Overhead line, KGL- LSMFEZ, 50km	Committed	2020
	Lower Power Evacuation	• 1x330kV Overhead line, KGL- Lusaka West, 106km		
		• 1x330kV Overhead line, KGL- Kafue Gorge, 11km		
		• Kafue West-Lusaka West 1 x 330kV Overhead line, 48km		
15	Sesheke - Mongu - Shangombo	• 1x220kV Overhead line, Sesheke - Nangweshi, 165km	Planned	2025
		• 1x220kV Overhead line, Nangweshi - Mongu, 125km		
		• 1x220kV Overhead line, Nangweshi - Shangombo, 130km		
		• Nangweshi 220/66/33kV, 2x63MVA		
		• Shangombo 220/66/33kV, 2x63MVA		
		• Mongu 220/66/33kV, 2x63MVA		
16	SVC for Luano and Kalumbila	• 140 Capacitive and 220 Inductive	Planned	• 2020
		SVC at Luano 220kV		• 2021
		• 170 Capacitive and 180 Inductive SVC at Kalumbila 330kV and a 50		
		MVAr capacitor bank on the 330 kV busbar		

17	Livingstone - Kaprivi (ZIZABONA Phase 2)	• 1x330kv Overhead line, 230km	Planned	2022
18	Kalungwishi - Kasama Power Evacuation	• (See attached Kalungwishi Power evacuation plan document)	Planned	2025
19	Lufubu Power Evacuation	• 1x330kV Overhead line to	Planned	2025
		Mporokoso, 60km		
20	Lusaka West - Kabwe- Luanshya- Kitwe/Luano	• 2x330kV Overhead line, Lusaka West-Kabwe, 100km	Planned	2025
		• 2x330kV Overhead line, Kabwe- Luanshya, 160km		
		• 1x330kV Overhead line, Luanshya- Luano, 86km		
		• 1x330kV Overhead line, Luanshya- Kitwe, 50km		
21	Malawi 330kV	• 2x330kV Overhead line, 35km from Chipata West substation to the border and 125km from border to Lilongwe with 30MVAr line reactors at either end of each line	Planned	2024
	Interconnector	• Create 400/330kV substation at Lilongwe 2 x 250MVA capacity.		
		• Refer to the EAPP/SAPP case file issued		
22	Mozambique 330kV Interconnector	• 2x400kV Overhead line, 366km from Chipata West in Zambia to Matambo in Mozambique with 60MVAr line reactors at either end of each line	Planned	2023
		• Refer to the issued EAPP/SAPP case file.		
		• Create 400/330kV Chipata West substation extension with 3 x 315MVA transformers		

Annex 6: Communications Strategy and Stakeholder Engagement Plan

Please see separate document attached.