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Economic Cost of Electricity Outages: Evidence From a Sample Study of Industrial and Commercial Firms in the Lagos Area of Nigeria

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The purpose of this study is to estimate some of the measurable costs of electricity outages from a sample of industrial and commercial firms in the Lagos area. To achieve this objective, over 100 firms were surveyed. Analysis of the survey returns showed that firms in the area sustained substantial economic costs, consisting of adaptive costs (investments and operating costs on own generation), operating losses (raw and processed materials), equipment losses and unproduced output. Most of the firms indicated that NEPA's tariff was expensive. They also recommended among other things, private sector participation in the electricity industry and privatisation of the National Electric Power Authority (NEPA) in order to improve electricity supply and distribution in Nigeria. Policy issues arising from the study include urgent need for government policy on private sector participation in the electricity industry; privatisation of NEPA; granting of tax incentives to firms for investment on own generation so as to dampen cost-push inflation; the granting of legal rights to manufacturers to claim for certain losses resulting from electricity failure, while electricity firms should be allowed to enforce laws infringing on electricity supply, transmission and distribution, and the need to standardise generating sizes and regulate generating models to ensure maintainability and easier access to spare parts.

The incidence of electricity outage, voltage and frequency variation are well know phenomena of electrical power system.[2] Electricity outage becomes problematic when their frequency and duration are high because of the attendant disruption in economic activities. In the design of electric power systems, the objectives of minimizing electricity outage and providing high quality service are paramount in setting the system's reliability target.[3] While utilities aim at high reliability levels, their ability to achieve them are limited by high capital requirements and consumers' willingness to pay. Reliability can be improved by making adequate provisions for

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2. Electricity outage, failure and interruption are used interchangeably in this study to mean complete severance of electrical power to a consumer.
3. Reliability is a quality of constancy of service.

system peak demand and energy requirement for the rest of the year.

Factors affecting reliability include the accuracy of the forecast of current and future electricity demand, weather, soil texture, vandalization and proper maintenance culture. In a situation where population growth is very rapid and industrial, commercial and residential expansions are not well coordinated with the power authorities, overloading can be frequent even though adequate generation capacity has been provided. As an illustration, the National Electric Power Authority's (NEPA) network has an installed capacity of 5618 and 5876 MW[4] in 1991 and 1992. The available[5] portions of these capacities were 2690 and 3500 MW for system peaks[6] of 2219 and 2362 MW in those years.

Thus, reserve margin[7] improved from 3399 MW in 1991 to 3514 MW in 1992. The corresponding spinning reserve[8] increased from 471 MW or 21 per cent to 1138 MW or 48 per cent. The system's installed capacity of 5876 MW in 1992 has a plant mix of 1900 MW from hydro and 3976 MW from thermal sources. They provide base and peaking loads.[9] In spite of the capacity and plant mix advantages, the NEPA system was bedeviled with frequent power outages. NEPA's problem is related to energy shortage resulting from inadequate operating revenue, inadequate maintenance, fuel supply disruption and equipment vandalization, unlike in Ukpong (1976) where capacity constraint was the main cause of electricity failures. The energy problem is also supported by Sule and Anyanwu (1993) in their appraisal of electricity supply in Nigeria. The other factors identified in their study that affect electricity failures in Nigeria included inadequate transmission and distribution capacity.

Associated with electricity disruption are measurable and immeasurable economic costs. Measurable short-term costs of electricity outage include cost of raw materials and products due to spoilage, unproduced output, lost labour and destroyed equipments. Adaptive response costs include investment (long-term) and operating costs for auto generation. The loss in comfort and the rise in frustration during an outage are not readily measurable.

The main objective of this study is to estimated some of the measurable economic costs of electricity failure by examining a sample of industrial and commercial firms in the Lagos area of Nigeria. Because of the concentration of business firms and their headquarters in the Lagos area, the result of the survey will likely reflect the national trend. Estimates of outage costs are vital in setting tariffs (willingness to pay), system reliability in electric power system planning and in discriminating tariff categories

4. MW means MegaWatts (10^6 watts).
5. Available Capacity at a given moment is the maximum capacity at which the station can be or is authorized to be operated at a continuous rate under the prevailing condition assuming unlimited transmission capacity.
6. System peak load — The maximum load in the network at the stated time.
7. Reserve Margin is a measure of the generating capacity that is available over and above the amount required to meet the system load requirements.
8. Spinning Reserve — The generating capacity that can be readily called on to supply power.
9. Base Load — The minimum load over a given period.

based on the reliability level a consumer is willing to pay.

The paper is divided into four parts. Part I reviews the theoretical issues and antecedents in electricity outage cost estimation. The design of the survey questionnaire and analysis of survey returns are discussed in Part II. The policy implications and recommendations of the study are the subject of Part III, while Part IV summarises and concludes the paper.

I. THEORETICAL ISSUES IN ELECTRICITY OUTAGE COST ESTIMATION

The theoretical basis for estimating electricity outage cost is that there is welfare loss when there is electric power failure. Three major methods have been advanced and applied in estimating the measurable costs of electricity outage in general and in the industrial and commercial sectors in particular (see for instance International Atomic Energy Agency Report (IAEA), 1984; Sanghvi, 1982). The methods are production factor analysis, economic welfare analysis and empirical analysis or customer surveys.

The production factor approach assumes that outage cost is equal to the ratio of an economic index (output — value added by manufacturing, gross domestic product, or factor of production — wages) to input such as electrical energy consumed (Kwh) over the same period as the economic index. Some of the identified strengths of the method include the ease of application and ability to estimate direct and indirect economic impacts. However, the method's estimate approximates long-term average rather than short-term marginal costs. Also, the method assumes homogenous output for each industry. The IAEA Report reported an outage cost estimate in the range of $0.50 – $1.5 per Kwh. The high cost was attributed to low electricity consumption in the denominator of the factor analysis method rather than a high financial loss in the numerator of the equation. Munasinghe (1990) stated that the use of the assumption of proportionality between output and electricity consumption implied in the method may not be justified.

The second approach proposed in the literature is based on welfare maximization. Under this approach consumers' surplus, that is, the amount of electricity consumers could have consumed if there were no electricity outages, are estimated using the consumers' long-term demand curve for electricity. Advantages of the method include its theoretical underpinning on welfare theory, ease of use given long-term demand elasticities for electricity and its ability to capture factors affecting consumers' willingness to pay. One of the stated shortcomings of the method is the assumption that willingness to pay for electricity outage not actually experienced might not be equal to willingness to pay when the electricity outage was actually experienced by the consumer. Also, the use of long-term demand elasticities to estimate short-term impact of electricity outage cost may underestimate the actual cost of the electricity disruption.

The final method uses customer survey returns to estimate outage costs. Customer surveys have the advantage of measuring outage costs from information necessary to answer the specific concerns of the researcher. Munasinghe (1990) pointed out that survey methods are effective when used in situations where actual electricity outages have been experienced as in the Nigerian case. He cited studies by Sanghvi (1982, 1983), Anderson and Taylor (1986), Woo and Train (1988), and Keane, McDonald and Woo (1988) which showed that customers with actual and recent outage experience valued electricity higher than hypothetical customers without electricity outage experience.

While the methods discussed so far are applicable to industrial and commercial customers, Sanghvi highlighted the difficulties and methodological modifications needed in identifying commercial customers' outage costs. Some of the difficulties are the classification of commercial customers and the identification of their outputs. For instance, it is important to identify the appropriate measure of output of metal workshops (sheet metal, rods, etc.), laundries (clean cloths), supermarkets, petrol stations, restaurants, hotels and banks.

Sanghvi also urged caution in comparing different outage cost estimates between regions and countries. The limitations include differences in methodology, assumptions, economic and demographic mixes, outage response strategies, political climate, degree of electrification and social and cultural backgrounds.

One of the early studies on industrial and commercial sector electricity outage costs in Nigeria is that by Ukpong (1973).[10] He used a modified version of the production factor analysis method in analysing 1965 and 1966 consumer survey data on electric power outage costs on the industrial and commercial sectors in the Greater Lagos Area of Nigeria.[11] His production function was of the form

$$Q = f(x_1, x_2, x_3, x_4) \qquad (1)$$

where Q = Output for industry

x_1 = Capital

x_2 = Labour

x_3 = Materials

x_4 = Electric energy.

Holding other factors constant, he concluded that changes in output was directly related to changes in electrical energy. From a sample survey of 38 firms he estimated unsupplied electrical energy to be equal to 130 Kwh and 172 Kwh in 1965 and 1966,

10. Other studies on the Nigerian electricity market reviewed but found to be not directly related to the present study include Ayodele (1992 and 1981) and Taiwo (1982).

11. The Greater Lagos Area was defined as Lagos City, Mushin, Shomolu, Shogunle, Oshodi, Isolo, Ikeja, Maryland, Bariga, Agege, Apapa, Ajegunle and Ewekoro.

respectively. In order to estimate lost output as a result of these lost electrical energy he employed the relationship

$$q = \frac{Q.N.X.}{N.h.D} \qquad \text{..............................(2)}$$

where q = Output lost
Q = Actual output of industry
N = Number employed
X = Hours lost to electricity failure
D = Annual working days
h = Working hours per day

With value of D = 250, h = 8, Q = N £57017, N = 21,071 and X = 428, all for 1965, the overall industry loss was estimated as N£840,000.0. The corresponding figure for 1966 was N£1,378,000.0. He further extrapolated the loss in output to imply loss in national income, increased inflation and unemployment. On a sectoral basis, his analysis revealed that the cement and concrete industries suffered most from power failures, followed by the food, metal products, textiles and printing industries.

Ukpong's study concentrated on estimating unproduced output while neglecting other losses such as lost raw materials and output due to spoilage and long-term costs such as those resulting from auto generation. A disaggregated estimate of individual firms lost output could also produce better result than the aggregated sub-sector output he used. The inclusion of number of people employed in his equation was unnecessary since they cancelled out. The study also failed to exploit the superiority and feasibility of the survey in obtaining a more comprehensive loss measures.

Another study on the cost of electricity failure in Nigeria was conducted by Iyanda (1982). He surveyed high income households in the Lagos area consisting of Lagos Island, Ikoyi, Victoria Island, Yaba and Surulere in order to estimate costs of power failures. From the 70 returns out of the 120 households surveyed, he estimated an average electricity outage cost of ₦1.19 per hour for each household.

A recent World Bank (1993) study estimated the adaptive cost of electricity failure on the Nigerian economy as equal to US $390 million, divided between consumer back-up capacity (US $250 million), operating and maintenance costs of diesel autogenerators (US $90 million), fuel and lubrication (US $50 million). The estimate for NEPA's lost revenue due to unserved consumer energy amounted to US $40 million. However, the short-term losses incurred by consumers, including raw and finished materials, foregone output, and destroyed equipment were not estimated. The estimation of these costs are part of the objectives of the present study.

II. DESIGN AND ANALYSIS OF SURVEY RETURNS

This study is based on consumer survey or empirical method. The survey questionnaire was designed to capture the strengths of the production factor analysis and consumer surplus methods. Specifically, information was requested that would help in estimating short-term electricity outage costs consisting of lost raw materials, value of lost output, unproduced output, lost equipment and long-term adaptive costs.

The value of unproduced output was estimated as in Ukpong (1973) by assuming that the output of each firm is proportional to its operating hours. The total number of hours worked in a business day was assumed to be eight. Also, it was assumed that the total number of weeks worked was fifty-two. Effects of industrial actions and work stoppages were not taken into account. The effect of loss of output from dominant firms may affect sub-sectoral results.

With the above assumptions, and letting

Lost hours due to outage	=	HL
Total Annual Work hours	=	HT
Value of Annual Output from firm	=	VAQ

then, annual value of unproduced output for the firm

$$VUQ = \frac{HL}{HT} VAQ$$

The value of unproduced output for all firms in the sub-sector

$$V = \sum_{i=1} VUQ; \qquad i = 1 \ldots 65$$

The major improvement in this estimation is that the value of unproduced output for each firm was estimated, summed up for the sub-sector and for industrial and commercial sectors as a whole, unlike Ukpong who estimated the unproduced output at the sub-sectoral level. Where the output of a firm is not well defined as in banks and retail outlets their sales revenue would be used as a close proxy.

As recognized in the review of literature, firms prone to constant electricity outages device long-term strategies to stay in business. A good measure suggested in Munasinghe for the measurement of long-term adaptive responses and also used in this study is the investment and operating costs of auto generation. Information was sought on investment on own generation, capacity, make, model and year of purchase of the generator. Additional data on operating costs (fuel, wages and salary, and maintenance) were requested. Finally, questions were included to estimate the quality of NEPA's electricity supply, dearness and consumers' willingness to pay to obtain all their electrical energy requirements from NEPA. A copy of the survey questionnaire is available on request.

The survey covered the industrial and commercial sectors in the Greater Lagos area as in Ukpong (1973). The industrial sector consists of manufacturing firms in beer, stout and soft drinks; cement; vehicle assembly; steel; soap and detergent; radio, television and communications equipment; cotton and textiles; paints; pharmaceuticals; aluminium and footwear. Retail (merchandise and petrol stations), financial (banks), hotel and health services (hospitals) were covered in the commercial sector. A total of five officials conducted the survey in August 1993. Five days were spent to distribute the questionnaire and ten days to retrieve them.

Survey Return Analysis

A total of 106 questionnaires were distributed by the enumerators while 65 were completed and returned. This resulted in a 61.3 per cent overall response rate. On a sectoral basis 55.3 per cent of commercial and 66.1 per cent of industrial firms responded.

1. Total Electricity Consumption

A total of 109,155.5 MWH of electrical energy was consumed by responding firms in 1991. This figure increased by 39.0 per cent to 151,689.7 MWH in 1992. By mid-1993 a total of 77.721 MWH was consumed. The industrial and commercial firms generated 40,064.58 MWH, 76,408.79 MWH and 36, 258.07 MWH in 1991, 1992 and mid-1993, respectively. Thus, the estimates indicate that the firms generated 36.7 per cent, 50.0 per cent and 46.7 per cent of the electrical energy in those years. The likely reason for the high percentage of own generation in total energy consumption could be related to the increasing duration in outages from 47,045.25 hours in 1991 to 57,194.74 hours in the first six months of 1993.

2. Average Cost of Energy

The average cost of energy supplied by NEPA increased from 0.53 ₦/Kwh to 0.55 ₦/Kwh and 0.86 ₦/Kwh in 1991, 1992 and mid-1993, respectively. The corresponding average energy costs from firms' own generation, computed by dividing their running cost by the energy consumed from own generation, were 1.22 ₦/Kwh, 2.47 ₦/Kwh and 5.40 ₦/Kwh. The higher energy cost to the firms for their own generation was expected since NEPA is supposed to have economies of scale advantage in the production of electrical energy. Also, the devaluation of the naira, the upward review of wages and salaries in 1992 and the increase in average outage duration from 2.1 and 2.4 hours per outage to 4.4 must have contributed to the sharp increase in firms' energy cost.

3. Operating Cost of Own Generation

The cost of supplying electricity to support firms operations rose from ₦48.9 million in 1991 to ₦188.8 million in 1992 and escalated to ₦195.7 million by 1993 first half.

The upward trend in operating cost driven by increased fuel cost resulting from increased use of own generation as a result of increased outages, the rise in wages and salaries of the operators as well as increase in cost of spare parts, maintenance and lubrication.

4. Investment on Firms' Own Generation

The survey returns showed that ₦191.4 million had been invested in auto generation by 1991.[12] In 1992 and the first half of 1993, ₦40.9 million and ₦15.4 million were invested, bringing the total to ₦247.73 million by mid-1993. The capacity cost resulting from the 87891.5 KVA installed by the firms by June 1993 amounted to ₦2,818.5 per KVA.

The vintage of installed generating plants ranged from 1974 to 1992, while the capacities ranged from 250 to 1263.3 KVA. Different models of generators were also used by the firms. They included Caterpillar, Mercedes Benz, Rolls Royce, Cumins, MTV, ABC, Deutz, Lister, O'Brien, GEC/Rustrom, Nenaga Stamford, Petbow, Puma, Atlanta, Detriot and Renault.

4. Number and Duration of Outages During Business Hours

A total of 21, 948, 23, 332 and 13, 079 electricity outages were reported in 1991, 1992, and the first six months of 1993. The outages lasted for 47045. 25, 55, 277.58 and 57, 194.74 hours in those period. Thus, the average outage duration increased from 2.1, 2.4 to 4.4 hours.

5. Material and Equipment Loss

Firms minimised material and equipment losses due to electric power failures by the used of their own generators. The following losses in materials and equipment were estimated:

(i) Raw Materials

The sum of ₦43.5 million, ₦55.9 million and ₦36.6 million were recorded by firms as losses in 1991, 1992 and the first six months of 1993. The soft drinks, pharmaceutical, soap, paints and allied chemical industries accounted for most of the losses.

(ii) Loss in Output Due to Spoilage

Processed materials valued at ₦34.26 million was reported to have been lost due to electricity outage in 1991. The amount increased by ₦15.32 million or 44.7 per cent to ₦49.58 million in 1992. Following the increase

12. The amount assumes mixed-years money, which means the aggregation of monetary units of different purchasing power.

Table 1
Economic Cost of Electricity Outage
(in Millions of Naira)

A.	CATEGORY	*1991*	*1992*	*1993* (Jan-June)
1.	*Adaptive Cost*	48.8	188.7	195.8
	(i) Operating	191.4*	40.9	15.4
	(ii) Investment			
2.	*Operating Losses*			
	(i) Raw Material	43.3	55.9	36.6
	(ii) Output	34.3	49.6	50.0
	(iii) Equipment	7.4	10.4	8.5
	(iv) Unproduced Output	1,353.2	2,012.0	1,319.4
	TOTAL	1,678.5	2,357.6	1,625.8
B.	SECTOR			
1.	Steel, Cement, Aluminium, Radio and TV	88.3	110.4	41.5
2.	Food, Hotel and Health Services	23.3	157.5	133.5
3.	Retail and Financial Services	18.0	15.0	12.5
4.	Soap and Detergent, Paints, Pharmaceuticals, Textiles	137.3	203.2	243.7
5.	Beer, Stout and Soft Drinks; Vehicle Assembly	1,411.6	1,871.5	1,194.6
	TOTAL	1,678.5	2,357.6	1,625.8

* Cumulative to 1991.

compared with 85 kobo per Kwh for industrial firms in order to obtain all their electricity supply from NEPA. Overall, all the firms were willing to pay 73 kobo per Kwh to obtain their electricity from NEPA, a value lower than the current average of 86 kobo Kwh paid to NEPA. This reflects their overwhelming response (44 for and 6 against) that the unit price of electrical energy from NEPA was expensive. Thus, even though the firms are not actually satisfied with NEPA's supply they feel it is expensive. Also, they are not willing to pay more to improve NEPA's supply.

9. Suggestions on How to Improve Supply and Distribution of Electricity from NEPA

In general, most of the firms recommended privatisation/private participation in the provision of electricity in Nigeria. Specific suggestions on how to improve electricity in outages in 1993 first half, output spoilage rose to ₦50.07 million. As in (i) above, the losses were reported mainly by firms involved in chemical processes.

(iii) **Equipment Loss**

When electric power fluctuates or surges as when power is restored after power outage, equipment operating frequency and voltage rating are commonly exceeded. These often result in equipment damage. Firms reported that they lost ₦7.43 million, ₦10.36 million and ₦8.51 million in 1991, 1992 and mid-1993, respectively, to electricity outages.

6. Value of Unproduced Output

The value of unproduced output was estimated at ₦1,353.236, ₦2, 012 and ₦1, 319.4 million in 1991, 1992 and mid 1993. The soap, detergent, paints, pharmaceuticals, textiles and soft drinks sub-sectors were affected most by the loss. Some of the companies indicated that they minimized losses by dedicating generators with automatic switching devices to specific operational units of their firms.

7. Summary of Economic Costs

Table 1 summarizes the costs associated with electricity outages which are made up of adaptive and operating costs. They include value of unproduced output and spoilage cost (raw and processed materials). On a sectoral breakdown, the industrial sector (mainly soap, detergent, paints, pharmaceutical, textiles, and soft drinks) suffered the greatest loss. All the cost elements showed a rising trend.

8. Quality and Cost of Electricity from NEPA

All respondents of the survey indicated that they do not sell electricity. In order to determine how electricity consumers perceive the quality and cost of their supply from NEPA so as to determine their willingness to pay for improved reliability, they were asked whether (a) electricity supply quality was good, and (b) unit cost of electricity from NEPA was cheap, expensive or just about right. A slight majority (26) felt that the quality was good, while 25 indicated that the quality was bad.

Majority of the commercial firms indicated that the quality of NEPA's supply was good, while industrial firms thought otherwise. This could be linked to commercial firms' propensity to rent spaces in buildings that already have generating plants in them. On the other hand, many industrial firms build their factories to suit their production systems and the need to provide power plants to sustain their operations. Thus, they feel the impact of poor electricity supply from NEPA more than the commercial firms.

In the same vein, commercial firms were only willing to pay 52 kobo per Kwh law on all illegal electricity infringements (illegal connection, electric power vandalization, theft, and others) since they affect electricity reliability and outage.

5. It was noted from the survey returns that different models and auto generator capacities were being used by industrial and commercial firms. These have implications for expertise, maintainability and parts procurement. There could be the need for standardization. Government should explore the possibility of standardizing generating plants.

IV. SUMMARY AND CONCLUSIONS

The study set out to estimate measurable costs associated with electricity failures using data from the industrial and commercial firms in the Lagos area as a basis. Electricity outage cost estimation is based on the theory that there is reduction in welfare when there is electric power failure. The study employed the empirical method involving collecting primary data through survey of a sample of industrial and commercial firms in the Lagos area. The results of the study showed that more than ₦5, 662.56 million was lost to electricity outages between 1991 and June, 1993. The industrial sector suffered most of the losses. All the cost components showed a rising trend during the period. While the respondents were divided on the quality of electricity supplied by NEPA, most of them indicated that NEPA's tariff was expensive. Thus, NEPA may find it difficult raising tariffs to improve service.

In conclusion, the study identified some of the economic costs of electricity outages that are measurable. Besides, the study recommended, among other things, that government should take urgent steps to formulate policy on private sector participation in electricity supply, transmission and distribution so as to minimise electricity outages which have increased in frequency and duration over the years.

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supply included restricting NEPA's supply to Nigeria; construction of more thermal stations and a move away from hydrogeneration because of seasonality of water levels; decentralisation of NEPA; better maintenance by experts; proper funding; proper fueling from NNPC; pursuance of nuclear and solar generation options.

Some of the suggestions they proffered that would improve distribution included privatisation; government procurement and subsidy on power equipment; underground distribution; more distribution centres; efficient management; prompt payment of electricity bills; appropriate planning; informing customers on power disruption; and adequate metering and load distribution.

III. POLICY IMPLICATIONS AND RECOMMENDATIONS

1. Electrical energy is a vital component of modern production systems. It also provides the enabling environment and comfort for the performance of other services. Based on the huge economic cost of electricity outage to the firms and the economy as a whole and government's dwindling resources, there is urgent need for government to adopt a definite policy on private sector participation in the electric power industry. Many respondents to this study stressed the need for one form of privatisation or the other. This included privatising NEPA so that it can operate as a regulated utility.

2. While many firms indicated that the quality of electricity from NEPA was poor, they overwhelmingly believed that the cost of NEPA's electricity was expensive. This implies that NEPA may not be able to raise tariff under the circumstance to improve quality. The dilemma implies that NEPA has to look somewhere else to source funds in order to improve service. A possibility could be for NEPA, through government's subvention, to improve electricity supply and then recover cost through aggressive debt recovery and appropriate billing system. The Nigerian capital markets is another avenue available to NEPA to source finance. NEPA can experiment on reliability-based tariff system for firms. Those requiring higher reliability may be required to pay more. This is logical since the estimated energy cost to the firms for own generation is higher than what they pay for NEPA's supply.

3. The large investment and operating cost on own generation and the production losses add to the price of products and services. These cause cost-push inflation which also aggravates the rising price level from other sources. To dampen the pressure on the price level, government could give firms tax incentives in the form of tax write-offs on their investments on own generation. This could be extended to other self-provided infrastructure.

4. Because of the loss of valuable equipment to frequent electricity failures, provisions should be made in future electricity code for legal redress when a firm or a consumer losses a resource. On the other hand, the government should enforce the

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