Federal Ministry
for Economic Affairs
and Energy

energy solutions
MADE IN GERMANY

Subsector Analysis: Zambia

The power crisis and its consequences for solar energy in the Zambian mining sector

Facilitator

giz Deutsche Gesellschaft
für Internationale
Zusammenarbeit (GIZ) GmbH

Imprint

Publisher
Federal Ministry for Economic Affairs and Energy (BMWi)
Public Relations
D-11019 Berlin, Germany
www.bmwi.de

Text and editing
Thomas Hillig (THEnergy)

Editing
Tobias Cossen, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
Franziska Waitz, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Design and production
German Energy Solutions Initiative

Status
July 2016

The Federal Ministry for Economic Affairs and Energy has been awarded the berufundfamilie® audit certificate for its family-friendly HR policy. The certificate is granted by berufundfamilie gGmbH, an initiative of the Hertie Foundation.

Table of Content

Executive Summary

Zambia is currently facing a severe power crisis. Traditionally, electricity had been available in Zambia in abundance from amortized hydro-power plants at extremely low prices. In recent years, however, droughts have dried out many damns leading to severe restrictions of power generation capacity.
In order to reduce the pressure, Zambia has begun to ration electricity supply to mines which are consuming more than 50% of the country's electricity. Currently, mine production, which constitutes the backbone of the Zambian economy, is affected by load shedding and power outages. Every so often, back-up diesel gensets for generating baseload power have to be employed: an extremely expensive solution. Many mines are facing additional challenges, such as falling copper prices in the world market, and changing national tax policies. More and more mining companies are contemplating closing down their operations in Zambia. In addition, the power price for mining companies has almost doubled since the beginning of the year. The Zambian government has initiated emergency measures and has started to buy expensive conventional energy from neighbouring countries and private suppliers. At least in the short-term, the issue is expected to persist as the damns are not filling up significantly. What might further exacerbate the situation is the rather slow realization of new power infrastructure projects combined with large investments in mining assets which are expected to double the output capacity of the copper mines by 2020.
At the moment, the main hope on the horizon is a solar tender by Zambia's Industrial Development Cooperation for two 50 MWp solar power plants. The lowest offer was submitted at US¢6.02/kWh which is a significantly lower price than what Zambia is currently paying for the emergency solar power measures. The tender has once again illustrated that solar energy has become very competitive and can be a relative low cost source of energy. In addition, photovoltaic (PV) power plants can be constructed extremely quickly. Zambia has realized the opportunity and wants to issue tenders of up to additional 500 MWp of solar power. At the same time, these low prices for solar power have also pointed mining companies in the direction of becoming more self-sufficient regarding their energy supply. In the short-term, the competitive price of solar power can help to avoid high energy costs from back-up diesel generators; mid- and long-term electricity prices, which are expected to further increase in Zambia, can be hedged. In addition, so-called solar-diesel hybrid power plants or micro-grids can provide dependable power, which is extremely important for all safety relevant aspects of mines.
Given the current power lack in Zambia and the favorable economics of PV-diesel hybrid systems in combination with limited local knowledge and missing implementation expertise, there are good opportunities for German companies to enter the Zambian PV market. Regarding solar power plants, Zambia fully depends on imports.
Mines have now the opportunity to invest their own capital or – and in times of the global mining crisis this appears to be even more likely - commit to long-term power purchase agreements permitting investors to build PV power plants near mines and to buy the electricity of them.

Mining as the Backbone of the Zambian Economy

1.1 Economic Background

Located in Southern Africa, Zambia has approximately 15 million inhabitants and is relatively sparsely inhabited. In comparison to other countries in Southern Africa, Zambia occupies an average rank regarding economic wealth (see Table 1). This is also reflected in the *Global Competitiveness Report* of the *World Economic Forum* in which Zambia occupied rank 96 out of 140 in 2015-16.[1]

[1] Schwab, Sala-i-Martín (2015)

Table 1: GDP of several Southern African countries[2]

Country	GDP per capita [USD] 2014
Malawi	255
DRC	440
Mozambique	602
Zimbabwe	896
Zambia	1 781
Angola	5 424
Namibia	5 589
South Africa	6 479
Botswana	7 123

The primary sector consists mainly of 'Mining and Quarrying', 'Agriculture', and Forestry and Fishing'. In 2014, mining contributed to approximately 9% of Zambia's GDP. Copper is the most important resource and accounts for approximately two thirds of total exports. On the basis of estimates from the 2012 Labor Force Survey, the mining industry accounts for 21% of formal private sector employment in Zambia.[3]

After the Zambian economy has been on the rise for the last decade, its growth has been slowing down in recent years. The rate of growth has dropped from a peak of 10.6% in 2010, to 6.7% in 2013, to 5.6% in 2014, and, finally, to 4.6% in 2015. For 2016, the GDP growth rate is projected to be 5%. The decline in copper prices and growing energy shortages has caused the country's production, exports and foreign exchange receipts to decrease.

1.2 The Mining Industry in Zambia

Zambia is one of the main copper producers worldwide, and, after the Democratic Republic of Congo, the second biggest copper producer in Africa (see Table 2).

Table 2: Main global copper producers[4]

	Mine production		Reserves
Country	2014	2015e	
Australia	970	960	88 000
Canada	696	695	11 000
Chile	5 750	5 700	210 000
China	1 760	1 750	30 000
Congo (Kinshasa)	1 030	990	20 000
Mexico	515	550	46 000
Peru	1 380	1 600	82 000
Russia	742	740	30 000
United States	1 360	1 250	33 000
Zambia	708	600	20 000
other countries	3 600	3 900	150 000
World total (rounded)	18 500	18 700	720 000

[2] N.N. (2015a), p. 32
[3] N.N. (2015b), viii
[4] U.S. Geological Survey (2016), p. 55

At today's production rate, the reserves would last for approximately 20 more years. Most of Zambia's copper deposits have a very high grade between 2-3% in comparison to the global average yield of approximately 0.8%.[5]
Another mineral commodity that is produced in Zambia is cobalt: Zambia is endued with the third biggest cobalt reserves world-wide and was the 6th biggest cobalt producer in the world in 2014. Copper can usually be found where cobalt is found. Originally, Zambia used to be the world's 3rd largest cobalt producer; however, apparently due to administrational burdens, cobalt has lost some of its importance in the Zambian mining sector. The recent copper price crisis has demonstrated the risks associated with focusing on a few minerals only. In this context it is worth mentioning that the mining industry also engages in the production of nickel, lead, zinc, silver and gold.[6] Against the global trend, copper output in Zambia rose by 0.5% in 2015. Production increased from 708,254 metric tons in 2014 to 711,515 metric tons in 2015. The production rise can, to a large extent, be explained by First Quantum Minerals Ltd.'s Kalumbila operation starting its output.[7] In the contrary, the development of existing mines was rather negative.[8] In 2015, the mining industry was facing challenges regarding

- tax changes
- falling copper prices
- power deficit due to low-water levels in key hydro power plants

The fall in the price of copper, from USD6.829 per ton in 2014 to USD5.160 in 2015, has caused some mining companies to reconsider their activities in Zambia. Temporary adverse growth effects are likely to be experienced in 2016.[9] However, the International Monetary Fund (IMF) observed significant investments in the Zambian copper mines to be competed. Copper production is expected to reach over 1.4 million tons by 2020, almost twice the level of 2015.[10] The ongoing power crisis with load shedding and power outages might be one of the main challenges to realize this growth.

Power Generation in Zambia

In 2014, Zambia's total power consumption amounted to 10,720.5GWh. Mining was, with 54.8%, by far the biggest consumer of electricity, consuming more than twice as much as all households together. Electricity prices used to be extremely low in Zambia. The mining rate, however, gradually increased and rose from 8.20US¢/kWh to 10.35US¢/kWh by the beginning of 2016. Zambia, facing an annual bill of USD_660 million in fuel and power subsidies according to the International Monetary Fund, had to react.[11]

Table 3: Power consumption in Zambia[12]

Sectors	2014 [GWh]	2014 percentage
Mining	5871,3	54,8%
Domestic	2350,8	21,9%
others	2498,4	23,3%
Total	10720,5	100,0%

[5] KPMG (2013), p. 18 and cited sources
[6] KPMG (2013), p. 18
[7] Hill (2016a)
[8] Also compare Annex 1
[9] United Nations (2016), p. 2
[10] International Monetary Fund (2015), p. 4
[11] Hill (2016b)
[12] Energy Regulation Board (2014), p. 8

ZESCO is Zambia's vertically integrated state-owned power company. Producing about 80% of the electricity consumed in the country it is also Zambia's largest power company.[13] Copperbelt Energy Corporation Plc (CEC) is a regional utility that operates in the Copperbelt region. CEC was formed in 1997 when Zambia Consolidated Copper Mines (ZCCM) was privatized. It focusses on transmitting and supplying electricity to the mining industry. CEC does not have grid-connected generation assets.
Zambia is rich in water resources making it no surprise that power generation is dominated by hydro power plants. Traditionally Zambia has an electricity surplus and, until recently, managed to export a net power-surplus to its neighboring countries.

Table 4: Major power plants in Zambia[14]

Power	Type	Owner	Installed capacity [MW]	Available capacity [MW]
Kafue Gorge	Hydro - dam	ZESCO	900	900
Kariba North Bank	Hydro - dam	ZESCO	720	690
Kariba North Bank Extension	Hydro - dam	ZESCO	360	360
Victoria Falls	Hydro - dam	ZESCO	108	108
Kafue Gorge Lower	Hydro - dam	ZESCO	750	?
Itezhi Tezhi	Hydro - dam	ZESCO	120	?
Lunzua	Hydro - dam	ZESCO	0.75	0.75
Lusiwasi	Hydro - dam	ZESCO	12	11
Chishimba	Hydro - dam	ZESCO	6	6
Musonda	Hydro - dam	ZESCO	5	4
Shiwang'andu	Hydro - dam	ZESCO	1	1
CEC Diesel generator	Diesel	CEC	80	80
Maamba	Coal	Emco Zambia	300 (not connected yet)	0

Due to low water levels, the hydro production has been extremely low in recent years. The country has to cope with load shedding and power outages. The mining industry is severely affected. To some extent, production decreases of major Zambian mines are linked to missing electricity supply. Medium-term Zambia expects new coal-fired, hydro and renewable energy assets to be connected to the grid. Nevertheless, the situation might even worsen further, since the mining industry wants to double its copper production until 2020. In the short-term, the Zambian government has taken several measures to overcome the current power crisis as demonstrated in Table 5.

Table 5: Short term-emergency power supply

Source	Type	Capacity MW	Contract period	Price (USDc/kWh)
EDM	mix	80-150	Jan 2016- Dec 2017	14.00
Aggreko	LNG	148	Sep – Dec 2015	18.86
Aggreko	LNG	40	Jan – Dec 2016	18.86
Karpowership	HFO	100	Mar 2016 – Dec 2017	16.73
ESKOM	Mix	50-300	Jan – Dec 2016	6 – 19.00

The Turkish company Karpowership for example burns heavy fuel oil on sea and delivers the electricity through cross-border interconnection lines to Zambia. The contract might be extended to 200 MW in 2016. As ESKOM also has to cope with power outages in South Africa, this contract focuses on off-peak periods. The rates vary regarding the time of electricity being delivered.
The following table illustrates the consequences of the electricity crisis for six major Zambian mining businesses comparing the monthly average energy consumption in 2015 with the electricity provided in January 2016. The numbers have been published by the Ministry of Energy and Water Development.

[13] Future Climate for Africa (2016), p. 23
[14] Thiel, Hauser (2015), p. 15 and source cited there and own research

Table 6: Short term-emergency power supply[15]

Mine	Electricity provider	2015 Cons. [GWh]	Av. monthly cons. 2015 [GWh]	Cons. January 2016 [GWh]
Konkola	CEC	1 483	124	119
Kansanshi	ZESCO	1 207	101	102
Mopani	CEC	1 547	129	100
Kalumbila	ZESCO	344	29	59
Lumwana	ZESCO	294	25	27
Luanshya	CEC	382	32	24

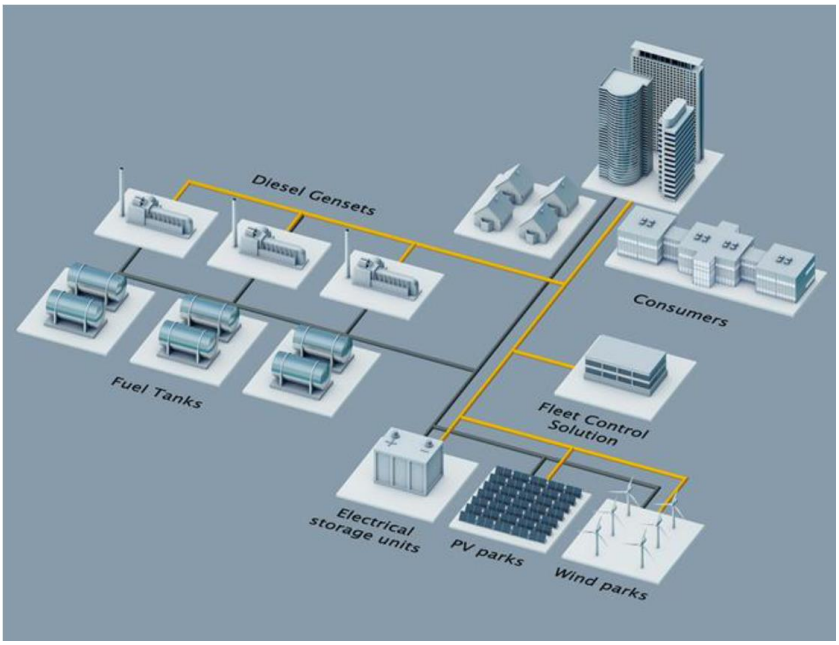
Solar Energy for Powering the Mines in Zambia

Although the power crisis might be suited for introducing large-scale solar power to Zambia, up to now, there are only very few small-scale solar power plants in the country. Mines, as the main power consumers, might become drivers in the development of the small-scale solar power sector. In light of the mining crisis, capital investments of mines into energy systems do not seem very probable. However, mines might commit to long-term power purchase agreements (PPA) in order to secure their electricity supply. Solar power plants have the advantage that construction time is extremely short. Further, first tenders have shown that solar energy can be very cost-efficient in Zambia. The bid tariffs for two 50 MWp PV plants start at US¢6.02/kWh[16] and are thus well below the power costs Zambia is experiencing concerning its current emergency measures (compare table 5). They are also below the new energy tariff for mines of 10.35US¢/kWh[17]. The tariff is expected to constantly increase over the coming years. The solar power plants could be either built centralized and provide power through the grid or decentralized, i.e. in proximity to a mine connected through a direct power line.

In the second case, the solar power plant would be part of a micro-grid. Back-up diesel gensets or stationary energy storage, such as batteries, could also be a part of the micro-grid, i.e. a solar-diesel hybrid power plant. In recent years, the technical feasibility of electricity generation for mines through solar-powered micro-grids has been proven, even in large scale applications.[18] Connecting the mining micro-grid to the national power grid might be advisable as it would reduce diesel genset usage considerably. In the micro-grid, diesel gensets are very likely to cause the highest direct costs and have the biggest environmental impact. In the grid-connect micro-grid scenario, diesel generators merely fill the gap between the solar output and the load from the mine not covered by the grid. This might for instance be the case during load-shedding. The objective of the micro-grid is to provide robust and stable power to the mine.

[15] Siliya (2016)
[16] IEA (2016), p. 4
[17] PWC (2015), p. 3
[18] For project examples have a look at solar-diesel hybrid plants and micro-grids at THEnergy's database for renewables and mining: http://www.th-energy.net/english/platform-renewable-energy-and-mining/database-solar-wind-power-plants/

Figure 1: Solar-diesel hybrid micro-grid



Source: Siemens AG

Energy storage solutions, e.g. in the form of batteries, can further stabilize the micro-grid by shaving peak loads and providing peak-power. Nowadays, critical processes are already often secured with UPS-system. Some manufacturers' aim is to use the UPS storage system for their micro-grid.
The combination of micro-grid and national power grid might also have additional advantages in the future: if the solar power plant generates more electricity than the mine consumes, the energy might be fed back into the grid. The decentralized micro-grid solution ensures that the grid is utilized less by the mine.
From a cost perspective, micro-grid solar power plants are more complex than grid-connected ones. The integration of generation, grid and mine requires additional infrastructure. On the one hand, the solar power plants in the micro-grid will be smaller than the one in the tender mentioned before. Economies of scale do not fully apply and the power price is expected to be significantly above the US¢6.02/kWh. On the other hand, the mine is likely to provide the land for free or at very low costs.
Many international investors are interested in financing power plants for mines and in selling electricity through power purchase agreements (PPAs) to solvent mines. In this model the mine is expected to guarantee for long term power take-off. The price per kWh decreases with longer off-take obligations. The physical life-time of solar power plants is well above 25 years.

Outlook

The current power crisis in Zambia presents a chance for solar energy. Many mining companies see the risk that arises from power outages and load shedding in form of higher energy costs or production losses. Electricity costs are expected to further rise in Zambia. After a long period of inexpensive energy from abundant hydro power, the paradigms have changed. Solar power can be installed extremely quickly and can contribute to save costs in comparison to power from expensive back-up diesel gensets immediately. Energy cost advantages can be an important differentiator in the very competitive copper market which is characterized by surplus supply due to falling copper demand from China. More and more mining companies have a strategic look at energy. Typically, energy accounts for 20-40% of their operating costs. The global mining crisis is currently slowing down this development to some extent. Management capacity and capital are used for more urgent problems. At the same time, mining companies have to convince their investors that they are prepared for future challenges. Doing things differently is more accepted by the investment community than it was during the mining boom. It can be expected that more and more mining companies will recognize the strategic importance of stable energy prices and robust power supply that solar power offers.

Appendix 1

Operation	Ownership (2014) / comment	Location	Type	Direct employees (2014)	Contract labor (2014)	Other (ext. project)	Total	Output (2015)19	Output (2014)	Capacity [metric tons]
Mopani	First Quantum 16.9%; Glencore 73.1%; ZCCM-IH 10%	Copperbelt	UG	10,000	10,000		20,000	93,260	109,870	250,000 copper 2,400 cobalt
Konkola / Nchanga	Vedanta 79.4%; ZCCM-IH 20.6%	Copperbelt	UG & OP	7,000	9,000		16,000	115,098	120,409	222,000 copper 2,500 cobalt
Lumwana	Barrick Gold 100%	Solwezi District	OP	1,882	2,054		3,936	130,363	97,058	140,000
Kansanshi	First Quantum 80%; ZCCM-IH 20%	Solwezi	OP	4,781	3,731	5,407	13,919	226,674	262,706	250,000
Lubambe (formerly Konkola North Mine)	Vale 40%; African Resources 40%; ZCCM-IH 20%	Copperbelt (near Chilila-bombwe)	UG	1,200	1,000		2,200	24,859	25,724	25,000 45,000 (by 2019)
Chibuluma	METOREX (Jinchuan Group) 90%; ZCCM-IH 10%	Copperbelt (Kitwe)	UG	602	345		947	12,956	15,825	19,000
Luanshya (Muliashi / Baluba)	CNMC 85%; ZCCM-IH 15%; Baluba halted in due to costs, copper price & power shortage	Copperbelt (Kitwe)	OP / UG	2,740[20]				44,038	44,421	45,000
Chambishi Metals	CNMC 85%; ZCCM-IH 15%	Copperbelt (Kitwe)	UG	741	147		888			
Chambishi Copper Smelter (CCS)	CNMC 60%; Yunnan Copper Group 40%	Copperbelt (Kitwe)	SM	1,600	400		2,000	-	-	-
NFCA	CNMC 85%; ZCCM-IH 15%; South East Ore Body (SEOB) under development	Copperbelt (Kitwe)	UG	1,064	1,219		2,283	26,041	28,600	100,000
Kalumbila / Sentinel	First Quantum 100%;	140km west of Solwezi	OP	1,264[21]				32,951		280,000 – 300,00
Kalumbila / Enterprise nickel mine	First Quantum 100%; 38,000 tons of nickel in concentrate per annum	140km west of Solwezi	OP							38,000
Munali nickel mine	Consolidated Nickel Mines (CNM); off operations since 2011; to be ramped up	75 km South of Lusaka	UG							10,500 nickel 1,650 copper 480 cobalt

Source: World Bank Group (2015), p. 33, own research incl. indicated sources.

[19] N.N. (2016)
[20] Luanshya (2016)
[21] Hill (2016c)

Sources

Energy Regulation Board, 2014, Energy Sector Report 2014.

Future Climate for Africa, 2016, Baseline assessment for Lusaka – prepared for FRACTAL.

Hill, M., 2016a, Zambia 2015 Copper Production Unexpectedly Rises on New Mine, Bloomberg, accessed online under http://www.bloomberg.com/news/articles/2016-01-22/zambia-2015-copper-output-unexpectedly-increases-on-new-mine on June 11, 2016.

Hill, M., 2016b, Zambian Mining Companies Disputing Power-Tariff Increase, accessed online under http://www.bloomberg.com/news/articles/2016-03-31/mining-companies-in-zambia-disputing-power-tariff-increase on June 11, 2016.

Hill, M., 2016c, First Quantum to Cut 730 Jobs at Zambia Copper Mine, ZNBC Says, accessed online under http://www.bloomberg.com/news/articles/2016-01-06/first-quantum-to-cut-730-jobs-at-zambia-copper-mine-state-tv on June 11, 2016.

IEA International Energy Agency, 2016, Renewable Energy - Renewable Policy Update.

International Monetary Fund, 2015, STAFF REPORT FOR THE 2015 ARTICLE IV CONSULTATION—DEBT SUSTAINABILITY ANALYSIS.

KPMG, 2013, MINING Zambia Country mining guide.

Luanshya, 2015, Company Statement in Zambian Daily Mail, accessed online under https://www.daily-mail.co.zm/?p=43836 on June 11, 2016.

N.N., 2015a, Bank of Zambia – Annual Report 2014.

N.N., 2015b, ZAMBIA ECONOMIC BRIEF Making Mining Work for Zambia.

N.N., 2016, Zambia's 2015 copper production remains below 800,000 MT, in: Open Zambia, accessed online under http://www.openzambia.com/2016/01/zambias-2015-copper-production-remains-below-800000-mt/ on June 11, 2016.

PWC, 2015, Weathering the storm - Zambia's 2016 National Budget.

Schwab, K.; Sala-i-Martín, X., 2015, Global Competitiveness Report 2015-16.

Siliya, D., 2016, MINISTERIAL STATEMENT ON POWER SITUATION IN THE COUNTRY, DORA SILIYA, accessed online under http://www.parliament.gov.zm/sites/default/files/images/publication_docs/Ministerial%20Statement-%20Ministry%20of%20Energy.pdf on June 11, 2016.

Thiel, D., Hauser, J., 2015, ZIELMARKTANALYSE SAMBIA, Photovoltaik 2015, Mit Profilen der Marktakteure.

United Nations, 2016, Country Profile – Zambia.

U.S. Geological Survey, 2016, Mineral commodity summaries 2016: U.S. Geological Survey, 202 p., http://dx.doi.org/10.3133/70140094.

World Bank Group, 2015. The Economic, Health, and Environmental Nexus of Zambia's Copper Mining Economy.

www.german-energy-solutions.de/en

www.bmwi.de