

Connective Power: Solar Electrification and Social Change in Kenya

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Summary. — Market-based rural electrification with solar energy is increasingly common in developing countries. This article revolves around three main claims about solar electrification in Kenya's unsubsidized market: (1) The benefits of solar electrification are captured primarily by the rural middle class. (2) Solar electricity plays a modest role in supporting economically productive and education-related activities, but "connective" applications such as television, radio, and cellular telephone charging often receive a higher priority. (3) Solar electrification is more closely tied to increased television use, the expansion of markets, more rural–urban communication, and other processes that increase rural–urban connectivity than to poverty alleviation, sustainable development, or the appropriate technology movement.

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1. INTRODUCTION

Solar electrification has emerged as a leading alternative to grid-based rural electrification in many developing countries. This may seem like a victory for appropriate technology advocates, but my research in Kenya indicates that solar electrification is, at best, only loosely linked to Schumacher's classic "small is beautiful" vision of building small scale, locally self-reliant alternatives to global capitalism (1973). Instead, the social uses of solar electricity in Kenya are more closely tied to increased rural TV use, expansion of consumer goods markets, more rural–urban communication, and other processes that increase social and economic interconnection between rural people and their counterparts in national and international urban centers.

These interconnections are facilitated when rural Kenyans, in most cases from the rural middle class, use solar electricity to power "connective" appliances, including televisions, radios, and cellular telephones. Connective applications are especially prevalent in households with the small solar photovoltaic (PV) systems (<25 W) that are most common in unsubsidized solar markets like the one in Kenya. Thus, while solar PV is commonly framed

as an element in efforts to promote sustainable development through the delivery of *lighting* services to unelectrified areas, evidence from Kenya indicates that the development implications of solar electrification are closely linked

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to its role in enabling the use of “connective” devices. This article provides an assessment of the social significance of rural electrification with solar energy. Kenya, which has one of the largest per capita markets for solar PV technology among developing countries, provides an excellent setting for this analysis.

2. SOLAR PV AND DISCOURSES OF DECENTRALIZED DEVELOPMENT

International donor support for rural electrification with solar energy began in the late 1970s, and grew especially rapidly in the years following the 1992 UN Conference on Environment and Development (UNCED) held in Rio de Janeiro, Brazil. Since then, the Global Environment Facility (GEF) and the World Bank together have leveraged over \$2 billion in support of solar electrification (*International Resources Group, 2003*). In recent years, the fraction of GEF and World Bank funding for renewable energy projects that has been allocated to solar PV has become so large that the advocates of other renewable energy technologies have started to complain¹ (e.g., *Inversion, 1996; Karekezi & Kithyoma, 2002; Villavicencio, 2002*). The enthusiasm for solar electrification is not, of course, limited to mainstream institutions like the World Bank and the GEF. Environmental groups such as Greenpeace, the World Watch Institute, and many others are also strong advocates (e.g., *Dunn, 2000; Greenpeace, 2001*).

The increase in donor support for solar electrification is widely associated with concerns about the environment—and especially global climate change—as well as rural poverty in developing countries. However, a growing number of analyses indicate that the carbon mitigation potential of rural electrification with solar PV in developing countries is expensive compared to alternative mitigation approaches (*Jacobson, 2004; Kammen & Pacca, 2004; Kaufmann, 2000; Villavicencio, 2002*). Many solar policy makers and advocates acknowledge this, and draw on neopopulist² “basic needs” style arguments about poverty alleviation and rural development to justify international support for solar electrification³ (e.g., *Greenpeace, 2001; Kaufmann, 2000; Ybema, Cloin, Nieuwenhout, Hunt, & Kaufman, 2000*). Singh and his colleagues at the Renewable Energy Policy Project (REPP), a Washington, DC-based policy research group, captured this perspective succinctly in regard to household solar electrification:

Installing a solar home system (SHS) in a developing country is not the cheapest way to reduce carbon emissions today. And yet people frequently mention SHS as an important tool in the global effort to combat climate change. Should people think of solar as a prime climate change mitigation strategy? You would say “no” if you are solely concerned about keeping the cost per ton of greenhouse gas (GHG) emissions as low as possible... You would say “yes” if you are concerned with pollution control as well as alleviating the inordinate amount of poverty in rural regions. The “co-benefits” to climate change mitigation, . . . , are too great . . . SHSs can play a role in promoting economic and social development in the developing world while protecting the environment (*Singh, Campbell, Roberts, & Serchuk, 2000*).

While concerns about the environment and rural development are central to discourses about the need for solar electrification, market-oriented approaches have emerged as the primary vehicle for disseminating solar PV systems in developing countries. The single largest trend in international solar policy circles over the past decade has been to shift solar dissemination strategies from heavily subsidized donor projects to private market-based approaches that seek to achieve—or at least move toward—“full cost recovery” (*Covell & Hansen, 1995; Martinot, Chaurey, Lew, Moreira, & Wamukonya, 2002; van der Plas & Hankins, 1998*).

Solar photovoltaic technology emerged as an important tool for rural electrification at a time when neo-liberal policies dominated mainstream development thinking. In the late 1980s and 1990s, a period that some have called the age of “market triumphalism” (*Peet & Watts, 1993*), mainstream development policies emphasized economic liberalization, privatization, and market-based approaches to service provision (*Kapur, Lewis, & Webb, 1997*). In the energy sector, donor financing for state-owned electricity infrastructure was reduced, while efforts to support liberalization, reforms, and private sector participation expanded. In this context, public support for grid-based rural electrification was sharply curtailed in many countries (*Dubash, 2003; Karekezi, Kimani, Mutiga, & Ameyya, 2004*). Thus, market-based solar electrification grew at a time when publicly financed rural electrification schemes were in decline.

Solar PV, a small-scale technology that can be used to provide decentralized electrical service to individual homes or businesses, is particularly compatible with market-based distribution. This

is especially true in comparison to the more traditional grid-based electrification, which has historically been implemented through centralized programs under the control of national governments or regulated utility companies (Dubash, 2003). Given the timing of its emergence and its market compatibility, the growing trend toward market-based dissemination of solar PV technology is unsurprising.

On the surface, the simultaneous use of “small is beautiful” style neo-populist and market-oriented neo-liberal arguments in support of solar electrification may seem like a happy confluence between the appropriate technology movement and neo-liberalism around decentralized development and the environment. However, while market-oriented visions of development have long included neo-populist elements, there are key contradictions between the classic “small is beautiful” neo-populist vision of increased local self-reliance and the development of small-scale alternatives to world capitalism, on the one hand, and the emphasis in mainstream neo-liberal thinking on the benefits of market-based service provision and the expansion of global capitalist markets, on the other.

The work presented here indicates that while solar electrification is frequently framed using neo-populist style arguments, the policies, practices, and social outcomes associated with solar PV in Kenya are more closely associated with the neo-liberal idea that poverty alleviation is best achieved through the integration of poor people into world economic markets. This fusion between neo-liberal economics and neo-populist expressions of concern for the poor is in direct lineage with the version of basic needs neo-populism promoted by the World Bank under McNamara in the 1970s (McNamara, 1973; Wood, 1986), and it is closely associated with contemporary claims by thinkers such as de Soto (2000) and Prahalad and Hart (2002) about the development benefits of globalization and the construction of an “inclusive capitalism.”

This does not mean, of course, that solar PV is merely a “neo-liberal technology,” as the social uses of the electricity are not pre-determined or controlled by any one group. Instead, like all technologies, its significance is shaped through social actions in multiple, overlapping arenas (Hart, 2002; Jacobson, 2004; Williams, 1974). This article includes an analysis of several key processes that have influenced the direction of solar electrification in Kenya, including previously under-explored linkages between solar

electrification and processes of middle class formation, broadcast media politics, and intra-household energy allocation dynamics.

3. SOLAR ELECTRIFICATION IN KENYA

Kenya has emerged as one of the global leaders, per capita, in the use of renewable energy technology. This is due largely to a growing market for solar PV systems among rural households, with cumulative sales since the mid-1980s in excess of 200,000 PV systems, and current annual sales topping 25,000 units (ESDA, 2003; Jacobson, 2004). Data from a year 2000 survey conducted by the Tegemeo Institute indicated that 4.2% of rural Kenyan households owned a solar system. The same survey found that 4.3% of rural households were connected to the national electrical grid, and other sources indicate that solar sales are growing faster than the rate of new rural grid connections (ESDA, 2003; Jacobson, 2004). In other words, solar electricity has emerged in Kenya as a key alternative to grid-based rural electrification.

The Kenya solar market is also notable, and in fact has served as a model in energy and development policy circles, because it developed with a minimal direct government support and only very moderate inputs from international donor aid groups. Solar sales in Kenya have long been (and continue to be) driven largely by unsubsidized over-the-counter cash purchases of household solar systems⁴ (Acker & Kammen, 1996; Hankins, 2000; Hankins & Bess, 1994; van der Plas & Hankins, 1998). This makes Kenya an important example of a growing international trend toward market-based approaches to rural energy service delivery.

While there is little doubt about the size and rapid growth of the Kenya solar market, there is an ongoing debate about how to interpret its significance. Solar advocates commonly make claims about the environmental, rural productivity, and poverty alleviation benefits of solar PV (e.g., Greenpeace, 2001; Kaufmann, 2000; Martinot *et al.*, 2002). Some skeptics challenge these claims, contending that the environmental benefits of solar electrification are minimal, economically 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 (e.g., Inversion, 1996; Karekezi & Kithyoma, 2002; Leach, 2001; Villavicencio, 2002).

The work in this article contributes to and moves beyond these debates. More specifically, evidence from Kenya indicates that:

- (1) The demand for solar PV systems in the Kenya market is driven by middle class purchasing power. That is, solar electricity use is neither confined to the rural elite, nor is it widely available to the “rural poor.” Rather, solar PV ownership is dominated by a rural middle class made up of small business owners, rural professionals such as school teachers, civil servants, and pastors, as well as the better off among the small holder cash cropping farmers.
- (2) Electric light from solar PV systems plays a minor role in supporting income generation activities in rural Kenya. Given the distribution of ownership of solar systems, nearly all of these productivity gains are captured by rural middle class families. As a result, the use of solar electricity appears to contribute—albeit in a very small way—to processes of differentiation and middle class formation.
- (3) Solar PV plays a more substantial role in supporting the use of electric light for key social activities such as evening time studying by children. However, in many families intra-household dynamics constrain these sorts of lighting-related uses, as the small amounts of energy available from PV systems are allocated to other applications such as TV viewing.
- (4) 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. The significance of solar electrification in Kenya, therefore, is closely linked to the role that it plays in supporting rural–urban connections for Kenya’s rural middle class.

Each of these findings merits additional discussion, which is provided in subsequent sections of this article. First, though, a brief discussion of the methods and evidence that were used to reach these conclusions is in order.

(a) *Methods and evidence*

In much of the literature, an emphasis on the household as the primary unit of analysis and a focus on lighting-related social uses have led to an overly narrow—and at times technologically

deterministic—view of the social significance of solar PV in places like Kenya. In order to avoid these problems, my goal was to go both “inside” and “beyond” the household to deepen understandings of the critical linkages between solar electrification and broader socio-historical and socio-spatial processes. In constructing a methodological approach, I sought to include insights about the limits and capabilities of solar technology, the distribution of access to solar PV in rural Kenya, and the intra-household dynamics that shape the allocation of solar electricity within homes. These elements, along with a concerted effort to situate solar electrification in the context of Kenyan society, provided the foundation for my analysis.

The corresponding work is based on a combination of original field research, interviews with key actors, archival research, secondary survey data, and existing literature on solar electrification in Kenya. I conducted original field research on a number of trips to Kenya over a period of five years from 1999 to 2004, with the majority of the work related to this article occurring in 2002–03. The work included key actor interviews, four different original surveys related to solar electrification, detailed observations of solar electricity use in 15 households complimented by electronic data monitoring of appliance use in these same homes, archival research from Kenyan newspapers and other sources, and media research on advertising in television and radio broadcasts. The survey and data monitoring activities were team efforts, with important supporting contributions coming from Maina Mumbi and Henry Watitwa of Kenya, as well as Shannon Graham and Rebecca Ghanadan of the University of California at Berkeley.⁵ The results presented here are also based on several key secondary sources, including two large cross-sectional surveys of rural Kenyan households. The first was conducted in 2000 by the Tegemeo Project for agricultural economic policy analysis ($n = 1,512$),⁶ and the second was commissioned by Kenya’s Ministry of Energy and conducted by Kamfor, Ltd., a Kenya based consulting firm, in 2001 ($n = 1,755$).⁷ This diverse array of evidence provided the foundation for a wide ranging analysis of the social significance of solar electrification in Kenya.

(b) *Solar electrification, battery-based systems, and television in rural Kenya*

A typical solar electric system in Kenya consists of a solar PV module (which converts solar

energy into electricity), a battery (which stores the electricity collected during the day for use at night), and electric loads.⁸ The average solar module size for a household system in Kenya is approximately 25 W, and the most common size is 14 W. Televisions, radios, and lights are the three main electrical appliances used with solar PV systems, while cellular telephone charging is a rapidly emerging use. Many appliances that are often used around the world in grid-connected homes, such as refrigerators, electric irons, and electric cookers, are generally not used with solar PV in Kenya. This is true because these appliances consume far more energy than the small solar modules that most Kenyan users can afford are able to produce. In other words, the quantity of electrical energy supplied by the solar PV systems used in Kenya is very small compared to the quantities that are generally available to grid-connected households,⁹ and this limits the range of possible uses.

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.¹⁰ 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. In a rural context, this means carrying the battery the distance to the charging station by foot, bicycle, car, or bus. This effort is both costly and time consuming.

The relationship between battery-based systems and solar PV has played an important role in the development of the Kenya solar market (Hankins, 2004). 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 TV and perhaps a radio, and it is carried to town every 7–10 days where people pay about \$0.50 for a charge. After some time (e.g., a year or more), many rural households then purchase a small solar module in order to avoid the time and expense of charging the battery at a shop.¹¹ Other system components may also be added over time. In this way, rural Kenyan households build their systems over several years through purchases of as little as \$50–100 at a time.

The priorities households reveal as they make their incremental purchases highlight the important role of television for stimulating

solar sales. A central driver for demand in the Kenya solar market over the past 15 years has been a desire to secure electricity for television in rural homes. This conclusion is supported by an extensive evidence, including the historical relationship between the growth of rural television use and the emergence of the solar market in Kenya (see Figure 1). In addition, survey data from 1997 as well as 2003 indicate that 90–95% of households that own a solar system also own a television, while smaller percentages use the power for lights and radios (84% and 75%, respectively, in the 1997 survey; Hankins, Omondi, & Scherpenzeel, 1997; Jacobson, 2004). Importantly, most rural Kenyans who can afford a solar PV system choose to buy a TV set before they purchase lights. This is particularly true among those who start with a battery system and then later purchase a solar PV module.¹² Finally, solar vendors generally recognize 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 2002–03 indicates that solar systems are four times more likely to be marketed as a means to power television than as a means to power lights.¹³ Figure 2 shows solar advertisements from Kenya featuring linkages to TV. All of these findings indicate the high priority given to television by the rural Kenyans who use solar PV as well as the vendors who sell the systems.

Although the evidence for linkages between rural TV use and solar sales is strong, this connection is under-acknowledged in the literature. Nonetheless, studies from China, Thailand, Sri Lanka, and Zimbabwe suggest similarly strong relationships between solar electrification and TV use (Greacen, 2004; Hammami *et al.*, 1998; Kapadia, 2004b; Nieuwenhout *et al.*, 2000). In other words, when it comes to the “TV–PV” linkage, Kenya is not an isolated case.

Regardless of the country, however, desire for TV is not sufficient to drive solar sales. In Kenya, it is the purchasing power of the rural middle class that has provided the engine for the growth of the solar market. The sections that follow focus on the relationship between solar electrification and rural middle class formation in Kenya.

(c) *Solar electricity and the rural middle class*

Solar advocates frequently note that solar power is a key technology for delivering elec-

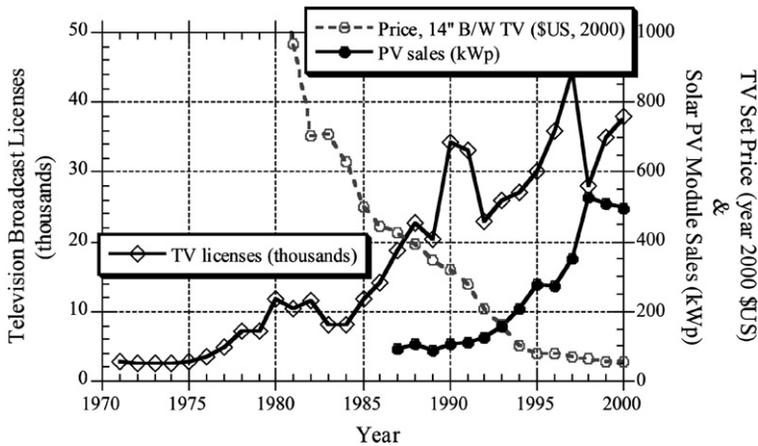


Figure 1. Growth of television and solar panel sales in Kenya, 1970–2000. (Note: Television license data are used as a proxy for TV set sales. Licenses act as a good proxy until the late 1990s, as all sets were sold with a KBC viewing license. In the late 1990s, TV liberalization and black market sales of TV sets have reduced the accuracy of this proxy.) Sources: TV licenses: Central Bureau of Statistics, various years from 1970–2003; TV prices: Manji (2001); PV sales: Hankins and Bess (1994) and ESDA (2003).



Figure 2. Newspaper advertisements that market solar electric systems as a means to power television sets. Source: Daily Nation newspaper, Nairobi, Kenya (May 29, 2002 and June 4, 2002).

tricity to the two billion people worldwide who lack access to modern energy (e.g., Greenpeace, 2001; Kaufmann, 2000; Martinot *et al.*, 2002; Prahalad & Hart, 2002; Ybema *et al.*, 2000). The implication is often that these two billion are among the world’s poorest, and that efforts to support solar electrification therefore qualify automatically as a form of poverty alleviation.

As noted above, many of solar electrification’s critics challenge this characterization, contending that only the rural elite can afford to buy a solar PV system.

Evidence from Kenya indicates that market-based solar electrification is neither confined to the rural elite alone, nor is it available to the large majority of “rural poor.” Instead, as

shown in Figure 3, most solar systems are owned by the top one-third of rural Kenyans by wealth. In Kenya, many households in this top one-third can be characterized as belonging to the rural middle class. Complimentary data presented in Figure 4 indicate that most families that own solar systems have annual household incomes that are well above US\$ 2,000 per year, while households below the median wealth level have incomes ranging from US\$ 660 to 1,300 per annum. Thus, while solar PV system owning households may not be wealthy

by OECD country standards, the majority are substantially better off than most of their rural neighbors. These results confirm that unsubsidized, market-based approaches to rural service provision may deliver solar electricity to wealthier households while bypassing their lower income neighbors. In addition, they also challenge the characterization of unelectrified populations as a large and relatively undifferentiated mass of rural poor. These findings therefore open the door to a more complete understanding of the social significance of mar-

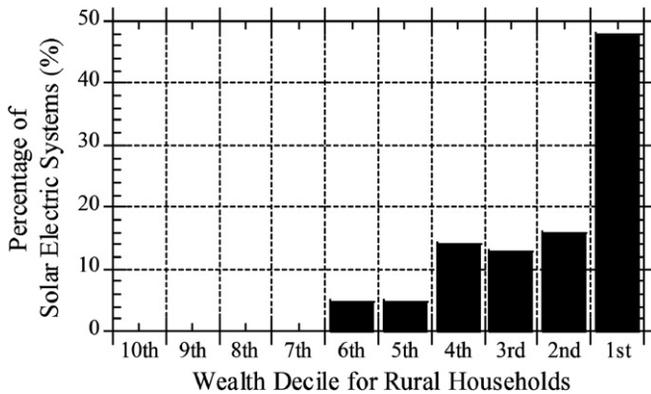


Figure 3. Distribution of solar module ownership among rural households in Kenya. (Note: Sixty-three of the 1,512 households in the year 2000 Tegemeo survey owned a solar PV system. The figure shows the distribution of the 63 households into wealth deciles estimated from the full sample. The wealth deciles are based on the combined monetary value of selected assets and livestock owned by each household. The wealthiest rural Kenyans are in the 1st decile, while the poorest are in the 10th. The original questionnaire form with a list of the assets and livestock included in the survey can be found at <http://www.aec.msu.edu/agecon/ifs2/kenya/>.) Source: Tegemeo 2000 household survey data, n = 1,512 households.

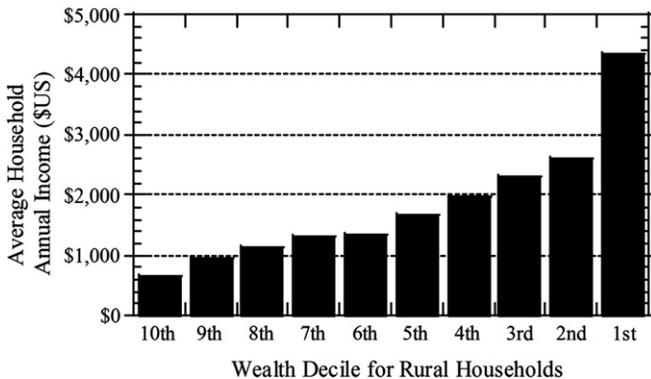


Figure 4. Distribution of income by wealth decile for rural households. (Note: The average exchange rate in 2000 was 76.3 Kenyan Shillings (KSh) per US\$ (World Bank, 2003).) Source: Tegemeo 2000 household survey data, n = 1,512 households.

ket-based solar electrification and other similar processes.

The large majority of “solar” households can be characterized as middle class not only in terms of their wealth, but also in terms of their occupations. Over 80% of the solar owning households in the 2000 Tegemeo survey reported a professional salary (e.g., school teacher¹⁴ or civil servant job) or small business earnings as their first or second most important income source (Table 1). This level is considerably higher than the rural population at large.

Nonetheless, agricultural production does make up a substantial fraction of income for these families. Farm earnings—including crop sales as well as livestock related income—account, on average, for 55% of earnings for households that purchase solar systems. Non-farm income is nearly as high, at 45% of the total. The data in Table 2 suggest that “solar” households are less dependent on crop and livestock income than the broader rural population, but that these income sources nevertheless remain very important for solar using families.

These findings indicate that many families that purchase solar systems cannot be categorized purely as middle class professionals or small business owners, nor do they fit strict definitions of “peasantry” (i.e., small family

farms). Instead, they are best described as a hybrid mix of these two categories. These families—which rely on a diverse set of income sources including farm earnings, salaried labor, and business income—are referred to here as a “rural middle class.” The solar market in Kenya depends heavily on the purchasing power of this hybrid social group.¹⁵

The findings presented in Figure 3 indicate that some rural households near the median wealth level also own solar systems. These data suggest a trend toward a deepening of access beyond the rural middle class, although only the smallest systems (e.g., 14 W) appear to be affordable to these lower income households. The trend is facilitated by falling prices for small solar PV modules, as shown in Figure 5, and an incremental cash-based purchasing pattern that allows rural Kenyans to spread the cost of buying a system out over time.

This modest deepening of ownership levels beyond the rural middle class may appear to be promising, and indeed—with some very important caveats—it is. However, three key issues suggest caution in viewing the cash-based approach as an unqualified success for delivering energy services to lower income households in places like Kenya. First, the small systems that are affordable to those at the “ownership

Table 1. *Primary and secondary income sources for rural Kenyan households*

Group of households	Salary or business 1st or 2nd (%)	Salary or business 1st (%)	Salary or business 2nd (%)	Crop sales 1st (%)
Top 33% by wealth (<i>n</i> = 452)	60	38	23	46
Middle 33% (<i>n</i> = 452)	52	29	23	52
Bottom 33% (<i>n</i> = 452)	59	32	27	45
“Solar” households (<i>n</i> = 62)	81	52	29	42

Source: Tegemeo survey, 2000 (*n* = 1,512 households).

Table 2. *Income sources for rural households in Kenya*

Group of households	Net crop sales (%)	Livestock production (%)	Non-farm income (%)	Mean HH income (KSh) ^a
Top 33% by wealth (<i>n</i> = 482)	40	26	34	217,191
Middle 33% (<i>n</i> = 482)	49	22	29	125,237
Bottom 33% (<i>n</i> = 482)	47	21	32	77,563
All HH (<i>n</i> = 1,446)	44	24	32	140,000
“Solar” households (<i>n</i> = 63)	38	17	45	249,000

Source: Tegemeo survey, 2000 (*n* = 1,512 households).

^a See Note in Figure 4 for the exchange rate.

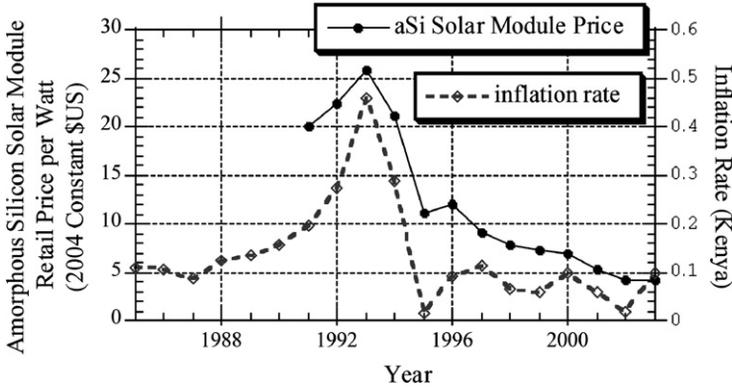


Figure 5. Retail prices for 10–14-W amorphous silicon (aSi) solar modules in Kenya, 1991–2003 and inflation rate, 1985–2003. Source: Price data courtesy of *Botto Solar* of Nakuru, Kenya (data compiled by Maina Mumbi); inflation data from Central Bureau of Statistics (2003).

frontier” provide households with only tiny amounts of electricity. Data presented below indicate that much of the electricity from these small systems is often allocated to television viewing, leaving relatively little energy for applications related to children’s education, income- and work-related activities, or domestic chores (see Figure 7). Second, many small systems purchased on a cash basis are plagued by quality and performance problems, which further reduces their energy generation. Third, given the extremely low incomes of those rural Kenyans below the median wealth level (see Figure 4), continued deepening of solar access through unsubsidized cash sales is likely to occur slowly.

(d) *Income- and work-related uses of solar electricity*

Evidence from Kenya indicates that the role of solar electricity in supporting economic activities is modest, but not insignificant. Moreover, given the distribution of solar ownership, the small economic productivity gains associated with solar use are captured primarily by the rural middle class. Thus, while solar electrification may play a small role in supporting rural economic productivity in Kenya, the fact that the benefits accrue primarily to the rural middle class challenges characterizations of solar PV as a tool for poverty alleviation.

Income generation and productive uses of solar electricity have received a lot of attention in policy circles not so much because they are economically significant, but because they can—if

present—serve as a powerful justification for international donor support for solar electrification.¹⁶ A literature survey indicates that the technology is used for income-related activities in some cases, but there is no evidence that solar electrification leads to widespread or substantial increases in rural income or productivity (Martinot *et al.*, 2002; Nieuwenhout *et al.*, 2000). Evidence from Kenya supports the conclusion that income generating uses of solar electricity are more modest than is suggested by some solar advocates, although they are nonetheless present in some form—albeit small—in nearly half of Kenya’s “solar” homes.

In the 2003 survey ($n = 76$ households), 32% of “solar” households reported using lights for income generation or work-related activities, and smaller percentages indicated income- or work-related uses of solar-powered televisions and radios (23% and 22%, respectively; see Table 3). In total, 48% of the households in the sample reported some sort of work- or income-related activity that was supported by the use of solar electricity.

Rural school teachers—who grade papers and plan lessons in the evening—accounted for a significant fraction of the income- and work-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 appeared to be relatively minor. Very few families

Table 3. *Income- and work-related uses of solar electricity in rural Kenya*

Appliance	% Reporting income uses (total)	% Reporting farming uses	% Reporting non-farm business uses	% Reporting teacher uses	% Reporting other salary work uses
Lights	32 ^a	13	7	16	1
Television	21	8	8	5	0
Radio	22	11	7	3	1

Source: Original 2003 survey of 76 households that use solar electricity.

^a 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.

reported using solar lighting directly for agricultural activities, and for most families economically productive activities were not the primary use of the solar electricity.

A minority of families also reported productivity-related benefits from television and radio.¹⁷ In nearly all of these cases, the families said that they periodically received information that was valuable for farming or business-related activities. Nonetheless, most solar users reported no productivity-related uses of television and radio, and these benefits, even when present, did not appear to be the main motivation for investing in the devices or the solar systems that power them. These findings suggest that while solar electricity can provide numerous benefits, the income- and work-related uses of solar PV are small in most cases. Moreover, the distribution of system ownership discussed above indicates that the productivity benefits that *are* associated with the use of solar PV are captured primarily by the rural middle class.

(e) *Solar electricity and rural education*

Education-related uses of household solar electricity feature prominently in international discourses about the social benefits of developing country solar electrification. The solar policy literature is filled with references to the role of solar lighting in improving children's educational opportunities (e.g., Cabraal, Cosgrove-Davies, & Schaeffer, 1996; Gustavsson & Ellegård, 2004; Wamukonya & Davis, 2001). Powerful images of children studying by solar light are also common (e.g., see, Figure 6).

Solar lighting can play an important role in facilitating studying, as the quality of the light from electric lamps is much higher than light from kerosene lamps or candles. In many rural Kenyan homes, solar electricity *is* used for studying, but education benefits are far from universal among "solar" households. Importantly,

intra-household energy allocation favors other uses in a significant fraction of homes. Nearly 80% of "solar" households in the 2003 survey ($n = 76$) had school age children, but solar lighting was used for studying in only 47% of these homes.¹⁸ These data indicate that while solar PV provides the *potential* to facilitate children's education, household energy allocation dynamics play a central role in determining the actual outcomes.

A number of factors influence household energy allocation, including the size and performance of the solar system (with corresponding linkages to family wealth), the spatial layout of the home, and gender and elder-junior relationships among household members. While a full discussion of these dynamics is reserved for a forthcoming article, detailed observations of energy allocation from 15 rural Kenyan homes demonstrate the role of solar system size on electricity utilization patterns. The data in Figure 7 indicate that in households with small systems (<25 W), the majority of the electricity from the systems (54%) was allocated to television viewing, leaving relatively little for lighting-related uses. In contrast, in the households with a larger system (>25 W), the bulk of the energy was used for lighting (see Figure 8). These results, while not conclusive given the limited sample size, suggest that children in households with a larger solar system are much more likely to have access to electric light for studying than children in households with smaller systems.

These findings complicate conventional framings of the relationship between solar electrification and children's education. Importantly, key studies that have documented an extensive use of solar lighting for evening time studying by children have been in areas with heavily subsidized solar electrification programs (e.g., Gustavsson & Ellegård, 2004; Schweizer, Shrestha, & Sharma, 1995; Wamukonya & Davis, 2001). The subsidized solar systems in the

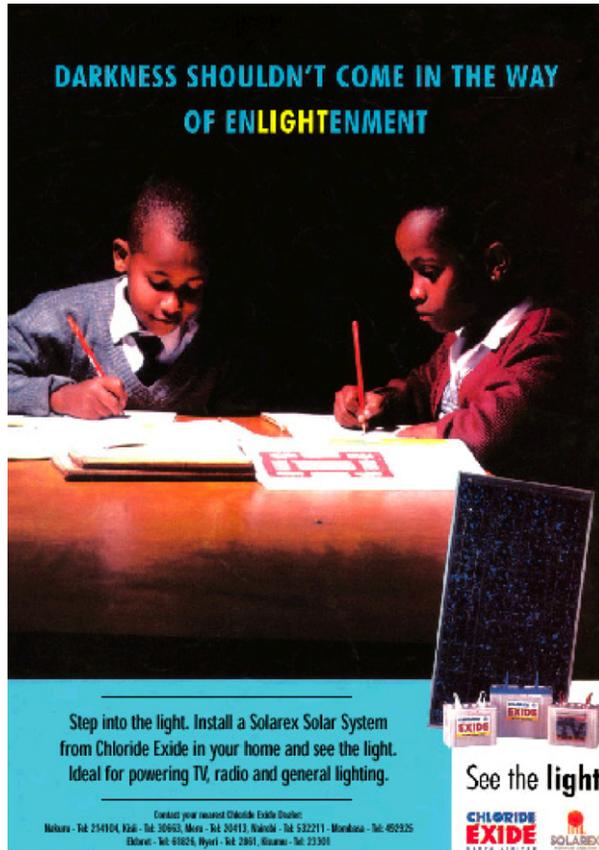


Figure 6. Advertisement for solar electricity that highlights education-related uses. Source: Solarnet (2000).

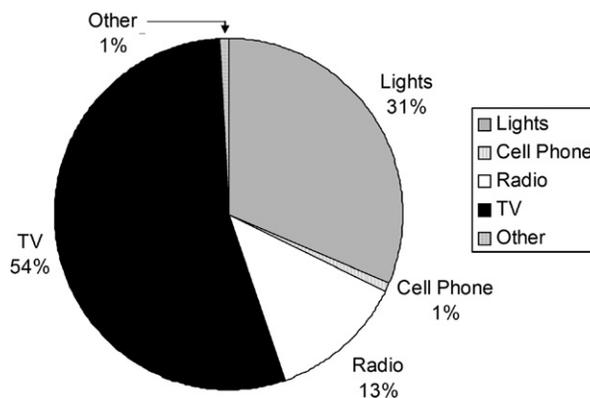


Figure 7. Energy allocation in solar systems smaller than 25 W. (Note: This figure and Figure 8 are scaled according to the average size of the solar systems in each group. The size of the “pie” in the graphs is intended to give a sense of the relative amount of energy available in the two sets of systems. The average solar module size for the larger (>25 W) systems was 40 W, while the average size for the smaller systems (<25 W) was 16 W. Thus, the ratio in the area between the two pie graphs is roughly 2.5.) Source: Data monitoring in 11 solar homes in Kenya over six months in 2003–04.

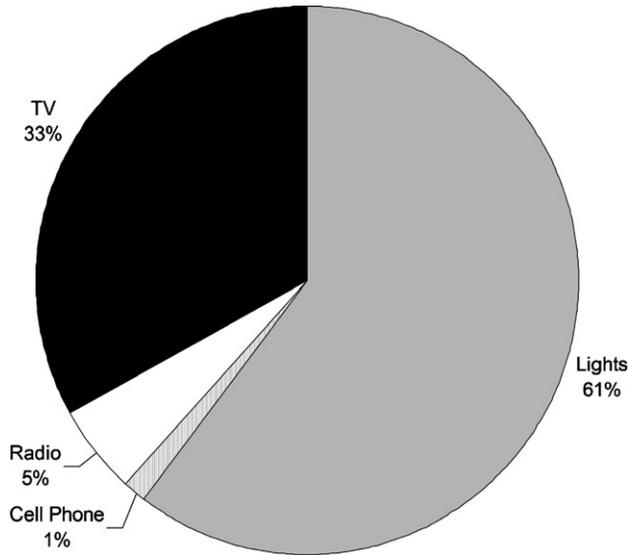


Figure 8. Energy allocation in solar systems larger than 25 W (see Figure 7, for legend). Source: Data monitoring in four solar homes in Kenya over six months in 2003–04.

respective areas were considerably larger (40–60 W) than the median system size in Kenya’s unsubsidized free market (20–25 W). This supports the conclusion that households need to have larger systems, and thus less constrained energy choices, before extensive studying benefits can accrue.

From a policy perspective, the results presented here indicate the importance of supporting the dissemination of larger and better performing systems, as important social uses such as evening time studying by children are often marginalized relative to television viewing and other uses in small systems where energy is in extremely short supply. However, while increasing system size may help to make more energy available, it does not eliminate the importance of intra-household dynamics, as the energy must still be allocated among competing uses. Solar home systems may, therefore, have the potential to support key social uses, but the outcomes are far from guaranteed. This highlights the need to go “inside the household” in order to understand the processes and factors that influence the allocation of energy.

(f) *The information-energy nexus: connective uses of solar PV*

Understanding the full significance of solar electrification also requires an analysis that

goes “beyond the household.” While economically productive uses are small and education benefits are mainly found in households with larger systems, nearly all “solar” households use the electricity to power “connective” appliances such as television, radio, and cellular telephones. In other words, solar PV is closely linked to activities that help rural Kenyans to increase their interconnections with people, markets, and ideas in urban centers.

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 imports like the hugely popular “Smackdown Wrestling” to Kenyan productions such as “Vipindi” and “Vioja Mahakama.”¹⁹ All of these forms of rural–urban connectivity are facilitated by the growing use of solar PV systems, and continued sales growth will enable the expanded use of wireless broadcast and communications technologies.

While the results presented in Figure 7 confirm the high priority given to TV and other connective applications, the social significance of these devices cannot be understood from

energy allocation patterns alone. A broad understanding of the significance of the technology requires an analysis that situates the use of solar PV in the wider context of Kenyan society. This section highlights key trends, and is intended to open the door to further work in this critical and largely neglected area for study.

Rural–urban connectivity in Kenya remains highly uneven, with some people—especially the rural elite and middle class—having greater access to connective technologies than the rural poor. Thus, while it is common to think of an increased rural–urban connectivity in terms of a “shrinking of space” between rural and urban areas, this conception is misleading as it suggests that the distance between the country and the city is reduced for everyone. Instead, connectivity can be conceived as a “stretching” of *certain* social relations over space. Certain connections between particular people, markets, and ideas are facilitated, but other connections do not get made (Cooper, 2001; Hart, 2002; Massey, 1994). This means that the benefits of greater connectivity are reserved primarily for those people and groups who have the highest levels of access to the technologies or who are otherwise well positioned to take advantage of their presence.

(i) *Television, radio, and solar PV*

Some forms of connectivity are also highly political and hotly contested. During the 1970s and 1980s, 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 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 electrification in rural Kenya, solar PV systems, automotive batteries, and dry cells have proven to be critical elements of a rural electricity “micro-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 an 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 TV and radio sets, has had important implications for politics. This was especially true during Kenya’s 2002 national 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 had diversified considerably (Jacobson, 2004). This brief discussion highlights the political nature of certain types of rural–urban connectivity as well as the shifts that can occur over time. It also shows how the social significance of technologies like solar PV 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 rural consumer goods markets. 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,²⁰ and the importance of television is growing rapidly as its use expands²¹ (Miriti, 2003; Waititu & Mwanzia, 2003; Waruhiu, 2003). Solar- and battery-based electricity, combined with dry cells in the case of radios, provide the main source of power for these devices in the rural areas (Jacobson, 2004). This configuration links solar electrification to a particular aspect of the deepening of capitalism in the rural areas of developing countries, namely, the ongoing integration of the rural middle class into international consumer goods markets.

(ii) *Cellular telephones and solar PV*

While televisions and radios have been used by rural Kenyans for decades, cellular tele-

phones are a relatively recent addition. Although mobile telephone networks only began to expand significantly into rural areas starting in late 2001, already they are increasingly common among the wealthy and middle class segments of rural Kenya. Solar electricity is one way to keep a cell phone charged in the rural areas.²² 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. The 2003 survey of 79 rural cell phone users indicated that 81% of recent calls were rural-to-urban calls, while the remainder were local "rural-to-rural" calls.²³ 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 over space due to historic rural-to-urban migration trends.

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 be in contact with their clients. In the 2003 survey, 35% of the recent calls were explicitly related to business activity of some sort. 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.

The linkages between solar electrification and the social uses of "connective" technologies such as TVs, radios, and cell phones indicate 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 to broader political and social processes ranging from the politics of broadcast media control to rural-urban migration and the resulting extended family configurations.

4. DISCUSSION AND CONCLUSIONS

The growing use of solar PV for rural electrification in Kenya and elsewhere, along with its international reputation as a key element in efforts to promote sustainable development, make it increasingly important to understand the socio-economic significance of the technology.

This article includes three central claims about solar electrification in Kenya's unsubsidized markets: (1) The benefits of solar electrification are captured primarily by the rural middle class. (2) Solar PV plays a modest role in supporting economically productive and education-related activities, but "connective" applications such as television, radio, and cellular telephone charging often receive a higher priority. (3) Solar electrification is more closely tied to increased rural TV use, expansion of consumer goods markets, more rural-urban communication, and other processes that increase rural-urban connectivity than to poverty alleviation, sustainable development, or the appropriate technology movement.

Delving more deeply, this analysis indicates that while rural middle class incomes provide the purchasing power behind solar sales in Kenya, income- and work-related uses of the technology are relatively modest. These findings, in combination with a broader analysis of the social use of household solar electricity (which is dominated by TV viewing in many homes), suggest that solar PV systems can often be viewed more as a middle class consumer good than as a productive investment. However, while direct linkages between solar electrification and income generation appear to be limited (though not non-existent), the use of solar PV is nonetheless connected to capitalist development in rural Kenya in some important ways.

First, solar electricity's role in supporting the use of television and radio in rural Kenya facilitates the ability of business advertisers to reach a wider audience. Substantial evidence supports the conclusion that television is the main driver for demand in the Kenya solar market, and solar PV is likewise a key component (along with lead-acid battery systems) of the micro-electricity infrastructure that supports the use of rural TV. Given the slow rate of grid-based rural electrification, decentralized micro-electricity technologies will continue to be an important component of a rural electricity infrastructure that is crucial to business sector efforts to

expand and develop rural consumer goods markets.

Second, while children's use of solar light for evening time studying is often marginalized, in some "solar" household education-related uses—by children as well as by school teachers—are a key application of the technology. This links solar electrification to rural education and, by extension, to rural-to-urban migration. Investments in education have long been viewed in rural Kenya as an important route for social and economic advancement, with the key prize being professional urban employment. Although many rural children never achieve this goal, children from rural middle class families are in a better to do so than their less advantaged neighbors. Solar lighting, if it is used to facilitate studying, can play an important role in supporting children's education. Given that most solar systems—and nearly all of the larger (>25 W) systems—are owned by the rural middle class, solar PV's connection to education may contribute in a small but perhaps significant way to long-term processes of economic differentiation as well as patterns of rural-to-urban migration.

Third, the use of solar electricity is playing a modest (but nonetheless significant) role in supporting the emerging use of cellular telephones in rural Kenya. Many families use the phones primarily for long-distance family communication, and there are important social and economic dimensions to these intra-family connections. In addition, certain types of rural businesses—including retail shops as well as many service-oriented businesses—are using cell phones to increase their productivity. Given that most cell phone owners appear to be members of the rural elite or middle class, this indicates another process in which solar electri-

fication may contribute in a small way to the deepening of middle class formation in rural Kenya.

The analysis presented in this article also provides a view of the multiple processes that shape the social significance of solar electrification in Kenya. These range from socio-economic trends such as the ongoing development of a rural middle class, to intra-household energy allocation dynamics, to national level broadcast media politics. Importantly, viewing solar electrification through this "multiple arenas" lens shows that the social significance of the technology is not fixed in time or space. Instead, it has shifted with social and political changes such as those generated by political struggles over media broadcast rights, as well as with the introduction of new technologies such as mobile telephones. At the same time, it also varies from household to household due to differences in family dynamics. Thus, the social implications of even a technology with solar PV's progressive "small is beautiful" reputation are not pre-given. Instead, they are multiply determined by a number of processes and factors that come together to shape the social use possibilities of the technology.

Finally, while local factors play a central role in shaping social uses, the evidence cited above from China, Thailand, Sri Lanka, Tunisia, and Zimbabwe suggests that solar electricity is commonly used in many settings for connective applications such as television viewing. In other words, the social significance of solar PV in Kenya is far from unique, and, in rural Kenya and beyond, the main significance of solar electrification may be its role in enabling rural-urban connectivity.

NOTES

1. Of course, support for solar electrification in particular and renewable energy in general still lags far behind funding for fossil fuel development at the World Bank. Over the period from 1992 to 2002 the World Bank favored investments in fossil fuel projects over renewable energy by a ratio of 18 to 1 (Institute for Policy Studies, 2003).

2. Drawing from Kitching (1989, p. 19), the terms populism and neo-populism are used in this article to mean a line of thinking that "... has been opposed to

large, concentrated production and has argued instead for a pattern of development based on small-scale individual enterprise both in industry and in agriculture."

3. Common claims about the development benefits of solar electrification include improvements in education for children, rural income generation, and reduced rural-to-urban migration (e.g., see, Nieuwenhout *et al.*, 2000). These claims are similar to Basic Needs development discourses from the 1970s, which emphasized the

importance of alleviating poverty, reducing urban bias in development policies, and creating income generation and employment opportunities in the informal sector (e.g., see, ILO, 1972; Lipton, 1977; McNamara, 1973; Schumacher, 1973; Seers, 1969).

4. Unsubsidized sales of solar PV for household use account for an estimated 75% of the market, while government and international donor financed sales make up the remaining 25% (ESDA, 2003). Interestingly, much of the unsubsidized segment of the market is geographically separate from the donor funded segment. Most of the household systems purchased through unsubsidized market sales are located in densely populated farming areas, while most donor projects are located in remote and sparsely populated regions.

5. The four original surveys include interviews with 391 solar technicians and data collection from 312 solar vendors in over 50 towns in Kenya during 2000–01. In each town, the research team worked to visit all of the businesses that sold solar equipments and to interview at least one-half of the locally based “solar” technicians. The team conducted the third and fourth surveys in 2003, drawing respondents from rural areas near the towns of Othaya (Central Province), Maai Mahiu (Rift Valley Province), and Webuye (Western Province). One of these surveys involved interviews with 76 rural households that use solar electricity, and the other was a separate survey of 79 rural cellular telephone users. The respondents in these latter two surveys were selected using a clustered snowball technique. While this process was not random, in the case of the “solar” survey the resulting sample was characteristically similar to larger sized, randomly selected samples of solar households. For example, the distribution of large and small systems and the distribution of primary income sources in the solar household survey are similar to the respective distributions found in the solar households in the year 2000 Tegemeo survey (see endnote 6) and a 1997 survey of 410 solar households reported in van der Plas and Hankins (1998). The observations of intra-household electricity allocation included interviews, observations, and electronic data monitoring in seven households near the town of Othaya and eight households near Maai Mahiu. The participating households provided informed consent after detailed discussions about the nature and purpose of the work. The distribution of solar system size and primary income sources for these households is roughly similar to the distributions found in the 2003 survey of 76 “solar” households. In all cases, the work was conducted in accordance with protocols to protect human subjects.

6. The Tegemeo Project is a joint effort of Egerton University (Kenya) and Michigan State University (United States). The 2000 survey was a proportional

random sample of rural households ($n = 1,512$) in all of Kenya’s agro-ecological zones. The survey included extensive data about the wealth, income, demographics, and farming practices of respondent households. Fortunately for the analysis presented here, it also included information about the ownership of assets such as solar PV modules, batteries, TVs, and radios. See Argwings-Kodhek, Jayne, Nyambane, Awuor, and Yamano (1998) for a detailed summary of the sampling regime, data collection methods, and a copy of the survey questionnaire.

7. The Kamfor survey data are from a random sample of 2,270 Kenyan households conducted in 2001. It included 1,755 rural homes and 515 urban homes. Only the rural portion was used in the analysis presented in this article.

8. Some solar systems also include additional components, such as a charge controller, an inverter, or a DC to DC converter.

9. Unlike grid-connected systems, where energy consumption is limited primarily by an ability to pay the power bill, the energy produced by a solar system is defined mainly by the size of their solar module and the amount of sunlight that reaches it during the day. In a relatively sunny area, a 25-W system can produce about 30 kW h/year. While this is more energy than is available to households that rely on a car battery (10–30 kW h/year) or dry cell batteries alone (<1 kW h/year), it is much less than the 500 kW h/year on an average for rural households that are connected to the Kenyan electrical grid (Kamfor, 2002). To put these numbers in further perspective, an average US household consumes about 10,000 kW h per year (Jacobson, Milman, & Kammen, 2005).

10. Tegemeo survey data indicate that 4.2% of rural households own a solar module, while 12.4% own a battery that is not charged with solar.

11. In the 2003 survey of 76 “solar” households, 66% reported using a battery alone prior to purchasing solar PV.

12. Data from the 2003 survey ($n = 76$) 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.

13. The newspaper advertisements were tracked daily, providing a systematic survey of all ads that appeared in print.

14. Rural school teachers account for about 30% of all household solar system sales, making them the single largest purchasing block in the market (Jacobson, 2004; van der Plas & Hankins, 1998).
15. The rural economy on which the Kenya solar market depends grew out of socio-economic configurations that have roots in the colonial period and the early post-Independence years (Berry, 1993; Chege, 1987; Cowen & Shenton, 1996; Kitching, 1980). Cash cropping small holder family farms form the foundation of this economy. Nonetheless, most households depend on multiple income sources, and non-farm earnings are significant for families at all wealth levels. The areas of Kenya with strong regional solar markets have active internal economies with a multiplicity of small-scale enterprises that provide products and services to local residents (Cowen & Shenton, 1996, p. 341). Professional salaries and urban to rural remittance transfers also make substantial contributions to household incomes in these regions (Economic Survey, 1991 to 2002 editions).
16. See Kapadia (2004a) for a report on economically productive uses of renewable energy in developing countries.
17. Cellular phones are also used for economically productive activities. See below for a further discussion.
18. In some cases (19%), this was because the system included a TV or radio, but not lights. This was true in 22% of homes with school age children. In other cases (34%), electric lights were present, but the solar electricity was allocated to other uses. In these homes, kerosene lanterns were the primary study light.
19. *Vipindi* is a popular comedy program about a family that runs a small restaurant. The title simply means “Program” or “Broadcast” (i.e., TV program) in Swahili. *Vioja Mahakama* means “Odd Courtroom” or “Marvelous Courtroom” in Swahili, and it is a comedy program about court cases.
20. While most rural users power their radios using dry cells, radios that are powered by solar electricity or battery systems are often used more frequently. 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).
21. 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. 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. The sample size for rural residents was 1,278 in 1998 and 1,020 in 2002 (Steadman, 2002).
22. Data from the 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% used 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 document the wide range of charging strategies used by rural cell phone users.
23. The survey team asked each cell phone user about the most recent call that she or he made as well as the most recent call received. The reported data are the combined results for these two sets of calls.

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