**Get rid of it: To what extent might improve reliability reduce self-generation in Nigeria?**

**Musiliu O. Oseni**

Faculty of the Built Environment

University College London

1–19 Torrington Place London, WC1E 7HB

*Email – m.oseni@ucl.ac.uk; musloseni@yahoo.com*

February 2016

## Abstract

Despite the global concerns surrounding the threats of climate change to both human health and sustainable environments, gasoline- or diesel-powered generators with non-negligible emissions have become a popular choice among Nigerian households due to the poor publicly provided electricity. This study examines the extent to which an improvement in publicly supplied electricity may reduce backup generation and, by implication, reduce emissions from Nigerian homes. The results from a random-effects probit analysis reveal that, although improved electricity service quality would significantly reduce self-generation, self-generation would continue in the country, especially among rich and educated households. The study concludes by highlighting the policy implications of the findings.

Keywords: Electricity, carbon emissions, generator disposal, Nigeria, supply reliability

## 1. Introduction

The benefits of reliable energy services cannot be overemphasised, as lack of access to quality electricity supply can reduce people's quality of life and limit growth on a range of socioeconomic fronts. Poor-quality electricity could reduce household income and employment opportunities, and affect school-going children's performance by limiting their ability to read during evening hours (see Khandker, Barnes, and Samad, 2012; Khandker, Samad, Ali, and Barnes, 2014). Electricity stimulates income growth by enabling businesses to stay open for longer, promoting productivity, and allowing the members of a household to be engaged in income-generating activities, including sewing and/or making headcrafts for women (World Bank, 2002). All these benefits are either completely lost or significantly reduced when electricity is not accessible or the quality of the service is low.

Despite the significant costs associated with unreliable electricity services, poor electricity supply is what households in many developing countries face on a daily basis. For instance, the average daily power outage in Zambia currently lasts eight hours (Engineering Institution of Zambia, 2015). The average Nigerian household enjoys electricity for just five hours daily (National Bureau of Statistics (NBS), 2012). This poor provision has resulted from underinvestment in new generation capacity and a lack of adequate maintenance for existing facilities. Since 1995, for instance, less than 300 MW of generation capacity has been added to the Nigerian electricity grid. The country's per capita electricity consumption remains less than 150 kWh per annum (Figure 1).

FIGURE 1 HERE

For most Nigerians, tackling the electricity supply deficit means the procurement and installation of private gasoline- or diesel-powered generators. Current estimates indicate that over 86% of businesses and almost a quarter of homes have gasoline- or diesel-powered generators (National Bureau of Statistics (NBS), 2012; World Bank, 2012). This implies that there are currently more than 6.7 million generators in use in Nigerian homes. Moreover, about 3% of Nigerian homes (a little under 1 million homes) rely solely on a generator as their only source of electricity (National Bureau of Statistics (NBS), 2012), a decision necessitated by people's dissatisfaction with the unreliable public power supply.

Generators installed for backup power during blackouts could help to reduce the losses (e.g. food spoilage, etc.) associated with unreliable electricity service, encourage children to study more during evening hours, reduce the time allocated to fuelwood collection, allow people to keep their businesses open for longer hours, and reduce the overall impacts of unreliability on consumer welfare. However, many of these generators are diesel-powered and produce non-negligible air emissions that may damage air quality and human health. In Nigeria, carbon emissions from domestic generation are greater than those from workplaces, buses and trucks, and pose potentially risky challenges to people's health and the environment due to long-time exposure and proximity (Awofeso, 2011).

Diesel exhaust contains many toxic contaminants, which result in irritation of the eyes and nose, asthma, chronic bronchitis and respiratory changes, and cancer-inducing substances such as benzene, arsenic, and formaldehyde. It also contains other harmful environmental pollutants that contribute in no small amount to ozone depletion and climate change. Several studies have found a link between diesel exhausts and health-related problems (Kagawa, 2002; Kenyon and Liu, 2011; Sydbom et al., 2001). Estimates are that up to 70% of the cancer risks attributable to the inhalation of toxic air pollutants in the United States stem from diesel exhaust (Loh, Levy, Spengler, Houseman, and Bennett, 2007). Empirical evidence has also suggested a link between occupational exposure to diesel exhaust and lung cancer in Europe and Canada (Olsson et al., 2011). Indirect evidence of the effect of diesel exhaust on lung cancer in Nigeria is indicative of its rising incidence among urban-based non-smoker adults (Salami, Adeoye, and Adegboye, 2010), most of whom are generator users.

Furthermore, there have been several cases of deaths attributed to the inhalation of fumes released by generators in Nigerian homes. A family of five reportedly died after being poisoned by carbon monoxide from generator fumes at Urum in Anambra State in April 2012.[1] In October 2013, a newly married couple was reported to have died from generator fumes in their new home on the outskirts of Calabar, Cross River State. Similar cases of generator-related deaths have been recorded in many other Nigerian cities, including Ibadan, Lagos and Abuja (the Nigerian capital city), among others (Ogundipe, 2013).[2] Moreover, backup generation tends to be more expensive than publicly provided electricity due to the diseconomies of scale in self-generation (Oseni, 2015b); therefore, self-generation reduces consumers' ability to spend on other needs.

Considering the negative effects of self-generation and the view that the importers of generators strategically contribute to the underdevelopment of the Nigerian power sector, the debates on whether the importation and use of backup generators should be banned in Nigeria have gained increasing momentum, especially among non-users. A policy question from this debate is: should the government discourage or encourage self-generation? Formulating laws or imposing tougher restrictions on the use of backup generators may well be acceptable to consumers, and non-users

---

[1] See Generator tragedy: Family rules out autopsy. http://www.gbooza.com/group/crime/forum/topics/generator-tragedy-family-rules-out-autopsy

[2] http://www.vanguardngr.com/2013/10/portable-generators-standby-power-standby-death/

in particular, considering the level of negative externality (e.g. noise and air pollution) they suffer from the use of generators in their neighbourhoods. However, many users would consider such a policy too harsh and may oppose it unless it is preceded by improved reliability. For such a policy to be considered fair, it would therefore be beneficial to investigate what level of reliability backup households would be willing to accept for them to dispose of their generators. Therefore, the main questions addressed in this study are: to what extent might improvements in electricity supply reduce self-generation? How do the socioeconomic characteristics of households affect their decision to dispose of their backup generators? What level of reliability would make households dispose of their generators? Answering the aforementioned questions would serve as a useful guide in power planning expansion strategies aimed at achieving the appropriate level of strategic reliability and environmental sustainability.

Given the problems associated with self-generation, this study examines the ownership and use intensity of backup generators in Nigerian homes, and the extent to which improvements in reliability might motivate users to dispose of their generators. To the best of author's knowledge, this study is the first attempt to differentiate between the factors determining households' ownership of backup generators and their use patterns. Moreover, the study marks the first attempt to investigate the extent to which improved reliability might affect users' willingness to dispose of their backup generators. The paper is organised as follows: the next section discusses the methodology; Section 3 presents the data; Section 4 deals with the presentation and discussion of the results; and the last section concludes and discusses the policy implications of the findings.

## 2. Methodology

### 2.1 Generator adoption and usage

The running of a generator by a household involves a two-stage decision process. At the first stage, the household has to decide whether to buy a generator, and, in the second stage, it decides the use intensity (i.e. the duration of its use).[3] These decisions may be affected by different factors, or by the same factors in different ways. For instance, while the decision to procure a generator might be affected by unreliable power supply and fixed capital costs, its intensity of use might be affected by fuel costs. In this section, we start by presenting a model of what motivates the uptake and use intensity of a generator using a two-stage decision process.

By defining $U_i^0$ as the individual household $i$'s utility given the current state of (un)reliability in electricity supply and $U_i^g$ as the expected utility they could gain by investing in a backup generator, we can express the household's utility under the two situations as follows:

$$U_i^0 = (\boldsymbol{x}_i^0)\beta^0 + \boldsymbol{\theta}_i\gamma^0 + \varepsilon_i^0 \quad (1)$$

$$U_i^g = \left(\boldsymbol{x}_i^g\right)\beta^g + \boldsymbol{\theta}_i\gamma^g + \varepsilon_i^g \quad (2)$$

From equation (1), the individual household current utility $(U_i^0)$ is expressed as a function of the vector of electricity service attributes, denoted $\boldsymbol{x}_i^0$, and a vector of household's characteristics, $\boldsymbol{\theta}_i$. A household's utility would also be subject to some unobserved error term, $\varepsilon_i^0$. Equation (2) indicates a similar arrangement for the utility if a household engages in backup generation (indicated by $U_i^g$) and so features the characteristics of both service quality and backup generation, $\boldsymbol{x}_i^g$. Parameters $\beta^0$ and $\beta^g$ respectively capture the impacts of the characteristics of the existing service quality, and the generator and service quality characteristics. $\gamma^0$ and $\gamma^g$

[3] 'Generator usage', 'use intensity', and 'degree of use' are used interchangeably.

capture the effects of households' characteristics on the utility drivable under the two (consumption) states, respectively. The demographic vector $\boldsymbol{\theta}_i$ remains constant since these are individual and specific characteristics that do not vary with the quality of service.

An individual household $(i)$ who engages in backup generation also faces a transaction cost $(C)$. This accounts for the fuel costs and other operating costs, and the characteristics of the existing consumption condition that may limit investment in a generator (e.g. no need to budget for a fuel-to-power generator). Moreover, transaction costs are affected by the individual household's characteristics, such as their ability to adapt quickly to the use of a generator. Equation (3) represents the transaction cost function:

$$C_i^{0\rightarrow g} = (\boldsymbol{x}_i^0)\beta^{C0} + (\boldsymbol{x}_i^g)\beta^{Cg} + \boldsymbol{\theta}_i\gamma^C + \varepsilon_i^C \quad (3)$$

A household is assumed to own a backup generator if they perceived positive net utility from doing so. Defining net utility from self-generation as $\psi_i$ and $C_i^{0\rightarrow g}$ as the generation costs associated with the use of a generator, the net utility from operating a generator can then be written as:

$$\psi_i^{0\rightarrow g} = U_i^g - U_i^0 - C_i^{0\rightarrow g} \quad (4)$$

If the net utility from engaging in generation is greater than zero, then the individual household would invest in backup generation. Thus, the probability of owning a generator is the probability that the net utility $\psi_i^{0\rightarrow g} > 0$. Following from the above, the probability that an individual household $i$ has a generator is:

$$Prob[yes|\boldsymbol{x}_i^0, \boldsymbol{x}_i^g, \boldsymbol{\theta}_i] = Prob[U_i^g > (U_i^0 + C_i^{0\rightarrow g})] \quad (5)$$

The model developed above (i.e. equations 1–5) is based on the assumption that a rational household will own a backup generator if, subject to his socioeconomic characteristics, the perceived net utility of doing so is positive. This is supposing that the deterministic part of equations (1) and (2) is linear in respondents' observed covariates and is re-parameterised such that the deterministic utility for owning a generator is $v_i^g = \boldsymbol{\alpha}_g \boldsymbol{z}_i$ and the non-backup utility is $v_i^0 = \boldsymbol{\alpha}_0 \boldsymbol{z}_i$, where $\boldsymbol{z}_i$ is a vector of a household's socioeconomic characteristics and the current electricity supply attributes. The change in deterministic utility due to investment in a generator is:

$$v_i^g - v_i^0 = (\boldsymbol{\alpha}_g - \boldsymbol{\alpha}_0)\boldsymbol{z}_i \tag{6}$$

Assuming $\boldsymbol{\alpha} = \boldsymbol{\alpha}_g - \boldsymbol{\alpha}_0$, the probability that a respondent (or a household) owns a generator becomes:

$$Pr(yes_i) = Pr(\boldsymbol{\alpha}\boldsymbol{z}_i + \varepsilon_i > 0) \qquad (7),$$

where $\varepsilon_i \equiv \varepsilon_i^g - \varepsilon_i^0$ and are independently identically distributed with mean zero. If we assume that $\varepsilon_i \sim N(0, \sigma^2)$, then:

$$Pr(\varepsilon_i < \boldsymbol{\alpha}\boldsymbol{z}_i) = Pr\left(\vartheta < \frac{\boldsymbol{\alpha}\boldsymbol{z}_i}{\sigma}\right)$$

$$= \Phi\left(\frac{\boldsymbol{\alpha}\boldsymbol{z}_i}{\sigma}\right) \qquad (8),$$

where $\vartheta \sim N(0,1)$ and $\Phi(x)$ is the standard cumulative normal. The log-maximum likelihood function for equation (8) is:

$$lnL(\boldsymbol{\alpha}|\boldsymbol{z}) = \sum_{i=1}^{n} w_i ln\left[\Phi\left(\frac{\boldsymbol{\alpha}\boldsymbol{z}_i}{\sigma}\right)\right] + (1 - w_i) ln\left[1 - \Phi\left(\frac{\boldsymbol{\alpha}\boldsymbol{z}_i}{\sigma}\right)\right] \qquad (9),$$

where $w_i = 1$ if respondent (household) $i$ answers 'yes' to the generator ownership question, and $n$ is the sample size.

So far, we have assumed a situation where a household stated that they had a generator without paying attention to their usage. As stated previously, running a backup generator is a two-stage decision process, including purchase (i.e. ownership) and usage (i.e. use intensity) decisions. An analysis of the household's usage of their generator is essential for understanding the heterogeneous drivers of their use pattern and provides more robust information for policymakers seeking to promote reliability and address self-generation problems (e.g. carbon emissions and occasional deaths).

A household's optimal generator usage can be determined within the constrained utility optimisation framework using certain assumptions. Assuming a continuous and quasi-concave utility function, the optimal use intensity (operating hours) of a generator can be expressed as a function of a household's socioeconomic and demographic characteristics, the operating (fuel) cost, and electricity service reliability attributes, among other factors. Suppose that the generator use intensity equation is linear and that we denote these determinants of use intensity as vector $\boldsymbol{S}$. Then, for household $i = 1, 2, \dots N$, the optimal hours of operating a generator in the event of a power outage can be expressed as:

$$H_i = \boldsymbol{S}_i \boldsymbol{\beta} + u_i \quad (10)$$

Equation (10) represents the second stage (generator usage) involved in self-generation. $H$ denotes the use intensity or the degree of use (measured by the average number of hours during which a generator is run by a household per day), and $\boldsymbol{S}_i$ is a set of variables including the running (fuel) cost and the household's socioeconomic characteristics and service-quality attributes, which affect how many hours a (generator-owning) household uses its generator daily. $\boldsymbol{\beta}$ is a vector of the parameters and $u_i$ is the error term assumed to be independently and normally distributed with the mean zero and constant variance.

Despite the poor quality of supply, a significant share of households in Nigeria do not use a generator. It may appear reasonable that a Heckman selection technique would be appropriate in this context because a large percentage of households report zero hours of backup generation. However, the Heckman technique is designed for incidental truncation where the zeros are unobserved values. In this context, a corner solution model is more appropriate than a selection model because backup generation as a coping strategy for service unreliability has been available for decades in Nigeria, and is well known to the vast majority of (electrified) households. Therefore, the zeros in the data reflect households' optimal choice instead of representing a missing value. One method of catering for corner solutions is to use a tobit model (Tobin, 1958).

However, the tobit model is fairly restrictive because it requires that the decision on whether or not to own a generator and the number of hours a consumer operates his/her generator (use intensity) are affected in the same ways by the same factors. This assumption may be unrealistic, however. It is reasonable to assume that the choice to own a generator might be affected by, for example, capital cost, which is independent of the total hours during which a household would operate the generator. While daily or monthly budgetary restrictions might not necessarily or significantly influence a consumer's decision to own a generator, for instance, they might significantly affect the actual hours during which a consumer operates the generator during outages. As an alternative to the tobit model, Cragg (1971) proposed a more flexible double-hurdle model that accounts for possible variation in the factors that influence the purchase decision and the actual usage. Cragg's model is a flexible double-hurdle model that accounts for possible variation in the factors that influence the (backup generator) adoption decision and the intensity of its use (operating hours). One other advantage of the double-hurdle model is that it allows the same factor to affect adoption and intensity of use in different ways. In the first hurdle, households decide whether or not to own a generator. If they choose to do so, the second hurdle considers the average duration (in hours) of generator use in the event of power outages.

Cragg's model is an integration of a probit model to determine the probability of owning a generator and the truncated normal model for usage patterns. The likelihood function for Cragg's model – combining equations (9) and (10) – is:

$$f(w, H \mid \boldsymbol{z}_i, \boldsymbol{\mathcal{S}}_i) = \{1 - \Phi(\boldsymbol{z}_i\boldsymbol{\alpha})\}^{1(w=0)}$$

$$\left[\Phi(\boldsymbol{z}_i\boldsymbol{\alpha})(2\pi)^{-\frac{1}{2}}\sigma^{-1}exp\{-(H - \boldsymbol{\mathcal{S}}_i\boldsymbol{\beta})^2/2\sigma^2\}/\Phi(\boldsymbol{\mathcal{S}}_i\boldsymbol{\beta}/\sigma)\right]^{1(w=1)} \quad (11),$$

where $w$ is a binary indicator variable equal to unity if a household owns a generator and 0 otherwise. Equation (11) allows for the ownership and use intensity of a generator to be determined by different mechanisms (the vectors $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$). Moreover, equation (11) places no restriction on the elements of $\boldsymbol{z}_i$ and $\boldsymbol{\mathcal{S}}_i$, implying that the factors influencing each decision may differ (Burke, 2009). Previous studies have found that the double-hurdle model outperforms the tobit estimator (Aristei and Pieroni, 2008; Garcia and Labeaga, 1996). The appropriateness of the double-hurdle model compared to the tobit estimator can be examined using a standard likelihood ratio test.

Cragg's (1971) original formulation assumed that, conditional on the covariates, the errors between the first and second hurdles were independent and normally distributed, and the covariance between the two errors was equal to zero. Although several studies have relaxed the independent error term assumption in their models, the results have, however, remained similar regardless of whether or not the assumption was relaxed (Aristei and Pieroni, 2008; Garcia and Labeaga, 1996; Jones, 1992). This study therefore maintains Cragg's original assumption of independent errors but tests for the relative performance of Cragg's model against the tobit model.

From equation (11), the average use intensity (average use hours per day) of a generator by a given backup householder is:

$$E(H|w > 0) = \overline{\boldsymbol{S}}_i\boldsymbol{\beta} + \sigma.\lambda\left(\overline{\boldsymbol{S}}_i\boldsymbol{\beta}/_{\sigma}\right) \quad (12),$$

where $\lambda(c)$ is the inverse Mills ratio (IMR) and $\overline{\boldsymbol{S}}_i$ is the mean vector of exogenous variables (i.e. household characteristics) in the second-hurdle (i.e. the usage) model.

**2.2 Improved reliability and generator disposal**

This section discusses the method used to examine how improved reliability might reduce self-generation by using a random-effects probit model. The choice of a random-effects probit model is informed by the desire to account for unobserved characteristics that might affect individual responses to various proposed reliability levels.

Consider the following model:

$$y_{it}^* = \boldsymbol{m}_i{}'\boldsymbol{\beta} + \varepsilon_{it} \qquad i = 1, 2, \dots, n \; and \quad t = 1, 2 \dots T \quad (13),$$

$$\varepsilon_{it} = v_i + u_{it} \quad (14),$$

and

$y_{it} = 1$ if $y_{it}^* > 0$ and 0 otherwise,

where the variable $y^*$ denotes the unobserved variable, $y$ is the observed outcome indicating whether a household would be willing to dispose of their generator, $\boldsymbol{m}$ is a vector of the household characteristics that influence $y^*$, $\boldsymbol{\beta}$ is a vector of the coefficients associated with $\boldsymbol{m}$,

$t = 1, 2 \ldots T$ indexes the proposed reliability level questions, and $i = 1, 2, \ldots, n$ indexing the respondents. $v_i$ denotes the individual specific unobservable effect, and $u_{it}$ is a random error term with a mean of zero and a variance of $\sigma_u^2$. The correlation between two successive error terms for the same individual is a constant:

$$\rho = corr(v_{it}, v_{it-1}) = \frac{\sigma_v^2}{\sigma_v^2 + \sigma_u^2}.$$

As shown in Heckman (1981), the model can be estimated, assuming that the distribution of $y_{it}^*$ is conditional on $v_i$ being independent normal, as:

$$Prob\ (y_{it} = 1 | v_i, \boldsymbol{m}_{it}) = Prob\left(\frac{u_{it}}{\sigma_u} > \frac{-\boldsymbol{m}_{it}'\boldsymbol{\beta} - v_i}{\sigma_u}\right) = \Phi(\mathbf{Z}_{it}) \qquad (15),$$

where

$$\mathbf{Z}_{it} = -(\boldsymbol{m}_{it}'\boldsymbol{\beta} + v_i)/\sigma_u \qquad (16),$$

and $\Phi$ is the distribution function of the standard normal variate.

The random-effects probit model is capable of handling multiple responses, although it does have its own set of restrictive assumptions. Alberini, Kanninen and Carson (1997) suggested that a random-effects/error-component model might be appropriate for analysing the multiple dichotomous-choice responses at different bid levels for the same program (e.g. the double-bounded approach). Such a modelling technique is considered useful where the same individual responds to a series of dichotomous questions regarding various proposed levels of reliability and their willingness to dispose of their backup generator. However, a notable disadvantage of this modelling structure is that it implicitly restricts the model to using the same coefficients and variables to explain all the dichotomous choices.

### 2.3 Selection of variables

The literature on the micro-level determinants of household energy consumption and the study objectives provide a useful guide to selecting relevant variables for our analyses. Several socioeconomic and demographic variables, including income, level of education, respondent's age, gender, marital status, household size, the nature of the housing unit (i.e. whether a respondent lives in shared accommodation), employment status, number of household electrical appliances owned, and whether a household operates a home-based business, are included. These variables have been found to have significant effects on household energy consumption (Ironmonger, Aitken, and Erbas, 1995; Narasimha Rao and Reddy, 2007; Özcan, Gülay, and Üçdoğruk, 2013), and are therefore expected to influence households' ownership and usage of a backup generator, and their disposal decisions. A priori, income is expected to be positively related to generator ownership and use intensity, but negatively related to generator disposal decisions. This is because affluent households are more likely to be able to afford the costs of procuring and running a generator. Moreover, wealthy families are more likely to own more electrical appliances that require electricity, which can only be provided by a generator during outages.

Empirical evidence has shown that the education status of household heads is positively related to their preferences for modern energy use (Narasimha Rao and Reddy, 2007). Thus, better-educated households are expected to have a higher probability of owning a generator and a higher use intensity, and be less likely to be willing to dispose of it, because their generator serves as a substitute for the poor grid electricity (i.e. modern energy) in light of the poor supply reliability. Similarly, households that own more appliances and those that operate a home-based business are expected to own a generator, have a higher use intensity, and be less willing to get rid of their generator. Conversely, households who reside in shared apartments are expected to have a lower generator adoption rate, low use intensity (if they do have one), and a higher probability of stating their willingness to dispose of their generator. This is because households sharing apartments are more likely to be low-income earners compared to households that do not live in shared apartments. Age is included to capture the effects of age on generator ownership, usage and disposal decisions. Leth-Petersen (2002) found age to be one of the significant determinants of household electricity consumption. Gender and marital status are expected to have significant effects, but their directions are ambiguous.

In addition to demographic variables, electricity service attributes – frequency and duration of outages – are included. Both attributes are expected to be positively related to generator ownership and its usage, but are expected to be negatively associated with generator disposal decisions. Moreover, generator capacity and fuel costs are included in the generator use intensity and disposal regressions in order to capture the extent to which generator size and fuel cost might affect usage behaviour and willingness to dispose of a generator. A priori, generator size is expected to be positively related to usage because bigger generators can run for longer periods. Its effect on the disposal decision is less clear, however. On the contrary, fuel cost is expected to negatively affect generator use but positively influence disposal decisions. Regional variables (i.e. state dummy – Osun being 1 and 0 otherwise) are included in all models in order to control for regional variation effects. Given the relatively low economic status of the state, Osun State's residents are less likely to own a generator, and are expected to have lower use intensity and be more willing to dispose of their generators in the face of improved reliability.

Finally, two variables reflecting the respondents' opinions regarding their perception of improvements in service and their expectations about future service performance are included. The variable labelled *perception* is a dummy variable denoting whether a respondent reported experiencing improvements in electricity supply within the three months prior to the survey. This variable is expected to be negatively related to generator use intensity and positively related to disposal decisions, because the running of a generator is expected to be inversely related to electricity service reliability. The second variable (*optimism/confidence*), denoting whether a respondent expressed confidence or optimism about improvements in service within six months following the survey, is included in the generator disposal regression. The latter variable is included to test for the extent to which consumer confidence in future improvement can explain generator disposal decisions. This variable is expected to be positively related to generator disposal decisions.

## 3. Data

The data used for this study were from the 2013 survey of Nigerian household electricity users residing in Lagos and Osun States. A detailed discussion on this survey is provided in Oseni (2015). Determining the optimal sample size of the target population is an essential step in survey studies. Determination of the optimal sample size followed the method proposed by the United Nations Statistics Division (2005), taking into consideration the population characteristics and study objectives.[4] Assuming a non-response rate of 25% based on Otegbulu's (2011) study, a 10% margin of error and a 95% confidence interval, the method yielded optimal sample sizes of 673 and 703 for Lagos and Osun, respectively. The survey was conducted from January through April 2013. Questionnaires were administered by the author with the help of three experienced research assistants. For the survey, 1,376 households were contacted, of which 1,008 responded.

[4] These include information on the number of electrified households, household size, etc. The proportion of electrified households was proxied by the national electrification rate, which was approximately 55% at the time of the survey.

However, only 835 responses, representing a 60.6% response rate, were analysed since the remaining responses were incomplete.

In the survey, respondents were asked questions regarding the level of unreliability in electricity supply, ownership of a backup generator and its usage (i.e. average hours of running their generators per day), and their willingness to dispose of their generators given various levels of improvements in the daily supply of electricity from the public grid. The proposed improvements in supply reliability range from 2–12 hours per day. The proposed improvements were based on the information gathered from focus group discussions held before designing the questionnaire. Table 1 presents the characteristics of the sample respondents. Around 58% of the respondents were males and the average age was 43 years. On average, there are four members per household, about 74% of the households reside in shared accommodation, and each household has an average of more than three electrical appliances. 85% of the respondents were actively employed. Around 23% of the sample belonged to the lowest 20% of income distribution, while 13% of the respondents occupied the top 20%.

On average, a respondent experienced power outages three times a day, with the average outage lasting for approximately four hours. Approximately 54% of the respondents own a backup generator with an average capacity of 1.9 kW. This high rate of generator adoption reflects the poor reliability of the publicly provided electricity in the country. On average, owners use their generators for approximately four hours daily and spend around N51.3 (US$0.33) on generator fuel per hour. The survey results also reveal heterogeneities in backup ownership among respondents. Overall, 61% of all the generator users are male respondent households. Around 59% of all male respondents own a generator compared to 50% of the females. Similarly, roughly 59% of the households operating a home-based business maintain a backup generator compared to 53% of households without a home-based enterprise. While around 85% of the richest households own a backup generator compared, only 31% of the poorest households are generator users.

TABLE 1 HERE

Figure 2 presents the percentages (%) of backup households according to their willingness to get rid of their generators in response to the proposed improved grid supply reliability. On average, only around one-fifth of backup-generator owners would be willing to dispose of their generators. However, willingness to stop self-generation increases as service becomes more reliable. The share of households who would be willing to get rid of their generator increases from 2% to 43% as service supply improves by an additional 2–12 hours daily (Figure 2), suggesting that improved reliability would go a long way in reducing the use of generators. However, almost 16% of backup owners (not shown on the graph) would still not want to dispose of their generators even when the proposed service improvements mean the unreliability they are currently experiencing is reduced. This suggests that improved reliability in service supply alone might not be enough to stop the use of private generators in Nigeria.

FIGURE 2 HERE

## 4. Results and Discussion

### 4.1 Generator ownership and use intensity

Table 2 presents the results obtained from equation (11) on the adoption and use intensity of backup generators in Nigerian homes. The reported estimates were obtained by estimating the double-hurdle model in equation (11), which is based on Cragg's (1971) methodology. Only the results from the double-hurdle estimator are reported because a specification test shows that the double-hurdle model fits the data better than the tobit estimator. The likelihood ratio statistic of comparing the tobit and double-hurdle models is 117.04, indicating that the tobit estimator could easily be rejected in favour of the double-hurdle model, even at 1% significance (Table 2).

The results show that wealth, gender, household size, having a home-based business, housing type, geographical location, and, to a lesser degree, service attributes (outage frequency and duration) and electrical appliances significantly affect households' adoption of a backup generator. Male respondents, high-income households, those who have a home-based business and households that have experienced relatively low reliability had a higher probability of owning a backup generator. That income significantly and positively influenced ownership of a backup generator is not surprising because richer households are more likely to be able to afford generator costs. Similarly, those who operate home-based businesses would likely demand a backup generator as a substitute for the unreliable grid service due to the benefits of having uninterrupted electricity for their income-generating business activities. Males might have a higher probability of having a generator because their lifestyles require more energy consumption than females' lifestyles, e.g. they own more energy-consuming appliances.

Conversely, older people, larger households, households living in shared apartments and those residing in Osun State were less likely to have a generator. Older people might have a lower probability of having a generator because their lifestyles require less energy use. In Nigeria, lighting, cooking, refrigeration and powering the television, radio and fan/air-conditioner are the main electricity-consuming activities of households. Changes in lifestyle due to old age might reduce engagement in such activities. Larger households might be unable to afford a backup generator due to their income constraints and large necessary expenditure (e.g. food, health, etc.), which might explain the lower probability of their having a backup generator. Those who live in shared apartments are more likely to be poor, and this might explain the low rates of generator adoption among sharers compared to households occupying a non-shared apartment. Relative to Lagos State, the fact that generator adoption in Osun State was low is unsurprising because Osun's economy is relatively underdeveloped compared to Lagos's.

TABLE 2 HERE

The results from the second-hurdle model indicate that service-quality attributes, generator size, running cost (i.e. fuel cost per hour), income, age, education, geographical location, and the consumer's perception of the improvement in electricity supply significantly influence the intensity of generator use. Although service-quality attributes (frequency and duration), income, education and generator size increased the use intensity of a generator, older people, Osun State residents and those who had perceived improvements in supply before the survey used their generator for fewer hours than other generator users. The significance of income in the two models (i.e. the ownership and usage models) indicates that wealthy households did not only have higher backup adoption rates, but also used their generators more intensively than poor householders.

Although larger households were less likely to engage in self-generation, their duration of self-generation did not differ if they owned a generator. Similar behaviour was observed for households residing in shared apartments. Similarly, male respondents only had a higher probability of engaging in self-generation; the duration of their self-generation did not significantly differ from that of female respondents. Similar behaviour was observed among those who operated a home-based business. Between the two service-quality attributes, the frequency of outages appears to be more significant than outage duration in making decisions regarding the usage of a backup generator. As expected, backup households' experience of improved service reliability prior to the survey was associated with a 2-percentage-point reduction in generator usage.

Based on equation (12), the average use intensity (i.e. average operating hours) of a generator among users is estimated. The estimate reveals that an average backup household operated its generator for 4.5 hours daily. Given the mean daily outage time of 12 hours experienced by respondents, this result indicates that the average backup household only operated their generator for about 38% of the time they experienced power outages per day.

### 4.2 Service improvements and willingness to dispose of generator

Table 3 shows the results of the factors affecting households' willingness to dispose of their generators based on equation (15). As expected, the results indicate that the higher the proposed reliability, the higher people's willingness to dispose of their generators would be. At a 1% significance level, an hour's increase in supply reliability increases the probability of ending self-generation by 3%. Surprisingly, respondents who had a home-based business were 2 percentage points more likely to express willingness to dispose of their generators. This decision might be related to their experience of the poor cost-competitiveness of self-generation. Gender differentials and consumer perception significantly (at a 1% level) increased the probability of expressing willingness to get rid of a generator. Male respondents and those who had perceived improvements in grid services were, respectively, 5 and 6 percentage points more likely to express willingness to get rid of their generators.

Conversely, rich households and better-educated respondents were less likely to express willingness to get rid of their generators compared to low-income and less-educated households.

At a 1% level of significance, a change in household income threshold status (such as the movement from a lower decile group to a higher income distribution) averagely reduced the probability of expressing willingness to get rid of self-generation by 3% (Table 3). Most notable (see Table A1 in the appendix) was the greater negative effect of a high income (especially in the top 20% threshold) on the probability of expressing willingness to end self-generation in the face of improved reliability. Respondents who have a degree or higher qualification were 5 percentage points less likely to express willingness to dispose of their generators, regardless of the proposed improvements in service reliability. This suggests that self-generation will probably continue among rich and educated households, even if the public supply improves.

Contrary to what might be expected, households sharing apartments were 5 percentage points less likely to express willingness to dispose of their generators (if they did have one), regardless of the proposed improvements in service reliability (Table 3). Their unwillingness to dispose of their generators might be related to their belief that their close neighbours might perceive their actions as a sign of a negative change in their socioeconomic status (e.g., inability to afford operating costs). Similarly, Osun State residents (who owned a generator) were less likely to express willingness to dispose of their generators, regardless of the proposed improvements in service reliability. However, the reason for this observed behaviour is not clear considering the relatively more affluent nature of Lagos.[5]

As expected, respondents who reported experiencing improvements in services prior to the survey were 6 percentage points more likely to express willingness to get rid of their generators. However, optimism/confidence about future improvements did not play a significant role in disposal decisions. Finally, the estimated results further show that the average household that

[5] One would expect residents of Osun State to be more willing to get rid of their generators considering the operating costs of maintaining a generator and the relatively low socioeconomic status of the state compared to Lagos.

expressed willingness to get rid of their generator would require an average of nine hours of improved service reliability in addition to the current reliability level.

TABLE 3 HERE

## 5. Conclusions and Policy Implications

We have studied the factors motivating the ownership and use of backup generators, and the extent to which improved electricity services might reduce self-generation in Nigerian homes. The results revealed that income significantly increased the probability of owning and operating a generator; however, it significantly reduced willingness to dispose of a generator in the face of improved reliability. Although the level of education was not significantly related to generator ownership, it did significantly reduce willingness to stop self-generation, regardless of improvements in service quality. However, improvements in service reliability were significantly associated with an increase in the probability of expressing willingness to dispose of a generator. These findings imply that, although a number of households would get rid of their backup generators as the quality of service improves, self-generation will continue in the country, especially among rich and educated households. This suggests that it would be difficult to totally eradicate the use of generators in the country, and, by implication, it would be hard to completely eliminate the negative effects of self-generation, such as carbon emissions and the occasional deaths associated with generator fumes.

A number of policy implications emerged from this study. Between the two service-quality attributes, the frequency of outages appears to be more significant than outage duration in making decisions regarding the usage of a backup generator. This suggests that improving the stability and continuity of power supply to reduce frequency of outages is urgently required before making efforts to shorten the outage duration. To address the adverse health and environmental effects of backup generation in Nigeria, ecologically friendly, affordable, and effective means of generating electricity centrally and/or off-grid are urgently required. Private sector investment in electricity needs to grow significantly. The government can consider implementing a monetary policy that offers low-interest loans to private investors willing to invest in power generation, distribution and supply, in order to ensure improved reliability and less dependence on backup generation. Considering the rising threat of climate change, combinations of renewable energy sources (such as solar, wind and nuclear energy) need to be seriously considered, adequately funded, and properly implemented in order to increase power generation. The introduction and proper implementation of green subsidies should be considered in order to promote environmentally friendly renewable power generation. Moreover, transmission and distribution networks need to be adequately funded and upgraded to reduce energy losses.

Considering the time lag between when investments in generation are made and when the impacts can be seen (e.g. building nuclear power plants takes time), there is a need for immediate policies to address the rising emissions from self-generation. In the short or medium term, liquefied gas-powered generators could be introduced to replace diesel-powered generators. The government could implement policies to regulate the emission efficiency standard of the diesel engines (including generators) to be imported into and used in Nigeria. In the longer term, and given that self-generation might continue among the rich, fiscal policies, such as raising import tariffs on the importation of generators and introducing a pollution tax in addition to improving reliability, can be considered.

However, the findings of this study should be interpreted with caution. The data used for this study were obtained from 2 of the 36 states (excluding the federal capital) in Nigeria. Although backup generation is a common phenomenon in Nigeria, the decisions identified on whether or not to get rid of generators might not accurately reflect the behaviour of households across all Nigerian states. Social and cultural differences might have a role to play. To conveniently examine the validity of this study's findings, it may be necessary to re-examine how proposed reliability might affect generator users' intentions to get rid of their backup generators using a nationally representative large-scale field survey.

## Acknowledgements

The author appreciates the helpful comments from the anonymous referees. The author also thanks the Journal Editor for his professional handling of the review process. Financial support with Grant number TT022014 from the African Economic Research Consortium (AERC) is gracefully appreciated. The usual disclaimer applies.

## References

Alberini, A., Kanninen, B., & Carson, R. T. (1997). Modeling Response Incentive Effects in Dichotomous Choice Contingent Valuation Data. *Land Economics*, *73*(3), 309–324.

Aristei, D., & Pieroni, L. (2008). A double-hurdle approach to modelling tobacco consumption in Italy. *Applied Economics*, *40*(19), 2463–2476.

Awofeso, N. (2011). Generator Diesel Exhaust: a Major Hazard to Health and the Environment in Nigeria. *American Journal of Respiratory and Critical Care Medicine*, *183*(10), 1437–1437.

Burke, W. J. (2009). Fitting and interpreting Cragg's tobit alternative using Stata. *The Stata Journal*, *9*(4), 584–592.

Cragg, J. G. (1971). Some Statistical Models for Limited Dependent Variables with Application to the Demand for Durable Goods. *Econometrica*, *39*(5), 829–844.

Engineering Institution of Zambia. (2015). *Report on ZESCO Load Shedding*. Engineering Institute of Zambia, Zambia.

Faiella, I. (2011). *The demand for energy of Italian households* (No. 822). *Temi di discussione series*. Retrieved from http://www.feem.it/userfiles/attach/20123261435152012.03.22_Ivan Faiella_paper.pdf

Garcia, J., & Labeaga, J. (1996). Alternative Approaches to Modelling Zero Expenditure: An

Application to Spanish Demand for Tobacco. *Oxford Bulletin of Economics and Statistics*, *58*(3), 489–507.

Heckman, J. J. (1981). Statistical models for discrete panel data. In C. F. Manski & D. McFadden (Eds.), *Structural Analysis of Discrete Data with Econometric Applications* (pp. 114– 178). Cambridge, MA: MIT Press.

Ironmonger, D. S., Aitken, C. K., & Erbas, B. (1995). Economies of scale in energy use in adult-only households. *Energy Economics*, *17*(4), 301–310. http://doi.org/10.1016/0140-9883(95)00032-P

Jones, A. M. (1992). A Note on Computation of the Double-Hurdle Model with Dependence with an Application to Tobacco Expenditure. *Bulletin of Economic Research*, *44*(1), 67–74.

Kagawa, J. (2002). Health effects of diesel exhaust emissions—a mixture of air pollutants of worldwide concern. *Toxicology*, *181-182*, 349–353.

Kenyon, N., & Liu, F.-T. (2011). Pulmonary effects of diesel exhaust: neutrophilic inflammation, oxidative injury, and asthma. *The American Journal of Pathology*, *179*(6), 2678–82.

Khandker, S. R., Barnes, D. F., & Samad, H. A. (2012). The Welfare Impacts of Rural Electrification in Bangladesh. *The Energy Journal*, *33*(1), 187–207.

Khandker, S. R., Samad, H. A., Ali, R., & Barnes, D. F. (2014). Who Benefits Most from Rural Electrification? Evidence in India. *The Energy Journal*, *35*(2), 75–96.

Leth-Petersen, S. (2002). Micro Econometric Modelling of Household Energy Use: Testing for Dependence between Demand for Electricity and Natural Gas. *The Energy Journal*, *23*(4), 97–122.

Loh, M. M., Levy, J. I., Spengler, J. D., Houseman, E. A., & Bennett, D. H. (2007). Ranking cancer risks of organic hazardous air pollutants in the United States. *Environmental Health Perspectives*, *115*(8), 1160–8.

Narasimha Rao, M., & Reddy, B. S. (2007). Variations in energy use by Indian households: An analysis of micro level data. *Energy*, *32*(2), 143–153. http://doi.org/10.1016/j.energy.2006.03.012

National Bureau of Statistics (NBS). (2012). *LSMS – Integrated Surveys on Agriculture: General Household Survey Panel 2010/11* (Vol. 2012). Abuja, Nigeria.

Ogundipe, S. (2013, October 9). Portable generators: Standby power or standby death? *Nigerian Vanguard*. Lagos, Nigeria. Retrieved from http://www.vanguardngr.com/2013/10/portable-generators-standby-power-standby-death/

Olsson, A. C., Gustavsson, P., Kromhout, H., Peters, S., Vermeulen, R., Brüske, I., … Straif, K. (2011). Exposure to diesel motor exhaust and lung cancer risk in a pooled analysis from case-control studies in Europe and Canada. *American Journal of Respiratory and Critical Care Medicine*, *183*(7), 941–8.

Oseni, M. O. (2015a). Assessing the consumers ' willingness to adopt a prepayment metering system in Nigeria. *Energy Policy*, *86*, 154–165.

Oseni, M. O. (2015b). *Essays on Self-generation and Payments for Quality of Service in Electricity Markets. Unpublished PhD Research*. University of Cambridge, UK.

Otegbulu, A. C. (2011). A contingent valuation model for assessing electricity demand. *Journal of Financial Management of Property and Construction*, *16*(2), 126–146.

Özcan, K. M., Gülay, E., & Üçdoğruk, Ş. (2013). Economic and demographic determinants of household energy use in Turkey. *Energy Policy*, *60*, 550–557. http://doi.org/10.1016/j.enpol.2013.05.046

Salami, M. A., Adeoye, P. O., & Adegboye, V. (2010). Bronchogenic carcinoma: Clinicopathologic pattern in Nigerians. *Journal of Clinical Oncology*, *28*, e12065.

Sydbom, A., Blomberg, A., Parnia, S., Stenfors, N., Sandstrom, T., & Dahlen, S.-E. (2001). Health effects of diesel exhaust emissions. *European Respiratory Journal*, *17*, 733–746.

Tobin, J. (1958). Estimation of Relationships for Limited Dependent Variables. *Econometrica*, *26*(1), 24–36.

United Nations Statistical Division. (2005). *Designing household survey samples: practical guidelines* (Studies in). New York: Department of Economics and Social Affairs, United Nations Statistical Division. Retrieved from http://unstats.un.org/unsd/demographic/sources/surveys/Handbook23June05.pdf

World Bank. (2002). *Rural Electrification and Development in the Philippines: Measuring the Social and Economic Benefits*. *UNDP/Energy Sector Management Assistance Program (ESMAP) Report No. 255/02*. Washington DC.

World Bank. (2012). World Bank Surveys of Business Enterprises. Retrieved from http://www.enterprisesurveys.org/

LIST OF TABLES

Table 1: Description of variables used

| Explanatory variable | Description | Observation | Mean/percentage |
|---|---|---|---|
| Gender | male (%) | 835 | 58.0 |
| Age | age of respondent (mean) | 815 | 43.0 |
| Employed | employed (%) | 835 | 85.0 |
| Marital status | married (%) | 835 | 80.0 |
| Household size | number of household members (mean) | 835 | 4.2 |
| Shared house | if the respondent lived in shared accommodation (%) | 835 | 73.7 |
| Appliances | average number of electrical appliances per household | 835 | 3.4 |
| Income distribution: | lowest 20% distribution (% of population) | 177 | 22.9 |
| | 40% distribution (% of population) | 225 | 29.1 |
| | 60% distribution (% of population) | 168 | 21.7 |
| | 80% distribution (% of population) | 101 | 13.1 |
| | highest 20% (% of population) | 102 | 13.2 |
| Home business | the respondent had a home business (%) | 835 | 41.0 |
| Education | if the respondent had a degree or higher qualification (%) | 835 | 14.0 |
| Outage time: | frequency of power outage per day (mean) | 830 | 3.1 |
| | duration per outage (mean) | 830 | 4.0 |
| Perception | the respondent had recently experienced improvement in service (%) | 835 | 42.9 |
| Optimism/confidence | if the respondent was confident/optimistic that service would improve within six months after the survey (%) | 835 | 55.3 |
| Generator capacity | average capacity of generator held by respondents (kW) | 447 | 1.9 |
| Generator use intensity | average hours for which a generator was run per day (mean) | 444 | 4.3 |
| Fuel cost | fuel cost of running a generator per hour (Naira) | 444 | 51.3 |

Source: Author's Survey of Nigerian households 2013.

Table 2: A double hurdle model of generator ownership and intensity of use

| Dependent variable | **generator ownership** | | | **use intensity** | | |
|---|---|---|---|---|---|---|
| | coefficient | std. error | marginal effect | coefficient | std. error | average partial effect (APE) |
| Frequency of outage (daily) | 0.09* | (0.05) | 0.03 | 0.29** | (0.13) | 0.08 |
| Duration | 0.04* | (0.02) | 0.01 | 0.11* | (0.06) | 0.03 |
| Generator capacity | | | | 0.46*** | (0.12) | 0.13 |
| Fuel cost per hour | | | | -0.02*** | (0.005) | -0.02 |
| Perception | | | | -1.10*** | (0.40) | -0.31 |
| Appliances # | 0.08* | (0.05) | 0.02 | 0.09 | (0.14) | 0.03 |
| Education | -0.09 | (0.19) | -0.03 | 0.92** | (0.46) | 0.26 |
| Income | 0.21*** | (0.05) | 0.06 | 0.28* | (0.16) | 0.08 |
| Age | -0.02*** | (0.004) | -0.01 | -0.04** | (0.02) | -0.01 |
| Household size | -0.05** | (0.02) | -0.01 | -0.02 | (0.06) | -0.01 |
| Shared house | -0.76*** | (0.19) | -0.21 | -0.19 | (0.49) | -0.05 |
| Employed | 0.07 | (0.17) | 0.02 | -0.98 | (0.57) | -0.27 |
| Male | 0.32*** | (0.12) | 0.09 | 0.13 | (0.36) | 0.04 |
| Married | 0.24 | (0.16) | 0.07 | 0.59 | (0.52) | 0.17 |
| Home business | 0.33*** | (0.11) | 0.09 | 0.24 | (0.36) | 0.07 |
| State (osun=1) | -0.97*** | (0.13) | -0.27 | -2.04*** | (0.47) | -0.57 |
| Constant | 0.60 | (0.44) | | 4.37*** | (1.99) | |
| Number of observations | 682 | | | | | |
| Log-likelihood | -1159.26 | | | | | |
| Wald –statistics | 194.07*** | | | | | |
| Sigma ($\sigma$) | 2.73*** | | | | | |
| LR Test Statistics | 117.04. *p- 0.00* | | | | | |

***, **, *, denotes significant at 1%, 5% and 10% respectively.

Table 3: Improved reliability and willingness to dispose of a generator

| Dependent variable: decisions on generator disposal | coefficient | std error | marginal effects |
|---|---|---|---|
| Proposed reliability (hours) | 1.40*** | (0.14) | 0.03 |
| Frequency of outage (daily) | 0.52** | (0.21) | 0.01 |
| Duration per | 0.06 | (0.10) | 0.001 |
| Fuel cost per hour | -0.001 | (0.01) | -0.0001 |
| Use intensity | 0.04 | (0.09) | 0.001 |
| Perception | 2.57*** | (0.61) | 0.06 |
| Optimism/confidence | -0.53 | (0.54) | -0.01 |
| Appliances # | 0.15 | (0.19) | 0.003 |
| Education | -2.40*** | (0.67) | -0.05 |
| Income | -1.20*** | (0.24) | -0.03 |
| Age | -0.02 | (0.20) | -0.001 |
| Shared house | -2.50*** | (0.62) | -0.05 |
| Employed | 1.28 | (0.85) | 0.03 |
| Male | 2.42*** | (0.53) | 0.05 |
| Married | 1.12 | (0.67) | 0.02 |
| Home business | 1.01* | (0.52) | 0.02 |
| State (osun=1) | -1.71*** | (0.61) | -0.04 |
| Constant | -19.74*** | (2.62) | |
| Number of obs | 1,930 | | |
| Number of groups | 386 | | |
| rho ($\rho$) | 0.98*** | | |
| Wald-statistics | 132.50*** | | |
| Log likelihood | -524.69 | | |

***, **, *, denotes significant at 1%, 5% and 10% respectively.

# Appendix

Table A1: Improved reliability and willingness to dispose of a generator

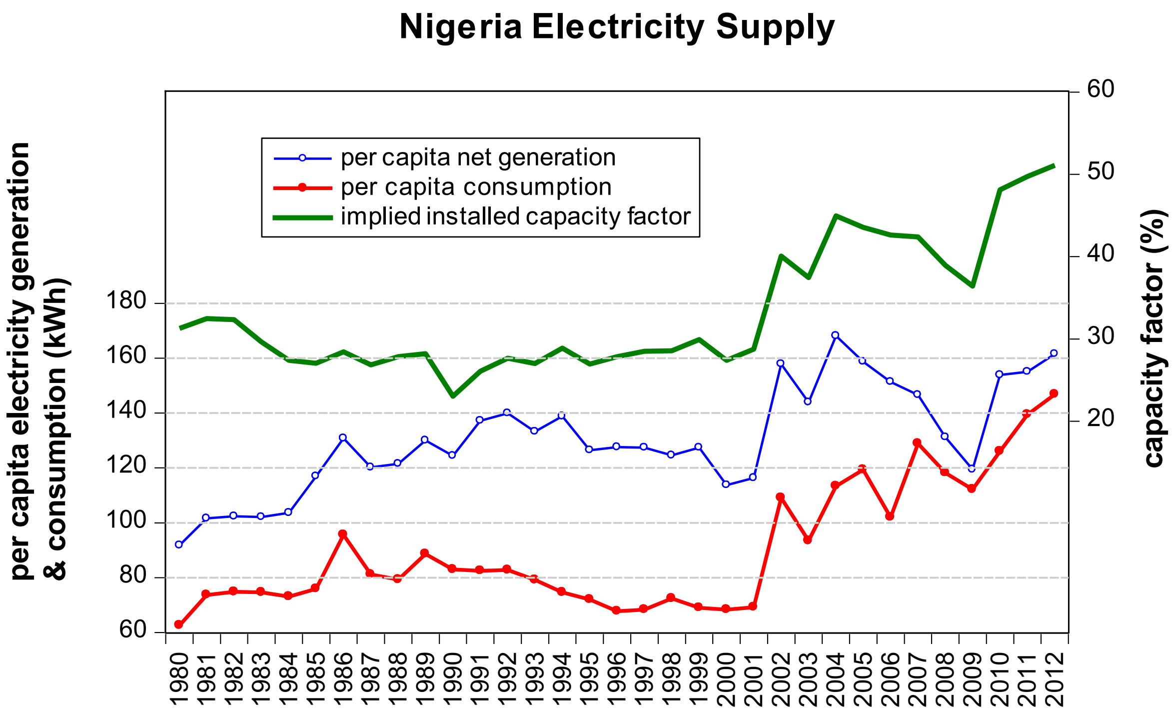
| Dependent variable: decisions on generator disposal | coefficient | std error | Marginal effects |
|---|---|---|---|
| Proposed reliability (hours) | 1.43*** | (0.16) | 0.03 |
| Frequency of outage (daily) | 0.52** | (0.22) | 0.01 |

| | | | |
|---|---|---|---|
| Duration per outage | 0.05 | (0.10) | 0.001 |
| Fuel cost per hour | -0.003 | (0.01) | -0.0001 |
| Use intensity | 0.04 | (0.10) | 0.001 |
| Perception | 2.53*** | (0.62) | 0.05 |
| Optimism/confidence | -0.52 | (0.55) | -0.01 |
| Appliances # | 0.18 | (0.20) | 0.004 |
| Education | -2.50*** | (0.68) | -0.05 |
| Income distribution | | | |
| bottom 40% | -2.12*** | (0.67) | -0.06 |
| bottom 60% | -3.25*** | (0,80) | -0.08 |
| top 40% | -2.93*** | (0.94) | -0.08 |
| top 20% | -5.51*** | (1.09) | -0.10 |
| Age | -0.02 | (0.02) | -0.0004 |
| shared house | -2.52*** | (0.62) | -0.05 |
| Employed | 1.33 | (0.87) | 0.03 |
| Male | 2.46*** | (0.54) | 0.05 |
| Married | 1.30* | (0.70) | 0.03 |
| Home business | 1.02* | (0.52) | 0.02 |
| State (osun=1) | -1.89*** | (0.61) | -0.04 |
| Constant | -21.28*** | (2.80) | |
| Number of obs | 1,930 | | |
| Number of groups | 386 | | |
| rho $\rho$) | 0.99*** | | |
| wald –statistics | 125.59*** | | |
| Log likelihood | -523.93 | | |

***, **, *, denotes significant at 1%, 5% and 10% respectively.

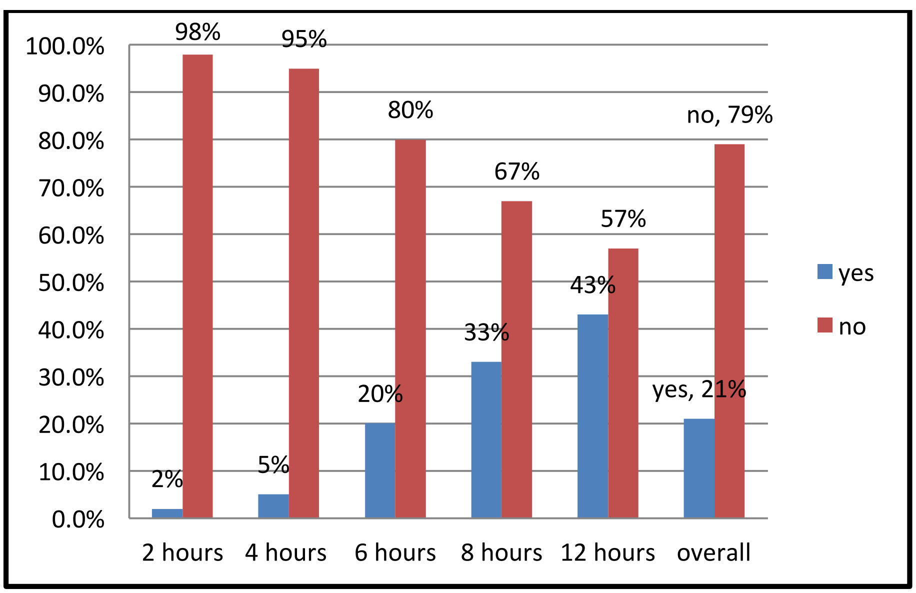
LIST OF FIGURES

Figure 1: Nigeria Electricity Supply




Data from EIA http://www.eia.gov/countries/country-data.cfm?fips=NI#elec

Figure 2: Shares (%) of respondents willing to sell backup generator, by improved reliability




Source: Author's Survey of Nigerian households 2013.