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THE MARKET FOR MICRO-POWER: SOCIAL USES OF SOLAR ELECTRICITY IN RURAL KENYA

By

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Introduction

Solar electric systems are being sold to end users in Kenya through a competitive and growing free market network that includes more than 10 import and manufacturing companies, as well as hundreds of vendors, installers, and after-sales service providers. On a per capita basis, Kenya has one of the largest and most dynamic markets for solar energy products in the developing world. Most of this activity is in the market for household solar electric systems, with cumulative sales in excess of 200,000 units and current sales of about 20,000 systems per year. During the 1990s solar electricity emerged as one of the main alternatives to the electrical grid for household rural power,[1] and sales growth in the solar industry - 18% from 1991-2001 - was higher than the rate of new grid based rural electricity connections (11% over the same period) [Hankins, 2000a; Duke, et al., 2000; ESDA, 2003; Economic Survey of Kenya, 1991-2002].

While there is little doubt about the size and relatively rapid growth of the Kenya solar market, there are a number of debates about how to interpret its significance. Solar advocates commonly make claims about the environmental, rural productivity, and poverty alleviation benefits of solar electrification [e.g. Kaufmann, et al., 2000; Ybema, et al., 2000; Martinot, et al., 2002]. Some critics challenge these claims contending that the environmental benefits of solar electrification in rural developing country contexts are minimal, productive uses are few and far between, and that, in the absence of large subsidies, solar sales are primarily to the rural elite rather than the rural poor. These authors argue that the cost of solar electrification is too high relative to its environmental and development benefits to merit significant international support, and that donor funds supporting solar market development should instead be diverted elsewhere [e.g. Karekezi and Kithyoma, 2002; Villavicencio, 2002; Leach, 2001; Inverson, 1996].

In this paper I will review solar technology and examine its social use in rural households as well as addressing key aspects of these ongoing debates. The data and analysis that I present lead to three key findings about solar electrification in Kenya:

1) The solar market delivers electric service primarily to the rural middle class. While recent trends indicate some deepening of access beyond this group, only the smallest solar systems are available to households at the 'access frontier'.
2) Solar electrification plays a very minor role in supporting income generating activities in rural Kenya. It plays a more substantial role in supporting activities related to "improving" the home and for rural education, although in many families the household dynamics of energy allocation constrain these uses.
3) Solar electricity in Kenya is "connective" power for the rural middle class. Solar electricity in Kenya is widely used for household applications such as television, radio, and cellular telephone charging that help increase interconnectedness between the rural middle class and people, markets, and ideas in national and international urban centers. Of the connective uses, television has historically been the most important.

These findings challenge some of the key claims of solar advocates, while supporting others. Importantly, my work indicates that market based solar electrification is neither confined to the rural elite alone, nor is it available to the large mass of "rural poor". Instead, most solar systems are owned by the top one-third of rural Kenyans by wealth. These solar

[1] Data from the 2000 year Tegemeo household survey (n = 1,512 households) indicate that approximately 4% of rural homes use solar energy for electricity (63 homes in the survey), and an almost identical percentage are connected to the national electrical grid (65 homes in the survey). See footnote 3 for more information about the Tegemeo household survey.

users consist largely of a combination of small business owners, rural professionals such as school teachers, civil servants, and ministers, as well as the better off among the small holder cash cropping farmers, and can be therefore be described a 'rural middle class'.

My findings do not support the claim that solar electrification contributes directly to income generation activities in any substantial way, but I do identify a number of widespread and socially important education related uses. However, education benefits from solar use are far from universal, as household energy allocation dynamics that favor other uses prevail in many families.

Finally, solar electrification is often associated with E.F. Schumacher's appropriate technology movement, but my findings indicate that the social uses of solar electricity are far removed from his classic "small is beautiful" vision of building small scale alternatives to global capitalism [Schumacher, 1973; Kitching, 1989]. Instead, solar electricity is widely used in rural Kenya to power wireless communications technologies that are linked to processes of economic integration and greater rural-urban connectivity. Nonetheless, while solar electrification is unquestionably beneficial to corporate TV and radio advertisers seeking to expand consumer goods markets to small towns and rural areas as well as to rural residents who wish to increase their urban connections, solar electrification and the use of wireless communications technologies should not be described simply as fitting into a broader pattern of "globalization" that is bringing rural Kenya into its embrace. Instead of using this overly vague characterization, it is more useful to identify and analyze the socio-economic implications of the specific types of connections that are enabled through solar electrification, as well as the significance of those connections that do not get made. In this paper I will identify key linkages between solar electrification and rural-urban connectivity, with a focus on the important role of television.[2]

In making my case in relation to the three findings outlined above, I will draw on a combination of original field research, interviews with key actors, archival research, analysis of rural household survey data from the Tegemeo Project,[3] and existing literature on solar electrification in Kenya. However, before proceeding into the analytical section of the paper I will begin with an introduction to solar technology and key technical aspects of its use in rural Kenya.

1. Rural Micro-Electricity Basics

A typical solar electric system in Kenya consists of a solar module (which converts solar energy into electricity), a battery (which stores the electricity collected during the day for use at night), and electric loads (i.e. the lights and appliances which use the electricity). Some solar systems also include a few additional components, such as a charge controller,[4] an

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[2] I explore these issues in greater detail in my forthcoming Ph.D. dissertation (titled "Connective Power: The Political Geography of Rural Electrification with Solar Energy in Kenya") and associated publications.

[3] I gratefully acknowledge the Tegemeo Project for generously provided me with access to this data set. The sampling regime was designed as a proportional random sample of rural households in all of Kenya's agro-ecological zones. See Argwings-Khodek, et al., 1998 for a detailed summary of the sampling regime. For additional information about the sampling regime and data collection methods (including the year 2000 original survey questionnaire), as well as more information about the Tegemeo Project see http://www.aec.msu.edu/agecon/fs2/kenya/. See also http://www.tegemeo.org/

[4] The main function of the charge controller is to protect the battery from being over-charged. Many charge controllers also prevent the battery from being discharged too deeply. Overcharging and deep discharge can both lead to premature battery failure. Most solar electric systems in Kenya do not include a charge controller, and this reduces the typical useful lifetime of the batteries in these systems considerably. Data from several surveys indicate that approximately 10% to 20% of solar systems in Kenya include a charge controller [Hankins, et al., 1997; Duke, et al., 2000; Jacobson 2003 survey].

inverter[5] or a DC to DC converter.[6] See Figures 1 and 2 for images of a typical solar electric system during the day and at night, respectively.

Figure 1: Solar electric system during the day. The solar module is on the roof, and a wire delivers the electricity the battery which is located inside. An arrow indicates the flow of electricity into the battery during the day. (image by Michael Okendo)

Figure 2: Solar electric system at night. An arrow indicates the flow of electricity from the battery to power the light. (image by Michael Okendo)

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5 Inverters convert the direct current (DC) electricity (usually 12 volts DC) of the solar system into alternating current (AC) electricity that is similar to the power from the electrical grid (i.e. 240 volts at 50 Hertz in Kenya). Inverters are used to power appliances such as color TVs that are only available for use with AC electricity. Most of the appliances used with solar electric systems in Kenya are compatible with DC electricity, and so the use of inverters is relatively rare. An estimated 5-10% of household solar systems in Kenya include an inverter [Jacobson 2003 survey].

6 DC to DC converters are inexpensive devices that are used to reduce the voltage from the battery down to a lower voltage. These are typically used with transistor radios, which often require 3 or 6 volt electricity instead of the 12 volts from the battery. DC to DC converters are relatively common in Kenya. An estimated 40% to 50% of "solar" households use a DC-DC converter [Jacobson 2003 survey].

Solar Electricity and Battery Based Systems

Solar electric systems have received a good deal of attention internationally because of their reputation as an environmental, "small is beautiful" appropriate technology for rural development. However, battery based systems that do not include a solar module are even more common in rural Kenya than the more celebrated solar system.[7] Although they do not have the same international reputation as an environmentally friendly technology for sustainable development as solar systems, battery systems are widely used to provide a similar set of rural micro-electricity services. Battery systems are generally charged by carrying them to a grid or diesel generator powered "battery charging shop", where they are left overnight (or sometimes for several days) for charging. See Figure 3. Some rural Kenyans use other methods to charge the batteries that they use for household electricity. One common approach involves installing the discharged battery in a car or a truck for charging while the is vehicle being driven, and then removing the battery for use in the home later.[8]

In fact, it is arguably accurate to classify solar electric systems as simply one variant of the battery-based system. This characterization recognizes the central importance of the battery in these household micro-electricity systems. The distinction between the different types of battery systems is then based on the various charging schemes that are utilized. In some households the battery is charged at the battery charging shop, in others by a vehicle, and in still others by a solar module. Many rural Kenyans mix a combination of these methods, using - for example - a solar module when it is sunny and the battery charging shop during the cloudy months.[9]

Figure 3: Man bringing a battery to a grid connected battery charging shop. (image by Michael Okendo)

This relationship between battery-based systems and solar systems has played an important role in the development of the Kenya solar market. A common purchasing pattern for rural Kenyans is to first buy a battery and a television set. The battery is typically used to power the television and perhaps a radio, and it is carried to town every 7-10 days to a battery

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[7] Data from the 2000 Tegemeo survey indicate that 4% of rural households own a solar module, while 12% own a battery that is not charged with solar.

[8] It is of course necessary to push start the vehicle initially when the discharged battery is installed.

[9] I thank Mark Hankins for these insights about the relationship between solar systems and battery-based systems.

charging shop where people pay about $0.50 for a charge.[10] After a few years of this routine, the household decision makers may decide to invest in a solar module.[11] Many people report making this decision primarily because they have grown tired of the hassle of carrying the battery to town [Hankins, 2000a]. An important feature of this purchasing pattern is its incremental modularity, which allows rural families to purchase a solar system in small "chunks". For the smallest and most common solar systems the first "chunk" - for the TV and the battery - may come to a total of about $100. The later addition of a small solar module could be as little as $50, with perhaps a little more added on for wiring and labor. Fluorescent lights can be added for about $20 each, while incandescent bulbs can be added for under $5. Importantly these purchases can be spread out over several years, so while the overall cost is not trivial, the incremental nature of the expenditures make them manageable for many rural families.

Solar Modules Sold in Kenya

There are three main types of solar modules used in Kenya. Mono-crystalline solar modules were the first type to be used in Kenya. Poly-crystalline solar modules were introduced later, but in many ways they are similar to their mono-crystalline counterparts. Both types of modules are characterized by relatively high efficiencies,[12] and their prices per Watt of electricity delivered are generally comparable. Both of these types of solar modules are available in a range of sizes from a few watts to 100 watts or more. Amorphous silicon solar modules were first sold in Kenya in 1989, and these small wattage, low cost, and low efficiency[13] modules quickly gained market share in the household solar systems market. Amorphous silicon modules (sometimes called "a-Si" modules) are generally only available in small sizes. The most common a-Si module size in Kenya is 14 watts, although somewhat larger sizes are also available.[14] See Figure 4 for images of mono-crystalline and amorphous silicon solar modules.

Appliance Use and Energy Consumption

Televisions, radios, and lights are the three most common electrical appliances used in solar electric systems. A 1997 survey of 410 rural solar system owning households indicated that 90% had a TV set, 84% had at least one light, and 70% had a solar powered radio[15] [van der Plas and Hankins, 1998]. Cellular telephones are a recent phenomenon in rural Kenya,[16] but already they are becoming a common appliance in households where solar electricity is used. My 2003 survey of 76 "solarized" homes indicated that about 50% used the solar

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[10] The price of a charge is generally 40 Kenyan Shillings (KSh), which is roughly equivalent to $US0.50.

[11] In my 2003 survey of 76 solar owning households, 66% reported using a battery alone prior to purchasing a solar module.

[12] The solar energy to electrical energy efficiency for most mono-crystalline modules is from 10 to 13%, while for polycrystalline modules it ranges from 10 to 12% [Sandia National Laboraties, 1991].

[13] Amorphous silicon modules have efficiencies that range from 2% to 8% depending on the technology type [Sandia National Laboratories, 1991]. The most common types available in Kenya have efficiencies in the 2-4% range [Jacobson, et al., 2000]. Note that efficiency is simply a measure of the amount of electricity that can be generated from a given area of active surface on a solar module. Thus, low efficiency modules must be larger than high efficiency modules to generate a similar amount of power. If space is not limited relative to the sizes of the solar modules, then low efficiency is not a drawback. This is true in most instances in rural Kenya, as nearly all families have ample roof space compared to the size of the solar modules that they can afford to buy.

[14] Amorphous silicon solar technology has a mixed reputation for quality, and some solar experts claim that they are a poor investment due to performance problems. However, field tests from 1999 indicated that while some brands did perform poorly, others have a good performance track record for long-term reliability [Jacobson, et al., 2000].

[15] It is likely that nearly all of the households in the survey had a radio. The 70% figure indicates those that operated the radio using solar electricity. The remaining 30% of households likely used dry cells to power their radio.

[16] Cellular telephone networks expanded to many rural areas of Kenya beginning in the latter part of 2001.

electricity to charge a mobile phone.[17] Households that use a battery alone (i.e. without a solar module) tend to use the power to operate TV sets, radios, and cellular telephones, but not lights.[18]

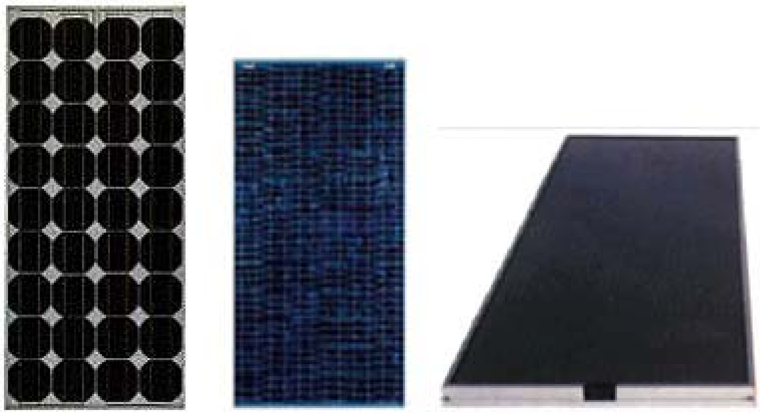

Figure 4: Monocrystalline, Polycrystalline, and Amorphous Silicon Solar Modules. The mono-crystalline and polycrystalline images are for modules that are rated at approximately 60 watts, while the amorphous silicon module is rated at 12 watts (images are not to scale).

The quantity of electrical energy supplied by solar and battery based systems is very small. Unlike grid connected systems - where the amount of energy that can be consumed is generally limited only by the one's ability to pay the power bill - solar system users are limited to a quantity of energy that is defined by the size of their solar module and the amount of sunlight that reaches the module during the day.

The average size for a household solar electric system in Kenya is about 25 Watts. This means that in a relatively sunny area (e.g. near the towns of Nakuru or Kisumu) the system can produce about 40 kWh per year.[19] This compares with over 500 kWh per year on average for those few rural households that are connected to the electrical grid[20] [Kamfor, 2002]. In other words, grid connected rural households are able to use about 10 times more electricity than solar households.[21] As a result, solar households are limited to using a handful of low power appliances for a few hours per day. See Table 1 for approximate power consumption levels for appliances common in solar and grid-connected homes. I have also included estimates of typical energy use levels based on rough assumptions about the number of hours the appliances might be used in a day. This latter amount (daily energy use) is the critical value for determining which appliances can be used in a small household solar system.

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[17] The ownership levels for the other appliances in this 2003 survey are similar to those from the 1997 survey (see above). 95% of the households owned a TV set, 83% had at least one light, and 84% had a solar powered radio.

[18] My 2003 survey of 76 households indicated that 50 used a battery alone before buying a solar module. During this period before buying a solar module, 82% of these 50 households reported using the battery to power a TV set and 54% used a radio. Only 8% used the battery to power a light.

[19] Battery systems typically deliver on the order of 20 to 60 kWh per year depending on the size and condition of the battery as well as the frequency with which it is taken to a battery charging station for a charge.

[20] For comparison purposes, an average US household consumes about 10,000 kWh per year [Jacobson, et al., 2004]. That is, 20 times more than grid connected rural households in Kenya and 250 times more than solar using households.

[21] The energy estimate for the 25 Watt solar system was made for a relatively sunny area. The difference is more extreme for cloudier areas such as the Mt. Kenya region. Even more importantly, while the average system size is 25 Watts, the typical size is on the order of 14 Watts. Thus, rural grid connected home is able to use about 25 times more electricity than a 14 Watt system near the town of Meru or other areas of the cloudy Mt. Kenya region.

A 25 Watt solar system - e.g. near Kisumu - that produces 50 kWh per year can generate, on average, about 110 Watt-hours per day. With this amount of energy some appliances (i.e. lights, B&W TVs, radio/cassette players, and cell phones) can fit within the energy budget of a small solar electric system; other household appliances (e.g. refrigerators, electric irons, and cookers) cannot.

Table 1: Electricity Consumption for Household Appliances Used in Rural Kenya

Appliance	Power Use (Watts)	Daily Energy Use[22] (typical, Watt-hours)	Used in Solar Systems?
15 Watt Incandescent Light Bulb	15	45	OFTEN
10 Watt Fluorescent Lamp	10	30	OFTEN
14" Black & White Television	10	30	OFTEN
Radio/Cassette Player	1	6	OFTEN
Cellular Phone (charging)	3	6	OFTEN
14" Color TV	70	210	SOMETIMES
Small Refrigerator	80	960	VERY RARE
Electric Iron	1,500	1,500	NEVER
Electric Cooker (1 element)	1,500	1,500	NEVER

[data sources: field measurements in Kenya 2002/03 for the first six items; SEI, 1998 for refrigerator, electric iron, and electric cooker]

The data in Table 1 also indicate significant differences in energy use among those appliances that are used in solar systems. For example, radios and cellular telephones use only a very small fraction of the electricity generated by the solar system, while lights and TV sets represent the bulk of the energy usage. Another important distinction can be made between incandescent lights (bulbs) and fluorescent lamps. Fluorescent lamps are generally three to four times more efficient than bulbs.[23] This means that a 10 Watt fluorescent lamp provides substantially more light output for less electricity than a 15 Watt bulb. Nonetheless, dim low wattage bulbs remain common in rural solar systems in Kenya because their initial cost is about one fourth as much as fluorescent lamps.[24]

Solar Energy and Grid Based Rural Electrification

These calculations give a sense of the difference between grid, solar, and battery based electricity for rural electrification. Simply stated, grid electricity provides a LOT more electrical energy than solar and battery based systems. However, the initial cost per household is also much higher for a grid connection, and grid-based rural electrification has moved slowly in Kenya.[25] As a result, many rural Kenyans have turned to solar and battery based systems in order to get at least a minimum level of access to electricity.

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22 The daily energy use is calculated by multiplying the power use (in Watts) by an estimate of the number of the number of hours each appliance is "on" per day.

23 In this instance efficiency is defined as the light output (in lumens) divided by the electricity consumption (in Watts). Fluorescent lamps generally produce 60-80 lumens per watt, while incandescent bulbs produce 15 to 20 lumens/watt [Craford, et al., 2001; Mills, 2000].

24 This cost comparison includes typical installation labor costs as well as the cost of wires, a switch, etc. that are common to both light types. If these common costs are omitted then the retail purchase price of a fluorescent lamp is about 10 times higher than an incandescent bulb and its fixture.

25 An estimated 4% of rural Kenyans are connected to the grid [Tegemeo 2000 survey]. This is approximately equal to the fraction who own a solar system [Tegemeo 2000 survey]. However, rural grid electricity planning has - perhaps wisely - focused on delivering power to towns and market centers rather than to rural homes, and most rural Kenyan households have little hope of being connected within the next decade or more [Walubengo and Onyango, 1992].

It is difficult to estimate exactly how much it costs per household for grid based rural electrification in Kenya. In practice, the cost varies widely depending on distribution line distances, topography, and the concentration of houses in a given area. Nonetheless, rough estimates indicate that the cost for a grid connection per household is generally thousands of US dollars. This compares with solar system costs that typically run from $150 to $500 for small solar electric systems. Battery systems are even less expensive at $50 to $100 per household. However, due to the differing levels of service, the cost *per unit* of electrical energy is generally lower for grid electrification. Rural Kenyans who are connected to the grid pay about $0.15 per kWh[26] [Kamfor, 2002]. This compares with an amortized life cycle cost of $1.00 to $2.00 per kWh for solar and battery based systems in Kenya[27] [Duke, et al., 2000].

This highlights one of the classic tradeoffs between grid and solar-based electrification. Grid electrification, where and when available, is more costly in terms of the initial investment per household, but it provides a significantly higher level of service than solar electrification. Solar systems, by comparison, may be a good option to deliver very small amounts of electricity at relatively low cost to dispersed rural households.

However, it would be misleading to suggest that the growth of the solar market in Kenya is part of a deliberate policy approach to rural electrification. Instead, solar electrification has occurred primarily through private, unsubsidized purchases by rural Kenyans, and the frustration on the part of rural Kenyans with slow pace of government sponsored rural electrification has clearly been a key factor leading to high sales in the solar market. Nonetheless, solar electrification cannot be explained by these frustrations alone. The solar market emerged in Kenya through the result of a number of key processes an factors including - importantly - government policies to expand TV broadcasting to rural areas as well as the purchasing power of Kenya's rural middle class. I will now turn to a short historical analysis in order to tell this part of the story.

2. A Brief Historical Profile of the Kenya Solar Market

Solar electric systems were first used in Kenya in the late 1970's for government funded telecommunications projects. In the 1980s falling module prices combined with awareness and enthusiasm generated by the United Nations Conference on "New and Renewable Sources of Energy" held in Nairobi in 1981 led to an increase in the use of solar systems in Kenya and elsewhere in the region. During this period international donor organizations began to fund PV-powered projects for a range of applications including electricity for Christian mission compounds, health clinics, water pumps in arid areas, schools, and others [Musinga, *et al.*, 1997]. Several solar import companies set up shop in Nairobi to meet this new donor driven demand, but little thought was given to direct sales to rural Kenyans. The conventional wisdom at the time was that rural residents did not have enough money to buy solar PV systems [Hankins, 1992].

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[26] This is the retail cost of the electricity, but it does not reflect the true cost of delivering the power to rural Kenyans. The revenues from Kenya's rural electrification program cover less than 50% of the cost of maintaining the distribution lines [Okello, 2002]. This indicates that the true cost for rural electricity is likely on the order of $0.30 to $0.40 per kWh, and that substantial direct and cross subsidies are involved in supporting Kenya's rural electrification program.

[27] The range of costs depends on the size and complexity of the system as well as assumptions about the discount rate. These numbers are for a 20 year life cycle calculation.

In 1984, Harold Burris, an ex-Peace Corps volunteer from the US, set up a small business in a coffee growing region near Mt. Kenya.[28] Burris' was the first business in Kenya to sell solar PV systems from a shop outside of the capital city of Nairobi, and during the mid to late 1980s he sold hundreds of PV systems [Hankins, 2000b]. Burris' business and several others that began operating during this period[29] showed that it was possible to sell solar electric systems without donor aid by marketing directly to rural Kenyan families. These early specialist solar dealers demonstrated the advantages of regionally based sales and service, and their business success led other groups to begin selling solar equipment in rural areas.

Solar sales began to grow significantly in the later half of the 1980s. This growth was facilitated by declining solar module prices on the world market as well as the removal of a 30% import duty on solar modules by the Kenyan government in 1986 and the introduction of small, low cost amorphous silicon modules in 1989 [Musinga, et al., 1997]. During the 1990s rapid sales growth led to the emergence of solar electrification as a significant alternative to grid based electrification in Kenya. See Figure 5.

This narrative of the early development of solar electrification in Kenya indicates a division between two key market segments. The first segment, which emerged in the early 1980s, is driven by donor aid project sales as well as a few government sponsored projects. This "donor aid" segment currently accounts for about one-quarter of annual equipment sales in the market [ESDA, 2003]. The second segment is the solar home systems (SHS) market which developed in the late '80s and early '90s. The SHS segment of the market grew out of the supply chain infrastructure that was put into place in the early 1980s to serve the donor aid market. By 1990, Kenyan families accounted for 40% of all PV sales in Kenya, and they now (as of 2003) account for about three-quarters of sales [Hankins, 1992; ESDA, 2003]. This market evolution took place beginning in the mid-1980s and continued into the 1990s.

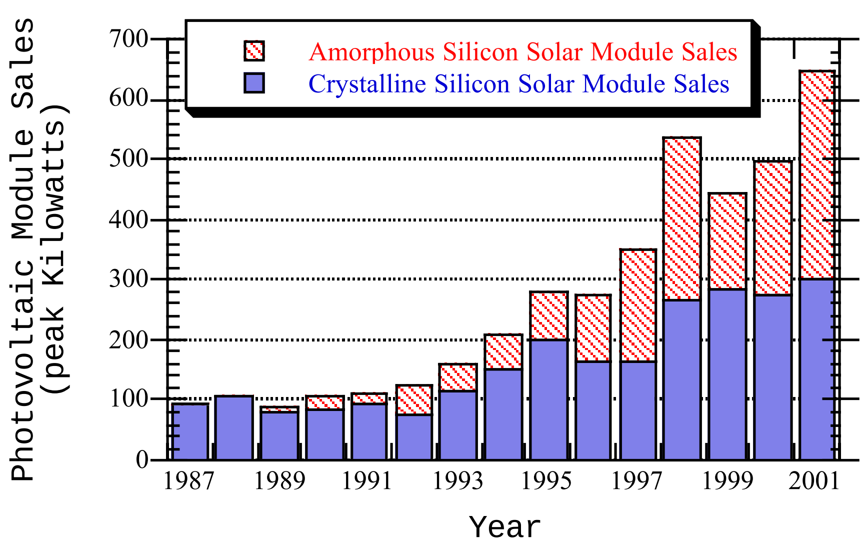

Figure 5: Solar Module Sales from 1987 to 2001
Data sources: Acker and Kammen, 1996; Hankins, 2000a; ESDA, 2003

[28] Burris had initially set up a solar business called "Kidogo Systems" in the town of Machakos in 1982. In 1984 he renamed the business "Solar Shamba" and moved it to the town of Embu in the coffee growing belt around Mt. Kenya. This move to a more lucrative market marked the beginning of successful cash market direct sales of solar PV systems to rural customers in Kenya [Hankins, 2000b; Kithokoi, 2000].

[29] These included Kiiru Electrical & Solar in Chuka town beginning in 1987, Solar Electrical Systems (Meru, 1987), Botto Solar (Nakuru, 1987), Kirinyaga Electricals (Kirinyaga, 1988), Hensolex (Gilgil, 1989), and others [Kithokoi, 2000].

Although the SHS market supply chain was dominated by small businesses that specialized in solar sales and service during its early years in the late 1980s, the rapid sales growth during the 1990s occurred in conjunction with an increased participation in the solar market by "non-specialist" businesses. These are businesses that sell solar equipment as one among many products, and they generally have no particular specialization or knowledge about solar electric systems. Typical among these businesses were general merchants, electronics shops, electrical hardware shops, vendors of automobile spare parts, and the like. These businesses began to include solar equipment in their shops beginning in the late 1980s and early 1990s, and they now dominate the retail side of the Kenya solar supply chain.[30]

Many of these "non-specialist" solar vendors did not offer installation or maintenance services for the systems, focusing exclusively on over the counter equipment sales. As a result, independent small town electricians began to market their electrical wiring skills to solar customers. These technicians - who generally had experience in electrical wiring for grid AC mains installations, but who often had no special experience or training in solar installations - quickly became the dominant group in the service sector of the solar supply chain.[31] This configuration of non-specialist vendors on the one hand and non-specialist technicians on the other essentially splits the solar supply chain between the sales and the service segments of the market, respectively. This split - along with a lack of specialized knowledge about solar among vendors and technicians - has had important, and mostly negative, repercussions for the quality and performance of solar systems in Kenya. At the same time, the active involvement of these players allowed the solar market to expand quickly through pre-existing supply chains. The resulting extensive presence of solar equipment and services in Kenya's regional towns has been associated with intense competition, downward pressure on prices, and increasing consumer awareness about solar electricity. Thus, non-specialist vendors and technicians played a critical enabling role in the rapid sales growth beginning in the 1990s. See Table 2 for 2001 market presence data for selected towns.

Table 2: Solar Vendors and Technicians in Selected Regional Towns of Kenya

Town Name	Province	Population (1999 census)	# solar vendor businesses	# solar technicians
Mombasa	Coast	665,016	10	> 25
Kisumu	Nyanza	332,734	18	> 50
Nakuru	Rift Valley	231,262	19	> 50
Meru	Eastern	126,427	12	> 50
Bungoma	Western	73,048	14	> 40
Kerugoya/Kutus	Central	35,595	13	> 40
Chuka	Eastern	7,271	5	> 20

Source: Jacobson, 2002

I have so far discussed five factors that contributed to the emergence of the Kenyan solar market. These include: a) falling equipment prices; b) the absence of a strong grid based electrification program; c) the existence of the solar supply chain that supplied the donor aid segment of the market; d) the actions of catalytic solar entrepreneurs; and e) the expansion of

[30] A 2000/01 survey of 312 solar vendors from 46 towns in Kenya indicated that 95% were non-specialists [Jacobson, 2002a]. This contrasts sharply with descriptions of the supply chain in the late 1980s [Hankins, 2000b].

[31] Survey data from 2000/01 indicate that 89% of 366 "solar" technicians interviewed consider AC mains electrical wiring or electronics repair to be their *main* source of income, while 9% stated that solar installations were their main income (2% reported other occupations). Additionally, only 6% of the technicians had attended a specialized training course for solar energy [Jacobson, 2002b].

the solar market through pre-existing non-specialist supply chains. Two additional factors played a central role in the emergence of the Kenya solar market and its subsequent growth into one of the largest per capita among developing countries.

First, the increased availability of television in rural Kenya during the 1980s, including expansion of the Kenya Broadcasting Corporation's (KBC) signal to rural areas by the Kenyan government, the introduction of 12 volt DC televisions by electronics importers, and a decrease in the retail price of televisions played an important role in the growth of demand for solar electric systems [Musinga, et al., 1997; Hankins, 2000a; Abdulla, 2001; Muriira, 2001; ESDA, 2003]. See Figure 6. Perhaps the main driver for demand in the Kenya solar market over the past 15 years has been securing electricity for television in rural homes. This is supported by previously mentioned survey data which show that over 90% of "solar" households own a TV, while smaller percentages (84% and 75%, respectively) use the power for lights and radios [van der Plas and Hankins, 1998]. Perhaps more importantly, most of those rural Kenyans who can afford solar electricity have chosen to buy a television that they power with a battery before they purchase lights or a solar module.[32] This highlights the high priority given to TV.

Many solar vendors recognize the critical importance of television as a driver for sales growth. An analysis of 391 advertisements for solar products in Kenya's leading daily newspaper (*The Daily Nation*) during 2002 and 2003 indicates that solar systems are four times more likely to be marketed as a means to power televisions than as a means to power lights.[33] See Figure 7 for sample advertisements featuring television.

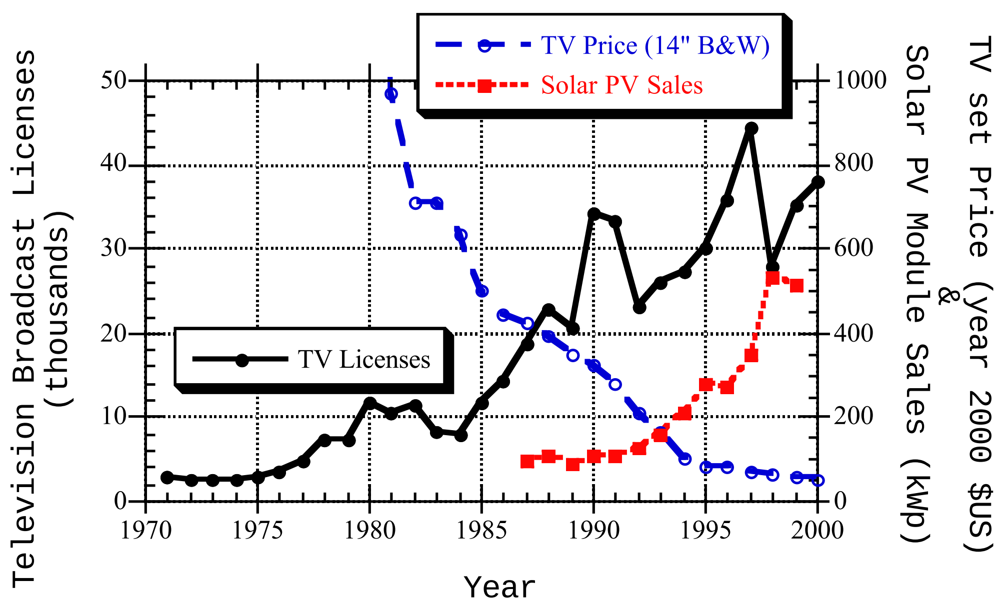

Figure 6: Growth of Television and Solar Panel Sales in Kenya, 1970-2000[34]
Sources: TV license source: Central Bureau of Statistics, Statistical Abstract, Republic of Kenya, various editions; TV price source: Manji (2001); PV sales source: Hankins, 2000a (for 1989-99 data); Acker and Kammen, 1996 (for 1987, 1988 data).

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[32]Data from my 2003 survey indicate that 61% of solar households bought a TV prior to buying lights, while only 4% bought lights first. The remaining 35% bought TV and lights at the same time.

[33] The newspaper advertisements were tracked on a daily basis, providing a systematic survey of all ads that appeared in print.

[34] I use television license data as a proxy for TV set sales. Licenses act as an excellent proxy up to the late 1990s, as all TV sets were sold with a KBC viewing license. In the late 1990s TV liberalization and black market sales of TV sets have reduced the accuracy of this proxy.

Figure 7: Newspaper Advertisements that Market Solar Electric Systems as a Means to Power Television Sets. Sources: Daily Nation (May 29, 2002 & June 4, 2002)

While a desire to secure electricity for television viewing may be an important motivator for demand, the purchasing power of the rural middle class provides the foundation of this opportunity, and, indeed, the engine for the growth of the solar market. The 2000 Tegemeo Project survey data indicate that about 80% of households using solar energy fall within the top one-third of rural Kenyans by wealth. See Figure 8.

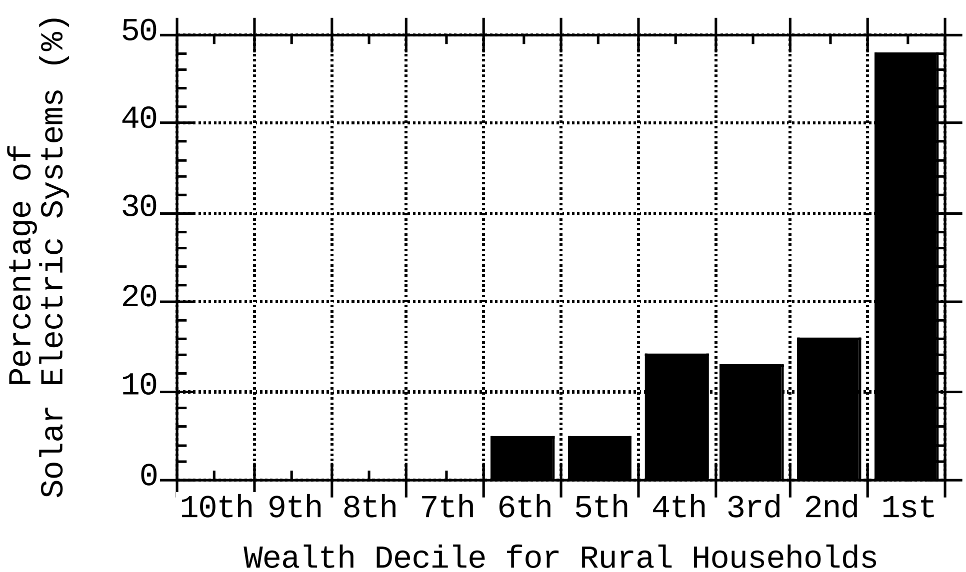

Figure 8: Distribution of Solar Module Ownership Among Rural Households in Kenya[35]
Data source: Tegemeo Project year 2000 rural household survey, n = 1,512 households.

The data in Figure 8 show that while most solar systems are owned by the top one-third wealthiest households - and indeed nearly 50% are owned by the top 10% - a few household

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[35] I estimated wealth deciles from the combined monetary value of key household assets and livestock owned by each household. The original questionnaire form with a list of household assets and livestock included in the survey can be found at http://www.aec.msu.edu/agecon/fs2/kenya/. The wealthiest rural Kenyans are in the 1st decile, the poorest are in the 10th.

near the median wealth level have begun to acquire solar systems. As I will argue in a subsequent paper, this modest deepening of access to solar electricity has occurred primarily through the sales of very small and inexpensive solar modules (e.g. 14 watt amorphous silicon solar modules).

Most solar system owners fall into what can be called a "rural middle class" not only in terms of their wealth, but also in terms of their occupations. Nearly 80% of the solar owning households in the Tegemeo survey reported a professional salary (e.g. school teacher or civil servant job) or small business profits as their first or second most important income source. Moreover, many of the "solar" households in the remaining 20% are among the relatively well off small holder farmers who rely on high value cash crops such as tea, coffee, and pyrethrum. Interestingly, rural school teachers make up a particularly large fraction of the market; households with a teacher accounting for approximately 30% of all solar electric systems. This indicates a strong connection between solar electrification and rural education, as teachers frequently use solar powered lights to mark papers and to plan lessons in the evening.

Through this brief historical analysis I identify seven key factors and processes that have been important for the emergence and development of the Kenya solar market. I show that solar electrification has been - to date - a largely "middle class" phenomenon in Kenya. I also introduce the important role that "connective" technologies - especially television - have played in the growth of the market. I will now present data and analysis on a selected set of social uses of solar electrification in Kenya in order to explore key aspects of the significance of the technology for development and social change in the context of rural Kenya.

3. Social Uses of Solar Energy in Rural Homes

I have already discussed the central - though not unitary - role that television has played as a driver for demand in the Kenya solar market. My work also indicates that the social significance of solar electrification is closely linked to television as well as two other "connective" technologies: cellular telephones and radios. These technologies are being used - especially by the rural middle class - to increase interconnectedness between rural Kenyans and people, markets, and ideas in national and international urban centers. Lighting related uses of solar electricity are also very important, but their significance has often been overstated in the literature in relation to the importance of the connective applications.

Although a comprehensive discussion of the social significance of solar electrification is beyond the scope of this paper, I will include preliminary results related to some of the most important uses. I will organize this section around brief discussions of three key themes related to the social use of solar energy in rural Kenyan households. These are (1) rural productivity and income generation, (2) rural education, (3) "connective" uses of solar electricity. In addition, I will present a short discussion about non-household uses of solar electricity in rural Kenya.

It is useful here to re-emphasize that solar electric systems are only one of several energy technologies that rural households use to support lighting and connectivity services. For each of the four common uses of solar electricity - lighting, television, radio, cell phone charging - there are other alternatives that are even more common that solar electric systems. For example, most rural households (90%) rely primarily on kerosene for lighting [Kamfor, 2002]. For those who can afford it, solar electricity allows for a transition to electric lights.[36]

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[36] Note that many households that use solar lighting continue to use kerosene as well. In other words, the transition is rarely a "clean break". This is consistent with the 'eclectic energy' hypothesis of Masera *et al.* (2000).

Likewise, while an estimated 69% of rural Kenyan households own a radio, in most cases (85%) these are powered by dry cell batteries [Kamfor, 2002]. The transition from dry cells to a car battery or a solar system (or the electrical grid) is significant in terms of the social use patterns, as the cost per hour to operate the radio drops substantially.[37] In many homes this transition results in a shift in radio use from a pattern of listening to specific programs that are of primary interest to the wage earner(s) who buys the dry cells to a pattern in which the radio is often on during the day whenever anyone is at home. Thus, while solar electricity does not "enable" the use of rural radio in any broad sense, its use is part of a dynamic that allows for important changes in radio listening patterns.

Solar electricity is perhaps more closely connected with enabling rural television, but battery based systems that do not include a solar module are used in even greater numbers to power TV sets.[38] Again, solar electrification generally allows for an expansion in the use of the television relative to the non-solar battery based systems. And while solar energy is used increasingly to charge cellular telephones, rural cell phone users have other options at their disposal.[39]

Thus, for most households solar electricity does not "enable" access to these services in any simple sense. Rather, for many the use of solar electricity represents an improvement in the quality or the quantity of the service relative to other household energy alternatives. And of course while solar electricity may be an improvement over kerosene for lighting, dry cells for radios, and automotive batteries for televisions, etc., the electrical grid - when it is available - is almost universally viewed as an improvement over solar electricity.

Before proceeding with a discussion of the social uses of solar electricity in rural homes, I will first discuss other (non-household) uses of solar electricity in Kenya. I use this discussion to emphasize the relative significance of household uses in the high population density rural areas of the country.

Non-Household Social Uses of Solar Electricity in Kenya

In addition to household electricity, solar power can be used for a number of other off-grid applications. Important uses include electricity for small businesses,[40] water pumping projects, health clinics, schools, churches, remote administrative offices (e.g. offices at refugee camps or in national parks), telecommunications towers, and others. In rural Kenya household systems are by far the most common, but many of the other applications are also present.

As I noted in the history section of this paper, about 25% of solar module sales are for the "donor aid" segment of the market, and most of the non-household applications fall into this category. The remaining 75% of solar sales are for the household market. However, there is an important geographical division between these two segments. Although the division is not absolute, a significant majority of the "donor aid" systems are installed in the low population density regions of Kenya[41] [Ndun'gu, 2003]. Meanwhile, the household market is largely

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[37] It is about 10 times more expensive to operate a radio on dry cells than with a solar electric system.

[38] Data from the 2000 Tegemeo survey indicate that approximately twice as many rural households power TVs with a battery alone than with a solar electric system.

[39] Data from my 2003 survey of 79 cell phone users indicated that for the most recent charge, 24% used solar electricity at home, 22% paid to have their phone charged at a grid connected shop (the typical cost was $0.25), 22% were able to charge using grid electricity at work, 11% used a battery-based system at home, 10% charged the phone at a friend's house using grid electricity, and the remainder used a variety of other strategies. These data indicate the wide range of charging strategies used by rural cell phone users.

[40] Retail shops, bars, and barber shops make up a large fraction of these solar energy using rural businesses.

[41] Many of these systems are installed by Christian missionary groups as well as international aid agencies working with refugee populations in the northern regions of Kenya.

concentrated in the areas of high population in the central and western parts of the country.[42] Therefore, the types of solar systems associated with donor aid projects - i.e. projects in schools, health clinics, water pumping, etc. - have to date played a relatively small role in the socio-economic development of the high population density areas.

Moreover, the use of solar electric systems by small businesses is modest in rural Kenya. A survey of recent installations by 366 solar technicians conducted in 2000-01[43] indicated that 94% of the installations were in homes, while only 2% were at dedicated business locations.[44] Schools, health clinics, churches, and water pumping systems each accounted for 1% of the solar installations in the survey. This further supports that claim that in the high population density areas of Kenya, the most significant social use of solar electricity is in the household.

Income Generation and Solar Home Systems

Income generation and productive uses of solar energy have received a lot of attention not so much because they are common, but because they can - if present - serve as a powerful justification for international donor support for solar electrification.[45] A literature survey of solar electrification in developing countries indicates that income related uses of household solar energy are present in some cases, but concludes that there is no evidence that solar electrification leads to widespread increases in income or productivity [Nieuwenhout, et al., 2000]. My research results from rural Kenya support the conclusion that income generating uses of solar lighting by rural households are - at best - modest. In a 2003 survey, 32% of "solar" households reported using lights for activities related to income generating activities. See Table 3. Rural school teachers - who grade papers and plan lessons in the evening - accounted for much of the productivity related uses of solar lighting. In addition, some farmers and small business owners reported using solar lighting for activities such as evening time accounting or planning. For most of these farmers and small business owners the contribution of solar electricity to the associated income related activities was relatively minor. Very few families reported using solar lighting directly for agricultural activities, although there were a few notable cases. One family had an egg business, and they used solar powered lights in the chick brooding room to provide 24 hour lighting.[46] Another used solar lights to distribute milk to customers in the evening several times a week. Distributing the milk at night allowed them and their customers to engage in other farming activities until later in the day. However, these innovative uses of solar lighting were the exception rather than the rule, and for most families productive activities were not the primary use of the solar energy.

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[42] The largest household solar markets are in the Mt. Kenya region, the central Rift Valley (i.e. Nakuru, Naivasha, Nyahururu, Eldoret, etc.), Western Kenya, and Nyanza.

[43] In the survey we asked each of the technicians a series of questions about his most recent solar installation job.

[44] One reason for the relatively low use rates for solar systems by rural businesses may be related to the geography of the rural electrical grid. According to data from the 2000 year Tegemeo survey, 71% of rural Kenyan households are within 5 km of the electrical grid, 86% are within 10 km, and 93% are within 20 km. A relatively small fraction of the rural Kenyan population lives in remote areas that are far from the electrical grid. This means that many businesses serving rural customers can locate in towns or market centers that have grid access while remaining relatively close their customer base. However, while the rural grid reaches most towns and many market centers, it generally does not extend across the countryside to reach rural households. As a result, sales in the solar market are dominated by household purchases by those rural families who are able to afford the systems. I thank Mark Hankins for this insight.

[45] See Kapadia [2004] for a detailed report on productive and income generating uses of renewable energy in developing countries.

[46]The family used charcoal braziers to heat the room, and solar lights to keep it lit. Chicks grow to maturity faster if the room is lit 24 hours per day, as they eat more under these conditions.

Some families also reported productivity related benefits from television and radio.[47] In nearly all cases these families said that they periodically received information that was valuable for farming or business related activities. Most of those farmers who reported information benefits cited educational programs (especially on the radio) or - less frequently - market price information. Several small business owners cited radio and television advertisements as a key source of information about products that they might want to carry in their shops. Nonetheless, most solar users reported no productivity related uses of television and radio, and these benefits, even when they are present, do not appear to be the main motivation for investing in the devices or the solar systems that power them.

Table 3: Income Related Uses of Solar Electricity in Rural Kenya

Appliance	% Reporting Income Uses (total)	% Reporting Farming Uses	% Reporting Business Uses	% Reporting Teacher Uses	% Reporting Other Salary Work Uses
Lights	**32%**[48]	12%	8%	16%	1%
Television	**23%**	8%	8%	5%	0%
Radio	**22%**	11%	7%	3%	1%

Source: original survey data, n = 76 “solar” households

Solar Electricity and Rural Education

I noted above that teachers are the single largest group reporting work related uses of household solar lighting. This activity, of course, does not increase their incomes (i.e. they do not get a salary raise as a result of the lighting), but it may help them do their work more effectively. This is one important connection between solar electricity and rural education. Another is evening time studying by students in homes that have solar power.

Solar lighting can play an important role in facilitating studying by children, as the quality of the light from electric lamps is generally *much* higher than light from kerosene lamps or candles. In many homes solar energy is used for studying, but education benefits are far from universal among "solar" households. Importantly, household energy allocation dynamics favor other uses in a significant fraction of homes.

Nearly 80% of the "solar" households in the 2003 survey had school age children, but solar lighting was used for studying in only 47% of these homes. In some cases (19%) this was because the system did not include lights.[49] In others (34%) electric lights were present, but the energy from the solar system was allocated to other uses.[50] These data indicate that while solar electricity provides the *potential* to facilitate children's education, household energy decision making dynamics - including choices about which appliances to buy (e.g. TV or lights) as well as choices about how to allocate the energy in systems that do include a light - play a central role in determining the actual outcomes.[51]

Solar electricity can also be used for activities that detract from children's education. For example, in the 2003 survey 40% of parents indicated that television was a major distraction

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[47] Cellular telephones are also used for economically productive activities. I will discuss these later in this paper.

[48] The number of families reporting productive uses of lighting is not equal to the sum of the various productive use types because some families reported more than one productive use.

[49] i.e. the household used solar electricity to power a television and/or a radio, but not lights. This was true in 22% of homes with school age children.

[50] In these homes, kerosene lanterns were reported to be the primary light used for studying. Electricity from the solar system was allocated to other applications, including television and other (non-studying) lighting uses.

[51] Solar system size (i.e. the Wattage of the solar module) can also play an important role in these processes. Children in households with larger systems appear to have greater access to solar lighting for studying than children in households with smaller systems.

from studying for their children, and an additional 18% said that TV was a minor distraction. The remaining 42% said that TV had no negative influence on their children's study habits.[52] It is not surprising that parent-child dynamics around education appear to play a strong role in determining the influence of TV viewing on children's study habits. Many of the parents who said TV had little influence on studying indicated that this was true only because they did not allow their children to watch television before they had finished their studies. Likewise, ethnographic observations in a limited number of households suggest that the rules around television viewing by children may have been more 'relaxed' in some of the homes where TV viewing was reported to be a larger distraction.

And of course, the relationship between television and education can have a positive dimension as well. Parents in 54% of the surveyed homes cited some educational benefits to television viewing, particularly in relation to news, nature, and technology related programs.

These discussions suggest a complicated relationship between solar electrification and children's education. They indicate the potential for the electricity to be used in a way that enhances children's education opportunities, but they also show that the possibilities for the benefits to be realized depend heavily on family dynamics around education and household energy allocation.

The Information-Energy Nexus: Connective Uses of Solar Electricity

The third category of social uses that I will discuss - "connective" uses - is a broad category that encompasses several end use technologies (i.e. televisions, radios, and cellular telephones) and which spans a number of different social activities. Although there are important differences between the various connective technologies, I discuss them together because in each case their social use is associated with important changes in socio-spatial relations of interconnection between rural and urban areas of Kenya and beyond.

Wireless communications technologies, powered by solar electricity as well as dry cells, automotive batteries, etc., are being used to connect the countryside with urban centers in a number of critically important ways. An increasing number of rural Kenyans get national and international news through radio and television broadcasts. Many can now call their urban relatives or business clients using cell phones. Their radios deliver the latest music hits from the United States, Europe, and other countries on the African continent as well as from Nairobi's growing pop music scene. They watch TV shows ranging from foreign programs such as the hugely popular "Smackdown Wrestling" and "The Bold and the Beautiful" to Kenyan productions including "Vipindi" and "Vioja Mahakama". And of course, increased rural television and radio use helps business advertisers such as Coca-cola, Unilever, and Colgate-Palmolive to expand and deepen consumer goods markets in small towns and rural areas.

Solar electrification is linked to these processes of rural-urban connectivity, as it is one of the key power sources facilitating the use of wireless broadcast and communications technologies in rural Kenya. Continued sales growth in the Kenya solar market will almost certainly be associated with enabling expanded access to and use of wireless broadcast and communications technologies.

A significant fraction of the energy used in household solar systems is allocated to connective applications. In households with small solar systems (e.g. systems with a 14 Watt solar module) "connective" uses often account for 50-100% of the total energy budget,[53] with

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[52] There may be, of course, a bias in these data, as some parents may have understated the influence of television viewing on their children's study habits.

[53] Households in which 100% of the energy is allocated to connective uses are those that do not include lights. Note that television accounts for the large majority of the energy in the "connective" use category.

lighting accounting for the balance of the energy. In larger systems (e.g. 30-40 Watts) the actual *amount* of energy used for connective applications generally goes up relative to the smaller systems, but the *fraction* of the total energy allocated to connective uses goes down to the 30-50% range (again, with the balance being allocated to lighting).[54] This further supports the idea that many families prioritize connective uses over lighting uses, as it suggests that when energy is in short supply (i.e. in small systems) much of it is allocated towards powering TVs, radios, and cell phones. As more energy becomes available (i.e. in larger systems) the demand for connective uses begins to level off and a greater fraction is allocated to lighting related uses.[55]

Of course, the social significance of connective uses cannot be judged based on household energy allocation patterns alone. Much more important is a discussion that situates their use in the broader context of Kenyan society. While a full analysis of the implications of solar electrification and its connection to technology mediated connectivity is beyond the scope of this paper, I will briefly present observations and results from my research that highlight some important aspects of rural-urban connectivity.

First, rural-urban connectivity in Kenya is remains highly uneven, with some people - especially the rural elite and middle class - having greater access to connective technologies than the rural poor.[56] Lower prices for the communications devices - especially radios - as well as for solar equipment and automotive batteries have resulted in varying degrees of expanding access, but substantial differences between rich and poor remain. Thus, while it is common to think of increased rural-urban connectivity in terms of a "shrinking of space" between rural and urban areas, this conception is misleading as it suggests that distance between the country in the city is somehow reduced for everyone. Rather, connectivity might be conceived as a "stretching" of *certain* social relations over space. Certain connections between certain people, markets, and ideas are facilitated, but other connections do not get made [Massey, 1994; Cooper, 2001; Hart, 2002]. This means that the benefits of increased connectivity are reserved primarily for those people and groups who have the greatest levels of access to the technologies or who are otherwise well positioned to take advantage of their presence.

Some forms of connectivity are also highly political and hotly contested. For example, during the '70s and '80s, the then ruling KANU party invested heavily in expanding its state monopoly in television and radio broadcasting into rural areas [Jacobson, 2004]. This network, which by the mid-1990s reached nearly every corner of Kenya, gave the ruling party immense control over news and information in the country. This was especially true in rural areas, where access to print media and other forms of news were more limited. In a country where 75% of the population and a similar fraction of the voters live in rural areas, monopoly

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54 For example, a small 14 Watt system can generate about 50 Watt-hours per day (with variations depending on geographical location and seasonal weather patterns). If 30 Watt-hours of this energy are allocated TV, radio, and cell phone charging each day, then these "connective uses" will account for 60% of the total energy. In this example lights account for the remaining 20 Watt-hours per day. A 40 Watt system in a similar location can generate about 150 Watt-hours per day. It is common for a family with one of these larger systems to allocate somewhat more energy to connective uses than their counterparts with small systems. For example, this family might allocate 50 Watt-hours per day for connective uses, and the remaining 100 Watt-hours per day to lighting uses. In this home the "connective uses" would therefore account for 33% of the total energy. In other words, the amount of *energy* allocated to connective uses would increase in the family with the larger solar system, but this energy would represent a smaller fraction of the total energy generated by the system. This example is based on typical of patterns of energy allocation in small and larger systems as observed in *preliminary* results for the data set described in footnote 55. I will present a more complete account of these results in my forthcoming dissertation.

55 These data are based on preliminary results from a detailed study of energy allocation in 15 "solar" households conducted in 2003 in Kenya. The households in the sample include a range of system sizes and demographic characteristics that is roughly proportional to the distribution of sizes and characteristics from my 2003 survey of 76 "solar" homes as well as other larger studies.

56 These patterns of access are, of course, consistent with expectations for access in unsubsidized markets.

control over broadcast media gives huge advantages to those who run the television and radio networks. However, the broadcasts to rural areas would be largely wasted in the absence of electricity to power the televisions and radios in people's homes. Given the slow pace of grid electricity in rural Kenya, solar systems, automotive batteries, and dry cells provide critical elements of a rural electricity "infrastructure" to power these devices.

Kenyan broadcast politics in the 1990s were characterized by a bitter struggle over broadcast media liberalization, as ruling party strategies to maintain monopoly control over television and radio slowly gave way to increasing coverage by private broadcasters. This liberalization began first in urban areas; rural areas were the last stronghold of KANU's broadcast media monopoly. Private broadcasters were only very recently able to begin to expand beyond Nairobi into Kenya's regional towns and the countryside. This decade long shift from state controlled to semi-pluralistic private broadcast media in combination with rural use of solar and battery powered television and radio sets has important implications for politics - including during recent elections in which the ruling party lost power for the first time since independence - as the news and information available to those rural Kenyans with broadcast media access has diversified considerably [Jacobson, 2004]. This brief discussion highlights the highly political nature of certain types of rural-urban connectivity, and the shifts that can occur over time through context specific historical struggles. It also shows how the social significance of technologies like solar electric systems can be linked in small but meaningful ways to highly important socio-political processes on a national scale.

The process of broadcast media liberalization combined with the growing use of solar and battery powered televisions and radios in rural Kenya is important not only in the context of Kenyan politics, but also for the expansion and growth of consumer goods markets in small towns and rural areas. Business advertisers in Kenya depend heavily - though certainly not exclusively - on radio and television to market their products. Radio is especially important for reaching rural consumers,[57] and the importance of television is growing rapidly as its use expands[58] [Miriti, 2003; Waruhiu, 2003; Waititu & Mwanzia, 2003].

Advertising money has played an important role in supporting radio and television broadcasting for decades, as the government's radio and television operations through the Kenya Broadcasting Corporation (KBC) have long relied heavily on ad sales. Thus, business advertisers have been able to reach most parts of Kenya with radio and TV commercials for nearly two decades. The recent broadcast media liberalization is highly beneficial for these advertisers, as an increase in the number of private broadcasters has resulted in an expansion in the number of stations, heightened public interest in radio and television, and lower advertising rates through competition[59] [Miriti, 2003; Waruhiu, 2003]. Large international corporate advertisers appear to be the main beneficiary of these changes in the advertising scene. Companies such as Unilever (consumer products), Coca-Cola (beverages),

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[57] While most rural users power their radios using dry cells, radios that are powered by solar electricity or battery systems are often used for more hours each day. This is good for advertisers, as the effectiveness of an "ad" is directly linked to the number of times a person hears (or sees) it [Miriti, 2003]. See also p.15 for more details on this topic.

[58] A 2002 media survey by Steadman Research Services indicated that 27% of rural households owned a TV set in 2002, compared to 19% in 1998. These data indicate 8% annual growth in rural TV ownership. The same survey reported that 57% of rural Kenyan adults (15+ years old) watched at least some television on a daily basis, up from 22% in 1998. These data suggest that many rural Kenyans watch TV either at the house of a neighbor or at a commercial establishment (e.g. a bar or restaurant). The sample size for rural residents was 1,278 in 1998 and 1,020 in 2002 [Research International and Steadman Research Services, 2002]. Similar data from the 2000 Tegemeo survey indicates that the large majority of these rural TV sets are powered by solar and battery based systems.

[59] The changes have been especially notable in radio broadcasting, which has seen a proliferation of private FM stations including many that have a distinctly regional focus. This latter point is of particular interest to advertisers, as the regional focus allows them to target their ads more effectively to regional or ethnic sensibilities [Miriti, 2003].

Glaxosmithkline (pharmaceuticals), and Colgate-Palmolive (consumer products) account for a substantial fraction of television and radio advertising in Kenya.[60]

Radio and television are centrally important to business advertisers seeking to expand and develop markets for their products. Solar and battery based electricity, combined with dry cells in the case of radios, provide the main source of power for these devices in rural areas. This configuration links solar electrification with processes through which many rural Kenyans are becoming more integrated into world consumer goods markets.

While televisions and radios have been used by rural Kenyans for decades, cellular telephones are a relatively recent addition. Although cellular telephone networks only began to expand significantly into rural areas starting in late 2001, already they are widely used among the wealthy and middle class segments of rural Kenya.[61] Solar electricity is one key way to keep a cell phone charged in rural areas (see footnote 39). Electronics shops and solar dealers are beginning to recognize the importance of this new application; from July to December of 2003 nearly 20% of all advertisements for solar equipment in Kenya's leading daily newspaper featured cellular telephone charging as a key application.

Cellular telephones in rural Kenya are used primarily to make long distance rural to urban calls. My 2003 survey of 79 rural cell phone users[62] indicated that 81% of recent calls were long distance rural to urban calls, while the remainder were local "rural to rural" calls.[63] These data further indicate that over half (55%) of the rural-urban calls were between family members. This highlights the important link between rural cell phone use and long distance communication among extended families that are stretched across rural and urban spaces due to long term rural to urban migration patterns.

Cell phones are also very important for certain types of rural or small town businesses. Many shopkeepers, auto mechanics, electricians, veterinarians, and other similar professions have come to depend on mobile telephones to place orders, make business deals, or to be in contact with their clients. In my survey, 35% of the recent calls were explicitly related to business activity of some sort. It may be of note that relatively few calls in the survey were related to farm business. However, further research is needed to explore the linkage between farm activities and the growing use of rural cellular telephones.

I will present a more detailed analysis of the significance of cellular telephone use and its connection to solar electrification in a subsequent article, but these preliminary results indicate that rural cell phone use plays an important role in facilitating long distance family communication as well as business activity among certain segments of the rural economy.

This preliminary exploration of the linkages between solar electrification and the social uses of "connective" technologies indicates several different ways that rural Kenyans - and especially the rural middle class - are using technology to increase their degrees of connection to people, markets, and ideas in urban centers in Kenya and beyond. Importantly, the possibilities for and the significance of these connections are linked not only to the dynamics of technology access, but also on broader political and social processes such as the

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[60] For example, data for television advertisements shown during the prime time evening hours (7 pm to 9 pm) on two of Kenya's leading stations (KBC - government, NationTV - private) over 13 days in 2002 indicated that 58% of the advertisements were for products made by large international corporations. Products from five corporations (Unilever, Beta Healthcare, Glaxosmithkline, Colgate-Palmolive, and Coca-Cola) accounted for 44% (KBC) and 42% (NationTV) of the observed advertisements on the respective TV stations. There were a total of 206 advertisements in the sample.

[61] For example, as I mention above (p. 6), 50% of the "solar" households in my 2003 survey had a cell phone.

[62] Note that this survey is separate from and in addition to the survey of 76 "solar" households conducted in 2003. The cell phone user survey sampling framework was largely independent of the solar household survey, although there is some limited overlap between the groups as they were conducted in the same regions.

[63] I asked each cell phone user about the most recent call that she or he made as well as the most recent call received. The data reported in this section are the combined results for these two sets of calls.

politics of broadcast media control as well as rural-urban migration and the resulting extended family configurations.

Conclusion

Solar electrification emerged during the 1990s as one of the key alternatives to grid based household rural electrification in Kenya. Rapid growth in solar sales for household use can be linked to a number of processes and factors, including the slow pace of grid electrification, falling prices for solar equipment, pre-existing supply chains, rural middle class purchasing power, and the expanded use of television in rural areas. Importantly, although the technology remains out of reach for the large mass of rural poor, solar access has expanded beyond the rural elite to the "rural middle class".

Solar electric systems are only one of several small-scale decentralized technologies used for electricity in rural areas. Dry cell batteries and automotive batteries play a particularly important role in delivering rural power for radios, flashlights, televisions, and cell phones. Kerosene lanterns, while not electric, fit into this schema as an important source of lighting in many homes. And of course generators and grid electricity are important sources of energy for many households. The growing use of solar electricity must be understood as one element in this array of rural energy technologies.

Solar electricity is used increasingly by the "rural middle class" for household lighting, televisions, radios, and cellular telephone charging. Although solar electric systems are often touted as having important income generating potential, my results from Kenya suggest that with two exceptions, the use of solar electricity makes only modest contributions to income generation or salaried work related activities. Cellular telephone charging is one of the uses of solar electricity that has important implications for rural productivity, although it must be recognized that solar electricity is only one method for charging the phones. A second important productive use of solar electricity is in the area of education, where many rural school teachers grade papers and plan lessons using solar lighting. Many rural schoolchildren also use solar lighting to study during the evening hours, although in perhaps half of all "solar" homes household energy allocation dynamics limit the possibilities for this type of use.

In addition to lighting uses, solar electricity is widely used for "connective" applications that facilitate greater interconnection between rural people and ideas, markets, and people in national and international urban centers. Technology mediated connectivity links solar electrification to several important societal processes, including the politics of news, information, and media broadcasting, the expansion and growth of consumer goods markets in rural areas, and extend family configurations related to processes of rural-urban migration.

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