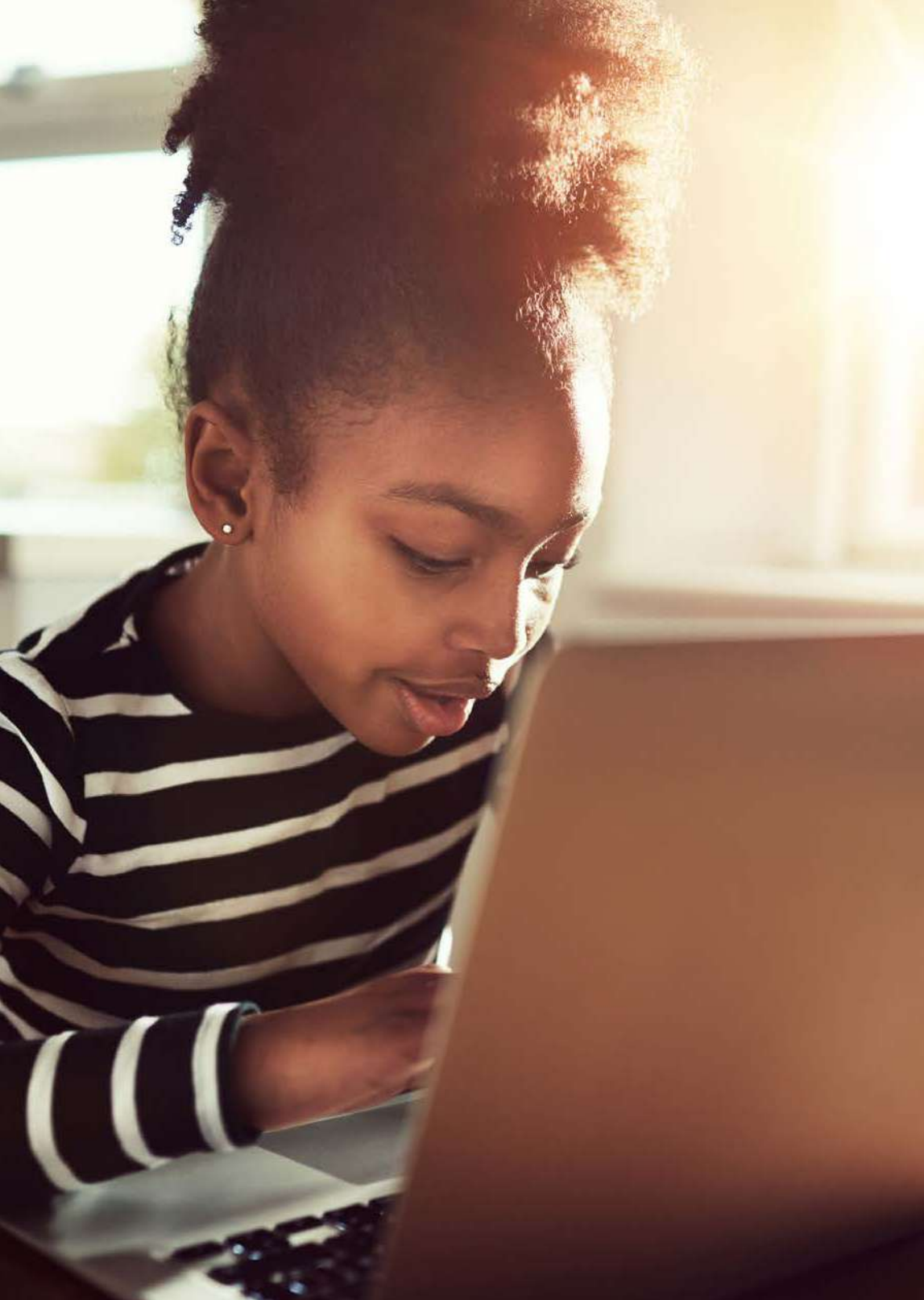
A Brighter Future

Powering Zambia's Economy

Zambia Chamber of Mines
March 2017



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Foreword
by Nathan Chishimba

Zambia has been blighted by power cuts for a number of years now. They are deeply inconvenient for the ordinary citizen, and have caused untold damage on businesses and the wider economy.

Why do we have power cuts? In short, because demand for power now outstrips the nation's installed generation capacity.

As this booklet shows, increasing demand is to be celebrated – it is a sign of economic and social development marching hand-in-hand. However, unless Zambia revitalises its once-envied power sector, we risk undoing the progress achieved since the early 2000s.

Building more power plants is critically important; but it is not the only consideration.

Power infrastructure is hugely expensive. There is little point building more if the resulting electricity becomes unaffordable, or saddles our businesses with additional costs that make them uncompetitive.

New and affordable power can facilitate economic development, as it did at the turn of the millennium. But new power that is unaffordable will be a burden for the nation to bear.

At present, the signs are not good. Procurement of new power, from a range of new Independent Power Providers, appears to be overpriced. Most stakeholders, including the Energy Regulation Board, question the efficiency of the State electricity supplier, ZESCO. Fortunately, a Cost of Service Study is being commissioned this year, funded by the African Development Bank, so Zambians should know the real picture soon enough.

The decisions that must be taken to reform the power sector will have a multi-decade impact on the future of Zambia, for good or for ill. A clear vision and a strategy, informed by a thorough and impartial understanding of the state of the current system, is essential. To carry all stakeholders with them, the government and regulator must persuade Zambians that they are prepared to take all necessary actions to provide the best possible service to citizens.

Zambia is at a crossroads. We must take the path that leads to a brighter future.

Nathan Chishimba
President, Zambia Chamber of Mines

Understanding the basics

How electricity gets from the power station to the home

Electricity – a fascinating story

It lights our streets, powers our homes and businesses, and even keeps our mobile phones running. But where does electricity come from? And how does it get into our lives in a form so safe and convenient that we can get it simply by flipping a switch? There are three key stages in the story of electricity – generation, transmission and distribution.

GENERATION

Fossil fuels

Electricity is generated at a power station, where mechanical energy is converted into electrical energy. Typically, fossil fuels (oil, coal, gas, etc) are burned to produce heat energy in the form of steam, which then drives a rotating generator that produces electricity.

Alternative sources

In Zambia, where hydroelectric power is more common, water is stored in a dam and is released to drive turbines at the base of the dam – this creates the rotational power to produce electricity. Then there are nuclear power stations; they use nuclear reactions to generate heat energy. Electricity can also be generated using wind turbines, tidal energy and solar panels – so-called renewable energy sources.

TRANSMISSION

Transporting the electricity

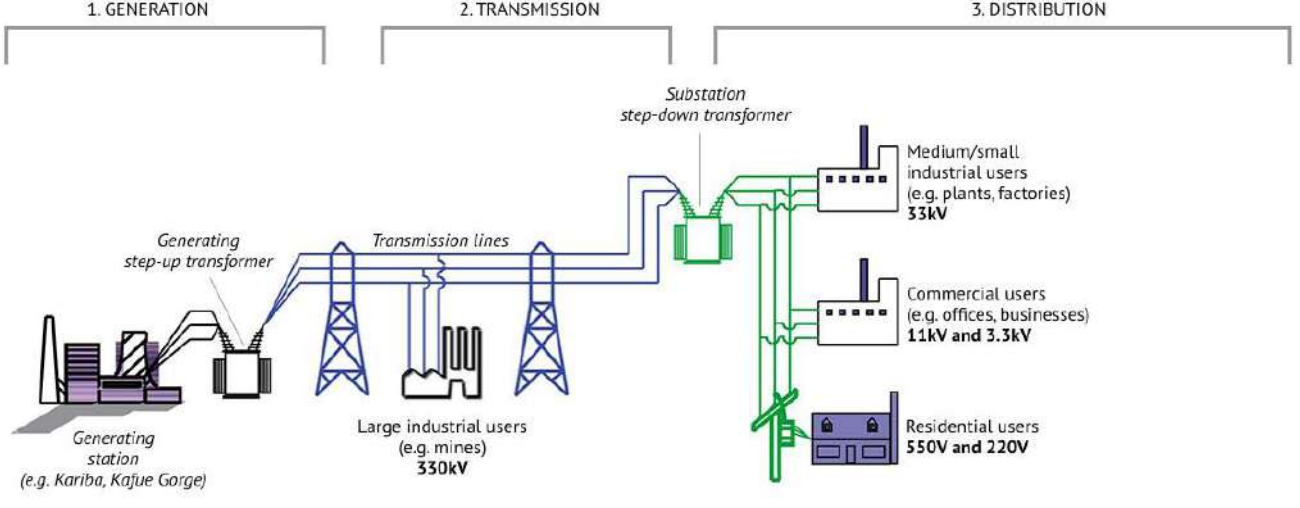
To get the electricity from the power station to where the users are, it has to be transported around the country. The electricity flows along powerlines, which are strung together over great distances and supported by large steel towers – or pylons. It flows at very high voltages, because this helps to reduce energy losses. Electricity in this raw form is suitable for large industrial users, but not for commercial or residential users.

DISTRIBUTION

Making the electricity safe for use

There are three broad categories of customer – industrial users, commercial users and residential users. They each have different voltage requirements, and this influences the way in which electricity is distributed to them from the high-voltage powerlines, and made safe for use.

Delivering electricity to users



Industrial users
Industrial users (e.g. mines, big plants and factories) require high-voltage electricity for their heavy machinery and equipment. A mine, for example, will take its electricity straight from the high-voltage transmission lines, in raw form, and feed it into its own purpose-built network of substations, transformers and distribution lines. The power is then distributed to its operations and mining communities. Essentially, the mine builds and runs its own distribution network.

Medium and smaller industrial users (such as plants and factories) also require high-voltage electricity, though not at the same level as mines. Also, they do not build and run their own distribution networks.

Commercial users
Commercial users (e.g. office complexes, malls, hotels) need their electricity to be reduced – or stepped down – to medium voltage, before being delivered to their premises. All of this is done by the electricity supply company (e.g. ZESCO) via a complex network of substations, transformers and distribution lines.

Firstly, the electricity from the high-voltage transmission lines is fed into distribution substations that reduce it to medium voltage. It is then carried by primary distribution lines (typically mounted on wooden poles) to distribution transformers located near the commercial customers' premises.

Residential users
At the end of the chain is the domestic or residential user, who requires low-voltage electricity for use in household appliances, ovens, lighting and heating/cooling systems.

This involves a further layer of distribution transformers to reduce the electricity from medium to low voltage. The low-voltage electricity is then transported to residential neighbourhoods via secondary distribution lines, which are a common sight on roadsides.

Operating power stations

Power station	Generating capacity (MW)	Available capacity (MW)
Kafue Gorge	900	630
Kariba North Bank	1080	275
Victoria Falls	108	108
Itezhi-Tezhi	120	120
Lunzua	14.8	5.9
Lusiwasi	12	8.6
Chishimba	6.2	3.5
Musonda	5	4
Shiwang'andu	1	1
Total	**2 237**	**1 156**

Source: ZESCO website

The importance of energy losses

The electricity entering the transmission and distribution network is never the same as the electricity coming out at the other end – and the reason for this is losses, or "leakage". World Bank figures show that these losses are as low as 4% in developed Western countries, and as high as 20% or more in many developing countries in Africa and Asia.

The losses occur for both technical and non-technical reasons, and they are most significant at the distribution stage.

Technical losses are affected by the design, quality and maintenance of the grid. Losses are particularly high during the process of stepping down, or reducing, the electricity from high to low voltage.

There are also non-technical losses, for reasons such as theft, meter fraud, unmetered supply and poor energy accounting. These are more prevalent in developing economies.

Losses are a measure of the efficiency and financial sustainability of the power sector, and is an indicator of the operational soundness of the electricity supply company. The smaller the losses, the greater the revenue generated and recovered, which improves the ability to offer lower tariffs and invest in new infrastructure.

Why is Zambia short of electricity?

From a surplus to a deficit

1960s: A model of energy supply

Zambia's first power station, built at Livingstone in 1906, was a thermal plant. The bulk of all subsequent power generation has been hydro-electric, given Zambia's geography and abundant water resources.

Hydroelectric power was first harnessed at Mulungushi power station in 1923, and between then and 1971, the majority of Zambia's present power-generation capacity was installed. Indeed, the Kariba North Bank extension, commissioned in 2014, is the only power plant to have been commissioned since 1977.

In the 10-20 years after independence in 1964, Zambia was blessed with first-class energy infrastructure and experienced a period of surplus, exporting power to both Zimbabwe and South Africa. Electricity was competitively priced and reliable; power outages were non-existent; the economy had all the power it needed for future growth and expansion. However, this growth and expansion failed to materialise.

1970s-90s: The economy contracts

Zambia's costly power plants had been built primarily to service the nation's mining industry. However, from 1973 onwards, the Zambian economy struggled under the dominant effect of neglected investment and shrinking production in the newly nationalised mining industry, compounded by a falling copper price and a rapidly rising oil price.

As the mining industry contracted, so did demand for electricity – a combination of external factors and harmful policies saw the economy go into a long period of decline. By the end of the 1980s, Zambia's economic situation, along with living standards, had deteriorated considerably. The country emerged from this painful economic period at the end of the 1990s with a new government and a new economic policy. Given the continuous contraction of the economy, Zambia now had a significant surplus of electricity that needed to be utilised, particularly as surplus electricity cannot be easily stored.

Late 1990s: Energy surplus facilitates privatisation

The energy surplus turned out to be a big competitive advantage when the government privatised the mining industry. ZESCO was both willing and able to offer the new mining companies competitively priced tariffs, in order to generate an income from its surplus power capacity, which in turn greatly improved the attractiveness of Zambia as an investment destination. The privatised mines invested more than $10 billion into expansion and new mines over the next decade, enabling Zambia to boost copper production and benefit from the worldwide commodity boom.

2000s: Zambia's economy booms, driving up energy usage

The wave of mining investment boosted economic growth, and this would not have been possible without Zambia's affordable, fully depreciated (i.e. fully paid for) energy supply. New businesses were created, people were employed throughout the economy, and disposable incomes increased. Figures by the World Bank show that from 2000 to 2013, Zambia's GDP per capita – which measures the average income of the population – grew more than fivefold, the biggest and fastest increase since independence.

Industrial investment and increased production drove energy consumption by industrial users; and growing employment and earning power led to increasing energy demand from a rapidly growing class of residential users. "As countries develop and living standards improve, energy demand grows rapidly," says a 2016 report from the U.S. Energy Information Administration.

So, far from being in competition, domestic and industrial users are actually partners in energy usage, as their increasing consumption goes hand-in-hand, and taken together is a sign of overall national development. However, inevitably, Zambia's electricity surplus started to erode during the decade of economic boom. With insufficient planning, given the time that it takes to build new capacity, and insufficient investment in new power-generating capacity, the country started drifting towards the power deficit it is still experiencing today.

The future

A range of new power plants, ranging from mini-hydroelectric projects to coal-fired power stations and solar farms, are currently at various stages of planning or development. Zambia's energy deficit is expected to start

easing in the coming years as these projects gradually come on stream. However, this new electricity-generation capacity is only one part of the answer to Zambia's energy crisis. As Zambia's history shows us, unless investments in expensive power generation infrastructure have the effect of boosting economic activity, they can become a millstone round the neck of the nation.

Why mines consume so much electricity

Modern mining is increasingly mechanised

It's the very nature of the business

Because of the huge amount of work, heat and processing required to produce metals, mining is one of the most energy-intensive industries in the world, and accounts for about 5% of global electricity consumption. Explosives blast open the earth, releasing millions of tonnes of ore which have to be crushed and ground into smaller pieces. It then undergoes various chemical and heat-treatment processes before emerging at the other end as finished metal ready for export. And mining is not a nine-to-five business where everything shuts down at the end of the day; it operates around the clock and throughout the year.

The sheer magnitude of the work done is staggering. For example, KCM's Konkola Deep mine on the Copperbelt runs electrically driven underground pump stations that pump 450 million litres of water to the surface every day – that's enough to fill 180 Olympic-size swimming pools.

Also pushing the consumption of electricity in the world's mines is a move away from diesel-powered machinery to electrically powered machinery, which is safer, more efficient and more environmentally friendly.

Mines often biggest users of electricity

In mining countries, the industry typically represents a significant – and sometimes the largest – slice of national energy consumption[1]. In Chile, the world's largest copper producer, mining accounts for more than 20% of total power consumption; in South Africa, the proportion is about 15%; in Australia, it is 9%; in Zambia, it is more than 50% – reflecting Zambia's small installed energy base compared to that of larger, more diversified economies. The United States, for example, has a huge mining industry that produced $110 billion of coal, metals and industrial metals in 2015. Yet, because of the country's large installed energy base, mining there only uses about 10% of national electricity consumption.

Mines do not "deprive" the rest of the country of energy

In the current loadshedding environment in Zambia, it's easy to draw the conclusion that there would be fewer power outages if it wasn't for the mining industry consuming more than half of the country's output.

However, the problem isn't the mining industry's power consumption, which is well within global norms, but insufficient power supply. Zambia's mines cannot be any less energy-intensive than they already are, and are already running at around 70% of their operating power requirements. Reducing power to the mines means reducing production, which negatively impacts employment, export earnings, government tax revenue and economic growth.

Did you know?

First Quantum Minerals' high-tech $2.1-billion Sentinel Mine, in North-Western province, uses the world's largest rope shovels. They lift up to 120 tonnes (120 000 kg) of ore in a single scoop. This $25-million electrically powered machine is manufactured by mining-equipment supplier, Caterpillar, and is one of a fleet of three. It operates 20 hours a day, filling haul trucks which take the ore out of the open pit for processing. The rope shovel's average power requirement is 11 000 kW – by comparison, the power demand of an average household oven is 2.4 kW. Just one of these giant machines consumes twice as much electricity in the course of a single day as the average home in the United States consumes in an entire year.

The cost of providing electricity

It varies according to customer requirements

Factors influencing electricity prices

Electricity, like all products and services, comes at a cost. As we saw in the first chapter, *Understanding the basics*, electricity has to be generated at power plants, transmitted via high-voltage transmission lines all over the country, and then distributed to customers via a vast, complex network of substations, transformers and distribution lines. First and foremost, the price of electricity therefore reflects the cost of building, financing, maintaining and operating the power plants, as well as the complex system of power transmission and distribution infrastructure – more commonly known as the grid.

Electricity costs not uniform

The cost of providing electricity to various categories of customer varies significantly; therefore, they are charged significantly different prices.

Electricity prices are usually highest for residential customers, because it costs more to distribute electricity to them; the reason is the extensive infrastructure (substations, transformers and distribution lines) required to step down the voltages to levels safe for household use.

It is much cheaper to provide electricity to large industrial customers – such as mining operations. Because they receive it at high voltage straight from the transmission lines, there is no need for all the additional and expensive infrastructure that comes with building and maintaining the residential distribution network. In addition, their demand pattern is stable (i.e. the need for electricity doesn't fluctuate dramatically during the day). Therefore, it is more manageable for the supplier.

Finally, because they operate their own electrical infrastructure, they manage and carry the cost of energy losses in distributing power to their operations and communities – and we already saw in Chapter 1 how significant these can be. Energy losses for residential and commercial users, on the other hand, are managed and borne by the electricity company.

"The price of power to industrial customers is generally close to the wholesale price of electricity," says a U.S. Energy Information Administration (EIA) factsheet[2].

Some international comparisons

Figures[3] by the EIA show that in 2014, the average price of electricity per kWh in the United States was 12.5 cents for residential users, and 7.01 cents for industrial users – a 44% difference. European Union statistics[4] for 2016

show that the average price of electricity was 0.219 euros for households, and 0.124 euros for industrial users – a 43% difference.

A similar difference exists in Zambia. According to estimates by First Quantum Minerals, Zambia's largest mining company, it is 5 cents per kWh cheaper to supply high-voltage electricity to the mines than low-voltage electricity to households.

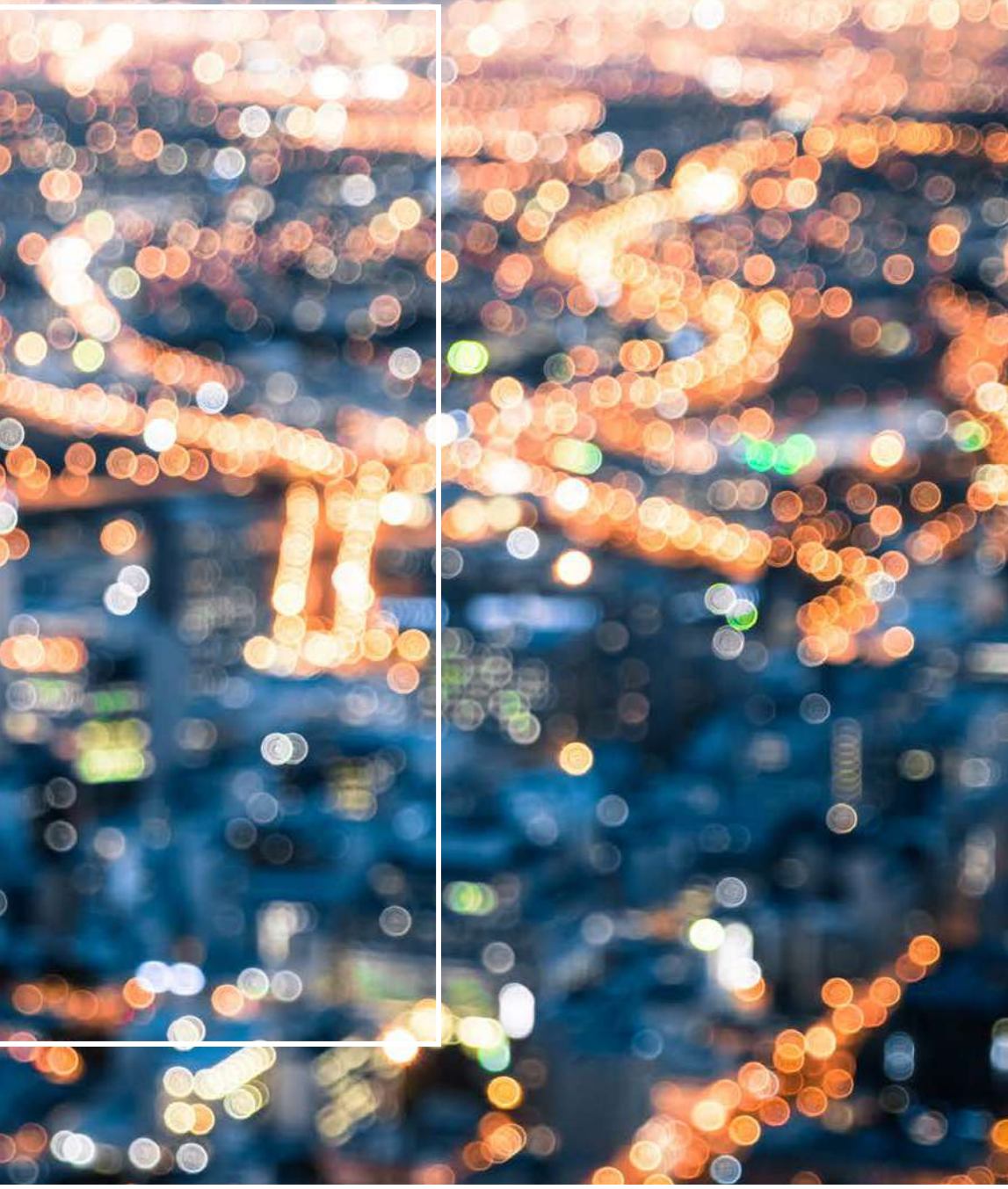
A global competitiveness issue

In many countries, energy-intensive industries such as mines, chemical plants and other heavy-duty factories compete in global markets. Energy costs are a key driver of their competitive advantage, and play a primary role in business decisions.

This is not just a problem in developing countries such as Zambia, but is increasingly prevalent in the developed world too. In Germany, where increasing use of expensive renewable energy has greatly increased energy costs, big-name companies such as BASF, BMW and SGL Carbon have shifted new multibillion-dollar investments to the United States, where energy is much cheaper. "As green policies drive up the cost of power, entire industries are shrinking," says the German newspaper *Handelsblatt*[5].

In Britain, *The Times*[6] reports that Tata, Britain's biggest manufacturer, blamed "cripplingly high" energy costs for a decision to shed 1 200 jobs at its Scunthorpe plant in 2015. And in India, where industrial users pay high prices for electricity, an official committee looking into tariff reform has recommended lower tariffs for them as the country moves from a deficit to a surplus, reports India's *Economic Times*[7].

Industrial users play a key role in generating employment, tax revenue and economic growth; and countries are becoming increasingly aware of the importance of competitively priced energy for them.



The cost of electricity – the mines' perspective

A major element of the industry's cost structure

Electricity major cost element

Electricity is one of the largest single elements in the cost structure of the average mine, keeping equipment, machinery and infrastructure functioning around the clock, year-round. "When considered as a portfolio that includes diesel, heavy fuel oil, grid electricity, gas, LNG and other sources, energy can represent up to 30% of a mining company's total operating costs," says professional services firm Deloitte, in its *Tracking the Trends* report[8] for 2016.

In Zambian mines, grid electricity is the most significant element of the energy mix. The typical large Zambian mine spends several million dollars a month on electricity. Together, electricity and labour account for up to 50% of total operating costs for Zambian mines[9].

Factors affecting a mine's electricity costs

A mine's electricity consumption depends on factors such as its size, its design (underground, open-pit or incline), the grade of copper ore (high or low) and its technological sophistication. Together, they affect how much work – and hence energy – goes into producing a tonne of copper.

Ultimately, production is the deciding factor: a mine producing a lot of copper will consume a lot of electricity. So, a small, compact underground incline mine such as Chibuluma, which produces 10 000 tonnes of copper a year, will have a smaller energy bill – both in absolute and proportional terms – than a large, open-pit mine such as Kansanshi, which produces more than 200 000 tonnes of copper a year.

Geology matters too: under-ground mines on the Copperbelt, such as Mopani and KCM, have to pump hundreds of millions of litres of underground water to the surface every day. Keeping the electrically driven pump stations running around the clock is the single-largest element of their electricity bills.

Producing their own electricity

Access to affordable, reliable electricity is so important to the world's mining companies that some of them have had to invest in their own power sources. Mopani's parent company, Glencore, has invested $368 million and more than four years building a

450-MW hydroelectric plant[10] in the Democratic Republic of Congo (DRC), where power availability is a critical problem. The decision by a mine to build a power station is typically factored into the original investment decision, and can easily double the project cost. In the DRC, the rich grades of copper – among the highest in the world – make the huge additional upfront power costs worth the investment.

Zambia's mines have never – so far – had to embark on building their own power stations, because the country already had an abundant source of competitively priced electricity at the time of privatisation in the late 1990s. In any event, as Zambia's century-old copper mining industry is now experiencing declining grades of copper – often just 0.5% – massive independent power investments in the future are unrealistic. The mines' power investments to date have been mainly to supplement the existing infra-structure: for example, by building transmission lines to connect new mines to the grid. First Quantum Minerals has built 600 km of powerlines, at a cost of nearly $100 million, to bring power from the national grid to its Sentinel mine, in Kalumbila.

The current state of the Zambian power sector

Progress has been made, but challenges remain

Insufficient supply

Zambia currently cannot generate enough electricity to meet its daily needs. Power continues to be imported at very high cost, putting severe pressure on the Treasury; the mines are running on reduced power, curtailing their ability to operate efficiently or expand production; and the country is subjected to almost daily loadshedding. These outages cause immense hardship for ordinary citizens, and put huge commercial strain on businesses, many of whom have to run expensive stand-by generators to keep their operations going.

Insufficient long-term investment

According to a 2015 World Bank report, *Powering the Zambian Economy*[11], prior to the 360MW Kariba North Bank Extension completed in 2015, the last major power plant to be commissioned in Zambia was the Kariba North Bank, in 1977. That situation has now finally been addressed. The report says there are six power plants at various stages of development, some of which have been in the pipeline for more than a decade. Their total capacity is more or less 1 730 MW; that compares with ZESCO's current installed base of 2 330 MW. However, the report says that despite these projects, and even with above-average rainfall for the country's existing hydroelectric plants, "current power shortages will continue through 2018".

Uncompetitively priced new power projects

Proposed tariffs on some of the new power projects coming on stream are considerably above international benchmarks. The US Energy Information Administration has benchmarked tariffs globally for new power plants, enabling comparisons with similar plants in countries around the world. According to an internal study on comparative energy costs done by First Quantum Minerals, Zambia's largest mining company, the proposed electricity tariffs for Maamba Collieries and Itezhi-Tezhi are, on average, 23% higher than global benchmark costs. The study attributes these differences to lack of strict cost controls, lack of transparency around the cost of producing electricity, and pressure from ZESCO for higher tariffs to generate urgently needed revenue.

Cost of producing electricity not known

The cost of procuring electricity from Zambia's new generation of Independent Power Producers is just one side of the coin. On the other, is

ZESCO's internal costs – staff costs, overheads, etc. – as well as the actual costs of producing and supplying electricity, and the losses or "leakage" that occurs in the course of it. These costs are, in time, passed on to the consumer; that is at the heart of the call for 'cost-reflective tariffs'. However, as Finance Minister, Hon. Felix Mutati said in his 2017 national budget speech, cost-reflective tariffs "does not mean that consumers should end up paying for inefficiency".

But Zambians do not know how efficiently their national electricity supplier, ZESCO, is operating, or what the real cost of producing electricity is. The last time a formal Cost of Service Study was done was ten years ago, in 2007. The importance of knowing the true cost of producing electricity in Zambia, and how it compares with international benchmarks, cannot be understated.

Users certainly shouldn't pay for the provider's inefficiency. However, they must benefit from greater efficiency, through the lowest possible tariffs.

For, to be a facilitator of economic development, power must not only be plentiful and reliable – it must be competitively priced too. Plentiful, reliable power that users cannot afford is little better for the nation than having no power at all.

Lighting up Zambia

Towards a brighter future

It starts with reform

Zambia needs a reliable supply of cost-efficient, competitively priced electricity. The health and well-being of citizens, businesses and the broader economy depend on it. Zambia's ability to grow and diversify over the coming decades depend on it.

The power sector in its present form has not been able to deliver this electricity supply. This implies an urgent need for reform. As the Energy Regulation Board itself concluded in its paper, *Electricity Sector Market Reforms*[12]: "[The] persistence of underperformance of the power sector in developing countries justifies calls for reform."

The paper highlights multiple concerns, which include reservations about ZESCO's "efficiency and fairness" in operating the power system. Some stakeholders are calling for "radical reforms" such as unbundling and privatisation.

And as Finance Minister Hon. Felix Mutati himself said in his 2017 national budget speech, government will conduct a "review of the overall structure, governance and operations of the sector, including generation, transmission and distribution."

This suggests that no aspect of the power sector will be overlooked, and nothing is being ruled out.

Reform starts with costs

While reform is inevitable, the outcome of that reform is not. The shape a newly reformed Zambian power sector will take is impossible to imagine now. It might involve privatisation and unbundling to a greater or lesser extent; or it might involve something completely different. What is certain at this stage is that no serious reform can be contemplated until the cost of producing electricity in Zambia is known – for it this very cost that will dictate the nature and extent of the reform.

It will also determine the nature and extent of any tariff increases, and will ensure that these reflect the true cost of providing an efficient, internationally competitive service.

Mining sector's vision on energy

"We in the mining sector have never shied away from the reality of cost-reflective tariffs. We are business people, and costs are something we deal with every single day," says Nathan Chishimba, President of the Chamber of Mines. "We are committed to tariffs that reflect the cost of providing electricity in an efficient, transparent and internationally competitive manner. However, these must be introduced in such a way as not to destabilise the economy, but to promote continued growth, employment and disposable income."

References

1. "Energy and the mining industry" (2016), www.miningforzambia.com
2. "Electricity Explained: Factors influencing electricity prices", US Energy Information Administration, https://www.eia.gov
3. "Electricity Explained: Factors influencing electricity prices", US Energy Information Administration, https://www.eia.gov
4. "Electricity price statistics. Eurostat: statistics explained", http://ec.europa.eu/eurostat/statistics-explained
5. "How to kill an industry"; 24 March 2016; Handelsblatt
6. "UK industry 'crippled' by electricity costs twice as high as in Germany"; 21 October, 2015; The Times
7. "Modi government's new power plan: Heavy electricity users will now pay lower tariffs"; 21 January, 2017, The Economic Times
8. "Tracking the trends 2016: The top 10 issues mining companies will face in the coming year", Deloitte, 2016
9. "Counting the kwacha", (2016), www.miningforzambia.com
10. Sustainability Report 2015. Glencore.
11. "Zambia Economic Brief: Powering the Zambian economy", December 2015, Issue 6, World Bank Group
12. "Electricity sector market reforms: Getting it right in developing countries – SADC", Conference paper, March 2016, by Besa Chimbaka, Energy Regulation Board

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