African Review of Economics and Finance | ISSN 2042-1478 | Volume 10 | Issue 2 | December 2018

The economic costs of electrical power outages in Eswatini

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Abstract

Eswatini has been experiencing power outages that have muted the country's efforts to increase access to electricity. As it stands, electricity supply is unreliable which has resulted in harsh penalties and costs to the economy. Using a sample of customers from both the residential and business sector, this study assessed the economic costs of power outages in Eswatini. The costs of power outages on the residential sector as a proportion of Eswatini's gross domestic product were found to be 1.67% using the Direct and Indirect Cost Method. Using a binary logistic regression, the study identifies weekly frequency of power outages, perception of current price of electricity, possession, and maintenance cost of back-up equipment to be associated with consumers' willingness to pay for improved supply. Under the business sector, the industrial sector reported the highest direct costs compared to the other sectors, which shows that it is the sector which is mostly affected by power interruptions. It is clear that the challenges experienced by the Eswatini electricity sector have resulted in high costs to the economy. The paper therefore recommends the need for policy attention towards improving the electricity sector through investments in electricity generation by renewable energy sources, expedite the promotion of decentralised electricity generation to vulnerable areas, and setting of standards for the generation and distribution of electricity.

Keywords: Energy; Power Outages; Economic Costs; Eswatini.

1. Introduction

Energy poverty is a problem in many developing countries more especially in Africa, for example Nigeria and Zimbabwe. The International Energy Agency (IEA) states that only 15% of the population in Africa has access to electricity, and one quarter of the 2.5 billion people cooking with biomass live in Africa (International Energy Agency, 2012). This lack of access to efficient modern energy has a substantial impact on economic development and small-scale enterprise, educational opportunities and quality of life (Hachimenum, 2015).

Energy raises a country's productivity by making it possible for the country's industries to automate production processes, deploy improved technologies, and increase industrial outputs and economic growth. In Eswatini, energy is essential for the country's expanding manufacturing and services sectors. Electricity is also an important input in the country's agricultural sector, especially in sugarcane production, which is heavily reliant on electricity to drive irrigation technology. Moreover, the growth in uptake of modern cooking, heating, and lighting technologies in the country has positioned the energy sector as an important contributor to reducing the release of greenhouse gases into the atmosphere. In education, electricity plays an important role in the provision of extra hours to study and work.

However, Eswatini has been experiencing problems in its energy sector. According to the Eswatini Energy Policy (2003), challenges faced by the sector include unreliability of supply as the local electricity supply often experiences power cuts (Government of Eswatini, 2003). In recent years, power shortages have been on the increase at the back of increasing energy demand for the country (World Bank, 2015; Government of Eswatini, 2014). The power shortages are attributable to a confluence of factors such as poor weather conditions with excessive lightening, a weak power grid with little reserve capacity, and heavy reliance on energy imported from South Africa, who has pressured the country to reduce consumption by, at least, 5% (Government of Eswatini, 2003; Government of Eswatini, 2014). Unexpected power outages have also continued to occur due to issues of technical inefficiencies in power delivery mechanisms by the Eswatini Electricity Company (EEC) (Dlamini, 2012).

Compounding the problem is that available evidence suggests that very little is known about the energy sector in Eswatini. To illustrate, the Sustainable Energy for All Rapid Assessment, Gap Analysis, and Country Action Plan of Eswatini (2014) states that there is a lack of consumer energy research in the country. This is in spite of the fact that such studies are crucial in informing energy improvement strategies.

Against this backdrop and notwithstanding that Eswatini has made considerable investment to improve access to electricity, power supply is not reliable, which has resulted in harsh penalties to the economy which have not yet been quantified, raising questions of what else can the country do to enhance efficiencies in its energy sector. This study estimates the economic costs of power interruptions with the aim of providing possible policy solutions to curb power interruptions. By estimating the costs of power outages, the study attaches a monetary value to power interruptions, which will go a long way in providing policymakers with evidence to make informed decisions regarding strategies and policies that will bring stability and reliability in the supply of electricity in Eswatini. The study conducts a spatial and sectorial analysis of the costs power outages across the country in a bid to identify vulnerable locations and business sectors. Lastly, the study investigates consumer's willingness to pay for improved electricity services in Eswatini and identifies factors associated with the willingness to pay.

Section 2 reviews literature and provides the conceptual framework while Section 3 presents the methodology. Results and discussions are presented in Section 4 and Section 5 concludes and makes policy recommendations.

2. Literature review and conceptual framework

2.1. Review of previous studies

Electricity supply reliability has become a critical policy issue due to massive costs that electricity users have to face due to unreliable supply (Ado & Josiah, 2015). Because of this, quantifying the costs of power outages has been a topic of interest to many policy-makers and researchers more especially in developed countries. The general theory of the cost of the electric power unreliability has been a challenging area of study for the researchers (Kufeoglu & Lehtonen, 2016).

In recent years, developing countries have attempted to estimate the costs of power interruptions due to the unreliability and energy crises. Despite the unreliable nature of electricity supply in developing countries, empirical evidence on the economic costs of power outages in Africa is still very limited (Oseni & Pollitt, 2013).

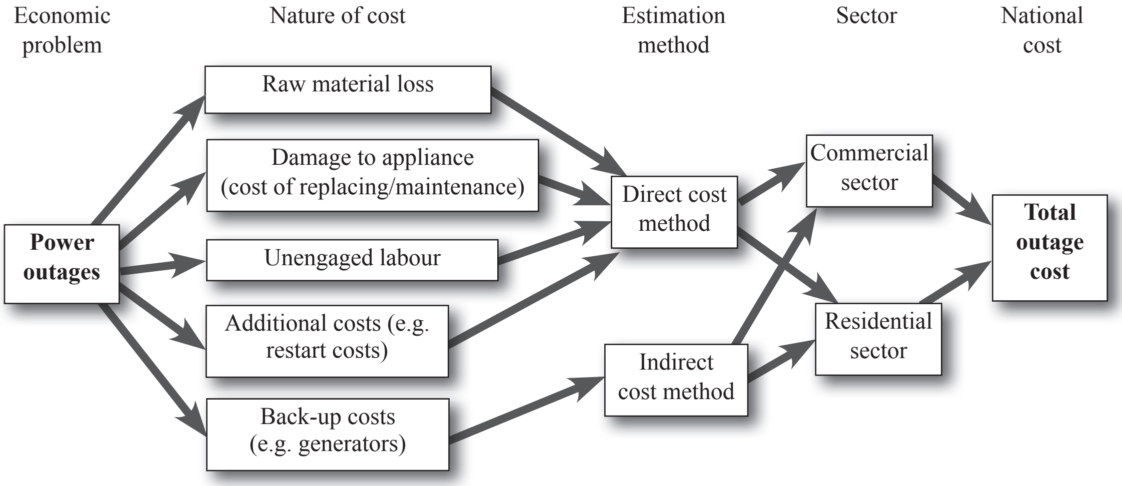
Due to the differences in the impacts of power interruptions studied in high-income and low income countries, it is important to ensure that the methodology applied is relevant to the type of economy that is being studied (Goldberg, 2015). In developing countries, customer surveys have been the most preferred method to estimate the cost of power interruptions. This method is more superior because it provides more accurate and sufficient outage cost data for planning purposes especially in cases where there is insufficient country level data to estimate the costs (Kufeoglu, 2015).

Goldberg (2015) estimated the cost of load shedding in the South African retail sector to be approximately R14 billion using a subjective survey evaluation method of the costs of back up. Akuru & Okoro (2014) employ an inductive comparison approach with other neighbouring countries to test whether the low numerical value of the Nigerian GDP is a consequence of its poor electricity structure, which has affected the development of businesses. Using the Average Value of Lost Load method based on survey data, Bourie & El Assad (2016), estimate that over the period 2009–2014, the total losses for the Lebanese economy reached 23.23 billion USD. Twerefou (2014) used the Contingent Valuation Method (CVM) to estimate that households in a rural area in Ghana were prepared to pay on the average about US$ 0.06 for a kilowatt-hour, which is about one and a half times more than what they were paying at that time. Kaseke (2014), using the Direct Cost and Indirect Cost Method, found that power outages cost Zimbabwe US$1.8 billion which was equivalent to 32.6% of their GDP in 2010. The author (Kaseke, 2014) also found that the total outage cost impact as a percentage of GDP generated varied across sectors. For example, it was 1.24% for households, and 22.1 % for industry, 7.7% for mining, and 1.5% the agriculture sector (Kaseke, 2014).

2.2. Conceptual framework for power outages' estimation

The approach used to estimate the economic costs of power outages in Eswatini draws from Kaseke (2014), who used the Direct Cost and Indirect Cost Method to estimate the economic costs of power outages in Zimbabwe. Figure 1 illustrates the different steps followed in estimating the economic costs of power outages in Eswatini. The Figure illustrates that to estimate the economic costs of power outages (economic problem), consideration must be taken of the effect of power outages on GDP (nature of costs), the estimation method used to quantify the costs, and the affected sectors of the economy.

FIGURE 1: A FRAMEWORK FOR ASSESSING ECONOMIC COSTS OF POWER OUTAGES



Source: Author's own representation from literature reviewed

A number of scholars have identified different types of costs of power outages, which include raw material costs, production costs, unengaged labour costs and restart costs (Goldberg, 2015; Hachimenum, 2015; Sena, 2015). These costs are a direct result of a power interruption. To be clear, unreliable power may motivate customers to invest in back up equipment (Goldberg, 2015). Foster & Steinbucks (2008) estimate that own generated electricity is, on average, 313 percent more expensive than that from the grid, which is an indirect cost on its own, as most customers will only use this back up during a period of outage. Both these direct and indirect costs form a total outage cost as shown in Figure 1.

To identify strategies for improving supply service the study complements the Direct and Indirect Cost Method with the stated preference method (SP) for willingness to pay for improved electricity supply in order to identify factors associated with customer's willingness to pay.

3. Methods and Materials

3.1. Target Population, Sampling, and Data Collection

The target population was all EEC customers. From this and drawing from Yamane's (1967) sampling technique , an adequately large sample size (of 400 customers) was selected from EEC's residential customer database (see equation 1). The study selected 60 more customers in order to replace non-usable questionnaires which might have been as a result of errors which could have arisen during data collection. The paper used a two level stratified random sampling technique (first sampling by region then by electricity depots).

$$n = \frac{N}{1 + N(e)^2} \tag{1}$$

Where n is sample size, N is the population size, and e is level of precision (5%).

For commercial customers, purposive sampling was used to sample those businesses who have reported power outages in recent years. A sample of 115 commercial customers was selected from EEC's business customer database. Focus was placed on commercial and industrial hubs of the country which include all industrial sites, central business districts, and agricultural hubs for example Malkerns. Data was collected from the target population using two sets of questionnaires. The survey instruments were pre-tested prior to commencement of the study to allow for correction of errors. For residential customers, the study administered questionnaires through telephone interviews from the SEC customer database which had a 1.52% non-response rate (453 out of 460). Personal visits to each commercial customer selected in the sample were used to solicit data from the commercial sector.

3.2. Data Analysis

Data were collated in Microsoft Excel and analysed in stata. The study used a Logistic regression model to identify factors associated with willingness to pay for improved electricity supply.

3.2.1. Estimating the Cost of Power Outages

3.2.1.1. Direct Cost Method

The Direct Cost Method is an approach where a customer is directly asked on the economic losses that resulted from power interruptions (Kufeoglu, 2015). This method reduces the biases that resulted from quantifying the costs of power outages using total output losses only. When using the Direct Cost approach, the loss of raw material, damage to appliances, loss of manpower, restart and indirect costs are included in the total cost estimation.

In order to obtain accurate and reliable results, the approach requires the researcher to reach out to a large number of customers in order to mitigate the effect of non-responses (Amadi & Okafor, 2015).

Quantification of the direct costs of power outages for households was done based on estimations made by respondents on material destruction (e.g. spoilage of food) damage and maintenance (cost of damage to household appliances, lights burnout, and cost of replacement or maintaining damaged appliances) and additional costs (e.g. cost of buying already prepared food) for the year 2016. The figures obtained from these estimations were then extrapolated to all households connected to the electricity grid in 2016 (149,433 customers) to give a total direct cost estimate.

3.2.1.2. Indirect Cost Method

The Indirect Cost Method is an approach where a customer is asked on the costs incurred due to mitigating the impact of power outages. For indirect costs, the back-up equipment cost was annualised by dividing the initial capital cost by the expected life (in years) of the generator, taking off depreciation for each year using the prevailing reducing balance method at 10% per annum and then discounting the values using the prevailing interest rate, i.e. 10% as done by Kaseke (2014). Other costs such as maintenance costs, annual fuel costs were added to the annualised initial capital cost to come up with a total indirect cost.

The total cost for power outages was obtained by summing the direct and indirect (backup) costs and expressing the sum as a percentage of GDP of the country.

3.2.1.3. Contingent Valuation Method (CVM)

The study does not quantify consumers' WTP due to bias issues, however it does identify the factors associated with a consumer being willing or not willing to pay for improved electricity in order to establish recommendations for improving service. The objective of the CVM is to measure the compensated or equivalent variation of the good or service in question of which in this case is the cost of power outages (Vercueil, 2000). This method provides the basis for determining the subjective valuation by households of the cost of outages to them (Pasha & Saleem, 2012). However, households may understate their willingness to pay on the expectation that other households may exaggerate a high WTP to rationalize investments to improve the reliability of the electricity supply (Pasha & Saleem, 2012). The CVM is grounded on the consumer choice problem, which theorises that if utility increases, then a consumer may be willing to pay for improved electricity supply provided the price increase does not lower utility beyond the base level (Twerefou, 2014). Therefore, the CVM views a household's WTP as a function of the change in utility arising from the consumption choice.

3.2.2. Vulnerable Areas and Sectors

In order to identify the most vulnerable groups in terms of total costs of power outages, the study cross-tabulated the costs according to the different locational, regional, and business sectors to determine whether their costs varied and thus identify the vulnerable area, region, and business sector which is mostly affected by power interruptions.

3.2.3. Identifying Factors Associated with Willingness to Pay

3.2.3.1. Empirical Model and Specification: Binary Logistic Regression

A binary logistic regression was used to capture the net effect of the different possible factors on the choice of willingness to pay for improved electricity supply. There were two categories which formed the binary outcome of Willing to Pay (WTP) coded as 1, or Not Willing to Pay (NWTP) coded as 0. Odds ratio were used to interpret the associations between the outcome variables and independent variables.

The probability of a household being willing to pay for improved power can be written as follows:

$$\text{P}i = \epsilon\ (\gamma = 1) \mid \text{X}i = \left(\frac{1}{1+e^{-(\beta_0+\beta_i X_i)}}\right) \qquad (2)$$

Where, $\beta_0 + \beta_i X_i$ to be zi then the formula can be broken down as follows;

$$\text{Prob (WTP)} = \left(\frac{1}{1+e^{-zi}}\right)$$

$$= \left(\frac{1}{1} + \frac{1}{e^{-zi}}\right)$$

$$= 1 + e^{zi}$$

$$= \ln 1 + \ln e^{zi}$$

$$\text{In } P = 0 + \text{zi}$$

$$\text{Where } zi = \beta_0 + \beta_i X_i + \beta_2 X_2 + \beta_3 X_3 + \cdots + \beta_n X_n \qquad (3)$$

Which implies a linear combination of correlates, X_i with i ranging from 1 to n and the β_i (i = 1 to n) represents the coefficients for the correlates. The value of zi ranges from $-\infty$ *to* $+\infty$ and therefore, Pi ranges between 0 and 1. Given that Pi is the probability of WTP then 1-Pi becomes the probability of not WTP.

For empirical estimation, the logistic regression model is specified as follows:

$$zi = \beta_0 + \beta_i X + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \text{U}_i \qquad (4)$$

Where,

X_1 = Frequency of Outages Per Week
X_2 = Duration of Outage
X_3 = Possession of Back-up Equipment

X_4 = Household Size
X_5 = Maintenance Cost of Back-up
X_6 = Average Monthly Income
X_7 = Satisfaction with Electricity Service
X_8 = Monthly Electricity Expenditure
X_9 = Perception of Current Price of Electricity
U_i = Random Error Term

Table 1 below provides a description and classification of the regressors of the model.

TABLE 1: DESCRIPTION OF EXPLANATORY VARIABLES

Varaible Name	Description	Classification
Frequency of outages Pper week	Households who have many incidents of electricity power outages are expected to be more likely to be willing to pay for improved electricity service in order for the weekly frequency of power outages they experience can be reduced.	Continuous
Duration of outage	As with the frequency of power outages a week, households who have longer durations of electricity power outages are expected to be more likely to be willing to pay for improved electricity service in order for the duration of power outages they experience can be reduced.	Continuous
Maintenance cost of Back-up	As the frequency of power outages increases, the more times that back-up equipment has to be used. This results in a higher chance of having to maintain the equipment due to its constant use and therefore expenses increase in the process. To avoid this, households with back-up equipment are expected to be more willing to pay for improved electricity service.	Continuous
Household size	According to Adjei-Mantey (2013) households with larger sizes will have more people benefiting from the use of electricity for varying uses. As such, the absence of improved electricity will cost households greatly and thus such a household will be willing to pay more for improved electricity. On the other hand, a household with large numbers is likely to incur huge household expenditures especially if many of them are unemployed and dependent on the household head. Such a household may not be willing to pay any higher for improved electricity supply as this will increase their expenditure.	Continuous
Possession of back-up equipment	Households who invest in back-up equipment are those who can afford it and also those who really require reliable electricity. As a result, they are expected to be willing to pay more to have uninterrupted power supply as the use of back-up equipment is more expensive compared to using electricity as stated by Foster & Steinbucks (2008).	Dummy (0 = No, 1 = Yes).
Average monthly income	It is expected that households who are willing to pay for improved electricity service are those who have a higher income compared to those who have a lower income, hence as income rises, the more likely that a household will be willing to pay for improved electricity service.	Continuous
Satisfaction with electricity service	It is expected that households who are willing to pay for improved electricity service are those who have a higher income compared to those who have a lower income, hence as income rises, the more likely that a household will be willing to pay for improved electricity service.	Dummy (0 = No, 1 = Yes).
Perception of current price of electricity	Households who perceive the current price of electricity to be high are expected to not to be willing to pay for improved electricity service compared to those who perceive the price to be satisfactory or too low.	Categorical (1= Too Low, 2 = Satisfactory, 3 = Too High)
Monthly electricity expenditure	Households who already pay a high amount for electricity may not be willing to pay any higher because they consider the amount that they pay to be already high while households who pay lower amounts may be willing to increase the amount they pay for improved electricity. On the other hand, other households who pay a high amount for electricity do it because they really require electricity for their household needs. Such people may be willing to pay even higher in order to obtain reliable service at all times while those households who pay a lower amount because they barely use electricity may not be willing to pay any higher to improve the service because they hardly use it.	Continuous

4. Results and Discussion

4.1. Residential Sector: Socio-Demographic Characteristics

A total of 453 household heads participated in this study. Most households (41.2%) reported to having four to five household members as shown in Table 2. In terms of educational level, 39.6% reported to have attained a tertiary education followed by high school education (35%). Only 4.5% respondents reported that they had no formal education. In terms of economic activity, 56.6% of the respondents reported to be employed and 43.8% were unemployed. For those who indicated that they did not have a primary job, 18.5% reported to rely on self-employment, whilst 6.6% relied on remittances from family members and 4.4% relied on farming. Most households fell in the E1001 – E5000 average monthly income category (34.1%) followed by those who had an average monthly income of less than E1000 (20.5%). The majority of households (32.6%) spend between E101 – E200 on electricity a month.

Table 2: Socio-Demographic Summary Table

Characteristics		**Percentage (%)**
Location Area of Household	Rural	63.7
	Semi-urban	20
	Urban	16.3
Sex	Female	50
	Male	50
Education	No Formal Education	4.6
	Primary School Education	8.1
	Secondary Education	11.5
	High School Education	35
	Tertiary Education	39.6
Average Monthly Income	Less than E1000	20.5
	E1001 - E5000	34.1
	E5001 - E10000	17.8
	E10001 - E15000	7.7
	E15001+	8.4
	Missing	11.5
Size of Household	Between 1-3	22.3
	Between 4-5	41.2
	Between 6-9	27.3
	10+	9.3
Employment Status	Employed	56.2
	Unemployed	43.8

Primary Source of Income for Unemployed	Farming	4.4
	Self-employment	18.5
	Remittances	6.6
	Other	14.1
Average Monthly Electricity Expenditure	Less than E100	10.4
	Between E101 - E200	32.6
	Between E201 - E300	18.3
	Between E301 - E400	13.9
	Between E401 - E500	8.4
	E501+	16.3

Source: Authors' survey

4.2. Residential Sector: Perceptions of Features of Existing Electricity Supply

A majority of the respondents (57.3%) stated that they were dissatisfied with the service of the country's electricity provider. 89.6% of the respondents indicated that the current price of electricity was too high and 10.2% indicated that it was satisfactory. With respect to the frequency of outages experienced in a week about 85% of respondents reported that they had power outages roughly between 1 to 3 times a week. Rural areas reported longer durations of power outages compared to urban areas. Regionally, the Lubombo region reported longer durations of power outages compared to the other regions as shown in Table 3 below.

Table 3: Average Duration of Power Outages

Location	Average Duration of Power Outage (Hours)
Hhohho	9.37
Manzini	12.02
Shiselweni	10.48
Lubombo	22.3
Rural	14.62
Urban	5.3

Source: Authors' survey

4.3. Residential Sector: Direct Cost Method

4.3.1. Direct Cost by Type of Cost for Households

Using the total of the direct cost components, the total costs of power outages of the surveyed households was calculated to be E646,711.50 (see Table 4.3.1) with the damage to appliance category accounting for the highest cost type for the year 2016. Dividing the total direct costs of power outages by the number of households surveyed, it can be concluded that on average, in 2016, power outages cost each household E1,427.62 or E118.96 per month. This average value was extrapolated to the total number of households connected to the grid in order to calculate the total direct costs of power outages from estimations made by the respondents which came up to be E213,333,421.00 for the year 2016.

Table 4: Direct Cost by Type of Cost for Households

Cost Type	**Actual Cost (E)**
Material Loss	178 445.00
Damage to Appliance (Cost of Replacing/Maintenance)	458 431.50
Additional Costs	9 835.00
Total	646 711.50

Source: Authors' survey

Sub-Saharan Africa's cooperative activities are substantial with deposit-taking SACCOs far-reaching throughout the region. However, Kenya's financial cooperatives are demonstrably continental leaders across metrics of membership, market penetration, savings and credit statistics. Furthermore, as Table 1 shows, Kenyan deposit-taking SACCOs globally, rank high in loan and savings value. The extent to which Kenyan SACCOs grew to be global and regional leaders can inform African counterparts, like Ghana (Boamah, 2010), and others in financial sector development to possibly achieve similar results.

4.3.2 Decomposition of Direct Cost by Regional and Residential Area

In order to identify the most vulnerable groups in terms of total costs of power outages, the costs were cross tabulated according to the different locational and regional areas to determine whether their costs varied. Among locational areas, households in rural areas reported the highest direct costs, followed by households in the semi-urban areas. Among the four regions, Lubombo reported the highest cost of power outages closely followed by Hhohho region as seen in Table 5.

Table 5: Decomposition of Direct Cost by Regional and Residential Area

Location Area	Raw Material Loss (e.g. spoilt food) (E)	Damage to Appliance (cost of replacing/ maintenance) (E)	Additional costs (E)	Total costs (E)
Hhohho	34 010	156 791.5	1 665	192 466.5
Manzini	51 880	102 380	3 400	157 660
Shiselweni	29 190	71 700	1 380	102 270
Lubombo	63 365	127 560	3 390	194 315
Total	178 445	458 431.5	9 835	646 711.5
Rural	109 015	256 791.5	6 070	371 876.5
Semi-urban	53 030	85 180	2 070	140 280
Urban	16 400	116 460	1 695	134 555
Total	**178 445**	**458 431.5**	**9 835**	**646 711.5**

Source: Authors' survey

This basically means that rural and semi urban areas are most vulnerable to the direct costs of power outages compared to the other areas. In terms of regions, Lubombo and Hhohho region are the most vulnerable regions to the direct costs of power outages. This is consistent with Layton & Moeltner (2004) who state that the costs of power outages for households has been found to differ according to area of residential location. This could be explained by the fact that rural areas experience longer durations of power outages compared to urban areas and that Lubombo experiences longer durations of power outages compared to the other regions.

4.3.3 Indirect Cost Estimation

Investment in backup equipment is seen as an insurance against unreliable power supply. This investment imposes huge costs on customers as use of it is more expensive compared to electricity from the grid (Kaseke, 2014). Indirect costs for residential areas are estimated at E1 475 915.6 as shown in Table 6. Notably, the fuel cost category takes the biggest share of the total indirect costs compared to the annualised initial capital cost of acquiring the back-up equipment which could indicate that the equipment is used on many occasions due to the several power outages experienced.

TABLE 6: DECOMPOSITION OF INDIRECT COST BY TYPE

Cost Type	Actual Cost (E)
Net Book Value of Back-up equipment Cost (2016)	398 522.6
Maintenance Cost Per Year	330 285
Fuel Cost Per Year	747 108
Total	1 475 915.6

Source: Authors' survey

Dividing the total indirect costs of power outages by the number of households surveyed, the study concludes that on average, in 2016, power outages cost each household E3,258.09. The study then extrapolated this average value to the total number of households connected to the grid in order to calculate the total indirect costs of power outages from estimations made by the respondents which came up to be E486,866,436.77 for the year 2016.

4.3.4. Total Outage Estimation

The total costs of power outages were obtained by summing the direct and indirect costs. In this case, the total cost was calculated to be E700,199,857.77 (E213,333,421.00 + E486,866,436.77). The impact of the costs of power outages for the residential sector was assessed by comparing it to the GDP of Eswatini. The costs of outages as a proportion of GDP using the direct cost was 0.39% percent and indirect cost, 1.28% of which the total is 1.67%. These proportions are consistent with findings by Kaseke (2014), USAID (1988) and Kessides (1993) who reported 1.24%, 1.5% and 1.5% of GDP for Zimbabwe, Pakistan and India respectively for the residential sector.

4.4. Residential Sector: Contingent Valuation Method

In terms of willingness to pay for improved electricity service, 68.7% of the households were not willing to pay whilst 31.3% of them were willing to pay.

4.4.1. Binary Logistic Regression Model Results

To investigate the factors that influenced willingness to pay for improved electricity supply, responses from the survey were subjected to a binary logistic model. To begin with, a Hosmer and Lemeshow Test was used to check if the binary model is a good fit to the data provided. The Hosmer and Lemeshow test of goodness of fit suggests that a binary model is a good fit to the data provided $p>0.5$ (National Centre for Research Methods, 2011). Therefore, for this study, the Hosmer and Lemeshow test suggests that the model is a good fit to the data used since p = 0.74 as shown in Table 7.

Table 7: Factors Associated with Households' Willingness to Pay for Improved Electricity Service

Factors	Coefficient	Wald	Std. Error	P>|Z|
Possession of Back-up Equipment	1.860	5.48	0.794	0.019**
Average Monthly Household Income	0.000	0.06	0.000	0.806
Household Size	0.022	0.031	0.124	0.861
Weekly Frequency of Power Outages	0.124	4.643	0.058	0.031**
Duration of Power Outage	-0.008	2.389	0.005	0.122
Monthly Electricity Expenditure	0.000	0.11	0.000	0.916
Maintenance Cost of Back-up Equipment	0.000	6.159	0.000	0.013**
Satisfaction with Service Provider	0.153	0.448	0.228	0.503
Perception of Current Price of Electricity	-1.689	21.307	0.366	0.000***
Constant	2.314352			
			HR chi2 (9)	5.164
			Hosmer and Lemeshow Test	0.74

Source: Authors' Estimation

Notes: *Significant at 10%, **Significant at 5%, ***Significant at 1%

From the results, the frequency of power outages in a week, possession of back-up equipment, maintenance cost of back-up equipment and the perception of the current price of electricity were found be factors associated with willingness to pay for improved electricity supply.

The frequency of power outages, maintenance cost of back-up equipment and possession of back-up equipment have a positive relationship with the household's willingness to pay for improved service whilst the perception of the current price of electricity has a negative relationship as seen in Table 6. Specifically, the results mean that as the weekly frequency of power outages experienced by the household increase, the more likely that a household will be willing to pay for improved electricity service and the odds of this happening are

4.643 times greater than households who experience lower incidents of power outages as seen in the Wald column.

Moreover, households who invest in back-up equipment are those who can afford it and who really require reliable electricity and thus would be willing to pay more to have uninterrupted power supply as the use of back-up equipment is more expensive compared to using electricity as stated by Foster & Steinbucks (2008). As the households' maintenance cost for back-up equipment increases, the more likely that they will be willing to pay for uninterrupted electricity supply. As the households' perception of the price of the current electricity supply changes, that is from too low to too high, the more likely they were not going to be willing to pay for improved service and the odds of this occurring is 21.307 times compared to those who were of the view that the price of electricity is too low.

4.5. Business Sector: Perceptions of Features of Existing Supply of Electricity

From the 115 purposively sampled businesses, 83 responded. Businesses were classified according to three types as done by SEC which are Industrial, Commercial and Agricultural Sectors as well as the different tariff classification structures provided by SEC.

Under the business sector, 61.4% of the respondents stated that they were dissatisfied with the service of the country's electricity provider. With respect to the frequency of outages experienced in a month about 48.2% of respondents reported that they had power outages roughly between 1 to 3 times a month. 65.1% stated that the duration of each outage lasted between 1 to 3 hours.

4.6. Business Sector: Direct Cost Method

4.6.1 Direct Cost Estimation

Quantification of the direct costs of power outages for businesses was done based on estimations made by businesses on raw material destruction costs, output loss costs, unengaged manpower costs and additional costs such as restart costs for the year 2016. The figures obtained from these estimations were not extrapolated to all businesses connected to the electricity grid due to the fact that the businesses were purposively sampled. However, it was possible to identify sectors which require crucial attention. Using this method, the direct cost for the businesses surveyed was found to be E26,970,915.00 based on survey data with the loss of output taking the largest share of the direct cost (E19,098,050) as shown in Table 8. This direct cost figure for businesses is greater than the one obtained for households thus showing the huge impact power interruptions have on businesses.

TABLE 8: BUSINESS DIRECT COST BY TYPE

Cost Type	Actual Cost (E)
Raw Material Loss	4 692 510
Output Loss	19 098 050
Unengaged Manpower Costs	1 925 712.2
Additional Costs (e.g. Restart Costs)	1 254 643
Total	26 970 915.2

Source: Authors' survey

4.6.2 Decomposition of Direct Cost by Business Type

In order to identify the most vulnerable business sector in terms of total costs of power outages, the study then divided the costs according to the different business sectors to determine whether their costs varied as seen in Table 9.

TABLE 9: DECOMPOSITION OF DIRECT COST BY BUSINESS TYPE

	Raw Material (E)	Output Loss (E)	Unengaged Manpower Costs (E)	Additional Costs (E)	Total Costs (E)
Industrial	541 510	1 748 9500	1 041 400	51 700	19 124 110
Commercial	1 913 000	1 365 550	871 312.2	172 680	4 322 542.2
Agricultural	2 238 000	243 000	13 000	1 030 263	3 524 263
Total	4 692 510	19 098 050	1 925 712.2	1 254 643	26 970 915.2
Major	2 218 010	13 208 500	62 500	1 015 003	16 504 013
Minor	2 474 500	5 889 550	1 863 212.2	239 640	10 466 902.2
Total	4 692 510	19 098 050	1 925 712.2	1 254 643	26 970 915.2

Source: Authors' survey

The industrial sector reported the highest direct costs (E19 124 110), followed by the commercial sector (E4 322 542.20). Major customers, although few in number (21 customers), reported the highest costs compared to small commercial customers (62 customers). This is in line with findings by Kaseke (2014), who found the industrial sector to incur the highest total electricity costs of power outages in Zimbabwe which is 22.1 percent of the total GDP generated by the economy.

4.6.3. Indirect Cost Estimation

The total indirect cost estimate was found to be E2,617,063 as shown in Table 10. The industrial sector takes the largest share of total indirect costs which is closely followed by the agricultural sector. The annualised capital cost of acquiring the back-up equipment takes the largest share of the costs (E1,284,403.30) followed by the fuel cost category (E828,518.40). Moreover, despite that they are few in number, the major customers take the largest share of total indirect costs compared to minor customers. This is also in line with findings by Kaseke (2014) for indirect cost estimation in Zimbabwe.

Table 10: Decomposition of Indirect Cost by Business Type

	Annualised Value of Back-up Equipment (E)	**Annual Maintenance Cost (E)**	**Fuel Cost Per Year (E)**	**Other Overhead Costs (E)**	**Total (E)**
Industrial	613 600	101 500	521 760	9 000	1 245 860
Commercial	132 715	41 420	200 042.4	321	374 498.4
Agricultural	538 088.3	351 500	106 716	400	996 704.3
Total	1 284 403.3	494 420	828 518.4	9 721	2 617 062.7
Major	805 545.8	431 800	540 924	300	1 778 569.8
Minor	478 857.5	62 620	287 594.4	9 421	838 492.9
Total	1 284 403.3	494 420	828 518.4	9 721	2 617 062.7

Source: Authors' survey

5. Conclusions and Policy Recommendations

The study sought to quantify the economic costs of power interruptions on both the residential and business sector in a bid to provide possible policy solutions to curb electricity unreliability. Customer surveys from a sample of customers from both the sectors were used to come up with a monetary value of the costs of power outages.

From the results, the costs of outages on the residential sector as a proportion of GDP were found to be 1.67%. The average value for willingness to pay for improved electricity supply is E1.525 per kWh in winter and E1.530 per kWh in summer. The study identifies weekly frequency of power outages, perception of current price of electricity, possession and, maintenance cost of back-up equipment as having a role in consumers' willingness to pay for improved supply.

Under the business sector, the industrial sector reported the highest direct costs compared to the other sectors, which shows that it is the sector which is mostly affected due to power interruptions.

It is clear that the challenges experienced by the Eswatini electricity sector have resulted in many consequences which include the loss of raw material, output loss, damage to equipment, material destruction, restart costs, idle productive time of unengaged workers, consumer welfare loss and high costs of investing in back-up equipment to keep the business sector going. Notably, the impact of the power interruptions varies from sector to sector. Amongst locations, rural areas are mostly impacted by power outages. Amongst, businesses, the industrial sector is mostly impacted by power outages. If not addressed, the problems with the electricity sector will severely undermine the government's effort to improve the development of the country. In essence, the benefits of increased access to the electricity grid will not be realised if the power is unreliable as it currently is. The main intervention for the electricity issues currently being faced by Eswatini would be to heavily invest in the country's generation capacity. Therefore, based on the results, this study recommends the following:

- Invest in own generation of electricity using one of our most abundant resources: solar energy. The Sustainable Energy for All Action Plan of 2014 states that solar radiation is abundant in the country with the best potential towards the South East, but there are limited solar energy assessments (Government of Eswatini, 2014). The country should fast track the comprehensive nationwide renewable energy resource assessment in order to inform investment decisions.
- Diversify electricity imports other than solely relying on South Africa which currently faces issues in the energy sector. There is evidence that there is cheap generation in countries such as Zambia, Mozambique and Tanzania who are all part of the South African Power Pool (SAPP).
- Expedite the establishment of mini-grids in the rural areas in order to alleviate the problems experienced by the vulnerable location areas in terms of electric power.
- Set up customer compensation schemes whereby a customer is compensated for facing a prolonged power interruption than the certain acceptable period (this could be determined by the regulatory authority) in order to increase standards of service for electricity customers.
- Expedite the implementation of a tariff differentiation strategy between low income and high income groups.

Biographical Notes

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Acknowledgements

We are grateful to ESEPARC research Team for their inputs in every step of the work. we are also indebted to the anonymous reviewers who made valuable contribution. We would also like to express our gratitude to the entire editorial Team for their support without which we would have not made it through the process. Special thanks goes to Chief Editor, Prof. Alagidede, for his guidance during the publication process.

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