Energy and Economic Growth
Applied Research Programme

Electricity in Zambia

EEG Energy Insight

Dr Iliana Cardenes and Katherine Cooke

March 2020

Oxford Policy Management

UKaid
from the British people

Introduction

Zambia's development plans are outlined in two documents: Vision 2030, which sets out the high-level goal of becoming a prosperous middle-income country by 2030; and the Seventh National Development Plan (7NDP) covering 2017–2021, which aims to create a diversified and resilient economy that will produce sustained growth and socioeconomic transformation. Based on these two documents, four energy sector goals are summarised in the Ministry of Energy's (MoE's) SREP Investment Plan (2018):

1. Enhance the generation, transmission and distribution of electricity.
2. Promote renewable and alternative energy.
3. Improve electricity access in urban and peri-urban areas.
4. Reduce development inequalities[1].

Beyond national development plans, the National Energy Policy, adopted in 2008, provides the overarching sector policy framework. It sets targets and strategies to promote diversification of the energy mix through greater renewables and private sector investment. Other major policy and regulatory frameworks (adapted from MoE, 2018) include:

- the Power Systems Development Master Plan (2010) – provides a blueprint for least-cost power system development up to 2030;
- the Rural Electrification Master Plan (2008–2030) – guides the rural electrification agenda up to 2030;
- the Renewable Energy Feed-in Tariff (REFiT) Strategy (2017) – aims to promote small- and medium-sized renewable energy projects of up to 20 megawatts (MW);
- the Electricity Amendment Act (2003) – followed on from the Electricity Act of 1995, which regulated and, in theory, liberalised the sector; the 2003 amendment further opened the sector up to private investment;
- the Energy Regulation Act (2003) – also followed on from the Energy Regulation Act of 1995, which established the Energy Regulatory Board (ERB), with the intention of strengthening the ERB's powers;
- the Rural Electrification Act (2003) – established the Rural Electrification Authority;
- the Zambia Electricity Grid Code (2013) – legally establishes the technical requirements of parties using the transmission system, and the principle of non-discrimination;
- the Zambia Distribution Code (2016) – provides clear procedures for both planning and operations, and promotes grid integration of renewables.

Reform of the sector, including a new Electricity Act, is a current focus for the Government of the Republic of Zambia (GRZ) and stakeholders.

The Energy and Economic Growth (EEG) applied research programme aims to address pressing policy questions in low-income countries to help shift energy systems towards a more sustainable, efficient, reliable, and equal paradigm. EEG's current 25 research projects derive from one general and two country-specific (Ethiopia and Sierra Leone) calls for proposals. The UK Department for International Development (DFID) is now considering the possibility of future additional energy research investments and, alongside its ongoing research projects, EEG is carrying out scoping studies on behalf of DFID in several countries, including Zambia.

[1] This strategic area envisages the promotion of integrated rural development through *inter alia* rural electrification and the reduction of gender inequalities.

The aim of the Zambia scoping study was to identify potential research questions of use to decision makers and practitioners in the energy sector, and to explore the extent of research capability in the country. Interviews were carried out with key stakeholders in the energy sector to ascertain the most pressing issues affecting the sector that would benefit from further research. A follow-up workshop was then carried out in conjunction with the Department of Planning and Information (DPI) of the MoE to solidify findings and prioritise key research themes. The DPI's Energy Sector Research Strategy was presented and validated during the workshop, and the themes influenced the EEG process.

This paper provides an overview of the energy sector in Zambia, including the main challenges it faces, and the research themes that emerged during the scoping study.

Institutional structure of Zambia's electricity sector and key players

ZESCO, a vertically integrated, state-owned utility, dominates the day-to-day delivery of electricity. It owns over 90% of Zambia's power infrastructure and runs the majority of its generation, transmission, and distribution. It supplies residential and most industrial customers. Further, it holds the licence to act as the country's system operator[2]. By default, ZESCO acts as the single buyer for all power from independent power producers (IPPs). ZESCO faces significant challenges, including political interference and unsustainable operating losses.

After ZESCO, the next largest entity is the Copperbelt Energy Corporation (CEC), a private locally-owned company that owns transmission/sub-transmission infrastructure in Copperbelt Province. CEC purchases power from ZESCO under a long-term bulk supply agreement and sells this on to its mining customers. CEC co-owns the Zambia-Democratic Republic of Congo (DRC) interconnector with SNEL, the DRC's national power utility, through which it sells and wheels power. Further, it operates embedded thermal capacity of 80 MW (used for emergency supply and voltage control). CEC has recently also invested in IPPs. CEC has been operating efficiently and is viewed by sector stakeholders as a well-run, profitable business.

On a smaller scale, North-Western Energy supplies electricity to mines and industrial customers in North-Western Province, and Zengamina Power Company operates an off-grid hydroelectric station with an installed capacity of 0.75 MW.

IPPs feed additional power into the network and power is sold to CEC and North-Western before ZESCO's distribution network delivers power to consumers.

A number of government ministries and institutions directly influence the power sector in Zambia, as summarised in

Table 1 below:

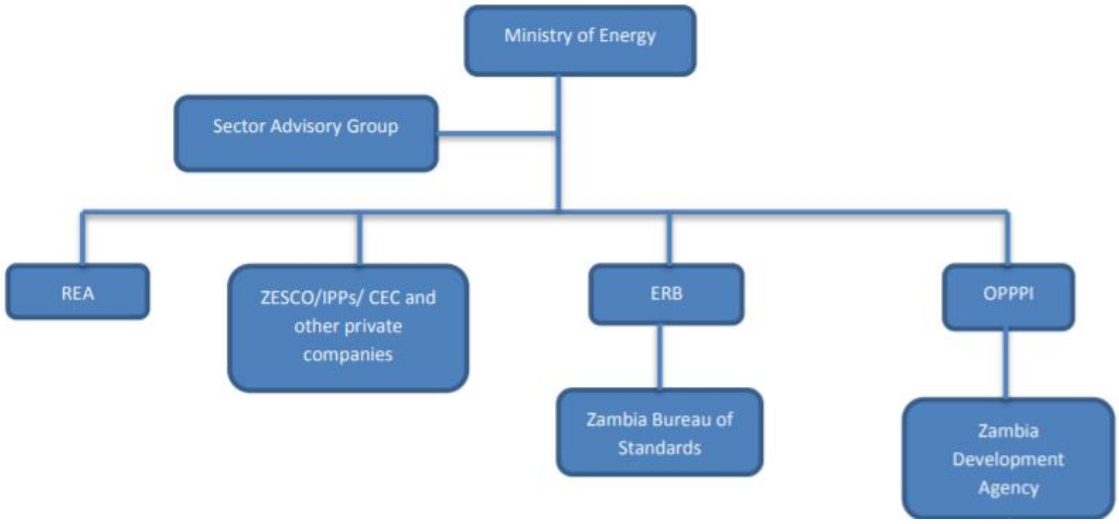
[2] Which creates conflicts of interest, stifles competition, and acts as a barrier to entry for potential investors (Chimbaka, 2017).

Table 1 Government ministries and institutions with direct influence the power sector in Zambia

Institution	Role / activities
MoE	Oversees electricity policy in Zambia through the preparation and monitoring of energy policies, strategies, plans, and programmes, and the coordination of stakeholders in the sector.
Energy Sector Advisory Group	A committee containing representatives from GRZ, development agencies, and the private sector, which coordinates on energy policy and provides an informed opinion on energy matters to policymakers.
Rural Electrification Authority	Responsible for electrifying rural areas, including through the development and implementation of the Rural Electrification Master Plan.
ERB	Acts as the independent regulatory agency and is responsible for 'licensing, tariff setting, and quality of supply and service standards' (World Bank, 2016).
Zambia Bureau of Standards	Provides quality assurance, import and export quality inspections and certification, and the removal of technical barriers to trade.
Office for Promoting Private Power Investment	Promotes private sector involvement in the development of power projects in the country (but is considered to focus on large hydro).
Zambia Development Agency	Is responsible for fostering economic growth and development by promoting trade and investment, innovations promoting high skills, and productive investment.
Ministry of National Development Planning	Coordinates cross-cutting climate change activities and links sector targets to wider national goals.
Industrial Development Corporation	An investment company owned by GRZ, which supports industrialisation and job creation. It owns ZESCO (which is around 70% of its balance sheet) and led the recent Scaling Solar procurement.
Ministry of Finance	Sets budgets and subsidies and underwrites guarantees for the sector.
Public-Private Partnership Unit	Aims to promote, facilitate, implement, and monitor the procurement, contracting and delivery of infrastructure through public and private partnerships.

An overview of some of the sector institutions is provided in Figure 1.

Figure 1 Zambia's electricity sector (source: Chimbaka 2017)



Electricity supply and demand

Supply/generation

Zambia is in the top 10 of sub-Saharan Africa's power systems. Current total installed capacity in Zambia is around 2.9 gigawatts (GW), dominated by hydropower. As at 2018, approximately 85% came from hydropower, with the remainder from coal (10%), heavy fuel oil (HFO) (4%), diesel (3%), and solar (under 0.1%) (Energy Regulation Board, 2017). Much of the hydropower capacity comes from four large ZESCO-owned stations: Kafue Gorge (990 MW), Kariba North Bank (720 MW), Kariba North Bank Extension (360 MW), and Victoria Falls (108 MW).

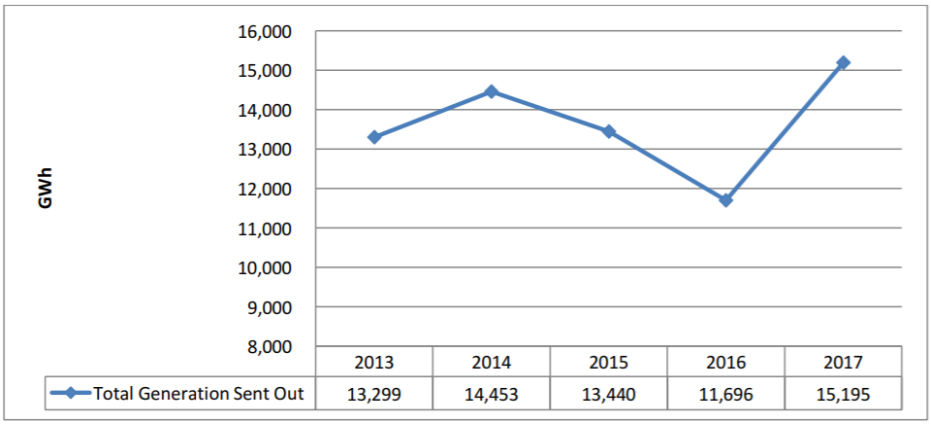
Figure 2 shows total annual electricity generation in Zambia between 2013 and 2017.

A joint Zambia and Zimbabwe project to build a 2.4 GW hydro station on the Zambezi continues to be supported by GRZ. This would be built upstream of the Kariba Dam, close to the famous Victoria Falls, at a cost of US$ 3 billion. According to the project's initiators, electricity output will be shared equally between Zambia and Zimbabwe, with excess production sold on to other member countries of the Southern African Development Community (SADC). However, developing such a project will be challenging, and some non-GRZ stakeholders believe GRZ should concentrate on other, more attainable projects – and also believe the feasibility study's assessment of demand is too high.

Much of the country's installed capacity is located in the south, along the Zambezi. As the majority of demand is located in the north, electricity must be transported over long distances. The transmission infrastructure required is capital-intensive, requires ongoing maintenance, incurs significant technical losses, and creates the potential for system congestion and bottlenecks.

The large proportion of hydropower in the electricity mix also leaves the country exposed to the variability of rainy seasons. Since 2013, generation has fluctuated, in large part due to the impact of droughts on the water availability at large dams.

Figure 2 Electricity generation in Zambia (ERB, 2017)



Increases in non-hydro renewables, such as solar photovoltaics (PV), may reduce the imbalance and mitigate the impact of increasingly unpredictable seasons on hydro generation. It could also potentially lower the cost of electricity and reduce the use of fossil fuels.

GRZ aims to bring additional renewable and thermal capacity online in the coming years. Total hydro potential in Zambia has been estimated at 6 GW and there is significant solar potential, with 3,000 hours of sunshine a year. Further analysis is required to determine the country's wind and geothermal potential, although initial assessments have been positive.

However, the intermittency of such generation, and lack of alignment with the country's daily demand profile, will create new challenges. For example, solar PV generation ramps up through the day and does not generate over the evening peak. As such, it does not fit the demand profile of mines (the Zambian economy is mainly built around copper mining, which requires reliable electricity supply to maintain production) and other large consumers (which are incentivised through capacity charges to keep their demand flat), or residential consumers (whose consumption is driven by the use of lighting and appliances during the evening hours).

A number of other barriers to renewables exist:

the absence of a transparent and competitive procurement framework, standardised power purchase agreements, indicative term sheets to raise debt, etc.;

a lack of clarity on how off-grid, mini-grids, and the national grid will be developed, which increases risk for developers and reduces the attractiveness of investments; and

the absence of a least-cost expansion plan, which prevents ZESCO efficiently expanding the power sector in a transparent manner.

The private sector is playing an increasing role in Zambia's power sector. Five IPPs are currently operational, as outlined in

Table 2.

Table 2 IPPs in Zambia[3]

	IPP	Installed generation capacity (MW)	Technology
1	Itezhi Tezhi Power Company	120	Hydro
2	Lunsemfwa Hydro Power Company	52	Hydro
3	Ndola Energy Corporation	105	HFO
4	Maamba Collieries Limited	300	Thermal (coal)
5	Bangweulu	48	Solar PV

Further to the above, there is Ngonye, a 34 MW solar PV station that is in the final stages of commissioning, and Zengamina, which is a 0.75 MW off-grid station.

ZESCO's poor financial position makes it difficult for bankable projects to be identified and progressed to financial close bilaterally. Instead, development finance-backed programmes, such as Scaling Solar and the Global Energy Transfer Feed-in Tariff (GET FiT)[4], are required.

Demand

Table 3. The largest consumer of electricity is the mining sector (50.9%), followed by domestic consumption (34.0%).

According to the International Energy Agency (2016), electricity demand in Zambia is growing at 150–200 MW per year. The MoE expects demand to be at 3,000 MW by 2021 (MoE, 2018). However, no further detail is available on which sectors will drive growth, or the overall rate of increase in the medium term. The lack of reliable demand data was highlighted by several stakeholders during the EEG scoping study and obtaining a robust demand forecast is a priority for the sector.

Zambia has a population of around 17 million (expected to rise to 24 million by 2030). The country has very low electrification rates[5]. As at 2015[6], only 31% of the population had access to electricity via the grid: 67% of the urban population and 4% of the rural population (down from 5% in 2010).

Electricity consumption is low, at 700 kWh/capita (MoE, 2018). ERB provides an annual breakdown of national electricity consumption by economic sector. Total consumption in 2017 was 12,200 GW per hour (GWh), up from 10,900 GWh in 2016 (ERB, 2018), as shown in

Zambia opted into the SEforALL Initiative in 2016 and, under this and GRZ's Vision 2030, has a target in place for 90% urban access and 51% rural access by 2030 (MoE, 2017). However, no clear electrification plan exists and grid extension projects are reported only once they are underway or complete.

As such, sector stakeholders have limited understanding of planning. A Japan International Cooperation Agency- (JICA-) funded Rural Electrification Master Plan was published in 2008 (JICA, 2008). However, this was not properly implemented and is now out of date. Many stakeholders, inside and outside of GRZ, feel that an Integrated Resource Plan, setting out a clear

[3] The Kariba North Bank Extension (360 MW) can be classified as an IPP but is not included here as it is a special purpose vehicle owned and operated by ZESCO.

[4] The Scaling Solar programme is a World Bank initiative delivered through the International Finance Corporation as a 'one-stop-shop' solution for governments in Africa to facilitate privately-funded on-grid solar PV (Stritzke, 2018). GET FiT is the official implementation programme for the Zambian REFiT Strategy and aims to develop small- and medium-sized renewables projects. Both have attracted significant international and local interest.

[5] Despite low access rates, electricity remains the third-biggest export from the country, as payments for exported power are significantly higher than domestic tariffs.

[6] No up-to-date electricity access figures are available.

development path for the electricity sector, would be of significant benefit.

In 2018, the United States Agency for International Development launched a geospatial tool to guide Zambia's electricity sector[7]. The main conclusion was that 'only 34 per cent of unserved households should be serviced by the grid, with off-grid solutions servicing the other 66 per cent'. Off-grid access among the rural population was 7.4% in 2015 (Ministry of National Development Planning, 2017). It is understood that off-grid connections have increased significantly since then, but no reliable figures are available.

Furthermore, GRZ has set a goal of reducing energy usage by 2% per year (as against business as usual) until 2030. Unlike the Global North, the purpose of this drive is not only to reduce emissions, but also to maximise the use of the country's limited supply. Global experience has in recent years increasingly demonstrated the benefits of energy efficiency. For Zambia, efficiency offers significant economic, development, and environmental benefits. Of particular interest to GRZ is the potential for increased competitiveness in the industrial sector (as costs are reduced). However, no energy efficiency strategy exists.

Table 3 Electricity consumption in Zambia by sector (ERB, 2018)

Sectors	2017	2016	2017	2016
	GWh		Proportion (%)	
Mining	6,202.0	5,918.0	50.9	54.5
Domestic	4,146.9	3,382.9	34.0	31.2
Finance and Property	640.0	498.6	5.2	4.6
Manufacturing	503.4	469.8	4.1	4.3
Agriculture	261.5	227.9	2.1	2.1
Others	87.3	80.1	0.7	0.7
Trade	110.2	97.4	0.9	0.9
Energy and Water	80.9	87.7	0.7	0.8
Quarrying	118.2	59.6	1.0	0.5
Transport	32.0	28.4	0.3	0.3
Construction	9.6	7.1	0.1	0.1
Total	**12,192.0**	**10,857.5**	**100**	**100**

Regional integration and the Southern African Power Pool

Zambia is a member of the Southern Africa Power Pool (SAPP). Established in 1995, the SAPP has 17 members, of which 12 are national utilities and five are transmission companies or utilities. Three of the latter are in Zambia: Lunsemfwa Hydro Power Company, Ndola Energy Corporation, and CEC. SAPP facilitates the buying, selling, and auctioning of power and the sharing of resources, and provides mutual support in emergency situations, as well as technical and economic efficiency benefits.

Currently, nine of the 12 SAPP countries are interconnected, with Angola, Malawi, and Tanzania expected to be connected in the coming years. Electricity trade in the region is done either through bilateral agreements or via SAPP's Coordination Centre and trading platform, which enables short- and long-term trading. Zambia trades bilaterally with neighbouring countries, with total traded volumes of 3.0 GWh in 2016 and 1.7 GWh in 2017, against national consumption of 10.9 GWh in 2016 and 12.2 GWh in 2017 (ERB, 2018). Although SAPP is the most developed power pool in sub-Saharan Africa (ahead of those in western, central, and

[7] www.usaid.gov/southern-africa-regional/news-information/press-releases/05-15-2018-usaid-launches-geospatial-tool-guide-zambia

eastern Africa), volumes traded across the region remain low compared to more established markets, such as Europe.

The expected benefits of increased regional integration are:

- costs are lowered through economies of scale over the long term and the provision of energy from the lowest-cost generation in the short term;
- generation reserves can be shared, reducing investment requirements;
- energy security is increased through increased access to imports;
- renewables integration is increased through a larger power system with greater dispatch options; and
- legal and regulatory systems are strengthened.

Ultimately, these benefits can feed through to end users in the form of reduced tariffs, higher electrification of remote areas, and increased reliability – and there is significant development partner support for integration and power pools in Africa.

However, to realise the expected benefits, significant investment in infrastructure, institutions, and regulations will be required across the region. Experience across the continent shows that competing political demands, limited capacity, and a lack of focus can undermine power integration efforts. Further, it is not clear how the anticipated long-term impacts of climate change will affect the operation and benefits of power pools.

Challenges

A number of challenges face the power sector in Zambia. Tackling these will require both steps to mitigate immediate effects and longer-term policies to tackle fundamental vulnerabilities (International Growth Centre, 2018).

Impact of climate change

Climate change is already affecting Zambia's electricity sector, with reduced and delayed rainfall, as experienced over the last five years, reducing the energy stored in the hydro stations that generate the majority of the country's power.

In recent years, there have been declining water levels in the Kariba Dam, which is the single biggest power source for Zambia and neighbouring Zimbabwe.

The 2014/2015 droughts led to a 50% decline in the country's hydroelectric generation. It resulted in extended load shedding (many customers experienced blackouts lasting more than eight hours a day) aimed at preserving water and avoiding a complete shutdown of generating plants, and started a deficit that is becoming increasingly difficult to manage.

To keep the economy running, GRZ, through ZESCO, procured emergency power from HFO generators off the coast of Mozambique at up to 18 US cents/kWh. As a result, ZESCO currently owes Electricidade de Mozambique US$ 53 million. It also had to buy expensive power from thermal-based IPPs (10 US cents/kWh). Around the same time, to support ongoing operations, ZESCO borrowed at rates far higher than its traditional financing arrangements.

Beyond the direct costs of purchasing emergency power, GRZ analysis shows that GDP growth dropped following the droughts and subsequent blackouts. During the severe drought of 2015, mines – which consume 60% of the country's electricity – were asked to cut their electricity use by 30%. This plunged the Zambian economy into crisis, with GDP growth rates falling by around 6% to a low of 2.6% (from levels above 10% only five years previously), and the Zambian currency depreciated dramatically. Although influenced by other factors, this indicates the significant impact drought can have on economic development.

A drop in generation in 2016 created a deficit of around 600 MW against demand, which necessitated expensive imports from the SAPP region. Although improved rain patterns and increased water flows contributed to increased generation in 2017, lower rainfall in 2018 and 2019 again reduced reservoir levels and there is currently a deficit.

After a brief recovery, rainfall performance in the 2018/19 season was poor for the Zambezi and Kafue basins. According to ZESCO data, allocations

from the Zambezi River Authority were reduced from the agreed 19 billion cubic metres of water (equivalent to 500 MW of generation between May and December 2019) down to 17 billion cubic metres (392 MW) in April 2019.

There is an urgent need to revise generation programmes to avoid over-drawing reservoir capacity; to understand how climate change will continue to impact hydroelectric generation in Zambia; and to build robust climate and water availability projects to avoid further drought.

Tariffs

As in many sub-Saharan African countries, establishing cost-reflective tariffs is a key step in order to limit the pressure on public finances and help attract greater private investment into the sector.

There is a need to understand how the institutional landscape in Zambia needs to change in order to address the dual objectives of tariff affordability and financial sustainability.

Tariffs in Zambia should be set through a request from ZESCO and review and approval from ERB, and should reflect costs incurred while incentivising efficiency savings and least-cost planning and operations. However, tariffs are highly politicised.

Tariffs were increased in 2017 and, as at June 2018, the average consumer tariff was estimated at 6.33 US cents/kWh and the average mining industry tariff at 9.30 US cents/kWh – but even with this rise, tariffs in Zambia are the second lowest in the SADC region. An application for a tariff increase by ZESCO to ERB in May 2019 was cancelled by the president on the grounds of public opposition[8].

As such, tariffs remain significantly below the cost of supply, meaning that ZESCO loses money on the power it sells – an unsustainable position that undermines all efforts to modernise and improve the electricity sector. Consumer opposition to tariff increases is, however, understandable, given the unreliable power supply across the country, and the (not inaccurate) perception that ZESCO is inefficiently managed and operated.

A cost of service study was commissioned in 2017. While GRZ stakeholders stated that this was being implemented the consultant chose not to continue with the study. GRZ stakeholders now state that a new consultant is being procured. However, given the politically sensitive nature of tariffs, it is not certain the study will go ahead in any meaningful way.

ZESCO financial viability

ZESCO is facing severe challenges, and is essentially bankrupt. In particular, political interference undermines its ability to operate sustainably:

Overstaffing adds significant unnecessary costs, but job losses are politically unpalatable.

Dispatch is not always based on least-cost principles, with certain customers and areas prioritised. For example, Kariba water levels have been reduced through baseload running of peaking capacity.

New connections are made even when they are economically inefficient due to low tariffs and low consumption by many households.

Tariffs are not cost-reflective, so ZESCO is unable to recover its costs or invest in improvements or expansion without subsidies. As explained previously, a cost of service study announced in 2017 has been delayed.

ZESCO's poor financial state, combined with its position as the country's sole offtaker, explains the very limited progress in adding new capacity since the droughts of 2014–2015. Despite a push for renewables, only the 48 MW Bangweulu solar plant has come online. Projects are not bankable without significant development partner support.

Where IPPs have come online, significant fixed costs have been incurred and ZESCO has struggled to keep up with payments. Further, each IPP adds contingent liabilities, which are underwritten by GRZ. As with many utilities in sub-Saharan Africa, dollar-denominated contracts, and a depreciating currency (the kwacha was the second-worst performing currency against the dollar between

[8] www.xinhuanet.com/english/2019-05/04/c_138033530.htm

January and May 2019[9]) create significant problems.

Limited planning capacity

Zambia requires significant investment in generation capacity, network infrastructure, and off-grid solutions. With growing demand and increasing impacts from climate change, new capacity must be procured and integrated to reduce the deficit and diversify supply. Further, improved management of water resources is required. Network infrastructure must be planned and delivered to match supply (largely in the south of the country) with demand (in the north) and connect Zambia to its neighbours. Infrastructure investment will require appropriate charging methodologies and processes that reduce transmission losses and congestion as far as possible.

However, Zambia's national energy workforce is still relatively small, with expertise and experience focused on large-scale hydropower. An increased number of IPPs will not necessarily build capacity, as developers (and development partners) tend to hire international energy experts on a project-by-project basis. Further, the requirement for climate change resilience, efficiency, renewable generation, and off-grid access necessitates new skills across a range of functions, from the operation of a power system with highly intermittent renewables penetration, to marketing pay as you go solar home systems.

Capacity appears to exist within the key sector institutions, but this does not translate into sufficient planning or oversight, with analysis ignored by senior management and politicians. Highlighting this, two Scaling Solar projects were delayed by a lack of appropriate regulatory and coordination processes, as well as limited institutional capacity and a lack of understanding of the specific requirements that such a development imposes.

Further, the Office for the Promotion of Private Power Investment, a specialised unit in the MoE tasked with increasing private investment in power generation and transmission, does not have a clear legal mandate to procure new power and is known to lack the capacity and resources needed to drive these processes (Kapika and Eberhard, 2013).

Sector reform

Sector reform is required – and a process to liberalise the Zambian power sector is underway, offering the potential for increased private sector participation and open access (the option for generators to sell to offtakers other than ZESCO). However, progress to date has been slow.

A new Electricity Act has been proposed and is now moving through GRZ sign-off processes, with cabinet approval required before it can be implemented. Further, there is support for the unbundling of ZESCO among some development partners. However, it is not clear that the political will for change exists.

Further, unbundling ZESCO may not resolve the sector's problems if the fundamental cost–income balance is left in place. The cancellation of the tariff increase application by the president did not follow the due process of law and went against the central rationale of reform. Despite the decision, ERB (working with Power Africa) aims to establish a transparent, predictable mechanism for setting tariffs through the introduction of a Multi-Year Tariff Framework.

A move away from the current single-buyer model will increase the requirement for an independent system operator, but the willingness of ZESCO to give up its role as system operator is unclear. The alternative is that ZESCO continues to fulfil the role, but with strict rules in place and significantly increased transparency.

Conclusion

[9] Bloomberg, Zambian President Threatens to 'Divorce' Vedanta, Glencore, 17 May 2019, https://www.bloomberg.com/news/articles/2019-05-17/zambian-president-threatens-to-divorce-vedanta-glencore-jvs18ls3

After engaging with a wide range of stakeholders, EEG has identified priority research areas for Zambia's energy sector. Seven research themes were derived from the scoping process. The impact of climate change on the Zambian energy system emerged as the top request from stakeholders. This was followed by: the potential of electric cooking in Zambia; the political economy of tariff structuring; innovation in electrification and achieving universal access; developing innovative market structures to match supply and demand; experimental measures to promote energy efficiency in buildings, industry, and appliances; and capacity building/power systems' evolving skills profile and workforce gaps.

About the authors

Dr Iliana Cardenes is a consultant at Oxford Policy Management, specialising in climate change policy, water resources management, and disaster risk management. She has a DPhil from the University of Oxford's Environmental Change Institute, a master's degree in Climate Science and Policy from Columbia University's Earth Institute in New York City, and a degree in Environmental Sciences from the School of Civil Engineering and the Environment at the University of Southampton. Prior to starting her doctoral studies, Iliana worked in the Environmental Statistics Department at the United Nations Department of Economic and Social Affairs in New York City and at the Environment Directorate of the European Commission in Brussels, and was then appointed as a senior consultant for the United Nations Development Programme in Mexico City, where she worked directly with the Mexican Environment Ministry.

Katherine Cooke is a senior technical policy and sustainability consultant for Oxford Policy Management, specialising in international and domestic climate change policy. She has particular experience in climate finance, mitigation, institutional capacity building, and urban resilience. With over 10 years of experience working with industry, on energy efficiency and mitigation projects, until 2016 she was an advisor in providing technical policy support to DECC on the Climate Change Levy (CCL). Within this programme she worked with a variety of industry sectors (through sector associations) to help them manage their Climate Change Agreement (CCA) and renewables targets. She was closely involved in assisting them to determine their evidence base for their 2014–2020 CCA targets, and presenting their energy-saving commitments to DECC. This involved close scrutiny of the current state of play of energy efficiency within the sectors, and the capacity and capability (both economic and technical) for further improvement for the duration of the second phase of CCL agreements. Katherine also implemented, monitored, and reviewed carbon management and energy efficiency training programmes across 50 industrial sites. She was responsible for the design and presentation of training, and train the trainer workshops. Katherine has high-level experience in training and capacity building, including the design and delivery of workshops for LDC and country negotiating teams under the United Nations Framework Convention on Climate Change. She has recently developed and delivered TNAs and training programmes for the Ministry of Foreign Affairs of Sudan, the Ministry of Environment of Peru, and the Ministry of Environment Forest and Climate Change of Ethiopia. Katherine has an MSc in Applied Geoscience and Environmental Management from Manchester University and a BSc in Engineering Geology from Liverpool University.

Front cover image: View of the Kariba hydroelectric dam in the Kariba gorge of the Zambezi river between Zimbabwe and Zambia in southern Africa.

The views expressed in this Energy Insight do not necessarily reflect the UK Government's official policies.