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# How households adapted their energy use during the Zambian energy crisis

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ABSTRACT

The recent Zambian energy crisis began in June 2015 when ZESCO, a parastatal electric utility, implemented country-wide load-shedding (an intentional disruption of power) nominally lasting 8 h per day. The cause of the energy crisis is a confluence of several factors: infrastructure under-investment, over-reliance on and mismanagement of hydro-power generation resources, rapidly growing demand, and reduced reservoir inflow from lower than average rainfall. This research investigates how Zambian households adapted their energy consumption to cope with load-shedding. The research is based on the responses from 261 oral surveys conducted in four provinces. The results show that fuel-switching, load-shifting and conservation strategies were widely employed, but generally differed across socio-economic dimensions. These strategies in turn affected the net economic expenditure on energy and total energy consumed by each household. An estimation of the economic impact showed an increase in fuel-related expenditure and energy consumption of nearly 50%, largely attributed to fuel-switching to charcoal and generator sets.


## Introduction

Access to electricity is frequently part of the national discourse in Zambia, where just 22% of the population are connected to the electrical grid (International Energy Agency and the World Bank, 2015). Zambia, like many others of the so-called "least developed countries", has struggled to maintain adequate generation capacity to meet its indigenous demand (Business Monitor International Ltd., 2015; Energy Regulation Board of Zambia, 2016). In June 2015, a load-shedding program was implemented in an attempt to ration the dwindling water in the Lake Kariba reservoir, the site of Zambia's highest-capacity power station (Energy Regulation Board of Zambia, 2016; Engineering Institute of Zambia, 2015).

Load-shedding is the deliberate interruption of electricity supply to all or a subset of consumers according to a pre-defined duration and schedule. Load-shedding programs are often implemented as a precaution to prevent a complete system-wide blackout or to ration limited energy (International Energy Agency, 2005). Typically, load-shedding is implemented on a rotating and non-overlapping basis, so that at any given time, a portion of the consumers will have access to grid electricity, and others will not. In Zambia, the disconnection is manual and performed at the substation level, so that at any given time, only a subset of the distribution feeders are energized.

Numerous developing and developed countries have experienced load-shedding (Heffner, Mauer, Sakar, & Wang, 2010; International Energy Agency, 2005). Presently, at least 270 million people live in countries with widespread, chronic and severe load-shedding. In 2017, this list includes regions of India (Central Energy Authority, 2016), Ghana (Asmah, Myrzik, & Ahunu, 2015), Malawi (Electricity Supply Corporation of Malawi, Ltd., 2017), Nepal (Nepal Electricity Authority, 2016), Pakistan (Kessides, 2013), Venezuela (Miroff, 2016), Zambia (Energy Regulation Board of Zambia, 2016; Engineering Institute of Zambia, 2015) and others.

When load-shedding occurs in developing countries, it is often at least partially due to under-investment in electricity infrastructure, including power plants. Rapid population growth and growing economic activities exacerbate the problem (Heffner et al., 2010). In Zambia, a growing population base and expanding economy, primarily driven by the energy-hungry copper mines (Business Monitor International Ltd., 2015), have increased electricity demand by 3.3% per year. Additionally, failure to diversify the generation

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resource mix has led to energy shortages. For example, Ghana's present energy crisis is ostensibly due to interruption in the natural gas and oil supply, which 45% of their power plants rely on (Asmah et al., 2015). Venezuela, like Zambia, is dominated by hydro power. Low seasonal rainfall or mismanagement of the hydro system can drastically reduce the available energy, causing a shortage.

The load-shedding program in Zambia was the longest-lasting and most severe the country has experienced. The program began in June 2015 and ended in March 2017. The supply disruptions nominally lasted 8 h per day, rotating between one of three schedules on a monthly basis. Despite the prevalence of the use of load-shedding as a tool to manage an energy shortage, it is generally accepted that it should be a tool of last resort (Energy Sector Management Assistance Program, 2005; Heffner et al., 2010; International Energy Agency, 2005; Kessides, 2013). More efficacious methods include demand-side and/or market-based programs (Camargo, Oliveira, & Figueiredo, 2002; Energy Sector Management Assistance Program, 2005; Heffner et al., 2010; International Energy Agency, 2005).

Regardless of how the energy consumption is reduced, there are collateral implications. Load-shedding affects industrial, agricultural, commercial, government and residential sectors. The research presented in this work focuses on the residential sector.

Electricity access is closely associated with human development (Arto, Capellán-Pérez, Lago, Bueno, & Bermejo, 2016; Ferguson, Hill, Craggs, & Forbes, 1997; Mattick & Allenby, 2010), and indeed it is one of the United Nation's sustainable development goals (United Nations, 2015). The transition of households fuel usage from traditional solid fuels such as wood, crop residue and animal dung to modern fuels—the so-called "energy ladder"—has been studied in many contexts. The extant research highlights the prevalence of fuel source diversification ("fuel-stacking") in rural, peri-urban and urban settings. It has been observed that some households with access to electricity often do not abandon the use of traditional solid fuels (Baiyegunhi & Hassan, 2014; Davis, 1995; Peng, Hisham, & Pan, 2010).

Interestingly, this body of research is focused on those climbing up the energy ladder. What is less understood is what happens when the higher-quality energy rungs—for example, electricity—are removed from the energy ladder. What is the experience of people that are forced to climb *down* the energy ladder? As energy crises persist globally, better understanding of the implications of load-shedding and other forms of energy rationing becomes increasingly important.

Social media was used in Butgereit (2015) to gauge the people's emotional response to load-shedding. Not surprisingly, the overwhelming emotional association is negative. Research reported in Mukoni (2012) showed that load-shedding disproportionately affects women more than men.

Research reported in Musademba, Kanyepe, Madiye, and Hov (2012) examined the effects of load-shedding on residents of Chinhoyi, Zimbabwe. A written questionnaire was used to investigate the role of fuel-switching as a coping strategy during load-shedding. The results show that fuel-switching was common, with most residences relying on firewood for cooking, and candles for lighting. The study also noted an increased economic burden associated with load-shedding.

This article investigates how households have adapted their energy usage and behavior to cope with load-shedding in Zambia. The results of a pilot survey on this topic were documented in Ngoma, Tambatamba, Oyoo, and Louie (2016). The pilot study was limited in survey responses ($N = 52$) and geographic scope—it considered just one city in Zambia. Although data were collected regarding changes in fuel-related expenditure and total energy consumption, these results were not presented. However, the study did show that the respondents adopted several coping strategies. These can generally be classified as fuel-switching, load-shifting and conservation behaviors. The pilot study was an impetus for the expanded study presented in this article. The research has been expanded in several important ways. First, an additional 209 surveys were conducted ($N = 261$); second, the geographic scope now includes ten regions across Zambia; third, coping strategies related to laundry activities, lighting and temperature regulation are included; and finally—and importantly—this article includes an quantitative analysis of how consumption and fuel expenditure changed during load-shedding. In total, the results provide a more complete picture of how households are affected by load-shedding. This in turn provides insight into the efficacy of load-shedding programs, and the economic burden it imposes on households.

The remainder of this article is arranged as follows. The section on Zambia's energy crisis provides background information on the Zambian energy crisis and the load-shedding program. The survey methodology is detailed in the Survey methodology section. The survey results related to coping strategies are provided in the Coping strategies section and a quantitative analysis of the changes in overall fuel consumption and expenditure is detailed in the Changes in fuel consumption and expenditure section. Discussion and conclusions are provided in the Discussion and Conclusions and future work sections, respectively.

## Zambia's energy crisis

The Republic of Zambia is a landlocked country in Southern Africa whose geographic size is 753,000 $m^2$. Zambia's Human Development Index is 0.586, and is considered by the United Nations to be a least developed country. Zambia's population has been rapidly growing since its independence from the United Kingdom, rising from 3.5 million in 1964 to 16 million in 2016. Zambia's population growth is among the most rapid in the world, averaging 3% per year (Barrientos & Soria, 2016).

Zambia has been challenged to maintain an adequate electricity supply to this growing population base. Just 22% of urban Zambians are connected to the electrical grid whereas in rural areas, the rate drops to 3% (International Energy Agency and the World Bank, 2015). The per capita consumption in 2014 was 707 kWh/year, about one fifth of world average per capita consumption. This is appreciably lower than when the per capita consumption in peaked at 1182 kWh/year in 1974 (World Bank, 2017).

The generating capacity of Zambia was 2411 MW in 2015 (Zambian Invest, 2017). The majority of this is attributed to Zambia's two major hydro generating stations, Kariba North (1080 MW) and Kafue Gorge (990 MW). These are owned and operated by Zambia Electricity Supply Company (ZESCO), the parastatal electric utility company.

ZESCO is a vertically-integrated utility that generates, transmits and distributes electricity to its consumers. ZESCO has been challenged by an unsustainable, government-subsidized tariff structure. In 2016, Zambia had the second lowest average tariff among the Southern African Development Communities region (SADC), at approximately US$0.06/kWh. Forced to sell electricity at rates that are not cost-reflective, ZESCO is challenged to invest in its infrastructure.

Table 1 gives the trend of how available generation capacity, production, consumption, imports and exports changed from 2012 to 2015 (Energy Regulation Board of Zambia, 2017). In 2015, the year load-shedding began, the available generation capacity was only 68% of the total installed capacity of 2411 MW. This was mainly because Kafue Gorge and Kariba North Bank were limited to 540 MW (of 990 MW capacity) and 760 MW (of 1080 MW capacity), respectively. This was attributed to low retention levels in the reservoirs.

The peak demand in 2015 was 2616 MW, giving a reported deficit of 975 MW over the available capacity. This is sharp increase from the peak deficit of 150 MW to 200 MW recorded in the previous years. To maintain grid stability, there was an increase in