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INDUSTRY AND ENERGY DEPARTMENT WORKING PAPER
ENERGY SERIES PAPER No. 29

Interfuel Substitution and Changes in the Way Households Use Energy: The Case of Cooking and Lighting Behavior in Urban Java

October 1990

The World Bank Industry and Energy Department, PRS

Interfuel Substitution and Changes in the Way Households Use Energy:

The Case of Cooking and Lighting Behavior in Urban Java

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October 17, 1990

Abstract

A major shortcoming of standard methods for estimating household fuel demand as a function of fuel choice is that, for cooking, end-use services are treated as constant, while not taking into account behavioral changes that accompany interfuel substitution. For lighting, the amount of electricity required to displace kerosene is often estimated on the basis of assumptions about unmet lighting demand in households lighting with kerosene. In this paper we develop a statistical procedure to analyze interfuel substitution based on the actual behavior of urban households. Applied to data from a recent survey of energy consumption in urban households on Java, the amount of energy that is actually consumed by comparable households using different fuels (fuel substitution ratios) can be estimated. The analysis of fuel use by urban households on Java provides a sound basis for projecting the substitution potential of kerosene for wood and LPG for kerosene in the cooking end-use, thereby clarifying the range of estimates commonly derived from various assumptions about average stove efficiencies. Results also show that the assumptions traditionally used to estimate the benefits of electric lighting are far off the mark. For households lighting with electricity versus those lighting with kerosene it was found that electricity is less costly to the country and to households, and households also enjoy roughly six times more light.

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I. Introduction [1/]

1.1 When a household changes fuels for cooking or lighting, it affects their way of life. One common finding is that when people change from kerosene to electricity for lighting, they use the lights for longer hours (Barnes, 1988; Butler and coauthors, 1980; Foley, 1989; Cecelski, 1982; Tourkin and coauthors, 1981). This is quite understandable because, in addition to electric lighting being more convenient than kerosene lighting, more activities are possible under the brighter light produced by electric light bulbs and fluorescent lamps. This is especially true for activities that involve very close and detailed work such as reading, sewing, and other recreational activities. Likewise, the switch from wood to kerosene for cooking can result from a change in lifestyle, such as a move from rural to urban areas where indoor kitchens discourage the continued use of wood for cooking. The point is that in most developing countries switching between fuels is not a mechanistic process involving the substitution of similar end use utility, but rather, involves changes in lifestyle, in the quality of life, and in demand for the fuels.

1.2 The main shortcoming of standard methods used to analyze fuel substitution in households is that end-use energy use are assumed to be identical for cooking (and to hold to a fixed ratio for lighting services based on unmet demand in households lighting with kerosene) while other changes in behavior that accompany a switch from wood to kerosene for cooking or from kerosene to electricity for lighting are not explicitly addressed. For instance, one common method for evaluating the benefits of electricity is based on an estimate of consumers' willingness to pay for electricity (see Webb and Pearce, 1985; Munasinghe and Warford, 1982). In many cases the increase in benefits enjoyed by the household, namely increases in lighting levels due to a switch from kerosene to electricity for lighting, are not adequately quantified. Likewise, the conventional procedure for estimating how much of one fuel will substitute for another in meeting cooking needs is to treat the useful energy for both fuels as a constant. This approach has the shortcoming of relying only on differences in stove efficiency estimates for different fuels, while not accounting for changes in the way households behave after switching fuels. People may use a stove at different power settings, or they may cook different kinds of foods after they switch fuels. In this paper we include under the term 'behavior' any changes in patterns of energy use such as power setting, speed, and amount of time for cooking, kinds of food cooked, and lighting hours at night.

1.3 In this paper we present a household energy demand model that not only accounts for fuel prices, income, and family size, but also for differences in access to and availability of fuels (Leach, 1988 and 1987; Munslow and coauthors, 1988). The actual differences in fuel use between comparable households using different fuels for cooking and lighting are estimated. When applied to data from urban Java, the model clarifies some of the conventional wisdom concerning stove efficiency estimates as a basis for planning and challenges our previous understanding of household lighting. The analysis of cooking fuel use by urban households on Java indicates that wood is used

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[1/] The present paper is an updated version of a paper presented at the 12th Annual International Conference of the International Association of Energy Economists in New Delhi, India, January, 1990. The authors wish to thank the following reviewers for their constructive comments and suggestions: Jeffery Dowd, Joseph Gilling, Andres Liebenthal, Kenneth Newcombe, Frans Nieuwenhout, Gunter Schramm, Witold Teplitz-Sembitzky, and Michael Webb. The data analyzed in this paper is from a survey of urban households on Java conducted by the Central Statistics Bureau of Indonesia in early 1988. The survey was undertaken as part of an Urban Household Energy Strategy Study administered by the UNDP/World Bank/Bilateral Assistance Energy Sector Management Assistance Program (ESMAP) in coordination with the Directorate General of Electricity and New Energy of the Government of Indonesia (DJLEB).

the typical range of technical stove efficiencies commonly used in planning. This has direct implications for projections of the substitution potential of LPG for kerosene and kerosene for wood. An even more surprising result of the analysis is that after accounting for some of the most relevant factors that play a role in determining the amount of lighting consumed, a household that switches from kerosene to electricity generally will use less fuel (even on an electricity thermal replacement basis) at a lower cost while enjoying roughly six times the amount of light.

1.4 The main conclusion of this paper is that households do change behavior when changing fuels. The traditional approach to estimating how much of one fuel is necessary to displace another for cooking, based on the notion of fixed energy demand calculated through technical efficiencies of stoves for each fuel, does not necessarily account for these behavioral changes. When lighting behavior of households with electricity is compared to that of households without electricity, it is evident that the benefits of electrification may be significantly underestimated by methods based on broad assumptions of unmet demand.

1.5 This paper first briefly reviews existing methods of household energy demand analysis. We then modify a traditional demand model by accounting explicitly for variation in household energy use practices, resource availability, and fuel choice. This modified demand model is then applied to recent household energy survey data from urban Java to analyze fuel use for cooking and lighting.

II. Modeling Household Energy Demand in Developing Countries

2.1 A common method to estimate the effects of interfuel substitution on residential energy consumption in developing countries is to use income group means to observe fuel switching behavior (Alam and coauthors, 1985; Leach, 1987; Reddy and Reddy, 1983; Natarajan, 1985; Nair and Krishnaya, 1985; Macauley and coauthors, 1989). The resulting patterns are often used to estimate the costs of switching between fuels both for individuals and for a country (World Bank 1987, 1989a, 1989b). For instance, one might estimate how much kerosene would substitute for wood by converting the useful energy for cooking with wood to the same amount of useful energy for cooking with kerosene (multiplying the heat content of each fuel by average stove efficiencies). This method can be questioned for several different reasons. First, the results of controlled cooking tests suggest that fuel efficiency is influenced significantly by the power settings at which kerosene and LPG stoves are used. Second, different fuels may be associated with different lifestyles and cooking habits. The change in cooking habits may significantly affect the amount of one fuel that is substituted for another fuel. A better method is to observe the difference in fuel consumption between comparable households that use different fuels.

2.2 In the model that follows we develop a method to estimate fuel switching behavior, while controlling for all factors in a traditional energy demand model. The first step is to estimate household fuel use behavior as it relates to income, family size, fuel and appliance prices, and other factors (see Bohi, 1981 for a review of energy demand models). Standard demand models include a dependent variable that is commonly some measure of fuel use in the household that is normalized according to family size or total fuel use. The following equation is typical of a standard model to estimate fuel consumption:

$$Q_{ij} = f(Y_i, N_i, P_{ij}, P_{ik}, A_{ij}, A_{ik}) \quad (1)$$

Where:

Q_{ij} = the energy content of fuel j used by household i - this equation is estimated separately for each fuel and each major end-use, such as cooking, space heating, and lighting;
Y_i = household income for household i;
N_i = family size for household i;
P_{ij} = the price of fuel j facing household i;
P_{ik} = the prices of competing fuels k (k = 1, 2,..n) facing household i;
A_{ij} = appliance prices facing household i for appliances for fuel j;
A_{ik} = appliance prices facing household i for appliances for fuels k = 1, 2,..n.

However, due to imperfect market conditions for fuels in developing countries and because data are generally unavailable on prices of competing appliances, the above equation is not satisfactory for our purposes. As a consequence, we must modify this standard demand model to fit the conditions of developing countries.

A Modified Demand Model

2.3 For this paper the standard fuel use model is modified to explicitly account for fuel availability and cooking practices. In the majority of developing countries, people do not have access to all fuels equally. As a consequence, we add a variable to gauge varying degrees of market access to fuels that is not captured in fuel prices. In addition, as variation in appliance prices faced by households is very difficult to ascertain from most developing country surveys, appliance prices are dropped from the equation. By contrast, cooking practices have been added to the equation, because they can affect the amount of fuel that is consumed by households. The form of the model that we will be using for estimating use of specific fuels is as follows:

$$Q_{ij} = f(Y_i, N_i, P_{ij}, P_{ik}, M_{ij}, M_{ik}, H_i) \quad (2)$$

Where:

Q_{ij} = the energy content of fuel j used by household i - this equation is estimated separately for each fuel and each major end-use, such as cooking and lighting;
Y_i = household income for household i;
N_i = family size for household i;
P_{ij} = the price of fuel j facing household i;
P_{ik} = the prices of competing fuels k (k = 1, 2,..n) facing household i;
M_{ij} = an index of resource availability for fuel j;
M_{ik} = an index of resource availability for fuels k (k = 1, 2,..n) and;
H_i = cooking practices for household i.

2.4 The inclusion of the resource availability/market access variable in the equation is often overlooked in studies of household energy demand in developing countries. Our assumption is that market prices may not fully reflect differences in fuel availability. A fuel may be readily available for short periods of time, it may be available in limited quantities at government controlled prices, and other conditions may distort the price of the fuel. Such market distortions can be partially captured in the market access variable. This variable helps to explain some of the differences in residential fuel consumption in urban areas.

2.5 We shall apply equation (2) separately to estimate use of each fuel for each major household end use. The statistical procedure used for estimating the coefficients is tobit analysis (Tobin, 1958). The reason for using tobit analysis for estimating use of individual fuels is that the decision to use a fuel has two components. A household chooses whether to use a fuel and how much to use. As a consequence, when estimating the use of each fuel as a dependent variable, households not using the fuel will have a value of zero while those that use the fuel will have a positive value. The use of ordinary least squares is inappropriate in such a case, so we have adopted the tobit procedure which statistically corrects for the zeros. The coefficients resulting from the tobit procedure are not directly interpretable as elasticities, as they include both the probability of fuel choice and the level of fuel use.

Fuel Substitution Ratios: Estimating "Liters of Kerosene Equivalent"

2.6 In addition to this extension of the standard demand model, a set of dummy variables indicating fuel choice are added to the equation to explicitly derive kerosene substitution ratios that we call "liters of kerosene equivalent". The dependent variables in this case represents the total energy used for each particular end use (lighting and cooking). The fuel substitution coefficients are estimated by including a set of dummy variables indicating whether or not a household uses a particular fuel or combination of fuels for either lighting or cooking, but without an explicit dummy variable for exclusive kerosene users. The rationale for adding these dummy variables is that the difference in energy use of people using fuels other than kerosene can be directly compared with those using kerosene, after controlling for other factors that affect energy demand. The equation takes the following form:

$$LN\ Q_i = f(LN\ Y_i, LN\ N_i, LN\ P_{ij}, LN\ P_{ik}, M_{ij}, M_{ik}, H_i, C_i) \qquad (3)$$

Where:

Q_i = the energy content of all fuels used by household i; - this equation is estimated separately for each major end-use, such as cooking and lighting;

C_i = the fuel or combination of fuels used by the household, leaving out those who choose only kerosene;

LN = natural logarithm.

2.7 The statistical procedure used to estimate substitution ratios through equation (3) is ordinary least squares. As opposed to the tobit model of fuel use corrected for choice described above, all households use energy for cooking and lighting, and the logged amount of energy use approximates a normal distribution in the sample of urban Indonesia. As a consequence, the coefficients for the logged variables are directly interpretable as elasticities. Likewise, the coefficients for the dummy variables for each fuel choice, C_i, indicate how much more or less energy is used by households using a particular fuel as compared to those not specified with a fuel choice dummy.[2/] Since kerosene is left out, the fuel choice coefficients can be interpreted as kerosene substitution ratios. These substitution ratios are based on the actual behavior of households with comparable socioeconomic and resource availability profiles.

2/ The use of dummy variables for fuel choice in the logged OLS model assumes that the resulting substitution ratios are constant.

III. Description of Indonesia Household Energy Data

3.1 The models presented above are used to analyze residential energy consumption in Urban Java for 1988. The sample for the survey included 2,700 households and was stratified to include representative proportions of households living in a range of urban area sizes. As the sample was drawn from the 1987 National Social and Economic Survey (SUSENAS) sample frame, it is a statistically valid representation of urban households on Java. All household characteristics, fuel prices, and fuel availability factors used in the analysis are directly from household and enumerator survey responses. Cooking and lighting variables are derived from a combination of survey responses, fuel use measurements, and a lighting estimation procedure that is summarized in the Annex. We assumed that monthly household expenditures are strongly correlated with household income and, hence, we use the terms 'income' and 'expenditures' interchangeably.

3.2 The patterns in Table 1 have much in common with similar surveys in other developing countries. The average size of an urban household in Java is just under 5 people and average monthly expenditures are about 155,000 Rupiah (US$ 90/month/household or US$ 225/person/year). As expected, wealthier households have been electrified longer than poorer households. Household expenditures increase with urban area size. The availability of fuelwood declines with income, while the availability of LPG increases. However, this variation in availability of different fuels may be more a function of city size than income.

3.3 Total energy use for cooking does not vary significantly across income groups, indicating that higher income families use less energy per capita than the poor (see Table 2). Though this pattern appears to indicate significant returns to scale in the cooking end-use, it may also be a reflection of fuel switching. This is explored in a multivariate context, controlling for fuel choice, in section IV of this paper. Also, the share of households using fuelwood declines dramatically as incomes rise: from 45 percent of low income households to about 8 percent of upper income urban households. Fuelwood users tend to live in smaller towns where wood is more easily available and, as will be shown below, wood availability is a very important factor in determining urban household fuelwood use on Java.

3.4 Urban dwellers on Java differ from city dwellers in many other developing countries in that the vast majority of urban households on Java use no more than one fuel for cooking (over 90 percent of the sample). Kerosene, sold at fixed prices below the average cost of supply, meets the bulk of urban household cooking demand. Over the entire sample, 76 percent of all households use kerosene for cooking. LPG has recently become a significant fuel of choice by upper income urban households, although it is still used by only 13 percent of households in this group. Electricity is rarely used for cooking. Of the very few surveyed households that use electricity for cooking, most use an electric rice cooker while preparing side dishes with other fuels.

3.5 The comparisons between those who use kerosene for lighting with those who use electricity are fairly dramatic. Almost all households with electricity light exclusively with it, with only 2% of households combining kerosene and electric lighting. As expected, kerosene use for lighting falls off dramatically with rising incomes. Fully one third of low income households light with kerosene while well over 90 percent of middle and upper income households use electric lights.

Table 1: Factors that Influence Fuel Choice and Use in Urban Households on Java, 1988

Expenditure Group	Low	Middle	High	All
Household Characteristics				
Number of Family Members (Mean)	3.72	4.93	5.73	4.8
Standard Deviation	1.84	1.92	2.24	2.17
Expenditures ('000 Rp/HH/Mo) (Mean)	56.50	119.55	291.99	155.91
Standard Deviation	18.21	21.79	207.51	156.31
Number of Rooms in House (Mean)	3.39	3.85	4.94	4.06
Standard Deviation	1.53	1.59	2.01	1.84
Years Since HH Electrified (Mean)	6.99	7.73	10.62	8.64
Standard Deviation	8.02	7.35	9.17	8.57
Valid Cases	538	720	774	2032
Urban Area Population (millions) (Mean)	1.00	2.54	3.88	2.48
Standard Deviation	1.92	3.16	3.57	3.19
Valid Cases (except where noted)	805	816	806	2427
Fuel Prices (Rp/MJ)				
Wood Price (Mean)	5.18	8.88	12.34	8.82
Standard Deviation	5.98	9.38	10.79	9.42
Charcoal Price (Mean)	8.71	10.26	11.69	10.23
Standard Deviation	3.40	4.04	4.28	4.11
Kerosene Price (Mean)	5.76	5.77	5.78	5.77
Standard Deviation	0.25	0.28	0.31	0.28
LPG Price (Mean)	12.96	12.95	12.94	12.95
Standard Deviation	0.25	0.21	0.23	0.23
Electricity Price (Mean)	37.65	28.82	26.4	30.91
Standard Deviation	30.57	11.97	7.59	19.92
Valid Cases	790	815	805	2410
Fuel Availability				
Availability of Fuelwood on the Block				
Not Available	21.14%	34.85%	37.27%	31.16%
Availability Problems	6.33%	14.11%	23.11%	14.56%
Available	49.62%	42.82%	32.80%	41.70%
Available in Own Yard	22.91%	8.22%	6.83%	12.57%
Availability of LPG on the Block				
Not Available	55.70%	31.04%	25.96%	37.43%
Availability Problems	2.53%	4.66%	3.98%	3.73%
Available	41.77%	64.29%	70.06%	58.84%
Valid Cases	790	815	805	2410
Rice Cooking Practices				
% of HH Boiling Rice	33%	21%	17%	24%
% of HH Steaming Rice	51%	73%	80%	68%
% of HH Steaming & Using Hot Water	16%	6%	3%	8%
Valid Cases	790	815	805	2410

Source: World Bank, 1990.

Table 2: Residential Fuel Use for Cooking and Lighting in Urban Java, 1988

Expenditure Group	Low	Middle	High	All
Cooking Fuel Use (MJ/HH/day)				
Total Cooking (Mean)	47.55	45.03	50.89	47.81
Standard Deviation	35.24	28.72	32.95	32.46
Wood Cooking				
% of HH Using Fuel	45.06%	18.28%	8.20%	23.69%
Mean for Users	61.94	60.42	64.48	61.84
Standard Deviation	41.32	43.55	67.74	45.61
Kerosene Cooking				
% of HH Using Fuel	57.85%	85.23%	86.71%	76.76%
Mean for Users	32.77	38.45	46.40	40.05
Standard Deviation	20.02	20.14	23.95	22.29
LPG Cooking				
% of HH Using Fuel	0.51%	2.70%	13.42%	5.56%
Mean for Users	28.61	32.98	35.92	35.22
Standard Deviation	5.55	11.18	18.40	17.18
Valid Cases	790	815	805	2410
Lighting Fuel Use (MJ/HH/Month)				
Total Lighting (Mean)	213.49	145.58	138.43	165.73
Standard Deviation	286.94	217.40	151.36	227.83
Kerosene Lighting				
% of HH Using Fuel	36.15%	12.37%	3.47%	17.47%
Mean for Users	482.28	594.38	644.91	520.78
Standard Deviation	331.01	340.06	336.82	337.90
Electric Lighting				
% of HH Using Fuel	66.71%	89.22%	97.52%	84.51%
Mean for Users	58.70	77.45	118.98	88.46
Standard Deviation	46.13	51.44	95.43	74.93
Valid Cases	805	816	806	2427
Illumination (kLm-hr/HH/Month)				
Total Illumination (Mean)	235.06	425.32	786.05	482.24
Standard Deviation	320.19	409.30	893.64	638.41
Kerosene Illumination				
% of HH Using Fuel	35.87%	12.76%	3.47%	17.33%
Mean for Users	43.28	55.49	65.24	47.76
Standard Deviation	49.07	55.50	49.52	51.12
Electric Illumination				
% of HH Using Fuel	66.87%	89.33%	97.52%	84.61%
Mean for Users	328.29	468.22	803.73	560.16
Standard Deviation	354.14	412.02	897.45	664.26
Valid Cases	803	815	806	2424

Source: World Bank, 1990.

3.6 The prices of energy reflect the difficulties for the poor who rely on traditional fuels in urban areas. Fuelwood and charcoal prices appear to vary much more across the sample than conventional fuel prices. This variation appears to increase with household income. At first glance this would appear to be favorable to the poor. However, as household income and urban area size are correlated, this relationship may actually be a reflection of low woodfuel availability and higher prices in larger cities where the poor may have to pay more for traditional fuels. Low-income households appear to pay much higher prices for electricity than middle and upper-income households. Many poor households are not formally connected to the grid, but rather, purchase electricity from neighbors at a shared cost or flat fee. As these households tend to use very little electricity, they *do* tend to pay higher prices on a kWh basis.

3.7 Modern fuels are available in urban Java to the poor at about the same price level as faced by higher income households. The fact that retail conventional fuel prices in Indonesia are administered centrally results in very little price variation across the sample.[3/] Also, variation in fuel availability to the households was explicitly addressed in the urban Java survey. As a result of government policy that charges the national oil company, Pertamina, with making kerosene available to all households nationwide, kerosene was found to be nearly universally available to all urban households on Java. Though the data also include estimates of percent of households electrified in each block, such a measure is actually a measure of use rather than access. As a consequence, we have left it out of the analysis.

3.8 In general, fuelwood becomes harder to obtain and LPG becomes easier to obtain as city size increases. Kerosene is available, almost without exception, to all urban households on Java. Indices of fuelwood and LPG availability were constructed from enumerator characterizations of market access in the vicinity of sampled household clusters. All households were assigned an availability score for fuelwood and LPG, based on enumerator assessment.[4/] As will be seen later, the difference in availability of fuels is a significant determinant of fuel choice and use.

3.9 Cooking methods also can be important for energy consumption. Generally, urban households prepare rice using several distinct methods--boiling, steaming, and jointly steaming and using the resulting hot water. The share of households boiling rice and using the joint products of steaming rice markedly declines as income rises. As will be evident from the later analysis, differences in cooking practices have a significant influence on total cooking energy demand, with rice boiling requiring less energy than steaming.

3.10 The results of the analysis so far indicate that people in urban Java are mainly using kerosene for cooking and electricity for lighting. However, there are still a significant number of people using wood fuels for cooking and many of the urban poor are still using kerosene for lighting. Traditional fuels cost more in larger cities and electricity costs more for lower income people who are likely to live in smaller cities. Finally, kerosene is available in most parts of urban

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3/ Fuel price data is comprised of household survey responses to fuel price questions for each fuel used by the household. For fuels not used by the household, the average price paid for the fuel by using households on the block or in the same urban area are used.

4/ Availability factors were assigned as follows: 0 = not available in the neighborhood; 1 = available with difficulty or unreliably; 2 = available in the neighborhood; and 3 = fuelwood available from own yard. The validity of these scales were confirmed through factor analysis.

Java at virtually the same price in all locations. These findings provide the background necessary to analyze cooking and lighting behavior, which is explored in a multivariate context in the next two sections.

IV. Cooking Fuel Choice and Use

4.1 The analysis of household energy demand for cooking in Java is important because a number of energy policies in the country are focussed on cooking energy use. Indonesia maintains an urban electrification policy and a subsidy for kerosene that are justified partially to improve the quality of life of the urban poor and to alleviate wood demand in the cities. The relationships described in the previous section indicated that there are significant correlations between income, family size, fuel prices, fuel availability, fuel choice, and fuel use. In the next two sections, we apply the model to the urban Indonesia data to sort out the relative influences of these factors on fuel choice and to investigate how much of one fuel will substitute for another for cooking and lighting under actual conditions.

Fuel Choice and use Model

4.2 As expected, the choice and use of fuels for urban households is dependent on income. The wood users are found mainly in the low income groups. Households using kerosene are found in all income categories. Finally, the families who use LPG are found mainly in the highest income groups. In addition to examining the number of users in each category, the energy demand model can be utilized to examine the factors that are associated with the different kinds of fuel use. As a consequence, a tobit analysis of the adoption and use of each fuel was completed for high, middle, and low income groups. The only exception is for the use of LPG, since there were too few households that use LPG in the low and middle income groups. Results are presented in Table 3.

4.3 As indicated, kerosene is universally available to urban households in Java. Kerosene provides the bulk of fuel demand for cooking and is used by households throughout the income spectrum. As such, the factors that affect its choice and use are family size, income, kerosene price, and once again wood availability. In the hierarchy of consumer preferences, kerosene is a transition fuel between fuelwood and LPG. This is indicated by the change in the household expenditures coefficient across income groups. In low and middle income households, an increase in income leads to an increase in kerosene use. But interestingly, the reverse is true for high income households who reduce their use of kerosene with increases in income. The own price coefficient for kerosene is negative, indicating predictably that higher prices lead to lower use of the fuel. But once again availability of wood is also important in predicting kerosene choice and use. Controlling for other factors such as price, if wood is more available, then less kerosene is used by urban households. Although this resource availability effect is evident in all income groups, it is strongest among low income households that use wood as a major fuel. Finally, households that prepare their rice by steaming consistently use more kerosene than those who boil rice. Since steaming is the preferred method for rice preparation in urban Java, this finding may not yield a direct potential for fuel conservation through interventions aimed at modifying cooking practices. It does indicate, however, that factors other than efficiency as measured in the laboratory can significantly influence fuel consumption under actual conditions.

4.4 Wood fuels are basically a low income fuel in Urban Java. The factors that are the most important in explaining the choice and use of wood are family size, income, wood price, wood availability, and LPG availability. As expected, the results are most robust in lower income groups where wood is an important fuel. The significance levels decline in middle and high income groups,

Table 3: Tobit Analysis of Residential Cooking Demand in Urban Java, 1988

MegaJoules of Daily Household Cooking Fuel Use by Fuel Type (MJ/HH/day)

Fuel Expenditure Group	Fuelwood Low	Fuelwood Middle	Fuelwood High	Fuelwood All	Kerosene Low	Kerosene Middle	Kerosene High	Kerosene All	LPG Low	LPG Middle	LPG High	LPG All
Household Characteristics												
Family Size	7.48	11.48	2.79	7.63	1.07	0.92	2.35	1.55	-	-	1.78	2.46
	4.90	4.98	0.68	7.10	1.79	2.04	4.88	5.62	-	-	1.00	1.69
LN Expenditures/HH/Mo	-21.87	-65.78	-20.13	-29.37	14.17	11.74	-4.87	6.90	-	-	38.43	46.09
	-2.73	-2.73	-0.66	-7.90	3.69	2.07	-2.35	7.46	-	-	4.79	7.10
Fuel Price												
Wood Price (Rp/MJ)	-14.40	-5.32	-6.38	-7.59	0.45	0.41	-0.12	0.14	-	-	1.72	1.75
	-6.13	-2.76	-1.21	-6.16	1.46	3.10	-0.65	1.46	-	-	2.61	3.04
Charcoal Price (Rp/MJ)	0.88	-0.67	0.97	0.83	0.31	0.24	0.43	0.28	-	-	-2.65	-2.88
	0.77	-0.35	0.33	1.08	0.71	0.73	0.97	1.25	-	-	-1.48	-1.85
Kerosene Price (Rp/MJ)	15.39	17.15	4.38	12.58	-16.47	-3.14	-9.94	-8.99	-	-	2.66	-2.32
	1.05	0.81	0.12	1.26	-2.62	-0.86	-2.29	-3.86	-	-	0.19	-0.19
LPG Price (Rp/MJ)	7.87	24.13	-4.26	7.92	-2.28	6.99	3.01	1.90	-	-	-33.89	-44.92
	0.53	1.07	-0.11	0.71	-0.50	1.61	0.50	0.69	-	-	-3.77	-5.26
Electric Price (Rp/MJ)	0.02	0.57	-1.13	0.11	-0.21	-0.19	-0.29	-0.27	-	-	0.56	-0.12
	0.19	1.56	-0.48	0.87	-3.13	-2.37	-1.40	-5.91	-	-	1.03	-0.24
Fuel Availability												
Wood Availability	38.49	55.02	88.81	49.10	-11.51	-6.89	-3.87	-7.60	-	-	-0.05	-3.56
	8.52	6.69	4.80	13.33	-8.02	-5.97	-2.77	-10.18	-	-	-0.01	-0.91
LPG Availability	-8.61	-20.02	-29.02	-15.36	4.36	2.34	-1.70	1.60	-	-	20.11	21.31
	-2.54	-3.08	-2.60	-5.40	2.77	1.96	-1.03	1.95	-	-	3.45	4.17
LN City Size	-3.71	2.41	-2.79	-1.94	0.39	-0.75	0.21	0.38	-	-	-2.92	-2.34
	-1.79	0.59	-0.34	-1.07	0.43	-1.00	0.23	0.81	-	-	-0.90	-0.81
Cooking Habits												
Steam Rice	-0.78	-30.20	-18.57	-12.34	11.28	8.32	10.12	10.69	-	-	-20.07	-12.32
	-0.12	-2.71	-0.68	-2.15	3.95	3.37	3.37	7.27	-	-	-2.50	-1.66
Steam + Hot Water	6.23	-12.50	1.99	4.01	3.17	9.38	7.32	3.77	-	-	8.08	2.10
	0.71	-0.73	0.05	0.49	0.74	2.02	1.07	1.37	-	-	0.39	0.11
(Constant)	36.69	174.61	105.17	65.54	-18.06	-175.05	103.43	-34.76	-	-	-112.48	-40.24
	0.16	0.41	0.15	0.40	-0.22	-1.98	1.22	-0.85	-	-	-0.65	-0.28
Sigma	52.06	74.59	108.82	67.44	26.90	24.06	29.33	27.50	-	-	55.37	59.15
	45.58	17.31	11.41	50.61	50.26	65.34	75.11	134.62	-	-	10.72	10.83
Log-Likelihood												
@ OLS Stage	-3890	-3826	-3721	-11538	-3419	-3643	-3764	-10923	-	-	-3215	-8606
@ Convergence	-2058	-987	-482	-3585	-2342	-3320	-3471	-9227	-	-	-755	-991
# Cases	790	815	805	2410	790	815	805	2410	790	815	805	2410
# Fuel Users	356	149	66	571	457	695	698	1850	4	22	108	134

Source: World Bank, 1990.

indicating that other factors become more important in these groups. The expenditure coefficients confirm that wood is an *inferior* good. Even in the lowest income category, as income rises the choice and use of fuelwood declines. One of the most interesting findings is that availability of fuelwood is a very influential factor in determining wood choice and use for cooking. It is remarkable that even in the highest income groups, if fuelwood is available in the local environment then it is used. This is complemented by the price results which indicate, as one would expect, that the price of fuelwood is negatively associated with wood fuel use. Thus, the suspicion that fuel availability is not always reflected in price in developing countries appears to be true in this case. The apparent weakness of cross-price effects may be due in part to noted difficulties with deriving price elasticities from cross-sectional surveys, especially for kerosene and LPG which do not have very much variation in Java.[5/]

4.5 LPG is definitely a high income fuel. Because so few low and middle income households in the sample reported using LPG for cooking, estimates of LPG use are reported only for high income households. The dominant factors in determining LPG choice and use are household expenditures, LPG price, LPG availability, cooking practices, and to limited degree wood price. However, the wood price finding once again may be explained by the fact that wood prices are higher in large cities. In the high income groups it is very unlikely that it is a competing fuel for LPG. The significant coefficients for LPG price and availability, also indicate that consumers are very sensitive to pricing and distribution policies of LPG, and once again reinforces the notion that market availability for fuels may not be fully reflected in their relative prices. The results generally confirm that LPG is the fuel of choice for high income households.

4.6 The main conclusio~ ~om analysis of the factors affecting fuel choice and use for cooking is that policies to make t. ~eadily available and give consumers a choice between fuels can be important in influencing fuel choice and use behavior. In the past, availability factors have not been explicitly included in most household energy demand models for developing countries. The transition from wood to kerosene to LPG is confirmed by the income coefficients, where fuelwood choice and use decline with income, kerosene increases in the low and middle income groups and declines in wealthier households, and LPG increases with income in the high income groups. Finally, an interesting but not very robust result is that cooking practices do affect the level of energy use by urban households.

Fuel Substitution Model: Estimation of the Kerosene Substitution Ratio

4.7 As stated above, over 90% of the urban households .. Java tend to use only one fuel for cooking. This characteristic allows the construction of five ~uel choice dummies, including one each for households cooking exclusively with wood, charcoal, or LPG, or with a combination wood-charcoal-kerosene or kerosene-LPG-electricity. The dummy variable for households cooking exclusively with kerosene is left out of the analysis, so that coefficients of each fuel choice dummy indicate how much more or less energy is used by households cooking with the indicated fuel

5/ Other cross-sectional studies of household energy demand have suffered from the same problems (Alam and coauthors, 1985; Reddy and Reddy, 1983). Most of the studies on fuelwood pricing issues have involved longitudinal analyses (Barnes, 1989; Bowonder and coauthors, 1988; Wardle and Palmieri, 1981). For Indonesia, Pitt, 1985 and Dick, 1980 also find weak cross-price elasticities, but interpret them as representing the actual effects of competitive prices. We are somewhat more cautious in our interpretation because of the possibility that regional 'fixed effects' may cause problems for estimating price elasticities from cross-sectional data.

compared to those cooking exclusively with kerosene. In the logged form OLS model, each fuel use coefficient can be interpreted as a 'kerosene substitution ratio'.

4.8 Results of the OLS model applied to cooking fuel data from urban Java are presented in Table 4. The coefficients for the fuel use dummies isolate the effects of fuel choice on total energy use for cooking while holding constant other household characteristics.[6] The coefficients for the fuel choice variables reflect factors that contribute to differences in fuel use under actual conditions, including variation in technical stove efficiencies, different stove power settings, cooking practices other than those explicitly included, and behavior change that may accompany a fuel switch. The choice of fuels also explains about 10 percent of the variation in fuel use for the households in the survey (see R^2 for fuel choice variables).

4.9 While certain factors may influence individual fuel choice, they do not all necessarily affect total cooking energy use.[7] For this analysis family size is a most significant predictor of cooking energy use. The family size coefficient (0.36) indicates that significant returns to scale exist. A ten percent increase in family size leads, on average, to an increase of about 3.6 percent in total cooking fuel use. The method of preparing rice also has a strong effect on total cooking fuel use, confirming the previous findings for kerosene use presented in Table 3. Households steaming rice and those using the joint products of steaming consistently use more energy for cooking than households that boil their rice.

4.10 Turning to the kerosene substitution estimates, because efficiencies of wood stoves used in urban households range between ten to twenty percent while the efficiencies of kerosene stoves range between thirty and fifty percent (World Bank, 1990), one would expect people who burn wood to consume more energy for cooking than those who use kerosene. On the basis of relative stove efficiencies alone, one liter of kerosene could be expected to displace at least 5 kg of wood, if not considerably more.[8] This is equivalent to saying that households cooking with wood consume almost twice as much energy compared to households relying on kerosene. However, the coefficient for wood users in Table 4 (0.50) indicates that a household cooking with wood consumes only 66 percent more energy than a similar household cooking with kerosene. Said another way,

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6/ This econometric method of deriving substitution ratios was first developed and applied to the urban Java data by G. McGranahan and F. D. J. Nieuwenhout for the ESMAP/DJLEB study (World Bank, 1990).

7/ Since an F-test on the fuel price variables showed that prices were not significant in explaining fuel use variation for the purpose of estimating substitution effects, we have not included fuel prices in this application of the fuel substitution model.

8/ Kerosene stoves in Indonesia range between 30% and 50% efficient while it is assumed that wood stoves in actual use can transfer between 10% to 20% of the thermal energy in the fuel into the pan. Using the most efficient estimate for wood stoves and a mid-range estimate of 40% efficiency for kerosene stove in actual use yields: (35.2 MJ/l kerosene) / (14 MJ/kg wood) * 40% efficiency of kerosene stove) / (20% efficiency of wood burning stove) = 5 kg wood / liter kerosene. This represents an estimate of the <u>minimum</u> amount of fuelwood that could be expected to be displaced by one liter of kerosene based on technical estimates of average stove efficiencies.

Table 4: OLS Analysis of Total Residential Cooking Demand in Urban Java, 1988

Natural Logarithm of Total Daily Household Cooking Fuel Use (LN MJ/HH/day)

Expenditure Group	Low	Middle	High	All
Demand Variables				
LN Family Size	0.40	0.36	0.37	0.36
	9.54	8.84	9.00	15.77
LN Expenditures/HH/Mo	-0.08	0.11	0.06	0.07
	-1.34	1.22	1.28	3.62
LN City Size	0.00	-0.01	-0.01	-0.00
	0.28	-1.11	-0.84	-0.78
Wood Availability	-0.05	-0.03	0.01	-0.02
	-1.98	-1.25	0.35	-1.40
LPG Availability	-0.02	0.02	-0.01	-0.01
	-1.00	0.98	-0.35	-0.54
Steam Rice	0.21	0.12	0.14	0.16
	4.59	2.69	2.67	5.92
Steam + Hot Water	0.29	0.26	0.20	0.27
	4.83	3.29	1.84	6.39
Fuel Choice				
Exclusive Wood Users	0.61	0.39	0.33	0.50
	11.18	6.67	2.86	14.25
Exclusive Charcoal Users	-0.54	-0.42	-1.17	-0.67
	-4.25	-2.01	-6.04	-7.23
Multiple Cooking Fuels	0.59	0.60	0.37	0.52
Biofuels and Kerosene	7.38	8.60	4.72	11.82
Multiple Cooking Fuels	-0.18	0.06	0.11	0.13
Kerosene, LPG, and Electricity	-0.48	0.52	1.57	2.43
Exclusive LPG Users	-0.30	-0.05	-0.23	-0.17
	-0.98	-0.33	-3.21	-2.82
(Constant)	3.69	1.78	2.45	2.25
	5.82	1.67	4.30	10.82
R^2 for whole equation	0.40	0.24	0.20	0.29
R^2 explained by Fuel Choice	0.13	0.10	0.07	0.11
F Statistic	42.22	21.47	14.43	80.15
# Cases	790	815	805	2410

Source: World Bank, 1990. Of the 2,410 households with valid values for all regression variables: 67% use only kerosene, 18% use only wood, 1% use only charcoal, and 3% use only LPG, for cooking. Mixed biofuel and kerosene users comprise 7% of valid sample households and households using more than one conventional fuel make up the remaining 4%.

for an average household, one liter of kerosene substitutes for 4.2 kilograms of wood for cooking.[9] Hence, in urban households of Java, fuelwood appears to be used more economically than would otherwise be predicted.

[9] Since $e^{0.50}$ = 1.66, this result indicates that households cooking with wood consume, on average, 66% more energy for cooking than kerosene using households. Transformed into physical units, this results in a substitution ratio of roughly 4.17 kilograms of wood/liter of kerosene [(35.2 MJ/l kerosene)*1.66 / (14 MJ/kg wood) = 4.17 kg wood / liter kerosene] with 95% confidence that the true substitution ratio is between 3.88 kg and 4.47 kg of wood replaced per liter of kerosene.

4.11 The efficiencies of LPG stoves are higher than those for kerosene. As a consequence, one would expect that the households using LPG would use less energy for cooking than those using kerosene. On the basis of relative stove efficiencies, the expected ratio would be 0.5 kg of LPG or less per liter of kerosene.[10/] However, the coefficient for LPG users (-0.17) indicates that households cooking with LPG consume, on average, 15.6 percent less energy for cooking than households cooking with kerosene. In physical units, this means that 0.65 kg of LPG substitutes for 1 liter of kerosene for cooking.[11/] Hence, in urban households of Java, LPG appears to be used less economically than would otherwise be predicted.

4.12 In conclusion, the behaviorally derived kerosene substitution ratios for wood and LPG are marginally outside of the range of ratios commonly used based on fuel heating values and relative stove efficiencies. Because these results are based on actual cooking fuel consumption patterns in urban households, they provide a much sounder basis for assessing the substitution potential of various fuels than technical estimates based on stove efficiencies alone. Though in the case of urban Java the observed ratios are only marginally different from technical estimates, this need not necessarily be the case if this method were applied to other end-uses or other countries with different resource and pricing conditions. This claim is supported by the surprising results that were found in the analysis of household lighting presented below.

10/ According to laboratory measurements, LPG stoves marketed in Indonesia have efficiencies of 60% or greater for cooking. Based on this, at most 0.51 kg of LPG should be expected to displace one liter of kerosene for cooking: (35.2 MJ/ liter kerosene * 40%) / (45.8 MJ/kg LPG * 60%) = 0.51. This represents an estimate of the maximum amount of LPG that could be expected to displace one liter of kerosene based on technical estimates of average stove efficiencies.

11/ Households cooking with LPG consume, on average, only 84% of the energy used for cooking by households that cook with kerosene ($e^{-0.17}$ = 0.84). Transformed into physical units, this can be interpreted as a substitution ratio of roughly 0.65 kilograms of LPG [(35.2 MJ/l kerosene * 0.84) / (45.8 MJ/kg LPG) = 0.65 kg LPG / liter kerosene] with 95% confidence that the true substitution ratio is between 0.57 kg and 0.73 kg of LPG per liter of kerosene replaced.

V. Lighting Fuel Choice and Use

5.1 The benefits of many residential electrification projects have often been evaluated based on estimates of consumer "willingness to pay" for the service. Though the concept of "willingness to pay" is certainly sound, if our analysis is correct, recent techniques used to estimate the benefits of electrification may be seriously understating the benefits of residential electricity use for lighting. Whereas households who switch cooking fuels are unlikely to change the amount of food they cook, it is widely recognized that when households switch from kerosene to electric lighting it is likely that they will light more, for longer hours, and perhaps change their behavior and engage in more activities that are made possible by high quality lighting. Such activities might include reading, sewing, and recreational activities in the evening. In other words, demand for electric lighting is qualitatively different from demand for kerosene lighting. The analysis presented in this section examines the extent of these differences. Before the fuel substitution analysis is presented, however, we explore the independent effects of household characteristics and other factors on lighting fuel choice and use.

Lighting Demand Model

5.2 Electricity is definitely preferred over kerosene for lighting in urban Java. Kerosene is used for lighting primarily by those who either cannot afford or do not have access to electricity. The lighting demand equations for electricity and kerosene take somewhat different forms. As stated in section III, the percent of households electrified in each sample cluster could not be used as an electricity availability index. Obviously, cooking practices would not have much effect on lighting behavior, so it was dropped from the analysis. Two variables have been added to the analysis, including number of years the household has been electrified and the number of rooms in the place of residence. Year since electrification is not included in the kerosene demand equation, because, with few exceptions, those with electricity do not use kerosene for lighting. Finally, the dependent variable in the lighting demand equation is kiloLumen-hours of lighting enjoyed per month, which is a more appropriate measure than a heating value because households are paying for light.[12/] Once again we examine each fuel separately.

5.3 Kerosene is not the fuel of choice for lighting in urban Java. Most of the factors that predict kerosene choice and use are governed by affordability or access to electricity service. For instance, household income and number of rooms in a residence reflect the level of well-being for a family. In both cases the relationship with kerosene consumption is negative (see Table 5). But even these findings are not overly robust within income groups, indicating that other factors may be somewhat more important in predicting use of electricity. The other factors are captured in part by city size. City size is strongly and negatively related to use of kerosene over all income classes. The city size result simply reflects the fact that the share of households with an electricity connection increases with city size. It is possible to interpret both the city size and the kerosene price factors as measures of access to electricity.

12/ Note that kLmh estimates are derived from survey responses about lighting fuel use and lamp types. The lamp efficiencies are given in Table A1 of the annex. Also, in this model and in the fuel substitution model presented in this section, we include fuel prices on a heating value basis instead of prices per kLmh. This is done to avoid the identification bias that would result from having the dependent variable in the denominator of an independent variable for which the numerator has a small range of variation. This problem is discussed further in the annex.

Table 5: Tobit Analysis of Residential Lighting in Urban Java, 1988

Kilolumen-hours of Monthly Residential Lighting by Fuel Type (kLmh/HH/Month)

Fuel	Kerosene Lighting				Electric Lighting			
Expenditure Group	Low	Middle	High	All	Low	Middle	High	All
Household Characteristics								
Family Size	3.12	7.70	8.72	5.18	24.47	-7.04	2.84	-2.62
	1.61	1.96	1.21	3.22	3.22	-0.85	0.18	-0.38
LN Expenditures/HH/Mo	-8.09	-28.10	-7.85	-32.87	27.33	168.00	420.12	234.05
	-0.73	-0.82	-0.12	-5.39	0.56	2.01	5.98	10.20
Number of Rooms	-2.36	-9.58	-24.71	-8.49	70.73	72.70	157.84	118.02
	-0.99	-2.34	-2.14	-4.56	8.20	7.92	11.59	18.16
Fuel Price								
Kerosene Price/MJ	18.82	51.16	30.62	61.89	-119.29	-120.46	-30.37	-206.38
	1.24	2.30	0.68	5.88	-1.65	-2.55	-0.27	-4.33
Electricity Price/MJ	0.23	0.44	0.65	0.25	-3.83	-4.05	7.81	-3.14
	1.62	0.54	0.24	1.54	-3.14	-1.96	1.54	-2.16
Fuel Availability								
LN City Size	-12.68	-16.01	-25.42	-14.91	50.94	19.40	62.12	47.56
	-6.23	-4.63	-2.83	-9.24	5.72	2.61	3.36	6.50
Years Since HH Electrified					17.52	13.45	14.47	17.00
					12.30	8.53	4.28	12.27
(Constant)	86.83	98.30	45.26	120.30	-388.03	-1354.35	-6314.56	-2241.85
	0.64	0.24	0.05	1.49	-0.59	-1.37	-6.54	-6.63
Sigma	71.42	109.81	146.13	88.05	361.80	406.85	789.53	589.99
	27.05	15.45	4.58	33.49	45.82	60.79	85.99	194.49
Log-Likelihood								
@ OLS Stage	-3994	-3829	-3314	-11421	-5664	-5985	-6507	-18675
@ Convergence	-1873	-811	-251	-2974	-4088	-5486	-6375	-16235
# Cases	803	815	806	2424	803	815	806	2424
# Fuel Users	289	104	28	421	537	728	786	2051

Source: World Bank, 1990.

5.4 One anomaly is that kerosene price is positively related to kerosene choice and use. This can be explained partially by the fact that the price of kerosene sold further than 40 km from the depot is allowed to include an additional mark-up for intra-city transport. Hence, the average retail price of kerosene tends to be marginally higher in towns further from large city centers. Although the data set does not indicate distances of each sample cluster from a large urban area, it is reasonable to assume that the availability of electricity connections for urban consumers may decline directly with distance from a large city center. In addition, poor households lighting with kerosene tend to purchase fuel often and in small quantities from neighborhood stores, at a higher price per liter than if purchased in larger quantities.

5.5 The lighting results indicate that electricity is the fuel of choice in urban Java. As might be expected, the results of the electricity analysis are basically the reverse of findings for kerosene lighting demand. Income and number of rooms in the residence are strongly related to the use of electricity for lighting. There is stronger demand for electric lighting in the larger cities in urban Java. For the reasons given above, kerosene prices are negatively related to the use of electricity for lighting. There are two other interesting findings in the table. The first is that the price of electricity has little effect on demand for electric lighting in the higher income groups, but it does have an impact for low income groups. The higher income groups install lights as they need them, and the existing price levels are not much of a hindrance to the amount of lighting that they consume. However, the low and middle income groups are more sensitive to the price of electricity, and for them higher prices mean less consumption. The second finding is that the number of years that a household has had electricity is strongly and positively associated with amount of electric lighting consumed, especially in lower income homes.

Lighting Fuel Substitution Model

5.6 Two standard methods are commonly used to evaluate the costs and benefits of lighting technology changes and electrification: least-cost analysis and an assessment of the willingness of consumers to pay for a service. Using least-cost analysis, lighting technologies and fuels are compared on the basis of annualized capital and fuel costs necessary to provide the same service, or cost per Lumen-hour. When considering a shift as extreme as that from kerosene to electric lighting, it is generally recognized that the amount and the quality of light "consumed" will probably change. The analysis below confirms that a recently electrified household can be expected to light significantly more with electric lamps than they did with kerosene lamps. Since the level of service can change dramatically, comparing the costs of similar service provided by different fuels for lighting is inappropriate. People are just not going to have twenty-five to fifty kerosene lamps in their households to provide the same level of light as electricity. As a consequence, the analysis of actual behavior is more insightful and provides a better basis for policy formulation.

5.7 Another accepted method for assessing the benefits of residential electrification within an economic framework, is to equate the value of electricity with how much consumers are willing to pay for the service in addition to the value of kerosene displaced for lighting. However, it is not a straightforward matter to assess consumer willingness to pay and consumer surplus in many countries characterized by imperfect access to and controlled prices for electricity and competing fuels and little data on demand behavior. These difficulties notwithstanding, the multivariate method employed below to analyze differences in lighting behavior between households with and without electricity provides an empirically sound basis for estimating consumer surplus.

5.8 In urban households in Java, electricity is used mainly for lighting, ironing, and other uses for which it is the only fuel. Lighting dominates other end-uses for electricity in these households and is the only major service in which electricity substitutes directly for kerosene. Once a household obtains an electricity connection, it stops lighting with kerosene. This provides an opportunity to analyze the tradeoffs for households with similar profiles using different fuels to provide lighting services based on actual behavior under existing conditions. Because actual behavior is taken into account, the statistical analysis of household lighting fuel use can yield accurate information on which to base estimates of the costs and benefits of providing this major service by substitute fuels. The analysis presented in Table 6 is intended to estimate both the

Table 6: OLS Analysis of Total Residential Lighting Fuel Demand in Urban Java, 1988

Natural Logarithm of Total Monthly Household Lighting Fuel Use and Lighting Obtained

	LN MJ/HH/Month				LN kilo-Lumen hours/HH/Month			
Expenditure Group	Low	Middle	High	All	Low	Middle	High	All
Demand Variables								
LN Family Size	0.12	0.02	0.12	0.10	0.19	0.04	0.03	0.12
	2.49	0.53	2.59	3.86	2.80	0.64	0.47	3.21
LN Expenditures/HH/Mo	0.27	0.11	0.20	0.21	0.36	0.32	0.28	0.30
	3.88	1.01	4.11	9.81	3.58	2.12	4.35	10.23
LN Number of Rooms	0.62	0.54	0.68	0.60	0.81	0.64	0.93	0.76
	11.79	11.34	12.81	20.86	10.59	9.62	13.30	19.10
LN City Size	0.06	0.01	0.03	0.03	0.08	0.02	0.06	0.05
	4.52	1.27	3.02	5.36	4.30	1.06	4.45	5.79
LN Kerosene Price/MJ	-0.96	0.20	0.29	-0.11	-2.52	-1.18	-0.77	-1.43
	-1.74	0.47	0.74	-0.44	-3.15	-2.00	-1.47	-4.04
LN Electric Price/MJ	-0.09	-0.31	-0.20	-0.18	-0.12	-0.31	-0.14	-0.19
	-1.99	-5.19	-2.34	-5.45	-1.80	-3.75	-1.22	-4.12
Years Since HH Elect.	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01
	2.58	1.19	3.00	4.28	2.72	3.43	4.50	6.14
Fuel Choice								
Kerosene & Electric Lighting	-0.56	-0.44	-0.91	-0.59	1.34	1.27	1.59	1.39
	-4.11	-2.96	-3.78	-6.52	6.78	6.14	5.06	11.03
Kerosene Lighting	2.42	2.24	2.36	2.34	-1.81	-1.95	-1.67	-1.87
	42.51	33.04	17.66	60.24	-21.95	-20.68	-9.49	-34.62
(Constant)	1.23	2.62	0.43	1.08	3.98	3.96	2.16	3.47
	1.03	1.81	0.45	2.18	2.30	1.98	1.74	5.03
R^2 for Whole Equation	0.76	0.65	0.44	0.66	0.62	0.51	0.40	0.64
R^2 Explained by Choice	0.55	0.53	0.25	0.53	0.23	0.27	0.07	0.17
F Statistic	283.09	163.47	68.37	529.31	145.55	91.32	58.29	484.91
# Cases	805	816	806	2427	803	815	806	2424

Source: World Bank, 1990. Of the 2427 households with valid values for all regression variables, 17% light only with kerosene, 2% use a combination of kerosene and electricity, and 81% light exclusively with electricity.

amount of electricity required to displace kerosene lighting and the relative change in amount of light obtained by such a switch.

5.9 Fuel choice dummy variables were introduced into the equation for households lighting exclusively with kerosene and for the few households lighting with both kerosene and electricity. As such, the resulting coefficient represents the difference between lighting fuel use by kerosene using households and the majority of urban households lighting with electricity. The coefficient associated with the kerosene lighting dummy (2.34) indicates that a household lighting with kerosene uses, on average, more than ten times as much energy (heating value) for lighting as a similar household lighting with electricity. This means that according to survey responses across the whole sample, *less than one kWh of electricity (0.94 kWh) is needed to displace one liter of kerosene for lighting in urban households of Java.*[13]

5.10 The implications of this result are compelling for several reasons.[14] First, the economic cost of supplying electricity to urban households for lighting at this substitution rate is roughly 60% to 80% of the cost of supplying kerosene for lighting (See Annex). Secondly, a household that switches from kerosene to electricity can be expected to cut lighting fuel expenditures in half.[15] Though we present these implications based on differences in fuels costs alone, a thorough analysis of the economic and financial tradeoffs between these fuels for lighting must also account for systematic differences in the economic and financial costs of kerosene and electrical lamps.

5.11 Results of an identical procedure to estimate illumination are just as compelling (see Table 6). In this case the dependent variable is lighting used by households in a typical month, derived from each household's use of different types of both electric and kerosene lamps (see Annex). The coefficient associated with the kerosene lighting dummy (-1.87) indicates that households lighting with electricity enjoy, on average, more than six times as much light as those lighting with kerosene.[16] This is in part due to the improved efficiency made possible by electric lights. Thus, when a household switches from kerosene to electric lighting, *not only are economic and financial fuel costs reduced, but the amount of lighting enjoyed increases six fold.* These results do not vary much across income groups in our analysis.

Estimation of the Benefits of Electric Lighting

5.12 With these convincing results from a multivariate analysis, we now turn to the issue of how the benefits of lighting may have been underestimated using standard assumptions in appraising most electrification projects. In most early projects, the incremental net benefits of

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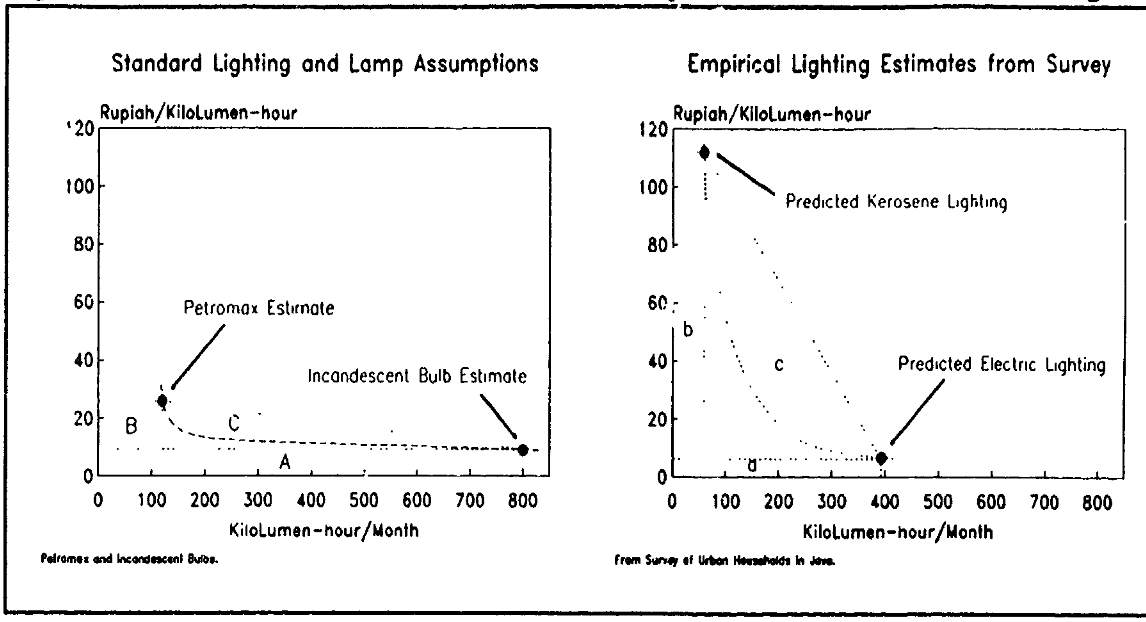
13/ The equation for all households is: $e^{2.34}$ = 10.38. This results in a lighting substitution ratio of 0.94 kWh per liter of kerosene [(35.2 MJ/liter) / (10.38 * 3.6 MJ/kWh) = 0.94 kWh/liter], with 95% chance that the true lighting substitution ratio lies between 0.87 kWh and 1.01 kWh per liter. This result does not vary significantly across income groups: mean substitution ratio estimates are 0.87, 1.04, and 0.92 kwh/liter for households in low, middle, and high income groups.

14/ From the perspective of effective energy resource use and energy economy, the thermal replacement value of 1 kWh of electricity is less than 1/3 of the thermal energy content in one liter of kerosene. Assuming 30% overall electricity system efficiency, the thermal replacement value of each kWh consumed in the urban residential sector is 10.7 MJ/kWh. In comparison, the heating value of kerosene averages 35.2 MJ/liter.

15/ Average prices faced by households at the time of the survey in early 1988 were 111 Rp/kWh for electricity and 203 Rp/l for kerosene (World Bank, 1990). Using official rates from late 1989 and 'average' and assumptions in the Annex about 'marginal' consumers, upon switching from kerosene to electricity, lighting fuel expenses of the average consumer would decrease to 48% of kerosene expenses. Similarly, the marginal consumer would decrease lighting fuel expenses to 54% of kerosene fuel expenditures.

16/ The equation is: $e^{-1.87}$ = 0.15. This means that, on average, a household lighting with kerosene will obtain only 15% of the illumination of a similar household lighting with electricity. Since 1/0.15 = 6.5, households lighting with electricity obtain 6.5 times the illumination, on average, of kerosene using households, with a 95% chance that the true estimate is between 5.8 and 7.2 times the illumination.

Figure 1: Estimation of Incremental Consumer Surplus from a Switch to Electric Lighting



electricity to consumers were estimated in terms of the value of displaced lighting kerosene (shown as area B in Figure 1). More recently, some estimate of additional consumer surplus (area C in Figure 1) has been added to the value of displaced kerosene, resulting in a reasonable estimate of the incremental net consumer surplus from the switch to electricity. The relevant questions are: how have kerosene and electric lighting estimates commonly been derived in the absence of data on actual fuel use patterns and how well do such estimates compare to the observations from urban Java?

5.13 A common approach is to compare lighting delivered by pressurized kerosene lamps and incandescent electric bulbs, and assume that 15% of lighting demand is satisfied by the kerosene lamp (see case study of Sri Lanka quoted by Webb and Pierce, 1985 pp. 196-197). A good presentation of the general economic framework for estimating consumer surplus derived from rural electrification by using the example of kerosene lighting being displaced by electricity can be found in Jechoutek (1990). Following this general framework and lighting assumption yields the two estimated points on the price per kiloLumen-hour plot entitled "Standard Lighting and Lamp Assumptions" in Figure 1. An estimate of the incremental net consumer surplus derived from a switch from kerosene to electric lighting is represented by areas B and C. Though the lighting demand curve may well have some curvature (one such plausible curve is sketched in Figure 1), we employ a straight-line approximation for comparing estimates of net consumer surplus derived from the standard lamp method to results of the multivariate model.[17] As such, the consumer surplus figures generated by each method and tabulated in the Annex are maximum estimates.

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[17] All assumptions and calculations leading to the estimates and predicted values displayed in Figure 1 can be found in the Annex. Issues on the estimation of a demand curve for lighting also are taken up in the Annex. Although, the actual lighting demand curve may have a significant degree of curvature as indicated in the diagram above the ratio of estimated net consumer surplus between the standard and empirical estimates presented above probably does not depend significantly on the assumption of straight line demand curve.

5.14 The multivariate lighting model presented in Table 6 was used to predict monthly kiloLumen-hours that would be consumed by each household in the sample in two cases: if all households used only electricity to light or of all households used only kerosene to light. Sample means for each of these cases paired with observed mean prices/kLmh for households actually using each fuel are displayed in the plot entitled "Empirical Lighting Estimates from Survey" in Figure 1. As in the case of standard lamp assumptions, we have sketched resulting areas a, b, and c (tabulated in the Annex) corresponding to electricity value, kerosene displacement, and consumer surplus. When compared to the net consumer surplus based on the multivariate model of actual lighting consumption in urban Java (b+c), net consumer surplus commonly assumed in electrification projects (B+C) appears to be very conservative. In this case using the straight-line approximation method the quantity (B+C) is less than one-third of (b+c).

5.15 The main reason for this divergence from the standard lamp assumption is that households in Java often use kerosene wick lamps that are less efficient than petromax and fluorescent bulbs that are more efficient than incandescent ones. The extent to which each type of lamp is used can only be gauged by a survey or household monitoring instrument. Hence, the derived price per kiloLumen-hour in urban Java is much higher for kerosene than expected using a pressurized kerosene lamp as the standard lamp, while for electricity, the derived price/kLmh is less than what would be expected from incandescent bulbs alone.

5.16 Estimation of net consumer surplus by using means of predicted lighting across the entire sample may be suspect because it is mostly the poor who use kerosene for lighting. Both the total amount of electricity consumed and the share of electricity used for lighting are directly related to income. As such, the separate models presented in Table 6 were used to predict lighting and net consumer surplus for each income group. The results indicate that though low income households may obtain less surplus from the switch to electricity than high or middle income households, the benefits from the switch are still significant and well above the estimates derived from standard lamps (see Annex).

5.17 It as long been recognized that households using electric lamps obtain more and higher quality light than those using kerosene lamps. The incidence of major differences in lighting levels between households using each fuel has complicated efforts to evaluate the comparative costs and benefits of these fuels for lighting. The method of analysis applied above to data on household behavior under actual conditions from urban Java, aptly accounts for differences in fuel use and lighting provided. By displacing kerosene used for lighting, further urban electrification can serve to dramatically increase illumination enjoyed by households while reducing costs to consumers and the economy at large.

VI. Summary and Conclusions

6.1 The main conclusions concerning interfuel substitution in urban Java provide support for many existing energy policies. The more interesting results include that the benefits of household lighting appear to have been significantly understated in the past, and making kerosene universally available at a subsidized price has induced many of the urban poor to cook with it. However, the subsidy for kerosene also has the effect of keeping people in the upper middle and higher income families from switching to LPG. Other important findings include that fuel availability is a strong determinant of fuel use even after controlling for prices. This means that the extent to which traditional fuels such as wood are available for use is not always reflected in its market price. The findings also confirm the expected energy transition from wood to kerosene and finally to LPG with rising household income levels.

6.2 The use of kerosene for lighting in urban households appears to be significantly more costly to the nation and to households than lighting with electricity. In addition, after accounting for variation due to fuel price differences, income, and number of rooms in the home, a household lighting with electricity enjoys roughly six times more light than a similar household lighting with kerosene. As lighting is the major residential end use of electricity, continued urban electrification makes good economic sense. This result is compelling because it is based on the empirical rather than theoretical analysis of residential lighting. If the increase in lighting levels that accompany a switch from kerosene to electric lighting among urban households on Java are any indication of increase in services or benefits due to electrification, the benefits of electrification based on reference lamps may be severely underestimated.

6.3 Another major finding is that in the analysis of urban fuel use and interfuel substitution, we need to more closely examine fuel availability and markets. The general results confirm findings elsewhere in developing nations, that cooking fuel choice and use is affected by family size and income. The poor generally use wood for cooking, middle income households use kerosene, and the highest income groups use LPG. Although own price effects are evident, there were no strong cross-prices effects on fuel choice and use. The weak price relationship with fuel use undoubtedly can be explained by the little variation in conventional fuel prices across the sample, but price is not the only factor that can be used to influence fuel use by households. More work needs to be completed on the role of fuel availability and market imperfections on fuel choice in urban areas of developing countries.

6.4 The policy to make kerosene universally available and to subsidize it has both positive and negative impacts for urban Java. On the positive side, the poor *do* cook with kerosene. This is somewhat contradictory to other studies (Pitt, 1985; Dick, 1980) that have found that kerosene prices have little effect on expenditures on wood as a fuel. However, the use of kerosene has the benefit of providing a clean burning fuel for those who use it for cooking (50 percent of urban lower income households), while decreasing the problem of indoor air pollution. The environmental problems of alleviating deforestation in the urban hinterland also may be partially ameliorated because so many people cook with kerosene, although estimates of the benefits are hard to quantify. The subsidy policy also has the negative effect of holding the upper income groups in kerosene longer than might be expected. Only 12 percent of the highest income households use LPG, which is generally preferred over kerosene for cooking. Nevertheless, fuel distribution policies can be expected to have a strong influence on the mix of fuel used in the residential sector. As such, improving the LPG distribution system may serve to remove a substantial barrier to LPG adoption by high income households.

6.5 The methodological approach of deriving substitution ratios was very useful in analyzing differences between groups using distinct fuels for a particular end-use. However, the method will need to be further refined for broader application to situations in which households commonly use more than one fuel for cooking. In addition, as the method used for preparing rice was found to be important in determining overall cooking fuel demand, the effect of cooking practices on household energy use are an area for further research.

6.6 In the context of current energy policies in Indonesia, these results serve to support the rationale behind efforts of the government to diversify domestic fuel use away from exportable petroleum products. The analysis provides a sound basis for planning by yielding an estimate of the amount of LPG required to displace kerosene for cooking based on actual behavior. Plans to continue with rapid urban electrification appear to be well founded as additional households electrified will displace costly kerosene with cheaper electricity while consumers can be expected to enjoy a six-fold increase lighting levels.

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Annex

Energy Conversion Factors

Wood/Biomass	14	MJ / kg
Charcoal	25	MJ / kg
Kerosene	35.2	MJ / liter
LPG	45.8	MJ / kg
Electricity	3.6	MJ / kWh (final)
Electricity	10.7	MJ / kWh (thermal replacement)

1989 Exchange Rate: 1750 Rupiah = US $1.

Economic Cost of Kerosene and Electricity

1. The average economic cost of kerosene supply to urban households in mid-1989 was estimated at 290 Rupiah/liter (World Bank, 1990). According to the Indonesia Energy Pricing Review of the World Bank (in preparation), the long-run marginal cost of serving urban residential consumers in Java in the R1 category (the dominant residential tariff group) is estimated to be 8309 Rupiah/kVA + 99.42 Rupiah/kWh for connections limited at 250 - 500 VA.

2. Since roughly 53% of the electricity consumed in sample households was for lighting, if we assume the average household is connected at the high end of the R1 tariff class (or 500 VA) then 53% of the kVA charge + 99.4 Rupiah/kWh for lighting times the predicted mean monthly electricity consumption for lighting (using the socioeconomic characteristics of all households in the Sample) of 21.3 kWh/month results in an LRMC estimate of 203 Rupiah/kWh [((53% of 8309 Rp/mo/kVA times 0.5 kVA) + (21.3 kWh/mo times 99.42 Rp/kWh)) / 21.3 kWh/mo = 203 Rp/kWh]. At a substitution ratio of 0.94 kWh/liter, this amounts to 66% of the cost of supplying kerosene to the average urban consumer.

3. However, the marginal consumer in any extended urban electrification program is likely to be a low-income household with possibly higher costs of service/kWh. In the poorest third of surveyed households, roughly 80% of electricity was used for lighting, and the multivariate model predicts that the average household in this group would use 14.9 kWh/mo for lighting. The LRMC works out to be 267 Rupiah/kWh for serving this marginal consumer [((80% of 8309 Rp/mo/kVA times 0.375 kVA) + (14.9 kWh/mo times 99.42 Rp/kWh)) / 14.9 kWh/mo = 267 Rp/kWh]. At 0.87 kWh/liter, this amounts to 80% of the cost of supplying kerosene for lighting.

Cooking Fuel Estimates

4. The wood and charcoal consumption of all households using woodfuels were measured over a two day period. The resulting estimates of daily cooking fuel use for these fuels are a combination of survey recall responses and measured values. The amount of kerosene used for cooking over a two day period was also measured, but only in households using kerosene for more than one use. This allows a more accurate breakdown of kerosene consumption by end-use for these households than would have been possible through survey responses alone. LPG use for cooking is based entirely on household responses.

Lighting Fuel Estimates

5. Households were asked how many hours per day, on average, each bulb in the home is kept burning. The electricity use estimates used in the analysis are the products of wattages and hours per day estimates summed over all bulbs in the home. To check the validity of consumption estimates based on household responses, estimates of electricity use by major appliances were regressed against the average household electricity bill. This procedure generally confirmed estimates of electricity use for lighting in low and moderate income households. Though upper-income households appear to have systematically under-estimated lighting electricity use, this small bias was not deemed significant enough to warrant modification of the original data. Hence, the lighting electricity estimates used in this analysis are derived entirely from survey responses. As such, results presented here differ slightly from those presented in the ESMAP Report (World Bank, 1990) which presented data on all household uses of electricity, modified on the basis of these regression results.

6. The total amount of kerosene used for lighting is estimated directly from survey responses. As indicated above, kerosene use for lighting is derived from measurement and responses only for households using kerosene for multiple purposes.

Illumination Estimates

7. Using the household estimates of incandescent and fluorescent bulb usage described above, it is possible to estimate the amount of illumination from electric lamps. In general, fluorescent lamps emit roughly four times as much light per kWh as do incandescent lamps. The average luminous efficacies used to estimate illumination are shown in Table A1 below.

Table A1: Typical Lamp Efficacies

	(klmh/kWh)
Fluorescent	50
Incandescent	12
Petromax (kerosene pressure lamp)	0.8
Semprong (glass shielded wick lamp)	0.2
Sentir (small open wick lamp)	0.1

Source: van der Plas and de Graaff, 1988.

8. It can be seen from this table that the luminous efficacies of common kerosene lamps also varies significantly across lamp types. Since the survey reported total kerosene use for lighting, but did not break this estimate down by lamp type, further analysis was required to estimate the amount of light emitted from kerosene lamps.

9. On average, households using kerosene for lighting own 2 lamps which they use regularly, with only one in ten using more than 4 lamps. Most households using 3 or more kerosene lamps, use at least one Petromax, while those with only one or two lamps rarely use a Petromax. Statistical analysis of lamp ownership and lighting-kerosene consumption corroborates the notion that a Petromax uses more kerosene than a chimney lamp which in turn uses more than an open

wick lamp. Summary results of an OLS regression on households using kerosene for lighting and constraining the line through the origin are shown below:

$$\text{Lighting Kerosene Use (lt/day)} = 0.29P + 0.18C + 0.10SW$$

$$t = (11.6) \quad (13.4) \quad (12.2)$$

$R^2 = 0.71$ $F = 391$ Number of Cases = 468

Where: P = the number of petromax pressure lamps;
C = the number of chimney lamps, and;
SW = the number single wick lamps owned by the household.

10. Using these results, the amount of kerosene consumed in each lamp type was estimated by summing the relative daily consumption over all lamps owned by the household and normalizing by the total amount of kerosene used for lighting. The luminous efficacies of kerosene lamps shown above, were then used with the resulting estimates of kerosene use by lamp type to estimate illumination from kerosene lamps.

In sum: $\text{kLmh/HH/Month} = \Sigma_i \text{kWh}_i * \text{Eff}_i$

Where: kLmh/HH/Month = Monthly kiloLumen hours of lighting per household;
kWh_i = monthly energy used in each lamp type i (estimated as above);
Eff_i = luminous efficacy of each lamp type i.

Estimation of Consumer Surplus from a Switch to Electric Lighting

11. In this secton we explain the assumptions used in estimating the willingness to pay for lighting services. In the first section the typical assumptions that have been used in appraising electricity projects are presented. In the second section, the actual results obtained in the survey are detailed. The very last table, depicts the difference in consumer surplus between the standard approach and those based on empirical results from the survey. Finally, the effect of income on consumer surplus are explained.

i) Standard Lamps and Assumption of Unmet Lighting Demand:

12. To estimate benefits to consumers of a switch from kerosene to electricity for lighting, it has become common practice to assume a certain level of lighting demand is unmet by kerosene lamps. In addition, efficacies of 'typical' or reference kerosene lamps and electric lamps are usually employed as an integral part of the estimation procedure. Pressure kerosene lamps (Petromax) and incandescent bulbs are commonly used as reference lamps due to their widespread use and comparable light flux and color. According to the survey of urban households in Java, households lighting with kerosene consume, on average, ½ liter per day for lighting. Using this observation and the typical assumption that, on average, only 15% of lighting demand is met in households lighting with kerosene (see case study of Sri Lanka quoted by Webb and Pierce, 1985 pp. 196-197), the following illumination-price pairs result:

Table A2: Standard Lamp Assumptions

	Efficacy (kLmh/unit)	Estimated Lighting (kLmh/HH/Mo)	Observed Fuel Price (Rp/unit)	Resulting Fuel Price (Rp/kLmh)
Kerosene Pressure Lamp	7.8/l	120	203/l	26.0
Incandescent Bulb	12.0/kWh	800	111/kwh	9.3

Source: Table A1 and World Bank, 1990

ii) Lighting Predicted by the Multivariate Fuel Substitution Model:

13. Estimates of total illumination consumed in each sample household were derived from the survey data as indicated above by summing illumination estimates over all kerosene lamps and electric lamps utilized by the household. The illumination model presented in Table 6 was then used to predict the amount of light *each* household in the sample would consume if it were to light exclusively with kerosene. Similarly, lighting consumed by *each* sample household was predicted under exclusive electric lighting. The mean predicted kiloLumen-hours for kerosene (electric) lighting presented below can be interpreted as the predicted mean illumination if all households used only kerosene (electricity) to light. For simplicity and transparency, we have paired these predicted lighting values with observed mean prices per kLmh of households *actually using each fuel for lighting* both in Figure 1 and in the table below.

Table A3: Predicted Lighting Values Based on Survey

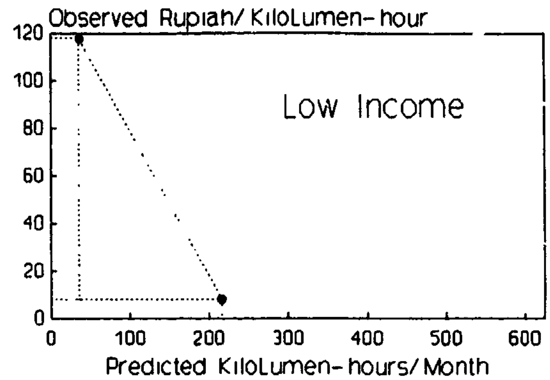
	Predicted Lighting (kLmh/HH/Mo)	Observed Fuel Price (Rp/kLmh)	Predicted Lighting Fuel Expenditures (Rp/HH/Mo)
Kerosene Lighting	63.82	112.13	7156
Electric Lighting	414.16	6.28	2601

14. The areas displayed in Figure 1 resulting from these estimates are shown below. Maximum surplus estimates refer to areas bounded by straight-line approximations between kLmh:Rp/kLmh pairs.

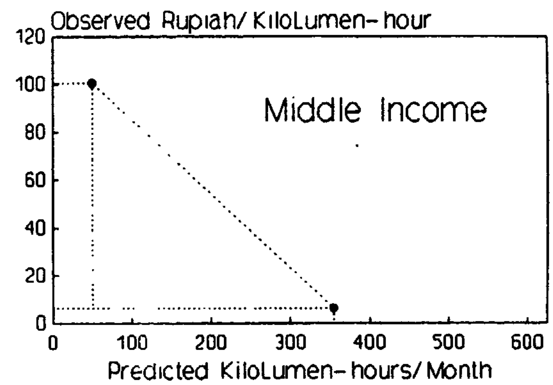
Table A4: Difference Between Standard Approach and Predicted Results Based on the Survey

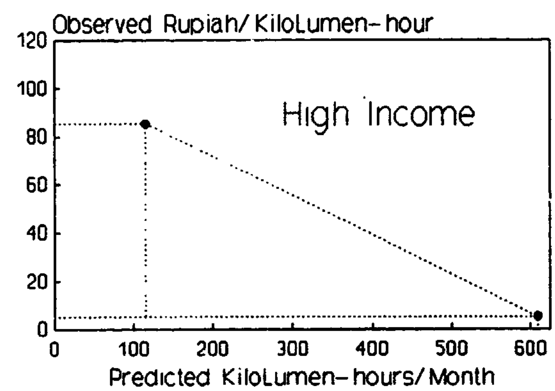
Rupiah/Household/Month	Electricity Value A (a)	Kerosene Displacement B (b)	Consumer Surplus C (c)	Net Consumer Surplus B+C (b+c)
Standard Lamp Estimates	7,440	2,000	5,680	7,680
Predicted Lumen-hours	2,600	6,750	18,540	25,290

15. Estimates of net consumer surplus from a switch from kerosene to electric lighting for each income group are presented here as a supplement to the estimation of net consumer surplus based on socioeconomic characteristics of the entire sample presented in Figure 1. Price-kLmh pairs around which each of these figures is constructed were predicted based on the parameters of separate models estimated for each income group presented in Table 6. As in Figure 1, the derived prices/kLmh are observed means for households actually using each fuel within the appropriate income group.



16. These figures appear to show that the benefits of electrification, as guaged by net consumer surplus, increase with income. Of course, these figures have been drawn under the assumption that the marginal utility of income is constant across income classes. As it is likely that the marginal utility of income is higher for the poor than it is for the wealthy, it would be preferable to increase consumer surplus estimates for the poor relative to those for the wealthy. However, since we do not know enough about the utility function underlying consumer demand for lighting services to derive marginal utility as a function of income, we assume it is constant across income classes and leave such a derivation as an area for further research. Recognizing that this assumption may lead to an under-estimate of net consumer surplus for the lowest income group, we note that this under-estimate is still roughly 40% higher than the estimate based on standard lamps for the whole population illustrated in Figure 1.

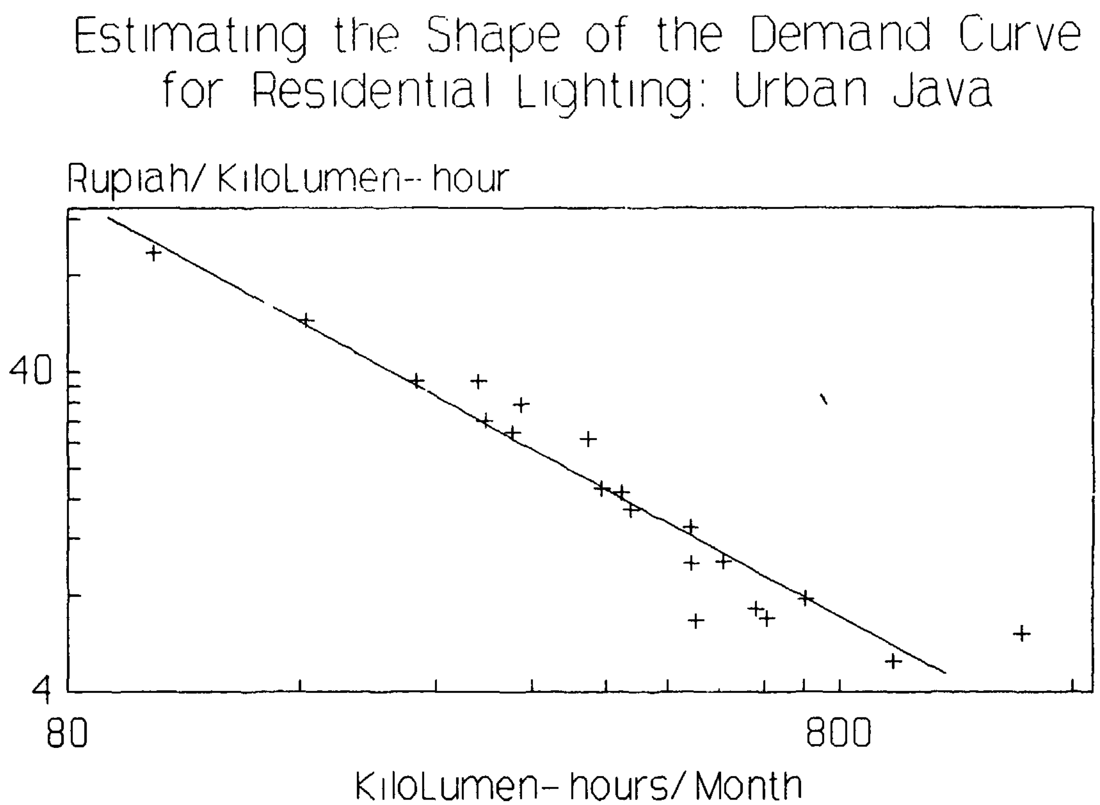




17. It is also apparent from these figures that the slope of the underlying lighting demand curve changes markedly with income, and/or the underlying demand curve for kerosene light may be much steeper than the demand curve for electric light.

18. In an attempt to better approximate the shape of the underlying demand curve for lighting services, observed means of prices/kLmh and kLmh/mo, without regard to the source of lighting, for households in 20 equal income groups (20tiles) are graphed in the log-log plot below. However,

recall that the prices/kLmh are derived from the amount of lighting each household actually uses. The mean values nearly approximate a linear relationship in log-log space. This illustrates a basic difficulty with constructing such a demand curve for lighting services when kLmh is plotted against Rupiah/kLmh.



Observed means of households in 20 income groups (20tiles) from the urban Java survey and a linear approximation.

Source: World Bank, 1990.

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