

Demand for Electricity and Benefits from Rural Electrification: Evidence from Kabupaten Musi Banyuasin (Muba)¹

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Abstract

Rural electrification programs are often the preferred policy to promote rural development in developing countries where many continue to live without access to electricity. This paper investigates household demand for electricity and potential economic benefits from a prospective rural electrification program, using data from a survey of households in Musi Banyuasin (Muba) District in South Sumatra. Electrification is defined as a move from unelectrified and non-grid sources, including those with generators toward grid electricity. First, determinants of electricity demand, including household socio-characteristics, are examined using an input demand equation. Second, potential economic benefits are estimated by using the concept of derived demand for electricity and consumer surplus analysis developed by the World Bank (2002). The paper also describes the survey findings on the types of energy currently used at home, current energy expenditures, and attitudinal responses regarding ability and willingness to pay. We found that both generator set and unelectrified households, which must pay high costs to generate electricity, look forward to grid electrification and that for the majority of unelectrified households the ability to pay is not an issue. Further, large increases in consumer surplus would result from the increase in demand for lumen and for information/entertainment when their prices decrease with electrification. The main conclusion is that rural electrification programs can generate considerable economic benefits that justify the cost.

Keywords: electric utilities, rural analyses, demand of energy

JEL classification: L94; O18; Q41

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1. INTRODUCTION

Assessing the socioeconomic impact of rural electrification is critical for policy purposes. Providing electricity to rural households can prove to be quite expensive and thus it is imperative that program benefits and costs are carefully weighed before any program is undertaken. This requires that both be valued, preferably in monetary terms, for an appraisal of the electrification project. Previous assessments have emphasized producing important information on the cost side, leaving an insufficient understanding of the benefits to be gained (World Bank 2002). One of the problems in estimating benefits in such a cost-benefit assessment is that they are simply hard to measure in monetary terms.

This paper provides an assessment on household demand for electricity and economic benefits to be generated if a rural electrification program is implemented, based on data from a survey of households in Musi Banyuasin (Muba) District in South Sumatra. Electrification was defined as a move from non-grid sources, including those using generators, toward grid electricity. First, the paper investigates the determinants of electricity demand which include household socio-characteristics using an input demand function. Second, it estimates the potential economic benefits of rural electrification using the concept of derived demand of electricity and consumer surplus analysis developed by the World Bank (2002).

The study collected survey data from 1551 randomly selected rural households in Musi Banyuasin district. About 22% of the households sampled lack electricity. Of the 78% electrified households, 59% are connected to grid electricity, while 40% use generators. Not surprisingly, the households without access to electricity are poorer than their electrified counterparts and those who use generators are among the richest. Due to the higher cost of fuel for lighting, households without electricity spend about 19% of total expenditure on energy, of which more than half of this goes to household lighting.

We estimated a model of rural households' demand for electricity based on a conceptual framework of the household production model in which electricity is a key input for non-marketed goods produced by a household. This model is used to test the relationship between electricity demanded and various determinants, such as household income level, family size, household education, and other household characteristics, and to simulate electricity demanded by non-grid households (i.e. households who solely use a generator set and households without access to electricity) should they be able to connect to an electricity grid. In a household, the input demand function and supply of non-marketed goods are results of (internal)

profit maximizing. Thus, apart from the demand function for electricity, we also estimated a profit function to highlight the important role of electricity in household production.

This paper assesses the potential benefits from a rural electrification program in Indonesia.² Electricity benefits rural areas in many ways, by providing power for domestic uses (lighting, cooling, TV, radio, communication), productive uses (water pumps, fencing, cooling, mills, sewing machines, etc) and public uses (schools, health clinics, police stations, etc). Rural electrification lowers production costs and thus improves business and farm productivity, makes many household tasks more convenient, provides a more efficient form of household lighting, and improves quality of life through its effects on education and better access to inexpensive communication sources. Though there are many benefits as seen above, this study focuses primarily on measuring the benefits of lower-cost lighting and lower-cost information and entertainment using the World Bank method (World Bank 2002). The method can be applied to measure other categories of benefits, such as education and home-business productivity, but these are beyond the scope of the study due to limitations in the survey questionnaire.

The electricity demand function can also be used to project benefits from rural electrification. Unlike the above individual benefits estimates, which are carried out separately across categories, benefits derived along this fashion include all surplus generated when a typical non-grid household switches to grid-electricity.

The main conclusion of this paper is that the economic benefits of rural electrification are high enough to justify the cost of rural electrification programs. We find the benefits (in monetary terms) to be considerable and the willingness to pay for grid-electricity to be sufficient even among households without access to electricity. This has direct implications on policymaking, particularly in pricing policy. In addition, as suggested by earlier studies (for example, Fitzgerald et al. 1990) electrification improves the livelihood of rural people, and promotes cottage industry.

² As this survey focuses on the likely socioeconomic impact of a rural electrification program, we analyzed the cost of the projects, by forecasting load, connection growth rates, and conducting least-cost studies.

2. METHODOLOGY FOR ESTIMATING DEMAND FOR ELECTRICITY AND BENEFITS OF RURAL ELECTRIFICATION

Demand for Electricity

In a household, electricity is one of many goods purchased in the market which does not bring direct satisfaction or utility to the household; rather electricity serves as an 'intermediate' input to a household production process (for example cooking meals) which generates 'non-marketed' goods, such as lighting, food, clothing and so on that brings direct utility to the household. By the same virtue, electricity is essential to cottage industry, enabling home-based businesses to earn additional income through the sale of goods to markets.

Electricity is treated as an input in the production of services by households. Electricity can only generate utility for households through electric appliances and other devices. Employing the framework of Deaton and Muellbauer (1980), the demand function for electricity is derived from household utility optimization. A typical household maximizes the following utility function

$$U = U(Z_i, Q_k, T_{Lh}, R_l) \quad (1)$$

subject to the household production function

$$Z_i = Z(X_j, R_l) \quad (2)$$

and the full-income constraint

$$\sum P_{Qk} Q_k + \sum P_{Xj} X_j + \sum P_{Zi} Z_i + \sum W_h T_{Lh} = Y \quad (3)$$

where

Z_i : vector of non-traded goods produced by household, $i = 1, \dots, m$

X_j : vector of market inputs used to produce Z-commodity, $j = 1, \dots, n$

R_l : vector of structural characteristics of the household

Y : full income = $\sum W_h T_{Mh} + V$

Q_k : vector of market goods and services purchased by household, $k = 1, \dots, o$

T_{Mh} : market labor time supplied by the h^{th} household member

T_{Lh} : leisure time spent by the h^{th} household member

P_{Qk} : price of market goods and services purchased by household

P_{Xj} : price of market inputs used to produce Z-commodity

W_h : wage rate of the h^{th} household member

V : non-wage income

P_{Zi} : internal price of non-traded goods produced by household

Electricity is one of the market inputs in household production, so assuming that the objective function and constraint are well-behaved, one solution to the above optimization problem is the vector of input demand functions for all market inputs, X , given by

$$X = f(Y, P_{Zi}, P_{Qk}, P_{Xj}, W_h) \quad (4)$$

Assuming a key input in X is electricity, the relevant function for electricity in kilowatt hours (kWh) is

$$\text{kWh} = f(Y, P_{Zi}, P_{Qk}, P_{kWh}, W_h)$$

where kWh is the monthly electricity usage, Y the household income, P_{kWh} the price of electricity input and P_{Qk} the price of market goods and services purchased by the household.

The price of non-traded goods P_{Zi} are unobserved as well as the wages of household members, W_h . Their effects can be controlled by the inclusion of the vector of households and housing characteristics, so that Equation 2.5 becomes

$$\text{kWh} = f(Y, P_{Qk}, P_{kWh}, R_l) \quad (5)$$

where R_l include vector of household characteristics such as the head's education, gender and age and vector of housing characteristics, such the types of roof, wall and tile, and the number of rooms. The inclusion of household and housing characteristics is also meant to control for the shift of input demand function by factors other than the relevant prices.

The input demand function is an outcome from the production decision process of the household. As a producer, the household chooses the optimal levels of inputs and outputs that will maximize a profit function. A general form of the profit function would be

$$\pi = f(Y, P_{Qk}, P_{kWh}, R_l) \quad (6)$$

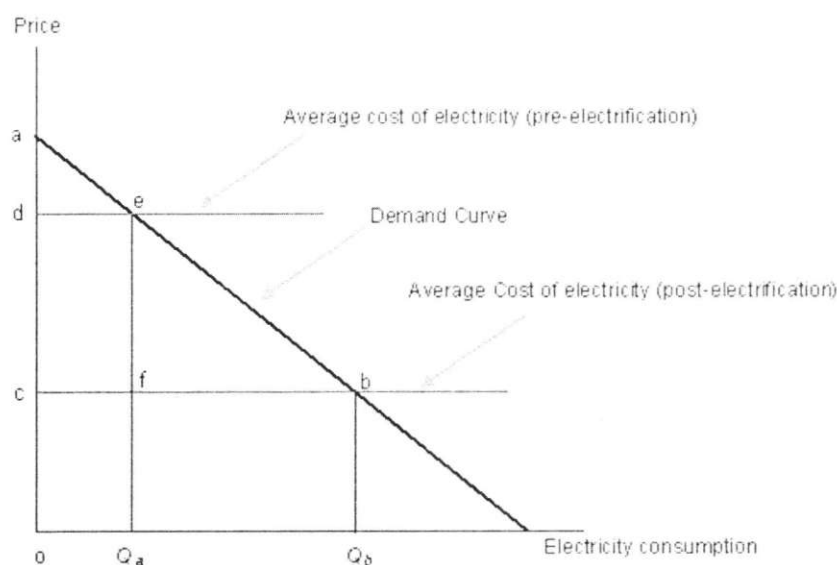
Measuring Benefits of Rural Electrification using Consumer Surplus Analysis

One common method for evaluating the benefits of electricity is based on an estimate of consumers' willingness to pay for electrification (Webb and Pearce 1985; Munasinghe and Warford 1982; Fitzgerald, Barnes and McGranahan 1990). In principle to estimate rural electrification benefits, one needs to calculate the difference in benefits enjoyed by each household "with (or after) and without (or before)" electrification. These benefits are equivalent to the household's willingness to pay for electrification. Summing these benefits over all households without electricity would yield the total (private) benefits for the population of households.³

By observing the quantity of household demand at all electricity prices and for all levels of consumption, benefits can be estimated under a demand curve (Figure 1). A demand curve indicates the amount a household would be willing to pay at each level of consumption. Assuming that this willingness to pay is at least equal to the benefit received, the demand curve provides a measure of household benefits for each level of consumption.

³ Most early project appraisals rely heavily on demonstrated expenditures and cost saving. These concepts focus on relative energy prices and associated outlays for the same level of energy service. They used the tariff (i.e. consumer cost) as the measure of the per-unit benefit of rural electrification. Reliance on the tariff was justified by hypothesizing that, if people are willing to pay for electrification services, they will place a value on it that is at least as high as the tariff. The use of the tariff as a benefit measure is especially misleading if the tariff is subsidized, in which case social benefits would depend arbitrarily on the degree of subsidization. With cost saving, there is no guarantee that cost will decrease after electrification as it will depend on the elasticity of demand for goods or services for which the electrification serves (World Bank 2002).

Figure 1
Demand Curve for Electricity Consumption



Benefits are derived using the concept of consumer surplus.⁴ Let's assume a small level of electricity consumed by a hypothetical household before electrification. The pre-electrification demand Q_a is associated with an average cost of electrification d .⁵ Applying the consumer surplus analysis, before electrification the hypothetical household is enjoying net benefits (consumer surplus) equivalent to the small triangle ade , which is the net of the household's willingness to pay after it spent an amount dQ_ae on electricity cost. After electrification, the household increases the electricity consumption to Q_b due to cheaper electricity price. The gross benefits become aQ_b , of which an amount cQ_b is spent as electricity cost. In this situation the net benefits (consumer surplus) of electrification corresponds to the triangle acb . The increase in net benefits when the household switches to electrification is

⁴ Consumer surplus can be defined loosely as the value of the service to consumers above what they pay for it.

⁵ The high cost of electricity in an un-electrified household derives from the use of batteries, for example, a practice which is common in developing countries.

the area $dcbe$, which is equivalent to the post-electrification consumer surplus acb minus the pre-electrification consumer surplus ade .⁶

It is, however, impossible to make such an observation when the purpose is to estimate the benefits of prospective policies to bring electricity to rural populations. It is also impossible to observe such "with and without" benefits using cross-sectional data generated by the type of survey used in this study. A practical method is to estimate the benefits for a hypothetical household undergoing electrification. The World Bank (2002) provides details of the method, as summarized below.

3. DESCRIPTION OF ELECTRICITY USAGE IN MUSI BANYUASIN

This section will describe Muba characteristics and discuss the types of energy used in households such as kerosene, grid and generators, as well as household energy expenditure.

Muba is the largest district in South Sumatra covering 14,265.96 sq km or 15 percent of the total area of the province. As of December 2005, Muba had 205 villages spread across 11 sub-districts or *kecamatan*, of which 200 are rural. About 53% of its area is swampland (the eastern part of Sungai Lilin sub-district, the western part of Bayung Lencir sub-district, and the Musi River surroundings) and criss-crossed by rivers. Central Muba is flat (35%), while further west the land rises to heights of 12 to 140 meters above sea level (12%). In 2005 the population was 475,793 with an annual average growth of 1.6%⁷ and population density of 33 people per square kilometre (unevenly distributed). Bayung Lencir sub-district which covers 40% of the total area of Muba is inhabited by 16% of the population, while the relatively smaller Sekayu sub-district is home to 15% of the population.

⁶ Application of this simple consumer surplus analysis raises several issues (World Bank 2002). First, it is nearly impossible to observe the demand curve for a wide range of electricity prices. Second, so far it is assumed that the demand curve is independent of income. A more reasonable assumption is that the demand curve for a wealthier household lies to the right of that of a poorer household. Moreover, as the price of electricity falls, there would be income effect that induces the households to consume more electricity. The above approach ignores such effective changes in incomes relative to price changes. Third, the demand curve is assumed independent of changes in the price and consumption of goods or services that may complement or substitute for electricity. Fourth, the method estimates only private household benefits. Estimating public benefits are beyond the scope of this paper.

⁷ BPS Kabupaten Musi Banyuasin (2005), *Musi Banyuasin dalam Angka 2005*.

In this study, we conducted two kinds of socioeconomic surveys at the household-level and village level. The household survey sampled 1,551 households in 52 villages (of 200 rural villages and 122,637 households) which were selected by using a two-stage random sampling method. The sample frame was based on the household lists provided by the Muba local government. This list recorded conditions in September 2006 and had been used to create a database for local elections in Muba. For practical reasons we kept the minimum number of sampled households at around 20 per village (in some villages less).

Type of Energy Used by Household

There are ten energy sources used by households in Muba: firewood, charcoal, kerosene, candles, car battery, dry battery, PLN (state electricity - the local government grid), generators, solar PV and LPG. Many households use more than one source of energy. Usually they combine the use of kerosene with other sources. Most households use kerosene, electricity and firewood by 98%, 78% and 76% respectively (see **Table 1**), for cooking and lighting. The main source of electricity is grid electricity (46%), followed by generators (31%).

Households are classified as electrified or non-electrified. Electrified households are connected to the PLN grid (direct and indirect connection), to a generator (direct or indirect) or to solar PV, while non-electrified households are not connected to the grid, a generator or solar PV. Households with access to electricity are sub-categorized into two groups, namely grid electricity and generator electricity. Grid electricity households include those connected to the PLN grid, to the Muba grid or to neighbors or families which are connected directly to the PLN grid. Meanwhile, generator households get electricity from a generator regardless of ownership. Most own their generator, some are connected to generators owned by neighbors or family and others use collective generators.

Electrified households have higher educational backgrounds, better housing materials (clay roofs, brick walls, tiles and ceramic flooring) and more rooms than non-electrified households. They also own a greater variety of electric appliances.

Taking into consideration weights applied to Muba, 95,658 households of 122,773 households are electrified in which 56,851 households are connected to the grid (59.4%), while 38,368 use generators (40.1%). In the sample, 38.7% of electrified households are connected directly to the PLN grid, while 16.1% are connected indirectly. Further, 293 households of 1,215 households use their own generator and 207 households are hooked up to someone else's generator.

Table 1
Household Distribution by Energy Use

Energy Sources	% Households	Number of Households
All Electricity	77.9	95,658
Grid Electricity	46.3	56,851
Generator	31.2	38,368
Solar PV	0.4	439
Firewood	76.3	93,726
Charcoal	2.8	3,494
Kerosene	98.1	120,434
LPG	8.6	10,595
Candle	10.8	13,300
Car Battery	3.3	4,042
Dry Battery	52.2	64,133

- Figures are based on weighted data.

- Households may use more than one type of energy.

Kerosene

The use of kerosene is very common in Muba, as 98.2% of the surveyed households use kerosene to start firewood, cook, as light and for other activities. Interestingly, many electrified households use kerosene for lighting, at 66.2% of grid households and 95.8% of generator households. Thus, electricity is not the only source of lighting for electrified households. This also implies that the grid is unreliable and the cost of running a generator is higher than kerosene, so that households continue to use kerosene for lighting. In non-electrified households kerosene is mainly used for lighting and starting firewood.

Households consume about 45% of kerosene for cooking, and around one third for lighting and 21% for starting firewood. Therefore, on average each household spends about Rp 27,591 on kerosene for cooking. If we assume that firewood is also used for cooking, the average expenditure is Rp 40,349. In total kerosene consumption, generator households spent the most on kerosene, followed by grid and non-electrified households. It appears that kerosene is a basic need, particularly for cooking. In one month each household consumes 14.9 liters at an average cost of Rp. 4,205/l, spending Rp. 61,000 (includes transportation fees). This might also take into account the cost of stocking

kerosene for reserve. The average annual income of households using kerosene for cooking is higher than those using kerosene for lighting. As incomes rise in non-electrified and grid households, fewer use kerosene.

Grid Electricity

Grid electricity generated by PLN has been available since 1978, and has been generated by PT Muba Electric Power (MEP) - a locally-owned company - since 2006. In theory, grid electricity is available 24 hours/day, averaging 22.5 hours/day in a 30-day month. However, this does not necessarily imply that the quality of the Muba grid is very good, as 68.8% of grid households still use kerosene for lighting. It can be concluded that blackouts occur frequently in Muba, so kerosene and candles are kept at the ready to anticipate power outages.

In the sample, 683 households were connected to a grid, with 68.8% (470 households) connected directly and only 2.5% of these (17 households) connected to the local company's grid. Households connected directly to a grid have their own individual electricity meter, while households connecting through a neighbor or family member's PLN connection do not have individual electricity meters. We found that 196 households are hooked up through households with direct access to grid electricity. There are 61 grid-electrified households acting as principal households which connect at least two other households. The households connecting to principal households either pay a fixed monthly amount or pay by the number of electrical lamps/appliances used according to individual agreements. Some also pay based on a cost-sharing method where the cost of electricity is collectively borne by all households connected to the principal (which can be a community or cooperative).

The payment method with the highest cost per kWh was paying by the total number of electrical lamps/appliances while the cost-sharing method was the cheapest. There was also no significant price difference between direct and indirect grid access households. The income distribution for grid electrified households is relatively low with 40% earning less than one million rupiah per month and 32% earning between Rp. 1,000,000 – Rp. 1,500,000.

Generator

In the sample, 527 of the 1,551 households use generators. More than 50% of generator households own their own generator and another 40% are connected through a generator owner. Only 5% of generator households are connected to collective generators operated by communities or cooperatives.

The cost of operating a generator varies and is determined by capacity, monthly usage and type of fuel. The price of fuel is also subject to location and distance from Sekayu: the farther from Sekayu, the higher the price. On average, owners used 51.9 liters of fuel each month at a cost of Rp 290,355. Most operate their generators from 6:00 pm to 10:00 pm or around 4.9 hours / day at an average of 25 days per month. As the cost of owning and operating a generator is quite high, these owners would be able to pay for grid electricity if available.

Similar to direct access grid households, generator owners provide connections for other households, at 5 households per owner. The generators with the largest capacities can provide electricity for up to 25 households. Again, the monthly bill is determined by payment method. Households paying at a fixed rate use the least kWh and pay the highest costs while those employing cost-sharing methods consume the most and pay the least. Cost-sharing is typically applied by cooperatives or communities operating a generator. The households connected to the generator have contributed to its purchase and are thus considered 'share holder' of the generator. In terms of income distribution, generator households are generally richer than those connected to grid electricity.

Household Energy Expenditure

The monthly expenditure for energy usage is Rp 67,260 for non-electrified households, Rp 113,357 for grid households and Rp 290,421 generator households at 19% of total expenditure for non-electrified, 21% for grid and 41% for generator households (**Figure 2**). This indicates that generator households spend the most on energy, at more than twice the price of grid household energy expenditure. This high energy expenditure can be interpreted as willingness to pay from generator households. If the electrification program is carried out, the greatest benefit will be felt by generator and non-electrified households.

Energy is mainly used for lighting, cooking and entertainment. Generator households spend up to four times as much on lighting compared to grid households, with similar figures emerging for entertainment – Rp 64,078 for generator households compared to Rp 17,774 for grid households.

In all households, the majority of energy expenditure goes to lighting (32%), followed by cooking (25%) and entertainment (20%) (**Figure 2**). Non-electrified households spend the most on lighting, with more than 50% of total energy expenditure devoted to this, compared to 21% for grid and 34% for generator households. Interestingly, the proportion of cooking expenditure for grid households is quite high at 50%. This implies that grid households use more high-wattage cooking appliances than other households. Generator households also treat

entertainment as a significant need with 22% of energy expenditure going to entertainment.

Figure 2
Proportion of Expenditure

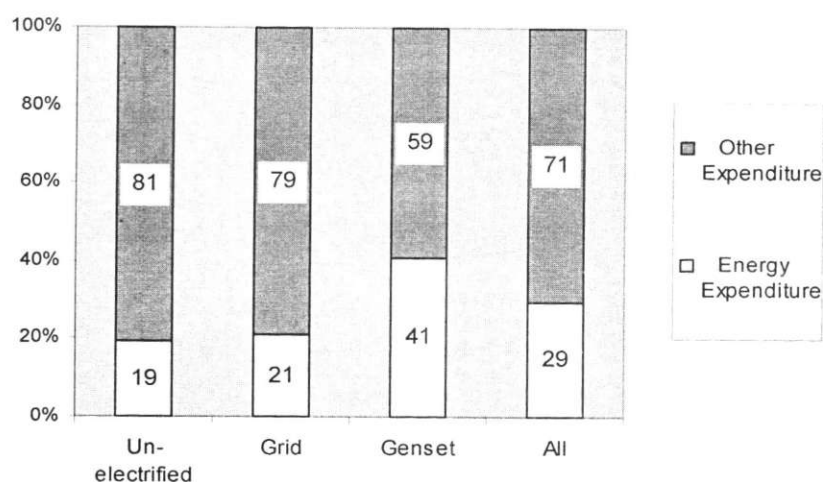
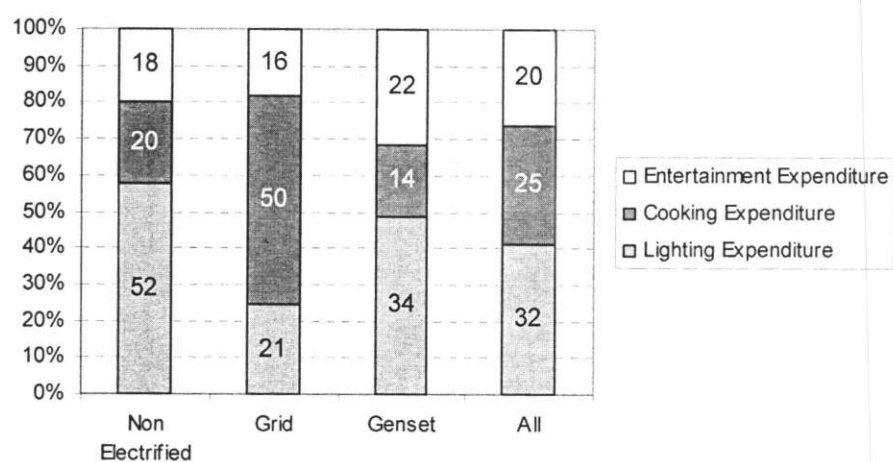


Figure 3
Percentage of Monthly Expenditure on Energy⁸



Source: Calculated from raw data

⁸ Note: the proportion of energy expenditure does not reflect the true proportion due to incomplete data.

Grid households spend the least on lighting. Non-electrified households use kerosene for lighting at a cost of almost seven times more than that spent by grid households. This high cost of lighting for non-electrified households implies an ability to pay for grid electricity. Likewise, generator households spend in excess of seven times more on energy than grid households making lighting by generator the most expensive method.

The study calculates the price per unit of energy for lighting. Non-electrified households pay a slightly higher price per unit of each energy source compared to generator households. The price for grid households is the lowest of the three. Generator households spend more on energy due to the high cost of generating electricity rather than due to the quantity of energy consumed.

Table 2

"The monthly electric bill would be a financial burden for my family"
Responses (%)

Responses	Grid households		Generator households		Non-electrified	
	Percent	Cum	Percent	Cum	Percent	Cum
Strongly agree	8.06	8.06	2.48	2.48	5.36	5.36
Agree	43.55	51.61	18.10	20.57	19.94	25.30
No opinion	13.64	65.25	40.19	60.76	47.92	73.21
Disagree	30.35	95.60	37.90	98.67	24.11	97.32
Strongly disagree	4.40	100.00	1.33	100.00	2.68	100.00
N	682		525		336	

Willingness to Pay for Electricity: Attitudinal Responses

Both generator and non-electrified households which pay high energy costs are looking forward to grid electrification. This can be seen in the responses to the attitudinal question "the monthly electric bill would be a burden to my family" (Table 2). The electricity bill is an official bill from the state electric company PLN or its local equivalent. Only 20% of generator and 25% of non-electrified households agree or strongly agree with this statement. This is far lower than the 51% of corresponding responses from grid households. Many grid households have never experienced life with generators, car batteries or no electricity at all and thus do not have a full understanding of the associated costs of other energy sources.

Other attitudinal questions shed light on the reasons many non-electrified households have not yet connected to the PLN grid and ability to pay. The households were asked to indicate whether a particular statement in the questionnaire was a major reason, secondary reason, or not a reason (Table 3). These statements helped assess the households' perception of costs associated with electrifying their homes. None of the questions were asked in monetary terms.

Table 3
Reasons for Not Connecting to PLN Grid: Non-electrified Households

Reasons for being unelectrified household	Percentage of household seeing the statement as			Obs.
	Major reason	Secondary reason	Not a reason	
a. Can not afford the PLN connection.	31.33	18.67	50.00	332
b. Can not afford the wiring installation within the house.	23.19	25.00	51.81	332
c. Will not be able to pay the monthly bill.	6.93	20.78	72.29	332
d. Can not afford to buy electronic appliances.	3.92	25.90	70.18	332
e. Electricity service is not available in our village.	71.30	3.32	25.38	331
f. We are satisfied with the current using of energy.	2.11	6.02	91.87	332
g. We do not see the benefit of electric application.	1.20	8.13	90.66	332
h. PLN does not want to make connection to the grid.	22.19	13.37	64.44	329
i. Other reason	7.78	4.44	87.78	90

Figures are based on un-weighted data. Observations of non-electrified households.

The upper panel of Table 3 shows the responses given by non-electrified households to questions regarding their ability to pay for grid electricity. The results are interesting. For each statement regarding the ability to pay, 50% or more of non-electrified households answered 'not a reason'. This means that for more than half of non-electrified households, the ability to pay does not prevent them from connecting to PLN. Only 30% could not afford the PLN connection and 23% could not afford wiring installation. Further, only 10% and 4% of these households are too poor to pay the electricity bill or buy electronic appliances. This confirms that the main issue is at least partly due to geographical conditions of the villages. A large proportion of households can pay for grid electricity, provided a connection to their village is made available. The main obstacle is that no party has been willing to extend the PLN grid to the villages due to the expense of prevailing geographical conditions like river crossings.

4. RESULTS

Demand for Electricity

In a household, electricity is one of many goods purchased in the market which does not bring direct satisfaction or utility to the household; rather electricity serves as an 'intermediate' input to a household production process (for example cooking meals) which generates 'non-marketed' goods, such as lighting, food, clothing and so on that brings direct utility to the household. By the same virtue, electricity is essential to cottage industry, enabling home-based businesses to earn additional income through the sale of goods to markets.

Of 1,551 respondents, 1,206 reported positive electricity consumption, while the rest were either missing or zero (non-electrified). If all electrified households and some non-electrified ones respond (non-missing) and the remaining non-electrified report zero kWh, the problem would be much simpler. The dependent variable, electricity consumption, is truncated at zero and the Tobit procedure can be applied. However, the Tobit requires that the decision not to consume electricity and not to report kWh must be determined by the same parameters that determine the decision to consume. This becomes an extremely complex econometric model beyond the scope of this study. We could assume all missing as zero but the potential problem stated above will remain. So instead, OLS is employed restricting our sample to households with observed positive electricity consumption in kWh.

The data on electricity consumption in kWh is obtained from the question on appliance wattage. The amount of kWh can be calculated for 640 grid and 504 generator households.⁹ For non-electrified households the difficulty is that many did not observe positive kWh. The only possibility to record positive kWh consumption is if they use an appliance for which the electricity consumption can be deduced.¹⁰ We use the electricity consumption from the 26 non-electrified households which reported positive kWh to infer the kWh usage of all non-electrified households. Taking into account inflation, there are 27,115 non-electrified, 56,851 grid and 38,368 generator households in Musi Banyuasin.

To assess households' willingness to pay for electricity we use the relationship implied by the electricity demand function. Other things being equal, for a given product higher incomes would imply greater ability to afford higher prices for the same product. **Table 4** demonstrates

⁹ The number of households using solar PV is very small, only 5 households in the sample or 439 for the whole of Musi Banyuasin after multiplied by the inflation factor.

¹⁰ Car batteries are frequently used to run appliances.

that the generator households are not poor and that in fact these households earn higher average monthly incomes than grid households (Rp 1.7 million compared to Rp 1.4 million). Non-electrified households have the lowest income at Rp 1 million. At this income level, generator households can afford to pay the highest unit cost per kWh, around Rp 11,800 compared to Rp 1,066 paid by grid households.¹¹ It is conceivable that electricity usage by generator households would increase with access to the PLN grid whose cost is far lower.

Table 4
Price and kWh by Household

Variable	Grid	Generator	Non-electrified
kWh used per month (unconditional mean)	74.38	30.96	7.68
kWh used per month (conditional mean)	74.38	30.43	10.05
Unit cost per kWh in Rupiah	1066.35	11853.44	8670.05
Monthly income (Rp. Thousands)	1400.82	1713.78	1068.35
kWh used by generator HH if paying grid price		79.67	
kWh used by non-electrified HH if paying grid price			56.05
Number of HH in the sample	640	504	26*
Number of HH in Musi Banyuasin	56851	38368	27115**

* Only non-electrified household with positive kWh, probably using car battery

** All non-electrified households in Musi Banyuasin both with and without positive kWh

Table 5 presents the OLS estimation of **Equation 6**.¹² Overall, the model has a reasonable explanatory power given that this is a cross-section household survey. In accordance to the standard input demand function, the price or unit cost per kWh has the right negative sign and is significant at one percent. As expected, households with higher incomes

¹¹The high cost of using a generator comes from the purchase cost and depreciation of a generator unit.

¹²We experimented with the Tobit procedure taking into the sample zero observation for kWh but the predictive power of this model was not satisfactory.

use more electricity. Housing size represented by the number of rooms is also an important variable with a positive and significant coefficient. In terms of household characteristics, the education of household head is significant and positive, so higher education is associated with higher electricity use. Households possessing home businesses are also more likely to use higher amounts of electricity. Households connected directly or indirectly to PLN use more electricity and thus confirm **Table 4**.

Table 5
Determinants of Electricity Consumption in kWh (OLS)

Independent variable	Coefficient	Level of significance
Unit cost per KWH***	-0.313	0.005
Monthly income***	0.016	0.000
Number of rooms***	8.347	0.000
Number of persons in HH	-1.487	0.178
Age of HH head	-0.054	0.722
Gender of HH head (Male=1 Female=0)	-0.632	0.927
Education of HH head***	5.928	0.000
Home business or not***	23.052	0.000
PLN grid (direct and indirect)***	46.008	0.000
Constant***	-41.280	0.004
R-Squared		0.250
Valid N		1206
*** significant at the 1 percent level		
** significant at the 5 percent level		
* significant at the 10 percent level		

The model is first used to calculate the conditional mean of kWh consumption at the mean values of all independent variables, yielding the base line consumption. It is then used to simulate a situation whereby a typical generator household is assumed to have access to the PLN grid and accordingly pays less for electricity, while other covariates are held constant at their original mean values. This exercise is then repeated for non-electrified households with observed positive electricity consumption in kWh.

Other things being equal, the conditional mean of generator households is 30.43 kWh. If these households obtain electricity at what the grid households pay then the mean jumps to 79.67 kWh, an increase of 162%. Using the formula to calculate net benefits with consumer surplus analysis, the increase of consumer surplus is estimated at Rp 594,000 per household per month or Rp 23 billion per month for all 38,368 generator households. In one year this is equivalent to Rp 276 billion or about US\$ 30.4 million at Rp 9,000 per US\$. We make a bold assumption that all non-electrified households use the same amount of electricity as the non-electrified households observed with positive kWh. The conditional mean of non-electrified households is 7.68 kWh. At the price of grid households, this increases to 56.05 kWh, an increase of 630%. The increase in consumer surplus is calculated to be Rp 406,000 per household per month or Rp 11 billion for all non-electrified households. In one year this equals Rp 132 billion or US\$ 14.7 million. The benefits, particularly to generator households moving to the PLN grid would be quite substantial.

In order to assess what happens to profit when generator households access the grid, we econometrically estimate the profit determinants (Table 6). High electricity costs lower profits, so generator households could profit more by switching to the grid. The number of household members has a positive impact on profits confirming the important role of family labor as by employing more people home businesses can operate for longer hours. Home businesses with female household heads tended to have higher profits. The education level of the household head is also important as higher education levels result in higher profits. The role of population agglomeration as represented by the sub-district or *kecamatan* population is positive in boosting profit. This also suggests that home businesses are more likely to be found in areas with higher population concentration.

The estimated profit function is used to simulate a situation in which generator households obtain electricity at grid costs. Profit would increase from Rp 9.8 million to Rp 10.53 million per annum, an increase of 7.5%. The total increase in profit for all generator households with home businesses would amount to Rp 28 billion or about US\$ 3 million.

As not every household has a home business, it is important to examine the factors behind this. We use the probit model to track the propensity to own a home business. The dependent variable is a dichotomous variable having the value of one if the respective household owns a home business and zero otherwise. The explanatory variables include household socio-economic characteristics like income, and other household characteristics like number of household members, age, gender and education of household head, as well as the sub-district

population to represent the local market. Electricity is represented by a dummy variable with the value of one if the respective household is connected to the PLN grid or to a generator. The results are shown in Table 8.

Table 7
Determinants of Household Profits

Independent variable	Coefficient	Level of significance
Unit cost per KWH*	-0.066	0.096
Income	-1.433	0.324
Number of persons in HH***	1.319	0.003
Age of HH head	0.043	0.535
Sex of HH head*** (Male=1 Female=0)	-10.523	0.001
Education of HH head**	1.861	0.014
Kecamatan population**	3.235	0.012
Native Musi Banyuasin or not	2.144	0.215
Access to generator*	2.032	0.099
Constant***	-41.280	0.004
R-Squared	0.204	
Valid N	139	

*** significant at the 1 percent level

** significant at the 5 percent level

* significant at the 10 percent level

The most important variable affecting a household's decision to start a home business is electrification, irrespective of grid or generator. Non-electrified households are less likely to own a home business. As reflected in the coefficient of marginal probability, household access to electricity will increase the probability of owning a home business by almost 10%. Another important variable is income. The higher the income the less likely a household is to own a home business, which signifies the role of home businesses in supplementing income. Since home businesses supplement income, grid electrification improves the well-being of rural households by increasing the likelihood of owning a home business. The older the household members' average age, the more likely a household is to start a home business. This indicates that household members are the main labor source in home businesses.

Table 8
Propensity to Have a Home Business (Probit)

Independent Variable	Probit Coefficient	Coefficient adjusted for marginal probability	Level of Significance
Income***	-0.259	-0.034	0.008
Average age of HH member*	0.010	0.001	0.097
Education of HH head	0.032	0.004	0.492
Number of rooms in the house**	0.085	0.011	0.032
Price of kerosene (village level)	-0.020	-0.003	0.832
Price of car battery (village level)	-0.007	-0.009	0.946
Native of Musi Banyuasin	-0.173	-0.024	0.117
Sub-district population	-0.018	-0.002	0.816
HH electrification status (1=Yes 0=No)***	1.127	0.099	0.000
Constant***	-2.596		0.006
LR Chi-sq		65.39**	
Valid N		1547	

*** significant at 1 percent

** significant at 5 percent

* significant at 10 percent

5. SUMMARY AND CONCLUSION

This paper investigates the demand for electricity and estimates the potential economic benefits of a rural electrification project in Musi Banyuasin District. In a household, electricity is one of many goods purchased in the market which does not bring direct satisfaction or utility to the household; rather electricity serves as an 'intermediate' input to a household production process (for example cooking meals) which generates 'non-marketed' goods, such as lighting, food, clothing and so on that brings direct utility to the household. Thus, the demand for electricity is considered an input demand.

Higher income levels, larger house size (number of rooms) and higher educational levels (head of household) all indicate increased electricity consumption. Households with home businesses are also more likely to use higher amounts of electricity as are all households connected directly or indirectly to the grid (as connection to the grid removes the constraint of the high cost of obtaining electricity from other means).

The actual average prices per kWh were Rp 1,066 for grid households, Rp 11,853 for generator households and Rp 8,670 for non-electrified households. These figures can be used to determine the willingness to pay for electricity. They tell us that households in Musi Banyuasin currently not connected to a grid show a sufficiently high willingness to pay for electricity. This implies that these households are able to pay, should grid electricity become available. The "producer surplus" that would be generated if one such household had access to the grid and accordingly paid less is Rp 594,000/ month for a generator household or Rp 406,000 for a non-electrified household. Assuming that there are 38,368 generator households and 27,115 non-electrified households, the total "consumer surplus" in Musi Banyuasin from electrification would amount to Rp 132 billion or US\$ 14.7 million at Rp 9000/1US\$.

High electricity costs lower profits and thus generator households would benefit by switching to grid electricity. The number of people in a household positively impacts profits, confirming the important role of family labor. With more family members, home businesses are able to operate longer hours. Home businesses with a female household head tend to earn higher profits. The education of a household head is also important for household profit – higher education levels translate to higher profits. The role of population agglomeration as represented by the sub-district population is positive in boosting profits. This also suggests that home businesses are more likely to be found in areas with higher concentrations of people. Electrification enhances the livelihood of rural people. Electrifying rural households increases the probability to own a home business by almost 10%.

These principal findings show that rural electrification projects, in this case in Musi Banyuasin District, have significant benefits. Non-electrified households, which tend to be low-income, are still willing to pay sufficiently large amounts for electricity. This is a major reason for the high benefit estimates.

Although the method employed in this research is straightforward and simple, careful interpretation is still necessary due to a number of limitations. These estimates rely on a simple linearity assumption and as a result may be too high. Since the estimated per household benefits are averages, they do not pertain to every household in the surveyed area. Real benefits for some households will vary. Further, a number of benefit categories were not quantified due to insufficient data. This paper only addresses the economic efficiency of the likely project, while other issues such as equity and effectiveness are equally important for investigation.

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