Asmara Power Distribution and Rural Electrification Project

Pre-electrification Survey Analysis

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June 2005 Exchange Rate: Nakfa 15.375 = 1 USD

Main Findings

- Households in the project area spend as much on dry cell batteries as they do on kerosene for lighting—both readily substituted by grid electricity. Those with the lowest incomes spend 76 Nakfa/month (US$ 5/mo) and those with the highest incomes 102 Nakfa/month (US$ 6.6/mo)on average
- These observed expenditures on these energy sources provide minimum estimates of household ability and willingness to pay for the higher quality services provided by grid electricity.
- Even the poorest households appear to be well-positioned to afford the monthly cost of electricity—at the national tariff, the average 76 Nakfa they currently spend on lighting fuel and batteries would buy 33 kWh/month (two 60 Watt bulbs used 4 hours daily would consume less than 15kWh/month and cost 37 Nakfa/mo or US$ 2.40 at the national tariff).
- Comparing low income households that currently buy electricity from a neighbor to those that light with kerosene shows that electrification could boost lighting levels more than twenty fold while cutting lighting fuel and battery expenditures, now consuming 10.2% of total cash outlays (US$ 5), by more than half (to roughly US$ 2).
- Costs incurred by households that operate gasoline or diesel generators, commonly at very low load factors, and irrigation pump sets rival and exceed other household expenditures. Grid electrification may substantially cut the costs of these productive end uses (this finding is indicative only).
- Several options for improving project evaluation during the second round survey are reviewed. All options are viable, but only those with a control group will be able to formally evaluate the impacts of the project itself.
    - Default option – re-survey original households after electrification.

- Default + control group – the preferred option for the second round: re-survey the original households as well as households in a comparison group from outside the Project Area.
- Post-electrification formal evaluation – the preferred option only if the original sample does not represent the population in the Project Area: survey newly drawn households from within and outside the Project Area.
- Suggestions for strengthening the survey include adding survey sections on housing type (material), water supply and sanitation, health measures, education levels achieved, biomass fuels sources and use, land cultivated and under irrigation, and distances to water supply, schools, clinics, major roads, and markets—all factors that have been found to distinguish households when explaining the impacts of electrification.

Introduction

During supervision of the project (supervision mission May 9 – 19, 2005) it was agreed with the Ministry of Energy and Mines that in order to evaluate the impacts of electrification in the four project areas (59 villages in the Keren, Barentu, Dekemhare and Adi Keih areas), an ex-ante survey would be conducted prior to electrification of the villages and an ex-post survey will be conducted in late 2008 or early 2009 prior to project closing (electrification will be carried out during 2006 and 2007 at a cost of approximately $11.5 million). Accordingly, the Ministry of Energy and Mines, designed and implemented a survey that was conducted during July to September, 2005. The survey covered 18 villages out of 59 targeted villages and 398 sample households were interviewed (there are approximately 4,200 households and 22,500 people living in the 59 villages). The survey was designed to characterize energy use in existing institutions, commercial enterprises and households before electrification and, thereby, set a baseline for monitoring and evaluation of the impacts of the project going forward.

The report prepared by the Eritrea Department of Energy and Mines in October 2005[1], presents findings at the village and household level. In addition to presenting a preliminary analysis of socio-economic characteristics and energy use in 398 sampled households, it summarized existing electricity (gensets and solar systems) and motive power sources (diesel pumps), institutions and commercial enterprises in each of the 18 villages. It documents income generating activity and social infrastructure services (schools, clinics, etc) and their use of energy.

The current inquiry complements the report of the Dept. of Energy and Mines. The objectives are twofold: (i) to the extent possible, make an ex-ante estimate of the benefits to households of electrification under the project and; (ii) review the survey

[1] Poverty and Social Impact Analysis in the Rural Electrification Component of the Asmara Power Distribution and Rural Electrification Project: Pre-electrification Survey Report, Eritrea Department of Energy, October, 2005.

methodology and suggest modifications to the survey instruments for the 2nd phase of surveying to be conducted ex-post (after the villages have been electrified)

1. Estimation of Benefits using Household Survey Data

The pre-electrification survey of households included 398 households in 18 of 59 villages to be electrified under the project. The sample frame, presented in the Appendix, was stratified by income group.

Caveats:
An initial exploration of the data showed that the sample frame itself was purposive: designed to characterize existing patterns of energy use, but also to make sure existing sources of electricity and motive power were not overlooked. For example, of nearly 1,800 households in Tokombia, 7 have private generators and 3 of these were included in the set of 33 households surveyed (DOE 2005). Since households with generators and irrigation pump sets were apparently over-sampled, relative to their frequency in the population, survey results that include them would bias results. This analysis does include these households, but expenditures for generating electricity and for irrigation pumping are reported separately.

Moreover, it is unclear if the sample frame is self-weighting by income group. Put differently, are 20%, 25% and 55% of households in the project area in higher, medium and lower income groups? Because the answer to this question is unknown, this analysis is done separately for sampled households in each income group and results pertain only to households that have the general characteristics of those surveyed. No generalizations are made to households in the sampled villages or in the Project Areas.

During data cleaning, 5 households were eliminated from the analysis due to extremely high expenditures on kerosene or electricity generation. 393 of 398 sampled households are included in the analysis below.

Family size

TABLE 1. HOUSEHOLD COMPOSITION

	Income Level						Table Total	
	Higher income		Medium Income		Lower income			
	Mean	Valid N	Mean	Valid N	Mean	Valid N	Mean	Valid N
Household size	6.80	80	6.36	97	5.26	216	5.84	393
Number of adult household members	2.80	80	2.60	97	2.24	216	2.44	393

Number of household members less than 5	1.18	80	1.11	97	.93	216	1.03	393
Number of household members between 6 and 8	2.83	80	2.65	97	2.09	216	2.38	393
No of children in the household that attend school	2.83	80	2.44	97	1.94	216	2.24	393

Asmara RE Project pre-electrification survey 2005.

Family size in Table 1 shows the expected correlation with income, but otherwise little variation across income groups with a mean of 6 members per household. The average family has a young child and two of school age. One of the chief benefits of electrification is provision of better and more reliable light for studying at night. Because the sampled families in the project villages have, on average, two children in school and one of pre-school age, they can be expected to benefit from the higher quality light that electricity provides.

The benefits of electrification at the household level have been examined using statistical methods in other countries. Such studies statistically compare similar households, with and without electricity, to draw valid inferences about the benefits of electrification. Since the survey fielded for this project characterized households in areas before grid electricity is available, this kind of approach to estimate the benefits of electrification will not be possible here. But it will be possible to examine existing fuel use for the chief end uses that grid electricity may provide more cheaply and reliably as a basis for drawing conclusions.

After reviewing overall income and expenditures in sampled households, current expenditures on end uses efficiently powered by grid electricity are examined. Namely: grid electricity substituting for lighting kerosene, candles and batteries and grid electricity displacing the fuel and operating costs of private generators and irrigation water pumps.

Household income

Following years of civil strife, Eritrea is now one of the poorest countries in the world. Latest figures for 2004 showed a total population of roughly 4.4 million with an average annual per capita income of US$ 210. Roughly 70% of the population live in rural areas, most engaging in subsistence agriculture.

Table 2 shows income sources for sample households. For reference, all Income and Expenditure Tables presented in the body of this report are reproduced in the Appendix using 2005 US Dollar equivalents. At an average per capita income of Nakfa 4,432/yr (US$ 288 USD), only the Higher Income households surveyed in the project area have incomes above the 2004 national average. Sampled households in Medium Income and

Lower Income categories reported annual per capita incomes averaging only Nakfa 2,315 and 1,054 (US$ 151 and US$ 69). As observed in DOE 2005, incomes may have been consistently under-reported by surveyed households, particularly in the Lower Income group. For this reason, expenditures are assumed to provide a more accurate picture of household cash resources. Nonetheless, by any measure, the sampled households in Medium and Lower Income groups are extremely cash poor.

Farm income makes up nearly half of total income across all income groups. Government aid and wages are very important in the Lower Income group, each making up roughly 1/3 of total income, on average. Higher Income households are much more likely to own a business, making, on average, nearly 1/3 of total income from trading.

TABLE 2. ANNUAL HOUSEHOLD INCOME (Nakfa/year)

	Income Level						Table Total	
	Higher income		Medium Income		Lower income			
	Mean	Valid N	Mean	Valid N	Mean	Valid N	Mean	Valid N
Income	30,139	78	14,725	94	5,545	202	12,981	374
Income/cap	*4,432*		*2,315*		*1,054*		*2,223*	
Farm income	16,459	80	6,700	96	2,182	210	6,264	386
Non-farm income	14,678	78	8,411	95	3,667	205	7,131	378
Wage income	2,698	78	3,749	95	1,941	206	2,550	379
Trading	9,426	78	3,587	95	902	208	3,317	381
Remittances	1,027	78	245	95	89	210	319	383
Suwa or injera	10	78	408	95	318	208	277	381
Home business	172	78	20	95	88	208	89	381
Government aid	2,212	79	2,609	97	2,389	216	2,408	392
Other	652	78	397	96	348	207	422	381

Asmara RE Project pre-electrification survey 2005.

TABLE 3. HOUSEHOLD EXPENDITURES (Nakfa/month)

	Income Level						Table Total	
	Higher income		Medium Income		Lower income			
	Mean	Valid N	Mean	Valid N	Mean	Valid N	Mean	Valid N
Income	*2,511.59*	*78*	*1,227.07*	*94*	*462.07*	*202*	*1,081.79*	*374*
Farm income	1,371.59	80	558.33	96	181.80	210	522.04	386
Monthly expenditures	*1,978.46*	*79*	*938.72*	*96*	*746.88*	*213*	*1,045.11*	*388*
Food	797.56	80	477.18	97	384.74	214	492.14	391

Clothing	152.18	80	121.55	97	81.12	214	105.68	391
Schooling & health	80.84	80	49.90	97	38.99	214	50.26	391
Firewood & biomass	52.03	80	30.48	97	29.60	213	34.42	390
Commercial fuel	557.63	79	154.69	97	115.53	216	214.32	392
Travel	316.10	80	76.51	97	46.73	216	108.91	393
Rent	29.48	80	20.67	97	10.91	214	17.13	391
Other	158.64	80	25.74	96	36.91	214	59.13	390

Asmara RE Project pre-electrification survey 2005.

Household expenditures

Table 3 shows average monthly expenditures by income group. Lower income households report substantially higher monthly expenditures than their reported incomes would support. But at Nakfa 747/month, low income households still spend, on average, under $50/month—half of which goes to purchase food.

Poor households in the sample paid, on average, US$ 2/month on firewood and other biomass fuels. This is a small but not insignificant amount for these households. As most rural dwellers in the developing world collect wood and agricultural residues, some times from considerable distances, paying cash for these commodities indicates scarcity.

Average expenditures on commercial fuels are more troubling. Taken by themselves, they would seem to indicate that sample households in Higher, Medium and Lower Income groups spend, on average, 28%, 17%, and 16% of all cash outlays on commercial fuels. If accurate, this would signal severe hardship. But these averages are misleading—they are biased upwards by the few households that generate electricity and those that use gasoline or diesel water pumps. These productive uses are treated separately below.

Energy expenditures

Table 4 breaks down expenditures for each fuel and major end use. Not all households pay for firewood and biomass fuels, but the share of those who buy at least some of their firewood increases with income. Across all households surveyed, the amount spent on biomass fuels is, on average, roughly equivalent to the amount spent on kerosene for cooking, boiling water and ignition.[2] Nearly all surveyed households use at least some kerosene for purposes other than lighting. Across the sample, households spend a substantial share, roughly 6%, of total expenditures on fuels for cooking and heating.

[2] Each household was asked to estimate the share of kerosene used for lighting, cooking, boiling water and fire ignition. These responses were used to allocate expenditures on kerosene to lighting and to other end uses.

This is nearly as much as they spend on lighting fuels. This analysis assumes that electricity will not displace kerosene or biomass fuels in cooking and water heating end uses in rural households.

Lighting & battery expense is the sum of expenditures for kerosene used for lighting, candles, dry cell batteries and car battery recharging, if used. While it is not surprising that almost all households use kerosene and candles for lighting, the widespread use of dry cell batteries is unusual. Moreover, the substantial share of expenditures to purchase batteries rivals the amount spent on kerosene for lighting. Dry cell batteries are almost universally used to power radios and flashlights (only one surveyed household used a battery powered lamp).

Lighting and battery uses are all substitutable by grid electricity. As such, the amount of cash that a sampled household now pays for these energy sources can be taken to indicate the household ability to pay for grid electricity. Each household may be willing to pay substantially more for reliable grid electricity and may in fact consume more services (light, radio, television, etc.) once connected to the grid, but it is a safe assumption that the amount now spent on lighting and battery powered end uses can be taken as a proxy for the household *minimum* ability and willingness to pay for grid electricity.

TABLE 4. ENERGY EXPENDITURES (Nakfa/month)

	Income Level						Table Total	
	Higher income		Medium Income		Lower income			
	Mean	Valid N	Mean	Valid N	Mean	Valid N	Mean	Valid N
ALL HOUSEHOLDS								
Income	2,511.59	78	1,227.07	94	462.07	202	1,081.79	374
Farm income	1,371.59	80	558.33	96	181.80	210	522.04	386
Monthly expense	*1,978.46*	*79*	*938.72*	*96*	*746.88*	*213*	*1,045.11*	*388*
Firewood & biomass	52.03	80	30.48	97	29.60	213	34.42	390
Kerosene for cooking, etc.	58.32	80	38.41	97	25.53	216	35.38	393
Lighting & battery expense	*102.86*	*80*	*83.76*	*97*	*76.42*	*216*	*83.61*	*393*
Kerosene for lighting	45.76	80	34.94	97	39.75	216	39.79	393
Candles	6.43	80	4.08	97	3.52	216	4.25	393
Dry cell batt	47.89	80	43.36	97	32.80	216	38.48	393
Storage batt	2.78	80	1.39	97	.35	216	1.10	393
Light/batt expense share	*5.2%*		*8.9%*		*10.2%*			
HH electric expense	85.61	80	4.97	97	8.02	216	23.06	393
Irrigation expense	623.26	80	53.71	97	2.12	216	141.30	393

USERS ONLY								
firewood cost	143.52	29	109.52	27	128.67	49	127.85	105
light+batt cost	102.86	80	83.76	97	77.13	214	84.04	391
electric cost	402.86	17	80.28	6	108.28	16	232.37	39
irrigation cost	1,994.45	25	868.38	6	114.58	4	1,586.56	35

Asmara RE Project pre-electrification survey 2005.

Sampled households in the Lower, Medium and Higher income groups spend, on average, 76, 84, and 103 Nakfa/month, on average, on lighting kerosene, candles and batteries. This amounts to 10%, 9% and 5% of total cash outlays by households in these groups, respectively. These current expenditures for lighting kerosene, candles and batteries by sampled households in the Project Area will be taken as proxies for *minimum* spending power on grid electricity. Cash outlays by sampled households for electric bills, electric generation and water pumping are discussed in the next section.

In 2004, the residential tariff for customers outside of Massawa and Assab, was composed of a fixed standing charge of 6 Nakfa/month + 2.15 Nakfa/kWh (Tariff Study Update, Table 8.1[3]). Median household consumption in 2004 (mostly urban households) was 60 kWh/month with a substantial share of households consuming 20 kWh or less per month (Tariff Study Update, Figures 8.1 and 8.2).

Households in the project area that are similar to the households sampled in the survey would likely be able to afford the monthly cost of electricity at the tariff rates cited above.

At 2.15 Nakfa/kWh, households consuming 20, 40 or 60 kWh/mo would have monthly costs of 6+43=49, 6+86=92 and 6+129=135 Nakfa/mo, respectively. These costs compare very favorably to existing expenditures 76, 84 and 103 Nakfa/month now spent by Lower, Medium and Higher income households, particularly when considering that newly electrified lower income rural households elsewhere have been found to rarely consume more than 30kWh/month during their first few years.

Even households in the Lowest Income group appear to be well-positioned to afford the monthly cost of electricity: at the national tariff, 76 Nakfa currently spent on lighting fuel and batteries, on average, would buy 33 kWh. Note that two 60 Watt bulbs used 4 hours daily consume less than 15kWh/month (37 Nakfa/mo or US$ 2.40 at the national tariff). Less than 20% of the entire sample reported spending under 37 Nakfa/month on lighting fuels and batteries. As such, the vast majority of households surveyed in the Project Area could afford electricity for at least two 60 Watt bulbs at the national tariff.

[3] Tariff Study Update, Asmara Power Distribution and Rural Electrification Project, Interim Report, PB Power, November 2005.

This indicative analysis uses current substitutable expenditures to proxy for ability to pay for electricity at the national tariff. If in addition to these recurrent charges, households were required to pay a substantial connection charges, those charges would likely limit connection rates, particularly in lower and medium income groups. The extent of the barrier that a substantial connection fee might place on actual connections cannot be estimated from this study.

The use of current expenditures as a proxy for electricity spending power does not require complete electric substitution for these other fuels. Experience in other countries shows that once rural households are electrified, they build up their electricity use slowly and do not stop using kerosene and candles for lighting. Depending upon the number and wattage of fixtures and appliances, loads for most lower income rural households rarely exceeds 30 kWh/mo in the first few years of electrification. The typical pattern is for newly electrified rural households to reduce their use of kerosene and candles gradually over several years as the household obtains lighting fixtures and appliances that use grid electricity.

Existing tariff rates for municipal systems in several towns in the sample frame as well as flat rate charges for some private mini-grids are reviewed in DOE 2005. Tariffs for most of these existing systems are higher than the national tariff cited above.

Accordingly, the current tariff rate in Akrur (page 17) and in Korbaris (page 25) is reported at 2.75Nakfa/kWh (standing charge not reported). The Municipal generator in Afabet charges households 20 Nakfa/month/lamp and 80 Nakfa/month/refrigerator. Finally, some households in the peri-urban areas around Tokombia are served by private generators and pay a fixed charge of 60 Nakfa per lamp and 20 Nakfa per radio per month. These isolated systems commonly run only a few hours each day, operate at very low load factors and even with charges higher than the national tariff, appear to run at a substantial financial loss.

Twenty-six of the households that were surveyed in the project area, in all income groups, use electricity and pay a monthly bill. All of these pay a flat charge based on number of bulbs/appliances. The average monthly bill is Nakfa 50/month (US$ 3.25/mo) (see Table 6 below). Most of these households that have already revealed their willingness to pay for electricity would benefit from more reliable grid electricity, particularly if charged the national tariff.

Lighting substitution potential

Lighting levels delivered by kerosene lamps were estimated for each household using survey responses and technical characteristics of standard kerosene lamps.[4] Average liters consumed and lighting delivered by lamp type are shown in Table 5. Simple wick lamps are not much brighter than candles. More than half the lighting kerosene is consumed in regulated wick lamps, commonly called hurricane lamps. Because hurricane lamps are more efficient than simple wick lamps, they deliver more than 75% of the light from kerosene in sampled households of every income group.

TABLE 5. KEROSENE LIGHTING Users Only (liters and klmh/month)

	Income Level						Table Total	
	Higher income		Medium Income		Lower income			
	Mean	Valid N	Mean	Valid N	Mean	Valid N	Mean	Valid N
Lighting kero (l/mo)	4.59	76	3.43	96	3.95	212	3.95	384
Simple wick share	.33	75	.34	96	.47	210	.41	381
Regulated wick share	.67	75	.66	96	.53	210	.59	381
Petromax share	.00	75	.00	96	.00	210	.00	381
Kerosene light (klmh/mo)	6.34	76	4.68	96	5.34	211	5.37	383
Simple wick (klmh/mo)	1.30	76	1.07	96	1.29	211	1.24	383
Regulated wick (klmh/mo)	5.05	76	3.61	96	4.05	211	4.14	383
Petromax (klmh/mo)	.00	76	.00	96	.00	211	.00	383

Asmara RE Project pre-electrification survey 2005.

To set these kerosene lighting levels in context, similar estimates were derived for the 26 sampled households that pay a monthly bill for electricity from a municipal system or a neighbor with a generator. Table 6 shows average estimated electric use and lighting delivered in households that use electricity by income group.[5] All of these households pay a flat monthly charge based on number of bulbs and appliances. The figures in Table 6 are not meant to predict electricity usage after electrification—the number of households is too few and the quality of service to different to be predictive. Table 6 merely illustrates the quality of service and lighting levels delivered in the sampled households that now pay an electric bill.

[4] Technical characteristics of standard lamps are presented in the Appendix and are from Nieuwenhout, FDJ, PJNM van de Rijt, and EJ Wiggelinkhuizen, 1998, Rural Lighting Services: A comparison of lamps for domestic lighting in developing countries, Energieonderzoek Centrum, Netherlands.

[5] Households that generate electricity for own use or for sale to neighbors were excluded from this Table. Household responses about the total installed wattage of various appliances and average hours of daily use were employed to estimate total monthly kWh consumed in each type of device.

Roughly half of the current electricity users in Table 6 report their source of electricity is available 30 days per month, with the rest reporting 15 days per month of service, on average. Most of these sources deliver electricity less than 5 hours per day.

Even though the observations are few, the lighting levels delivered by incandescent and fluorescent lamps are illustrative. The 13 households in the Lower Income group use electricity almost exclusively for incandescent lighting. They consume, on average, less than 10kWh/mo overall and enjoy about 145 klmh/mo.[6]

TABLE 6. ELECTRIC USE and LIGHTING Bill Payers Only (Nakfa, kWh & klmh/month)

	Income Level						Table Total	
	Higher income		Medium Income		Lower income			
	Mean	Valid N	Mean	Valid N	Mean	Valid N	Mean	Valid N
Days per month the household get electricity from gen-set	21.50	8	21.20	5	22.92	13	22.15	26
Gen-set service hours per day	3.88	8	4.60	5	4.46	13	4.31	26
monthly elec bill (Nakfa)	49.38	8	39.00	5	49.62	13	47.50	26
Total est. elect kWh/mo	24.16	8	14.17	5	9.68	13	15.00	26
incandescent (kWh/mo)	13.63	5	7.27	5	11.83	9	11.11	19
fluorescent (kWh/mo)	10.35	4	4.50	1	2.00	5	5.59	10
radio (kWh/mo)	.	0	.00	1	2.80	1	1.40	2
color TV (kWh/mo)	13.20	1	.00	1	6.60	1	6.60	3
B&W TV (kWh/mo)	9.00	1	.00	1	.	0	4.50	2
refrigerator (kWh/mo)	30.75	2	30.00	1	.	0	30.50	3
Total est. light klmh/mo	412.74	8	141.26	5	144.46	13	226.39	26
incandescent (klmh/mo)	163.58	5	87.26	5	142.00	9	133.28	19
fluorescent (klmh/mo)	621.00	4	270.00	1	120.00	5	335.40	10

Asmara RE Project pre-electrification survey 2005.

Using Lower Income households as an illustrative example of the benefits of electrification: they pay, on average, 50 Nakfa for 10 kWh delivered on 23 days each month. At the national tariff, these households' monthly cost would be cut roughly in half to 27.5 Nakfa for 10kWh and it should be available more than 23 days each month. Moreover, they would enjoy 145 klmh of electric lighting and would likely be able to

[6] Households in medium and Higher Income groups use more fluorescent lighting. Since fluorescent lamps are roughly 5 times as efficacious as incandescent lamps, they enjoy more light per kWh.

displace the bulk of their dry cell battery needs (for powering a radio) for under 30 Nakfa each month. Meanwhile, the average non-electrified Lower Income household would still be getting only 5.34 klmh (Table 5) for 39.75 Nakfa from kerosene and paying 32.80 Nakfa for dry cell batteries each month (Table 4).

This example indicates that making electricity available to Lower Income households in the project area could boost lighting levels more than twenty fold (145 klmh / 5.34 klmh = 27) and cut lighting fuel and battery expenditures, now consuming 10.2% of total cash outlays (76.4 Nakfa/month (US$ 5), Table 4), by more than half (to roughly 30 Nakfa/mo (US$ 2) as above).

Dramatic improvements in lighting are immediate benefits that are commonly observed in rural electrification programs. Cost reductions usually take several years as households build up electric lamps and appliances. But it may be reasonable to expect that substantial outlays for dry cell batteries may be reduced very quickly by electrified households in the Project Area.

Electric and irrigation expenditures

Table 7 shows household expenditures for electricity, generation and for operating irrigation pump sets. As stated at the outset, in *Caveats*, it appears that households owning and operating generators and pump sets may have been over-sampled relative to their frequency in the population at large. Moreover, it is clear from the figures reported in Table 7 that expenses for electric generation and irrigation are unique to these households and may not have been included in overall household expenditures. In addition, relying on mean expenditures across all households can be misleading when only a few sample observations have a generator or pump set. As such, electricity use, generation and water pumping are analyzed separately in this section.

Electricity consumption

Electricity use in the 26 sample households that reported paying a monthly bill have been analyzed above. These electric expenses were not included in the lighting and battery expenses reported above. But since so few households in the sample use electricity, the means used as proxies for spending power on grid electricity are biased downwards only slightly, by 3 Nakfa / month, on average.

Electricity generation

Fifteen households, almost all of which are in the Higher Income group, reported owning and operating a generator. Table 7 shows average monthly fuel and maintenance costs for these generators. These costs have been allocated evenly to the number of households served when the generator is operated. Even so, monthly expenses are substantial—more than 500 Nakfa/month/household served (US$ 32). The amount of electricity generated by these self-generators is unknown. However, even with costs allocated evenly across

the number of households served, they are an order of magnitude above the average electric bill reported by other households in the sample frame.

There are several possible explanations for these very high reported costs. These generators may be grossly inefficient. Old equipment and low load factors are commonly cited for the systems reviewed in DOE 2005. Another explanation may be that they are supporting demands that are more in line with higher income urban household consumption, including refrigeration and possibly even air conditioning. Perhaps both explanations are operative here. If the reported costs are accurate, however, the households that now generate electricity for own consumption and for their neighbors would likely benefit substantially, in terms of reduced costs, from grid electrification.

TABLE 7. ELECTRIC & IRRIGATION EXPENDITURES (Nakfa/month)

	Income Level						Table Total	
	Higher income		Medium Income		Lower income			
	Mean	Valid N	Mean	Valid N	Mean	Valid N	Mean	Valid N
HH electric expense	*85.61*	*80*	*4.97*	*97*	*8.02*	*216*	*23.06*	*393*
monthly elec bill	4.94	80	2.01	97	2.99	216	3.14	393
genset oper cost	54.97	80	2.84	97	4.15	216	14.17	393
genset maint cost	25.70	80	.12	97	.88	216	5.75	393
monthly elec bill	49.38	8	39.00	5	49.62	13	47.50	26
genset oper cost	399.77	11	275.00	1	298.78	3	371.25	15
genset maint cost	186.92	11	11.67	1	63.69	3	150.59	15
Irrigation expense	*623.26*	*80*	*53.71*	*97*	*2.12*	*216*	*141.30*	*393*
elec for irrig cost	27.91	80	.00	97	.00	216	5.68	393
irrig pump fuel cost	595.35	80	53.71	97	2.12	216	135.62	393
irrig monthly cost	1,994.45	25	868.38	6	114.58	4	1,586.56	35
elec for irrig cost	744.33	3	.	0	.	0	744.33	3
irrig pump fuel cost	1,905.13	25	868.38	6	114.58	4	1,522.76	35

Asmara RE Project pre-electrification survey 2005.

Irrigation water pumping

Thirty-five households reported operating a pump set for irrigation. Irrigation is a substantial productive use for motive power and pump sets are a primary target for electrification. Many other countries, where irrigation has been shown to dramatically increase yields and allow multi-cropping, have made electrification of irrigation pump sets a policy priority and have even premised their rural electrification programs on agricultural returns to irrigation.

This survey, because it was intended to characterize the baseline, did not go into agricultural yield details. As such, it is not possible to formally assess the economic returns to irrigation through electrification of pump sets using this data set. But it is clear from the costs reported in Table 7 that irrigation costs can easily dwarf household energy costs and even normal household expenditures. Average irrigation costs across all income groups (1,600 Nakfa/mo) exceed mean total household expenditures across the entire sample by 50%. Irrigation costs for households in the Higher Income group that irrigate are roughly equal to mean household expenditures by all households in that group.

Water pumping for irrigation, drinking water and sanitation are major productive end uses that merit further study, particularly owing to arid conditions in the Project Area and predominance of rain fed agriculture. Water pumping for irrigation and public water supply may provide an overall economic rationale for this and future rural electrification projects in Eritrea.

2. Recommendations for ongoing monitoring and evaluation of the project

The Poverty and Social Impact Analysis, DOE 2005, amply summarized village level and household level data from the pre-electrification survey of enterprises and households in 18 of the 59 villages to be electrified under the Asmara Power Distribution and RE Project. That report was comprehensive, identifying institutions and enterprises for electrification at the village level as well as giving an overview of findings at the household level. The team that fielded the survey and quickly turned it around in a few short months into the preliminary analysis contained in that report should be commended. The current report is intended to supplement the DOE 2005 report.

The survey instrument itself is well-designed for characterizing a baseline of energy use patterns and practices in enterprises and households that might be substituted by grid electricity. It goes into considerable detail on lighting kerosene use and lamps, electricity consumption and productive end uses—namely private electricity generation and irrigation.

Most sampled households use kerosene for lighting and the questionnaire was sufficiently detailed to support an estimation of lighting levels achieved by each household. The few surveyed households that consume electricity were not sufficient to undertake a statistical evaluation of the benefits of electricity substitution for lighting kerosene. But the survey was detailed enough to enable an indicative analysis to be completed.

Research design for assessing the impacts of electrification

When the impacts of any treatment, in this case electrification, are formally assessed it is common practice to use multivariate regression tools to control for the many differences between observations (in this case households) and, thereby, isolate the effects of the treatment (in this case electrification) on lighting, farm productivity, education achieved, incomes, health measures and other indicators of household welfare. Such analysis requires rich data sets that contain observations that get the treatment and those that don't.

This overall approach is called quasi-experimental design. Consider assessing the impact of drip irrigation on farm productivity. The researcher would properly apply the treatment (drip irrigation) to one part of the field, leave the other as rain fed and observe the difference in yields. Assessing the impact of rural electrification or any other project is no different.

To properly asses the impact of the project, the survey should include households in the Project Area as well as those in a control group outside the Project Area. For the present purposes, this could be done during the second fielding of this survey, after electrification. It would suffice to survey public institutions, enterprises and households that are similar to those in the Project Area. Energy use and expenditures by members of such a comparison group could then be compared to similar members within the Project Area using statistical methods to evaluate the impacts of electrification.

Survey instrument

The questionnaire served its purpose well—to characterize expenditures on and use of substitutable fuels. For the second round, however, several modules could be strengthened that will serve to enhance project evaluation. Some of the suggestions below may already be contained in the village-level survey, but most are particular to each household.

It has been found that highest levels of education achieved in the household, basic health indicators for household members, the type of housing structure and the quality of water supply or sanitation are all primary indicators of household welfare. Including some basic questions on these measures could be very helpful in evaluating the differential impacts of the project, particularly when trying to explain which households connected and which ones did not. In addition, it is important to ask distances to certain facilities, such as the closest school, health clinic, water supply, major road, market for selling farm goods water supply, and source for collecting wood fuels, if any.

More generally, the survey would benefit from asking a more detailed set of questions about the sources and consumption of wood fuels and agricultural residues. Even though these fuels are not substituted by electricity, it would allow a fuller examination of family resources (including time) devoted to meeting energy needs overall.

Finally, if economic impacts of lower cost irrigation power are a high priority to the project team, it would be prudent to ask detailed questions about farm holdings, livestock,

land under cultivation, land irrigated and yields from each harvest. In all fairness, such a farm and irrigation productivity study is usually well beyond the scope of even a thorough household energy survey, so the project team should consider this only if it is a high priority.

Sample frame
Eighteen villages were selected to be surveyed out of the 59 to be electrified. It is unclear whether these 18 villages were selected randomly or purposively. If not randomly, data from these villages may not be representative of the Project Area as a whole.

Even if the 18 villages surveyed are, in fact, representative of all 59 villages, the sample was stratified by income groups. It is unclear whether the shares of sampled households in each income group reflect the proper population proportions. On other surveys, it has been observed that when enumerators are allowed to select households, they tend to be clustered near each other as that is more convenient to interview. The enumerators' manual did, however, caution against this.

Finally and as noted above, households with generators and possibly those with irrigation pump sets appear to have been over-sampled. While there may be good reasons for over-sampling a particular group (to make sure there are enough observations to properly characterize their energy use), it is important to set them aside so that they do not bias the general evaluation of the overall project.

All of these potential problems are fairly common. Moreover, they can all be resolved. At this pre-electrification stage, no attempt was made to generalize findings to the Project Area as a whole. The indicative findings reported here appear to be sufficiently robust to overcome most concerns with the sample frame. But attention should be paid to these matters in the second round when a more formal evaluation of project impacts on public institutions, enterprises and households will likely be more important.

The Bottom Line
The pre-electrification survey and research design served its purpose well. The current level of substitutable expenditures in sampled households are more than enough to indicate a strong ability to pay existing tariff rates for electricity. The magnitude of benefits, in terms of increased lighting and reduced costs, from electrification at the household level have been illustrated. Moreover, households that currently use electricity from community or private generators and those that irrigate with non-electric pump sets would likely be able to cut costs substantially if grid electricity were made available at the national tariff.

Options

The observations and suggestions above aim to strengthen the research design, survey instrument and sample frame to be employed during the second round, after electrification. Making at least some of these modifications will improve the ability of the monitoring and evaluation team to complete a formal evaluation of the impacts of the Asmara Power Distribution and RE Project.

1. Default option. Re-survey the same villages and households after electrification—compare conditions before and after electrification and attribute changes to electrification. This would be the least-cost approach. It may be satisfactory if the original sample frame can be said to be representative of the population in Project Area. It would be a within treatment design—no control group. The evaluation team may be able to identify systematic differences between households that connect to the grid and those that do not. But it will not be able to evaluate project impacts generally, i.e., it won't be able to identify substantive differences between electrified and non-electrified villages and households that are otherwise similar. At any rate, the team should consider making some of the modifications to the survey instrument mentioned above.

2. Default option with added control group. Re-survey the same villages and households after electrification—but expand the sample frame to include a control group. As with the default option, this is premised on the original sample frame being representative of the population in Project Area. The advantage of this option is that the control group would allow a more formal evaluation of impacts of the project itself on villages and households, rather than just identifying differences between households that connected and those that did not. As above, the team should consider strengthening/adding survey sections on housing type (material), education, water supply and sanitation, health, biomass fuels, land cultivated and under irrigation, and distances to water supply, schools, clinics, major roads, and markets. These measures have been found to be important in explaining the impacts of electrification in other countries.

3. Bootstrapping option. Re-survey the same villages and households after electrification—but supplement the pre-electrification survey by administering it to a freshly drawn control group this summer. Such a control group should be drawn from outside the Project Area but contain otherwise similar villages and households, including some that have already been electrified. When combined with data from the pre-electrification survey, data from such a control group may allow a more formal evaluation of the anticipated impacts of the project itself. Of course, the viability of this option also requires that the existing sample represents the population in the Project Area. This option may be most costly as it would involve fielding the survey again, before the second round. If this approach is taken, the questionnaire should be modified as above.

4. Post-electrification evaluation. If the current sample is not representative of the population in the Project Area and cannot be weighted to make it so, the impact of the project may be assessed after electrification by drawing a fresh random sample, in a dozen or so project villages and half as many villages outside the project area that have

been electrified for some time, and enumerating the same questionnaire, modified as suggested above. If this option is select, the team may still choose to re-survey the same villages and households after electrification. But formal evaluation of impacts due to the project would be done on the basis of the random or stratified random samples drawn from inside and from outside of the Project Area.

RECOMMENDATIONS

The default option with added control group (Option 2.) is the recommended approach in the case that the original sample frame is representative of the population in Project Area.

Post-electrification evaluation (Option 4.) is the recommended approach otherwise.

APPENDIX

ANNUAL HOUSEHOLD INCOME (US Dollars/year)

	Income Level						Table Total	
	Higher income		Medium Income		Lower income			
	Mean	Valid N	Mean	Valid N	Mean	Valid N	Mean	Valid N
Income	1,960	78	958	94	361	202	844	374
Income/cap	*288*		*151*		*69*		*145*	
Farm income	1,071	80	436	96	142	210	407	386
Non-farm income	955	78	547	95	239	205	464	378
Wage income	175	78	244	95	126	206	166	379
Trading	613	78	233	95	59	208	216	381
Remittances	67	78	16	95	6	210	21	383
Suwa or injera	1	78	27	95	21	208	18	381
Home business	11	78	1	95	6	208	6	381
Government aid	144	79	170	97	155	216	157	392
Other	42	78	26	96	23	207	27	381

Asmara RE Project pre-electrification survey 2005.

HOUSEHOLD EXPENDITURES (US Dollars/month)

	Income Level						Table Total	
	Higher income		Medium Income		Lower income			
	Mean	Valid N	Mean	Valid N	Mean	Valid N	Mean	Valid N
Income	163.36	78	79.81	94	30.05	202	70.36	374
Farm income	89.21	80	36.31	96	11.82	210	33.95	386
Monthly expense	*128.68*	*79*	*61.05*	*96*	*48.58*	*213*	*67.97*	*388*
Food	51.87	80	31.04	97	25.02	214	32.01	391
Clothing	9.90	80	7.91	97	5.28	214	6.87	391
Schooling & health	5.26	80	3.25	97	2.54	214	3.27	391
Firewood & biomass	3.38	80	1.98	97	1.93	213	2.24	390
Commercial fuel	36.27	79	10.06	97	7.51	216	13.94	392
Travel	20.56	80	4.98	97	3.04	216	7.08	393
Rent	1.92	80	1.34	97	.71	214	1.11	391
Other	10.32	80	1.67	96	2.40	214	3.85	390

Asmara RE Project pre-electrification survey 2005.

ENERGY EXPENDITURES (US Dollars/month)

	Income Level						Table Total	
	Higher income		Medium Income		Lower income			
	Mean	Valid N	Mean	Valid N	Mean	Valid N	Mean	Valid N
Income	163.36	78	79.81	94	30.05	202	70.36	374
Farm income	89.21	80	36.31	96	11.82	210	33.95	386
Monthly expense	*128.68*	*79*	*61.05*	*96*	*48.58*	*213*	*67.97*	*388*
Kerosene for cooking, etc.	3.79	80	2.50	97	1.66	216	2.30	393
Lighting & battery expense	*6.69*	*80*	*5.45*	*97*	*4.97*	*216*	*5.44*	*393*
Kerosene for lighting	2.98	80	2.27	97	2.59	216	2.59	393
Candles	.42	80	.27	97	.23	216	.28	393
Dry cell batt	3.12	80	2.82	97	2.13	216	2.50	393
Storage batt	.18	80	.09	97	.02	216	.07	393
HH electric expense	5.57	80	.32	97	.52	216	1.50	393
Irrigation expense	40.54	80	3.49	97	.14	216	9.19	393

Asmara RE Project pre-electrification survey 2005.

ENERGY EXPENDITURES Users Only (US Dollars/month)

	Income Level						Table Total	
	Higher income		Medium Income		Lower income			
	Mean	Valid N	Mean	Valid N	Mean	Valid N	Mean	Valid N
Income	163.36	78	79.81	94	30.05	202	70.36	374
Farm income	89.21	80	36.31	96	11.82	210	33.95	386
Monthly expense	128.68	79	61.05	96	48.58	213	67.97	388
light+batt cost	6.69	80	5.45	97	5.02	214	5.47	391
firewood cost	9.33	29	7.12	27	8.37	49	8.32	105
electric cost	26.20	17	5.22	6	7.04	16	15.11	39
irrigation cost	129.72	25	56.48	6	7.45	4	103.19	35

Asmara RE Project pre-electrification survey 2005.

ELECTRIC & IRRIGATION EXPENDITURES (US Dollars/month)

	Income Level						Table Total	
	Higher income		Medium Income		Lower income			
	Mean	Valid N	Mean	Valid N	Mean	Valid N	Mean	Valid N
HH electric expense	*5.57*	*80*	*.32*	*97*	*.52*	*216*	*1.50*	*393*
monthly elec bill	.32	80	.13	97	.19	216	.20	393
genset oper cost	3.58	80	.18	97	.27	216	.92	393
genset maint cost	1.67	80	.01	97	.06	216	.37	393
monthly elec bill	3.21	8	2.54	5	3.23	13	3.09	26
genset oper cost	26.00	11	17.89	1	19.43	3	24.15	15
genset maint cost	12.16	11	.76	1	4.14	3	9.79	15
Irrigation expense	*40.54*	*80*	*3.49*	*97*	*.14*	*216*	*9.19*	*393*
elec for irrig cost	1.82	80	.00	97	.00	216	.37	393
irrig pump fuel cost	38.72	80	3.49	97	.14	216	8.82	393
irrig monthly cost	*129.72*	*25*	*56.48*	*6*	*7.45*	*4*	*103.19*	*35*
elec for irrig cost	48.41	3	.	0	.	0	48.41	3
irrig pump fuel cost	123.91	25	56.48	6	7.45	4	99.04	35

Asmara RE Project pre-electrification survey 2005.

ERITREA pre-electrification survey sample frame

			Income Level						Table Total	
			Higher income		Medium Income		Lower income			
			Count	Col %	Count	Col %	Count	Col %	Count	Col %
Dekemhare	Endadeko	Number	4	5.0%	5	5.2%	8	3.7%	17	4.3%
	Godeity	Number	3	3.8%	6	6.2%	13	6.0%	22	5.6%
	Alla	Number	14	17.5%					14	3.6%
	Gaden	Number	6	7.5%	6	6.2%	10	4.6%	22	5.6%
	Wekerty	Number	2	2.5%	4	4.1%	10	4.6%	16	4.1%
	Akrur	Number	3	3.8%	8	8.2%	9	4.2%	20	5.1%
	Degsa	Number	3	3.8%	6	6.2%	15	6.9%	24	6.1%
	Korbaria	Number	4	5.0%	6	6.2%	15	6.9%	25	6.4%
Adikeih	Mendefera	Number	3	3.8%	4	4.1%	11	5.1%	18	4.6%
	Halay	Number	3	3.8%	4	4.1%	12	5.6%	19	4.8%
	Embeito	Number	3	3.8%	4	4.1%	9	4.2%	16	4.1%
Keren	Debresina	Number	4	5.0%	6	6.2%	14	6.5%	24	6.1%
	Afabet	Number	8	10.0%	9	9.3%	18	8.3%	35	8.9%
	Libana	Number	5	6.3%	6	6.2%	15	6.9%	26	6.6%
Barentu	Tokombia	Number	5	6.3%	8	8.2%	20	9.3%	33	8.4%
	Bimbina	Number	4	5.0%	6	6.2%	12	5.6%	22	5.6%
	Mogolo	Number	4	5.0%	5	5.2%	15	6.9%	24	6.1%
	Areda		2	2.5%	4	4.1%	10	4.6%	16	4.1%
Table Total		Number	80	100.0%	97	100.0%	216	100.0%	393	100.0%

Asmara RE Project pre-electrification survey 2005.

ERITREA pre-electrification survey sample weights

			Income Level						Table Total	
			Higher income		Medium Income		Lower income			
			Count	Col %	Count	Col %	Count	Col %	Count	Col %
Dekemhare	Endadeko	Number	54	1.9%	68	1.9%	108	1.4%	230	1.6%
	Godeity	Number	39	1.4%	79	2.3%	170	2.2%	288	2.1%
	Alla	Number	312	10.8%					312	2.2%
	Gaden	Number	68	2.3%	68	1.9%	113	1.5%	249	1.8%
	Wekerty	Number	31	1.1%	62	1.8%	155	2.0%	248	1.8%
	Akrur	Number	90	3.1%	240	6.9%	270	3.6%	600	4.3%
	Degsa	Number	58	2.0%	115	3.3%	288	3.8%	460	3.3%
	Korbaria	Number	96	3.3%	144	4.1%	360	4.7%	600	4.3%
Adikeih	Mendefera	Number	38	1.3%	51	1.5%	141	1.9%	230	1.6%
	Halay	Number	38	1.3%	51	1.5%	152	2.0%	240	1.7%
	Embeito	Number	20	.7%	26	.7%	59	.8%	104	.7%
Keren	Debresina	Number	73	2.5%	109	3.1%	255	3.4%	437	3.1%
	Afabet	Number	1196	41.3%	1346	38.6%	2691	35.4%	5233	37.4%
	Libana	Number	265	9.1%	318	9.1%	795	10.5%	1378	9.9%
Barentu	Tokombia	Number	271	9.4%	434	12.5%	1085	14.3%	1791	12.8%
	Bimbina	Number	75	2.6%	112	3.2%	224	2.9%	410	2.9%
	Mogolo	Number	120	4.1%	150	4.3%	449	5.9%	719	5.1%
	Areda		56	1.9%	113	3.2%	281	3.7%	450	3.2%
Table Total		Number	2899	100.0%	3484	100.0%	7596	100.0%	13979	100.0%

Asmara RE Project pre-electrification survey 2005.

Luminous Efficacy of Standard Lighting Devices

	Power	*Light Output*	
	Watts	*lumens*	*klmh/kWh*
Incandescent bulb			
25 Watt	25	230	*9.20*
40 Watt	40	430	*10.75*
50 Watt	50	580	*11.60*
60 Watt	60	730	*12.17*
100 Watt	100	1,280	*12.80*
Fluorescent tube			
10 Watts	10	600	*60.00*
20 Watts	20	1,200	*60.00*
40 Watts	40	1,613	*40.33*
Non-electric lamps			*klmh/liter*
Paraffin Candle	60	12	
Kerosene Wick	118	11	*0.94*
Kerosene Hurricane	198	32	*1.57*
Kerosene Pressure	1,380	2,040	*14.37*

Source: Nieuwenhout, FDJ, PJNM van de Rijt, and EJ Wiggelinkhuizen, 1998, Rural Lighting Services: A comparison of lamps for domestic lighting in developing countries, Energieonderzoek Centrum, Netherlands.