The Impact of Power Rationing on Zambia's Agricultural Sector

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EXECUTIVE SUMMARY

A lack of electricity has devastating consequences for any economy. Since early 2015, Zambia experienced a 2,100 gigawatt-hours (GWh) power deficit triggering countrywide power rationing. We assess the impact of power rationing on Zambia's agricultural sector, and the costs to firms operating in the agricultural sector. Our analysis reveals economy-wide losses amounting to ZMW 32,496,100,813 (representing 18.8% of the GDP). Losses to the agricultural sector are estimated at ZMW 2,827,160,771 (representing 1.6% of the GDP), and are likely to stifle future economic growth.

Within agriculture, power rationing has increased the costs of commodity production and processing, driven primarily by the acquisition and operation of back-up generators, equipment start-ups, and idle labor. With generators in place, production losses among the large agro-processing firms are likely to be minimal. In commercial crop production, the effect has been through reduced yields. Power rationing has generally led to reductions in producer surpluses, especially for dairy and potato farmers. For other commodities, production costs passed on through price hikes are expected to increase the cost of living for consumers. Identified coping strategies among firms operating in agriculture include the acquisition of back-up generators, and altering of shifts in some cases. In some cases, excess labor (mainly temporary) has been laid off to reduce production costs.

To increase energy supply security, Zambia will have to increase the utilization of its hydropower, solar, thermal, and geothermal potential, and the private sector will have an important role to play. However, investment decisions by independent power producers will mostly depend on a market guarantee in the form of state-backed power purchase agreements; currently, ZESCO Limited enters directly into power purchase agreements without government involvement. Other key factors include a strong government commitment towards implementation of energy policies, and the associated legal and regulatory framework. There is also need to comprehensively lay down clear regulations, guidelines, and rules to operationalize private sector involvement in the sub-sector. For ZESCO, there will be need to address the inefficiencies in its operations in order to make finances available for investment and regular maintenance.

TABLE OF CONTENTS

LIST OF TABLES

TABLE **PAGE**

LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS

CGE	Computable General Equilibrium
COUE	Cost of Unserved Energy
CSO	Central Statistical Office
EIZ	Engineering Institute of Zambia
ERB	Energy Regulation Board
FAO	Food and Agriculture Organization
FCR	Feed conversion ratio
GWh	gigawatt-hours
GDP	gross domestic product
GRZ	Government of the Republic of Zambia
Ha	hectare
IEA	International Energy Agency
IPA	IPA Energy Consulting
kg	kilogram
kWh	kilowatt-hour
KPMG	A global network of professional firms providing audit, tax, and advisory services
kVA	kilo-volt-ampere
MAL	Ministry of Agriculture and Livestock
MCCs	milk collection centers
MW	Megawatts
MM	millimeter
NEC	Ndola Energy Company
NEP	National Energy Policy
PAZ	Poultry Association of Zambia
PPAs	power purchase agreements
REFIT	renewable energy feed-in tariff policy,
Rs	Pakistan Rupees (PKR)
SADC	Southern African Development Community
SSA	Sub-Saharan Africa
TERI	Tata Energy Research Institute
SAPP	Sub-Saharan Africa Power Pool
USAID	United States Agency for International Development
ZDA	Zambia Development Agency
ZESCO	Zambia Electricity Supply Corporation
ZIPAR	Zambia Institute for Policy Analysis and Research
ZMW	Zambian Kwacha
ZNFU	Zambia National Farmers Union

1. INTRODUCTION

As economies grow, the demand for electrical energy (hereafter power) grows in line with rising populations, industrialization, and rising incomes. Typically, for the developing world, investments in electricity generation capacity fail to keep up with the rapid demand growth, and this triggers power shortages and rationing. Therefore, it not surprising that some countries in the developing world continue to grapple with major power deficits. While a reduction in future power deficits are expected in Africa, the problem will still persist because growth in power generation capacity is unlikely to keep up with the rising demand for power as economies grow (IEA 2014). More recently, several countries in Sub-Saharan Africa (SSA) have experienced power shortages, with the regional shortage estimated at 8,247 mega-Watts (MW) (SADC 2015). Imported electricity from international sources or grids such as the Sub-Saharan Africa Power Pool (SAPP)[1] has failed to satisfy country-specific power demands, more because many countries in the region are simultaneously experiencing power shortages (e.g., South Africa, Mozambique, and Zimbabwe).

In instances where countries hit by power shortages cannot import enough power to meet their respective power consumption demands, power rationing results. The economy-wide negative effects of power rationing have been shown in a number of studies and are well understood (e.g., see Bose et al. 2006; Sangvhi 1999; Wijayatunga and Jayalath 2004; and Kaseke 2011). Through impacts on various consumers of power, power rationing ultimately leads to reductions in economic growth.[2] For example, in Zimbabwe, power rationing caused gross domestic product (GDP) losses of up to 32% for each kilowatt-hour (kWh) lost (Kaseke 2011). In India, losses from power rationing amounted to $2.7 billion for the period 1983/1984-representing 1.5% of the GDP, while $2.1 billion was lost in 1982/83 representing 2.1% of the GDP (Sangvhi 1999). In Pakistan 1.8% of the GDP was lost due to power rationing between 1975 and 1976, and this translates to Rs 9.3 billion (ibid). These examples show that the impact of load-shedding (or power rationing) on the Zambian economy are likely to be large and a progressive energy policy needs to be put in place to minimize the losses or avoid a recurrence of the problem.

More recently, a number of challenges have plagued the Zambian economy. The Kwacha has depreciated against the U.S. dollar, inflation has increased[3], and there is inadequate power generation to meet domestic consumption demand. Inadequate power generation has led to countrywide power rationing. On average, consumers experience 8–10 hours of power rationing per day, and this is likely to adversely affect the economy at large. To generate realistic policy options aimed at minimizing the impact of power rationing on the economy or minimizing the likelihood of severe power shortages in future, one needs to first understand how power rationing impacts different sectors within the economy, while identifying measures aimed at minimizing the potential impacts in the short- and medium- and long term. There have been a lot of commentaries about power rationing and its impacts on the

[1] The Southern African Power Pool was established in 1990 to provide electricity consumers in member countries with reliable and economical electricity. Membership is restricted to electricity companies that were members of the Southern African Development Community (SADC) in 1994. Countries connected to the electricity grid include the Democratic Republic of Congo, South Africa, Zambia, Mozambique, Lesotho, Botswana, Swaziland, Angola, Zimbabwe, Malawi, Namibia, and Tanzania. Participation by non-SADC countries is subject to approval (http://www.sapp.co.zw/members.html).

[2] Because future GDP growth depends on past GDP, a reduction in current GDP due to power rationing stifles GDP growth.

[3] In February 2016, the Kwacha cost per dollar is two times less than it was in 2014, and inflation rose from 7.7% to 21.8% for the year ending January 2016 (CSO 2016). http://www.boz.zm/(S(ktyyap55m0335j550xj0yn55))/ExRatesHistoricalSeries.aspx

economy, but none of these has attempted to assess its impact on particular consumers of electricity while providing a more forward-looking solution to power shortages. The only existing studies are of little relevance to the current situation (e.g., Sing'andu 2009). This paper fills this knowledge gap through an assessment of the impact of power rationing on the agricultural sector, and the costs to firms in the industry.

In this paper, we focus on Zambia's agricultural sector and how it has been affected by the current electricity shortage and rationing. Agriculture is an important sector in Zambia's economy accounting for 12.6% of the Gross Domestic Product (GDP) and employing two-thirds of the labor force (CSO 2010; Tembo and Sitko 2013). Power supply is an integral input of any economy with potential to catalyze economic growth especially in the lower- and upper-middle income countries.[4] In the agricultural sector, it provides electrical energy for operating various types of equipment used in primary production and agro-processing.

In production, it is especially important among the commercial farmers who use center pivots for irrigation and other electrically powered equipment for crop production. Livestock producers operating automated production systems also depend on power (e.g., in poultry production it is important for lighting and heating, pumping water, and operating automated drinkers and feeders, while in the dairy industry, it is important for operating milking equipment and cooling of milk). In agro-processing, it supplies the much-needed energy to power various processing plants. Agro-processors include animal feed manufacturers, millers, poultry processors, and milk processors. With power rationing, the already high cost of doing business is expected to rise further, and this will have major adverse effects on Zambia's agriculture in particular and the economy as a whole.[5]

From this discussion, one should expect that the effect on agriculture would mainly be through agro-processing and small-scale poultry production. This is mainly because crop production in Zambia is mostly rain-fed with the exception of irrigated commercial farming of winter maize, potatoes, soyabeans, and wheat. Also, power rationing in Zambia commenced after the 2014/15 agricultural growing and harvesting season, implying that smallholders are unlikely to be affected by power rationing.

Using data from qualitative interviews with key industry stakeholders, and historical data about the agricultural sector mainly from the Central Statistical Office (CSO), this study assesses the impact of electricity rationing on Zambia's agricultural sector. We answer four main questions as follows:

i. What is the impact of electricity rationing on agricultural production and productivity?
ii. What is the impact on the country's agro-processing industry and agricultural trade?
iii. What is the potential effect of the power shortage on the whole agricultural sector? and
iv. What should the country do to alleviate the immediate and long-term impacts of load-shedding on the agricultural sector?

The rest of the paper is organized as follows: Section 2 briefly discusses the history of load-shedding in Zambia and efforts to increase generation capacity; Section 3 describes the approach to assessing the impact of load-shedding on Zambia's agricultural sector; and Section 4 discusses the results of the analysis, and the power rationing strategies among firms

[4] Farhani and Ben Rejeb (2015) confirm a long-run Granger causality running from economic growth to energy consumption for low and high income countries and a bidirectional relationship for the lower-middle and upper-middle income countries.

[5] For the year 2016, Zambia Ranks 97th on the ease of doing business in Sub-Saharan Africa (a drop by six places from the 2015 rankings), it ranks 11th in accessing electricity (see http://www.doingbusiness.org/data/exploreeconomies/zambia/).

operating in the agricultural sector. In Section 5, we discuss the obstacles to the development of a reliable electricity sub-sector, and ways in which these can be dealt with. The conclusion and main implications are discussed in Section 6.

2. POWER RATIONING IN ZAMBIA

This section discusses the history of power shortages and rationing in Zambia, and historical efforts to resolve the problem. To do this, we discuss some of the investments in the energy sector since 1998.

2.1. Understanding the Causes of Power Shortages

2.1.1. Shortages

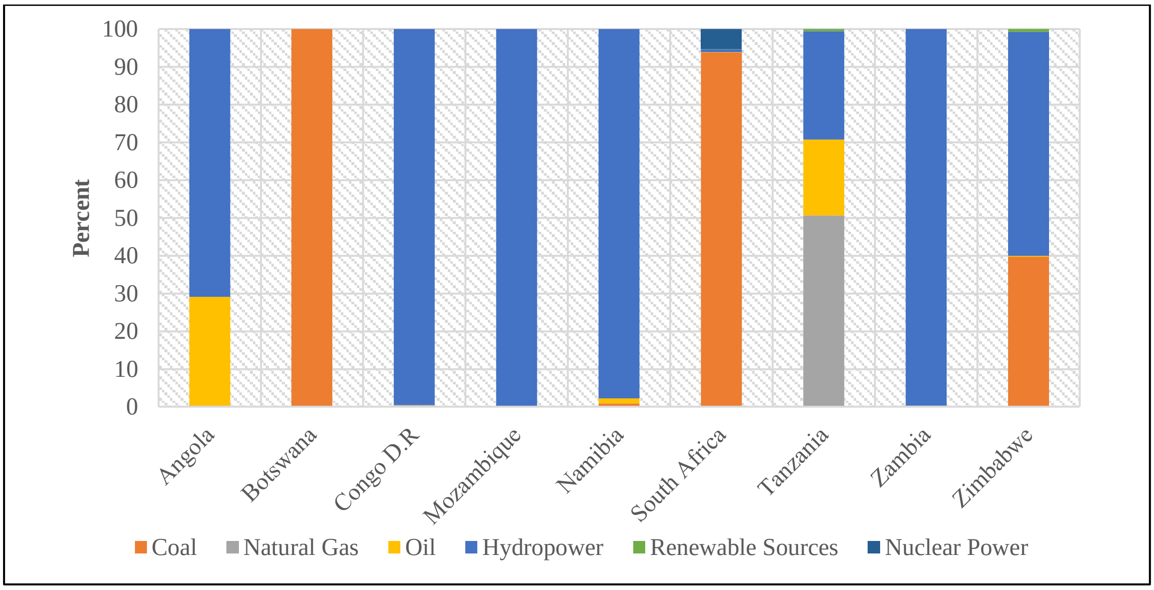
For many developing countries in Sub-Saharan Africa (SSA), electricity generation is hydro-based, with only Botswana, South Africa, Tanzania, and Angola producing significant amounts of power using other sources (Figure 1). As such, power shortages are usually associated with droughts and erratic rainfall patterns. Despite the rapidly growing electricity demand by various consumers, there have been limited investments in expanding electricity generation capacity, with few efforts made to replace the ageing electricity infrastructure (ERB 2014; KPMG 2014). What is also clear is that there is very little diversity in the energy generation mix, with only Angola, Zimbabwe, and Tanzania generating significant amounts of power from other generation sources than hydro.

Severe power shortages in Zambia are not a recent phenomenon; apart from Dr. Kenneth Kaunda's time, all other regimes have experienced sever power shortages. They were experienced in 1992, 2006, and 2007. More recent power shortages were experienced in 2008, 2009, and 2015 (Benson and Clay 1994; Kapika and Eberhard 2013).

For Zambia, a number of reasons have been advanced to explain power shortages over time; they include long-term mismanagement of water supply at the Kariba dam, limited and delayed investments in capacity expansion, and droughts.

One reason explaining the 1991/92 and 2015 power crises is the mismanagement and failure to adjust the offtake from the Kariba dam following changes in rainfall patterns over time.

Figure 1. Sources of Electricity Produced in 2012



Source: http://wdi.worldbank.org/table/3.7

The current offtake by the Zambian and Zimbabwean electricity generating authorities is still based on the more favorable rainfall years of the 1970s, the water offtake for power generation at the Kariba dam has not been adjusted to account for changes in rainfall patterns, making the system vulnerable to droughts (Benson and Clay 1994). More recently, the Kariba North Bank Power Station did not take into account timely advice by the Zambezi river authority to adjust offtake following poor rains, and this is also one contributor to the current crisis (EIZ 2015).

In 2008, power outages resulted from vandalism on the 120 Megawatts (MW) Zambia-Democratic Republic of Congo inter-connector (the only source of imported power at the time; power imports through this line started in 1956), but the effects were mainly on domestic supply. The 1992, 2000, 2006-2009, and 2015, power shortages have been a result of droughts—highlighting the heavy dependency on hydroelectric power whose current generation capacity (2,200 MW) is insufficient to counteract the adverse effects of droughts. Government's position has been that the 2015 power crisis is a direct consequence of low water levels in the Kariba dam following inadequate rainfall during the 2014/15 season (Mwale 2015; and ZESCO 2015).

While the above reasons are all valid, it is only fair to conclude that the main reason for the current and past power crises is related to the delayed investments in major capacity expansions given sharply rising consumption demand, and the failure to diversify the generation mix.[6] Since 1997, the amount of electricity demand for power has outstripped supply, and this is attributed to rapid demand growth from industries, households, and the mines (World Bank 2008; Kapika and Eberhard 2013). Additionally, the problem seems to be compounded by the failure to diversify generation sources amid climate change challenges, which is partly a consequence of the lack of autonomy by the regulatory authority due to political influence, and inefficiencies in ZESCO's operations (IPA 2007).

2.2. The 2015/16 Power Rationing and Schedule

In 2015 rationing of electricity supply by ZESCO Limited started in April following a reduction in generation capacity. This intensified around June 2015, with most areas receiving eight hours of load-shedding per day to manage the 2,100 gigawatt-hours (GWh) power deficit (ZNFU 2015b). ZESCO Limited indicated that without the power rationing, electricity supply would only last for two months from the country's two largest hydroelectric power plants, namely the Kariba North Bank and Kafue Gorge power stations, with capacities of 720 and 990 MW respectively (Kapika and Eberhard 2013).

The power rationing by ZESCO has been implemented through a load-shedding schedule for different locations.[7] These schedules are split by eight divisions across the country, namely Copperbelt, Central, Eastern, Lusaka, Northern, Southern, Livingstone, and Western divisions. The time of load-shedding as stipulated by ZESCO is eight hours in most cases and is rotated among the sub-areas of the divisions. The load-shedding varies according to the division. For example, in the Lusaka division October load-shedding schedule, the industrial area, where most agro-processing companies are situated, was being cut off from power from 4:00 am, the central business district from midnight to 08:00 am, while some commercial farms experience load-shedding from 06:00 am to 12:30 pm. This suggests that some commercial farms had power for irrigation during optimal irrigation periods (i.e., late afternoon).

[6] Electricity demand in Zambia grows at an annual rate of 4% (World Bank 2008; KPMG 2014).
[7] http://www.zesco.co.zm/customerCare/loadSheddingSchedule

Typically, ZESCO allows a 30 minute delay to allow switch-overs, as such restoration of power may only occur after the stated time.

2.3. Efforts to Resolve the Problem

In light of the power shortages experienced since the early 2000s and the growing energy demand, there have been several efforts to resolve the problem in the short, medium, and long term by different administrations. To address the problem of power shortages in the medium- to long-run, government and the private sector have in the past invested in the energy sector to increase electricity generation capacity and improve transmission. More recent investments are either underway or in the planning phase (see Table 1). In addition to investing in generation and distribution projects, the major role of the government has been to facilitate private sector investments, and this is evident from the 8.7% increase in generation capacity between 2013 and 2014. Government has also partnered with the private sector in electricity generation, e.g., for the 120 MW Itezhi-Tezhi Hydro-power project, ZESCO Limited has partnered with Tata Africa holdings of India (ERB 2014).

Table 1. Projects to Increase Generation Capacity

Project	Expected Completion Date	Capacity Addition (MW)
Itezhi-Tezhi Project	2015	120
Rehabilitation and Expansion of the Musonda Falls Power Plant	2015	5
Upgrading of the Lunzua Power Station	2015	14.8
Kalungwishi Project (Lunzua Power Authority)		247
Kabompo Hydro-power Project	-	40
Maamba Thermal Project	2016	300*
Kafue Gorge Lower Hydro-power Project	2018/19	750
Kariba North Bank Expansion Project		80
Shiwang'andu Mini-Hydro Power Station Project.	-	-
EMCO Energy Coal Power project	2017	600
Ndola Energy Company Thermal Power Project	-	60
Batoka Gorge Hydro Power Plant	2022	1,200MW

Sources: ERB 2014; Kambwili 2015; ZESCO, 2015b; Mwale, 2015
Note: * Phase 2 of the project will generate an additional 300 MW.

Most of the investment licenses in the energy sector were issued by the ZDA between 2008 and 2013, perhaps in response to the power shortages experienced in the 2000s. Some projects expected to contribute to the national generation capacity by next year. For example, the 300 Mega Watt (MW) thermal power plant at Maamba Collieries Limited (which is over 80% complete) will soon add to the current capacity—construction of this power plant started in 2010. In addition to the projects listed in Table 1, other efforts include rehabilitation of existing infrastructure, planned investments in 600 MW solar power plants, and the construction of thermal and hydroelectric power plants. It is expected that all power projects will contribute to a total power output of 4,521.8 MW by 2025 (Kambwili 2015).

From 2014, other government investments have been in power transmission and distribution. For example, the connection of Luangwa district and North-Western Province to the National grid, supply to Kalumbila mine, the Kariba North-bank to Kafue West transmission line, and the Itezhi–itezhi Mumbwa Lusaka West 330 kilo-volt (kV) transmission line (ERB 2014).

In the short term (especially for the current crisis), efforts to resolve the problem include the importation of 150 MW from the SAPP inter-connector, importation of 100 MW from Mozambique, rental power of 100 MW from a ship docked at Beira port in Mozambique, and 148 MW emergency rental power from Aggreko (EIZ 2015). Other efforts include daily power rationing, demand side management, and completion of the 300 MW thermal power station in Maamba. The forthcoming rainfall season is unlikely to address fully the power shortage, because by design, it takes more than a year to fill up the reservoirs at the Kariba dam (EIZ 2015). Until then, firms will have to adapt to the situation by acquiring alternative energy sources or modifying shifts among workers.

3. IMPACT OF POWER RATIONING ON THE AGRICULTURAL SECTOR

This section discusses the approach to assessing the impact of power rationing on the agricultural sector. This is done for two levels of impact, namely, the impact on industries within agriculture, and the impact on the economy and the agricultural sector.

3.1 Approach to Estimating the Economic Impact of Power Rationing

There are several approaches to estimating the impact of power rationing on the economy or individual sectors within the economy, with all approaches yielding an estimate of a cost of unserved energy (see Bose et al. 2006; Kaseke 2011; Amadi and Okafor 2015; and Hofmann et al. 2010 for summaries). The methods readily identifiable in the literature include:

i. Computable General Equilibrium (CGE);
ii. Input-output analysis;
iii. Production function ;
iv. Contingent valuation;
v. Production loss; and
vi. Captive generation.

To ascertain the impact of power rationing on industries within the agricultural sector, it is necessary to collect data on the costs associated with production losses and captive generation. This can be done through surveys, or by using a contingent valuation approach where firms are asked to provide estimates of how much compensation they would be willing to accept for a given period without power, or how much they are willing to pay to avoid a power outage. The production function approach achieves the same objective by providing estimates of the input cost effect and the output loss from switching to alternative power sources. This is usually done using panel data from firms on inputs and outputs (e.g., see Hunt, Collard-Wexler, and O'Connell 2014).

The main advantage of the production loss and captive generation approaches is that they provide accurate estimates of the costs to firms. It is disadvantageous because it is costly and time consuming to implement if the results are to be representative (Amadi and Okafor 2015; Kufeoglu and Lehtonen 2015). The production loss approach is disadvantageous in that it tends to overstate the costs to firms as it attributes all production losses to power outages (Bose et al. 2006).

The contingent valuation approach is disadvantageous in that it has been shown to yield lower estimates of the costs, mainly because respondents may fear that the reported values may be used in raising electricity tariffs (Eto et al. 2001). The production function approach requires detailed data on individual firms that may not be easy to collect.

For this paper, a combination of the production loss approach (direct costs) and the captive generation approach (indirect costs) is used to identify the cost impacts to firms. A summary of the direct and indirect costs considered is presented in Table 2. Costs are estimated for poultry firms, millers, commercial farmers of wheat and Irish potatoes, and animal feed manufacturers. Wheat and Irish potato farmers are chosen because these are commercially grown under irrigation using center pivots or other equipment.

Table 2. Variables for Estimating the Cost to Firms Operating in the Agricultural Sector

Direct Costs	
Poultry Firms (Layer and Broiler producers, and integrated firms)	• Average number of hours of load-shedding experienced per day • Value of lost output due to load-shedding • Overtime paid to staff due to power outages • Number of workers laid off due to power outages • Costs from equipment damage, restarts, and emergencies • Wages paid to idle labor (in Kwacha) • Mortality due to load-shedding
Wheat Farmers	• Average number of hours of load-shedding experienced per day • Value of lost output due to load-shedding (from lost output or reduced water availability) • Overtime paid to staff due to outages • Number of workers laid off due to power outages • Costs from equipment damage, restarts, and emergencies • Wages paid to idle labor
Millers, Milk Processors, and Animal Feed Manufacturers	• Average number of hours of load-shedding experienced per day • Lost output due to load-shedding (Value or tonnage) • Overtime paid to staff due to outages • Number of workers laid off due to power outages • Costs incurred from equipment damage, restarts, and emergencies • Wages paid to idle labor
Indirect Costs	

All firm categories	1. Cost of acquiring and installing alternative power sources:
	  • Generators
	  • Invertors
	  • Own power plants
	  • Solar panels
	  • Other power source (e.g., charcoal, gas, firewood)
	2. Costs of running alternative power sources
	  • Fuel
	  • Oil
	  • Maintenance costs
	  • Labor
	  • Spare parts
	  • Other costs not listed

Source: Authors.

To assess the impact of power rationing on the agricultural sector, a number of methods can be used. These include nationwide surveys on costs to all consumers within the agricultural sector, input-output analysis, and the CGE approach. CGE modelling requires detailed economy-wide data from a Social Accounting Matrix. The surveys would require adequate funds and time for analysis. In light of the data, funding, and time needs of the three approaches alluded to, we opt to indirectly assess the impact on the economy and agricultural sector using secondary data from the Zambia Central Statistical Office (CSO) on the cost of unserved energy (COUE), economic growth, and agricultural gross domestic product.

For the approach used in this study, the effect is likely to be over-estimated and should only be treated as a rough estimate. This is because estimation does not take into account the power rationing coping strategies among firms. However, it seems reasonable to assume that the over-estimation makes up for some of the non-monetary costs incurred and not accounted for in the estimates (e.g., leisure, worker safety, etc.). It is advantageous in that it uses readily available data making the assessment easy and quick without requiring a lot of resources (Kufeoglu and Lehtonen 2015).

4. STUDY FINDINGS

This section discusses the study's main finding. We first discuss the power rationing strategies being used by consumers of electricity in agriculture; this is followed by discussions on the costs to firms operating in the agricultural sector. Lastly, we discuss the impact of power rationing on the agricultural sector as a whole.

4.1. Power Rationing Coping Strategies

To mitigate the effects of power rationing on businesses within agriculture, a number of strategies have been employed. For example, commercial farmers and firms operating in agriculture have resorted to using their own generators to ensure continuous electricity supply as a mitigation measure—an expensive and unsustainable solution in the medium- to long-term. Generators also require some technical expertise as well as reliable supplies of fuel and spare parts. Furthermore, the use of generators for irrigation is not even an option for small-scale farmers because they cannot afford it. Mostly, generators are used for livestock and poultry production because these have processes that cannot stop even with power cuts, e.g., drinkers and feeders have to operate all the time. Moreover, power generated from generators is not adequate for irrigating large areas of crop land. The use of sustained use of fossil-fuel powered generators is an unwelcome act among climate change enthusiasts as they contribute to greenhouse gas emissions. Therefore, while generators are an alternative source of energy for agricultural producers, their use is costly and limited to a few firms that can afford them.

A second coping strategy involves shifting working hours for farm or factory workers especially where they have to operate equipment requiring ZESCO-supplied electrical energy with no other alternatives power sources. The working hours are scheduled in such a way that they coincide with the availability of power from the ZESCO grid. However, there are worker safety concerns with this practice, especially for employees working at night.

Thirdly, as coping measure to load-shedding, some agro-processors, and commercial farmers interviewed indicated that they have been forced to cut down labor, but the prevalence of this is especially true in commercial farms. Moreover, the laid-off workers are mainly temporary, and almost negligible.

4.2. Effect on Commercial Farmers of Irrigated Wheat and Irish Potatoes

From interviews with some commercial farmers, we assessed the impact of power rationing on crop production under irrigation. What is clear from this is that with power shortages the water supplied to irrigated crops was reduced, particularly if they were irrigated using center pivots and other irrigation equipment dependent on electricity. For example, farmers indicated that with power rationing, the net irrigation water that is likely to be achieved this year would be around 250-450 millimeter (mm) for wheat—about half the required amount. This means that wheat farmers will lose about 1–2 tons per hectare (Ha) of wheat.[8] The same scale of yield loses is also expected for soyabeans, and Irish potatoes.

To assess the impact on irrigated crops planted after the 2014/15 rain season, the costs to commercial farmers of wheat and Irish potatoes are estimated. Interviews with some commercial farmers of wheat and Irish potatoes reveal that power rationing may have caused

[8] Interview with Mr. Fred Nandala (Arable and Human Resource Manager) of Wanga Farms on 16th August, 2015.

Table 3. Costs to Commercial Farmers of Wheat and Irish Potatoes

	Direct Costs (ZMW)	Indirect Costs (ZMW)
Production loss	2,592,000	
Idle labor	36,750	
Maintenance on generators		30,000
Diesel		2,580 per day

Source: Authors.

reductions in producer surplus. For example, a farm planting 550 hectares of wheat lost one ton for each hectare of wheat planted. This translates to a $240,000 or ZMW 2,592,000 loss. The Central Statistical Office (CSO) and Ministry of Agriculture and Livestock (MAL) estimate wheat availability at 270,770 metric tons in 2015/16 marketing season—this is against a demand of 335,000 metric tons. With a Crop Forecast Survey estimate of 31,137 hectares of land under wheat, this means that the country would need to import 95,367 metric tons of wheat—a deficit higher than CSO's initial estimate of 64,230.

Other costs incurred include three hours of idle labor at ZMW 350 per hour, which translates to a total of ZMW 36,750 for 35 employees per working day. For potatoes, because they need additional processing, costs include ZMW 30,000 on maintenance for generators and burnt motors for the processing facility, and 300 liters of diesel per day, which is equivalent to ZMW 2,580 per day (Table 3). For the interviewed commercial farmer of wheat and Irish potatoes, production costs have risen by about 4%; however, the price of potatoes has not risen to compensate for this cost increase, implying that only profits are adversely affected.

Some farmers in Chisamba district were reported to have completely abandoned their wheat crop, meaning they have would incurred 100% revenue loss for the abandoned fields. In the medium-long term, such losses have several financial consequences, especially for farmers that have outstanding loans to payback and their ability to invest in agriculture.

Except for potatoes, whose price has remained constant due to the Kwacha's devaluation, it is expected that costs incurred by firms will be passed on to consumers through price hikes. Wheat supply is likely to contract, given the one ton decrease in output for each hectare planted.

4.3. Effect on the Milling Industry

To get a sense of the impact of power rationing on the millers, we interviewed feed and wheat flour millers. We find that for a feed firm with a capacity of 47,000 tons per month, 30% of the animal feed produced per month would be produced at a high cost due to captive power generation expense; this is then passed on to consumers in the form of price hikes. In fact, Novatek Animal Feeds has had to increase the price of animal feed by 5% to reflect extra costs resulting from load-shedding, inflation, depreciation of the Kwacha, and wheat/maize bran shortage (ZNFU 2015b). For the animal feed firm interviewed, the costs of acquiring and operating captive generators was estimated at $366,713 for two generators with a capacity of 833 kWh. This translates to ZMW 3,757,478,887.85 at an exchange rate of ZMW10.8 per dollar (Table 4). The two generators require 170 liters of diesel per hour, implying that total fuel costs amount to ZMW 300,000 per month (at 8 hours of load-shedding).

Table 4. Costs to Animal Feed Firms

	Indirect Costs (ZMW)
Generators	3,757,478,887.85
Diesel	300,000 per month

Source: Authors.

Table 5. Costs to Flour Millers

	Direct Costs (ZMW)	Indirect Costs (ZMW)
Production loss	618,000 per week	
Generators		5,400,000
Diesel		239,400 per month

Source: Authors.

For a wheat flour mill with a capacity of 9.5 tons per hour, power rationing has increased costs of production, and this has been passed on to consumers through price hikes. Costs incurred include diesel costs at ZMW 239,400 per month, 2 by 1,400 kilo-volt-ampere (kVA) generators valued at $500,000 (or ZMW 5,400,000) (Table 5). Production losses related to start-up of the machinery are estimated at 100 tons of flour per week (with 8-10 hours of lost time due to machinery start-ups).This translates to ZMW 618,000 per week at an average price of ZMW 309 per 50 kilogram (Kg) bag.

4.4. Effect on the Dairy Industry

For commercial dairy farmers, the effect of load-shedding is two-fold; first it works indirectly through key intermediate inputs such as animal feed, and directly through the effect on additional costs for pumping water, cooling milk, and milking cows as firms acquire and operate back-up power sources. A lack of feed or water (resulting from load-shedding) also causes cows to lose potential on their peak production (i.e., during early lactation). This causes them to continue on a downward trend in milk production, further reducing milk output (ZNFU 2015b).

To get a sense of power rationing's effect on the dairy industry, we interviewed an integrated dairy farm operating at a processing capacity of 10,500 liters of milk per day. The interview revealed that a combination of power rationing, currency devaluation, and inflation has increased operational costs for the dairy firm by about 30%. Mainly because cows have to be milked twice a day, with no possibility of altering shifts as is the case in crop production. Costs incurred involve the acquisition of a 5,000 kVA generator at £15,000 or ZMW 241,129 at an exchange rate of ZMW 16.08 per £(excludes shipping and duty), maintenance costs for the generator amounting to ZMW 3,000, and ZMW 25,000 of diesel per week (Table 6). Unlike in milling, the increased production costs have not been passed on to consumers as milk prices have remained constant; such producer profitability has been eroded with firms barely breaking even. Firm strategy given the current situation is to at least break even by altering feed formulations with hope that the situation will normalize soon enough.

Table 6. Costs to Dairy Firms

	Direct Costs (ZMW)	Indirect Costs (ZMW)
Production loss	618,000 per week	
Generators (Capital cost)		241,129.5
Diesel		25,000 per week

Source: Authors.

There are other effects readily identifiable in the literature. For example, through its effect on storage of fresh milk among the small- to medium dairy farmers, power rationing has reduced the amount of milk available at milk collection centers (MCCs) and ultimately to the large processors (ZNFU 2015a). In Monze, a milk cooperative experienced equipment damage, this caused losses amounting to ZMW 27,000 (Lusaka Voice 2015). There have been complaints by operators at the MCC's through the Zambia National Farmers Union (ZNFU) that ZESCO was not adhering to the load-shedding schedule, with load-shedding going beyond the stipulated 8 hours per day; this is perhaps a direct consequence of the 30 minutes delay due to switch-overs as stated by ZESCO. This complaint was also found during our interviews with other firms in the agricultural sector. Moreover, the quality of ZESCO's electricity was also a cause of concern among dairy firms, with the voltage fluctuating and causing equipment damage. In the past, this has forced firms to acquire and install stabilizing units.

In summary, the effect on large firms/processors operating in the dairy industry is expected to work through additional costs. The small dairy farmers appear to have reduced milk production and subsequent supply to MCCs. This is likely to reduce the processing capacity among the large processors who have the ability to acquire and operate generators, with a possibility of reducing their competitiveness.

4.5. Effect on the Poultry Industry

One of the rapidly growing industries within the livestock sub-sector is poultry. In 2014, the Poultry Association of Zambia (PAZ) estimated annual broiler and layer production at 372,285,812.16 tons and 1,005,910,434 tons respectively.[9] With power shortages and rationing, small-scale poultry growers are likely to be the most affected, as they cannot afford the available alternative sources of power such as generators. Effects in this industry are expected to work through rising input costs (e.g., feed and day-old chicks), as well as the direct and indirect costs mentioned earlier. For example, day-old chick prices increased from about ZMW 4.6 to about ZMW 5.45 per bird between June and November 2015.[10]

We find that for an integrated broiler production system with production and processing capacities of 20,000 and 1,000 birds per week respectively, additional costs incurred are for operating alternative power sources, with costs rising by 15% due to power rationing, currency devaluation, and inflation. These include monthly maintenance costs of ZMW 1,500 for generators, and fuel costs amounting to ZMW 1,000 per day (Table 7).

[9] 65% of the broiler market is dominated by small-scale producers while the 80% of the table eggs are produced by commercial farmers.
[10] http://paoz.org/sites/all/downloads/Poultry%20news%20number%2072-%2011th%20December%202015.pdf

Table 7. Costs to an Integrated Broiler Firm

	Indirect Costs (ZMW)
Diesel	1,000 per day
Maintenance (Generator)	1,500 per month

Source: Authors.

The interviewed firm already had a generator installed, and as such, no costs were incurred in acquisition of generators. There is no production loss resulting from load-shedding as the standby generators automatically kick-in whenever load-shedding occurs.

In other cases, poultry producers who cannot afford generators have had to incur additional costs of feed because it now takes longer for the chickens to reach market weight. Feed conversion ratio (FCR) of the birds is negatively affected by the long hours of darkness as a result of load-shedding. Meanwhile, efficient conversion of feed into live weight is important for profitability, and small changes in FCR can have a substantial impact on financial margins (Ross 2011). For example a farmer with 20,000 birds who used to buy 1,200 x 50 kg bags of feed for the chickens to reach market weight, now has to buy 70 additional bags for birds to reach the same market weight. In terms of the additional cost for the 20,000 birds, the farmer has to spend ZMW 14,350 for the 70 additional bags (ZMW 205/bag). This results in an increase in the cost of production, which consequently reduces profits for the farmer because the average price of broilers has remained static at ZMW 34.96. The Poultry Association of Zambia indicated that prices might be revised upwards if the negative impact of load-shedding on the industry continues (The Poultry Site 2015).

One other poultry sub-sector affected by load-shedding is the production of eggs. Adequate lighting is a key factor in egg production for layers because the process is stimulated by the presence of light, hence, increased hours of exposure to light increases egg production. Additionally, electricity is also essential for operating automated feeders and drinkers, temperature regulation, waste removal, and egg collection. In view of this, layer farmers require artificial lighting to increase egg output. Extended lighting of 2-3 hours is expected to increase egg production by 20 to 30% (FAO website 2015). Some poultry farmers interviewed reported losses in egg production of up to 25% due to the reduction of hours of lighting resulting from the current load-shedding. For example a farmer who grows 10,000 birds had a reduction in egg production from 80 trays to 60 trays per day, this translates to a loss of ZMW 500 (at a price of ZMW 25/tray) per day.

We also interviewed a layer farm with a capacity of 80,000 laying birds to assess the costs of power rationing on the business. The firm experiences power cuts for 6-14 hours every day, implying that it has no power for almost half of the normal working hours. As such, additional costs amounting to ZMW 30,000 per month are being incurred, and these are mainly associated with the operation of generators during the 6-14 hours of load-shedding experienced. There are no costs resulting from output losses recorded for the layer firms. They already had back-up generators installed at the farm given the importance of pumping water, heating and lighting in layer production. ZNFU (2015b) reported a layer farm with a capacity of 75,000 layers losing output by as much 300-400 trays of eggs per day.

For firms specializing in day-old chick production (i.e., hatcheries), load-shedding has created difficulties in planning production. This may lead to a reduction in day-old chick supplies in the next 1-3 years, as planning on how many day-old chicks to produce requires about 6-9 months, and because smallholders may decide not to produce chickens (due to load-shedding), firms become cautious in their production decisions. This uncertainty creates a ripple effect even in other poultry-allied industries (e.g., animal feed, animal health, equipment, etc.)

Thus in summary, the effect on the layer farmers is expected to be through reduced output and additional costs associated with the acquisition and operation of generators. Other effects are likely to result from the rising feed costs (a ripple effect resulting from high costs of feed manufacturing). For the small-scale broiler producers, enterprise profitability is likely to reduce given that animal feed prices have risen more than the price of birds can compensate for. Moreover, because the feed conversion ratio is negatively affected by the reduced lighting, the feed costs are higher than normal as it takes more time to grow birds to market weights. For the large-scale producers/processors of broilers, costs due to output losses are unlikely as most of them will acquire generators, while benefiting from economies of scale. Costs among these are mainly from acquisition and operation of back-up power sources. Production planning in hatcheries is likely to be adversely affected, and this will have an effect on the growth of the poultry industry in the near future.

4.6. The Effect on Agricultural Trade

The effect on agricultural trade is likely to be through reduced competitiveness of exports. This is likely to be true for table eggs, flowers, fruits, vegetables, and dairy and poultry products, as well as beef. Other small-scale farmers and traders who cannot afford back-up sources of power have completely stopped marketing perishable agricultural commodities.

With reduced milk production among small-scale producers, the supply of fresh milk is expected to reduce. As reported by the Zambia Weekly (2015), Kabayi Farms Limited in Kabwe incurred losses worth $1.15 million due to a two-day power outage, and as a result the farm is now in debt with its funder.

Through reduced trade, the tax revenue collection by the Zambia Revenue Authority is also likely to reduce—a situation that will ultimately lead to lower than expected economic growth.

4.7. Firm Size and Magnitude of Impact

The magnitude of the impact of power rationing on a firm is dependent on the size of the firm. This arises from the fact that they firm size impacts on a firm’s ability to respond to any such shocks. Moreover, it may not make economic sense for some firms to invest in mitigation measures such as acquisition of back-up generators. ZIPAR (2015) indicated that medium-sized firms experienced the highest losses from power rationing (i.e., 11% of annual sales), while the small and large firms experienced losses of about 6% of annual sales.

4.8. Effects on the Overall Agricultural Sector

Load-shedding results in lost economic opportunities in productive sectors like agriculture and the cost of this opportunity loss is estimated in terms of metrics such as Cost of Unserved Energy (COUE). The COUE is the value (expressed in Kwacha per kWh) that is placed on a unit of energy not supplied due to disrupted power supply. The COUE is obtained by dividing the country’s GDP by the total electricity consumption. In the agriculture sector the COUE by the production loss method is estimated based on the incremental output not realized (opportunity lost) due to non-availability of power (TERI 2001). For 2014, the estimated value was ZMW 1.38/kWh for the agricultural sector while for all sectors was at ZMW 15.53/kWh (Table 8). This implies that the agricultural sector is paying an implicit price of ZMW 1.38 per unit of electricity.

Using an average electricity consumption growth rate of 4% per annum (World Bank 2008; KPMG 2014), we estimate electricity consumption in 2015 at 11,149,320,000 kWh. Using a GDP growth rate of 3.6% in 2015 (Times of Zambia 2016), the COUE in 2015 translates to ZMW 15.47/kWh. With an electricity shortfall of 2,100,000,000 kWh, the value of lost opportunity for all sectors would be ZMW 32,496,100,813 in 2015 (i.e., 18.8% of the GDP). For the agricultural sector, assuming an 8.7% contribution to GDP in 2015, the estimated cost of the power shortfall in 2015 translates to ZMW 2,827,160,771 (1.6% of the GDP).

Table 8. Cost of Unserved Energy (COUE) in ZMW per Kilowatt Hour (2012 – 2014)

Year	Total Electricity Consumption (kWh)	Zambia GDP (ZMW)	COUE: ZMW/ kWh	COUE: ZMW/kWh (% of Agric. GDP)	Value of lost opportunity in the economy (ZMW)	Value of lost opportunity in agriculture (ZMW)
2012	10,317,400,000	128,370,131,107	12.44	1.21		
2013	10,845,700,000	144,722,388,550	13.34	1.21		
2014	10,720,500,000	166,533,106,598	15.53	1.38		
2015	11,149,320,000	172,361,765,329	15.47	1.35	32,496,100,813	2,827,160,771

Source: Central Statistical Office 2016.

5. TOWARDS A MORE RELIABLE POWER SUB-SECTOR

In this section, we identify steps that are essential to ensure power supply security in the long-run. This is done through the identification of the main impediments toward private sector investment in the electricity sub-sector. This is important given the limited public resources and the private sector's ability to invest in profitable projects. To achieve this, we review key documents such as the National Energy Policy, draft renewable energy feed-in tariff (REFIT) policy, and the 2007 ZESCO cost of service study.

5.1. State of Affairs

5.1.1. The Policy and Regulatory Framework

The National Energy Policy (NEP) of 2008 lays an important foundation for the development of a reliable power sub-sector. Through its vision 2030, the NEP is committed to securing electricity supply to all consumers through increases in generation and transmission capacity. Additionally, it highlights the need to promote private sector investment in the sub-sector through cost-reflective tariffs. For a reliable electricity sub-sector, the policy paves way for energy diversification by highlighting the importance of other power generation sources such as coal, natural gas, wind, solar, and geothermal energy.

The NEP is also committed to promoting investment in the sub-sector by continuously reviewing and enacting relevant legislation. Acts of parliament that are relevant to the power sub-sector include:

- The Constitution;
- The Electricity Act;
- The Energy Regulation Act;
- The Rural Electrification Act;
- The Environmental Protection Act;
- The Zambezi River Authority Act; and
- The ZDA Act of 2006.

Among the above listed Acts, the ZDA Act of 2006 is of particular interest as far as private sector investment is concerned. It outlines a number of fiscal and non-fiscal incentives for investors wishing to invest in the electricity sub-sector. These include investment guarantees, protection against nationalization, duty exemptions on imported capital equipment, tax breaks, free facilitation for application of immigration permits, secondary licenses, land acquisition, and utilities (ZDA 2014).

However, despite the NEP setting a foundation for ensuring energy supply security, there is a lack of clear regulations, guidelines, and rules to operationalize private sector involvement in the electricity sub-sector. In addition, it does not aid the private sector in securing funds for investment from lenders through clear and standardized power-purchase agreements (USAID 2014).

Nevertheless, there have been efforts towards operationalizing private sector investments in the electricity sub-sector via the introduction of cost-reflective tariffs and formulation of REFIT policy. In 2015, the Energy Regulation Board (ERB) introduced new electricity tariffs to reflect costs. However, this was an unwelcome move especially among the domestic consumers. This prompted the President to issue a directive for the old tariffs to be re-instated, and instead introduce the new tariffs gradually.

Zambia is in the process of drafting and implementing a REFIT policy to further allow private sector investment (including households, and firms) into power generation and supply to the national grid at an agreed price. Having a REFIT policy is one step towards allowing for renewable energy feed-ins by independent producers.

5.1.2. Electricity Generation Potential from Various Sources

Currently, Zambia's electricity is almost entirely hydro-based. However, the hydropower potential is underexploited, with only 29.3% of the country's potential currently in use. As the north and northwestern areas of the country usually receive high annual rainfall, they have been identified as strategic for construction of small power plants in an effort to spread hydrological risk amid climate variability. In the same vein, there is potential to generate electricity using other sources such as wind, geothermal, coal, and solar. The solar potential is estimated at 5.5 kWh/m2/day, while average wind speeds of 2.5 m/s make them highly suitable for irrigation purposes. Actual coal deposits are unquantified but estimated at several hundred million tons, while there are about 80 hot springs for geothermal power generation (GRZ 2008).

5.2. Obstacles to the Development of a Reliable Energy Sub-Sector

From section 5.1., we can see that there is a lot of untapped potential related to power generation, and this is somewhat backed up by a National Energy Policy that is committed to ensuring private sector participation in the power sub-sector. How then do we increase energy security by promoting private sector investments? Such a process requires identification of the main obstacles to any such investments. From the literature, the following barriers are readily identifiable:

i. The temporary suspension of the cost reflective tariffs will negatively impact on investment decisions if not enacted soon enough. Enactment will largely depend on government will and commitment towards the SADC agreement to reach cost-reflective tariffs by 2019.[11] Zambia's electricity tariffs are currently half the regional average (SADC 2015).
ii. Existing bulk power supply agreements with the mines mean that it will take time for cost-reflective tariffs to yield the intended effects, considering that mines are the major consumers of electricity in Zambia (Adamu 2015).
iii. The lack of a REFIT-policy and associated technologies to encourage private sector generation and supply of power to the ZESCO grid.
iv. Lack of clear and government-backed power purchase agreements (PPAs) which are crucial in aiding independent power producers to access finances for investments in power generation and/or transmission. In South Africa, early efforts to procure power from independent producers failed because of the lack of political support (Montmasson-Clair and Ryan 2014). Power purchase agreements in Zambia are usually between ZESCO Limited and the private sector, with the Energy Regulation Board as the regulator. There are records of PPA's between ZESCO and Itezhi-tezhi Power Corporation, Ndola Energy Company (NEC), and Maamba Collieries Limited[12], but the government plays no part in these.
v. Inefficiencies in ZESCO's operations that contribute to the unavailability of funds for maintenance and upgrades of the ageing infrastructure. The major sources of

[11] So far only Namibia and Tanzania have cost-reflective tariffs in place within Sub-Saharan Africa (SADC 2015).
[12] See http://www.erb.org.zm/content.php?viewpage=stmt

inefficiency are a high share of unmetered customers (about 1/3rd), underpriced mining loads, and rising staff costs per megawatt hour of supplied electricity (USAID 2014). Because ZESCO is inefficient, it remains to be seen how they will successfully implement the REFIT policy.

5.3. Enhancing Electricity-supply Security

A more reliable electricity sub-sector first and foremost will require increased and sustained private sector participation in the sub-sector, coupled with strong government commitment in the sector. Therefore, an electricity secure Zambia will require:

1. Private sector investments and these will be dependent on:
    a. A gradually introduced cost-reflective tariff system. For this to work, existing bulk power supply agreements need to be revised to allow for adjustments (Adamu 2015). No private entity will engage in electricity generation unless it makes economic sense.
    b. Identification of a suitable Independent Producer Power Procurement Programme. This should be backed up by clear processes and documentation for power procurement and contracting. This was key in the implementation of South Africa's Independent Producer Power Procurement programme (Eberhard and Kolker 2014).
    c. Increased access to finance for the private sector via government backed power-purchase agreements. Access to finance will also depend on the profitability of proposed investment. Smaller power projects are likely to yield positive risk-adjusted returns as compared to large hydropower projects (see Ansar et al. 2014).
    d. A comprehensive REFIT policy that is well implemented and backed-up by up to date technologies.
    e. Strong government commitment towards implementing the National Energy Policy and other associated policies. In particular, the executive branch of government will play an important role given the powers it has over decisions made by the ERB and ZESCO. Very recent experience has shown policy inconsistencies, for instance in February 2015, government approved a 24 month freeze on domestic electricity tariffs for all domestic consumers, by the last quarter, ZESCO implemented new cost reflective tariffs on all consumers, only to be reversed by executive orders (Adamu 2015).
2. Implementation of the National Energy Policy and its vision 2030 in a way that increases exploitation of the hydropower potential while keeping in mind the need to spread hydrological risk. Investments in the high drought-risk Southern parts of the country should not come at the expense of highly potent sights in the northern and northwestern parts of the country. This is key for long-term energy security in light of climate variability. Other electricity generation sources will also play an important role in reducing the load on the ZESCO grid—wind and solar technologies will be key in this respect, especially for irrigation on commercial farms, and for feeding excess power into the ZESCO grid. Diversification into thermal and geothermal power will also be vitally important.
3. From ZESCO's side, a reliable power sub-sector will require increased efficiencies, which will contribute to regular maintenance and upgrades to infrastructure.

6. CONCLUSIONS AND RECOMMENDATIONS

The purpose of this paper was to (i) assess the impact of power rationing on the agricultural sector in Zambia and (ii) identify obstacles to the development of a reliable electricity sub-sector, and ways in which these can be dealt with.

Our findings reveal that on average, firms operating in agriculture experience 8-12 hours of power rationing, with power in some cases restored an hour beyond the stipulated time. For the whole economy, the effect of the power shortfall is estimated at ZMW 32,496,100,813, which represents 18.8% of the 2015 GDP. This means that the power shortfall is likely to induce losses amounting to ZMW 2,824,431,851 in the agricultural sector, representing 1.6% of the GDP.

On specific industries within agriculture, the following effects are readily identifiable:

- Production costs have increased, as firms acquire and operate alternative power sources, while fixing damaged equipment. The increase in production costs is estimated at 30% for dairy farmers, 4% for commercial wheat and Irish potato farmers, and 15% for an integrated broiler farm.
- In some cases, temporary labor has been laid off, but the number of laid off workers is most likely negligible.
- Production losses among the major processing firms are almost inexistent as most of them have acquired alternative power sources. The same applies for the large producers of broilers and layers. However, future growth of the poultry industry is likely to be adversely affected.
- In irrigated crop production, some production losses are identifiable, with wheat farmers losing a ton of wheat for each hectare planted.
- Producers of potatoes and milk are likely to experience significant reductions in margins given that the price of milk has not risen to buffer against the high production costs.

In combination, these factors are likely to induce reductions in general welfare among producers and consumers of agricultural produce.

To increase energy supply security, Zambia needs to exploit its hydropower potential, especially in areas least affected by climate variability. There is also need to diversify the energy generation mix by investing in solar, geothermal, thermal, and wind energy in such a way that it is reliable, sustainable, and affordable. Because the private sector will have an important role to play, there is need to increase their access to capital finance through issuance of government-backed power-purchase agreements. However, compared to investments in large-scale hydropower plants, investments that can be implemented over a shorter time frame are more likely to be more profitable and, hence, attract financing. Other key factors include: clear power procurement processes, strong government commitment towards implementation of energy policies, and the associated legal and regulatory framework. For ZESCO, there will be a need to address the inefficiencies in its operations in order to make finances available for investment and regular maintenance.

STUDY LIMITATIONS

While this study provides a rough estimate of the likely impact on the agricultural sector as a whole, the impact on individual sub-sectors is mainly illustrative. A nation-wide survey would be required to give a holistic picture on how different firms have been impacted by power rationing. This is important especially because firms in different locations are subject to different power rationing schedules, and because the effect is likely to differ with and without alternative power sources, and by scale of production. As such, all results presented in this paper should be interpreted with this caveat in mind.

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