Connective Power:
Solar Electrification and Social Change in Kenya

by

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Abstract

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Household solar photovoltaic systems have emerged as a key alternative to grid-based rural electrification in many developing countries. This may seem a victory for appropriate technology advocates, but my research indicates that the social significance of solar electrification in Kenya, which is among the largest developing country solar markets per capita, is far removed from the classic "small is beautiful" neo-populist vision of building small-scale alternatives to global capitalism. Instead, solar electrification is more closely connected to neo-liberal goals of market-based service provision and economic integration.

In this study I combine quantitative and qualitative methods, including surveys, intra-household energy allocation studies, and historical analysis, to analyze the social significance of solar electrification in Kenya. I find that "connective" applications, including television, radio, and cellphones, are centrally important. Television is especially notable; the expansion of TV broadcasting to rural areas was a key condition for solar market development. Solar electricity is also used for lighting. In Kenya, income and work related uses of solar lighting are modest, while education uses are

more significant. However, in many households, especially those with small systems, intra-household dynamics constrain key social uses (e.g. children's studying), as the energy is allocated to other uses.

Social use patterns combine with access dynamics in Kenya's unsubsidized market to shape the social significance of solar electrification. Solar ownership is dominated by the rural upper and middle classes. Thus, productivity and education uses make small contributions to differentiation and middle class formation. Additionally, solar electrification's role in supporting rural television and radio use improves business advertisers' ability to expand consumer goods markets. These findings link solar electrification to important processes of rural development and social change.

Mainstream policy makers have sought to expand the market through credit-based sales. However, my analysis indicates that, without subsidies, credit-based sales are unlikely to deepen access beyond levels established in the existing cash market. Thus, while solar electrification may potentially contribute to sustainable development, concerns about equity and other social issues indicate a need for careful attention to the implications of policy choices and processes that influence the social use possibilities of the technology.

Dedication

I dedicate this work to Pat and Jake, who taught me about creativity and why working to make the world even just a little bit better is always worthwhile...

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Introduction

> Solar energy has brought me nothing but trouble. My children only want to watch TV and I cannot get them to study for school. Because of all the TV they watch we never have enough energy for the lights, and the radio drives me crazy. The kids want to listen to that KISS FM Nairobi station all of the time and I do not like that music at all! The only good thing is that the battery is not working well and this limits the time they can use the TV. My wife and children keep asking me to buy a new battery, but that will have to wait until December when we get the tea crop bonus money.
>
> George Murungi,[1] when asked about the solar PV system installed at his rural home in Kenya.

Mr. Murungi's experience with solar electricity contrasts with those of James and Regina Kariuki, who live a few kilometers away. On one of my visits to their home we watched the evening news while eating dinner, and then Regina switched off the TV set so that she could prepare her primary school teaching lessons for the following day while their two daughters did homework under the bright fluorescent solar light. James, who works as the local health clinic's medical officer, slipped outside to use his mobile phone to call his brother in Nairobi to inquire about visiting on an upcoming work related trip to the city. Later, after the girls were in bed, James, Regina, and I talked politics, joked, and played cards by solar light until late into the evening.

These contrasting accounts give a glimpse into the every day dynamics of the social use of solar electricity in Kenya, where the Murungi's and the Kariuki's are two out of approximately 200,000 rural families that have purchased solar power systems through an unsubsidized and highly competitive free market sales network. This growing base of sales makes Kenya one of the leading countries in an increasing trend towards

[1] This quotation is a paraphrased translation from an unrecorded interview conducted in Swahili during August, 2003. The names used in this dissertation have been changed to protect the privacy of the respondents.

decentralized, market-based approaches to rural service provision, and many have cited the Kenya solar market as an example of sustainable development in action [Acker and Kammen, 1996; van der Plas and Hankins, 1998; Martinot et al., 2002; and others].

At an international level, support for market-based rural electrification with solar energy has grown rapidly over the past two decades. In the eyes of many energy and development professionals, solar electric systems are emerging as one of the primary alternatives to extension of national electricity grids for rural electrification. However, despite broad claims by solar advocates about the environmental, economic development, education, and poverty alleviation benefits of solar electrification [e.g. see Cabraal, et al., 1996; Kaufmann, et al., 2000; Nieuwenhout, et al., 2000; Martinot, et al., 2002; GEF, 2004a; and many others], the accounts about the Murungi and the Kariuki families suggest that the social uses of solar electricity vary from family to family in important ways, and, at least in some cases, differ substantially from common conceptions about this "small is beautiful" "appropriate" technology. Moreover, in contrast to much of the literature on solar electrification, which emphasizes the lighting related uses of solar energy, this brief story hints that the "connective" uses of solar energy - that is, the use of solar electricity to power televisions, radios, and mobile telephones - represent an emerging driving force behind solar market sales growth.

The Emergence of Solar Photovoltaic Technology

Although the photoelectric effect was discovered in 1839, the real push to develop solar electric technology began in the 1950s at Bell Laboratories in the United States.[2]

[2] The photoelectric effect - in which certain materials emit an electrical current when exposed to a beam of light - was discovered by Edmond Becquerel in 1839 and explained by Albert Einstein in 1905. Modern photovoltaic modules are made of semi-conductor materials (usually silicon) that have been

Early advances came primarily through research on space related applications for satellites, and photovoltaic (PV) technology - or "solar PV" as it is often called - did not become widely available on a commercial basis for "terrestrial applications" until the mid-1970s [Perlin, 1999]. Following this initial commercialization, world solar module sales have grown at a rapid 28% annually (see Figure 1), and prices have dropped from over $80 per peak Watt (Wp) in 1974 to about $3 per Wp today[3] (see Figure 2).

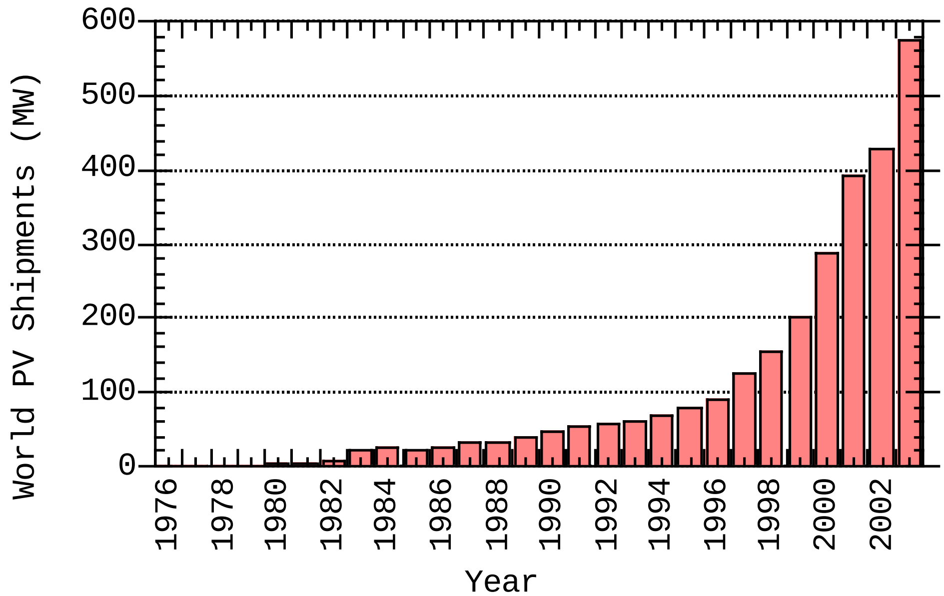

Figure 1: International Solar Module Shipments in Megawatts, 1976-2003
Sources: 1976-1993: Maycock, yearly Feb. editions of "PV News"; 1994-2001: Maycock, 2002; 2002-2003: http://www.solarbuzz.com/Marketbuzz2004-intro.htm

While industrialized countries such as the United States, Japan, and Germany have accounted for the majority of production and sales, solar PV technology began to appear

'doped' with small amounts of impurities (e.g. phosphorus and boron) that enhance the photoelectric effect. While early solar cells had light to electricity conversion efficiencies below 1%, commercially available photovoltaic modules currently reach efficiencies as high as 15% [Perlin, 1999; Brown, et al., 1991; Sandia National Laboratories, 1991]. See also Appendix A.

[3] Solar modules are generally rated according to the maximum amount of electric power (in Watts) that they can produce in bright sun conditions. This is referred to as the 'peak Watt' rating, and it is often abbreviated as Wp. See Appendix E for a list of abbreviations and acronyms used in this dissertation.

in developing countries within a few years of initial commercialization. The first solar electric systems in Africa were installed through donor funded projects in the late 1970s, and by the end of the 1980s countries like Kenya and Zimbabwe had emerging commercial markets. Today, sales of solar equipment in developing countries account for just over 10% of world totals [Kaufmann, et al., 2000].

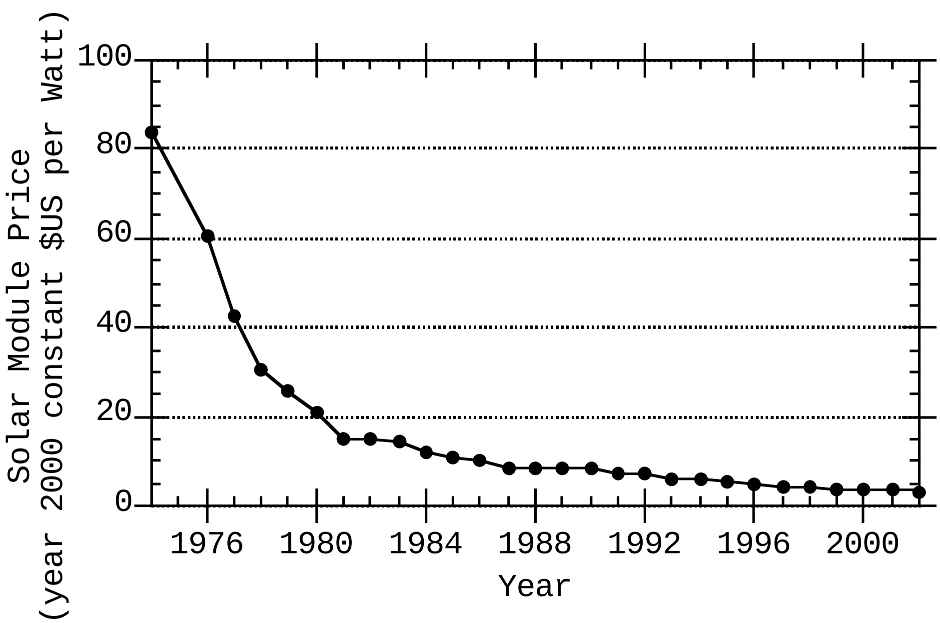

Figure 2: **International Solar Module Price, 1974-2002**[4] (constant year 2000 prices)
Data sources: Strategies Unlimited (2003)

Rural Electrification with Solar Energy in Developing Countries

International donor support for rural electrification with solar energy began in the late 1970s, and grew rapidly especially in the years following the 1992 United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro, Brazil. Since then, the Global Environment Facility (GEF)[5] - which was set up in conjunction

[4] Prices are average f.o.b. prices for solar PV modules 50 Wp and larger. The f.o.b. (free on board) price is the pre-tax and pre-import duty wholesale price at the port of entry for a purchaser in an importing country, minus any transport or insurance costs incurred en route from the country of export.
[5] The GEF was set up in 1991 to "…(help) developing countries fund projects and programs that protect the global environment." The GEF receives funds from donor countries and distributes them to

with the UNCED meeting in Rio - has 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 advocates of other renewable energy technologies have started to complain[6] [e.g. Inverson, 1996; Karekezi and 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. Greenpeace, 2001; Dunn, 2000].

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, while environmental and neo-populist[7] "small is beautiful" arguments are used to justify support for solar electrification, private markets are increasingly the preferred vehicle for disseminating the technology. 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 towards - "full cost recovery" [e.g. Covell and Hanson, 1995; Martinot, et al., 2002]. Thus, discourses

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developing countries through projects managed by the World Bank, the United Nations Environment Programme (UNEP), and the United Nations Development Programme (UNDP). See http://www.gefweb.org/

[6]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].

[7] Drawing from Kitching [1989, p.19], I use the terms populism and neo-populism 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."

in favor of solar electrification often draw simultaneously from environmental, neo-populist basic needs, and neo-liberal market-oriented lines of thinking.

At first glance this confluence may seem like a happy consensus of neo-populist left and neo-liberal right perspectives around energy and the environment. However, as I explore at length in Chapter 1, upon closer inspection the situation is not so simple. Importantly, there are key contradictions between the classic neo-populist goal of building small scale alternatives to world capitalism on the one hand and the neo-liberal agenda of increased economic integration on the other.

This simultaneous use of neo-populist and neo-liberal arguments in favor of solar electrification combined with the contradictions in the associated development visions raises important questions about the relationship between the rhetoric in international policy debates and the realities of solar electrification on the ground. In other words, to what degree do the realities of solar electrification in places like Kenya fit classic neo-populist ideals about building small scale alternatives to world capitalism? And in what ways does the use of solar technology conform more closely to the neo-liberal vision of global economic integration?

This confluence of neo-populist and neo-liberal ideas around solar electrification also raises questions about the motives behind the discourses themselves. For example, some have accused the World Bank and other similar institutions of seeking to "greenwash" their images by funding limited but highly visible environmental projects without altering the underlying "environmentally unsustainable" nature of their investment portfolio [e.g. Danaher, et al., 1994; Rich, 2001], and others have argued that despite strong rhetoric on poverty alleviation, a number of countries that have

adopted IMF and World Bank sponsored reforms "remain mired in poverty" [e.g. Watts, 1994; p.374]. Solar electrification is widely perceived as an environmental technology that brings crucial energy services to the poor in developing countries. As such, relatively modest investments in solar projects may provide organizations like the World Bank with valuable political mileage on both the environmental and poverty alleviation image fronts. For some donors, these image benefits may provide an even stronger incentive to support solar electrification than the purported contributions of the technology to rural development.

While my research in Kenya cannot provide definitive answers regarding the motivations behind funding for solar electrification by the World Bank and others, it does address key issues related to the discrepancies between neo-populist and neo-liberal discourses, on the one hand, and on-the-ground realities of solar electrification, on the other. In this dissertation I argue that the mainstream policies link solar electrification much more closely to neo-liberalism than to the classic "small is beautiful" neo-populism of E.F. Schumacher and other similar thinkers. Nonetheless, solar PV should not be viewed merely as a "neo-liberal technology," as the social uses of solar electricity are not pre-determined or controlled by any one group. I use my research in this dissertation to show how the significance of solar PV systems is shaped through social action in multiple arenas, including previously under-explored linkages between solar electrification and processes of rural middle class formation, broadcast media politics, and intra-household energy allocation dynamics.

Solar Electrification in Kenya

Kenya, an East African country of approximately 30 million people, is an excellent setting in which to engage with these issues. Its solar market emerged in the mid-1980s and grew rapidly during the 1990s into one of the largest solar markets per capita among developing countries [e.g. see Nieuwenhout, 2000, p. 16]. It is served by a dynamic and highly competitive supply chain that includes more than 10 import and manufacturing companies, as well as hundreds of vendors, installers, and after-sales service providers. Cumulative sales are estimated to exceed 200,000 systems, and annual sales regularly top 20,000 solar modules per year [ESDA, 2003]. Moreover, during the 1990s solar electricity emerged as one of the main alternatives to the electrical grid for household rural power, 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]. Thus, among developing countries, Kenya is a place in which the use of solar electricity is relatively high (indeed, it is among the largest solar markets per capita). This makes it an good setting in which to evaluate the social significance of the technology.

In addition to its relatively large size, the Kenya solar market has been described as a "true free market" [PVMTI, 1998]. This market developed with minimal direct government support and only very moderate inputs from international donor aid groups. Solar sales in Kenya have historically been (and continue to be) driven largely by unsubsidized over-the-counter cash purchases of household solar systems [Acker and Kammen, 1996; van der Plas and Hankins, 1998; Hankins, 2000a]. These

characteristics make Kenya a good setting in which to analyze the significance of market-based dissemination approaches to rural electrification with solar energy.

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 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].

My findings from Kenya contribute to and move beyond these debates. More specifically, my work in Kenya indicates that:

1) Access to solar electricity in Kenya's unsubsidized market is driven by rural middle class purchasing power. That is, solar electricity is neither confined to the rural elite alone, nor is it available to the majority of "rural poor" households. Nearly half of all solar systems are owned by households in the top 10% of rural families by wealth, and 80% of systems are owned by the top one-third. While recent trends

indicate some deepening of access beyond this group, only the smallest solar systems (e.g. 14 Watts) are available to households at the "access frontier."

2) Solar electricity is sometimes used for income and work related activities that contribute to small gains in economic productivity. Nearly all of these productivity gains are captured by rural middle class families. As a result, solar electrification appears to contribute - albeit in a very small way - to processes of middle class formation.

3) Solar powered electric lights are often used for activities ranging from housework to socializing to evening time studying by children. However, in many families intra-household dynamics constrain these lighting uses of solar electricity, as small amounts of energy available from the systems are allocated to other uses. Key social uses of solar electricity by women and children appear most likely to be marginalized in the smallest and most affordable solar systems (i.e. < 25 Watts).

4) Solar electricity is "connective power" for the rural middle class. Connectivity related uses, including powering televisions, radios, and cellular telephones, are among the most socially significant applications of solar PV systems. These uses 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. One of the central drivers for demand in the Kenya solar market over the past two decades has been securing electricity for television in rural homes, and in many households with small systems (i.e. < 25 Watts) the majority of the energy is often allocated to TV viewing.

5) The significance of solar electrification is closely linked to the social and political dynamics of rural-urban connectivity. For example, the social significance of solar electrification in Kenya has shifted in subtle but important ways over the past two decades as the result of political struggles over media broadcasting rights. These politics, which have seen a change in media broadcasting from a state monopoly to a semi-pluralistic system that includes privately owned corporate broadcasters along with the government owned network, have important implications for national electoral politics as well as for business advertisers that use the networks to reach rural consumer goods markets. Thus, the possibilities for different people and groups to benefit from the use of solar electricity are contingent in part on ongoing political struggles over television and radio broadcast licensing and regional reach.

My findings about the distribution of solar system ownership are consistent with what one would expect in a free market setting. This highlights the equity implications of the unsubsidized market-based approaches to rural service provision that are favored within neo-liberalism. My work also challenges conventional framings of the social use of solar electricity, which fail to account for the role that intra-household energy allocation dynamics play in shaping the social use possibilities. As a result, conventional framings often overstate the use of solar electricity for lighting related applications such as kitchen lighting and evening time studying by children, even as these framings trivialize the importance of connective uses such as television and radio.

Finally, my findings provide a view of the multiple processes that shape the possibilities for and social significance of solar electrification in Kenya. These range

from rural 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.[8] 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.

It follows, of course, that the social significance of solar electrification in other regions and countries may differ from my findings in Kenya. In many cases these variations will be small, while in others they may be substantial depending on the similarities and differences in the socio-historical and socio-spatial configurations that are involved in shaping the meanings of solar electrification in each context. The degree to which my specific findings from Kenya will "travel" to these other places depends on these configurations, but - and this is critical - the multiple arenas framework that I employ will prove useful for unpacking the social significance of solar electrification in any context. In other words, even if some of the specific findings from my work do not "travel" universally beyond Kenya, the framework that I employ in this dissertation can.

These findings and re-framings of several classic debates are important for expanding current understandings of solar electrification, where an emphasis on the household as the primary unit of analysis and a focus on lighting related social uses has

[8] See Hart [2002] for an explanation of the 'multiple arenas' framework. See also Chapter 1.

led to an overly narrow - and at times technologically deterministic - view of the social significance of the technology. By going both "inside" and "beyond" the household I deepen understandings of the critical linkages between solar electrification and broader socio-historical and socio-spatial processes. My work is also important for rethinking broader debates related to "sustainable development" - including climate change mitigation motivated development policies - as it highlights the fact that the use of "environmental" technologies does not guarantee particular social outcomes. This indicates a need to strengthen the role of social science analysis - particularly political economic and social geographic analysis - in debates about sustainable development in general and climate change mitigation in particular. Finally, the explicitly socio-spatial "multiple arenas" framework that I employ contributes to theoretical understandings of the relationships between technology use and social change, and it may prove especially useful for unpacking the social significance of other "connective" technologies such as the expanded use of cellular telephones and the emerging use of the internet in developing countries.

Methods and Evidence

In this dissertation I draw from both quantitative and qualitative forms of evidence to analyze the social implications of rural electrification with solar energy in Kenya. My original data collection work for this research project was collected on a number of trips to Kenya over a period of four years from 1999 to 2003, with the majority of the work occurring in 2002 and 2003.

I employed a variety of techniques in my field work including key actor interviews, four different original surveys related to solar electrification, observations of solar

electricity use in 15 households complimented by 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.

In addition to my field work, which I will describe in more detail below, I was able to use a number of other key sources that greatly facilitated my work. Foremost among these was a large cross sectional survey of rural Kenyan households conducted in 2000 by the Tegemeo Project for agricultural economic policy analysis (n = 1,512 households).[9] I use these data especially to compare the wealth dimensions of solar owning households with the broader rural Kenyan population. The Tegemeo data set also includes valuable information about the ownership of key energy technologies such as solar PV, lead-acid batteries, and electrical grid connections. See Appendix B for more information about this survey as well as the other data sets discussed below.

I also had access to a large sample household energy survey commissioned by Kenya's Ministry of Energy and conducted by Kamfor, Ltd., a Kenya based consulting firm (n = 1,755 rural households),[10] in 2001. I use the "Kamfor survey" to compliment

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[9] I gratefully acknowledge the Tegemeo Project - which is a joint effort of Michigan State University (USA) and Egerton University (Kenya) - 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/

[10] Data collection in the Kamfor survey was based on a random sample of 2,270 Kenyan households, including 1,755 rural homes and 515 urban homes. I used only the rural portion for my analysis. The survey was conducted in 2001 and the results were published in 2002 [Kamfor, 2002]. I thank Mbiri Gikonyo of the Kamfor Company, Ltd. for providing me with access to this data set. There are some important differences between the sampling regimes for the Tegemeo and Kamfor surveys. Importantly, in the Kamfor survey all households outside of the major urban centers (i.e. Nairobi, Mombasa, Kisumu, Eldoret, and Nakuru) were counted as "rural." This means that in some cases households in towns with populations over 100,000 were counted as being "rural" (e.g. the town of Naivasha has a population of 158,678 and Nyeri has a population of 101,238 according to the 1999 census [GoK, 2001]). In contrast, in the Tegemeo survey the population of "rural" households was defined as only those lying outside of town boundaries. In practice, this means that as many as 25% of the households in the Kamfor survey

the Tegemeo data set, and especially for information about rural kerosene lighting and dry cell battery usage patterns.

In addition, I used secondary sources including extensive historical literature on rural development and social change in Kenya, a number of articles and documents related to the emergence and development of the Kenyan solar market, and reports on broadcast politics and the Kenyan media.

The four original surveys that I directed include interviews with 391 solar technicians and data collection from 312 solar vendors in over 50 towns in Kenya. These data, which were collected in 2000 and 2001, provide key information about the characteristics and extent of the Kenyan solar supply chain.[11] I carried out the third and fourth surveys in 2003, when I directed a survey effort that included interviews with 76 rural households that use solar electricity and a separate survey of 79 rural cellular telephone users.[12]

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may fall outside of the definition of "rural" that was used in the Tegemeo survey. See also Appendix B for more information about these two data sets.

[11] Maina Mumbi and Henry Watitwa of Kenya provided indispensable assistance in conducting these surveys in 2000 and 2001. Maina and Henry carried out the bulk of the survey interviews. Shannon Graham of UC Berkeley also played a central supporting role in the design and implementation of these survey efforts. The solar technician surveys were collected through a snowball sampling approach in randomly selected towns. In each town the research team worked to visit all of the businesses that sold solar equipment and to interview at least one-half of the locally based 'solar' technicians.

[12] Maina Mumbi and Henry Watitwa also made key contributions to these survey interview efforts, along with Rebecca Ghanadan of UC Berkeley. The respondents for both the 'solar' household survey and the cellular telephone survey were selected from within three different regions of Kenya. These include rural areas near the town of Othaya in the Central Province, near the town of Maai Mahiu in the Rift Valley Province, and near the town of Webuye in Western Province. The respondents were selected on a snowball basis, with initial contacts being made through solar technicians who worked in each area. Although the sample selection was not random in any strict sense, in the case of the 'solar' survey the resulting sample was characteristically similar to larger sized, randomly selected samples of solar households (e.g. the distribution of large and small systems and the distribution of primary income sources in my solar household survey are similar to the respective distributions found in the solar households in the Tegemeo survey and a 1997 survey of 410 solar households reported in van der Plas and Hankins [1998]). See Appendix B for more details about these data sets.

The survey of "solar" households provided key information about intra-household energy allocation, appliance use, and key social uses of solar electricity for applications such as income and work related activities, lighting to support housework in the kitchen, and evening time studying by children. These data were complimented by detailed observations of energy allocation in 15 "solar" homes, including ethnographic observations as well as electronic data logging of appliance use patterns over a period of 6 months in 2003 and 2004.[13]

"Environmental" Technologies, Markets, and Sustainable Development

I use my work in Kenya as a lens through which to view key international debates about sustainability, decentralized approaches to development, and rural energy service provision. In making my analysis, I work to challenge a disturbing trend to reduce the concept of "sustainable development" to a process of building sustainable (i.e. profitable) markets for "environmental technologies" [e.g. see Leggett, 2001; Martinot, et al., 2002; Prahalad and Hart, 2002; GEF, 2004b]. This approach serves to marginalize concerns about equity and social change, as it suggests that sustainable development is primarily a process of increasing the use of "environmental" technologies in the context of status quo social arrangements. Implicitly contained within this vision of sustainability is the idea that certain (beneficial) social outcomes can be automatically associated with the use of particular technologies. Rural electrification with solar energy, for example, is widely touted as a factor contributing

[13] Maina Mumbi provided critical assistance in this data collection effort, which included 7 households near the town of Othaya (Central Province) and 8 households near Maai Mahiu (Rift Valley Province). The homes for these observations and measurements were selected following detailed conversations with each family. 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. See Appendix B for more details.

to poverty alleviation, increased rural productivity, improved educational opportunities, and quality-of-life improvements that especially benefit women and children [e.g. see Cabraal, et al., 1996; Kaufmann, et al., 2000; Greenpeace, 2001; and many others]. However, while these sorts of social outcomes are - to varying degrees - possible, they are far from guaranteed. Instead, like all technologies, the social significance of solar electrification is shaped by a number of place specific social, economic, and political forces, as well as by the every day practices of the rural people who use the systems.

In my research I work to situate solar electrification in the broader context of Kenyan society, and to understand the sets of forces that influence the social use possibilities of the technology. In doing this work I do not seek to dismiss the important potential of renewable energy in general or solar energy in particular as tools for supporting socially and environmentally progressive development efforts. On the contrary, I view their use as a critically important component of an environmentally sustainable future. I am arguing, though, that it is *not enough* simply to promote the use of renewable energy and other "environmental technologies." As I show through my work in Kenya, there are a number of crucial policy choices - with often diverging implications - that influence the equity dimensions of rural access as well as the social use possibilities of solar technology. Moreover, many of the programs emanating from the market-oriented mainstream of international solar electrification policy do little to ensure social outcomes that are in line with the progressive reputation of the technology. If renewable energy technologies are to deliver on their potential, there is a great need for better understandings of the social implications of key policy choices, as

well as greater levels of critical engagement on the part of renewable energy advocates with these social and policy issues.

In chapter one (titled "Small can be beautiful, but there are no guarantees: International debates about solar electricity, sustainable development, and rural energy markets"), I situate solar electrification in the context of international climate change mitigation policy discussions as well as neo-populist and neo-liberal ideas about decentralization and rural development policy, setting the stage to use my research in Kenya as a lens through which to view these broader debates.

I use chapter two ("Rural micro-electricity basics") to provide an introduction to the technical and economic dimensions of the use of small solar electric systems, as well as to situate their use among the other main technologies used for household rural electricity in Kenya.[14]

In chapter three ("Poverty alleviation or middle class formation? Solar electricity and Kenya's rural middle class") I argue that solar electrification is more the *result* of decades old processes of middle class formation than a contributing factor to poverty alleviation. I also discuss the use of solar PV for income and work related activities, arguing that the technology may be associated with small economic productivity gains, nearly all of which are captured by the rural middle class.

Chapter four ("The solar revolution *will* be televised: An historical analysis of market-based solar electrification in Kenya") is an historical analysis of the emergence of the solar market in Kenya, and it includes a discussion of the importance of key

[14] These include dry cell batteries and automotive style batteries that are carried to town for charging at a grid connected battery charging shop as well as less commonly used technologies such as electric generators and the national electrical grid.

trends related to the development of the market ranging from solar market price dynamics to Kenyan Government investments in the expansion of television broadcast signals to rural areas during the 1980s and 90s.

In chapter five ("Cash or credit? Equity, access, and subsidies in the Kenya solar market") I use household economic survey data from the 2000 Tegemeo survey along with solar market price trends to examine the equity and access dimensions of market-based solar electrification in Kenya.

In chapter six ("Sometimes small is not enough: Intra-household allocation on a tiny energy budget") I go inside the household to unpack the relationships between household energy allocation dynamics and the social use of solar electricity, focusing especially on case studies of the gender and elder-junior dynamics surrounding the use of solar electricity for evening time studying by children, on the one hand, and lighting in the kitchen, on the other.

Chapter seven ("Solar electrification and the political economy of rural-urban connectivity in Kenya") is a political geography analysis of the linkages between solar electrification and processes of rural-urban connectivity, with an emphasis on the role that political struggles over media broadcast rights have played in shaping the significance of solar electrification in Kenya. I also include an analysis of the emerging use of cellular telephones in rural Kenya - many of which are powered using solar electricity - and the connection between their use and extended family structures that spread across rural and urban spaces. Finally, I use a closing chapter to revisit international debates about climate change mitigation, development, and solar electrification in light of my research findings from Kenya.

Chapter 1:

Small Can Be Beautiful, But There Are No Guarantees: International Debates about Solar Electricity, Sustainable Development, and Rural Energy Markets

> "Decentralization" is one of the foggiest, most often abused concepts in political language.
>
> Langdon Winner, 1986, p. 85

Solar electrification has emerged as the primary alternative to grid based rural electrification in many developing countries. This may seem a victory for "small is beautiful" appropriate technology advocates, but my research indicates that the social uses of solar energy in Kenya - which is one of the largest solar market per capita among developing countries - are far removed from the classic "small is beautiful" neo-populist vision of building small scale alternatives to global capitalism. Instead, I find that solar electrification is more closely connected to neo-liberal goals of promoting decentralized market-based approaches to service provision and of deepening the integration of rural people into world consumer goods markets.

While international support for solar electrification is often linked to concerns about the environment as well as rural poverty in developing countries, mainstream solar electrification policies are increasingly dominated by market-oriented dissemination approaches. In addition to claims about the environmental benefits of solar PV, proponents of solar electrification draw from two different "discourses of decentralization" in their call for continued donor funding for the dissemination of the technology. On the one hand, advocates often suggest that the small scale, decentralized nature of the technology make it particularly well suited for delivering electricity services to poor people in developing countries [e.g. Kaufmann, et al., 2000;

Ybema, et al., 2000; Greenpeace, 2001]. On the other, they draw from a neo-liberal ideas about the economic efficiency benefits of decentralized, market-based approaches to rural service provision [e.g. Hankins, 1993; World Bank, 1996; van der Plas and Hankins, 1998; Martinot, et al., 2002].

While this appears to suggest a convergence between Schumacher's "small is beautiful" neo-populism and market-oriented neo-liberalism around rural energy service provision and the environment, there are important contradictions between the development visions of these philosophies. In this chapter I explore the relationships between neo-populism and neo-liberalism in the context of debates about solar electrification, with an emphasis on understanding the political implications of the apparent confluence as well as the very real differences between the two lines of thinking.

I begin by noting that arguments in favor of international support for solar electrification depend heavily on claims about the development dimensions of the use of the technology, as the environmental carbon mitigation benefits - while positive - are small. I go on to argue that the convergence between neo-populism and neo-liberalism around solar PV can be understood by recognizing that while solar advocates often make claims that are reminiscent of "small is beautiful" philosophy of E.F. Schumacher [1973], the mainstream of international solar electrification policy is more strongly tied to a market-oriented discourse that subscribes to the idea that poverty alleviation is best achieved by incorporating the poor more deeply into global capitalist markets. This fusion between neo-liberal economics and neo-populist oriented expressions of concern for the poor is in direct lineage with the version of basic needs neo-populism promoted

by the World Bank under Robert McNamara in the 1970s, and it is closely associated with contemporary claims by thinkers such as Prahalad and Hart [2002] about the development benefits of globalization and the construction of an "inclusive capitalism."

> This is a time for MNCs [multinational corporations] to look at globalization strategies through a new lens of inclusive capitalism. For companies with the resources and persistence to compete at the bottom of the world economic pyramid, the prospective rewards include growth, profits, and incalculable contributions to humankind. … MNC investment at "the bottom of the pyramid" means lifting billions of people out of poverty and desperation, averting social decay, political chaos, terrorism, and environmental meltdown that is certain to continue if the gap between rich and poor countries continues to widen [Prahalad and Hart, 2002, pp. 1-2].

Thus, the key to understanding the social significance of market-based solar electrification in places like Kenya lies not in evaluating solar PV's potential as an "appropriate technology" for rural development, but rather its relationship to discourses about and the realities of the ongoing expansion of capitalism into rural areas of developing countries. At the heart of this evaluation lie key questions about the social implications of solar electrification, as well as its relationship to the promise and perils of an "inclusive capitalism" (e.g. who is to be "included", under what terms, and to what effect?). This work involves an analysis of the political stakes of policy choices, including especially the distributional access dimensions of mainstream policy approaches. At the same time, many of the processes and factors that influence the social significance of solar electrification lie well beyond the domain of policy makers. Understanding the implications of solar electrification therefore requires a broad "multi-arenas" analysis of the forces that shape the social use possibilities of the technology. Such an analysis is the work of this dissertation. I begin here with a discussion of environmental, neo-populist, and neo-liberal elements of solar electrification discourse.

Solar Electrification and Climate Change Mitigation

While solar PV is often framed as an "environmental technology" for "sustainable development," a brief analysis of the carbon mitigation potential of solar electrification in developing countries indicates that the environmental benefits are currently too small to warrant the amount of support it is receiving. As a result, justifications for donor funding rely heavily on arguments about the "development co-benefits" of the use of the technology.

The carbon mitigation benefits of household solar electrification appear to be positive, but small.[15] Several studies indicate that the use of household scale solar electric systems (e.g. 10 to 100 Wp) often results in net carbon dioxide emissions reductions on the order of 0.15 to 0.30 tonnes of CO_2 per system per year [Kaufmann, et al., 2000; Ybema, et al., 2000]. The reductions occur as solar electricity displaces fossil fuel based household energy activities, including kerosene lighting and grid based lead-acid battery charging.[16]

Data from Kenya indicate that the cost of carbon mitigation from solar electrification in on the order of $110 to $140 per tonne of CO_2 (see Table 1). This is substantially more expensive that the cost of many alternative approaches. For

[15] My analysis in this section focuses on the carbon mitigation potential of household solar electrification in developing countries, where PV systems are generally between 10 and 50 Watts. My analysis does not extend to current industrialized country efforts to promote grid-connected household solar PV systems. These industrialized country systems are almost invariably much larger (e.g. 1 kW or larger), and the overall market is substantially greater. Systems sold through this larger grid connected solar market may have considerably greater long term potential to mitigate CO_2 emissions than the off-grid developing country solar electrification efforts that I discuss here [e.g. see Duke and Kammen, 1999; Duke, 2003].

[16] The actual emissions reductions associated with grid based battery charging depends on the fuel mix of the electricity grid. In many African countries the electrical grid relies heavily on hydro-electricity, so the emissions reductions from solar use are relatively smaller than in countries where coal or oil fired power plants are more prevalent. Some lead-acid battery charging shops rely on diesel generators, and solar systems which displace this type of battery charging result in relatively higher emissions reductions. See Kaufmann, et al., 2000 for further discussion.

example, investments in energy efficiency often provide net positive economic savings as well as carbon mitigation benefits. As a result, the cost of carbon mitigation for these investments is actually negative[17] [Kammen and Pacca, 2004]. In other cases the cost of mitigation is positive, but still much smaller than solar electrification. By one estimate carbon mitigation from grid connected wind turbines that replace coal fired electricity generation can cost from - $15 to + 37 per tonne CO_2, and mitigation for the same scenario from biomass generated electricity ranges from -$17 to + $33 per tonne CO_2 [Sims, et al., 2003]. Thus, if environmental concerns about climate change were the primary motivation, solar electrification would be a lower priority than a number of alternative investments.

Table 1: Carbon Dioxide Emissions Reductions from Household Solar Electric Systems in Kenya

Solar System Size[18]	Life Cycle Cost (20 year)[19]	Lifetime Net Avoided Carbon Emissions (tonnes CO_2)[20]	Cost per Tonne CO_2
12 Watt a-Si	$350	3.1	$110
20 Watt c-Si	$500	3.6	$140
40 Watt c-Si	$600	5.0	$120

Contrary to this logic, however, the GEF has made substantial investments in developing country solar electrification projects. Martinot, et al. [2000a] report that as

[17] Kammen and Pacca [2004] estimate CO_2 mitigation costs ranging from -$35 to +$119 per tonne CO_2 from a variety of possible energy efficiency and conservation measures.
[18] The 12 Watt a-Si system includes a 50 Ahr battery, but no charge controller. The 20 Watt and 40 Watt crystalline silicon (c-Si) systems include a 50 Ahr and 70 Ahr battery, respectively, and both include a charge controller.
[19] These life cycle cost estimates are based on current (2003) prices, battery replacement every 2 years, and a 10% net discount rate. In the case of the amorphous silicon (aSi) solar system I assumed that the solar module was replaced after 10 years, while in the crystalline silicon (cSi) system cases I assumed that the module lasted the full 20 years.
[20] Carbon emissions estimates based on empirical data from Kenya presented in Ybema, et al., 2000.

of 2000 the GEF had supported 23 solar projects involving \$1.4 billion in total investments.[21] The direct GEF contribution to these projects was \$210 million, with the remainder coming from private investments as well as other donor funds. If these projects reach their combined goal of 500,000 installed household solar systems, if the investments result in average avoided emissions of 0.25 metric tonnes CO_2 per system per year over a lifetime of 20 years,[22] and if carbon trades at \$20/tonne CO_2,[23] then the total amortized value[24] of the avoided carbon dioxide emissions will be about \$21 million. Even under these optimistic assumptions, this is only about 10% of the direct GEF investment and just 1.5% of the total investment in the projects. This strongly suggests that while solar electrification may provide some level of carbon emissions reductions, the climate change related environmental benefits of the technology provide only a small portion of the overall motivation to invest.

In recent years solar advocates have also argued that household solar electric systems in developing countries should be eligible to receive credit for avoided CO_2 emissions under the Clean Development Mechanism (CDM) of the Kyoto Protocol[25] [e.g. see Kaufmann, et al., 2000; Martens, et al., 2001]. Given the difficulties associated with monitoring carbon emissions from small, dispersed solar systems as well as the transactions costs associated paying individual households for the carbon

[21] A 2003 report indicates that the total has since increased to over \$2 billion [International Resources Group, 2003].
[22] This is based on avoided CO_2 emissions estimated in Ybema, et al. [2000] for 40 Wp solar systems.
[23] Currently CO_2 emissions credits are selling in Europe at about \$10 per tonne on the future's market. However, some analysts indicate that the price may rise to \$20 or \$25 per tonne over the coming decade [Nichols, 2004; Hultman, 2004].
[24] At a 10% net discount rate.
[25] The Kyoto Protocol was negotiated during the 1990s and signed by all of the major industrialized countries in 1997. Although the United States has since withdrawn support for the treaty, countries representing 55% of the total CO_2 emissions produced by the signatory countries have ratified the treaty, and it will go into effect in early 2005 [e.g. see UNFCCC website, http://unfccc.int/2860.php].

they displace, these authors propose that solar systems should receive carbon emissions reductions credits based on a fixed formula.[26] Moreover, to simplify payment, they suggest that all of the carbon reductions for the estimated life of the system (often given as 20 years) should be credited on an amortized basis at the time of purchase. Under this arrangement, the value of the carbon credits could reach 8-12% of the initial retail cost of a solar system if the price of carbon were at $20 per tonne CO_2[27] (see Table 2).

Table 2: **Estimated Value of Carbon Credits as a Percentage of Initial Retail Cost for Household Solar PV Systems in Kenya Under Proposed CDM Guidelines**

Solar System Size	$5 per Tonne CO_2	$10 per Tonne CO_2	$20 per Tonne CO_2
12 Watt a-Si	3%	6%	12%
20 Watt c-Si	2%	4%	8%
40 Watt c-Si	2%	4%	8%

The results presented in Table 2 are significant in two ways. First, they indicate that the predicted monetary value of the displaced carbon is likely to be small, but not insignificant, compared to the overall cost of the system. Second, they show that if the price of carbon is high enough, modest subsidies can be generated from Kyoto protocol carbon trading to support solar electrification. The subsidies created from this initiative would help to reduce the cost of solar electrification to rural residents, with a resulting expansion in solar market sales. However, while rural solar system users - as well as the solar companies who sell the equipment - may benefit in the future from small

[26] The formula is as follows: Annual Carbon Emissions Credit = 75 kg CO_2 + 4 kg CO_2 X System Size (in Watts). Thus, a 12 Watt system would get an annual credit of 123 kg CO_2 and a 40 Watt system would get a credit of 235 kg CO_2.

[27] This assumes a 20 year system lifetime, a 10% net discount rate, and 2003 solar market prices. The estimated initial costs for the systems were $180 (12 Watt amorphous solar module, 35 Ahr battery, wiring, & installation), $350 (20 Watt crystalline solar module, 50 Ahr battery, charge controller, wiring, & installation), and $500 (40 Watt crystalline solar module, 70 Ahr battery, charge controller, wiring, & installation). The carbon credit calculations are based on the formula given in footnote 26, above. See Spalding-Fecher [2002] for a more detailed analysis with a slightly different set of assumptions.

subsidies under the proposed CDM scheme, the overall significance of carbon emissions reductions from rural electrification with solar energy will remain small, even in the most optimistic of scenarios.

In 2000 there were an 1.3 million solar home systems (SHS) worldwide [Nieuwenhout, 2000], out of an estimated 400 million households that lack access to grid electricity. If the use of solar electricity were to grow from its current level (about 0.3%) to reach 10% of the unelectrified population worldwide, then the associated annual carbon dioxide emissions reductions would be on the order of 9 million tonnes of CO_2. At 50% solar use among this group, annual emissions reductions would reach an estimated 45 million tonnes CO_2 [see Kaufmann, et al., 2000 for a similar set of calculations]. World carbon dioxide emissions from fossil fuel use currently total 24.5 billion tonnes CO_2 per year [IEA, 2004], so even in the most wildly optimistic of scenarios solar electrification would account for only 0.2% of this amount.

These rough calculations confirm that while solar electrification may provide a positive carbon benefit, the effect is small in comparison to the overall scope of world fossil fuel use and CO_2 emissions. This remains true even in the most optimistic growth scenarios for solar electrification. This does not indicate that the benefit is not worth pursuing, but the high cost of carbon mitigation and the small overall potential for CO_2 emissions reductions does confirm that international support for solar electrification cannot be justified on environmental grounds alone.

Many solar policy makers and advocates acknowledge this, and draw on neo-populist "Basic Needs" style arguments about poverty alleviation and rural development

to justify international support for solar electrification[28] [e.g. Kaufmann, et al., 2000; Ybema, et al., 2000; Greenpeace, 2001]. Virinder 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, et al., 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 technologies in developing countries [e.g. Covell and Hansen, 1995; van der Plas and Hankins, 1998; Martinot, et al., 2002]. Solar photovoltaic technology emerged as an important tool for rural electrification at a time when neo-liberal ideas dominated mainstream development thinking. During the late 1980s and 1990s, a period that some have called the age of "market triumphalism" [e.g. see Peet and Watts, 1993], official development policies

[28] Common claims about the development benefits of solar electrification programs include improvements in education for children, income generation and job creation in rural areas, reduction in rural to urban migration, and others [see Nieuwenhout, 2000 for a survey of claims made in the solar electrification literature]. These claims are similar to Basic Needs style development discourses from the 1970s, which emphasized the importance of poverty alleviation, reducing urban bias in development policies, and creating income generation and employment opportunities in the informal sector [e.g. see Seers, 1969; ILO, 1972; Schumacher, 1973; McNamara, 1973; Lipton 1977 for basic needs discourse and Leys, 1973; Kitching, 1989; Wood, 1986 for key critiques].

from the World Bank and other multilateral institutions emphasized economic liberalization, privatization, and decentralized, market-based approaches to service provision [e.g. Kapur, et al., 1997].

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. Given the timing of its emergence and its market compatibility, the growing trend towards market-based dissemination of solar PV technology is perhaps unsurprising.

This apparent confluence between neo-populist and neo-liberal ideals around rural energy service provision and the environment is enabled in part by solar electrification's environmental reputation in the popular consciousness. Perhaps equally important, though, is the high value placed on decentralized approaches to development in these two lines of thinking [Mohan and Stokke, 2000]. This convergence on the importance of decentralization, I contend, is at the heart of solar electrification's seeming compatibility with both neo-populism and neo-liberalism.

However, as I noted in the Introduction, this confluence also contains key contradictions. Perhaps the central contradiction is found in the core development visions of, on the one hand, Schumacher style "small is beautiful" neo-populism, with its ideal of building small scale alternatives to world capitalism, and, on the other, neo-liberalism with its goal of integrating people more closely into global capitalist markets.

The convergence between these two lines of thinking around decentralization and the contradictions between their visions of development create possibilities for confusion as well as duplicity, as the respective discourses may sound remarkably similar. This makes it critical to pay close attention to the details of the discourses as well as the realities of solar electrification on the ground.

Neo-Populism, Decentralized Development, and Solar Technology

Discourses about decentralization and small scale approaches to development have long been a part of populist and neo-populist movements in opposition to industrial capitalism. Thinkers from Robert Owen to Mohandas Ghandi, Julius Nyerere, and E.F. Schumacher have "argued…for a pattern of development based on small-scale individual enterprise both in industry and agriculture…" combined with significant redistributive mechanisms as a more humane and socially just alternative to industrial capitalism[29] [Kitching, 1989, p.19].

A related and interconnected discourse on decentralization can be found in the literature on technology and society. The linkages between these discourses is perhaps most evident in the "small is beautiful" philosophy of appropriate technology led development [Schumacher, 1973]. Schumacher's writings combine elements of neo-populist theories about small scale industries, local self-reliance, and basic needs poverty alleviation with ideas from technologists such as Lewis Mumford. The core concept that Schumacher drew from Mumford was the idea that technologies are not "neutral." That is, technologies with particular characteristics lend themselves more

[29] There are, of course, important differences among these and other neo-populist thinkers. Nonetheless, their emphasis on small scale approaches as an alternative to large scale industrialization situates them in a common lineage [Kitching, 1989].

easily to certain uses - and hence their use can offer more advantages to some people and groups than to others.[30]

Mumford [1964] contended that small-scale, decentralized technologies were more compatible with democratic decision making, while large-scale, centrally controlled technologies were more compatible with authoritarianism. Writers ranging from Schumacher [1973] to Amory Lovins [1976] and Langdon Winner [1986] drew from this line of thinking to argue that when choosing between alternative approaches for achieving the same goal (e.g. electricity generation), "society" would do well to choose "democratic technics" (e.g. solar energy) over "authoritarian technics" (e.g. nuclear energy). Nuclear energy systems, for example, are considered to be more authoritarian because they rely on the use of an extremely long lived fuel source that is highly toxic and, in some cases, could be diverted or stolen for use in manufacturing nuclear weapons. Thus, they argued that the "safe" and "successful" operation of the technology would require a highly centralized and carefully controlled mode of operation and management, heavy reliance on elite experts, and a rigid system of security. Moreover, given that the waste products remain highly toxic over thousands of years, opting for widespread use of nuclear power would require the maintenance of this highly centralized and authoritarian system over a very long time period. The use of solar energy technologies, in contrast, does not involve serious weapons

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[30] These writers were not the first (nor the last) to note that technologies are not "neutral." See (for example) Marx and Engels (ed. Arthur), [1970; original written 1846]; Williams [1974], Pacey [1983], Smith and Marx [1994], and others.

proliferation, environmental, or human health risks, and can be safely deployed through a much less centralized and controlled set of social arrangements.[31]

However, while solar energy technologies have emerged as one of the key "democratic" technologies favored by "small is beautiful" advocates [Winner, 1986], the small-scale, decentralized nature of the technology provides no guarantees for particular social outcomes - egalitarian or otherwise.[32]

> …some proponents of energy from renewable resources now believe they have at last discovered a set of intrinsically democratic, egalitarian, communitarian technologies. In my best estimation, however, the social consequences of building renewable energy systems will surely depend

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[31] There is a danger of technological determinism in these arguments, as it is all too easy to overstate the role of technology or even to assume that technological characteristics alone determine who will benefit from the use of a technology and how particular socio-historic processes will unfold. However, technological determinism is not inevitable if the argument is merely that technological characteristics are one factor among many, and that social actions by multiple people and groups - including but certainly not limited to the social uses of technology - are the driving forces of history [Winner, 1986; Willoughby, 1990]. Schumacher appears to avoid serious problems of technological determinism, although many in the appropriate technology (AT) movement that he helped to inspire arguably do not. There were, in fact, a series of debates within the AT movement about how to define what was and what was not "appropriate technology." See Willoughby [1990] for a review of this literature. Some argued that the concept "appropriate" required a situation based approach to determine what qualified. Others contended that a situational method was too amorphous and open to interpretation, arguing instead that specific technological characteristics - e.g. small-scale, locally manufactured, low capital cost, low environmental impact, etc. - provided a more "practical" set of criteria for determining which technologies were "appropriate" [Willoughby, 1990, pp. 15-24]. The latter position has strong tendencies towards technological determinism, while the former arguably avoids these problems. Given the variety of ideas, definitions, and debates surrounding the concept of appropriate technology, it should come as no surprise that there was some contention about whether solar electrification in developing countries "qualified" as AT. For example, some noted that although solar PV was undoubted small-scale as well as less polluting than many alternative approaches to rural electrification, it was neither low cost nor (in most cases) locally manufactured [Willoughby, 1990; Inverson, 1996].

[32] Schumacher and other neo-populist theorists have been criticized for a tendency to oversimplify and romanticize social relations of power within "local communities," as well as to maintain an unrealistic view of the interests of elite groups (locally based or otherwise) *vis a vis* a transition from status quo arrangements to a system characterized by small-scale, locally controlled economies that include significant levels of redistribution. A number of authors have noted that the interests arrayed against the creation of such alternative realities is substantial [e.g. see Leys, 1973; Kitching, 1989; Thomas, 1992]. Moreover, due to unequal arrangements of power at the local level, there is no guarantee that small-scale, locally based development approaches will result in greater levels of empowerment of the disadvantaged [Mohan and Stokke, 2000].Thus, while the neo-populist vision of creating small scale, egalitarian alternatives to global capitalism through decentralized development and appropriate technology may seem appealing, insufficient attention to historical realities and social relations of power - not to mention economic and institutional constraints - sharply limit the possibilities for these small scale utopias to be realized in practice.

> on the specific configurations of both hardware and the social institutions created to bring that energy to us. It may be that we will find ways to turn this silk purse into a sow's ear. [Winner, 1986, pp. 32-33]

In the end, market-based solar electrification in places like Kenya has little in common with Schumacher's goals of increasing local self-reliance and building small-scale, more socially equitable alternatives to large scale industrial capitalism. For example, while Schumacher and other similar thinkers did not reject markets per se, they did emphasize the importance of distributional equity [e.g. Schumacher, 1973; Willoughby, 1990; Greenpeace, 2001; see also Kitching, 1989]. This suggests strong support within this line of thinking for redistributive policies that counter the inherent bias of markets against people with less purchasing power. This focus on equity is at odds with the current trend within mainstream solar electrification policy towards market-based sales with "full cost recovery."

Solar Electrification and Market Oriented Policies

Although solar electrification was initially funded in the 1970s and 80s through heavily subsidized and centrally planned projects,[33] by the mid-1990s the focus was shifting decisively towards market dissemination approaches. This shift coincided with the broader move towards markets in mainstream development discourse and practice,

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[33] Early projects included electricity for water pumping, schools, and health clinics in off-grid areas, as well as household electrification in rural areas [e.g. see Hankins, 1987; Perlin, 1999]. These projects were funded through a variety of organizations, including international aid programs, national governments, and multi-lateral institutions, as well as missionary groups and non-governmental organizations. In some cases, the recipients of these projects were asked to make financial contributions to cover a portion of the initial and/or ongoing costs of the projects. Frequently, however, the full initial investment was covered through donor funding [e.g. see Perlin, 1999; Jacobson, 1999; Morgenstern, 2002; and many others]. Donor funded solar projects remain common, but their relative role in developing country solar electrification has declined substantially over the past two decades. During this time, market-based sales have emerged as the dominant approach for solar electrification.

but there are nonetheless a number of specific issues and debates in the policy literature related to solar electrification that are worth discussing.

Problems with Early Solar Electrification Projects

First, the early donor projects were criticized for having high technical failure rates. The high failure rates have been widely attributed to insufficient attention to the need for ongoing operation and maintenance (O&M) of the systems.[34] A number of solar electrification efforts took the form of "parachute projects" in which outside organizations came into a "community" to install the solar systems. In many of these cases nearly all of the investment and planning for the project was associated with the initial installation of the systems, with little or no provision for important "O&M" issues such as periodic replacement of system components,[35] skills training for locally based technicians, or end-user training for good system operation practices[36] [e.g. see Akrich, 1992; Hankins, 1993; Foley, 1995; Cabraal, et al., 1996; Jacobson, 1999; Morgenstern, 2002; and many others].

Many suggested that market-based approaches would help address the O&M issue, arguing that rural solar users who purchased systems (rather than receiving them as a "gift") would be more "motivated" to take good care of them [e.g. Nieuwenhout, 2000]. Viewed from another perspective, Morgenstern [2002] attributes maintenance problems in solar systems installed under Mexican government funded projects in part to the low

[34] However, see Morgenstern [2002] for a broader analysis of the reasons for system failures.
[35] Battery replacement in particular represents a significant ongoing cost for the systems.
[36] However, while many solar projects did not include provisions for ongoing O&M issues, some did. For example, heavily subsidized solar electrification projects implemented in the Ladakh region of India by the Social Work and Research Center (SWRC), a non-profit group associated with the Tilonia school movement of Rajasthan, provided for long term O&M by charging customers monthly fees and through the development of technical service networks. Solar systems installed through the SWRC network had good performance record over a number of years [Jacobson, 1999].

incomes of many of the recipients. That is, many recipient households were simply too poor to pay for periodic battery replacement and other O&M related costs, so many systems installed through the projects were inoperational within a few years of installation. A market approach addresses this problem through the rigid law of purchasing power and prices, as those who cannot afford to maintain a system are unlikely to be able to purchase one in the first place.

In addition to these O&M problems, the project approach was deemed economically "unsustainable" due to its heavy reliance on donor aid. During the 1980s and 90s, which were characterized by structural adjustment and austerity budgets in many countries, donor aid and subsidies became less available in a number of sectors. The energy sector was no exception, and some solar advocates and businesses saw the industry's dependence on heavily subsidized projects as a liability [e.g. see Covell and Hansen, 1995; Martinot, et al., 2002]. At the same time, in many countries a number of more established "competing" energy technologies - including the rural grid, diesel generators, and kerosene for lighting - were even more heavily subsidized than solar PV. The decline in subsidy support across the entire energy sector could therefore be seen within the solar industry as an opportunity of sorts, as it represented a "leveling of the playing field" [World Bank, 1996].

Solar Market Success Stories

The shift towards market approaches to solar electrification was facilitated by falling solar equipment prices[37] as well as a series of market "success stories" that emerged during the mid to late 1980s in the Dominican Republic, Kenya, Zimbabwe,

[37] See Figure 2.

and Sri Lanka, among others [e.g. Hansen and Martin, 1988; Hankins, 1993]. While there were important differences among these cases, there were also a number of key similarities.

First, in each of these countries a catalyst group[38] demonstrated the possibility of commercially viable private sector sales of solar systems directly to a segment of the rural off-grid population (i.e. the relatively better off). In so doing they challenged the idea that solar PV was too expensive to support an industry based on direct, unsubsidized sales to rural people in developing countries [Hankins, 1993; Covell and Hansen, 1995]. In addition, each of these groups reported relatively high success rates in terms of customer satisfaction and system performance over a number of years, thereby providing support for the claim that market sales could address the O&M issue more effectively than the projects had [Hankins, 1993]. Finally, in many cases the catalyst groups were supported in their efforts by small donor grants[39] that were used not to subsidize equipment sales, but instead to develop the respective businesses.[40] These small grants were tiny compared to the cost of fully subsidizing a similar number of solar system installations, and they therefore could be viewed by donors as a much more effective investment in terms of the number of systems installed per dollar of support [Hankins, 1993; Covell and Hansen, 1995; Martinot, et al., 2002].

[38] In some cases the catalyst groups were small or medium sized businesses, while in others they were non-government organizations that later started "spin-off" businesses [Hansen and Martin, 1988; Hankins, 1993].
[39] U.S. AID provided a number of the early small grants, including funding for solar catalysts in Kenya, Sri Lanka, and the Dominican Republic [Hansen and Martin, 1988; Hankins, 1993].
[40] Small grant monies were used by the catalyst groups for activities ranging from technical training to market studies to the capitalization of a small revolving loan program [Hansen and Martin, 1988; Hankins, 1993].

Solar Markets, Soft Subsidies, and Sales Growth

As solar sales grew and costs declined in these and other emerging solar markets during the 1990s, the role of the World Bank, the GEF, and a handful of other large donor organizations increased.[41]

> In the early 1990s, the World Bank recognized that solar-home-system technology was maturing, costs were declining, and commercial markets were developing. At the same time, population growth was outpacing the ability of electric utilities to extend rural electricity grids and developing countries were increasingly recognizing the economic difficulties of achieving full grid-based rural electrification. The World Bank and many governments began to perceive that solar home systems could provide least-cost rural electrification and could supplement grid based electrification policies... In many projects, solar home systems are but one component of a larger project with a variety of development objectives like power sector reform, rural electrification, and rural development [Martinot, et al., 2000b].

While some donor funding continued to be directed towards heavily subsidized solar projects, the focus was increasingly on the development of commercially viable markets. To this end, a growing fraction of donor aid for solar electrification was directed towards what some have termed "soft subsidies."[42] A substantial percentage of this "soft" aid has been geared towards the introduction or strengthening of market institutions such as consumer credit-based sales or quality assurance mechanisms [e.g. see Covell and Hansen, 1995; Cabraal, et al., 1996; Miller and Hope, 2000; Martinot, et al., 2002; Duke, et al., 2002; Banks, 2004; Hankins, 2004; and many others]. Thus, while international donor support for solar electrification has continued (and indeed expanded), the trend has been away from equipment subsidies and towards market-based sales that seek to achieve "full cost recovery" [Martinot, et al., 2002].

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[41] See Figure 2 for data on the world solar PV module price trend.

[42] The term "soft subsidy" generally refers to support for capacity and institution building and other non-hardware related costs [Harvey, 1996].

Although some businesses have lamented the reductions in subsidy support for direct equipment sales,[43] the shift towards market-based sales was a success for the solar industry as a whole. World developing country solar sales grew from a few thousand systems installed cumulatively by the late 1980s to an estimated 1.3 million by 2000 [Nieuwenhout, et al., 2000], and there are now established commercial solar markets in a number of countries. See Table 3 for sales data for the largest developing country solar markets.

Table 3: **Cumulative Developing Country Solar System Sales through 2000**

Country	Cumulative Solar System Sales (est. through 2000)	Population (millions, 1998)	Share of Population with a Household Solar System (%)
Kenya	150,000	29.3	2.6
India	118,000	980	0.06
China	100,000	1,239	0.04
Mexico	90,000	96	0.5
Indonesia	80,000	204	0.2
Zimbabwe	80,000	11.7	3.4
Morocco	50,000	27.8	0.9
Other Dev. Countries	390,000	1,948	0.1
Total	1,058,000[44]	4,536	0.1

Source: Nieuwenhout, et al., 2000

However, the number of solar systems installed - while important - does not tell the whole story. The distribution of solar system ownership through market-based sales appears to remain strongly skewed towards the wealthier segments of off-grid populations, raising important questions about equity and electricity access for the

[43] e.g. see Covell and Hansen, 1995 for commentary on the reluctance of some solar businesses to enter developing country solar markets without subsidy support.

[44] Nieuwenhout and co-authors estimate that the data in the table underestimate the number of small solar PV systems in developing countries by about 250,000, and that the worldwide total was therefore on the order of 1.3 million as of the year 2000 [Nieuwenhout, et al., 2000].

poor.[45] While debates in the policy literature on solar electrification have focused on consumer finance business models as a tool to expand rural electricity access [e.g. see Covell and Hansen, 1995; Cabraal, et al., 1996; Martinot, et al., 2002; Eckhart, et al., 2003; Hankins, 2004; and others], subsidies and the relationship between solar and grid based rural electrification are centrally important to the access question. These two dimensions - i.e. rural electrification subsidies and the solar/grid relationship - of rural electricity access must be understood together, as they overlap and interrelate in important ways.

Solar PV and Rural Electrification with the Grid

Advocates of solar electrification have long attributed its growth in part to the failure of grid based rural electrification to reach large segments of developing country rural populations [e.g. Hankins, 1993; Acker and Kammen, 1996; van der Plas and Hankins, 1998]. Solar is therefore often portrayed a technology that can offer the possibility of electricity, albeit in modest amounts compared to what is available from a grid connection, to rural people who would otherwise have to do without due to the failure of grid electrification.

The practical effect of mainstream policies associated with electricity sector reform, on the one hand, and solar electrification, on the other, may take this logic one step further by using solar PV as a potential replacement for grid based rural electrification in certain regions and contexts. In a number of countries - including Kenya - market-based solar electrification schemes are being implemented simultaneously with

[45] See Chapters 3 and 5 in this dissertation for further discussion of the distribution of solar system ownership in Kenya.

electricity sector privatization and restructuring programs that were initiated at least in part due to World Bank conditionality [Dubash, 2003; Karekezi, et al., 2004]. In the context of developing country electricity sector restructuring, subsidies for grid based rural electrification are often reduced or eliminated [e.g. see Dubash, 2003; Williams and Dubash, 2004]. The simultaneous support for solar electrification by the World Bank and other multilateral funding agencies may therefore represent an attempt to replace heavily subsidized grid based rural electrification with unsubsidized (or at least less subsidized) market-based schemes using solar PV.[46]

It should come as no surprise, then, that some have criticized solar electrification as "2nd class electricity."[47] These critics suggest that solar electrification is being pushed by governments and multi-lateral agencies such as the World Bank who are seeking to roll back the promise of grid based rural electrification [e.g. Annecke, 2002; African Ministerial Meeting on Energy, 2004]. The prevalence of this critical perspective varies from one developing country to another, and it appears to be linked strongly to the politics and possibilities for grid based rural electrification within the country. For example, in South Africa there is significant criticism and resistance to plans to electrify some rural areas with solar PV rather than the grid, as grid power is viewed by many as an entitlement as well as a real possibility [e.g. Annecke, 2002]. By contrast, in Kenya

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[46] I thank Rebecca Ghanadan for this insight.

[47] Solar PV is often viewed as inferior to the grid in large part because the amount of electricity available from the standard household solar system (e.g. 40 Watts) is tiny compared to the amount that is available through a grid connection. Standard solar PV systems can power a few lights as well as appliances such as TVs and radios, but they cannot power many of the appliances that are often used in grid connected homes (e.g. electric irons and cookers). In addition, while a grid connection can deliver sufficient power for farm related applications such as water pumping or power tools, the standard household solar system cannot. See Chapter 2 for further discussion of this issue.

few rural people appear to have much hope of receiving grid electricity,[48] and solar PV is viewed more favorably (especially by those who can aspire to afford it) [e.g. Acker and Kammen, 1996; van der Plas and Hankins, 1998].

Neo-liberalism,[49] Decentralization, and Solar Electrification

The link between electricity sector reform and solar electrification suggests a potential rational for neo-liberal support for solar PV in developing countries. As suggested above, solar electrification's appeal to neo-liberal oriented policy makers may be closely linked to the potential to use solar technology to realize unsubsidized - or at least less subsidized - rural electrification in developing countries. Rural electrification has historically been carried out primarily through the extension of the national electrical grid to rural areas, and these efforts have almost always involved large subsidies.[50]

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[48] See Chapter 4 for further discussion.

[49] Neo-liberalism is based largely on neo-classical economic theory, and it is similar to *laissez faire* economic liberalism from the 19th century. This line of thinking centers on the idea that markets are always better (i.e. more efficient) at allocating resources than government bureaucrats. Therefore, resource allocation should be left primarily to markets, and the role of the state in markets should be minimized [Lal, 1985]. One of the most frequently repeated ideas of neo-liberalism is that efficient allocation depends on "getting the prices right." This entails eliminating subsidies that may "distort" price incentives as well as removing any other "barriers" to the free exchange of goods or services. This strong pro-market, anti-state intervention agenda contains within it a certain type of push towards decentralization. This is true in the sense that under a neo-liberal framework, resource allocation decisions are intended to depend as much as possible on the actions of private actors operating in a market setting rather than the decisions of government bureaucrats. See Lal [1985] and Williamson [1993] for influential contemporary articles on neo-liberal thinking on development.

[50] See, for example, Brown [1980] for a discussion of the role of subsidies for rural electrification in the United States. Historically, household electricity has been treated in part as an entitlement in many countries. Policies that provide subsidies on the cost of electricity and/or connection fees for low income customers are part of this legacy. In some cases these subsidies are paid directly from general government revenues, but often the funds are generated through a "cross-subsidy" in which the rates paid by the general customer base cover the cost of the subsidies for low income customers. Steps that effectively reduce or eliminate subsidies to low income and rural customers are part of a trend towards treating electricity less like an entitlement and more like a commodity. See Dubash [2003].

Rural grid extensions are often unprofitable (i.e. they require subsidies),[51] and as a result electric utilities are often unwilling or unable to expand their grid to reach rural customers in the absence of significant subsidy support that is specifically earmarked for this purpose. In many rural areas solar electrification is substantially less expensive in terms of the cost per household receiving service than rural electrification through grid extensions.[52] Solar PV's lower cost per household creates the possibility for rural electrification without - or at least with substantially reduced - subsidies. In the era of structural adjustment and fiscal austerity, this possibility may appear highly attractive to policy makers with limited budgets.

Solar electric systems are further compatible with approaches favored by neo-liberals because they can be distributed through decentralized, market-based channels. This approach to rural electrification can be used to bypass centralized electric utilities, which are often characterized as being corrupt and inefficient.[53]

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[51] This is true in part because of the high cost of delivering power lines to dispersed households and communities, and in part because rural customers usually use relatively small amounts of electricity even when they are connected to the grid.

[52] This is true largely because, unlike a grid system which involves centralized electricity generation and a network of electrical distribution lines, decentralized solar PV systems generate small amounts of electricity on site at individual homes. As a result, with solar electrification there is no need to invest in a costly grid distribution network. However, while the cost per household for solar electrification is relatively low, the amount of electricity available from solar PV systems is very small compared to the amount available in grid connected homes. See Chapter 2 for further discussion of this issue, including cost data from Kenya for the respective technologies (Table 5).

[53] This characterization appears to be accurate in some - though certainly not all - countries. For example, Kenya's government run rural electrification program has a history of corruption, embezzlement, and politicized decision making [e.g. see Walubengo, 1992; Mwangi, 2003; East African Standard, 2004]. However, this does not mean that centralized approaches should be abandoned altogether or that market-based approaches are not without their own sets of problems. For example, Dubash notes that "In many cases the problems (with corruption and efficiency problems in centralized public utilities) lie less in an inherent weakness in the approach and more in a failure to successfully implement the public utility approach as it was practiced in the north." [Dubash, 2003, p. 144]. In other words, corruption and efficiency problems are an issue of management and governance, and do not necessarily represent a flaw in the centralized public utility institutional approach.

"Revised" Neo-Liberalism and Subsidies for Market Development

Perhaps because solar PV offers the possibility of unsubsidized rural electrification in the future, many neo-liberal policy makers at the World Bank, the GEF, and elsewhere favor limited subsidies for the development of solar market institutions in the present.[54] In other words, although solar electrification may create the potential for economic efficiency gains through lower per household costs and a decentralized, market-based dissemination approach, realizing these gains may require investments in "market development." This approach is part of a larger shift in the late 1990s within neo-liberal thinking towards what some have termed the "new institutional economics" (NIE)[55] [e.g. see Harriss, et al., 1995 and Bardhan, 1989] and what others have called "revisionist neo-liberalism" [e.g. see Mohan and Stokke, 2000].

From a policy perspective, this suggests that limited interventions aimed at introducing new institutional arrangements or "improving" existing ones can be used to increase market efficiency. Correspondingly, policy literature emanating from the World Bank and other groups that have adopted NIE thinking are filled with references to market "barriers" that must be "overcome" through policy measures geared towards changing market institutional arrangements [e.g. see World Bank, 1996; Martinot, et al., 2002].

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[54] However, there continues to be some debate on these issues. For example, Barnes and Halpern [2000] of the Energy Sector Management and Assistance Project (ESMAP) - a joint project of the UNDP and the World Bank - argue for targeted subsidies (including equipment subsidies) that assist the poor to gain access to rural energy services.

[55] NIE thinking builds on a neo-classical economics foundation, but it differs from "classic" liberal and neo-liberal interpretations in its acknowledgement of the roles of transactions costs and imperfect (and often asymmetrical) information in shaping economic outcomes. Importantly, NIE theorists recognize that markets do not necessarily produce pareto optimally efficient outcomes due to transactions costs and information problems [e.g. see Akerlof, 1970; Hodgson, 1988; Bardhan, 1989; Harriss, et al., 1995; for an overview of the literature]. Pareto optimal efficiency is defined as an allocation of resources in which the condition of any one individual cannot be made better without making the condition of someone else worse.

The solar policy literature is no exception to this trend. Perhaps the central thrust of solar policy over the past decade has been towards the previously mentioned "soft subsidy" support for "market development" efforts. These involve the introduction or strengthening of key market institutions such as credit-based sales or quality assurance mechanisms [e.g. see Covell and Hanson, 1995; Cabraal, et al., 1996; Miller and Hope, 2000; Martinot, et al., 2002; Duke, et al., 2002; Banks, 2004; Hankins, 2004; and many others]. The Photovoltaic Market Transformation Initiative (PVMTI), which began in 1998 and earmarked $30 million for solar market development in India, Morocco, and Kenya, is a classic example of a NIE inspired solar project.[56]

Thus, neo-liberal support for rural electrification with solar PV appears strongly tied to the potential for economic efficiency gains relative to grid electrification. From this perspective, these gains are to be achieved through cost saving on a per household basis, as well as through the shift from centralized government subsidized rural electrification through grid extension to a decentralized, market-based approach with solar.

Solar electrification, expanding markets, and "globalization"

In addition to economic efficiency gains, solar electrification is linked to the neo-liberal goal of incorporating rural people more deeply into the "marketplace." Rural electrification programs have long played a role in these processes, in part through requiring users to pay regular bills for service as well as through the purchase of electrical appliances [Bose, 1993; Caron, 2002]. Some solar electrification schemes do not require monthly payments as the systems are purchased outright by end users,[57] but

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[56] See Chapter 5 for further discussion of the PVMTI project.

[57] "Fee-for-service" and credit-based solar electrification schemes do require regular bill payments, and these arrangements are increasingly common around the world. For example, Sri Lanka has a growing

the widespread use of solar electricity for "connective" applications such as television viewing indicates another path for rural residents to become more deeply involved in consumer markets.[58] Expanding consumer markets to rural areas through media advertising has obvious benefits for businesses that have the potential to sell products in these locations.

Neo-liberals argue that there are important welfare gains for rural populations associated with a greater participation in the market system [e.g. Lal, 1985; Williamson, 1993; Prahalad and Hart, 2002]. However, a greater dependence on market transactions does not guarantee increasing welfare, and quite the opposite can be true. For example, for many poor people the transition from having at least some access to subsistence farming to complete reliance on labor markets for income, as well as food and consumer goods markets for consumption, can involve a significant increase in economic insecurity.[59]

Markets are a double edged sword. They can be full of opportunity for those who have the means to take advantage of them. At the same time, they are unforgiving of those who do not have sufficient purchasing power. Sen [1999] notes that people's

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solar market-based primarily on credit sales [Caron, 2002] and companies in South Africa, Zambia, Argentina, Honduras, and elsewhere have initiated "fee-for-service" arrangements in which the "solar utility company" retains ownership of the solar equipment and charges the end users a monthly fee for the electricity [Banks, et al., 2000; Gustavsson and Ellegård, 2004; ISES, 2001a and 2001b]. The Kenya solar market is based primarily on cash sales, although credit arrangements have grown in importance in recent years. See Chapter 5 for further discussion.

[58] Although the use of television in rural areas of developing countries does not have a set of fixed "effects" [Wilk, 2001], several studies have documented a connection between television viewing and increased interest in purchasing consumer goods [e.g. Miller, 1998; Reis, 1998].

[59] This statement is not meant to romanticize subsistence agriculture or pre-capitalist forms of production. Peasant family farming in feudal societies nearly always involved significant hardship, insecurity, and coercive relationships with landowners. Nonetheless, complete dependence on markets may result in an increase in hardship and insecurity for many, especially during difficult or volatile economic times [e.g. see Polanyi, 1944; Scott, 1976; Meiksins-Wood, 1999; and many others].

ability to use markets to their advantage depends critically on their "endowments and capabilities" - or in other words the power that they bring to the market. In addition, a number of authors criticize both "classic" and "revisionist" (i.e. NIE) neo-liberalism alike for neglecting the roles that social relations of power between market participants play in shaping social and economic outcomes. In other words, the power that some people seek to exercise over others, as well as counter-moves of resistance influence market transactions in important ways [e.g. Hart, 1986 and 1992a; White, 1993; Watts, 1994; and others].

Understanding the role that power plays in markets, including purchasing power as well as social relations of power, requires attention to the specific historical and geographical conditions that shape the possibilities and limits of economic action by market participants. For example, the purchasing power that determines access in the Kenya solar market is closely linked to decades old processes of rural middle class formation,[60] and purchasing decisions within rural households are often heavily influenced by gender and elder-junior power relationships among family members.[61]

In summary, neo-liberal market-based approaches to rural service provision - revised increasingly according to NIE analysis - play a central role in shaping solar electrification policy at key groups such as the World Bank and the GEF. The decentralized, small scale nature of solar technology is particularly amenable to these approaches. Solar PV is compatible with neo-liberal policies because of its perceived potential to increase economic efficiency and its compatibility with a decentralized,

[60] See Chapter 3 for further discussion.
[61] See Chapter 6.

market-based approach to rural energy service provision. Moreover, "connective" social uses of solar electricity such as increased rural television viewing appear to be compatible with the neo-liberal goal of global economic integration. However, the neo-liberal perspective tends to ignore the equity implications of the market approach to rural service provision, and it also neglects the critical roles that context specific social and political processes - including power relationships - play in shaping the market dynamics and social uses patterns of solar electrification.

Discourses of Decentralization and Neo-populism from "the Right"

Neo-populism has long had an ambiguous and complicated relationship with capitalism. One the one hand, neo-populism is often associated with thinkers such as Julius Nyerere and E.F. Schumacher who favor small scale alternatives to mainstream capitalism. As discussed previously, in recent decades neo-populists in this tradition have focused especially on the potential of small scale schemes to achieve high levels of productivity, contending that a small scale approach to capitalism that included properly designed poverty alleviation schemes (e.g. informal sector employment or labor intensive agricultural development programs) could deliver a form of capitalism "with a human face" [e.g. ILO, 1972; Schumacher, 1973]. Importantly, although market-oriented approaches are typically associated with economic liberalism, neo-populists like Schumacher did not oppose markets per se, but rather they opposed centralized, large scale industrialization in both its capitalist and socialist forms [Schumacher, 1973; Kitching, 1989]. In other words, classic neo-populism did not break with capitalism outright, but rather suggested that small scale approaches provided an opportunity to create a more humane alternative version of capitalism.

On the other hand, scholars have noted that people and groups working to promote the expansion of mainstream global capitalism have often combined neo-populist rhetoric with limited policies aimed at poverty reduction and social protection in order to soften the harsh realities of market-based capitalist development [Polanyi, 1944; Cowen and Shenton, 1995]. Thus, while neo-populist thinking is often associated with attempts to create alternatives to global capitalism, neo-populism has also been used powerfully by forces within capitalism to soften it just enough to allow for the continued expansion of capitalist markets [Peet and Watts, 1993].

For example, while the "Basic Needs" concept of development emerged from the ideas of "left leaning" neo-populists during the 1970s [e.g. Seers, 1969; ILO, 1972; Schumacher, 1973], the World Bank, U.S. AID, and other similar groups adopted some aspects of the original Basic Needs approach and adapted them to fit their mainstream pro-capitalist agenda [e.g. see McNamara, 1973; Chenery, 1974]. In the end, the World Bank - not E.F. Schumacher or others in the left leaning camp - was the largest and most influential player in the Basic Needs development debates of the 1970s [Wood, 1986].

However, despite great fanfare about their commitment to poverty alleviation, support for small scale producers, and "growth with redistribution," the actual changes in World Bank aid and lending in the 1970s relative to the strongly pro-industrial growth policies of the 1950s and 60s were quite modest [Wood, 1986]. In addition, even those policies that were specifically geared towards the Basic Needs approach did less to help the rural poor or to alter the distribution of wealth than was advertised. For example, "green revolution" agricultural technologies that were introduced in the 1960s

and funded heavily in the 1970s were widely touted by the World Bank and others as a major component of the Basic Needs strategy to address rural poverty in developing countries [e.g. see McNamara, 1973; Chenery, 1974]. The contention was that "green revolution" technologies could be used to increase the productivity of small holder farmers, and that they therefore contributed to poverty alleviation. However, in most developing countries land owning small holder farmers are significantly better off than the large majority of the rural population, many of whom are landless [Wood, 1986, pp. 223-231]. Thus, while "green revolution" technology deployment was framed as a major poverty alleviation effort, a small and relatively well off fraction of the rural population was in a position to capture most of the associated productivity benefits. Ultimately, while the World Bank and others placed major emphasis on a neo-populist, small-scale development approach in their *rhetoric* during the 1970s, their lending patterns and policies during this period did not represent a significant departure from the central agenda of supporting the expansion of large scale global capitalism.

Mainstream policies for the promotion of solar electrification - while much smaller in scope and significance than the green revolution - can be seen in a similar light. That is, while arguments in favor of solar electrification may sound remarkably similar to "small is beautiful" neo-populist arguments from the left, the core policies remain deeply rooted in market-oriented approaches linked to the larger project of global capitalist expansion.

From this perspective, support for solar electrification among mainstream development agencies (e.g. the World Bank) may be seen in part as one small part of an emerging (or rather re-emerging) populist discourse from the right. Neo-liberalism, the

process of "globalization," and free market approaches have come under increasing pressure to address issues of the environment, equity, and social justice [e.g. Peet and Watts, 1993; Danaher, et al., 1994; Wade, 1997; Rich, 2001; see also Aninat, 2001 as a example of a populist response to this pressure from within the IMF]. Solar energy's reputation as an "environmental technology" that can be used for "sustainable development" and poverty alleviation make it a powerful symbolic tool for constructing an image of "globalization" that appears to be inclusive of the poor and sensitive to environmental issues. Thus, in the face of public pressure, neo-liberals at the World Bank, the G-8, and elsewhere may draw from neo-populist and environmentalist rhetoric and policies to diffuse and weaken criticisms - or in other words, to limit the effectiveness of the counter-movement seeking to contain market expansion. These right leaning groups may therefore support rural electrification using solar energy in part for the associated image benefits for their institutions in particular and for the market expansion aspects of globalization in general. The fact that solar electrification is simultaneously compatible with market-based approaches to rural service provision and expanding consumer markets to rural areas may make it doubly attractive.

This does not mean that solar PV systems are merely a "neo-liberal technology" in the broader process of "globalization," as the social significance of a technology cannot be controlled by any one agenda or group. It does mean, nonetheless, that understanding the social significance of solar PV in places like Kenya is closely linked to analyses of market-oriented solar electrification policies employed by groups ranging from the World Bank to the Kenya Government.

Here the distributional dimensions of market-based service provision are a central issue. This does not mean that markets do not have their merits, as the efficiency gains associated with this approach can be very real. However, the economic efficiency of unsubsidized rural electrification - whether through solar PV, the grid, or another technology - can have very real costs in terms of equity and electricity access for the poor and otherwise disadvantaged. This highlights the importance of analyzing the distributional dimensions of public policy choices, where subsidies can have the effect either of reducing the inherent pro-wealthy bias of markets or of reinforcing existing inequalities.[62]

While these policy questions are critically important, understanding the social significance of solar electrification goes well beyond issues of equity and access. It is also, of course, closely tied to the social uses of the technology. In the section that follows I outline the "multiple arenas" framework that I use in this dissertation to analyze the forces that shape the social use possibilities of solar electrification in Kenya.

Solar Electrification and the "Multiple Arenas" Framework for Analysis

The multiple arenas framework is built around the understanding that processes of social change are shaped by multiple forces that come together to "…set limits and exert pressures…" on people's ability to act in the world [Williams, 1974, p. 124; see also Williams, 1977; Hart, 2002]. This approach therefore involves analyses that view

[62] See Barnes and Halpern [2000] for a discussion of subsidy approaches that seek to increase energy access for low income groups.

human actions as the driving forces of history, even while recognizing that our agency is constrained by historical realities and the actions of others.[63]

In an analysis of the role of technology in processes of social change, this framework of course involves an explicit rejection of technological determination (i.e. the idea that the "effects" of the creation and use of a technology are given, though perhaps not always foreseen, regardless of existing social arrangements or processes). It also requires a rejection of the equally mono-causal error of viewing the technology/society relationship in terms of "determined technologies" [Williams, 1974; p.7]. This is the misconception that the creation and use of technologies is entirely determined by the prevailing dominant forces – and that the effects of the use of a technology are therefore set by the intentions of those within the dominant group. While these two problems of "technological determinism" and "determined technologies" are at opposite extremes with respect to their views on the chain of causality between technologies and social consequences, they share a common thread in that they rely on a simplistic and singular concept of determination.

Instead, the multiple arenas framework draws from the concept of "over-determination" (i.e. "determination by multiple factors") to analyze social processes, including but certainly not limited to the social use of technologies [Williams, 1974; Williams, 1977, pp. 83-89]. Here the key concept, in addition to the obvious statement that multiple forces are involved, is that social structures and existing realities matter,

[63] A foundational statement related to this concept is found in Marx's famous remark that "Men make their own history, but they do not make it just as they please; they do not make it under circumstances chosen by themselves, but under circumstances directly encountered, given and transmitted from the past." [Marx, 1963 (original 1852), p. 15].

but they do not set the course of history in any rigid or wholly controlling way. In the words of Raymond Williams,

> …the reality of determination is the setting of limits and the exertion of pressures, within which variable social practices are profoundly affected but never necessarily controlled. We have to think of determination not as a single force, or a single abstraction of forces, but as a process in which real determining factors – the distribution of power or of capital, social and physical inheritance, relations of scale and size between groups – set limits and exert pressures, but neither wholly control nor wholly predict the outcome of complex activity within or at these limits, and under or against these pressures. [Williams, 1974, p.124]

In other words, technologies are created and used by people on complex and contested ground, and the implications of the use of technologies cannot be understood based simply on the characteristics of the technologies nor from the intentions of dominant social forces. Instead, the implications of the use of technologies can be understood only by situating them in the context of broader socio-historical processes and struggles, where multiple forces come together to influence the social use possibilities of the technologies. This concept embraces the complexity of history without reducing it to an unknowable or "undetermined" process.[64]

[64] The application of the multiple arenas framework to the analysis of the role of technologies in processes of social change contrasts with the concept of "soft technological determinism," which has emerged in the scholarly literature over the last few decades [e.g. Heilbroner, 1967 & 1994; Rosenburg, 1994; Castells, 1996]. The soft technological determinism concept depicts history as a complex and 'multivariate' process, and it accepts human agents as the primary actors. At the same time, authors within this line of thinking conclude that technological innovation and the use of technology are the central forces driving socio-historical change [Smith and Marx, 1994]. The key for examining these claims lies in the concept of determinism that is employed by each author. The danger is that in framing a complex historical process, one may *a priori* favor technological factors over others, and therefore over-estimate the role of technology. Castells, for example, in the process of concluding that the emergence of information technology in the 1970s and 1980s was the single most important force shaping change in the 1990s (and beyond), describes socio-historic processes as "half-conscious" and "undetermined." That is, in the face of complexity he suggests that we cannot know precisely which factors were the most important, even as he concludes that technology is the key [Castells, 1996; see especially p.52].

The multiple arenas approach combines this concept of "over-determination" with key concepts from social geography to allow for an analysis that explicitly includes both socio-historical and socio-spatial dimensions. At the center of the spatial aspect is an emphasis on viewing a "…place not as a bounded unit, but as always formed through relations and connections with dynamics at play in other places, and in wider regional, national, and transnational arenas" [Hart, 2002, p. 14]. That is, while social actions always take place in "local places," these localities are not bounded in any rigid way, but instead are connected to processes and forces from other places through social relations that are stretched across space [Massey, 1994]. This socio-spatial dimension of the framework is particularly important because it moves beyond vague notions of abstract "outside factors" that "impact" local actions through one way transactions. Instead, the focus is on identifying specific socio-spatial processes and relationships that are important to the analysis.[65]

In addition to the multiple arenas framework, I draw from new ideas about the concept of access in making my analysis. While the issue of access is not all defining, it is a centrally important element contributing to the social implications of solar PV technology in particular and rural electricity more generally. Traditional definitions of access focus on ownership and use rights. In the case of electricity, access is generally defined in terms of grid connections - and the corresponding rights to use electricity

[65] Standard conceptions of "economic globalization" and its "impact" on "the local" provides a classic example of the dangers of thinking in terms of abstract "outside factors." Hart [2002] notes that this conception suggests the existence of abstract but active technological and market forces that somehow roam the globe to impact passive localities. This framing of globalization is problematic both because it does not allow for a clear identification of the socio-economic processes and relationships that constitute contemporary capitalism, and also because it treats people in "local places" as passive participants with no agency to influence the course of history.

from the grid - or in terms of the ownership of equipment that can be used to generate electric power (e.g. a generator or a solar system). However, while property and use rights are centrally important to the question of access, they are not the whole story.

Ribot and Peluso define "access" as "…the *ability* to derive benefits from things…," where the focus on the *ability* to access things rather than on access *rights* broadens the definition of access beyond classic framings in the property rights literature to include "…a wider range of social relationships that can constrain or enable people to benefit from resources without focusing on property relations alone." Under this definition "access…is more akin to a 'bundle of powers' than to property's notion of a 'bundle of rights'." [Ribot and Peluso, 2003; pp.153-154; emphasis in original].

This definition of access allows for a broad examination of the various processes and factors that influence the dynamics of rural electricity access in Kenya. Among rural households purchasing power is a centrally important factor governing access to most electricity technologies, including solar electric systems. Nonetheless, a number of other processes, relationships, and factors influence electricity access. For example, the quality and performance of solar electric systems influences people's ability to use them effectively. That is, the performance of equipment sold in the market, the availability of high quality technical support services, and the accessibility of information about proper system operation practices all contribute to the level of access to electricity for those people who do own a system.

Combining the multiple arenas approach with Ribot and Peluso's theory of access provides a framework for moving beyond the many studies of the social use dimensions

of solar electrification that focus almost exclusively on the household as the primary unit of analysis[66] to research that goes both "inside" and "beyond" the household.

Inside the household levels of electricity access may differ substantially from one person to another according to the household dynamics of energy allocation. These dynamics - which have been largely overlooked in the academic and policy literature on solar electrification - can include important gender and elder-junior dimensions, and they are centrally important to the processes that determine the social implications of electricity use in the home.

Looking beyond the household, we find that the people who use solar electricity are not the only ones with an interest in solar electrification. Groups ranging from corporate businesses who advertise on television and radio to the urban based relatives of families who use solar PV have a stake in the way that solar electrification unfolds. All of these people and groups must be included in analyses of solar electrification in order to capture the full picture.

However, it is not enough to simply identify those who have an interest in solar electrification. Beyond the household there are a number of social, economic, and political processes that influence the social use possibilities of solar PV. These range from long term processes of rural development and middle class formation that determine which families have the purchasing power to buy a system, to the market dynamics of solar equipment price and availability, to the politics of media broadcasting and regional reach. While these processes may appear to be separate from one another, they constitute a set of overlapping "arenas" that are all linked to solar electrification. It

[66] See Nieuwenhout, et al., 2000 for a review of the literature. See also Chapter 6 in this dissertation.

is the confluence of socio-economic dynamics, political struggles, and everyday processes in these multiple arenas that come together in a particular time and place to set the stage on which the social uses of the technology by end-users take place.

For example, the intra-household energy allocation dynamics that I describe in chapter 6 play a centrally important role in defining the social uses of solar electricity, but they cannot be viewed in isolation. Long term historical processes of rural development and middle class formation as well as the market dynamics of solar equipment price and availability are key determinants of which households can actually afford to buy a system and - for those that can - how large that system will be (see Chapters 3 & 4). Thus, issues of wealth and class overlap with market dynamics, the gender and elder-junior dimensions of intra-household allocation, and technical issues related to solar system size and performance to influence the "terrain" on which social use decisions take place.

Given the complex terrain that is created by all of these processes, actions, and events, a number of different social use trajectories are possible in different geographical and historical contexts, and no one person or group is in a position to control the outcomes. At the same time, not all paths are open and it is important to recognize that each process may create constraints that limit the range of possibilities. In other words, in analyzing the social implications of solar electrification it is important to strike a balance between - on the one hand - the overly structuralist idea that only one set of social uses is possible (i.e. the that the social uses of solar PV are pre-given), and - on the other - the overly agency oriented idea that any range of social uses is possible [Hart, 2002]. Of course, this recognition of complexity and multiple

possibilities does not mean that common social use patterns will not emerge from one place to another. Indeed, commonalities in the processes and conditions shaping the social use possibilities of solar technology can lead to significant similarities. However, these similarities cannot be assumed *a priori*, as historical and geographical specificity can also lead to key differences.

In making my analysis of these overlapping processes in multiple arenas, I break with the neo-liberal conception of the state as being separate from and antagonistic to the workings of markets. Instead, I draw from both Polanyi [1944] and Gramsci [1988] to view the state, markets, and society as one deeply interconnected whole.[67] Stated simply, markets cannot function without government. The real question is not one of whether states should intervene in markets or not, but rather what sorts of market interventions are desirable, which are not, and - given that market transactions and relations invariably involve conflicting interests - in whose interests the government should intervene (or not). These political questions - which involve balancing issues of economic efficiency, equity, redistribution, and others - cannot be separated from the economic functioning of markets. The linkages between state and market are present even in cases where direct interventions appear to be minimal, as is true in the Kenya solar market, as government policies may play an important indirect role in shaping market development. This is certainly true in Kenya, as I outline in chapters 3 and 4.

Importantly, while solar policy makers may be in a position to influence some of the processes that shape the social significance of solar PV (e.g. the market dynamics of access), other processes may lie largely beyond their reach (e.g. intra-household energy

[67] See also Hart [2002] and Burawoy [2003].

allocation or broadcast media politics). Nonetheless, in order to maximize the effectiveness of policy as well as to comprehend its limits, it is important to understand not only those processes that are more easily influenced but also others that are not.

Finally, although I have focused on outlining a framework for analyzing the social, economic, and political dynamics that influence the implications of solar technology use, its technical characteristics are not unimportant. As students of the social use of technology from Marx to Mumford and from Schumacher to Winner have noted, technical characteristics play a central role in shaping the range of possible uses. In chapter 2 I discuss the technical dimensions of household solar electric systems in order to understand the capabilities and limits of the technology. I also work to situate the use of solar PV in the broader setting of rural electricity, where solar is only one of several important technologies.

Chapter 2

Rural Micro-Electricity Basics

Solar electric systems are often treated as a "special" technology in international debates because of their environmental characteristics, but to rural Kenyans they are just one option among several "micro-electricity" technologies.

Veronica and Peter Wamalwa, for example, use a 12 Watt solar module and a battery to power a black and white TV, a radio, and one fluorescent light in their home in rural Kenya. The solar module, however, does not provide as much electricity as they and their two children would like, so they also charge the battery from time to time by putting it in Peter's taxi while he is driving customers on his daily route. In addition, they use kerosene for lighting in the four rooms of the house where they do not yet have electric light, as well as dry cell batteries for a flashlight and a small radio. Veronica is a school teacher and her husband Peter drives the collective taxi, so they have two incomes to pay for these energy costs.

However, their neighbors - the Wanambisi's - have not been able to pull together the cash to buy a solar module. Instead, to power their TV, they use a car battery that their son takes to town about once a week for charging at a grid connected battery charging shop. They use kerosene for lighting and dry cell batteries for a radio and a flashlight.

A kilometer away, the village pastor - a relatively wealthy man - and his family enjoy the services of a larger 80 Watt solar system. They have solar powered electric lights in every room as well as a TV and two radios. They also have a gasoline powered generator that they use to operate a well pump as well as to charge the solar system battery if the need arises. And, of course, most of the families in the area are too

poor to buy a solar system, a car battery, or a TV set. They rely entirely on kerosene and candles for lighting, and their access to electricity is limited to dry cell batteries for radios and flashlights.

These brief descriptions highlight the diverse range of micro-electricity and lighting technologies used by rural Kenyans, as well as important differences in energy use between higher and lower income households.

In this chapter I situate the use of solar technology among these other rural energy options, including automotive style lead-acid batteries that are charged using grid electricity and disposable dry cell batteries.[68] In addition, I compare the use of these "micro-electricity" technologies to household energy use for those fortunate enough to be connected to Kenya's rural electrical grid.

As I will explain below, the amount of energy available from the micro-electricity technologies used in Kenya - including solar systems - is very small compared to the amount available through grid electrification. On average, grid connected homes in rural Kenya are able to use about 15 times more electricity than "solar" households. This influences the potential uses of the respective technologies in important ways. The small amounts of electricity from solar systems are generally used in four main applications: television, lighting, radio, and cellular telephone charging. Household appliances that are often used in grid connected homes - e.g. electric irons, cookers, and refrigerators - remain out of reach for solar users, as they require too much energy.

[68] Cooking energy is not included, as it is beyond the scope of the current analysis. Most rural families depend largely on firewood for cooking, although wealthier families sometimes also use charcoal, kerosene, or LPG.

While grid connected homes have access to substantially more energy, many authors have noted that electricity tends to have diminishing marginal value, and that small amounts of electricity are often valued highly by those who have limited access to the resource [e.g. Jacobson, et al., 2005]. Thus, while the energy production by solar electric systems may be limited, the significance of solar PV should be evaluated based on the social uses of the technology rather than on energy production values alone.

Household Solar Electric Systems

A typical solar electric system in Kenya consists of a solar module (which converts solar energy into electricity), a battery[69] (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 additional components, such as a charge controller,[70] an inverter,[71] or a DC to DC converter.[72] See Figures 3 and 4 for images of a typical solar electric system during the day and at night, respectively.

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[69] See Appendix A for additional information about solar modules and batteries. In addition, see Jacobson, 2002c and 2002d.

[70] 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 their batteries considerably. Data from several surveys indicate that about 10% to 20% of solar systems in Kenya include a charge controller [Hankins, et al., 1997; Jacobson 2003 survey]. See also Jacobson, 2004a.

[71] 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 operate appliances such as color TVs that are frequently available only for use with AC electricity. Most of the appliances used with solar electric systems in Kenya are compatible with DC electricity, and the use of inverters is relatively rare. About 5-10% of household solar systems in Kenya include an inverter [Jacobson 2003 survey]. See also Jacobson, 2004b.

[72] DC to DC converters are inexpensive devices used to reduce the battery voltage 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. An estimated 40% to 50% of "solar" households in Kenya use a DC-DC converter [Jacobson 2003 survey].

Figure 3: **Solar electric system during the day.** The solar module is on the roof, and a wire delivers the electricity to the storage battery which is located inside. An arrow indicates the flow of electricity into the battery during the day. (image by Michael Okendo)

Figure 4: **Solar electric system at night.** An arrow indicates the flow of electricity from the battery to power the light. (image by Michael Okendo)

Micro-Electricity in Rural Kenya

Solar electric systems are only one of several energy technologies that rural Kenyans use for electricity and lighting applications. Table 4 shows the percentage of households that use each of the main technologies available in rural Kenya. These data show that while kerosene lighting and dry cell batteries are widely used, solar power, the electrical grid, and lead-acid battery based systems are available to a smaller fraction of the population. Nonetheless, the fact that the number of households that use solar electricity is essentially equal to those with grid electricity access indicates the growing importance of solar technology. Lead-acid battery systems are even more common, with usage rates that are about three times as high as solar and the rural grid.

Table 4: **Access Levels for Five Energy Technologies in Rural Kenya**[73]

Technology Type	Rural Households with Access (%)
Solar Electric System	4.2%
Rural Grid Connection	4.3%
Lead-Acid Battery System	12.4%
Dry Cell Batteries	72.4%
Kerosene Lighting	91.6%

Sources: for grid, solar, and lead-acid battery systems source is Tegemeo 2000 data (n = 1512 HH); for dry cell battery and kerosene the data source is Kamfor 2001 household energy survey (n = 1755 HH).

Lead-acid Battery Systems

While grid electricity, dry cell batteries, and kerosene lighting are well known technologies, lead-acid battery systems require a few words of explanation. Although they do not have the same international reputation as an environmentally friendly technology for sustainable development as solar systems, battery systems that do *not*

[73] The data presented in Table 4 come from two different sources. Data on solar electric systems, battery systems, and grid connections are from the Tegemeo 2000 rural household survey, while data on dry cell, kerosene, and generator use come from a household energy survey conducted by Kamfor, Ltd. on behalf of Kenya's Ministry of Energy. See footnote 10 and Appendix B for more information about these two data sets.

include a solar module 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[74] (see Figure 5).

The relationship between battery and solar systems has played an important role in the development of solar markets in Kenya as well as in many other countries [Hankins, 1993; Hankins, 2004]. A common purchasing pattern 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 charging shop where people pay about $0.50 for a charge.[75] After a few years of this routine, the family may decide to invest in a solar module.[76] An important feature of this purchasing pattern is its incremental modularity, which allows rural families to purchase a solar system in small "pieces." For the smallest and most common solar systems the first "piece" - for the TV and the battery - costs 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 cost 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

[74] 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. It is of course necessary to push start the vehicle initially when the discharged battery is installed.
[75] The price of a charge is generally 40 Kenyan Shillings (KSh), which is roughly equivalent to $US0.50.
[76] In my 2003 survey of 76 solar owning households, 66% reported using a battery alone prior to purchasing a solar module. Many people report making this decision primarily because they have grown tired of the hassle of carrying the battery to town [Hankins, 2000a].

many rural families. I will explore the significance of this modular purchasing pattern in Chapter 5.

Rural Electricity Economics

Table 5 includes information about typical initial and ongoing costs for each of the energy technologies discussed in this chapter. The median "wealth rank" of the households that use each technology is also presented in the table. The wealth rank is an indicator of "depth" of access, as it situates the wealth level of households who use each technology in relation to the broader population of rural Kenya.

Figure 5: **Battery Charging at an Electronics Shop in Nyeri District.**
(Photograph by Arne Jacobson)

With the exception of grid connections, all of the technologies presented in Table 5 are obtained in Kenya primarily through cash transactions. The data show a strong - if unsurprising - relationship between purchasing power (represented by the median wealth level for users of each technology) and the cost to obtain access.

The distribution of access to solar PV - which is more confined to the wealthier segments of the population than the other listed technologies - can be understood by its high initial cost. Obtaining a grid connection can also be expensive, but subsidies reduce this expense for some. None of the other technologies are subsidized to any significant degree, although solar modules and kerosene receive favorable tax treatment.[77]

Table 5: Rural Electricity Costs and Access Levels for Rural Kenya

Technology Type	Median Wealth Rank (percentile)[78]	Typical Initial Cost to Begin Using Technology ($US)	Cost per kWh for Electricity ($/kWh)[79]
Solar Electric System	10%	$200 to $600	$0.25 to $1
Rural Grid Connection	17%	$50 to $1,500[80]	$0.08
Lead-Acid Battery System	29%	$50 to $100	$1 to $1.50
Dry Cell Batteries	46%	$5 to $30	$50 to $100
Kerosene Lighting	50%	$2 to $20	n/a[81]

Sources: for grid, solar, and lead-acid battery systems source is Tegemeo 2000 data (n = 1512 HH); for dry cell battery and kerosene the data source is Kamfor 2001 household energy survey (n = 1755 HH). Solar and battery system, dry cell, and kerosene lighting initial costs based on typical retail prices in Kenya; rural grid connection costs from Hankins, 2004; Solar and battery system per kWh electricity cost from Duke, et al., 2000; grid electricity cost from Karekezi, 2004; dry cell battery per kWh electricity cost from original measurements of dry cell battery performance and typical retail costs in Kenya.

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[77] Solar modules are now duty and tax free. See Table 16. The standard value added tax (VAT) rate of 18% does not apply to kerosene, although there is a 5.2 KSh/liter levy on the fuel [Kamfor, 2002]. The current price of kerosene is about 33 KSh/liter (as of December, 2003).

[78] The 'median wealth rank' refers to the wealth rank of the median household using each technology. The wealth rank is given in percentiles, where the percentile is calculated by dividing the rank of the median household for each technology by the total number of households in the sample. Wealthier families have lower ranks (i.e. the wealthiest families fall in the top 1%, while the poorest have a 'rank' of 100%). Ranks for grid, solar electric, and battery system users are based on wealth rankings estimated from the Tegemeo 2000 survey. Dry cell, kerosene lighting, and generator ranks are based on household income estimates from the Kamfor 2001 household energy survey data set. See Appendix C for more information about how wealth ranks were estimated for the respective data sets.

[79] The electricity costs are for approximate ongoing operating costs per kWh. The amortized initial cost to gain access to each technology is not included.

[80] The low end cost is for a system installed with full subsidy from the Rural Electrification Program [Acker and Kammen, 1996]. The cost for unsubsidized connections may range from $250 to $1,500 or more [Hankins, 2004].

[81] According to Mills, "…the cost per useful lighting energy services ($/lumen-hour of light) for kerosene lighting is 600-times higher than that for "inefficient" incandescent lighting and 3000-times higher than for compact-fluorescent lighting." [Mills, 2000, p.2]. On an cost per hour basis (with no adjustment for the substantially lower lumen output of kerosene lighting), I estimate that kerosene lighting is about 3 times more expensive than a 7 Watt fluorescent tube light in a small solar system.

The data on per kWh electricity costs indicate that the technologies that have a high initial cost are generally less expensive to operate and use. This highlights the central role of initial costs - whether for obtaining a grid connection or purchasing a solar system - as an obstacle to electricity access for rural Kenyans.[82] In other words, once the initial cost barrier is overcome, the cost of electricity from the grid or a solar system is lower than the other alternatives.

Solar Power and Electric Appliance Use in Rural Kenya

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[83] [van der Plas and Hankins, 1998]. Cellular telephones are a recent phenomenon in rural Kenya,[84] but already they are becoming a common appliance in households where solar electricity is used. My 2003 survey of 76 "solar" homes indicated that about 50% used the solar electricity to charge a mobile phone.[85]

The data in Tables 6 and 7 indicate that for each of the four common uses of solar electricity - lighting, television, radio, cell phone charging - there are other alternative technologies that are even more common than solar PV systems. However, as I will discuss below, each technology provides a different level of electrical service.

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[82] Grid access dynamics are partly determined by the price of obtaining a connection, although other factors are also important. See Chapter 4 for further discussion.

[83] 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.

[84] Cellular telephone networks expanded to many rural areas of Kenya beginning in 2001.

[85] 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.

The data in Tables 6 and 7 show that while radio is relatively common, most rural Kenyans do not have access to electric light or television. In the case of lighting, most rural households (92%) rely on kerosene (see Table 7). For those who can afford it, solar electricity or grid access allows for a transition to electric lights.[86] Households that use a battery alone (i.e. without a solar module) rarely use it to power lights.[87]

Table 6: **Source of Electricity for Selected Appliances Used in Rural Kenyan Households** (percentage of households in population)

Appliance	Grid	Solar	Lead-acid Battery	Dry Cell Battery	No Access
Electric Light	3.9%	3.5%	0.8%	n/a[88]	92%
Television	3.7%	3.8%	7.1%	n/a	85%
Radio	3.3%	2.9%	9.0%	64%	21%
Cell Phone	no info	no info	no info	n/a	No info

Sources: 2000 Tegemeo 2000 rural household survey and Kamfor 2001 household energy survey;

Television use in rural Kenya follows a pattern that is similar to lighting, except that battery based systems are more widely used to power TVs than either solar electricity or the electrical grid. An estimated 79% of rural Kenyan households own a radio, most of which are powered by dry cell batteries.

[86] Note that many households that use solar lighting continue to use kerosene as well, as the solar electricity often does not meet all of their lighting needs. Grid connected households also tend to keep kerosene on hand for use during frequent blackouts. In other words, the transition from kerosene to electric lighting is rarely a "clean break." This is consistent with the ‘eclectic energy’ hypothesis of Masera *et al.* [2000].

[87] My 2003 survey of 76 households indicated that 50 used a battery alone before buying a solar module. During the 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. These data appear to be consistent with the results reported in Tables 6 and 7.

[88] Flashlights (torches) were not considered as "electric light" for the purposes of this table. According to the Kamfor 2001 survey, 52% of rural households own a flashlight that they power with dry cells.

Table 7: Primary Electricity Source for Selected Appliances Used by Rural Kenyan Households (percentage of appliance users using each electricity source)

Appliance	Overall % of Rural Population with Access	Primary Electricity Source for Users of Each Appliance (% of appliance users)[89]				
		Grid	Solar	Lead-acid Battery	Dry Cell Battery	Other[90]
Electric Light	8%	47%	43%	10%	--	<1%
Television	15%	25%	26%	49%	--	<1%
Radio	79%	4%	4%	11%	81%	<1%
Cell Phone	no info	58%	24%	11%	--	7%

Sources: Estimates of the primary electricity source for electric lights, televisions, and radios are from the 2000 Tegemeo survey and the 2001 Kamfor study; estimates for cellular telephones are based on a 2003 survey of 79 rural cell phone users by the author.[91]

The levels of service provided by each technology differ in important ways. For example, while dry cells are the most common way to power a radio, the cost per hour to operate it drops substantially for those who have access to a lead-acid battery, a solar system, or the grid.[92] In many households the transition from dry cells to these other technologies 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, lead-acid battery systems, and the grid do not "enable"

[89] This table designates the *primary* electricity source for each of the appliances. Many households use multiple sources of electricity and a given appliance may be operated using multiple sources.
[90] This category includes electric generators (in the case of lights, television, and radios) as well as cell phone charging in vehicles (cars and trucks). In the 2003 survey of cell phone users, 3% charged their cell phone in a vehicle, while 4% used an electric generator at their place of work.
[91] The 2003 cell phone survey is based on a "snowball" sample technique in three districts in Kenya. Given the small sample size and the non-random nature of the sampling technique, the primary electricity source estimates for cell phones are less reliable than the estimates for the other appliances.
[92]On a life cycle basis, it is about 10 times less expensive to operate a radio with a solar system than with dry cells; battery based systems are somewhat more expensive than solar systems, but they are still much less costly than dry cells. Once a grid connection is in place, it is even less expensive to run a radio with the grid than with solar power. See Table 5.

rural radio in any broad sense, their use is part of a dynamic that allows for important changes in radio listening patterns.

Solar electricity is perhaps more closely linked with enabling rural television, but the grid is just as common as solar for powering TVs, and battery based systems are used twice as often. In this case solar electrification generally allows for a modest expansion in TV viewing time relative to battery based systems, while the grid allows for a substantial increase in television viewing over solar.

Finally, although information on the fraction of the rural population with cell phone access is unavailable, survey data from 2003 reported in Table 6 indicate that most of those who *do* own a cell phone charge it using grid electricity.[93] Solar power is the second most important charging source, followed by battery based systems and several others.

Thus, solar electricity does not "enable" access to the use of these appliances in rural Kenya in any simple sense. Rather, solar electricity is one of several technologies that are used to support their use. In general, solar electricity represents an improvement in the quality and/or the quantity of the service relative to kerosene lighting, dry cells, or battery based systems, while the electrical grid - when it is available - is almost universally viewed as an improvement over solar electricity.[94]

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[93] In the 2003 survey of 79 rural cell phone users, we asked each person about the electricity source that they used the most recent time that the phone was charged. The grid charging data presented in Table 7 can be further divided as follows: 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, 10% charged the phone at a friend's house using grid electricity, and 5% charged the phone in their own home using grid electricity. The categories do not add up to 58% due to rounding errors.

[94] Note that while lights, television, radios, and cell phones are the main technologies powered by solar and battery systems, households with a connection to the electrical grid can use a number of other appliances. These may include electric irons, hot plates, refrigerators, and others. See the discussion on energy availability below for more details.

Electrical Energy Availability from Solar Electric Systems

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 primarily 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 town of Nakuru) the system can - in theory - produce about 30 kWh per year.[95] This is somewhat more energy than most households with a battery system are able to use (10 to 30 kWh per year[96]), and substantially more energy than people get from using dry cell batteries (0 to 1 kWh per year). However, it is much less than the 500 kWh per year on average for those rural households that are fortunate enough to be connected to the electrical grid[97] [Kamfor, 2002]. See Figure 6 for a graphic comparison of typical energy use from these rural electricity technologies. These results highlight the striking difference in energy

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[95] This estimate is based on the following calculation. Nakuru receives, on average, approximately 6 kWh/m^2 of energy per day. This is equivalent to 6 hours of bright sun at 1000 W/m^2. Under these conditions a 25 Watt solar module can charge a battery at about 1.5 amperes of electrical current, for a total of 9 ampere-hours per day. Multiplying this value by 12 volts (the nominal voltage of the storage battery) results in 108 Watt-hours (Wh) of energy produced per day. Efficiency losses typically reduce this value by 20%, so 86 of these Wh are actually stored in the battery. Multiplying by 365 days and then dividing by 1000 W/kW results in a total of 31.4 kWh per year. This is approximately equal to 30 kWh per year. Data monitoring in 2003 and 2004 of 15 solar systems with an average solar module size of 22 Watts indicated that, in practice, many systems in this size range may tend to produce somewhat below this amount (21 kWh per year on average for those in the data set). This is due in part because some of the systems were in the Mt. Kenya area where the solar resource is smaller than in Nakuru and in part due to the use of substandard components that resulted in significantly higher energy efficiency losses.

[96] This amount varies 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. Most households that use a battery system appear to be at the lower end of this estimate (i.e. 10 to 20 kWh per year).

[97] For comparison purposes, an average U.S. household consumes about 10,000 kWh per year [Jacobson, et al., 2005]. That is, 20 times more than grid connected rural households in Kenya and 250 times more than solar using households.

consumption between grid connected households, on the one hand, and those families who are limited to micro-electricity technologies, on the other.

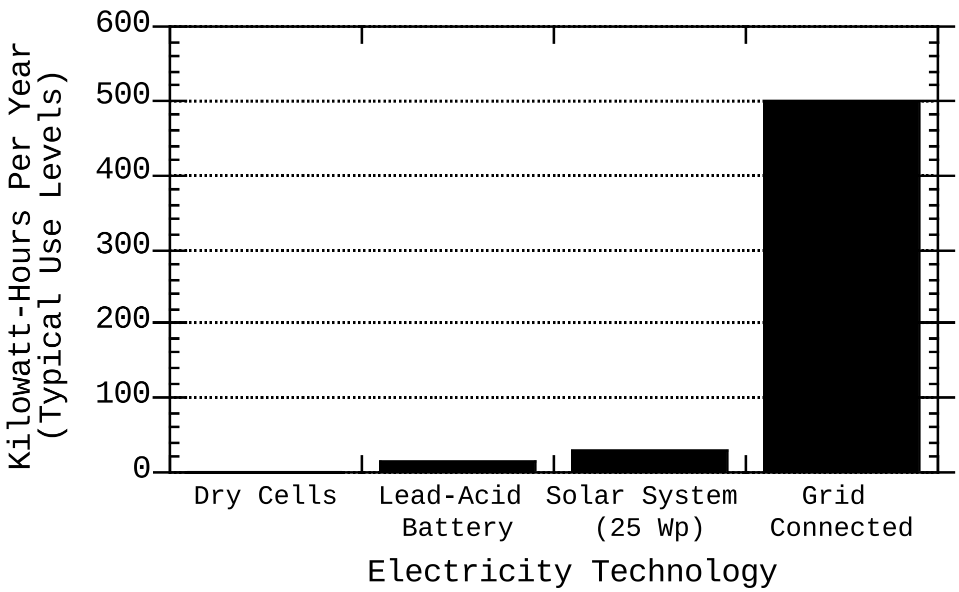

Figure 6: **Typical Domestic Annual Energy Consumption for Four Electricity Technologies in Rural Kenya**

Because the energy available to solar system users is limited, they are only able to use a handful of low power appliances for a few hours per day. See Table 8 for approximate power consumption levels for appliances common in solar, battery, 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.

A 25 Watt solar system that produces 30 kWh per year can generate, on average, about 80 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. This brief discussion highlights the difference in energy use possibilities between households that use solar and battery systems, on the one hand, and those with grid connections, on the other. Typical solar and battery systems simply do not produced sufficient energy to support the use of a number of appliances that are commonly used in many grid connected homes.[98]

Table 8: Electricity Consumption for Household Appliances Used in Rural Kenya

Appliance	Power Use (Watts)	Daily Energy Use[99] (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
60 Watt Incandescent Light Bulb	60	180	VERY RARE
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 seven items; SEI, 1998 for refrigerator, electric iron, and electric cooker.

Energy Allocation in Household Solar Systems

The data in Table 8 also indicate significant differences in energy use among those appliances that are used in solar systems. For example, radios and cellular telephones use very small amounts of energy, while lights and TV sets consume relatively greater amounts. There is also an important distinction between incandescent lights (bulbs) and fluorescent lamps. Fluorescent lamps are generally three to four times more efficient

[98] In addition to the household appliances listed here, it is very expensive to operate many farming related devices such as water pumps and grain milling machines with solar electricity. This limits - but does not eliminate - the utility of solar electricity for farm productivity related activities.
[99] 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.

than bulbs.[100] 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 incandescent bulbs remain common in rural solar systems in Kenya because their initial cost is about one fourth as much as fluorescent lamps.[101]

Information from electronic data monitoring in 15 rural Kenyan homes during 2003 and 2004 provides insights into energy allocation patterns for households that use solar electricity.[102] The data in Figures 7 and 8 suggest that a greater fraction of energy is allocated to lighting in larger systems (> 25 Watts), while television dominates in smaller systems (< 25 Watts).[103] Radios and cellular telephone charging make up a relatively small amount of energy in both systems, although radio use is a relatively larger fraction of the total in the smaller systems.

These results indicate the high priority given to connective uses - and especially TV - in rural Kenyan homes. That is, in smaller systems where energy availability is limited, the majority of the energy is allocated to television. A smaller but still substantial portion is allocated to radio, and the combined energy allocated to radio and

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[100] 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].

[101] 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.

[102] The data set includes four homes with solar systems that are larger than 25 Watts, and 11 with systems that are smaller. These households were located in two different regions of Kenya. Seven were located near the town of Othaya in a tea farming area in the Mount Kenya region (Othaya is about 20 km south of the larger town of Nyeri), and eight were located near the town of Maai Mahiu in the Rift Valley (Maai Mahiu is about 35 km southeast of Naivasha). The average system size in the data set was 22 Watts, and the median system size was 20 Watts. This is roughly similar to the average and median values for solar systems in large sample studies from Kenya [e.g. Hankins, et al., 1997]. See Appendix B for more information about the households in this data set, including information about the selection process.

[103] The average annual energy production in the four systems larger than 25 Watts was 39 kWh, while the average for the smaller systems was 14 kWh.

television together accounts for about two-thirds of total production. As the system size increases, the results in the figures suggest that there may be diminishing marginal demand for television and radio, with the excess energy being allocated to lighting.[104]

This hypothesis is supported by data on the *hourly* use rates for each of the appliances. In the smaller systems (< 25 W), televisions are used on average for 2.1 hours per day, radios are used for 4.8 hours, and lights are used for 1.5 hours. In the larger systems sampled, the television and radio usage rates do not increase (2.1 and 4.2 hours per day, respectively), but lighting use increases on average to 7.6 hours daily.[105]

These results have important implications for the social significance of solar electrification. They strongly suggest that while television and radio use may be associated with both small and large systems, lighting related uses of solar energy are much more prevalent in larger systems (e.g. > 25 Watts). In Kenya's unsubsidized solar market, solar access is strongly determined by purchasing power. As a result, solar use is mainly confined to the rural middle class (see Chapter 3), but there are also important differences among those middle class families that can afford a system. The data in Figures 7 and 8 suggest that lighting uses of solar energy may be more prevalent in wealthier families that can afford a larger system than in their somewhat less wealthy neighbors who can only afford a small solar system.[106]

[104] Given the small sample size in this detailed energy monitoring study, these results are not conclusive. Additional research is warranted to confirm these energy allocation patterns.
[105] The number of hours of lighting reported is for the combined hours among all the lights in the house.
[106] See Chapter 6 for a detailed discussion of intra-household energy allocation issues.

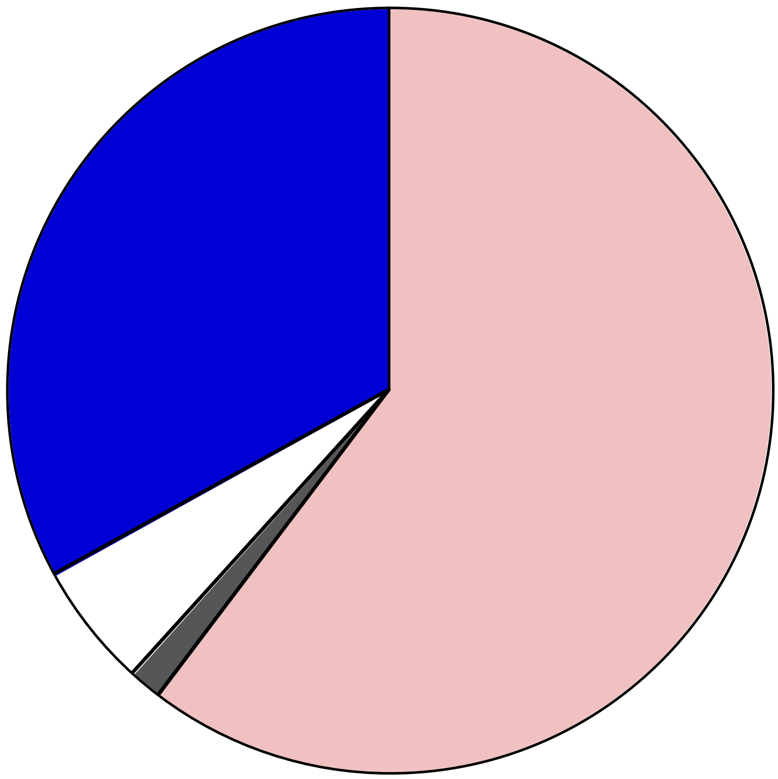

Figure 7: **Energy Allocation in Solar Systems Larger than 25 Watts** (see Figure 8 below for legend) Source: Data monitoring in four solar homes in Kenya over six months in 2003-04

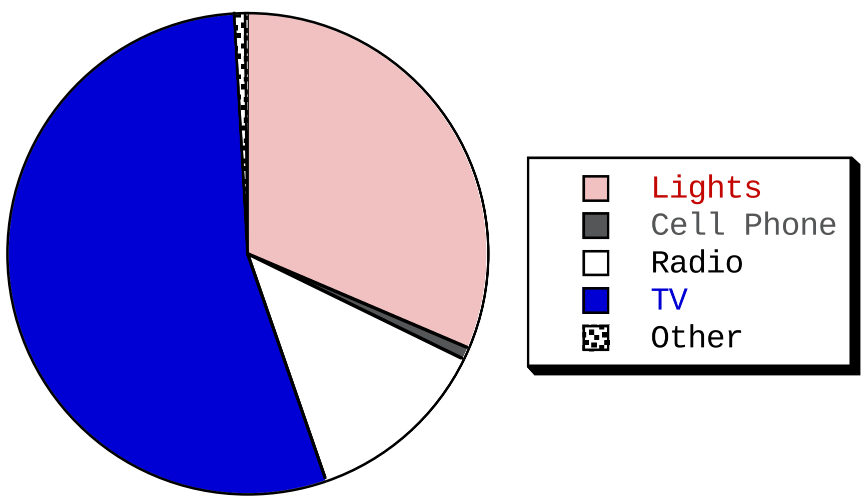

Figure 8: **Energy Allocation in Solar Systems Smaller than 25 Watts**[107]
Source: Data monitoring in 11 solar homes in Kenya over six months in 2003-04

[107] Figures 7 and 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 Watts, while the

Conclusion

Solar electricity has emerged as a viable alternative to grid based rural electrification in Kenya. Data from 2000 indicate that the number of households that use solar is approximately equal to those with a grid connection. However, solar power is not the only important alternative. Lead-acid batteries are about three times as common as solar or the grid, and nearly three-quarters of rural Kenyans use dry cell batteries.

Micro-electricity technologies deliver small amounts of energy compared to the electricity grid, and this has important implications for the social use possibilities of the respective technologies. Thus, while the grid can power electric cookers, irons, and refrigerators - as well as farm equipment such as irrigation pumps - the amounts of energy generated by solar systems limit their use to low power appliances. Despite these limitations, solar electricity provides highly valued services to those who do not have grid access, as the use of the appliances that solar PV can support - i.e. lighting, television, radio, and cellular telephones - can have important social implications.

While there are key differences in the amount of energy supplied by the various electricity technologies, there are also significant differences among solar systems according to system size. These variations may lead to contrasting social use possibilities, as highlighted by the energy allocation patterns for smaller and larger solar systems presented in Figures 7 and 8. These results, along with the economic cost data presented in Table 5 and the strong role of purchasing power in determining electricity

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average size for the smaller systems (< 25 W) was 16 Watts. Thus, the ratio in the area between the two pie graphs is roughly 2.5.

access among rural households, provides an important linkage between family wealth and the social uses of micro-electricity, including solar power.

In the coming chapters I build on the technical discussion presented here to explore key social aspects of solar electrification in rural Kenya. In chapters 3 and 4 I situate solar electrification in a set of long term historical processes, including rural middle class formation as well as government policies around land reform, education, and television broadcasting. I follow this with an analysis of the market dynamics of electricity access in Chapter 5, and the intra-household dynamics of energy allocation in Chapter 6. I finish with a discussion the social significance of the solar electricity for facilitating the use of "connective" technologies such as television, radio, and cellular telephones. In these chapters a number of elements ranging from national level political struggles to family wealth to gender relations within the home play central roles in shaping the social uses of solar electricity. In each of these chapters, though, the technical and economic aspects of solar electric systems and the other rural electricity technologies discussed here are also a key element of the story.

Chapter 3

Poverty Alleviation or Middle Class Formation?
Solar Electricity and Kenya's Rural Middle Class

> A key global imperative, if governments are ever to reach the agreed objective of the Convention on Climate Change, will be the delivery of sustainable energy for development in the developing world, where 2 billion people currently have no electricity … the most realistic form of alternative supply… is solar PV [i.e. solar electric systems]… we need to fashion huge global solar PV markets in order to win the endgame in the battle against global warming.
>
> Jeremy Leggett, former director of Greenpeace's Climate Campaign, 2001, p. 287

Solar advocates commonly make claims about the rural productivity and poverty alleviation benefits of solar electrification. One of the most frequently repeated statements is that solar power is a key technology for delivering electricity to the two billion people worldwide who lack access to modern energy [e.g. Kaufmann, et al., 2000; Ybema, et al., 2000; Greenpeace, 2001; Martinot, et al., 2002; Prahalad and Hart, 2002; and many others]. 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.

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 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].

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, most solar systems are owned by the top one-third of rural Kenyans by wealth. These solar 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."

In this chapter I link the purchasing power behind the emergence and growth of the solar market in Kenya to long term historical processes of middle class formation. This analysis is important because it challenges the characterization of unelectrified populations as a large and relatively undifferentiated mass of rural poor, and this opens the door to a more complete understanding of the social significance of market-based solar electrification and other similar processes.

The work that I present in this chapter indicates that market-based solar electrification in Kenya to date should not be viewed as making a *contribution* to poverty alleviation so much as it should be seen as the *result* of particular processes of rural development and social change that have unfolded over a period of decades. Two processes in particular have been important in generating the purchasing power behind solar market growth in Kenya. These are the commercialization of agriculture through small, family owned farms and the development of a relatively extensive rural education infrastructure with a correspondingly large number of rural school teachers. I will begin the chapter by outlining these histories and their linkages to solar electrification.

While solar electrification in Kenya can be understood mainly as the result of middle class formation, there are some important economic benefits associated with its use that indicate that it also contributes, albeit in a very small way, to processes of economic differentiation and middle class formation. Indeed, survey data that I present in the second part of this chapter indicate that a significant minority of rural families derive modest economic productivity benefits from the use of solar electricity. Given the pattern of solar system ownership, most of these productivity gains are captured by families in the rural middle class.

The Distribution of Wealth and Income in Rural Kenya

The purchasing power of the rural middle class provides the main engine for growth in 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. Many of these families may not have high incomes by international (i.e. OECD country) standards, but they are better off than most of the rural population. The data in Figure 9 show that most solar systems are owned by the top one-third wealthiest households - and indeed nearly 50% are owned by the top 10% by wealth.[108]

[108] The data also show that a few households near the median wealth level also own solar systems. As I will argue in Chapter 5, 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).

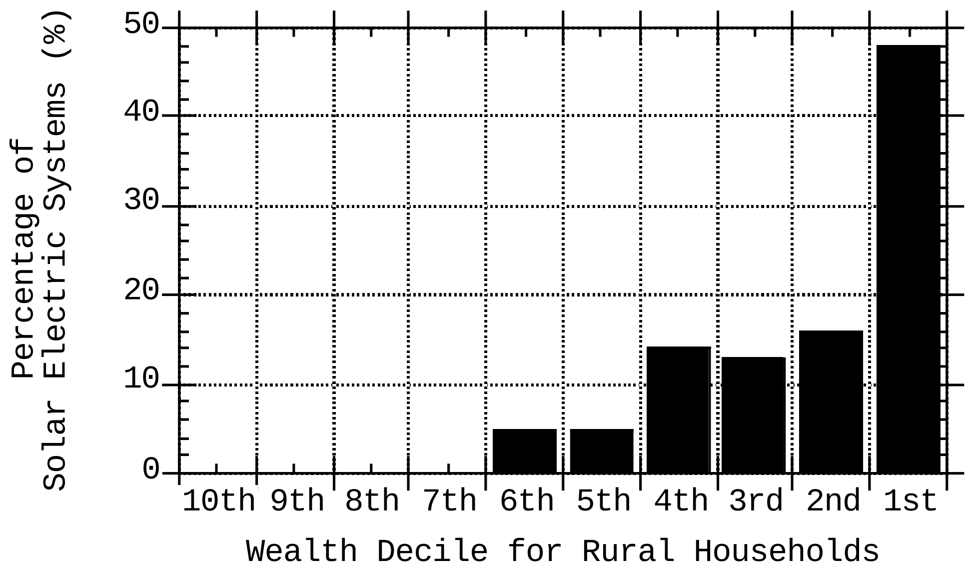

Figure 9: **Distribution of Solar Module Ownership Among Rural Households in Kenya**[109] Data source: Tegemeo Project year 2000 rural household survey; n = 1,446 total households; 63 of the households owned a solar electric system; the figure shows the distribution of these 63 households into wealth deciles estimated from the full sample of 1,446 households.

The distribution of wealth is highly uneven in rural Kenya, and this - of course - gives wealthier households a distinct advantage over the poor when it comes to obtaining access to electricity - including but not limited to solar electricity - through market channels.[110] The data in Figure 10 indicate that nearly half of all wealth is owned by the top ten percent of the rural population. The top 30% of the population combined owns 77% of the wealth, and the remaining 70% of the population owns only 23% of the wealth.

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[109] 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. See footnote 78 as well as Appendix C for more information about the process through which I estimated the household wealth levels.

[110] Of course, the wealthier segments of the population are also generally at an advantage in securing resources through political channels. I will discuss this issue in relation to grid based electrification through Kenya's Rural Electrification Program (REP) in chapter 4.

The distribution of income in rural Kenya is also uneven, although the data are not as skewed as in the case of wealth.[111] The average household income levels for rural Kenyans in each of the wealth deciles are presented in Figure 11. These data show that the average household income for the wealthiest 10% of rural Kenyans was about $4,300 in the year 2000. This is significantly higher than the average income for those in the next decile group, which was approximately $2,600. The average household income for the entire data set was $1,835, and the average income per person was $284.[112] Income levels for those below the median wealth level (i.e. the 6th to the 10th deciles) all fall below $1,350 per annum, and the poorest 10% earn a paltry $660 each year. This works out to $17.20 per person per month for families in the 6th wealth decile, and just $8.50 per person per month for the poorest group. With these income levels, it is no surprise that few among the rural poor have purchased solar systems or other similar expensive commodities.[113]

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[111] The reason for the difference between the distribution of wealth and the distribution of income is likely due in large part to the fact that low income people spend most of their income on meeting basic needs, while higher income families can spend more on accumulating the durable assets and livestock that I used to estimate the wealth levels. The wealthy also tend to benefit more from inheritances from one generation to another, and this may also contribute to the difference observed in Figures 10 and 11 in these two measures of material well being.

[112] This compares with a per capita GDP for Kenya of $298 for the same year [Central Bureau of Statistics, 2002]. For reference purposes, the average number of people per household in the Tegemeo data set was 6.5. This is based on the number of people who lived in each house full time for at least 7 months during the previous year.

[113] These wealth and income data can be used to calculate Gini coefficients, which are a measure of the distribution of each category [e.g. see Gillis, et al., 1996]. The Gini coefficient for the distribution of wealth in rural Kenya is 0.62, while the Gini coefficient for the distribution of income is 0.49. A Gini coefficient of 0.0 indicates perfect equality while a coefficient of 1.0 indicates perfect inequality.

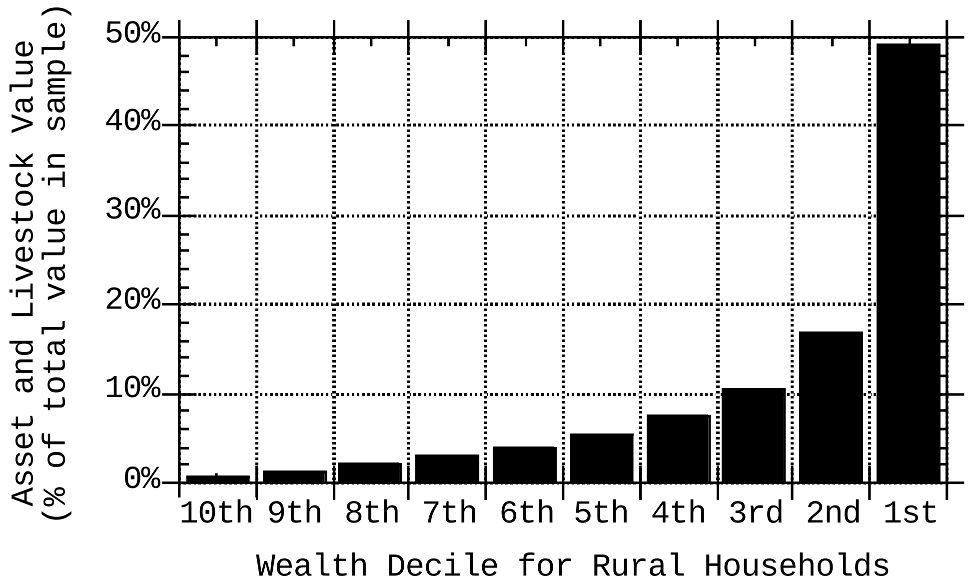

Figure 10: **Distribution of Wealth in Rural Kenya**. Wealth estimate based on value of selected assets and livestock owned by each household; Source: Tegemeo 2000 survey data.

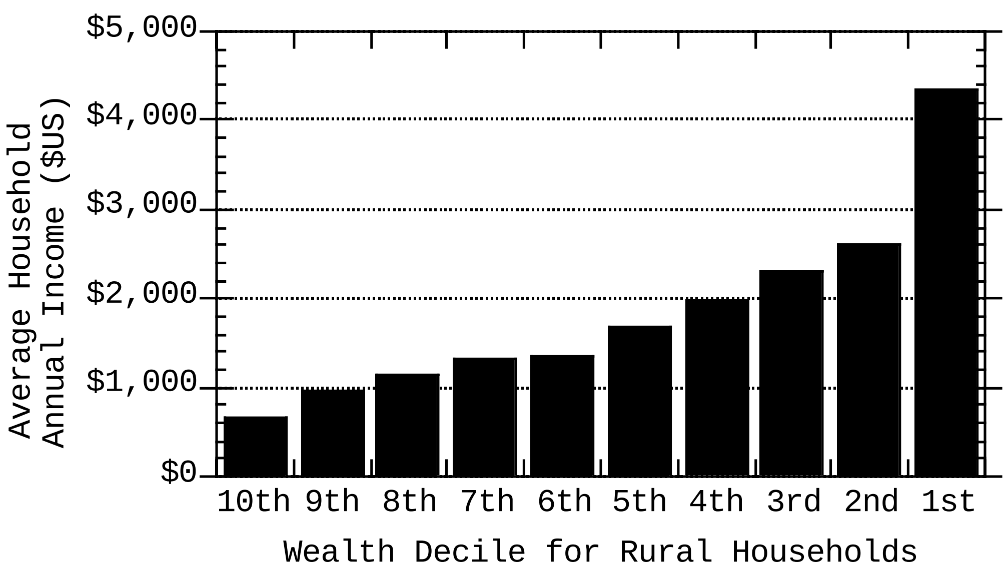

Figure 11: **Distribution of Income by Wealth Decile for Rural Households**[114]
Source: Tegemeo 2000 household survey data, n = 1,446 households

[114] The average exchange rate in 2000 was 76.3 KSh per $US [World Bank, 2003].

Solar Electricity and Kenya's Rural Middle Class

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 teacher or civil servant job) or small business earnings as their first or second most important income source. The data from Table 9 indicate that "solar" households are more likely to depend heavily on a professional salary or a non-farm business income than the rural population at large.

Table 9: Primary Income Sources for Rural Kenyan Households
(Professional salaries, non-farm business incomes, and crop sales as 1st or 2nd main income sources)

Group of Households	Salary or Business 1st or 2nd	Salary or Business 1st	Salary or Business 2nd	Crop Sales 1st
Top 33% by Wealth (n=452)	60%	38%	23%	46%
Middle 33% (n=452)	52%	29%	23%	52%
Bottom 33% (n=452)	59%	32%	27%	45%
"Solar" households (n = 62)	81%	52%	29%	42%

Source: Tegemeo 2000 data (n = 1,356 households)

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[115] - account, on average, for a substantial 55% of earnings for households that purchase solar systems. Non-farm income[116] is nearly as high, at 45% of the total. The data in Table 10 suggest that "solar" households are less dependent on crop and

[115] Livestock related income includes meat and dairy production as well as egg sales.

[116] Rural families at all wealth levels in Kenya may depend in part on non-farm earnings. However, there are key qualitative and quantitative differences between the non-farm earnings of the wealthier "rural middle class" and the larger mass of rural poor. For the rural middle class "non-farm" earnings may include salaried labor as well as business earnings. For the rural poor day labor and other forms of "self-employment" are more common. Both groups may depend on business earnings as well as remittance transfers, but the income amounts for rural middle class families from these activities are generally larger.

livestock income than the broader rural population, but that these income sources nevertheless remain very important for solar using families.

Table 10: **Income Sources for Rural Households in Kenya**

Group of Households	Net Crop Sales	Livestock Production	Non-Farm Income	Mean HH Income (KSh)[117]
Top 33% by Wealth (n=482)	40%	26%	34%	217,191
Middle 33% (n=482)	49%	22%	29%	125,237
Bottom 33% (n=482)	47%	21%	32%	77,563
All HH (n=1,446)	44%	24%	32%	140,000
"Solar" households (n=63)	38%	17%	45%	249,000

Source: Data from 2000 Tegemeo Survey

These data 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 what I refer to as a "rural middle class." The solar market in Kenya depends heavily on the purchasing power of this hybrid social group.

Historical Roots of the Kenyan Rural Middle Class

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. Cash cropping small holder family farms form the foundation of this economy. Nonetheless, most households depend on multiple sources of income, and non-farm earnings are significant for families at all wealth levels. The areas of

[117] See footnote 114 for exchange rate.

Kenya with strong regional solar markets have active internal economies characterized by a multiplicity of small scale enterprises that provide products and services to local residents[118] [Cowen & Shenton, 1996, p. 341]. Professional salaries - especially for rural school teachers - and urban to rural remittance transfers also make substantial contributions to household incomes in these regions.

These rural economies cannot be understood in isolation. Cyclical patterns of rural to urban migration and the associated urban to rural money transfers have played a centrally important role in the development of rural Kenyan economies. Most Kenyan extended families are stretched over rural and urban spaces, and non-farm income - including remittance transfers from urban family members - have historically accounted for a significant fraction of investment capital for rural agricultural activities [Kitching, 1980; Cowen and Shenton, 1996].

Education has played an important role in this rural-urban dynamic. Rural families commonly view investments in education for their children as a key element for social and economic advancement. For many, education signifies the possibility of a good urban job, and investments in education are closely linked to two-way rural-urban flows of people and money. As I will explore in more detail below, the high value placed on education in rural Kenya has - over many decades - resulted in an extensive school system with a relatively large per capita concentration of teachers.

The roots of these three interrelated elements - the cash cropping small holder farm economy, rural-urban interconnections, and rural education - are to be found in the

[118] e.g. small restaurants and bars, private health care services, transport, veterinary services, carpentry, and many others.

colonial period, and their combination goes a long way towards explaining the emergence and development of the solar market in Kenya.

Small Farms in Cash Crop Regions of Kenya

The main cash cropping areas of rural Kenya, also known as the "Kenyan Highlands," are among the most productive agricultural regions in Africa. A number of factors have contributed to the relative success of this region, including a favorable climate, fertile soil, and relative political stability over the last 40 years. An additional and highly significant factor is related to land tenure patterns - influenced heavily by post-Indepedence land redistribution policies - which have placed a substantial fraction of the high value land in the hands of small farming families.[119] Importantly, unlike many other cash crop areas elsewhere in Africa and around the world, small farms have consistently accounted for over half of the overall agricultural production in the Kenya[120] (see Figure 12). Academic work from a number of authors substantiates the contributions of small farmers to the relatively high levels of agricultural productivity in Kenya's central Highlands [e.g. Cowen and Shenton, 1996; Chege, 1987; Collier and Lal, 1986; Cowen, 1981; Heyer, 1981; Kitching, 1980].

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[119]Small farms are defined by the Central Bureau of Statistics in Kenya as farms between 0.2 and 12 acres in size (this is approximately 0.5 to 5 hectares). I observe this convention throughout this dissertation.

[120]For example, in Zimbabwe and Zambia the majority of the high productivity land is owned by a relatively small number of wealthy land owners [Moyo, 2001; Berry, 1993].

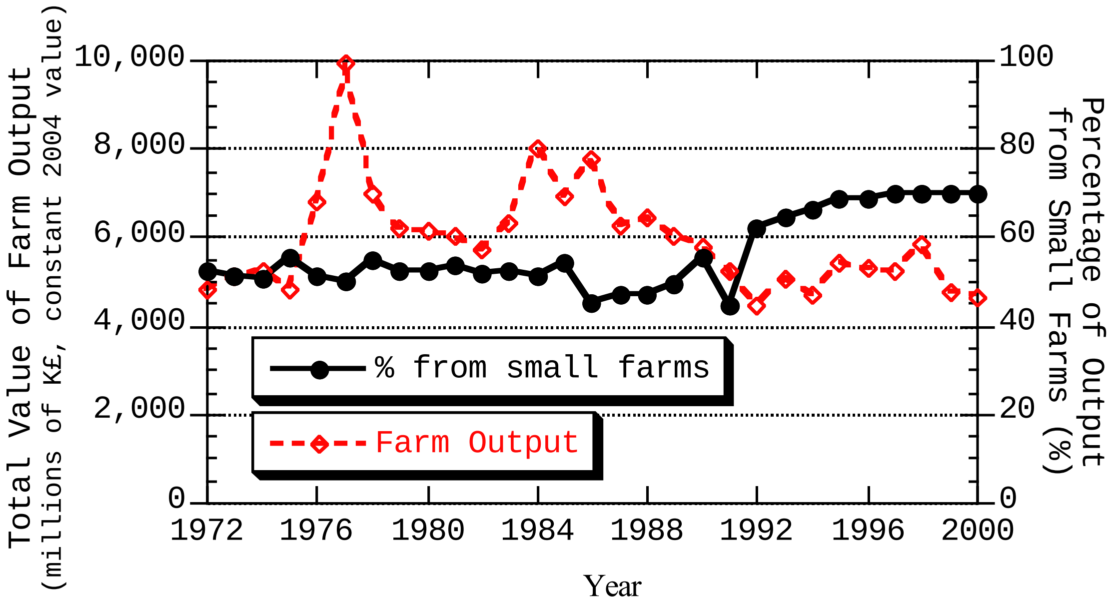

Figure 12: Value of Total Farm Output and the Percentage Produced by Small Farms in Kenya, 1972 to 2000. Data source: Central Bureau of Statistics, various editions

In this subsection, I argue that the history of land tenure and cash cropping by smallholder farmers has been an important factor in the development of the solar market in rural Kenya. In brief, my argument is as follows.

1) In a number of districts of Kenya's Highlands, a substantial portion of the agricultural output is generated on small farms;

2) households in these regions depend on multiple sources of income, including subsistence farming, cash crop farming, and non-farm incomes to make ends meet;

3) the dynamics of socio-economic differentiation in these areas depend largely on a combination of historically specific struggles over land tenure, rural-urban linkages and other dynamics related to non-farm income sources, and government rural

development policies (including but not limited to expenditures on public education);

4) these dynamics have produced a moderate, but not excessive, level of differentiation;

5) the resulting "rural middle class" that has emerged is relatively large and wealthy compared to similar groups in most other Sub Saharan African (SSA) countries;

6) rural middle class households are poor by industrialized country standards,[121] but they are better off than the larger majority of rural families in Kenya as well as most households in SSA;

7) their middle class incomes allow for occasional purchases of "non-essential" consumer goods such as televisions and solar electric systems.

At the same time, I will note that moderately higher levels of economic differentiation would have led to a larger and wealthier group of rural middle class households, and that this would have likely led to more demand for solar modules and other similar consumer goods. That is, many of the limits on differentiation that I will outline in the following paragraphs have likely limited the growth of the solar market.

A great deal has been written about the history of economic differentiation in rural Kenya over the last 50 years. Many researchers have focused on smallholder

[121] Typical household incomes for a family of 7 for this group range from $US 2,000 to $US 4,000 per annum. The mean household income for a family of 7 in rural Kenya is estimated at $US 1,500 [World Bank, 2000].

agriculture in the cash crop regions of Central Kenya because they were interested to contribute to debates about the ways that the commercialization of peasant agriculture affects the economic development of a region. The debate centered around competing theories put forth by Lenin and Chayanov about the result that the commercialization of agricultural markets should have on peasant agriculture. In brief, Lenin proposed that commercialization would lead to progressive differentiation among the peasantry and the proletarianization of those small farmers who could not compete. Chayanov, in contrast, argued that peasant families would respond to commercialization by intensifying the use of family labor (rather than wage labor) in a way that would limit proletarianization and differentiation among smallholders [Lenin, 1962 (originally published in 1908); Chayanov, 1966 (orig. 1925); Chege, 1987]. A careful analysis of smallholder agriculture in Kenya's Central Province may seem to favor Chayanov's theory more than Lenin's, as proletarianization has been limited and the use of family labor has intensified. Nevertheless, by the late 1970's it is clear to most authors that neither framework adequately explained the history of small farms during this period [Chege, 1987]. Instead, new competing theories have been developed that attempt to account for events in Kenya.

Near the center of these debates are land reform policies enacted by the British colonial government in the 1950's and by the Kenyan government following independence in 1963. These policies involved two main components. First, the colonial era Swynnerton Plan of 1954 included provisions for the legal registration of

land titles by African Kenyans.[122] The second key component of the Swynnerton Plan was a relaxation of restrictions on the farming of cash crops such as coffee and tea by African Kenyans.[123]

Both of these policies were maintained and expanded by the Kenyan government after independence [Kitching, 1980; Chege, 1987; Berry, 1993]. Additionally, in the years immediately following independence, the Kenyan government distributed just over one million acres of high value agricultural land that had been vacated (with compensation) by European settlers to small holder African farmers.[124] During this period the government also set up subsidized credit programs for small farmers [Kitching, 1980; Heyer, 1981].

Much of the land redistribution to small holders occurred in the Central Province and can be viewed at least in part as an effort to rectify the same colonial era policies that spawned the Mau Mau rebellion. Cowen and Shenton [1996] also attribute post-independence support for small farmers as an attempt to reduce social tensions and pressures associated with urban unemployment. The hope on the part of the Kenyan government policy makers was that small family farms would be more effective at absorbing labor than larger farms and therefore would reduce the rate of rural-urban migration.

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[122] The motivations for the Swynnerton Plan policies were tied closely to the political struggles of the 1950's, as colonial officials sought to drive a wedge between the Mau Mau guerrilla and rural African land owners. [See, for example, Kanogo, 1987; Chege, 1987]

[123] Cash crop farming in Kenya had been largely restricted to white settlers prior to the Swynnerton Plan.

[124] According to a 1972 ILO report, 1,062,000 acres of land were transferred to small holders through a combination of high and low density settlements. This represents 45% of all of the land that was redistributed to Africans from departing European settlers. The bulk of the remainder of the redistributed land was sold in large plots to wealthy African farmers through internationally financed transactions.

Following the trend set out in the Swynnerton plan, post-independence policies favored the formalization of private land ownership, consolidation of fragmented land holdings, and market-oriented production. The expectation was that in the long term, the creation of exclusive rights to land by individuals through land registration would lead to increased investment in farms as well as the consolidation and concentration of land ownership. Many felt that these processes were necessary for the sustained growth of agricultural output [Heyer, 1981; Kitching, 1980]. The result did include substantial growth in the agricultural sector, with much of the growth coming from small holders [Heyer, 1981; Chege, 1987; Collier and Lal, 1986; World Bank, 1981, and others]. However, despite the growth of agricultural production, the concentration of land and capital accumulation from agriculture were much more limited than had been expected [Kitching, 1980; Berry, 1993]. Moreover, some authors have pointed out that the rural differentiation that has occurred is due more to non-farm incomes than to financial gains from commercial farming [Chege, 1987; Kitching, 1980]. That is, remittances from urban areas and non-farming related rural incomes (e.g. professional salaries and non-farm business incomes) have been used to buy land and to invest in farming, and the differentiation in rural Kenya that has been observed is due more to these income streams than to the re-investment of farm profits.

Sara Berry [1993] presents a set of convincing arguments on the history of smallholder farming in the Central Province of Kenya. She proposes that the registration of land has led to some concentration, but that re-fragmentation has limited both concentration of land ownership and capital accumulation. According to Berry, land registration in Kenya does not appear to have created exclusive rights to

ownership. Instead, Kenyans continue to gain access to land through multiple social and political channels, as they had done prior to the Swynnerton Plan and, indeed, prior to the arrival of the British colonists. In this context, registration of land leads to contestation of the land rights through the court system as well as through social and political channels. In many cases, contestations have been successful, and plots have changed hands or been sub-divided.

This situation limits capital accumulation and differentiation in two ways. First, contestation of land rights diverts money away from investment in farms. Land registration laws have led to a proliferation of court cases, and, as a result, many Kenyan small holders have invested money in legal battles over land instead of in their farms [Chege, 1987; Berry, 1993]. Access to land is also contested through social and political channels, and land registration may have led many Kenyans to invest even more heavily in social and political networks than they otherwise would have. Second, re-fragmentation of land holdings in successful contestations has reversed the concentration of land ownership in many cases [Berry, 1993].

In addition to increased contestation, at least one additional factor also limits capital accumulation in rural Kenya. Namely, the small farm size (in part due to re-fragmentation) and lack of access to capital by many farmers has limited their ability to hire wage labor. Instead, small holders have continued to rely heavily on family labor. This has occurred in a period of substantial rural to urban migration, so the number of family members available to work on farms has decreased. This reduced access to labor further limits the possibilities for capital accumulation by small holders in rural Kenya [Berry, 1993].

At this point, the story that begins to emerge from the literature about small holder agriculture in Central Kenya is of a region that has a moderate number of "rural middle class" households who depend at least in part on small holder farming for their income.[125] The majority of the "middle class" households are poor by OECD country standards, but they do have access to land that they use for both subsistence farming and cash crop production [Chege, 1987]. Some differentiation has occurred in this region, but it has been limited by heavy investments in social and political networks, re-fragmentation of land holdings, and a limited ability to hire wage labor. Furthermore, many families are dependent on multiple sources of income, and the resulting diversification of investments also limits differentiation [Berry, 1993].

Significantly, the economic activity generated by the agricultural output of small farmers in the cash crop regions has contributed to the emergence of relatively robust internal regional economies characterized by large numbers of small businesses and self-employed entrepreneurs. Many of the more successful among these small businesses are owned by rural middle class households. Salaries for school teaching and other professions also contribute to rural middle class incomes. And while some of these businesses and professional salary jobs would exist if most of the land were controlled by wealthy land owners (i.e. if significantly more differentiation existed), Cowen and Shenton [1996] credit the dynamism of the rural regional internal

[125]In addition to the rural middle class, Central Kenya also has a number of wealthy farmers with large land holdings, a much larger number of poor farmers with very small land holdings, and many who have no access to land at all. Chege [1987], working from analysis by Njonjo from 1981, describes the large mass of poor small holders in the Central Province as a group "whose precarious existence was based increasingly on off-farm earnings - an incipient proletariat clinging to 'patches of land' with illusions of itself as 'a property-owning class.'" My point here is not to dispute this characterization, but rather to note that there is a moderately large group of "rural middle class" households along with these other groups.

economies - especially for food, private health, education, and transport related services - to the small farm economy.[126] They suggest that small farmers spend a substantial majority of their earnings locally on items such as food, transport, and other day to day necessities. In contrast, wealthier farmers save a larger fraction of their earnings and they also spend more of their money in distant (urban) markets [Kitching, 1980; Cowen and Shenton, 1996]. However, it seems likely that while excessive differentiation might reduce the demand for solar electric systems, somewhat more differentiation than has occurred in the Mount Kenya region would likely lead to a larger and wealthier rural middle class group and hence more demand for solar systems and similar types of consumer goods. Thus, while the relative success of smallholder agriculture in Kenya has contributed to the development of the market for household solar systems, factors such as re-fragmentation that have limited differentiation may have also limited demand for solar.

The largest regional market for photovoltaics modules in Kenya is in the Mount Kenya region, which includes the Central Province. Most of the literature cited here on smallholder agriculture focuses on the Central Providence, which is generally acknowledged to be the wealthiest agricultural area in Kenya. Nonetheless, several other regions share some similar characteristics with the Mount Kenya region. For example, the Western Province and some areas of the Rift Valley (e.g. the Nakuru, Bomet, and Uasin Gishu Districts) also have high rural population densities and a relatively large number of cash cropping smallholder farmers. These regions also account for moderately large sales of solar electric systems.

[126] See especially pp. 340-341 in Cowen and Shenton [1996].

Even in some areas where smallholder farming is not so lucrative, rural school teachers provide a key block of purchasing power for the solar market. In the section that follows I will outline key connections between the growth of the solar market and the history of education in Kenya.

Rural School Teachers, the History of Education, and the Solar Market in Kenya

Rural school teachers are perhaps the single largest purchasing block in the Kenya solar market. Households with a school teacher are nearly four times more likely to buy a solar system than the rural population at large,[127] and they account for about 30% of all household solar systems in Kenya [van der Plas and Hankins, 1998; Tegemeo 2000 survey]. There are several possible explanations for the high incidence of solar use by households with teachers.

First, teacher salaries provide a stable income stream that is reasonably high by rural Kenyan standards. Most rural "teacher households" combine the teacher salary with farm earnings, and many also have small business incomes as well. A large number of "teacher" households therefore fit squarely into the multiple income "rural middle class" group that is in a better position to afford a solar electricity system than the bulk of the rural population.[128] Second, teachers have a professional interest in the lighting services that solar systems provide, as many regularly use solar lighting to grade papers and plan lessons at home during the evening hours. Third, most teachers are urban educated

[127] According to Tegemeo survey data from 2000, 15.4% of rural "teacher" households in Kenya own a solar module, compared with 4.2% of the rural households at large.

[128] Tegemeo survey data from 2000 indicate that 61% of households with a school teacher fall in the top one-third of households by wealth, while 27% are in the middle third, and 12% are in the bottom third. According to Tegemeo survey data, average rural "teacher" household income in 2000 was approximately 209,000 KSh per year (see Table 10 for comparison with the broader population). In households with a school teacher, teacher incomes and other non-farm sources made a significant contribution, at 39% of total income. Crop sales also accounted for 39%, while livestock related income contributed 22%.

people who may have a greater awareness, on average, about new technologies such as solar systems than the rural population at large.

On a per capita basis, Kenya has an unusually large number of teachers when compared to most other Sub Saharan African countries[129] (see Table 11). These data indicate an important link between the historical development of education in Kenya and the subsequent emergence of the solar market in the 1980s and 1990s. In other words, the particular historical dynamics of education in rural Kenya that began during the colonial period and continued - albeit with some important changes - after independence have resulted in a relatively large number of reasonably well paid rural teachers, and these teachers are an important contributing factor to the growth of the solar industry.

Table 11: Teachers per 1,000 People in Selected Sub Saharan African Countries

Country	Teachers per 1,000
Botswana	11.9
Cameroon	3.9
Ethiopia	1.9
Ivory Coast	4.0
Kenya	**7.7**
Rep. of Congo	2.7
South Africa	8.2
Tanzania	3.4
Uganda	5.6
Zambia	4.4
Zimbabwe	7.0

Sources: UNESCO Institute for Statistics, 2001 & http://devdata.worldbank.org/

[129] Kenya teachers are reasonably well paid in comparison to their counterparts in neighboring Tanzania, but they have lower salaries than teachers in a number of other countries (e.g. teachers in Botswana, Ethiopia, Ivory Coast, and Zimbabwe are all better paid than Kenyan teachers) [Mehrotra and Buckland, 1998]. Data were not available for other countries listed in Table 11. For solar market growth, a large number of moderately well paid rural teachers likely leads to higher sales figures than a smaller number of better paid teachers.

Rural Kenyans have long viewed formal education as an important element of socio-economic advancement [Sheffield, 1973; Rado, 1974]. Early British colonial strategies for the creation of a labor market likely contributed to this dynamic. The colonial government imposed a hut tax beginning in 1901, and combined this with a ban on the production of the most lucrative cash crops (e.g. tea and coffee) by African farmers. These policies provided European farmers with a labor market, since wage labor was the primary feasible route for Africans to generate the cash to pay the hut tax, even as it simultaneously gave the Europeans unchallenged rights to farm the most profitable cash crops [Sheffield, 1973, p.7].

Schools run by Christian missions - which had originally focused exclusively on securing converts - soon began to serve a dual role as a key source of vocational skills training for aspiring workers. The colonial government, recognizing the importance of the educational role of the missions, began subsidizing mission schools starting in 1911 [Sheffield, pp. 10-11]. Thus began a dynamic in which rural Kenyans came to see education as the key for obtaining better paying employment in particular, and socio-economic advancement more generally.

African resistance to British colonial rule, present from the start, began to be organized into formal political associations in what is now Kenya during the 1920s.[130] A widespread demand of these associations was a call for improved access to education for Africans.

[130] The foremost among these groups was the Young Kikuyu Association (YKA) led by Harry Thuku [Sheffield, 1973 and many others].

The growth of these organizations parallels the emergence of what some have called "cultural nationalism," and this movement was closely tied to struggles related to education. For example, many Africans wanted access to education, but resented the conditions that European missionaries sought to impose on school and church attendees.[131] In some areas - especially in the Central Highlands around Mount Kenya and Nairobi - a movement to establish independent, African run schools emerged.[132] Over time, this movement established "…an entire school system independent of the missions", complete with its own teacher training college [Sheffield, 1973, p. 28]. The colonial government took a number of steps to bring these independent schools under their regulatory control, and by the late 1930s most independent schools did use the official government curriculum. This interplay between local initiatives by Africans to set up schools, and government attempts to contain and regulate these initiatives without opposing them outright, played an important role in shaping rural education in Kenya in the late colonial period. Although the independent schools only accounted for a small minority of overall African enrollment,[133] their existence acted to pressure both government and missionary run schools to take a less patronizing approach towards

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[131] The missionaries' push to end female circumcision is a frequently cited complaint by African "cultural nationalists." See Ngugi [1965] for a literary depiction of these struggles in relation to education. While resistance to constraints on female circumcision was almost certainly a key rallying point for "cultural nationalists," some have pointed out that it was only one issue among many. Welbourne, cited in Sheffield, claims that female circumcision "was no more than an emotional peg onto which a far wider area of social discontent could readily be hung. It enabled a general unrest and desire for independence to be focused at a point - in the churches and church schools - where rules could be disobeyed and independence asserted with the least danger of interference by an all-powerful government." [Sheffield, 1973, p.29].

[132] The largest group in the independent schools movement was the Kikuyu Independent Schools' Association (KISA) [Sheffield, 1973, p.28].

[133] In 1936 independent schools accounted for an estimated 5% of total African enrollment [Sheffield, 1973, p. 29].

African education, including allowing for greater community participation in the process of school operation [Sheffield, pp. 28-30].

However, despite some improvement, educational policies during the colonial period remained racially segregated and highly unequal. In the period from 1957-60, the colonial government's education budget allocated over 10 times more money per capita to education for students of European descent than to Africans.[134]

These historical inequities combined with the high value placed on education within the African population made investments in education a high priority for the post-Independence Kenyan government. In addition, the precedent of local community initiative around education set by the colonial era independent schools movement continued in the post-colonial period in the form of the *harambee* movement.[135] This movement played a central role in expanding the number of schools - and especially secondary schools - in rural areas of Kenya. Cowen and Shenton state that

> …for the period 1965-72, the period when local self-help [i.e. *harambee*] was most active and during which the number of secondary schools tripled, 60 per cent of both general education expenditure and the funds for new schools came from *harambee* contributions. These contributions were made for the clear purpose of making it possible to obtain certificates of education necessary for wage employment outside the rural household [1996, p. 312].

Although there are a number of debates around the significance of *harambee* - including debates about whether the movement is best characterized in terms of bottom up grassroots initiatives or top down, controlling patronage relationships[136] - for the

[134]The government allocated about half as much money per capita to Asian students as they did to Europeans [Sheffield, 1973, p. 64].
[135] "Harambee" can be roughly translated to mean "coming together for self-help."
[136] e.g. see Cowen and Shenton, 1996, pp.309-316 for a brief review of the literature.

purposes of the analysis at hand its main significance is tied to the rapid expansion of rural public education in Kenya that began in the 1960s and 70s and the corresponding increase in the number of teachers in rural areas (see Figure 13).

Education continues to receive high priority in Kenya, and despite a slight decline in the number of teachers employed by the Kenya government during the late 1990s, the per capita employment numbers remain high compared to other countries in Sub Saharan Africa (see Table 11). A stagnant economy and government fiscal crises have led to a general decline in the inflation adjusted value of teacher salaries over the last two decades (see Figure 14), but these salaries still remain respectable by rural Kenyan standards. These relatively well paid rural teachers are an important part of the rural middle class that provides most of the purchasing power behind solar sales in Kenya.

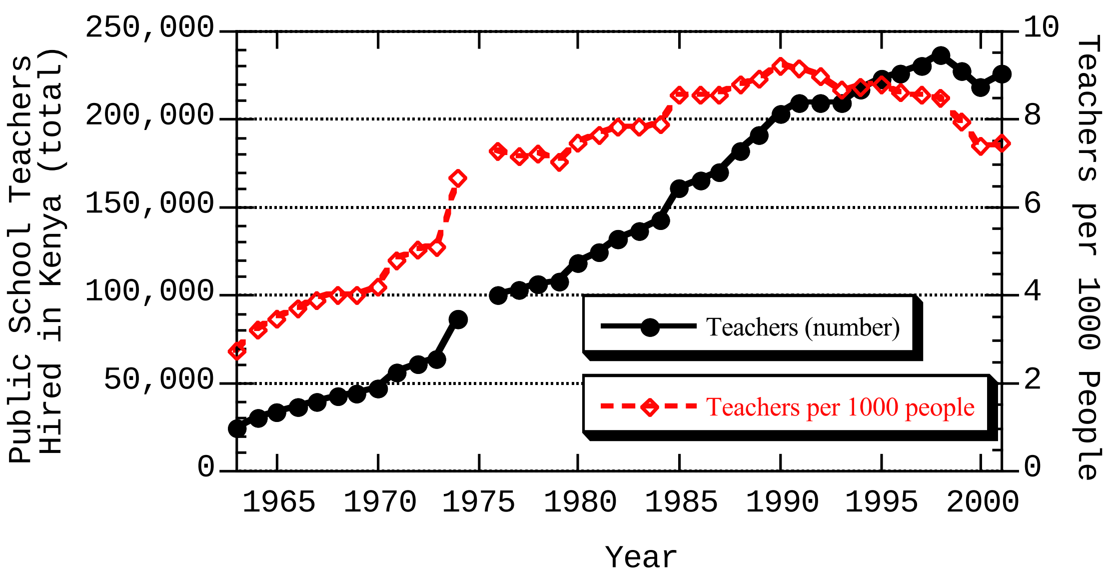

Figure 13: **Public School Teachers Employed in Kenya, 1963-2001**
Source: Kenya Bureau of Statistics, Statistical Abstract, various editions (data for 1975 not available)

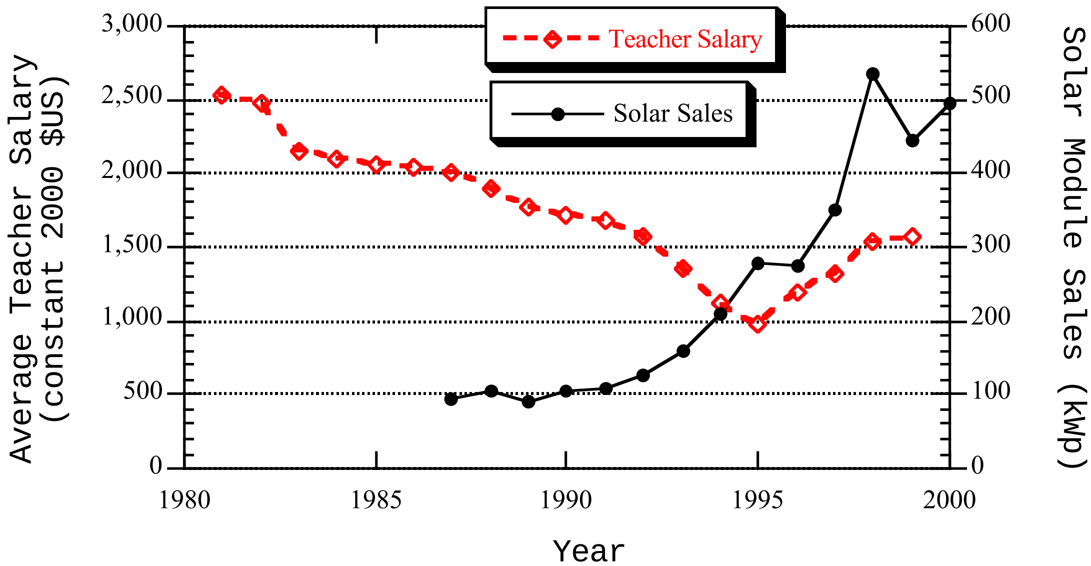

Figure 14: **Average Public School Teacher Salary and Solar Module Sales, 1980-2000**. Teacher salary data reported in constant year 2000 $US
Source: Teacher salaries from Kenya Bureau of Statistics, Statistical Abstract, various editions.

This brief analysis shows the important contribution that historical dynamics around rural education have played in laying foundation for the eventual emergence of the Kenya solar market. It also highlights the deep rooted connection between the solar market on the one hand, and education, socio-economic advancement, rural to urban migration, and urban to rural money flows on the other. I will return to these important interconnections in Chapter 7.

More generally, my work in this section of the chapter highlights the importance of what I call the "rural middle class" - that is, relatively well off families who depend on a combination of farm income and professional salaries or business earnings - for the development of the solar market in Kenya. This social group emerged through a set of historically specific social processes over many decades, and the social implications of solar electrification in Kenya are closely linked to these histories.

Solar Electrification and Economic Productivity

Rural middle class purchasing power is the central force behind the growth of solar sales in Kenya. In other words, rural middle class formation has contributed to the development of the solar market in clear and compelling ways. A key question at this juncture is one of whether solar electrification, in turn, is contributing to ongoing processes of capital accumulation, differentiation, and middle class formation. That is, does the use of solar electricity by the rural middle class help them to increase their income or decrease their expenditures in a way that gives them an economic advantage over their unelectrified neighbors?

Evidence from Kenya suggest 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.

Data that I present below indicate that the use of solar electricity leads to small cost savings from avoided energy expenditures. Additional evidence shows that while solar electricity is rarely used at dedicated business locations, it is used to support income generation and salaried work related activities in nearly half of "solar" homes. It is true that the use of solar power to support income and work activities often appears to make a relatively small contribution compared to the overall economic activity at hand. Nevertheless, the use of solar PV does provide real, if modest, economic advantages to many "solar" households. Thus, by supporting economic productivity gains for the mainly rural middle class families who use the systems, solar electricity may play a

role, albeit minor, in processes of capital accumulation and middle class formation in rural Kenya.[137]

Savings on Energy Expenditures from the Use of Solar Electricity

In 1998, van der Plas and Hankins published data from a study of 410 household solar systems in Kenya that indicated significant economic savings in avoided energy costs for solar using families. These savings - which are presented in Table 12 as average monthly amounts for different solar system sizes - came primarily from reduced expenditures on kerosene for lighting, dry cell batteries for radio and flashlight use, and lead-acid battery charging for television viewing. The authors suggested that these savings indicate a strong economic incentive for rural families to buy a solar system, and claimed that families could recuperate the investment for a 12 Watt solar system in as little as two years based on these savings alone.[138]

Table 12: Monthly Energy Savings for Solar System Users in Kenya

Cost Savings from Reductions in…	**Solar PV System Size**			
	< 16 Watts	16 - 25 Watts	26 - 45 Watts	46 - 200 Watts
Battery charging	$1.71	$1.45	$1.75	$1.42
Kerosene lighting	$2.93	$3.87	$5.64	$6.78
Dry cell use	$3.89	$3.75	$5.02	$4.24
Other	$0.00	$0.31	$0.27	$0.33
TOTAL	**$8.53**	**$9.38**	**$12.68**	**$12.77**

Source: van der Plas and Hankins, 1998, p. 299, Table 4; the original data were presented in Kenyan Shillings. I converted these amounts to $US using the exchange rate given in the paper (55 KSh/$US).

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137 Economic activity in the home is not, of course, limited to income generation, salaried work related activities, and savings on expenditures. Unpaid household labor is economically important, and children's educational opportunities are linked - though sometimes in very tenuous ways - to long term economic possibilities for the children in particular as well as the larger family in general. Solar electricity is often used to support housework and education related activities, although household energy allocation dynamics limit these uses in many homes. I will discuss energy allocation dynamics as they relate to housework and education in Chapter 6.

138 This estimate was based on a simple payback calculation that did not discount future costs, nor did it include any ongoing costs for solar system use (i.e. the payback estimate was based entirely on the reported savings and the initial cost of the solar system).

A full life cycle assessment comparing the savings presented in Table 12 with the costs associated with the use of a solar system over 20 years paints a somewhat more modest picture. The results presented in Table 13 indicate amortized *annual* savings over 20 years for three solar system configurations.[139] This analysis indicates that the cost savings from the use of solar electricity are often present, but small.

For example, the typical solar owning household[140] with a 12 Watt solar system may achieve energy cost savings on the order of 2-3% of their annual income. Households that purchase larger (and more expensive) systems tend to have diminishing returns in terms of the avoided energy expenditures per Watt of solar system size, and the amortized savings are therefore somewhat smaller for these larger systems (see Table 13). These results do not appear to support the claim that economic savings are a *strong* motivator for purchasing a solar system; evidence that I present in Chapter 4 indicates that other factors such as a desire for television are the central drivers for demand in the Kenya market. Nonetheless, savings on the order of 2-3% of annual income over a period of 20 years is non-trivial for an investment that costs \$200-\$300 initially.[141]

These calculations indicate that many rural households may achieve small - but not insignificant - savings on energy expenditures from the use of a solar PV system. These savings, however modest, contribute in a small way to capital accumulation among rural middle class households that have invested in a solar electric system.[142]

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[139] A 20 year time period is commonly used for life cycle assessments of solar systems, as solar modules often last at least 20 years.
[140] i.e. a household at the median income level for solar owning households; this amounts to an annual income of \$2,466 according to data from the 2000 Tegemeo survey.
[141] i.e. the initial investment is on the order of 10% of annual household income for the median income solar owning household. See footnote 140, above.
[142] Note that the cost savings amounts presented in Table 13 are unlikely to serve as a good predictor for savings for less wealthy households - e.g. those in the 4th, 5th, and 6th wealth decile or below - as lower

Table 13: Average Annual Life Cycle Energy Savings for Three Solar System Configurations[143]

Solar System Type	Net Discount Rate[144]		
	0%	15%	30%
a) 12 Watt a-Si	$105.79 (3.3%)	$26.55 (2.6%)	$9.74 (1.8%)
b) 20 Watt c-Si	$97.42 (3.0%)	$18.56 (1.8%)	$2.10 (0.4%)
c) 40 Watt c-Si	$90.30 (2.8%)	$10.15 (1.0%)	-$6.46 (-1.2%)
System Configuration Assumptions[145]:			
a) 12 Watt a-Si PV module, 30 amp-hour battery, 2 year battery life, no charge controller			
b) 20 Watt c-Si PV module, 50 amp-hour battery, 2 year battery life, no charge controller			
c) 40 Watt c-Si PV module, 75 amp-hour battery, 3 year battery life, 6 amp charge controller			

Solar Electrification and Income Generation in Rural Kenya

Income generation and productive uses of solar energy have received a lot of attention in the solar policy literature 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.[146] 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 or substantial increases in income or productivity [Nieuwenhout, et al., 2000; Martinot, et al. 2002]. My research results from rural

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income households tend to spend less on dry cell batteries, kerosene, etc. In other words, the avoided expenditures on energy for lower income households that are able to buy a solar system may be lower because they generally use less energy to begin with.

143 The dollar values are the amortized average annual savings, and the percentages given in parenthesis are an estimate of the savings as a fraction of the amortized 20 year income for the median solar owning household in the 2000 Tegemeo survey.

144 The net discount rate is the discount rate over and above the rate of inflation. A net discount rate of 15% may serve as a reasonable base case, although some studies have suggested that even higher discount rates - as high as 50% or more - are appropriate for estimating the future value of money for rural people in developing countries [e.g. see Patel, et al., 1995; Duke et al., 2000]. All money amounts were adjusted to 2004 values for the calculations in the table.

145 I assumed that future battery prices would drop at a rate of 2.8% per year in real terms based on the price trend in Kenya from 1998-2003. I assumed that the crystalline silicon (c-Si) PV modules last the full 20 years, while the amorphous silicon PV module must be replaced after 10 years.

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

Kenya support the conclusion that income generating uses of solar electricity by rural households are more modest than is suggested by the claims of some solar advocates, but that they are nonetheless present in some form - albeit small - in nearly half of the rural Kenyan homes that own a system.

Evidence from Kenya indicates that relatively few rural businesses use solar electric systems. In a survey of recent installations by 366 solar technicians conducted in 2000-01,[147] 94% of the installations were in homes, while only 2% were at dedicated business locations.[148] 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 year 2000 Tegemeo survey, while just over 4% of rural Kenyan households are connected to the grid, 25% live within 1 km of the electrical grid yet do not have a connection. Continuing outward, 40% live within 2 km of the grid, 82% are within 10 km, 89% are within 20 km, and only 6% live further than 20 km away (see Figure 15). In other words, a relatively small fraction of the rural Kenyan population lives in remote areas that are far from the electrical grid. This means that while few rural *households* are connected to grid electricity, many *businesses* serving rural customers are able to locate in towns or market centers that do have grid access while remaining relatively close their customer base. This may explain the relatively small number of rural businesses that use solar electricity.[149]

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[147] In the survey we asked each of the technicians a series of questions about his most recent solar installation job.
[148] Schools, health clinics, churches, and water pumping systems each accounted for 1% of the solar installations in the survey. The 8 businesses identified in the survey that used a solar system included a small retail shop, a wholesale shop, 2 rural bars, 2 small town business offices, and 2 tourist hotels. The tourist hotels were near the coast, while the other systems were located in various inland areas.
[149] I thank Mark Hankins for this insight. It may be of additional interest that most households with a solar PV system are very close to the electrical grid. Data from the 2000 Tegemeo survey indicate that

Income and work related uses of solar electricity are more common in rural homes than in dedicated business locations. In a 2003 survey (n = 76 households), 32% of "solar" households reported using lights for income generation or work related activities, and somewhat smaller percentages indicated income or work related uses of solar powered televisions and radios (23% and 22%, respectively; see Table 14). 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.

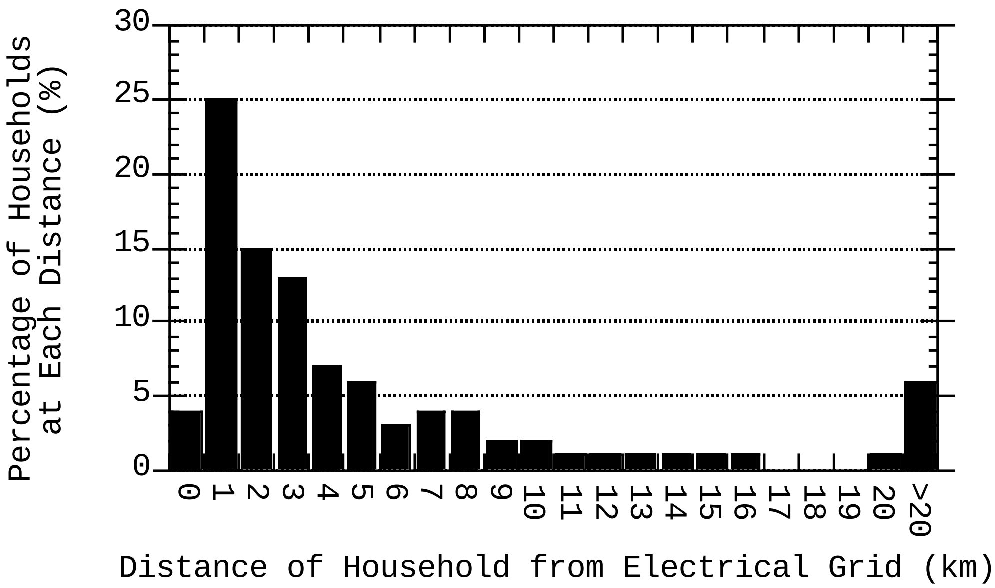

Figure 15: **Distance of Rural Households from the Electrical Grid** (households at "zero" distance are those that are connected to the grid) Source: Tegemeo 2000 survey data

Rural school teachers accounted for about half of the reported productivity related uses of solar *lighting*. See Figure 16 for an artist's depiction of a school teacher using solar lighting to work at home in the evening. This result is perhaps unsurprising given

52% of "solar" households are within 2 km of the grid, 73% are within 10 km, and 92% are within 20 km. The similarity between these results and those for the population at large suggests that households that are close to the grid may be no less likely to purchase a solar system than those that are further away.

the large numbers of teachers who purchase solar systems as well as the obvious professional benefit that they gain from evening time lighting. Approximately half of the teachers in the 2003 sample (46%) reported using solar lighting in relation to their job.[150] The use of solar electricity did not, of course, help teachers to increase their incomes (i.e. they do not get a salary raise as a result of the lighting), but many said that it did help them do their work more effectively.

Table 14: 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%**[151]	13%	7%	16%	1%
Television	**23%**	8%	8%	5%	0%
Radio	**22%**	11%	7%	3%	1%

Source: interviews with 76 households that use solar electricity

Figure 16: **Many School Teachers Use Solar Electricity to Grade Papers and Plan Lessons in the Evening Hours** (image by Michael Okendo)

[150] This means, of course, that 54% of the teachers in households with a solar system did *not* use solar lighting to do evening time teaching related work. In the survey 23% of the 'teacher' households with solar did not include lights, while 31% had lights but did not use them to do teaching related work.

[151] 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.

In addition to school teachers, some families reported using solar lighting for farming activities. One family had an egg business, and they used solar powered lights in the chick brooding room to provide 24 hour lighting.[152] 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. Several others reported using solar lighting for an hour once a week or so for planning or accounting related to their farming activities. These brief accounts indicate that - with a few exceptions such as the chicken and milk related businesses - solar lighting played a relatively small role in supporting the respective farming activities. Also of note is that 75% of the "solar" households in the sample where farming was a major source of income reported that they did not use solar lighting for *any* activity related to farming.

Although non-farm business related uses of solar lighting were less common than farming uses, most of those who did report usage indicated that it played an important role in supporting their work. Planning or accounting related activities were the most common,[153] although one person operated a small tailoring business from home.

Some families also reported economic productivity related benefits from television and radio. In nearly all of these cases the families said that they periodically received information that was related to farming or non-farm business activities. Most of those farmers who reported information benefits cited educational programs (especially on the

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[152]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.
[153] Four people - an electrician, a veterinarian, a shopkeeper, and a furniture maker - in the sample of 76 reported frequent use of solar lighting for accounting and/or planning related to their business.

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.

The newly emerging use of cell phones provide substantially greater opportunities for economically productive uses than either radios or televisions. While long distance, rural to urban family communication appears to be the central driver behind rural cell phone use (see Chapter 7), they are also very important for certain types of rural or small town businesses. Many shopkeepers, auto mechanics, electricians, veterinarians, and people with other similar professions have quickly come to depend on mobile telephones to place orders, make business deals, or to be in contact with their clients. In a 2003 survey of 79 rural cell phone users, 38% said that they had derived an important work or business related economic benefit from the use of the phone. Moreover, 35% of all recent calls in the sample were explicitly related to business activity of some sort.[154] It may be of note that relatively few calls in the survey were related to farm business. These results strongly suggest that cell phones are coming to play an important role in supporting productivity in rural Kenya, and while further research is needed, certain types of businesses appear to be particularly well positioned to capture the benefits.[155]

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[154] Each cell phone user was asked a number of questions about the most recent call that she or he received as well as the most recent call made. The information on "recent calls" is compiled from these data.

[155] Of those who reported specific business related uses of cellular telephones (i.e. 38% of the sample as reported above), 60% were engaged primarily in service or trade related activities (e.g. auto mechanic, veterinary business, health clinic officer, electrician, etc.), 20% were shopkeepers, 10% had natural resource extraction related businesses (e.g. forestry), and 10% reported that farming related uses were the main business activity associated with the use of the cell phone. It may be of interest that 3 of the cell phone owners surveyed reported that they used the cell phone itself as a business by charging a fee for phone calls (these are included in the "service and trade" business category).

In addition to work and business related productivity benefits, cell phone use is also associated with economic savings through avoided travel costs. Many in the sample - 48% - said that while they did not use the cell phone for any work or business related activities, the use of the phone helped them to save money and time by allowing them to communicate without travelling. Only 15% of the cell phone users in the sample said that they did not perceive any economic benefit from the use of the phone.

While cellular telephones clearly provide significant productivity benefits to many users, solar electricity is only one option among several for charging the phones in rural areas. As I noted in Chapter 2 (see Table 7), in the 2003 survey solar electricity accounted for only 24% of recent cell phone charging, while various grid connected charging sources accounted for 58% of cell phone charging by rural users.[156] This was true despite the fact that none of the cell phone users in the survey had grid electricity at home.[157] Thus, while solar electricity plays an important role in supporting rural cell phone use, other electricity sources - and especially grid electricity - appear to be even more important.

The data from the two 2003 surveys (i.e. the solar household survey, n = 76, and the cellular telephone survey, n = 79) do not allow for a quantitative evaluation of the significance of solar electricity for supporting the various income or work related activities. Nonetheless, a few observations are warranted.

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[156] Common grid connected charging locations for rural cell phone users included workplaces, shops where cell phones are charged for a fee, and the house of a friend or relative. See Table 7 and footnote 93.
[157] The remaining charging sources were divided as follows: 11% of recent charges were made using a lead acid battery systems (i.e. a battery system that did not include a solar panel), 3% of the charges were made in cars, and 4% were made using various other sources.

First, the tasks supported by solar electricity make up a relatively small part of the overall economic activity in nearly all cases. For example, 1-2 hours per week in the evening doing account by solar light is, of course, small in comparison to the full set of activities and labor associated with operating a small family owned tea farm. Likewise, grading papers and planning lessons 2-3 times per week in the evening may be valuable, but teachers spend much more of their work time during the day in the class room.

However, the hours spent on an activity are not always a good measure of their value. In some cases the ability to do a task in the evening using high quality light from a solar system rather than doing the same task during the daytime or with a kerosene lamp is merely convenient, but of no great economic significance. In other cases it may be highly valuable.

The value of information from radio or television is particularly difficult to evaluate. Sometimes the information gained from these sources - e.g. information about agricultural practices for a farmer or the availability of a particular product for a shopkeeper - is crucial and in other cases it may be of little consequence.

And while there is little doubt that cell phones can be highly valuable for a number of business and work related uses, it is important to keep in mind that solar electricity is only one charging source among several available to rural Kenyans, and the same is also true - to varying degrees - for lights, televisions, and radios (see Table 7). Thus, the farmer who gets information through the use of a solar powered radio could also power the radio using dry cell batteries. The cost per hour of operating the radio is higher with dry cells, but the point is that those who cannot afford a solar system generally have alternatives to receive similar services. This is especially true in the case

of radio, but it is also true for television and cellular telephone charging. For lights, kerosene is the primary energy source for most, but it should be noted that the quality of the lighting is much lower with kerosene than with an electric light.[158] This adds another layer of complexity to the task of estimating the differential value of a solar system for supporting economic activities, as the value must be situated in relation to these other alternatives. The availability of other sources of energy indicates that solar users may have only a slight advantage over their neighbors when it comes to getting information through the radio, and a modest advantage when it comes to watching television or charging a cellular telephone. In the case of lighting, the advantage depends on the task; those tasks that require high quality lighting - including much of the work done by teachers as well as accounting and other similar tasks - are much easier to do with solar lighting than with kerosene.

Despite these caveats, solar electricity appears to play a small but potentially significant role in supporting income and work related activities in almost half of those rural Kenyan families that use the technology. This suggests that the use of solar power has led to modest productivity gains for many of its users. The distribution of ownership of solar systems discussed earlier in this chapter indicates that nearly all of this productivity benefit is captured by the rural middle class. Therefore, solar electricity may contribute - in a small way - to ongoing processes of middle class formation. Its role in these processes is almost certainly smaller than the Kenyan rural

[158] People who use kerosene lighting may also be exposed to higher levels of carbon monoxide emissions than those who use solar electricity. This may be especially true for people (e.g. school children) who read while sitting very close to the kerosene lamp. See Ezzati, et al., 2004 and Bates, 2002 and for further discussion of indoor air quality and the health implications of kerosene lighting.

electricity grid, which provides electricity to many rural businesses and commercial enterprises[159] in small towns and market centers, but in rural households beyond the power lines solar electricity does provide some economic advantages to those who can afford it.

Conclusion

Despite frequent claims about its poverty alleviation benefits, solar electrification in Kenya is driven by the purchasing power of the rural middle class. The families in this hybrid social group - which gain income from multiple sources including farm earnings, business profits, and professional salaries - may not be wealthy by OECD country standards, but they are substantially better off than most of their rural neighbors. Teacher salaries and cash crop earnings from small farms that grow tea, coffee, and other high value commodities have been especially important to sales growth in the Kenya solar market. Thus, the findings presented in this chapter indicate that solar electrification is better characterized as the *result* of long term processes of rural middle class formation than as a significant factor contributing to poverty alleviation.

Rural middle class formation has occurred in Kenya through a historically specific set of interactions between government policies (including policies of both the colonial administration and the post-Independence Kenyan government), organized grass roots pressure from below (especially in the case of rural education), and the everyday practices of rural Kenyans. These processes took place over many decades, and a similarly large rural middle class could not be created quickly in a country or region where it did not already exist in some form. This does not mean that solar markets with

[159] e.g. a number of coffee and tea processing facilities are powered by grid electricity.

similar sales volumes to the one in Kenya cannot emerge elsewhere; indeed, similar markets - also heavily driven by rural middle class purchasing power as well as urban to rural remittance transfers - exist in a number of countries including Zimbabwe, Morocco, Sri Lanka, Mexico, and elsewhere [Nieuwenhout, 2000; Mulugetta, et al., 2000; Kapadia, 2004b]. Nonetheless, there are a number of countries where solar markets have yet to emerge. My work in Kenya suggests that middle class purchasing power may be a necessary, if not sufficient, condition for solar market growth. Policy makers interested to promote solar electrification around the world would do well to pay close attention to country specific histories of rural development, agrarian change, and middle class formation, as the possibilities for solar electrification appear to be heavily contingent on these processes. I will build on this argument in Chapter 4, where I examine a set of additional processes and factors that set the stage for the emergence and growth of the solar market in Kenya.

Finally, the social implications of solar electrification are closely linked to processes of rural middle class formation. Most solar systems in Kenya are owned by this group, and they are therefore likely to capture the bulk of any benefits from the social use of the technology. In this chapter I present data results on economically productive uses of solar electricity in Kenya. These results indicate that many families gain modest economic benefits from the use of solar electricity, and that the technology therefore appears to contribute in a small way to processes of economic differentiation and middle class formation. However, as I will discuss in the coming chapters, substantial evidence indicates that productive uses are not the central motivating factor for investments in solar electricity. Other social uses, including especially television

viewing but also other (non-income related) lighting uses, appear to be more important drivers for solar sales to rural middle class families than income generation and work related uses of solar electricity.

Chapter 4

The Solar Revolution *Will* Be Televised
An Historical Analysis of Market-based Solar Electrification in Kenya

> Photovoltaic [solar energy] dealers realized that, as much as electric light was a priority, rural people also wanted television. The rapid mass-market growth of the photovoltaic industry [in Kenya] had much to do with the expanded reach of the local television network. Among rural Africans there is a huge desire to be connected to the outside world and to be entertained.
>
> Mark Hankins, 2000, p. 94

The emergence of the Kenya solar market in the 1980s and its rapid growth during the 1990s to become one of the largest per capita among developing countries depended heavily on rural middle class purchasing power. As I discussed in Chapter 3, the processes of rural development and middle class formation that enabled solar market sales growth have their roots in the colonial period and the early post-Independence years. Nonetheless, while rural middle class purchasing power was critical, other processes and factors were also centrally important. In this chapter I identify and analyze the historical conditions - in addition to rural middle class formation - that set the stage for the emergence and rapid growth of solar PV sales in Kenya.

The widespread use of this small scale, decentralized, and environmentally friendly technology for rural electrification might seem like a victory for "small is beautiful" appropriate technology advocates. Indeed, in much of the solar policy literature the high sales numbers in Kenya have been hailed simultaneously as a prime example of appropriate technology led sustainable development in action as well as a triumph for market-based approaches to rural energy service delivery [e.g. Hankins, 1993; van der Plas and Hankins, 1998; Martinot, et al., 2002; van der Vleuten-Balkema, et al., 2003, and others]. Following this line of thinking, Kenya's "solar market success story" is due

in large part to private business initiative in the context of a relative lack of government involvement. Influential solar policy advocates from the World Bank and associated organizations accept the main premise of this interpretation, but argue that sales in the Kenya market could be dramatically increased through the use of a "better" business model. The prevailing logic here is that the cash sales approach that dominates the Kenya market limits long term sales growth, as the rural poor cannot afford the high up front costs of solar. In addition, these policy makers associate a number of solar system quality and performance problems with the cash sales business model. The solution to these growth and performance problems, they say, is to "transform" the solar market through the introduction of a consumer credit-based business model [PVMTI, 1998; Simm, et al., 2000].

This discussion in relation to Kenya is part of a larger "business model debate" in international solar electrification policy circles that has taken place over the last decade [e.g. see Cabraal, et al., 1995; Covell and Hanson, 1995; Nieuwenhout, 2000; Miller and Hope, 2000; Martinot, et al., 2002; Banks, 2004; Hankins, 2004; and others]. The goal of this debate is to determine which business models are the most effective for disseminating solar electric systems in developing countries, where "effective" is generally defined in terms of expanding sales growth and improving the quality and performance of installed systems.

While there is an active discussion about which business models are the most appropriate, there is considerable consensus among many engaged in the debate around a number of key issues. The "business model debate" fits within a conceptual framework that draws from neo-liberal convictions about the inherent superiority of

market-based approaches over state or donor project led efforts for resource allocation and service provision. Many authors also draw from an institutional economics framework which emphasizes the need to limit interventions primarily to those activities that support the development of critical market institutions [e.g. Covell and Hansen, 1995; World Bank, 1996; Martinot, 2002]. Within this framework, market principles are broadly viewed as universal, which means that a good business model can be transferred - within constraints set by market institutional development - from one context to another.

Although business models and private sector initiative have been a central focus in the solar electrification literature, some authors have worked to analyze a broader set of enabling conditions associated with the development of particular solar markets. These analyses differ from much of the business model oriented literature in their explicit recognition of the importance of country specific factors that influence the possibilities for solar market development. Key narratives in this line of analysis about solar electrification in Kenya include Hankins and Bess [1994], Acker and Kammen [1996], van der Plas and Hankins [1998], and Hankins [2000a], and I draw heavily from these previous studies. However, while these authors cite some of the same factors that I discuss below in this chapter, my work builds on and moves beyond these accounts in two key ways.

First, I place greater emphasis on the importance of historical analysis in order to identify the foundational roots of Kenya's solar market. That is, while some previous works have sought to identify enabling factors in Kenya's contemporary setting (i.e. the past 20 years), I work to situate solar electrification in the context of decades old

historical processes ranging from rural middle class formation to government broadcast media policies. This historical perspective is critical because it reveals linkages between solar electrification and a broader set of long term processes, and it is only by understanding these linkages that we can begin to identify the possibilities and limits for transferring lessons learned from the Kenya experience to policy initiatives in other countries and regions.

Second, my work shows that the Kenya government, far from being significant mainly by its lack of involvement, has played a central - though perhaps inadvertent - role in creating some of the necessary conditions for solar market growth. In fact, the emergence of the solar market in Kenya can be understood *in part* as an unintended consequence of government policies related to television broadcasting, land reform, and education. At the same time, some of the key *problems* in the Kenya solar market - especially problems related to quality and system performance - can be partially attributed to a *lack* of effective government involvement. All of this suggests a more complex relationship between the government and the market than is commonly acknowledged in either the business model oriented literature or in the more analytical, place based analyses of the development of the solar market in Kenya.

Understanding the emergence and rapid growth of the Kenya solar market requires attention to historical forces operating in multiple arenas, including international, national, and local processes. In the pages that follow I will explain how a combination of historical processes came together to shape the development of the solar market in Kenya. In this chapter I identify and analyze five key elements that were centrally important - along with the development of a relatively large rural middle class as

outlined in Chapter 3 - to the emergence and expansion of the Kenya solar market. These elements are: (1) a significant decline in solar equipment prices, (2) the slow pace of grid based household rural electrification, (3) relatively close connections between Kenya and Western donor countries during the 60s, 70s, and 80s, (4) the distribution of solar equipment through pre-existing supply chain networks that allowed for the rapid growth of sales, and (5) government investments in the expansion of television broadcasting to rural areas that allowed for a growth in the use of battery powered TV sets in rural households. None of these elements, taken alone, is sufficient to explain the rapid growth of solar sales in Kenya. Rather, it is the combined effect of these processes and factors that is critical for understanding the history of solar electrification in Kenya.

A Brief History 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 solar electric projects for a range of applications including power for health clinics, water pumps in arid areas, schools, electric fences in wildlife reserves, Christian mission compounds, and others [Hankins, 1987; 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 electric systems [Hankins, 1992].

In 1984, Harold Burris, an ex-Peace Corps volunteer from the US, set up a small business in a coffee growing region near Mount Kenya.[160] Burris' was the first business in Kenya to sell solar electric systems from a shop outside of the capital city of Nairobi, and during the mid to late 1980s he sold hundreds of systems [Hankins, 2000b]. Burris' business and several others that began operating during this period[161] 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 success led other businesses 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 prices on the world market as well as the removal of a 45% import duty on solar modules by the Kenyan government in 1986, the introduction of small, low cost amorphous silicon modules in 1989, and increased levels of competition in local markets that led to downward pressure on wholesale and retail profit margins [Hankins, 1993; Acker and Kammen, 1996; Musinga, et al., 1997;

[160] Burris had initially set up a solar business called "Kidogo Systems" in the town of Machakos in 1982 ("Kidogo" means "small" in the Swahili language). In 1984 he renamed the business "Solar Shamba" and moved it to the town of Embu in the coffee growing belt around Mt. Kenya ("Shamba" means "small farm" in Swahili). 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, 1992; Acker and Kammen, 1996; Hankins, 2000b; Kithokoi, 2000].

[161] 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].

Jacobson, 2002a]. Lower prices stimulated sales and helped to make solar systems affordable to a larger fraction of the rural population.[162]

Also important to the growth of the solar market was the slow pace at which the government's grid based rural electrification scheme was connecting rural households [Acker and Kammen, 1996; van der Plas and Hankins, 1998]. Although the scheme did manage to electrify a number of towns, agro-processing industries, and market centers during the during the 1980s and early 1990s, few rural *households* received service [Walubengo and Onyango, 1992]. In 1990 fewer than 1% of rural households were connected to the electrical grid [Central Bureau of Statistics, 1994]. Ten years later this number had increased to approximately 4% of rural homes [Tegemeo Project 2000 survey data], but most rural residents still have little hope of being connected for years or decades. As a result, a number of wealthy and middle class rural families have purchased a solar system in order to power a few electric appliances such as televisions, lights, and radios in their homes. 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 17).

Significantly, the rapid growth of the Kenya solar market in the 1990s occurred during a period of general decline in the broader Kenyan economy. On a per capita basis the Kenyan economy shrank during the 1990s, even while solar sales grew at a rate of 17% annually (see Figure 18). A large fraction of this contraction was associated with reduced income in the rural economy, as indicated by declining earnings from key agricultural commodities such as coffee, maize, and beef (see Figure

[162] See Chapter 5 for a discussion of the wealth dimensions of solar PV system ownership in Kenya.

19). Of Kenya's major cash crops, only tea production remained robust over the period of solar market emergence and growth (see Figure 20).

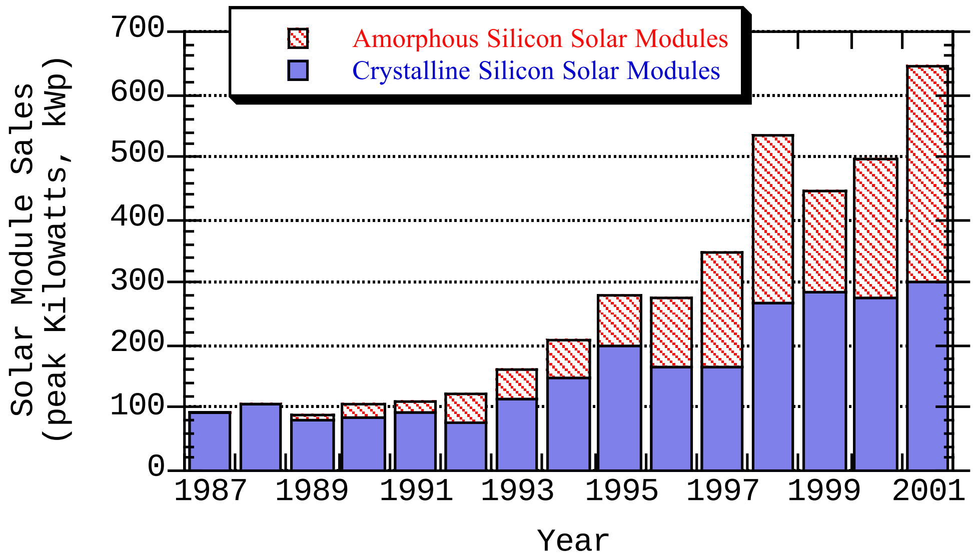

Figure 17: **Solar Module Sales from 1987 to 2001**
Data sources: Acker and Kammen, 1996; Hankins, 2000a; ESDA, 2003

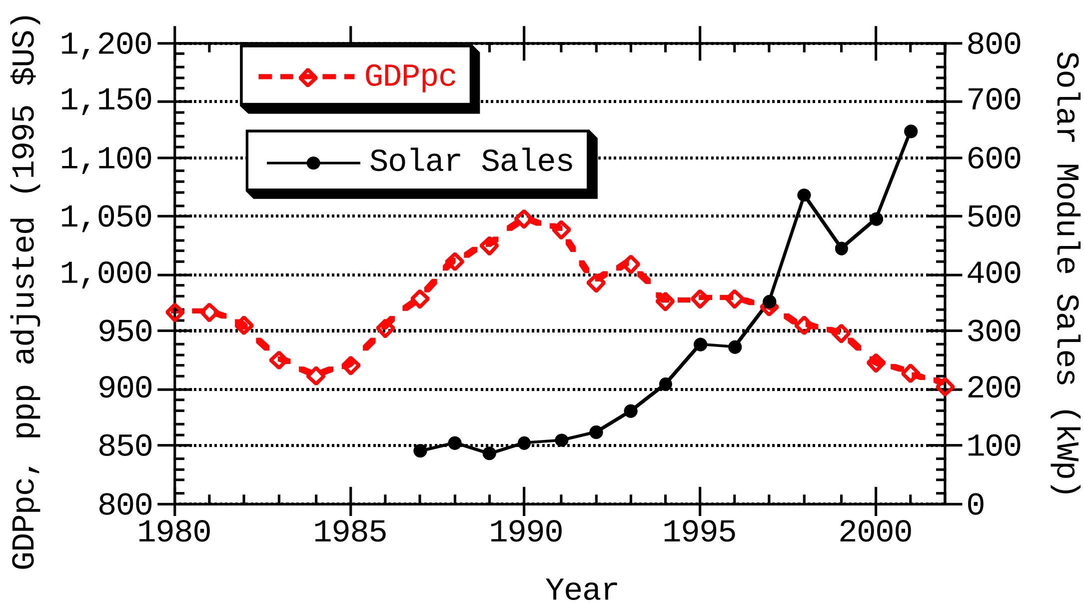

Figure 18: **Purchasing Power Parity (ppp) Adjusted Per Capita Gross Domestic Product and Solar Sales in Kenya from 1980 to 2002.**
Source: GDPpc data from World Bank online database (devdata.worldbank.org/query/NewResult.htm).

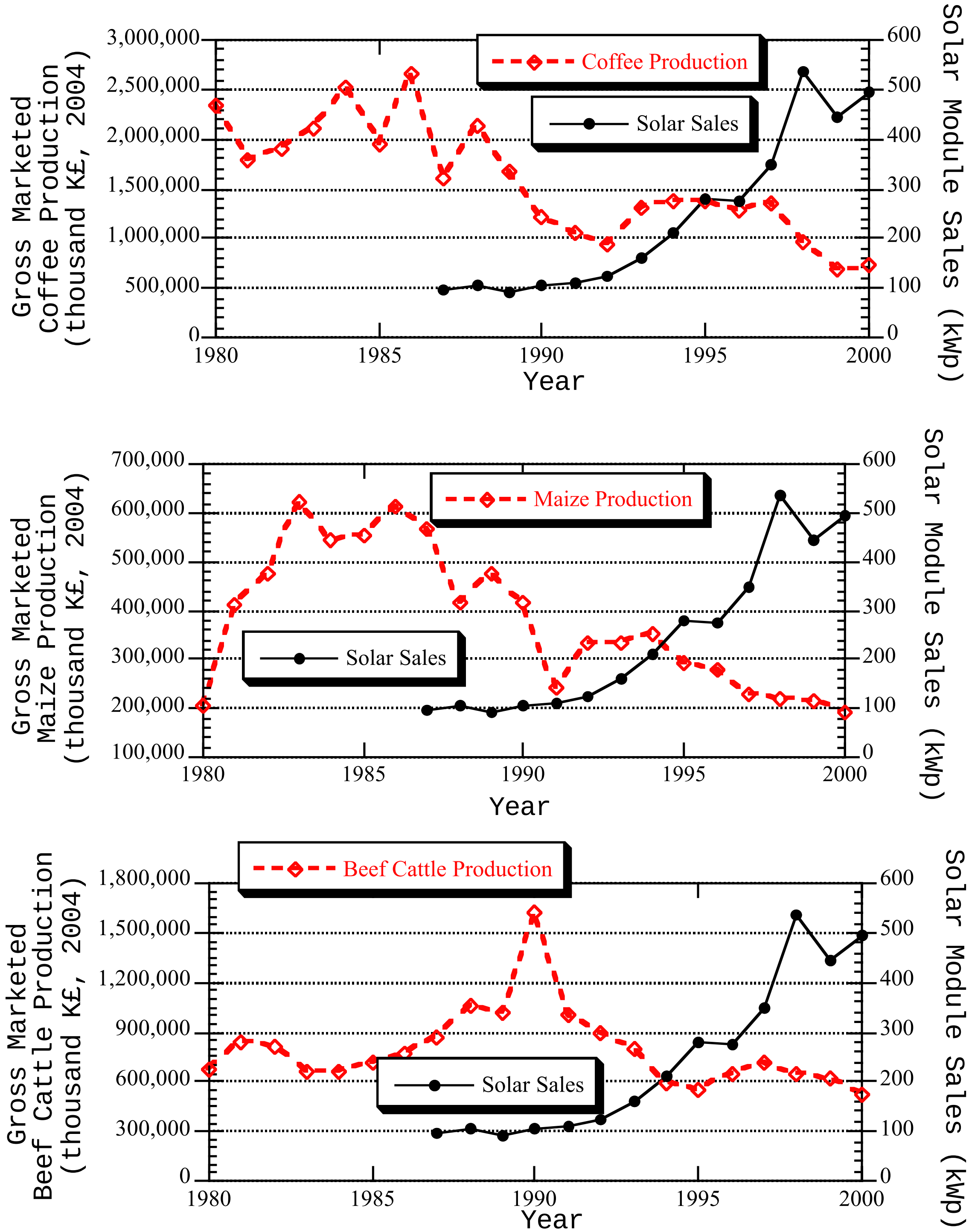

Figure 19: Marketed Value of Coffee, Maize, and Beef Cattle Production and Solar Sales in Kenya from 1980-2000 (production values in constant 2004 Kenyan Pounds[163]) Source: Statistical Abstract for Kenya, various editions.

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[163] A Kenyan Pound (K£) is worth 20 Kenyan Shillings (KSh)

Income from tea farming has, in fact, contributed significantly to the growth of the solar market. Figure 20 indicates a remarkable correlation between tea production and solar sales over the period from 1995-2000. Nonetheless, solar sales cannot be explained by tea alone, as tea farmers only account for about 20% of solar purchases.[164]

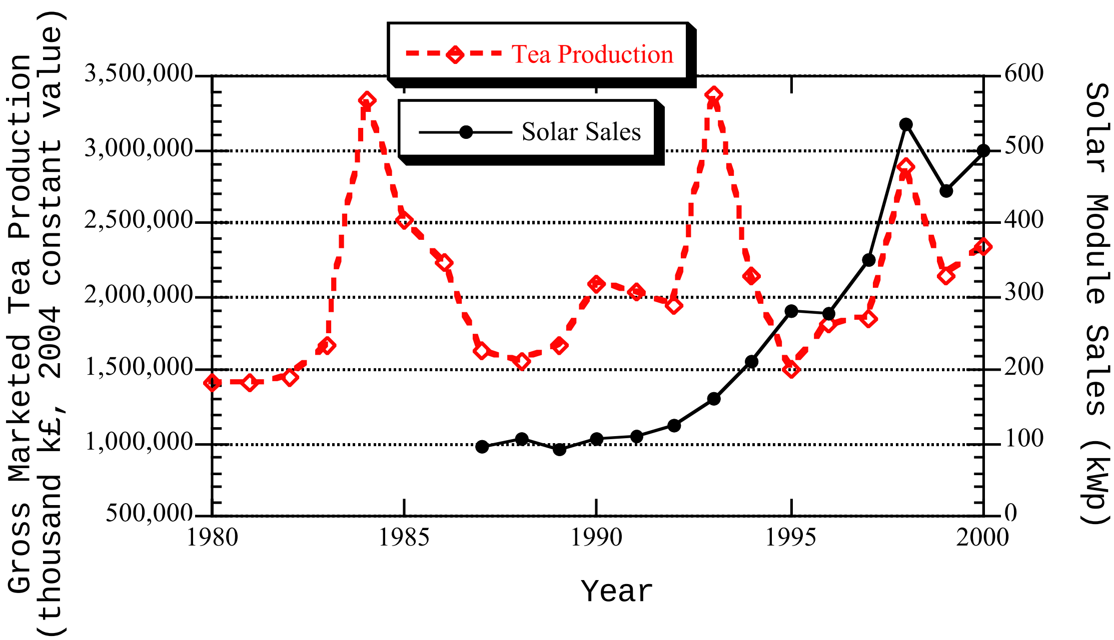

Figure 20: **Tea Production and Solar Sales, 1980-2000**
Source: Statistical Abstract for Kenya, various editions

The rapid growth of solar sales in the 1990s also occurred during and after the liberalization of the national economy. This process of liberalization, which was strongly influenced by World Bank and International Monetary Fund (IMF) pressure and conditionality, began haltingly in the 1980s only to emerge fully in the early 1990s [Mosley, 1991; Miller and Yeager, 1994]. By 1994 most of the price and foreign

[164] According data from the 2000 Tegemeo survey, 22% of "solar" homes grow tea as a cash crop. For comparison, 35% of "solar" households gained significant income from a small non-farm related business, 30% earned income from a school teacher salary, 33% earned income from other (non-teaching) professional salaries, and 14% grew coffee. These categories are not exclusive, as many families earn income from multiple sources.

exchange controls, high tariff barriers, and other import substitution industrialization related policies that had characterized Kenyan government economic development policy since independence had been removed. This liberalization made it much easier for import companies - including solar importers - to bring products into the country, and the associated tariff reductions contributed to lower commodity prices.

As I noted above, falling prices for solar equipment - due in part to liberalization measures, although decreasing international solar module prices were perhaps even more important - were an important factor driving solar market growth. The relative absence of access to grid electricity for rural households and the existence of a relatively large rural middle class with the purchasing power to buy solar electric systems, television sets, and similar commodities were also centrally important.

In addition, as outlined at the beginning of this chapter, three other processes and factors were centrally important in shaping the emergence and development of the Kenya solar market. These include Kenya's strong ties to Western donors in the decades following independence, the expansion of solar sales through pre-existing supply chains, and the growth of rural television use beginning in the mid-1980s. I will discuss each of these processes and factors below. This combined analysis demonstrates that the Kenyan solar experience cannot be seen simply as a free market success story that emerged in the absence of government interference. Instead, the emergence of the solar market was deeply rooted in the contextually specific historical processes that I discuss here, and the Kenyan government has played a critically important, if sometimes indirect, role in shaping its development.

None of the factors or processes that contributed to solar market development are unique to Kenya, and in fact some - such as the relative absence of grid based electricity for rural households - are quite common throughout Sub-Saharan Africa. While I leave a detailed comparative analysis between Kenya and other countries for another forum, the specific combination of elements that came together in Kenya appears to be unusual among African countries. This sends an important set of policy and planning messages, particularly to those who sometimes view Sub-Saharan Africa as a largely undifferentiated set of under-developed nations. Simply stated, historically rooted similarities and differences among countries play a central role in determining the possibilities for solar market development in each context. Thus, while business models and institutional arrangements may be important, policy initiatives to promote solar electrification would do well to incorporate historically and geographically specific analyses into their planning processes.

Solar Energy and Western Donors

The Kenya solar market can be divided into two main segments. The first, 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 [Acker and Kammen, 1996]. By 1990, Kenyan families accounted for 40% of all solar sales in Kenya, and they now (as of 2003) account for about three-quarters of sales [Hankins,

1992; ESDA, 2003]. This evolution of the market took place beginning in the mid-1980s and continued on into the 1990s.

Although donor driven solar projects were initiated in a number of Sub Saharan African (SSA) countries in the late 1970s and early 1980s, solar sales were sufficiently limited at that time such that some of the main solar suppliers elected to set up a single regional office to serve markets in several countries. In East Africa, Nairobi, Kenya served as the "hub" for the regional solar supply chain [Acker and Kammen, 1996]. Thus, while Kenya had the beginnings of a supply chain that was later expanded to serve the SHS market, this possibility only existed in a handful of SSA countries.[165]

Kenya's position as the regional "hub" for solar equipment in the 1980s is due largely to its close ties to "the West." In the decades following independence in 1963, Kenya had developed a reputation as a stable, pro-capitalist country that was a reliable Cold War ally to the US and the UK in particular, and NATO countries more generally. Meanwhile, several of its neighbors practiced various forms of socialism (e.g. Tanzania, Somalia, Ethiopia), while others were in the midst of independence struggles or civil wars (e.g. Uganda, Sudan, Mozambique) [Miller and Yeager, 1994;]. As a result, Kenya was able to attract relatively high levels of foreign investment and donor assistance, and many multinational companies and aid agencies elected to base their regional headquarters in Nairobi[166] [Coughlin, 1990 and others]. Nairobi's role as the regional hub for the donor driven solar industry was a small part of this larger trend.

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[165] e.g. South Africa [Hankins, personal communication, 2004].

[166] Kenya's role as the East African hub for international business is closely linked to its colonial history. Kenya was the British colony in East Africa with the largest number of European settlers, and it served as an administrative and business center for the region in the decades before independence in 1963.

Kenya's close ties to "the West" had a number of concrete manifestations that contributed to the subsequent growth of the solar industry. For example, as I mentioned previously, Nairobi was selected as the location to host the 1981 United Nations Conference on "New and Renewable Sources of Energy." This event greatly stimulated interest in solar energy in the country, including within the Nairobi based donor aid "community" [Hankins, 2002, personal communication].

Kenya was also (and continues to be) one of the largest recipients of U.S. Peace Corps volunteers on the continent.[167] As I noted above, it was an ex-Peace Corps volunteer, Harold Burris, who set up the first rural solar business in Kenya. Moreover, he and another Peace Corps volunteer, Mark Hankins, were able to secure a small U.S. AID grant to run workshops to train technicians to install and maintain small solar electric systems. A number of these trainees went on to establish rural solar dealerships of their own, and several still operate successful businesses. The U.S. AID grant and others that followed were critically important for the development of a base of skilled entrepreneurs that went on to carry out much of the technical and marketing work for the SHS market in the late 1980s and early 1990s [Hankins, 1992; Acker and Kammen, 1996; Hankins, 2000b]. It is perhaps possible that the solar supply chain for direct sales to rural Kenyans would have developed without the catalytic actions of these U.S. expatriates and the small grants that facilitated their work, but it is clear that their actions greatly accelerated the pace of events.

[167] Kenya has historically been the largest recipient of Peace Corps volunteers in Africa, with over 4,382 volunteers serving between 1964 and 2002. Ghana is the 2nd largest recipient on the continent, with 3,846 volunteers since 1961. As of 2002, no other country had received more than 3,000 total volunteers [www.peacecorps.gov].

Kenya's ties to Western donor groups also supported the growth of the solar market in other ways. For example, the World Bank reportedly played a key role in lobbying the Kenya government to remove a 45% import duty on solar modules in 1986, an action which greatly contributed to the subsequent growth of sales [Hankins, 2003, personal communication]. Additionally, a U.S. AID program to facilitate access to foreign exchange was important for supporting solar equipment imports in the late 1980s and early 1990s[168] [Hankins, 2004, personal communication]. And while the Kenyan government's relationship with some of the larger Western donors (e.g. the World Bank, the IMF, and the US and UK governments) deteriorated significantly in the late 1980 and 1990s,[169] by that point the solar market was already well established. In any case, those relationships now appear to be on the mend, and the donor aid segment of the solar market continues to be strong [ESDA, 2003].

Grid Based Rural Electrification and the Emergence of the Solar Market

As noted above, the emergence and growth of the solar market was strongly tied to the slow pace of grid based rural electrification in Kenya. Given the importance of the relationship between solar and grid based electrification, a brief discussion of the dynamics of grid electricity access are in order.

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[168] Prior to the liberalization of the Kenyan economy in early 1990s, foreign exchange was often scarce. During this period US-AID offered a forex program that assisted businesses that imported US goods. Several solar import companies took advantage of this program [Hankins, 2004, personal communication]. Companies that did not have access to the U.S. AID support - including many local firms - were often at a severe disadvantage.

[169] The close relationship between Kenya and its Western allies during the period from independence through the 1980s was strongly linked to Kenya's pro-Western stance in Cold War politics. However, while the US, UK, World Bank, IMF, and others tolerated corruption and crony capitalism during this period, after the fall of the Soviet Union they began to pressure the Moi administration for neo-liberal style reforms. When these were not immediately forthcoming, the relationship began to deteriorate and Kenya's access to foreign aid support declined significantly [Mosley, 1991; Miller and Yeager, 1994]. See also Chapter 7 for further discussion.

A number of factors influence the possibilities for households to access to grid electricity in rural Kenya. These can include the distance from the existing electrical grid to the community or households in question[170] and the corresponding cost of extending the grid,[171] the availability of subsidy funds through the national Rural Electrification Program (REP),[172] the priorities and decisions of the politicians and bureaucrats who influence the administration of these funds, and the ability of neighboring households in a community to organize themselves to jointly raise the necessary funds to pay the costs of extending the power lines to their area that are not covered by the subsidies.

Rural Kenyan households can obtain a grid connection through one of two main routes. First, community members can organize themselves to jointly raise the money to cover the various costs associated with extending the power line to their area and connecting the respective households. However, for many communities the amount of money required is prohibitive, and it is also often difficult to reach an agreement on

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[170] Few rural Kenyans live in remote areas that are very distant from the grid network, but many live far enough away to make the cost of a grid connection prohibitive (see Figure 15).

[171] The cost of extending distribution lines in Kenya is often on the order of $10,000 per kilometer [Hankins, 2004; Acker and Kammen, 1996; Walubengo and Onyango, 1992], but in practice this figure varies widely depending on the topography of the land that is to be traversed, the number and type of transformers that will be needed to deliver the electricity to the individual customers, and technical factors such as the voltage of the power that is to be carried in the distribution network. The cost per connected customer depends further on the density and geographical distribution of potential customers in the area. Hankins indicates a typical range from $250 to $1,500 per customer to connect rural households and businesses [2004, p.14], but these costs are likely for potential customers that are relatively close to the existing network (i.e. a few kilometers or less away). See Table 5.

[172] Importantly, the deterioration of the Kenyan Government's relationship with a number of Western donor groups and governments in the 1990s may have contributed to the slow pace of grid electrification [Miller and Yeager, 1994; Karekezi, et al., 2004]. See also Chapter 7 for further discussion of Kenya's relationship with the Western "donor community" in the 1990s.

how the costs should be distributed among the various households and businesses in the community that are to be connected[173] [Hankins, 1993; Acker and Kammen, 1996].

Second, in a limited number of cases rural residents are able to receive subsidy support from the Kenyan government for rural electrification. The Kenyan government[174] and the Kenya Power and Lighting Corporation (KPLC)[175] jointly operate the Rural Electrification Program (REP), which provides subsidy support for rural electrification activities on a limited basis.[176] Under this program, the government is responsible for deciding which areas should receive electric service, and the KPLC is responsible for carrying out the work [Walubengo and Onyango, 1992; p.35]. The amount of money allocated to rural electrification has been small compared to the non-electrified population, and the pace of extending grid connections to rural households has been slow.[177]

Historically the program has focused most of its energies on delivering electricity to small towns, market centers, and rural industries such as coffee and tea processing facilities.[178] Household electrification has been a low priority in comparison. In addition, a number of observers have described the process for allocating REP funds as

[173] Among other complications, Acker and Kammen note that "lower-income residents (often) resent having to share costs 'equally' with wealthier residents who will get more benefit from the electricity." [Acker and Kammen, 1996, p.89, citing Hankins, 1993].
[174] i.e. through the Electricity Development Committee of the Ministry of Energy
[175] The Kenya Power and Lighting Company (KPLC) is a parastatal agency that is 51% owned by the Kenya government [Karekezi, et al., 2002].
[176] Historically, 2% of KPLC revenues were set aside to support rural electrification activities. Donor support from Canada, Norway, and Denmark have also been centrally important [Walubengo and Onyango, 1992]. Amendments to the Kenyan Electricity Act in 1997 allowed for an increase in the levy to support rural electrification to 5%. However, the amount of money actually allocated to rural electrification does not appear to have increased in part due to misallocation of funds [Karekezi, et al., 2004].
[177] While the rate of household rural electrification in Kenya was never high, it dropped still further following electricity sector restructuring in the late 1990s [Karekezi, et al., 2004].
[178] See Chapter 3 for further discussion of this point.

"politicized," while others have noted problems of corruption [e.g. see Walubengo, 1992; Acker and Kammen, 1996; Mwangi, 2003; Karekezi, et al., 2004]. Households fortunate enough to be located in politically favored areas[179] are much better situated with respect to gaining REP subsidy support than their counterparts in other less well connected regions [e.g. Walubengo, 1992]. Many of the less wealthy families who have received grid connections through the REP likely received them because they happened to live along the route of a planned extension in one of these "politically favored areas." However, in at least some well publicized cases, REP funds have been used to deliver power to the rural homes of well connected individuals, by-passing others living in the area[180] [e.g. Mwangi, 2003].

The resulting allocation of funds has resulted in reasonable progress in terms of delivering electric service to small towns and rural industries, even as it tended to favor the politically well connected for household electrification. Nonetheless, even with these dynamics, the distribution of grid connections is modestly more "progressive" than solar electrification in terms of the wealth levels of the households using the respective technologies. See Figure 21 for a detailed breakdown of the wealth dimensions of grid connections and solar system ownership among rural households.

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[179] "Politically favored areas" range from those that are along the route of a grid extension to a coffee or tea processing facility to areas that have a special connection to an influential politician. In other words, in some cases the political decisions related to REP fund allocation are linked to rural economic development decisions, while in others they appear to be related more closely to patronage politics. Of course, in many instances these categories overlap.

[180] Recent reports also indicate a long term pattern of misappropriation and embezzlement of REP funds by KPLC officials [East African Standard, 2004; Daily Nation, 2004].

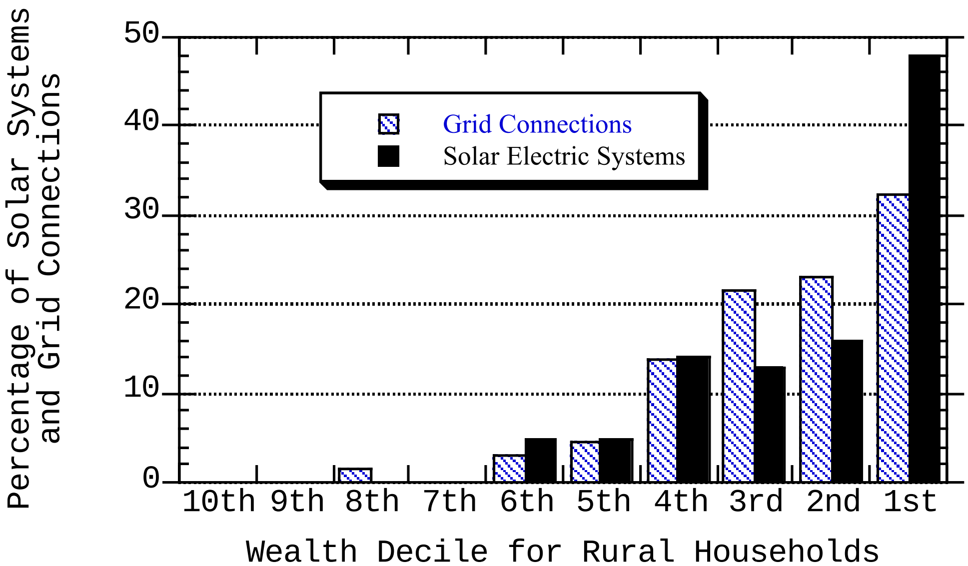

Figure 21: **Distribution of Grid Connections and Solar Electric Systems by Wealth in Rural Kenya** Source: Tegemeo 2000 survey data

These data provide a more fine grained picture of the wealth distribution of grid and solar electricity access than is shown in Table 5. The data in the figure show that solar system ownership is more concentrated in the top 10% of rural households by wealth, while grid connections are relatively more prevalent among the 2nd and 3rd deciles. For the lower wealth levels the distributions for the respective technologies are similar. These distribution patterns are consistent with the access dynamics for the two technologies as described above.

Solar system ownership depends primarily on purchasing power in an unsubsidized market, and it is therefore unsurprising that solar ownership is more concentrated among those with greater wealth. Obtaining a grid connection depends in part on purchasing power, but it also depends on factors related to the geography of the existing grid as well as political-bureaucratic decisions related to subsidy allocations from the REP fund. In other words, purchasing power is important for obtaining access to either

technology, but other factors also play a role in determining grid access, and these other factors appear to have enabled relatively higher access levels among the 2nd and 3rd wealth decile households. Nonetheless, the cost of obtaining a connection still puts grid power out of reach for the most rural Kenyans, even if they are fortunate enough to live along the route of a REP sponsored rural electrification grid extension.

This comparison provides an example of how even a high corrupt, inefficient, and politicized government electrification program can be modestly more progressive than a strictly market driven process. At the same time, it indicates important limitations for reaching the rural poor with either approach. Importantly, this is not in any way an endorsement of the corruption and inefficiency of Kenya's REP, but rather an indication of the important re-distributive *potential* of centrally planned programs relative to unsubsidized markets. The point here is that effective and accountable management is necessary if re-distributive subsidies are to play an effective role in delivering high quality electricity services to a broad segment of the population in places like Kenya, regardless of which technology is used [Dubash, 2003].

In any case, as a result of the slow pace of electrification through REP, many rural Kenyans have long since given up hope of receiving a grid connection any time soon. The emergence and growth of the solar market in Kenya has taken place in the context of this relative absence of a rural grid for household electrification.

Expansion of the Solar Market Through Existing Supply Chains

Although the nascent household solar system market supply chain was dominated by a handful of small businesses that specialized in solar sales and service during its early years in the late 1980s, the rapid sales growth of the 1990s occurred in

conjunction with increased participation in the solar market by "non-specialist" businesses. These are businesses that sell solar equipment as one among many products, and they often have no particular specialization or knowledge about solar PV. 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.[181]

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 services 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.[182] 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

[181] 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 solar supply chain in the late 1980s, when it was dominated by a handful of solar specialist businesses [Hankins, 2000b]. See Appendix D for additional information.

[182] 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]. See also Appendix D.

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 15 for 2001 data on the number of solar vendors and technicians in selected towns.

Table 15: **Solar Vendors and Technicians in Selected Kenyan Towns**

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

Declining Solar Equipment Prices

The solar vendors who were so essential for the rapid expansion of sales in Kenya would have had great difficulty selling the equipment in the economically difficult 1990s if solar prices had not been declining even more rapidly than rural purchasing power. Several factors contributed to the downward price trend.

First, international prices for solar modules dropped due to technological advances, manufacturing economies of scale, and production improvements [Acker and Kammen, 1996; Duke, 2003]. World solar module production grew at a rapid 22% clip over the 1980s and 90s (see Figure 1), and this contributed to a general decline in prices over

time (Figure 2). These data show that in real terms international solar module prices were cut in half from 1980 to 1990, and then in half again from 1990 to 2000.[183]

In Kenya, the removal of import duties on solar modules in 1986 contributed to lowering prices,[184] although duties were reinstated in 1992 during a government revenue crisis. These duties were then gradually reduced over the 1990s in conjunction with the general liberalization of the economy, and were eliminated entirely once again in 2002. Table 16 shows a summary of the cumulative import duty and tax rate for Kenya for selected years over this period. The changing tax policies on solar modules during this period indicate modest, though sometimes wavering, support for solar electrification on the part of the Kenyan government.

The introduction of small (10 Watt), amorphous silicon solar modules in 1989, as well as an increasing use of small crystalline silicon solar modules during the early 1990s, also contributed to lowering the cost of purchasing a solar system. During the period from 1986 to 1996 the average household solar system size in Kenya declined from 40 Watts to 25 Watts [Musinga, et al., 1997; Hankins, et al., 1997]. The increasing availability and use of small modules decreased the incremental cost of buying a solar module, and this helped to make solar systems more affordable.[185] Following the international trend, the prices of these small solar modules fell substantially during the 1990s, and by 2003 the price of a 14 Watt amorphous silicon

[183] That is, the price dropped from about $20/Watt in 1980 to about $10/Watt in 1990 and $5/Watt in 2000. This price trend is consistent with manufacturer experience curve theory, which predicts declining per unit prices with increasing cumulative production due to production efficiency gains, economies of scale, and other cost savings. See Harmon [2000] and Duke [2003] for experience curve analysis for the solar photovoltaic industry.
[184] The import duty on solar modules was 45% before 1986 [Hankins, 1992]. The decision to remove the import duty was at least partly related to lobbying from the World Bank [Hankins, 2003].
[185] I explore the relationship between solar module size and electricity access in Chapter 5.

solar module had dropped to about $50 on Kenya's retail market. The short term price increase observed in the early 1990s is highly correlated with a sharp increase in the inflation rate (see Figure 22).

Table 16: Cumulative Tax Rate for Solar Modules and Batteries in Kenya for Selected Years

	Cumulative Tax Rate (import duty plus VAT/Sales Tax)[186]				
Item	**1986**	**1992**	**1996**	**2000**[187]	**2002**
Solar Modules (w/o diodes)	0%	53%	27%	5%	0%
Solar Modules (with diodes)	0%	53%	27%	27%	0%
Batteries (lead acid)	not available	48%	44%	59%	59%

Sources: Musinga, et al., 1997; GoK, 2000; GoK, 2002.

A reduction in battery prices also contributed to a decline in the cost of purchasing a solar system (see Figure 23). For many small solar systems in Kenya, the initial cost of buying a battery is roughly equivalent to or only slightly less than the cost of buying the solar module. For larger systems the solar module is generally a significantly larger fraction of the initial cost (see Table 17). However, *over the lifetime* of the system, batteries generally account for the majority of the cost.[188] This is true because the solar module often lasts 10 to 20 years, while most batteries are replaced every 1 to 3 years. Thus, solar sales are influenced not only by solar module prices, but also battery prices.

[186] The cumulative import duty and tax rate is calculated by first applying the duty to the item at the port of entry, and then applying the VAT or sales tax rate to the dutied price.
[187] The import duty on "solar modules with diodes" was higher than the rate for "solar modules without diodes" for several years. The logic behind this distinction are not clear, but in practice this often meant that some types of crystalline solar modules were taxed at a higher rate than amorphous silicon modules (which never include diodes) [Musinga et al., 1997].
[188] For example, a life cycle cost analysis over 20 years for a system with a 14 Watt amorphous solar module and a 30 ampere-hour battery indicated that batteries accounted for 70% of the total life cycle cost. This analysis assumes battery replacement every 2 years, solar module replacement after 10 years, and a discount rate of 15%. A similar analysis for a system with a 20 Watt module and a 50 ampere-hour battery indicates that batteries account for 68% of the life cycle cost.

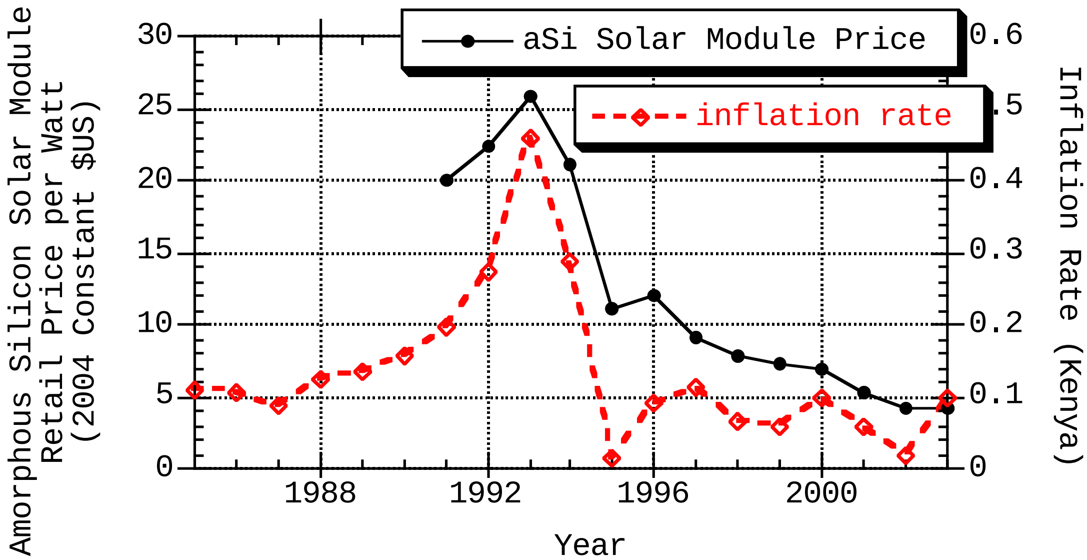

Figure 22: **Retail Prices for Amorphous Silicon (aSi) Solar Modules in Kenya, 1991-2003 and Inflation Rate, 1985-2003.** Source: price data courtesy of Botto Solar of Nakuru, Kenya (data compiled by Maina Mumbi); inflation data from Central Bureau of Statistics, 2003

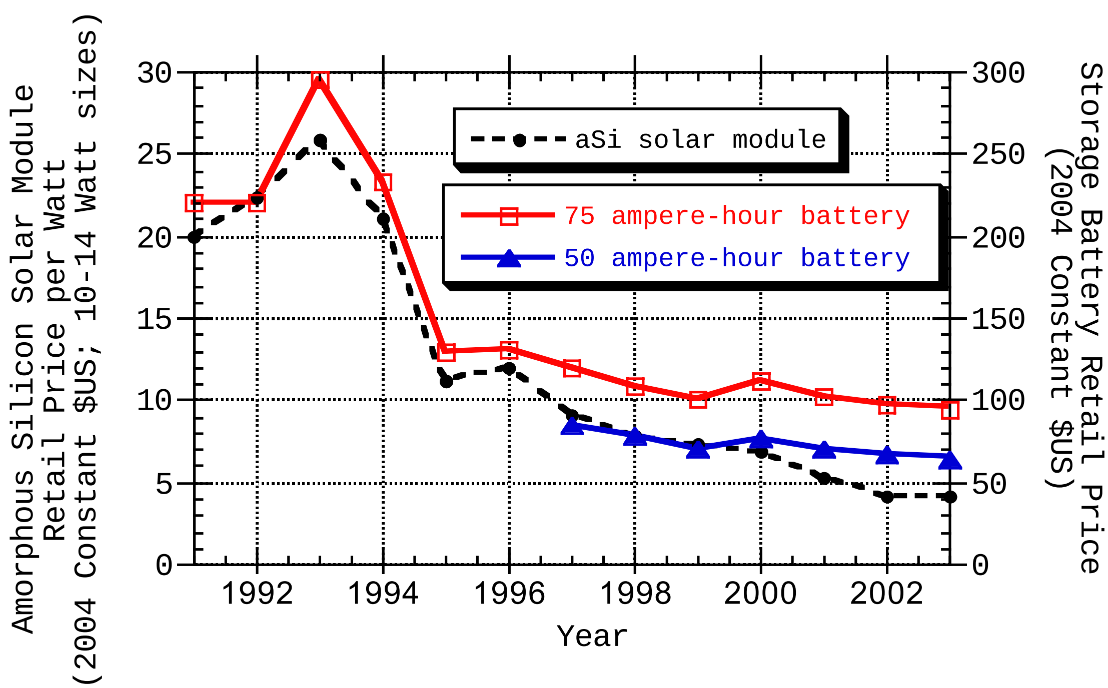

Figure 23: **Retail Prices for Storage Batteries in Kenya, 1991-2003.**
Prices are included for two types of storage batteries (75 Ahr and 50 Ahr sizes). Amorphous silicon solar module prices are included for comparison purposes. The 50 ampere-hour batteries were introduced in the late 1990s. Source: data courtesy of Botto Solar of Nakuru, Kenya (data compiled by Maina Mumbi)

Table 17: Solar Module and Battery Prices in Kenya for Typical Solar System Configurations (data from 2002, prices in Kenyan Shillings)

	Solar Module		Battery		Overall Initial System Cost		
Solar Module Description	Size (Watts)	Price (KSh)	Size (ampere-hours)	Price (KSh)	Total System Cost (KSh)	Solar Module (% of Total)	Battery (% of Total)
14 Watt amorphous	14	4,200	30	3,330	12,500	34%	27%
20 Watt crystalline	20	12,000	50	5,100	25,000	48%	20%
40 Watt crystalline	40	19,000	75	6,900	45,000	42%	15%
60 Watt crystalline	60	25,500	100	10,000	60,000	43%	17%

System Description Details (assumptions about additional items included in total system cost)[189]
14 Watt system: wiring, labor, 1 fluorescent lamp, and a mounting rack for the solar module
20 Watt system: wiring, labor, two fluorescent lamps, 2 light bulbs, and a mounting rack
40 Watt system: wiring, labor, 4 fluorescent lamps, 2 light bulbs, charge control, and a mounting rack
60 Watt system: wiring, labor, 6 fluorescent lamps, 4 light bulbs, charge control, and a mounting rack

Sources: Chloride Exide Kenya Ltd. price sheet, April 16, 2002 & author's estimates from field data.

Unlike solar modules, which are all imported, most of the batteries used in solar systems in Kenya are manufactured domestically.[190] This influences battery prices and sales in several important ways. First, as domestic manufacturers, these companies are in a position to customize products for the domestic solar market [ESMAP, 1999]. Second, these companies play an important role in actively marketing their products, and their activities have contributed substantially to solar sales growth [Hankins, 2003, personal communication]. Third, these companies have successfully lobbied the

[189] Note that the cost of a television set or a radio is not included in the total system cost estimate. A small black and white TV set costs about 4,000 KSh and a radio cassette player with an adapter for operation with a 12 volt battery costs about 2,500 KSh.

[190] Currently there are three companies that manufacture batteries in Kenya. The largest of the three is Associated Battery Manufacturers (ABM) of Kenya. Batteries made by this company are sold under several different brand names, including Chloride Exide Kenya, Dagenite, and Thomas White. The other two companies are Automotive and Industrial Battery Manufacturers (AIBM) - which sells batteries under the brand name "Voltmaster" - and Advanced Performance Batteries (AP).

government to maintain protective import duties on batteries, even while they have supported declining tariffs for solar modules (see Table 16) [Patel, 2003, personal communication]. The resulting tariff structure results in battery prices that are somewhat higher than they would likely be in a more open market.

So far I have described two sets of dynamics that have led to a reduction in solar equipment prices in Kenya. The first is related to experience related manufacturing improvements and efficiency gains, and the second is related to Kenyan national tax and tariff policy. The dynamics in these areas have generally led to falling prices, although tax and tariff policy for batteries has favored protection of a domestic industry rather than lower prices. A third dynamic influencing solar equipment prices is related to the level of competition within the Kenya solar market.

The competition among solar equipment vendors in Kenya has grown increasingly intense, and this has created a downward pressure on prices. This is especially true for small amorphous silicon solar modules, where retail profit margins have fallen to as little as five to ten percent. Competition occurs both at the wholesale level - where a dozen major importers and domestic battery manufacturers work to stake out market share for their respective products - and at the retail level where hundreds of shops sell solar equipment around the country. Retail competition is especially fierce in regional towns such as Nakuru, Meru, or Kisumu, each of which has from 10 to 20 shops that stock a range of solar equipment brands. Many small towns also have high competition levels, with five or more vendors peddling their solar wares. See Table 18 for information about solar vendors and brand availability for selected towns.[191]

[191] Appendix D contains additional information about solar vendors and technicians in Kenyan towns.

Table 18: **Solar Vendors and Brand Competition in Selected Towns**

Town Name	Population (1999 census)	# solar vendor businesses	Solar Module Brands (#)	Battery Brands (#)
Mombasa	665,016	10	8	8
Kisumu	332,734	18	10	7
Nakuru	231,262	19	9	7
Meru	126,427	12	7	6
Bungoma	73,048	14	5	6
Kerugoya/Kutus	35,595	13	5	9
Chuka	7,271	5	5	3

Source: author's original survey data from 2000/01

These data show relatively high levels of customer choice between vendors as well as between brands for both solar modules and batteries. In practice, competition is higher among solar module brands than among battery brands. Tables 19 and 20 show market presence data for leading solar module and battery brands.[192] These data indicate that Chloride Exide dominates the battery market in Kenya. The solar module market is somewhat more evenly balanced between several leading brands.

While competition has led to downward pressure on profit margins and prices, it has also contributed to quality problems and even outright fraud. A lack of government regulation and poor consumer information levels have contributed to a number of quality related problems in the Kenya solar market [Duke, et al., 2002]. Solar module over-rating is one of the most significant of these problems.

Technical measurements indicate that while many of the solar modules sold in Kenya perform adequately, several brands perform 20-50% below their rated output levels. For example, one type of amorphous silicon modules tested in 1999 had an

[192] These data are from a 2000/2001 survey of 312 solar vendors in 46 Kenyan towns. Shops from the capital city of Nairobi were not included in this survey. "Market presence" indicates the percentage of shops that carry each respective brand. Note that each shop may stock several brands.

average power output that was only 55% of rated power [Jacobson, et al., 2000; Jacobson, 2002c]. This over-rating problem is not limited to the amorphous silicon solar technology, as tests of a leading brand of crystalline solar modules (I will call it brand "X") gave power output results that averaged 71% of rated output[193]

Table 19: **Market Presence Data in Towns for Leading Solar Module Brands**

Company	Country of Origin[194]	Panel Type[195]	Market Presence (% of shops)
Helios	Italy (Italy & India)	Mono c-Si	54%
Free Energy Europe	Holland (France)	a-Si, 1-junction	41%
BP Solar (Solarex)	UK (USA)	Poly c-Si	27%
Intersolar	Wales, UK	a-Si, 1-junction	20%
BP Solar (Millenium)	UK (USA)	a-Si, 2-junction	15%
Sangyug[196]	India	Mono c-Si	11%

Source: author's original survey data from 2000/01 (n = 312 total shops)

Table 20: **Market Presence Data in Towns for Leading Battery Brands**

Company	Country of Origin	Market Presence (% of shops)
ABM (Chloride Exide)	Kenya	66%
Bosch	Germany	26%
Added Performance (AP)	Kenya	18%
AIBM (Voltmaster)	Kenya	16%
ABM (Lucas)	Kenya	16%

Source: author's original survey data from 2000/01 (n = 312 total shops)

193 These data are based on measurements of five mono-crystalline solar modules sold by a Kenyan firm (brand "X"). The tests were carried out in 1999 and 2000, and included two 15 Watt modules, two 18 Watt modules, and a 25 Watt module. These modules performed at 9.2, 9.9, 13.3, 14.2, and 18.6 Watts, respectively. See Jacobson, et al., 2000 for a description of the test procedure and accuracy.

194 The first country listed indicates the location of the company's business headquarters. If manufacturing is based elsewhere, this is indicated by the country in parenthesis.

195 The abbreviations in the table have the following meanings: "mono c-Si" = monocrystalline solar module, "poly c-Si" = polycrystalline solar module, "a-Si" = amorphous silicon solar module, "1-junction" = single junction design, "2-junction" = double junction, "3-junction" = triple junction.

196 Most of the modules imported by Sangyug at the time of the survey were manufactured by Udhaya Semiconductors, Ltd. of India.

Competition pressures in the context of a largely unregulated market provide the incentive to over-rate solar modules. A brand "X" solar module that is rated at 25 Watts and sold for 12,000 KSh (i.e. 480 KSh/Watt) may appear to be a "deal" when compared to other modules sold in the market. For example, the 20 Watt solar module (Solarex brand) listed in Table 17 sells for 12,000 KSh (600 KSh/Watt). However, if the 25 Watt brand "X" module actually performs at 18 Watts, the "real" cost per unit of power output is a much less appealing 667 KSh/Watt. Thus, while competition has led to downward pressure on prices, an absence of effective regulation has reduced this pressure by allowing for a difference between the "apparent" per Watt price and the "real" per Watt price as based on actual performance. The companies that have engaged in these fraudulent practices have generally been smaller firms that mainly sell in Kenya or similar largely unregulated settings.[197] The more established solar manufacturers are generally not in a position to take such steps given the need to protect their international reputation as well as the fact that a significant fraction of their sales are in markets where severe over-rating could potentially result in serious regulatory sanctions.

In this section I have identified three sets of factors that have contributed to a downward price trend. These include reductions in manufacturing production costs for international and domestic producers of solar equipment (including solar modules as well as batteries and other system components), reduced tariff and tax rates on solar equipment within Kenya, and intense competition that had led to reduced profit margins within the supply chain. These dynamics have combined to lower retail prices in Kenyan shops, and this has contributed greatly to increasing solar system sales.

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[197] Note that only a minority of the Kenya based import firms appear to have taken this approach.

At the same time, an absence of effective government regulation as well as consumer information problems have allowed some manufacturing and import companies to engage in fraudulent practices that have effectively counter-acted some of this downward pressure on prices. This indicates that some of the key problems associated with quality and performance in the Kenya market are due to the relative *lack* of effective government involvement in the market.

Rural Television and the Growth of the Solar Market

Falling equipment prices made solar PV more affordable, but it was the increased availability of television in rural areas that provided the key motivation for demand in the Kenya solar market. 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 a vitally important role in the growth of demand for solar electric systems (see Figure 24) [Musinga, et al., 1997; Hankins, 2000a; Abdulla, 2001; Muriira, 2001; ESDA, 2003].

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. There is a wealth of evidence for this conclusion, beginning with previously mentioned survey data which show that nearly 90% of "solar" households own a TV, while smaller percentages (84% and 75%, respectively) use the power for lights and radios [Hankins, et al., 1997]. Possibly 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.[198] This highlights the high priority given to TV.

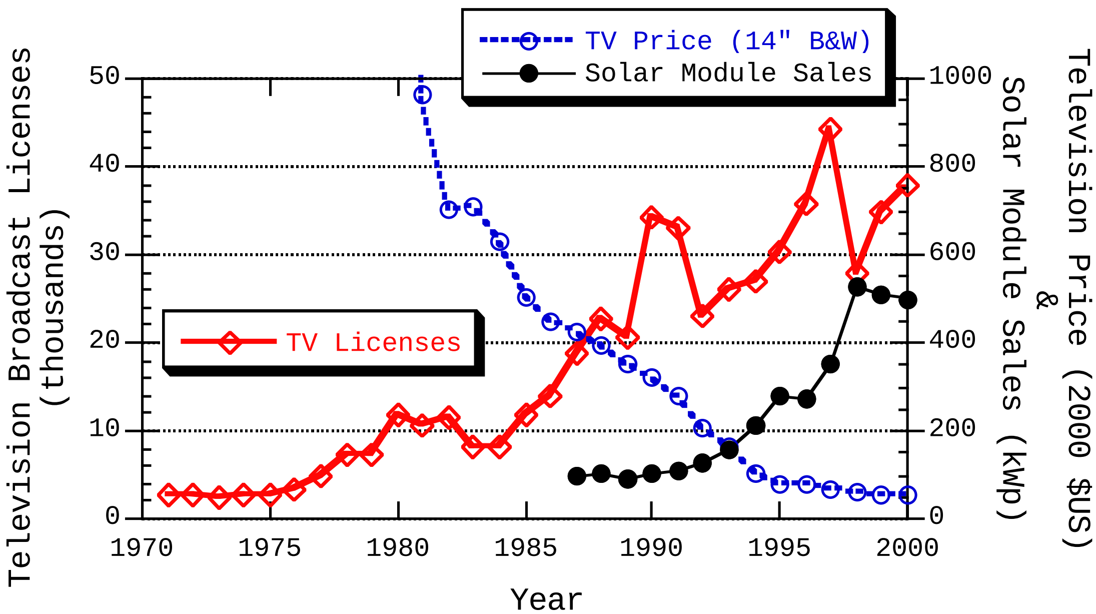

Figure 24: Growth of Television and Solar Panel Sales in Kenya, 1970-2000[199]
Sources: TV licenses: Central Bureau of Statistics, various years from 1980-2002; TV prices: Manji (2001); PV sales: Hankins, 2000a (for 1989-99 data); Acker and Kammen, 1996 (for 1987, 1988 data).

Many solar vendors recognize the critical importance of television as a driver for sales growth, as is noted in the quote by Hankins at the beginning of this chapter. An analysis of 391 advertisements for solar products in Kenya's leading daily newspaper (*The Daily Nation*) during 2002-03 supports the assertion that solar vendors recognize the importance of TV as a driver for consumer demand. These data indicate that solar systems are four times more likely to be marketed as a means to power televisions than as a means to power lights.[200] See Figure 25 for sample advertisements featuring TV.

[198]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.
[199] 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.
[200] The newspaper advertisements were tracked on a daily basis, providing a systematic survey of all ads that appeared in print.

I have discussed how solar market growth in Kenya is closely linked to the increased availability and use of television in rural Kenya. Rural television use, in turn, was made possible by substantial government investments in broadcast infrastructure during the 1980s and 90s as well as by falling TV set prices. The growth of the solar market, then, can be understood in part as an unintended - but not unwelcome from the government's point of view - consequence of Kenyan government broadcast policies.

Television broadcasting was first established in 1962 by the Kenya Broadcasting Corporation (KBC) during the final year of British colonial rule. The first transmitting station was set up just outside of Nairobi near the town of Limuru, and it delivered TV signals to wealthy (mostly white) residents living in the Nairobi area[201] [KBC, 2004]. Kenya gained independence in 1963, and shortly thereafter the KBC was nationalized and renamed the Voice of Kenya (VoK) [Heath, 1986].

Figure 25: **Newspaper Advertisements in which Solar PV Systems are Marketed as a Means to Power Television Sets**. Sources: Daily Nation (May 29, 2002 & June 4, 2002)

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[201]In 1963 a broadcast repeater station was setup in a mountain pass near the town of Timboroa, and this delivered a weak TV signal to towns in the western part of Kenya, including Kisumu and Eldoret. The Limuru transmitter was also upgraded so that it had a 95 mile broadcast radius [Heath, 1986].

The government made several key investments in the television broadcast infrastructure during the 1960s and 70s, including upgrades for the Nairobi (Limuru) and Timboroa sites as well as the introduction of TV service in the coastal city of Mombasa.[202] Nonetheless, although 75% of the population lived in rural areas, television broadcasting was relegated primarily to urban areas through the late 1970s.

The real expansion of TV broadcasting in Kenya occurred during the 1980s. See Figures 26 and 27 for graphic and map based representations of television broadcast expansion in Kenya, respectively. During this decade the Nairobi and Mombasa transmitters were upgraded, and new transmitters were added near the towns of Nyeri and Meru in the densely populated and economically important Mount Kenya region.[203] These investments substantially increased the range of TV broadcasting beyond the main urban centers. Additional investments in the 1990s led to further expansions of KBC TV's broadcast range.[204]

At present, television broadcast signals reach the areas of Kenya that are occupied by nearly 90% of the population.[205] According to the 1999 national census [GoK, 2001], 83% of Kenyans live within 100 kilometers of the towns shown in Figure 27 that are clustered in the south central and south western part of the country.[206] Nearly all of

---

[202] TV service was established in Mombasa in 1970. Initially this service was entirely independent of the Nairobi broadcasts. However, in 1975 a Nairobi-Mombasa transmitter link was installed, and from that time the Mombasa station carried the same programming as Nairobi [Heath, 1986].

[203] Color television service was also added in the early 1980s [BBC, 1980a].

[204] In 1989 the Voice of Kenya (VoK) was re-organized into a parastatal corporation. At this point it was re-named the Kenya Broadcasting Corporation (KBC) [BBC, 1989].

[205] In addition to the KBC, there are now 6 private TV broadcasting companies in Kenya. The first private broadcaster, Kenya Television Network (KTN), was licensed in 1990, but it did not expand broadcasting beyond Nairobi until 2000 [Media Institute, 2002a; East African Standard, November 27, 2001]. Other private companies began transmitting in the late 1990s, but they too remained confined to the Nairobi market until very recently. See Chapter 7 for a detailed discussion of the history of TV broadcast sector liberalization in Kenya.

[206] That is, they live within 100 km of Nairobi, Meru, Nyeri, Nakuru, Eldoret, Webuye, Kisii, or Kisumu.

these areas now have access to a KBC television broadcast signal, although there are some places in this region do not get a signal due to topographical obstructions (i.e. hills and mountains). Another 9% of the population lives on the coast, with the majority living close enough to Mombasa to receive that signal. Only 8% of the Kenyan population lives in the remote areas of northern Kenya, eastern Kenya near the Somali border, and the southern border with Tanzania that are as yet outside of the TV broadcast range. Thus over the period of two decades beginning in the early 1980s, the Kenyan government expanded television broadcasting from the main urban centers to almost every populated corner of the country.

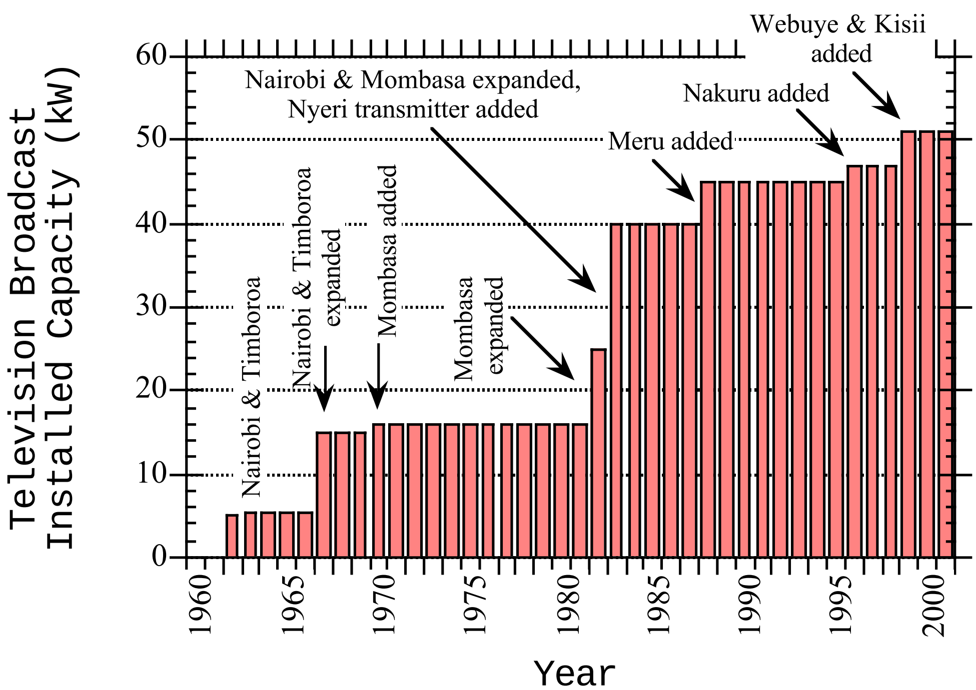

Figure 26: **VoK and KBC Television Broadcast Signal Expansion, 1962-2001**
Sources: KBC, 2004; Muriira, 2001; VOK, 1983; VOK, 1967

Figure 27: **Map of Kenya with Television Broadcast Station Locations**[207]
[original map from http://www.cia.gov modified by A. Jacobson]

Of course, television viewing does not depend on broadcast signals alone. The absence of electrical service among rural residents was a key concern at the Ministry of Information and Broadcasting during the early 1980s [e.g. BBC, 1981]. Although the rural grid failed to deliver services to a substantial fraction of the population, the introduction of television sets that could be operated using a car battery[208] provided a means to power TVs for those rural residents who were wealthy enough to afford them. Battery powered TV sets were one of the key precursors for solar sales in Kenya, as some rural families chose to buy a solar module to keep the battery charged [Hankins, 2000a; Jacobson, 2004c].

[207]TV broadcast repeater towers are located at Nairobi (Limuru/Hillcrest), Timboroa, Mombasa (Mazeras), Nyeri, Meru (Nyambene Hill), Nakuru, Kisii, and Webuye; Kisumu and Eldoret are major towns served primarily by the Timboroa broadcast repeater station. They are included in the map for reference purposes.

[208] The first 12 volt DC powered television sets were brought to Kenya in the late 1970s, and the market for these sets grew substantially during the 1980s [Abdulla, 2001].

A sharp decline in television set prices also contributed significantly to the expansion of TV - and solar system - use in Kenya. In the early 1980s TV sets were considered a luxury item that only the very wealthy could afford. Television sets are over 20 times less expensive in real terms now than they were in 1980, and the widely used 14" black & white sets are now available for less than $50 (see Figure 24) [Manji, 2001; Botto, 2004].

Declining import duties and taxes in Kenya played a role in reducing TV prices over time (see Table 21). Even more important has been the dramatic rise of the East Asian electronics industry. Nearly all television sets sold in Kenya come from East Asia, and the price of these imports have fallen substantially over time. One TV set brand in particular has played a key role in making television more widely affordable for rural Kenyans. The "Greatwall" television, produced in Tianjin, China, is the most widely used TV set in rural Kenya[209] (see Figure 28). These 14" black & white units are notable for their low cost, high electrical efficiency,[210] and their bright red plastic casing. The connection between East Asian firms like the Tianjin GreatWall Electronics Company and the growth of solar sales in Kenya highlights the global nature of the solar market supply chain.

[209] According to data on TV ownership from a 2002 media survey by the Steadman Research Group, 34% of all TV sets in Kenya are made by Greatwall. Its next nearest competitor, Sony, accounts for 14% of the TV sets [Steadman, 2002].
[210] Greatwall television sets consume an impressively low 10 Watts during normal 12 volt DC operation. These sets can also be operated using AC power.

Table 21: **Cumulative Tax Rate on Black and White Television Sets in Kenya**[211]

Year	Tax Rate
1980	180%
1985	260%
1990	96%
1995	65%
2000	48%

Source: Kenya Gazette Supplement documents, 1980-2000

Figure 28: **Greatwall Television Set Produced in Tianjin, China**
Source: Tianjin GreatWall Electronics Company, 2004 (http://www.greatwall-tj.com/greatwall/ef-3.htm)

This discussion highlights the role that Kenyan government television broadcast policies, in combination with the introduction of battery powered 12 volt DC TV sets and sharply declining prices, have played in the growth and development of the solar market. Thus, while the Kenyan government has had a relatively modest direct role in influencing solar electrification, its indirect role through avenues such as television broadcast policies has been centrally important to the rapid growth of solar sales.

Solar Electricity and Kenya's Rural Middle Class

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

[211] The cumulative tax rate includes import duties as well as sales tax. In 1989 the sales tax in Kenya was replaced with a Value Added Tax (VAT). The import duty rate is applied to the base price of the good, at the port of entry. Sales tax is calculated based on the retail price (which is inclusive of the dutied price plus any margins added in the supply chain after importation). The VAT is calculated based on the dutied price alone. The data reported here are for "fully assembled black and white television sets." The tax rates for "partially assembled" and "unassembled" black and white sets show similar trends.

market. As I discussed in Chapter 3, processes of middle class formation - including the commercialization of agriculture through small holder farming as well as dynamics around education - were critical for the emergence and growth of the solar market in Kenya. Government policies made important contributions to these processes. Of particular note are the post-Independence redistributive land reform that delivered a significant amount of high quality farmland to small holder farmers and education policies that resulted in a large number of rural school teachers. The government cannot, of course, take full credit for these policies. In many cases government actions were a response to pressure from within the citizenry, and the everyday actions of rural Kenyans were at least as important as the government role. Nonetheless, actions by the Kenyan government have been a central component of middle class formation in Kenya, and they therefore have played an indirect but crucial role in the development of the solar market.

Conclusion

The solar market in Kenya has emerged as one of the largest per capita among non-industrialized countries. While many have suggested that the high sales number in Kenya indicate a happy marriage between "small is beautiful" and the free market, I argue that the rapid growth of the solar market in Kenya cannot be understood in terms of market dynamics, private sector initiative, and business models alone. Instead, the solar market emerged as the result of a set of historical processes that came together to create the conditions for solar market growth.

In this chapter and the previous one I discuss six key factors and processes that have contributed to the development of the market. They are (1) declining solar equipment

prices, (2) the slow pace of grid based household rural electrification, (3) close connections between Kenya and Western donor countries during the 60s, 70s, and 80s, (4) the expansion of solar sales through pre-existing supply chain networks, (5) the increased use of television in rural areas due in large part to government investments in state television broadcasting, and (6) the purchasing power of the "rural middle class."

While none of these elements, taken alone, ensured solar market growth, several can be seen as necessary - if not sufficient - conditions for the development of the market. Declining prices, the relative absence of the rural grid for household electricity, the expansion of rural television access, and rural middle class purchasing power all fall into this category.

The historical focus in the analysis that I present here raises important questions about "business model" debates that suggest that the main policy questions related to solar electrification revolve around selecting the "right" business model for private businesses to implement in free market settings. This framing neglects the central role that historically and geographically specific conditions play in shaping the possibilities for solar electrification. It also ignores the important role of the state in creating some of the key conditions for the emergence of the solar market.

The government initiative to re-distribute high value agricultural land to small holder farmers just after independence was particularly important for the emergence of the solar market, as it contributed to the creation of the small holder cash cropping economy that forms one of the main foundations for the ongoing development of Kenya's rural middle class. Dynamics around education policy between the state and private citizens have also been important in the process of rural middle class formation,

and rural school teachers make up a particularly large purchasing block in the solar market. Last but certainly not least, government investments in television broadcasting allowed for the expansion of rural television use in Kenya. This was a necessary condition for solar market growth, as television has been the main driver for demand in rural Kenya. These three examples highlight the importance of government action in creating the conditions that made the solar market possible, even as they also indicate the important linkages and interconnections that exist between long term historical processes and market transactions.

In other words, the Kenya solar market, like all markets, is deeply embedded in its social context. It emerged as the result of a specific configuration of historically situated processes, some of which are, at the very least, unusual among African countries. This does not indicate that solar markets will not emerge elsewhere, or that the elements present in Kenya are the only ones that can create favorable conditions for solar market development. It does suggest, though, that attempts to transfer lessons from the Kenya market to other countries must be done with an eye towards contextually specific differences, including processes that may be beyond the control of solar policy makers. This indicates that policy can and should play a role in shaping and influencing solar electrification, but it must do so within limits set by long term historical processes.

Chapter 5

Cash or Credit?
Equity, Access, and Subsidies in the Kenya Solar Market

> Even as the first projects were being developed, it became clear to project planners that the solar home systems being promoted were far too expensive for the impoverished market to which they were supposed to be bringing benefits. … Consequently, a major challenge – the 'holy grail' of PV projects – has been making standard-sized PV solar home systems[212] affordable for low-income groups.
>
> Mark Hankins, 2004, p. 9

> It was agreed that in most cases, energy markets need to grow on their own strengths rather than through the use of subsidies. However, it was acknowledged that subsidies have a niche if they are time bound and designed appropriately.
>
> Ellen Morris, 2004, Summary statement from "Consumer Lending and Microfinance to Expand Energy Services" Conference in Manila. The conference was sponsored by the UNDP, the World Bank, U.S. AID, and GTZ of Germany.

As I noted in Chapter 3, solar electricity use in Kenya is dominated by the rural middle class. The decentralized market-based approach to household rural electrification using solar and battery based systems in Kenya emerged in part due to the slow pace of centrally planned grid based rural electrification, and in this unsubsidized market context[213] electricity access - including access to solar PV - is determined primarily by a combination of purchasing power and market prices. In this context small amounts of electricity from solar PV became affordable first to the rural elite in the late 1980s, and then to the rural middle class in the 1990s. Current trends indicate that, as solar equipment prices fall, solar ownership patterns are slowly

[212] "Standard sized PV solar home systems" refers to systems that include a 40 to 50 Watt solar module.
[213] i.e. for the overwhelming majority who are not in a position to get a grid connection through Kenya's Rural Electrification Program.

expanding beyond the top third of rural families, though only the very smallest solar electric systems (i.e. < 20 Watts) are affordable for those at the "ownership frontier." Meanwhile, for most of the rural poor electricity - whether from the grid, a solar system, or a car battery - remains well out of reach. These people generally depend on kerosene for lighting, and if they are able to use electricity at all, their use is limited to dry cell batteries for items such as radios and flashlights.

In this chapter I use empirical data on the wealth distribution of households that own solar electric systems in rural Kenya to engage with ongoing solar policy debates about equity, access, subsidies, and market-based approaches to service delivery. Issues of affordability and access are central to current policy debates about solar electrification in developing countries. Despite widespread characterizations of solar as a key technology for poverty alleviation and sustainable development, most solar policy makers acknowledge that in the absence of significant subsidies, solar electrification remains out of reach for the rural poor. Nonetheless, many argue that over the coming decades solar electrification can play a central role in expanding rural electricity access to the frequently cited 'two billion people who lack modern energy services', especially in countries and regions where grid based rural electrification efforts have failed to reach a significant fraction of the population [e.g. Cabraal, et al., 1996; Kaufmann, et al., 2000; Martinot, et al., 2002; and many others]. The current conventional wisdom in mainstream solar policy circles is that the key to realizing this goal is the adoption of policies that support the development of market-based schemes for solar electrification, combined with measures to attract international finance capital to developing country solar markets. Questions about whether, how, and to what extent subsidies should be

used to support solar electrification continue to be an important aspect of policy debates. Within solar policy and related literature there have been at least five positions with respect to subsidies.

First, as I outlined in Chapter 1, from the late 1970s to the early 1990s heavily subsidized solar projects were the norm. In many of these projects the recipients were required to make only small, if any, contributions to the initial cost of the PV systems, as these costs were covered by the funding agency. Thus, from the perspective of recipient households, initial access to solar electricity was often "free" or at least very inexpensive. Many of these projects failed to plan adequately for ongoing operation and maintenance for the systems. As a result, the failure rates of solar systems in many of these "parachute" efforts have been dramatically high. These projects have been widely criticized as both ineffective and "unsustainable" given the performance problems and the high subsidy levels that they require [e.g. Foley, 1995; Cabraal, et al., 1996].

The main response to problems associated with these projects was a move in the 1990s towards developing commercially viable solar markets, with an emphasis on private sector initiative and full cost recovery. However, not all subsidies were set aside with the transition to a market approach. Aid to support "market development" efforts such as the development of consumer credit institutions, technical and business training, and other "market conditioning" activities is deemed critical, while subsidies on the actual solar system hardware are frowned upon as "unsustainable" and the cause of price distortions as well as unrealistic expectations on the part of potential rural solar users [e.g. Hankins, 1993; Covell and Hansen, 1995; Cabraal, et al., 1996; Harvey;

1996; Martinot, et al., 2002]. "Soft subsidies" - as this aid for market development activities is sometimes called - are now viewed as a key element of strategies to expand solar sales and to attract private international investment capital into solar markets [Covell and Hansen, 1995 & 2000; Harvey, 1996, Martinot, et al., 2002].

While a move towards commercial market development through the use of "soft subsidies" is fast becoming dominant, there are at least three additional positions of note. First, there are those who are broadly skeptical of the value of subsidy support for solar electrification. These authors argue that the costs of solar PV are too high and the benefits are too low compared to other possible investments [e.g. see Inverson, 1996; Karekezi and Kithyoma, 2002; Villavicencio, 2002]. Second, there are those who argue for vastly increased public and donor funding for renewable energy in developing countries, including solar PV. These groups appear to support both "soft" and "hard" subsidies,[214] although they do not always distinguish between the two in their literature [e.g. see Greenpeace, 2001]. Finally, some mainstream policy analysts have begun to revisit the subsidy issue with an eye towards balancing concerns about market efficiency with equity and access for the poor. These authors appear to support both "hard" and "soft" subsidies, but focus on seeking subsidy approaches that "minimize market distortions" [See especially Barnes and Halpern, 2000].

While I leave a full discussion of subsidies and their relationship to renewable energy policy for another venue, my intention in this chapter is to use evidence from my research in Kenya along with supporting evidence from elsewhere to unpack some of

[214] In this context 'hard' subsidies refers to support for equipment costs, while 'soft' subsidies refers to support for institutional development, technical capacity building, and other 'market development' related costs. See Harvey, 1996.

the equity and access implications of mainstream approaches to solar policy. This line of thinking appears to be moving towards a position of using funding support exclusively for market development (i.e. soft subsidies only), with the eventual goal of achieving subsidy free commercial markets.

Within this mainstream position there is widespread agreement on the importance of market-based approaches, but there is some debate about which "business model" will work best to achieve sustained sales growth. The dominant view has been that over-the-counter cash sales are effective for the delivery of solar systems to the rural elite in the initial stages of market development, but that consumer finance mechanisms that spread the high initial cost of the systems out over time are needed to expand sales and to deepen solar electricity access to a broader fraction of the population [Covell and Hansen, 1995; Cabraal, et al., 1996; Martinot, et al., 2002; Eckhart, et al., 2003]. The implication is that with the right business model - i.e. some form of consumer financing - market-based solar electrification can enable high rates of sustained sales growth *and* a deepening of solar access to lower income segments of the population, all without the application of subsidies on the cost of the systems. Following this line of thinking, the main thrust of solar policy and donor aid from multilateral groups such as the World Bank and the Global Environment Facility (GEF) has been associated with efforts to support the development of market-based consumer finance schemes in Asia, Africa, and Latin America [e.g. PVMTI, 1998; Simm, et al., 2000; Miller and Hope, 2000; Martinot, et al., 2002; GEF, 2004b; and others].

Other solar advocates agree with the market-oriented focus of solar policy, but disagree on which business model works best. This group notes that consumer

financing schemes are often difficult to set up, and that in some developing countries (e.g. Kenya, Zimbabwe, and Morocco), an increasing fraction of the rural population is buying small, low cost solar systems through over-the-counter cash purchases. These authors suggest that international donor groups should do more to support the development of these cash markets rather than focusing almost exclusively on consumer finance type arrangements [van der Plas and Hankins, 1998; van der Vleuten-Balkema, et al., 2000; Hankins, 2000a & 2004].

Evidence from my research in Kenya's market, which is heavily dominated by cash sales, confirms that solar system ownership is not confined to the rural elite alone, and in so doing it challenges the claim that the introduction of consumer financing will necessarily lead to a significant deepening of access to solar electricity relative to the status quo. However, this does not indicate that unsubsidized cash sales are the panacea for delivering solar power to the rural poor. Rather, my work reaffirms that in the absence of significant subsidies, including both "hard" and "soft" types of subsidies, the large mass of rural poor are unlikely to gain access to high quality electricity services from solar PV anytime soon regardless of which institutional or business model is used.

My work in this chapter revolves around four key findings about market-based solar electrification in Kenya:

1) Solar electrification is neither restricted to the rural elite alone, nor is it widely available to the larger mass of rural poor. Instead, as I noted in Chapter 3, solar system ownership in Kenya's market is dominated by the rural middle class.

2) Small, low cost solar panels (i.e. 10 to 20 Watts in size) and a widespread use of battery powered TV sets have led to a gradual deepening of solar system ownership beyond the rural middle class. The key to this expansion is a "modular" cash-based purchasing pattern in which households first purchase a battery and a TV set, and later add a small solar panel as well as other components. This incremental system of purchasing allows rural households to "build" systems over several years through purchases of as little $50 to $100 at a time. However, the amounts of energy available from these small systems are tiny, and quality and performance issues are also significant concerns.

3) The introduction of consumer credit at commercially competitive interest rates is unlikely to expand the distribution of ownership to solar electricity beyond its present level in the already established cash market, although it may allow rural middle class Kenyans who can already afford a small solar system to buy a somewhat larger and perhaps better quality one.

4) In the absence of significant subsidies, electricity access levels in Kenya appear most likely to deepen primarily through cash sales of lead acid batteries and the smallest (<20 Watts) solar systems. Without substantial and perhaps targeted subsidy support, larger solar systems are likely to remain far out of reach for the large majority of rural poor for a long time to come.

The 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. First, the small systems that are affordable to those at the "ownership frontier" provide households with only tiny amounts of electricity. Data that I presented in Chapter 2 indicate that much of the electricity from these systems is often allocated to television viewing, leaving relatively little energy in many households for key applications related to children's education, income and work related activities, or domestic chores.[215] Second, many - though not all - small systems purchased on a cash basis are plagued by quality and performance problems, which further reduces the amount of energy that is available from them. Third, given the extremely low income and wealth of those rural Kenyans below the median wealth level (see Figures 10 and 11), continued deepening of solar access through unsubsidized cash market sales appears likely to move at a very slow pace. Meanwhile, GEF and World Bank sponsored programs to develop consumer financing for solar PV appear destined - if successful - to provide benefits primarily to the rural middle class.

Solar Electrification Business Model Debates

During the 1990s the mainstream of international policy in support of solar electrification efforts shifted from a focus on centralized donor funded solar projects to an emphasis on the development of solar markets. This shift followed a larger move towards neo-liberal market-based policies in broader mainstream development thinking[216] [e.g. Lal, 1985; Williamson, 1993; see also Watts, 1994 for a key critique].

[215] I will discuss intra-household energy allocation and the corresponding social use implications in more detail in Chapter 6.

[216] As I note in chapter 1, the general trend towards electricity sector restructuring and privatization can also be seen as part of this broader shift. Most restructuring plans - many of which were initiated in part due to World Bank conditionality - involved a reduction or elimination of public benefits charges and mechanisms used to generate funds for rural electrification and other programs intended to increase grid electricity access for marginalized groups [e.g. see Dubash, 2002].

In addition, the emergence of financially viable solar markets in several countries (e.g. Kenya, the Dominican Republic, Sri Lanka, Zimbabwe) played an important role in influencing mainstream solar policy opinion [Hankins, 1993; Covell and Hansen, 1995; Miller and Hope, 2000; Martinot, et al. 2002].

As I noted earlier, mainstream solar policy discussions over the past decade have centered around what might be called the "business model debate." Contending models include over-the-counter cash sales of solar systems, consumer credit sales, and fee-for-service arrangements.[217] Mainstream solar policy advocates have worked especially hard to develop consumer financing institutions[218] in emerging solar markets, while cash sales approaches have received less attention and support.

Consumer credit, fee-for-service, or other business models that are intended to make solar systems more affordable by spreading the up-front cost of purchasing a system out over time are deemed by many to be the critical element in setting the stage for massive solar sales growth [Covell and Hansen, 1995 and 2000; Cabraal, et al., 1996; Martinot, et al., 2000; Miller and Hope, 2000; Kaufmann, et al., 2000; Martinot et al., 2002; and others]. The conventional wisdom is that in most developing countries only the wealthiest among rural residents can afford solar through cash sales (e.g. the top 3-5%), but that "…market demand increases by a factor of ten with the provision of reasonable

[217] Under the cash sales approach, solar system components are sold through one time cash transactions. Consumer credit arrangements usually involve the sale of a complete solar system. A down payment is generally required, and the balance of the cost for the system is paid through periodic installments, often over 1-3 years. In fee-for-service sales arrangements a 'solar utility company' installs the systems and retains full ownership of the equipment. The electricity from the system is then sold to customers, often on a pre-paid basis (although post-paid billing is also common). See Cabraal, et al., 1996, Hankins, 2004, and Banks, 2004 for more details about these business model approaches.

[218] I use the term "consumer finance" here to refer both to consumer credit and to fee-for-service type business models.

levels of end-user financing." [Eckhart, et al., 2000; see also Simm, 2000; Martinot, et al., 2002; and others]. The implication is that consumer financing business models lead to the expansion of sales *and* the deepening of access to less wealthy portions of the rural population. See Figure 29 for a graphic representation of conventional wisdom about cash, credit, and fee-for-service business models in developing country markets.[219] The implication of this view is that solar sales and a significant deepening of access can occur without direct subsidies, provided that the correct business model - i.e. some form of consumer financing - is used. Initially, aid support is necessary for "market development" activities, but eventually - the theory goes - solar PV can deliver electricity to a broad segment of the rural population through unsubsidized commercial market channels.[220]

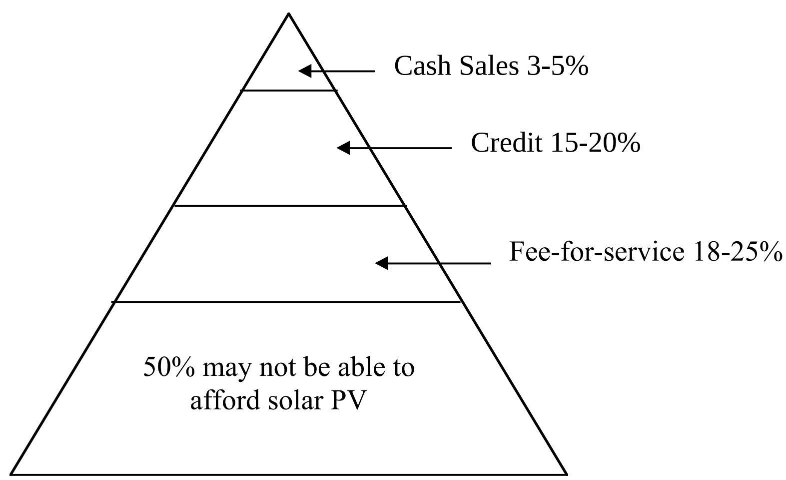

Figure 29: **Affordability of (Solar) PV Systems by Rural People in Latin America**
Source: reproduced in Eckhart, et al., 2003 from original created by Soluz, Incorporated based on market research in Latin America. The caption is from the original figure.

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[219] Although this figure was developed by Soluz International based on market data and experience in Central America and the Caribbean, it is widely regarded in mainstream policy circles to apply broadly to developing country solar markets.
[220] It is notable that this framework explicitly accepts that the bottom half of the unelectrified rural population will not be able to afford solar electricity through unsubsidized markets.

Hankins [2000a; 2004] - while accepting the importance of a market approach - has challenged the exclusive focus on consumer financing, noting that cash sales of small solar systems through a "modular" purchasing pattern have already made solar electricity affordable to a fairly wide segment of the rural population in Kenya.[221] Hankins has estimated that modular purchases have made solar systems affordable to the top 25% of the rural Kenyan population[222] [Hankins, 2000a]. In other words, cash sales in Kenya have resulted in solar ownership that goes well beyond the top 3-5%. He further argues that consumer finance may not always be the most appropriate model for solar market development. In making his case, Hankins cites a number of difficulties associated with the introduction of consumer credit sales for solar systems in countries that do not already have a developed micro-credit network that extends into rural areas. He notes that "consumer credit is expensive to administer…" due to high transactions costs and he claims that "…consumer loans do little to extend the (solar) PV market beyond the reach of affluent rural customers" [Hankins, 2004; p.16]. Fee-for-service arrangements also involve high transactions costs, and efforts to use this approach in South Africa have required massive subsidies to move forward[223] [Hankins, 2004, p. 19; see also Duke, et al., 2002]. In contrast, he says that cash sales involve relatively

[221] Hankins describes modular cash purchasing as follows: "Modular cash purchase is the most common form of (spreading the cost of purchasing a solar system out over time in Kenya). Through this method, rural people purchase the appliance and/or the battery first, and then add the (solar) PV system components later. … When cash is available, the consumer buys a battery based system, and with low outlays is able to keep it charged through a charging station. In a subsequent season, the consumer buys a solar module and affixes it to the battery. Later, the consumer may purchase another module, lights and a charge regulator" [Hankins, 2004; p. 20].

[222] The data that I present based on Tegemeo 2000 household survey data support Hankins' estimate, indicating that 80% of systems are owned by the top one-third or rural Kenyans by wealth.

[223] The fee-for-service approach has also been used elsewhere, including Argentina, Honduras, and Zambia. In each case significant amounts of donor funding were required to establish even limited programs [ISES, 2001a; Damm, 2002; Ellegård, et al., 2004].

simple transactions, and in many countries the supply chains are already in place. Based on these observations, he concludes that in some cases international donors should support the development of cash-based markets instead of focusing exclusively on consumer finance based business models [Hankins, 2004, pp. 20-22].

To date, mainstream policy makers at the GEF, the World Bank, and elsewhere do not appear to be interested to offer any substantial support for the continued development of the cash-based business model, despite its association with the expansion of solar ownership well beyond the rural elite in Kenya. Instead, these policy makers have maintained their focus on the development of consumer financing models.

This emphasis on consumer financing can be understood as part of a broader goal of attracting international finance capital into solar electrification in developing countries. In other words, the main objective of mainstream solar policy is to build a massive world market for solar products, and while some of the capital to support this expansion may continue to come from multi-lateral and public sources, there is an increasing push to attract private capital from international banks and investment companies [e.g. Covell and Hansen, 2000; Martinot, et al., 2002]. Thus, many solar policy initiatives emerging from the World Bank and associated groups can be understood as attempts to make developing country solar markets more attractive for international finance capital. Finance capitalists are, of course, most interested to invest in profitable ventures that do not involve undue levels of risk. Solar policy advocates are therefore under pressure to demonstrate that demand for solar electrification is large enough to generate significant and sustained profits, and that the risks associated with investments in these markets can be kept to a minimum.

Cash sales through a modular purchasing pattern may be viewed as less viable for attracting international finance capital than consumer financing models for two key reasons. First, cash markets like the one in Kenya are highly competitive due to low barriers to entry and the corresponding participation of many locally based companies. As a result, profit margins are generally low. This may dissuade international investors from entering this and similar markets.

The second reason is related to quality and performance problems that are often associated with systems purchased on a modular, cash sales basis. Investors view quality problems as a risk, since a technology that cannot deliver services over the long term may lead to reputation problems and a stagnation of sales.

Systems bought through modular cash sales are acquired in pieces, and often the various components come from different vendors.[224] As a result, the solar module and the battery are often poorly matched,[225] and the systems frequently do not include key components - such as a charge regulator - that can improve long term system performance. In addition, when systems are purchased with cash, operation and maintenance responsibilities fall on the system owners, who frequently have little knowledge of how to care for the system properly. Finally, the quality of solar system components has been a problem in many cash-based markets, in part due to a lack of effective government regulation [e.g. see Jacobson, et al., 2000; Duke, et al., 2002].

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[224] i.e. the battery might be bought from one vendor, and the solar module - purchased at a later date - might come from different vendor, etc.

[225] Many systems in Kenya have a solar module that is undersized relative to the battery as well as to the electrical loads that are used with the system. This can shorten the effective life of the battery. See Jacobson, 2001 for further discussion.

These problems are widely acknowledged, even by proponents of the cash model.[226] Nonetheless, most small solar systems in Kenya function well enough to provide higher levels of service than the battery systems they often replace, and some degree of technical support is generally available from small town electricians [van der Plas and Hankins, 1998; Jacobson, 2002a]. Proponents of cash models therefore argue that aid support for training technicians, raising awareness among solar users, developing in-country regulatory capability, and similar measures would go a long way towards addressing some of these quality and performance issues [e.g. van der Plas and Hankins, 1998; Hankins, 2000a and 2004, van der Vleuten-Balkema, et al., 2000].

In contrast, most mainstream solar policy makers appear to view consumer credit and fee-for-service business models - not an improved version of the cash sales approach - as the best way to address these quality and performance problems, and therefore to reduce the perceived risk for potential investors. Under these consumer finance oriented approaches, a single agency generally handles solar equipment purchases and the development of system design standards. This makes it much easier to regulate quality than in a cash market, even in the absence of effective government participation. In addition, consumer credit companies have a high incentive to ensure that systems continue to operate over the period of the loan, as loan repayment is highly correlated with system performance [Cabraal, et al., 1996]. Under fee-for-service arrangements, the incentive for the business sector to provide operation and maintenance support is even higher, as the fee-for-service utility company is the owner

[226] e.g. Hankins notes that "…because (systems purchased through modular cash sales) …are poorly sized, self-installed and usually do not include charge regulators, their performance is poor, and their battery life is short" [Hankins, 2004, p.20].

of the equipment and they are likely to get paid only if and when the system is working[227] [Cabraal, et al., 1996; Banks, 2004].

To summarize, mainstream solar policy advocates favor consumer finance oriented business models over cash-based models for their attempts to greatly expand developing country markets for household solar electric systems. They see international investment capital as key for realizing this project, and consumer financing is deemed more compatible with efforts to attract this capital than a cash-based approach. Moreover, they contend that consumer finance will make solar systems more affordable, and that this will simultaneously lead to a growth in sales *and* a deepening of access to solar electricity beyond the rural elite to those who cannot afford to buy through cash sales arrangements.

Cash sales advocates counter that "modular" purchasing of small solar systems has already led to a deepening of solar ownership beyond the rural elite to the rural middle class, and that consumer credit and fee-for-service approaches involve high transactions costs and may be difficult to establish in some contexts. Therefore, they suggest that more international aid should be allocated towards "soft subsidy" support for efforts to improve quality and performance in cash-based markets.

[227] I have framed this brief discussion of quality, performance, and risk primarily from the point of view of solar PV companies and their potential investors. An alternative framing focuses on the perspectives of the members of solar electrified households. Under the cash sales approach, one or more members of the household own the equipment and are responsible for all aspects of maintenance. They therefore bear the risks associated with system failure, along with the benefits of ownership. The ownership and maintenance responsibilities are similar under the consumer credit system, although solar companies may have considerably greater incentive to take steps to ensure adequate system performance, especially during the loan payback period. The fee-for-service approach differs from the cash and consumer credit systems in that the company maintains full ownership of the equipment. This shifts the risks and responsibilities of maintenance and equipment replacement from the end user households to the company. In exchange, the users must pay an electricity bill in perpetuity (i.e. as long as the system is in use). See Cabraal, et al., 1996, Duke, et al., 2002, Hankins, 2004, and Banks, 2004 for further discussion.

Distribution of Solar Electric Systems in the Kenya Solar Market

Data from the Tegemeo 2000 survey of rural households supports the claim that cash-based sales through a modular purchasing pattern have resulted in a distribution of solar ownership that goes well beyond the rural elite, and is in fact largest among the rural middle class. As I discussed in Chapter 3, these data indicate that while nearly half of all solar systems are owned by the wealthiest 10% of rural Kenyans and approximately 80% of the systems are owned by the top one-third by wealth, some households near the median wealth level have managed to purchase a system (see Figure 9). In other words, according to the Tegemeo 2000 data, almost 25% of all solar systems are owned by households in the 4th, 5th, and 6th wealth deciles.

Data from Figure 30 below, show that battery system ownership is more evenly distributed among rural households than solar electric system ownership. Given that battery system ownership is about three times more prevalent than solar ownership[228] and that many rural families purchase solar panels after first buying a battery and a TV set,[229] these data suggest that solar ownership levels are likely to deepen further provided that the prices of small solar panels continue their downward trend (see Figure 31). In other words, as solar panels become less expensive, some of the less wealthy battery system owners - e.g. those in the 5th, 6th, and 7th deciles - may be in a position to add a solar panel to their battery system.

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[228] Data from the Tegemeo 2000 household survey indicate that 4.2% of rural households own a solar system, while 12.8% own a battery system that does not include a solar module.

[229] i.e. following a "modular" cash sales purchasing pattern as described above

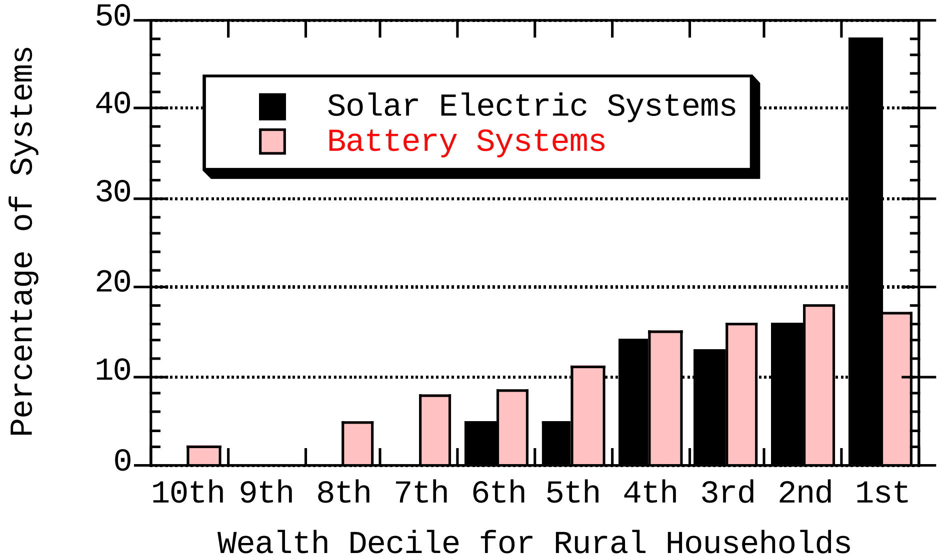

Figure 30: **Distribution of Solar and Battery Systems by Wealth in Rural Kenya**.
Source: Tegemeo 2000 household survey data (n = 1,446 total households; 193 households owned a battery, while 63 owned a solar system)

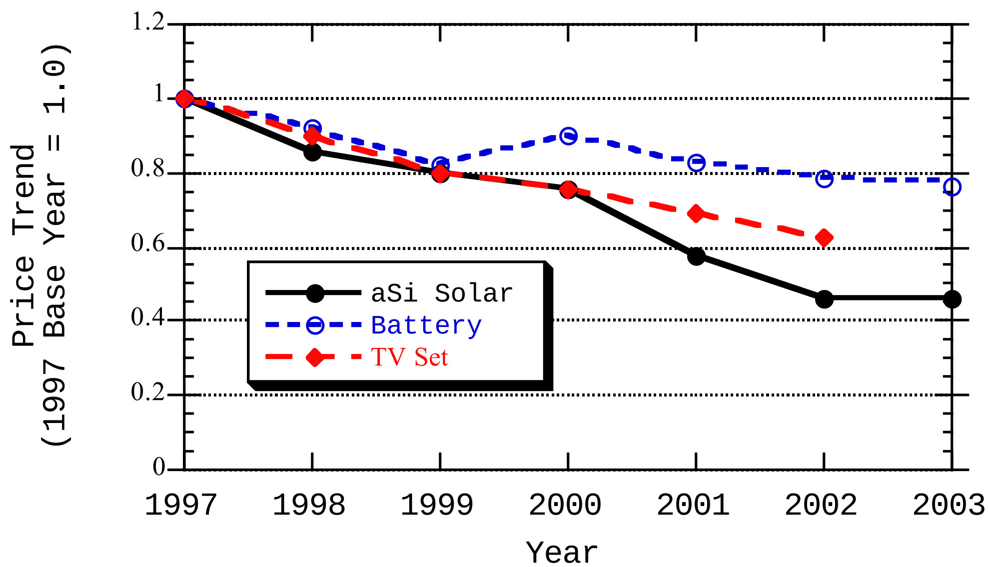

Figure 31: **Price Trend for Solar Modules, Batteries, and TV Sets, 1997-2003**
Sources: aSi solar module prices (12-14 Wp solar modules) and lead-acid battery prices (50 Ahr "solar" batteries) from Botto Solar (2004); TV prices (14" B&W TV) from Manji (2001) and Botto Solar (2004).

The data in Figure 31 indicate that TV and battery prices are also dropping, although the rate of decline for batteries is slower.[230] However, while these trends may increase the affordability of solar PV, the rate at which deepening occurs is likely to be slow due to the extremely low incomes of rural Kenyans below the median wealth level (see Figures 10 and 11). The large majority of solar sales will continue to be driven by rural middle class purchasing power, as this segment of the market remains highly unsaturated. Moreover, only the smallest solar systems[231] (i.e. < 20 Watts) will be affordable to low income households on the "ownership frontier" (see Figure 32).

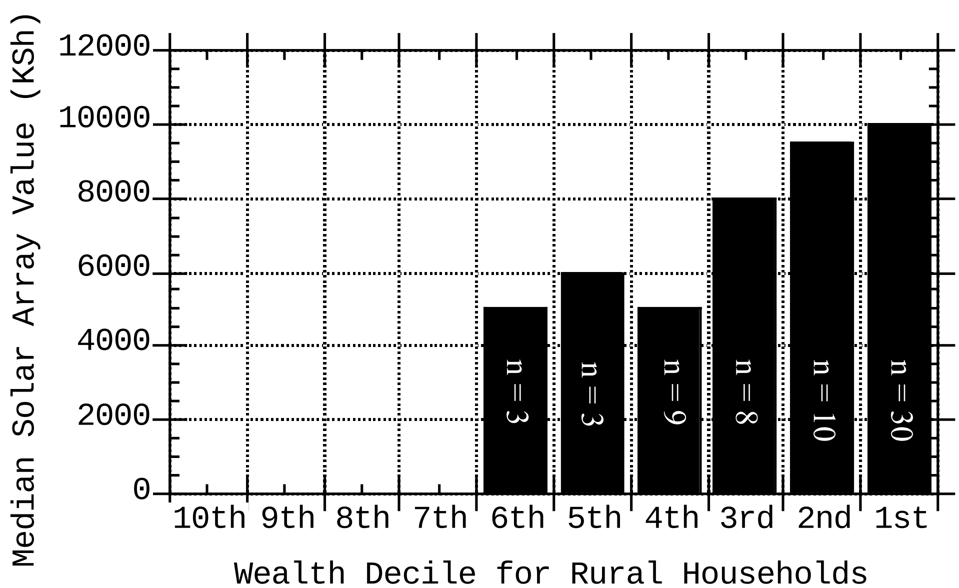

Figure 32: **Distribution of Solar Module Value (Cost) by Wealth in Rural Kenya**[232]
Source: Tegemeo 2000 data set, exchange rate = 76 KSh per $US

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[230] 14" black and white TVs and 12 -14 Watt a-Si solar module prices have dropped at annual rates of 9.4% and 9.7%, respectively, while the price of 50 ampere-hour 'solar' battery has declined 3.4% per year. See Chapter 4 for a discussion of battery and solar module price dynamics.

[231] These small systems produce tiny amounts of electricity that must be allocated among competing uses. This highlights the need to distinguish between solar system ownership, on the one hand, and the amount of electricity that is available from the systems, on the other. See Chapter 6 for further discussion.

[232] These data suggest that wealthier households - e.g. those in the 1st and 2nd deciles - generally purchase solar panels that are about twice as large as households in the 4th, 5th, and 6th wealth deciles. A statistical analysis supports this (unsurprising) finding, indicating with greater than 99% certainty that wealthier households tend purchase larger solar modules than less wealthy households ($p = 0.009$). This analysis is based on a linear fit to a plot of the household wealth level (x-axis) and the solar module value (y-axis). A statistical test confirmed with 99% certainty that the slope of the line was negative, where a negative slope indicates that less wealthy households tend to own less costly - and hence smaller - solar modules.

This pattern of expanding sales to people with less purchasing power through cash sales of small unit sized products is a common marketing practice for a wide variety of commodities. For example, corporate consumer goods manufacturers often package products ranging from laundry soap to beauty products to cooking oil in small packages in an effort to market to the poor in developing countries [e.g. see Prahalad and Hammond, 2002]. Likewise, some retail vendors of agricultural inputs sell fertilizer in 1-2 kg packets rather than the more common 50 kg bags [Wanzala, et al., 2001]. Selling fertilizer in small quantities can make it affordable to small farmers who may not qualify for agricultural credit [Jayne, 2004, personal communication]. As another example, charcoal vendors throughout Africa and elsewhere commonly sell this cooking fuel to the urban poor in tiny quantities.

Usually the cost per unit for items sold in small packets is significantly higher than the cost for large quantities of the same product. Thus the poor get access to these goods by purchasing small quantities, but the rich get a much better deal on a per unit basis. This price structure does not hold in all cases, however, as the products marketed to the wealthy may be different than those sold to the poor. For example, goods targeted to the wealthy are frequently advertised as being of higher quality than those aimed at lower income groups [e.g. see Irungu, 2004]. Whether these quality differences are real or apparent, the issue is that for some products the wealthy pay as much or more per unit than the poor even though they (the wealthy) generally purchase in larger quantities.

Solar module marketing practices in Kenya fit roughly into this latter category. The small, low cost 14 Watt amorphous silicon solar modules that account for the bulk of

sales to lower income households are widely perceived to be of inferior quality than the larger crystalline silicon solar modules that are marketed to households of greater means.[233] Thus, while a 14 Watt a-Si module typically sells for 4000 Kenyan Shillings (286 KSh/Watt), a good quality 50 Watt crystalline solar module might go for 18,500 Shillings (370 KSh/Watt).[234]

In any case, the main point is that the pattern of expanding solar ownership to less wealthy rural households through cash sales of small unit size systems is similar to trends for many products in many markets. It should not be seen, therefore, as an unusual pattern in a world that is increasingly dominated by market-based approaches to rural service delivery in which purchasing power and prices are the main determinants of access.

Consumer Credit and the Kenya Solar Market

Although the Kenya solar market is dominated by cash sales, there have been several efforts to establish consumer credit-based sales arrangements. In one case - that of hire purchase credit - the consumer credit approach has resulted in reasonably high sales numbers. Also of note is the Photovoltaic Market Transformation Initiative (PVMTI), which is a joint GEF - IFC[235] project to introduce consumer credit sales on commercial or near-commercial terms in India, Morocco, and Kenya. This high profile $30 million program was initiated in 1998, but it has yet to result in a significant

[233] The quality differences between the crystalline and amorphous solar technologies are not always as large as is commonly perceived. Some brands of amorphous silicon solar modules are of reasonably high quality (though others are not), while some brands of crystalline modules perform below their advertised levels [e.g. see Jacobson, et al., 2000; Jacobson, 2002c].
[234] Prices are from Botto Solar of Nakuru, Kenya, January, 2004.
[235] The GEF is the Global Environment Facility. The IFC is the International Finance Corporation, which is part of the World Bank Group.

number of installed systems in Kenya. In any case, none of the efforts to date indicate that consumer credit-based sales will deepen solar system ownership levels beyond the existing distribution established through the cash sales approach. Instead, ongoing attempts to establish consumer credit appear more likely - if they are successful at all - to help members of the rural middle class who can already afford solar to purchase a larger, and perhaps better performing, system than they could through the cash market. In this way consumer credit may contribute to an increase in solar sales, but in the absence of significant subsidies it will not enable solar access for the rural poor.

Hire purchase credit

Hire purchase is a common method of selling consumer goods in Kenya as well as elsewhere in Africa [Hankins, 2004]. Products ranging from sewing machines to furniture to electronic appliances have been sold through these *duka la kukopesha*[236] for decades. The terms of credit typically involve high interest rates (often > 40%) and short loan periods (6 to 18 month periods are common). Moreover, only a fraction of the population has access to hire purchase credit. Payments on these loans are made through automatic deductions from the buyer's salary. This restricts access to those who have a salary job with an institution that will guarantee automatic transfers from the employee's wages to the hire purchase company. School teachers, civil servants, and employees of large companies (e.g. Mumias Sugar Company) make up the bulk of those who are able to use hire purchase credit.

[236] *Duka la kukopesha* means "credit shop" in Swahili language. This is the common term for the shops in Kenya.

Although the first attempt to sell solar systems through hire purchase in the early 1990s failed, a second effort initiated in 1997 resulted in significant sales, and several major solar import companies now market their products through hire purchase supply chains. Hankins estimates that hire purchase sales now account for approximately 15% of solar sales in Kenya [Hankins, 2000a; 2004].

However, despite this growing sales success, hire purchase has not made solar electricity affordable for the rural poor. The overall price of a system purchased through hire purchase credit is often 80-150% higher than the same system purchased on a cash basis. These high prices, combined with the limitations on qualifying for the credit, restricts the possibilities for access through this route to a relatively small portion of the population.

In addition, hire purchase has a mixed reputation when it comes to quality.[237] The solar equipment sold through hire purchase chains is no better than that sold through cash vendors (i.e. some of the equipment is of good quality, but some is not). Furthermore, few hire purchase sales agents are knowledgeable about solar systems, and their shops only rarely offer technical support to customers.[238]

To conclude, while hire purchase credit may achieve modest success in terms of its sales figures, it will not lead to a deepening of solar ownership levels in Kenya.

[237] It is perhaps because of this mixed reputation for quality that the PVMTI project administrators elected not to include hire purchase companies in their efforts to develop consumer credit-based sales in Kenya.
[238] A 2001 survey of 126 hire purchase shops in 33 Kenyan towns indicated that only 6% of the shops offered installation services or any form of technical support to their customers.

Consumer Micro-Credit through Commercial and Cooperative Banks

There have been several efforts to set up consumer credit-based sales of solar PV systems to rural Kenyans through commercial and cooperative bank micro-lending programs. The largest (in terms of funding and system installation targets) and best known is the GEF funded and World Bank administered PVMTI program, but there have also been several other projects of note.[239]

To date these projects have resulted in a combined total of hundreds - but not thousands - of solar installations in Kenya over the *past decade*. In other words, they still represent a very small fraction of the solar market compared to cash and hire purchase based sales, which together account for more than 20,000 systems *annually*.

Nonetheless, these initial efforts at consumer credit micro-lending, combined with economic calculations, can provide some insights into the potential access dynamics of solar electrification in Kenya under this approach. Micro-credit access levels for rural people depend in part on people's ability to qualify for loans, and in part on the actual loan terms.[240] A typical 40 Watt solar system sold through a three year loan at 15% annual interest might require an $18 monthly payment.[241] This is more than five times the amount of money that the average low income household spends on kerosene, dry cell batteries, candles, and lead-acid battery charging.[242] This suggests that few poor

[239] These include several small projects funded through ESMAP (a joint UNDP/World Bank program) as well as the GEF funded Michimikuru solar electrification project (see below).

[240] Of particular importance are the interest rate and loan period, which determine the size of periodic payments that must be made. The timing of payments can also be very important, as many rural families receive income on a seasonal or irregular basis [Hankins, 2004].

[241] This assumes a total capital cost for the system of $600 and a 20% down payment. A 20 Watt solar system sold under similar terms would require payments of about $12 per month.

[242] According to the 2001 household energy survey conducted by Kamfor, the bottom two-thirds of rural Kenyan households (by income) spend an average of $3.30 per month on kerosene for lighting, dry cells, candles, and lead-acid battery charging (i.e. the main energy expenditures that the solar system might replace). Kerosene and dry cell purchases account for the large majority of these costs, as most poor families do not use a lead-acid battery, and candles represented a relatively small expense. Note that

households could afford to purchase such a system, especially since the investment is unlikely to have any immediate financial return.[243]

Experience from the Michimikuru solar electrification project,[244] which is located in a tea farming area on the east side of Mount Kenya near the town of Meru, further supports the conclusion that, in the absence of substantial subsidies, credit-based sales of solar systems are likely to be limited to a relatively small and well-off fraction of the population. In this project 40 to 80 Watt solar systems were initially sold through 2 year loans at a 15% annual interest rate.[245] These (already subsidized) terms were later reduced to a 10% overall interest rate over 3 years (i.e. ≈ 3.3% per year) in order to make the systems more affordable to the tea farming families[246] [Otieno, 2004, personal communication].

Moreover, even if subsidies are provided, lenders have a strong incentive to focus their attention on wealthier borrowers in order to ensure high repayment rates. Thus, in the absence of mandates or mechanisms that specifically target lower income households, even subsidized credit-based solar sales appear unlikely to deepen access beyond the levels already achieved by cash-based sales until demand from rural middle class families is exhausted.[247]

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these energy expenditures are substantially lower than those reported by van der Plas and Hankins [1998] for (wealthier) households that *had* purchased a solar system. See Table 12.

[243] See Chapter 3 for a discussion of income and work related uses of solar electricity in Kenya.

[244] The Michimikuru micro-finance solar electrification project is funded by the GEF, and administered in Kenya by Solarnet, a locally based non-government organization, in conjunction with the Thananga Tea Growers Savings and Credit Cooperative Society (i.e. Thananga SACCO). The project was initiated in 2002, and approximately 150 solar systems have been sold to date [Otieno, 2004].

[245] i.e. somewhat below the commercial rate for rural credit, which is often 25-40% or more.

[246] Note that tea farmers are, in general, relatively well off compared to most rural Kenyans.

[247] This is supported by evidence from other countries. For example, consumer credit-based sales of over 10,000 household solar PV systems through a GEF funded project in Zimbabwe reported went exclusively to the top 20% of the population by wealth, despite sub-commercial lending terms (15% interest, 3 year loan period for 45 Watt solar systems; note that the commercial interest rate in Zimbabwe

Finally, as Hankins has noted [2004], building consumer credit lending networks for solar PV systems is not an easy task. Many banks appear to view lending for solar electrification with some hesitation. This may be because, while the individual loans are too small to be of major value to the bank (i.e. $500-$1000 per customer), they nonetheless represent a relatively large investment for most rural families. Moreover, the use of solar systems generally does not contribute significantly to a household income stream that could be used to repay the loan. As a result, the transactions costs for the bank to evaluate the credit risk of each buyer as well as to enforce payment after the loan is made have a tendency to be high compared to the overall value of the loan. The reluctance on the part of some banks to embrace consumer credit for solar PV appears to have contributed to the slow implementation of the PVMTI project, which was initiated in 1998 but has yet to result in more than a few dozen installed systems [PVMTI, 1998; Graham, 2001; Hankins, 2004].

Fee-for-Service Schemes for Solar Electrification

A number of solar policy analysts have argued that fee-for-service based approaches to solar sales offer a more promising route for expanding access to a broader segment of the population [e.g. Cabraal, et al., 1996; Covell and Hansen, 2000; Banks, et al. 2000]. Although this approach has not been attempted in Kenya, experiences from elsewhere in Africa (i.e. South Africa and Zambia) provide some guidelines that can be used to estimate the access dimensions of this sales model.

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for similar loans was reported to be near 40% at the time of the project) [Mulugetta, et al., 2000]. This conclusion is further supported by estimates made by Soluz for Honduras, where they indicate that credit-based sales can be used to reach the wealthiest 20-25% of rural households. See Figure 29.

Both the South Africa and the Zambia cases involve subsidies, but the billing rate used in Zambia - $7 per month for a 50 Watt solar system - appears to be closer to a commercially viable level.[248] This is much lower than the monthly payment from the loan example,[249] but for the rural poor it is still more than twice the average expenditure for the energy services that the solar PV system would replace. The fact that the solar system would provide significantly larger amounts of energy and vastly superior lighting services may make them tempting for low income families, but in the absence of significant subsidies (e.g. on the order of those provided in South Africa) this option would also likely remain out of reach for most rural families.

Setting aside questions of equity and access for the moment, even if the rural middle class is to be the main customer base, it is unclear if a fee-for-service approach for solar electrification would be viable in Kenya in the absence of massive government or donor assistance. Companies engaged in fee-for-service solar sales would require a relatively large customer base - e.g. thousands of customers - to achieve commercial viability [Banks, 2004]. Thus, even if profitability is theoretically feasible in a country like Kenya, the path for developing a successful company would require large capital

[248] In South Africa thousands of systems have been installed, and households pay a heavily subsidized rate of $2.40 per month for 50 Watt systems [Banks, 2004]. The $7 monthly rate in Zambia may be closer to a commercially viable level, but significant subsidies were involved in setting up the system, and it is likely to be several years before the Zambian companies have sufficient experience to estimate a billing rate that will ensure long term profitability [Ellegård, et al., 2004]. Experience with fee-for-service solar sales in Honduras, where Soluz claims to have achieved full commercial viability, indicates that billing rates may need to be closer to $10 to $20 per month for long term profitability [ISES, 2001b]. Gustavsson notes that even at the $7 per month rate, the Zambian households that opted to buy solar electricity from the fee-for-service companies are among the better off rural families [Gustavsson, 2004, personal communication].

[249] It is important to remember, of course, that in the fee-for-service case the monthly payments must be made indefinitely, while in the loan case the payments only last a few years. At the same time, in the loan case the customer is responsible for all O&M costs including battery replacement, while in the fee-for-service case these costs are the responsibility of the company.

investments and correspondingly large financial risks. As a result, it appears unlikely that this "utility model" for selling solar will enter markets like the one in Kenya unless it is accompanied by large amounts of subsidized capital.

Conclusions

Although consumer finance business models, if they are successfully implemented, may lead to increased solar sales in Kenya, they appear unlikely to deepen access to solar electricity beyond the status quo set by the cash sales market for a long time to come. This is true even under the current set of World Bank and GEF sponsored programs, which include concessional interest rates. Instead, in the absence of large subsidies, consumer credit-based sales appear likely to go almost exclusively to the rural elite and middle class.

This indicates that cash sales of small solar systems are the most likely route for continued deepening of solar electricity access beyond the rural middle class to the rural poor. For the rural poor these small solar systems generally represent an important improvement relative to the use of kerosene lighting, dry cells, and lead-acid batteries. Nonetheless, the cash sales approach remains far from ideal.

First, as I will discuss at length in Chapter 6, the amounts of energy available from small solar systems (< 20 Watts) are tiny. This electricity must be allocated among competing applications, and a number of key social uses such as evening time studying by children and lighting in the kitchen are often marginalized relative to other applications such as television viewing. And while intra-household allocation dynamics remain important in larger systems, data from Kenya suggest that education and other key lighting related uses are much more prevalent in the larger systems (e.g. 40 Watts)

that are commonly included in consumer credit and fee-for-service solar electrification programs.

Second, small solar systems sold through a modular cash sales purchasing pattern often suffer from significant quality and performance problems. These problems are due in part to a lack of effective regulation of solar markets by the state, as well as information asymmetries, insufficient availability of high quality technical services, and low levels of knowledge about solar system energy management on the part of end-users[250] [Duke, et al., 2002]. These issues further decrease the amount of energy that is available from the systems.

Third, although solar access levels may deepen through an unsubsidized market approach, the low income and wealth levels of the rural poor indicate that this process is likely to be slow. Given the distribution of wealth in rural Kenya, most solar market sales growth will continue to be driven by rural middle class purchasing power for the foreseeable future.

The analysis presented in this chapter, therefore, supports the conclusion that both "hard" and "soft" subsidies are needed if electricity access for the rural poor is a priority. It is well known that from an equity standpoint, purely market-based approaches always favor the wealthy over the poor. In other words, even though access in the Kenya solar market is likely to slowly deepen through falling prices, wealthier

[250] Soft subsidies designed specifically to address these issues (e.g. funding for technical training for the small town technicians who typically service small solar systems, capacity building in government regulatory agencies, programs to increase end-user awareness about system management practices) can help to improve the performance of small solar systems. While most 'market development' subsidies from the GEF, the World Bank, and similar institutions have focused in recent years on consumer finance related programs, the PVMTI project in Kenya recently allocated some remaindered funds towards activities that may prove important for improving quality and performance in the cash market.

families will continue to retain a substantial advantage in terms of electricity access relative to their less wealthy neighbors. These questions of equity matter particularly to the degree that electricity is an important input for activities related to social and economic advancement, whether through direct income generation related applications or through uses that enhance educational possibilities and other factors that influence long term socio-economic prospects.

This does not, of course, mean that markets do not have their merits, but rather that concerns about equity require that they be managed and complimented by effective public policy approaches that temper or compensate for their distributional shortcomings. Targeted subsidies that work to overcome or at least reduce the bias inherent in markets towards wealthier segments of the population could go a long way towards increasing electricity access for the rural poor and reducing energy inequity.

Substantial experience in recent decades indicates that subsidy programs that deliver key services effectively to the rural poor are often difficult to implement [e.g. see Barnes and Halpern, 2000]. Once subsidies become available, wealthy and powerful constituencies commonly work to protect and further their own interests, often by seeking to capture or divert the benefits of the programs [e.g. see Dubash, 2003]. In general, marginalized groups and their allies can only maintain the redistributive focus of subsidy programs through sustained political pressure of their own. Thus, the political hurdles for achieving a subsidy regime that acts to ensure some degree of equity in the distribution of services such as rural electricity are many. Nevertheless, deciding opt for no subsidies at all is an equally political decision, with important

implications for equity. This approach leaves the distribution of access to services entirely in the hands of the market, and the poor always come in last in that arena.

In this chapter I described the dynamics of access to solar electricity in Kenya's unsubsidized market, where a modular pattern of cash-based purchasing is dominant. The dynamics of this market are, of course, critically important for understanding the social implications of household solar electrification in Kenya, since they determine which families are able to afford the technology. In the next chapter I turn to another key aspect of solar electricity access; namely, the intra-household dynamics within "solar" homes that shape the degree to which different household members are able to benefit from the electric power.

Chapter 6

Sometimes Small is Not Enough: Intra-household Allocation of Solar Electricity on a Tiny Energy Budget

> Women and children typically derive greater benefits than men do from the solar home systems.
>
> Anil Cabraal, et al, 1996, in *Best Practices for Photovoltaic Household Electrification Programs*, a highly influential World Bank report on solar electrification, p.68

> Although the awareness of gender issues has been a topic in social and development issues for a long time, in the dissemination of (solar) PV systems it is still commonly forgotten that it is relevant to look further than the boundaries of a household.
>
> Frans Nieuwenhout, et al., 2000, in *Monitoring And Evaluation of Solar Home Systems: Experiences with Applications of Solar PV for Households in Developing Countries*, a literature review conducted by the Netherlands Energy Research Foundation ECN, p. 59

Miriam Macharia wanted her kitchen light back. Two years ago when they first installed the solar system in their home her husband, John, had installed five lights: one in the sitting room along with the television and the radio, one in their bedroom, one in the boys' bedroom, one on the porch, and one across the walkway in the separate kitchen building.

At first she had been very happy cooking in the evening under the dim glow of the 15 watt bulb. Although it did not light the kitchen as much as the daylight coming in through the window during the afternoon, it was a big improvement over the kerosene lantern that she had been using. But the kitchen light did not last.

A month after they bought the system the trouble started. In the beginning they could watch television in the brightly lit sitting room from the seven o'clock news until they went to bed at ten or sometimes even eleven o'clock. But after a month the TV

began to shut itself off earlier. Often it would cut out around nine o'clock during "The Bold and the Beautiful," and on cloudy days the TV screen would begin its telltale shrinking even earlier.[251] After a few months, even turning off the sitting room light to watch TV in the dark did not help very much.

John said that the problem was the kitchen light. He said she used it too much, and that took away energy from the television and the sitting room light. The bedroom lights and the porch were OK, he said, because they were only used for ten or fifteen minutes a day, but the kitchen light had to go.

Miriam agreed that there was a problem. She liked entertaining guests in the sitting room and watching TV at night after she had cleaned up the dinner mess. But she liked having a light in the kitchen, too. Surely there must be a way to have both. She promised to use the light less, but this did not satisfy John for long. The problem with the TV continued, and, even though she was sure that she was not using the kitchen light as much as she had before, John insisted that it had to go. That was more than a year ago.

Maina Mumbi[252] and I pieced this story together from a number of conversations with Miriam and John in 2003. It was through these conversations as well as similar ones with other families that I began to understand the reason that many solar electrified

[251] The Macharia solar system, like most in Kenya, does not include a charge regulator, a low voltage disconnect, or a voltage meter that would indicate the charge level of the battery (see footnote 70 for more information about these devices). As a result, like many families, they often use the system until the battery voltage is too low to operate the television set. When this happens the image on the TV screen begins to shrink, and eventually it cuts out entirely. The quality of the sound from the TV set is also sometimes used as an indicator of low battery voltage.

[252] Maina Mumbi is an electrician who specializes in solar installations. He has assisted me in my research numerous times over the past 4 years, and his insights have proved invaluable.

homes have lights in the sitting room, in the bedrooms, and sometimes even on the porch, but not in the kitchen.

I had no problem understanding the importance of the sitting room light. After all, the sitting room is the social center of the home. It is where guests are entertained, it is where the family eats the evening meal, and it is the room where children do their homework. What I had a hard time grasping was why in many homes the kitchen seemed to be a lower priority than the bedrooms, including not only the parents' bedroom but also the children's bedrooms, and sometimes even the porch light. Surely light in the kitchen is more important than a porch light!

But this logic did not factor in the issue of competition in the use of energy for different electric appliances. The difference between the bedroom and the porch lights, on the one hand, and the kitchen light, on the other, is one of usage. Dinner is generally prepared after dark in rural Kenya, and, between preparation and cleaning, this room gets used for two to three hours or more every evening. In many homes breakfast is made before dawn, which can add another hour of lighting demand in the morning. By comparison, bedroom lights are usually used for less than half an hour at night, and the porch light might only get used briefly a few times a week. Simply stated, the use of these other lights does not compete for energy with the television and the sitting room light, which are usually the highest priority uses of electricity in the home. The kitchen light does, and, as a result, many women in solar homes continue to use kerosene lighting in the kitchen even while electricity is used for television, the sitting room light, and other uses. See Figure 33 for an artist's depiction of a common pattern of energy allocation in Kenyan "solar" homes.

This brief story about the Macharia family raises doubts about the optimistic assessment of women's ability to derive benefits from solar electrification as expressed in the quotation from Cabraal, et al. [1996] at the beginning of this chapter, even as it highlights the importance of gender relationships as a key element influencing the social uses of solar electricity in rural Kenyan homes.

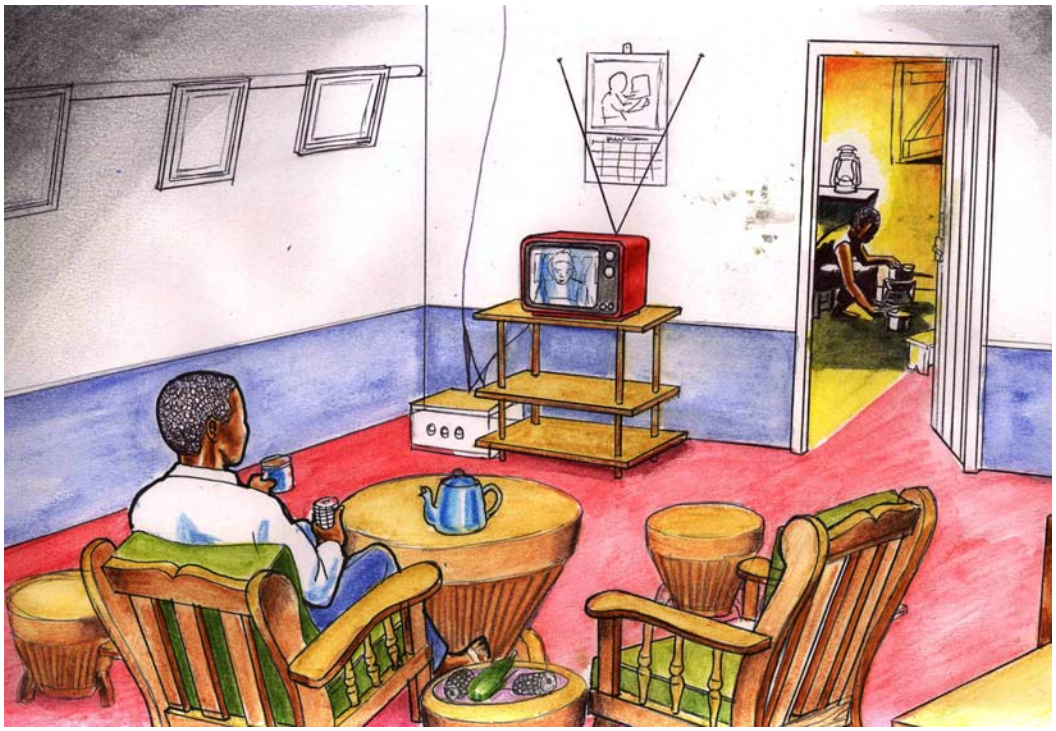

Figure 33: **Intra-household energy allocation dynamics in Kenyan "solar" homes often favor certain uses, such as television viewing and lighting in the sitting room, over others, such as electric lighting in the kitchen. As a result, many women in "solar" households continue to rely on kerosene lighting for work in the kitchen.** (image by Mike Okendo)

In this chapter I use two case studies to examine the role that intra-household energy allocation dynamics play in shaping the social significance of solar electricity in rural Kenyan homes. The first case emphasizes the use of solar power in the kitchen, with corresponding linkages to the possibilities for the use of solar electricity by women to improve conditions for doing housework. The second case study focuses on education

related uses of solar electricity, and especially on studying by school children in "solar" households.

These cases are important not only because they provide rich ground for examining the role of household relationships - including gender as well as elder-junior dynamics - in shaping the social significance of solar electrification, but also because of the prominence of claims about education and women's housework related uses of solar power in international discourses about developing country solar electrification. Solar advocates commonly cite improved conditions for studying, women's housework, and similar socially beneficial uses as key justifications in calls for international donor support for solar electrification [e.g. see Kaufmann, et al., 2000; Greenpeace, 2001; Stone, 2003; and many others]. Statements like the following quotation by Laurie Stone of "Solar Energy International," a leading non-profit organization that advocates for renewable energy, provide powerful arguments in favor of such support.

> Imagine not being able to read or study after the sun sets, having to walk for hours to get drinking or washing water or having to strain your eyes to work under the dim light of a candle. This is the reality for the 2 billion people on the planet who do not have access to electricity. … Although many people in rural areas of the developing world already have access to some form of light, it is usually not a high quality light. Throughout the world, children breathe the fumes of kerosene lanterns as they study, women strain their eyes working in candlelight and doctors perform operations by flashlight. … Solar home systems (SHS) with just one or two photovoltaic (PV) modules can provide enough electricity to power lights for studying, cooking, working and socializing. Many of these small SHS also power radios and televisions. The benefits of this small amount of electricity are numerous. Not only will it displace dangerous and unhealthy kerosene, but will also greatly improve education, health and economies. It particularly improves the lives and health of women and children. [Stone, 2003]

My work in this chapter - with its emphasis on intra-household dynamics - acknowledges the *potential* of solar electricity for many socially beneficial uses, but

challenges the implied universality of these benefits among solar users suggested in the quotation by Stone as well by many others [e.g. Cabraal, et al., 1996; Kaufmann, et al., 2000]. While my findings do indicate that solar electricity *is* used by many children for studying, and that some women *do* benefit when it comes to household chores from better lighting in the kitchen and elsewhere, the evidence also shows that these uses are far from guaranteed. In other words, the social uses of solar technology are not pre-given within households, but instead must be negotiated among family members in the context of a limited and scarce electricity resource.

In making this analysis it is not my intention to dismiss the potential of solar electricity to be used for education, housework, and other socially beneficial applications. Indeed, as I will describe, these sorts of uses are present in some, but not all, rural Kenyan "solar" homes. Rather, I am pointing out the need to go beyond arguments that simply advocate the deployment of certain technologies (such as solar electric systems) based on the assumption that these technologies can be automatically associated with specific (beneficial) social uses. Technologies can play an important role in enabling possibilities, but they do not guarantee particular social outcomes. There is a great need for studies that seek to identify the sets of processes and factors - including intra-household dynamics - that come together to shape the social uses of solar electrification as well as other household energy technologies.

As I will argue below in the case studies, certain policy approaches may prove more favorable than others in supporting - or at least not restricting - particular socially beneficial uses of solar power. It is only through better understandings of the processes that govern the social uses of these small amounts of household electricity that we can

identify what is at stake - for example for women and for children - in policy debates about particular approaches to disseminating solar technology and other rural electricity infrastructure building efforts.

Intra-household dynamics and energy allocation

> Economic analyses have by and large treated the household as a black box in which the preferences of all household members can be aggregated in a single joint utility function. Hart, 1995, p. 39

> Households that may look the same…can have very different economic structures. They may organize their work, and apportion costs and benefits quite differently. Wilk, 1989, p. 25

The household is commonly understood in much of the economics and policy literature as a single and undifferentiated unit that acts in the "collective interests" of its members [e.g. Becker, 1981; see Hart, 1995 for a review of the literature]. The solar policy literature on household rural electrification in developing countries is no exception to this broader trend. Many of the researchers analyzing solar electrification appear to adopt this model implicitly by drawing from household survey data about the social uses of solar electricity without engaging with or describing critically important processes and dynamics *within* the household that influence purchasing decisions, energy allocation processes, and - ultimately - social uses of the energy [e.g. Cabraal, et al., 1996; van der Plas and Hankins, 1998; Wamukonya and Davis, 2001; Gustavsson and Ellegård, 2004; and others].

Feminist critiques in economics, anthropology, and geography [e.g. Guyer, 1981; Guyer and Peters, 1987; Carney and Watts, 1990; Hart, 1992b; Moore, 1992; Agarwal, 1994; Hart, 1995; Guyer, 1997; Hart, 1997; and others] have been especially important

in challenging the unitary model, which tends to de-politicize the household by assuming that resources - e.g. electricity - are always allocated within the home in a way that serves the "collective good" rather than through negotiated processes that reflect the desires or interests of particular household members as well as gender and elder-junior power relationships within the home.

Within economics several alternatives to the unitary model have been proposed and debated over the past two decades. A series of household models based on variations of the Nash bargaining model have been used [e.g. Sen's "cooperative conflict" model, 1983]. These models use self-interested individual household members as the units of analysis, with their interactions modeled based on a set of "bargaining rules." These bargaining models represent a significant departure from the unitary model, as they attempt to unpack gendered dimensions of household resource allocation that remain unexamined in the unitary model [e.g. see Dasgupta, 1993; Agarwal, 1994]. Hart highlights the significance of the bargaining models as follows:

> Unitary and bargaining models not only provide very different interpretations of intrahousehold inequality; they also offer entirely different analyses of the effects of income subsidies or transfers. In the unitary model, it makes no difference who receives the subsidies since the household is a neutral medium through which policy actions pass in a way that maximizes the welfare of all its members. If, however, intrahousehold allocation is envisaged as a bargaining process, then the individual to whom resources are directed could make a great deal of difference to the way they are used [Hart, 1995, p. 46].

These models were followed in the 1990s by collective models of the household, which are in many ways a more general form of the bargaining models. Hart categorizes collective models into two groups. First are the "cooperative collective"

household models[253] that meet assumptions about Pareto optimal economic efficiency.[254] These are more common in the literature than "non-cooperative" collective models, which "…allow for informational asymmetries and enforcement problems, and are generally not Pareto efficient" [Hart, 1995, p. 49].

The "separate spheres" model discussed by Carter and Katz [1997], which falls into the "non-cooperative collective" group, is useful for conceptualizing resource allocation processes in rural Kenyan households. Drawing insights from qualitative studies in anthropology and geography, the authors note that "…although altruism plays some role in household labor supply and consumer demand decisions, gender-based norms, divisions, and conflicts are equally, if not more, important in the determination of household resource allocation" [pp. 95-96]. As an alternative to the unitary model, which assumes income pooling and altruistic decision making based on "common preferences", they propose that "…the household is better conceived of as consisting of separate, gendered spheres of decision making and activity that are related to one another by a "conjugal contract" - the terms under which household members exchange goods, income, and services among themselves" [p. 96].

Anthropological studies in Africa have long highlighted that many households pool income only partially, if at all. In many homes men and women keep budgets that are

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[253] The key difference between the original bargaining models and the more recent cooperative collective models is that the latter do not assume a pre-given set of bargaining 'rules'. Instead, they attempt to recover these rules from economic survey data through a series of nested tests [Deaton, 1994; see also Hart, 1995]. However, Hart notes that survey data collection must be based on a set of implicit or explicit assumptions, and these will bias the corresponding 'rules' that can be extracted from the data. In other words, it is necessary to have some sort of institutional understanding of the household in order to begin to collect the appropriate information. In this context, as I will discuss below, Hart urges the use of ethnographic studies in order to develop better understandings of these intra-household relationships.

[254] i.e. Pareto optimal efficiency in this case requires an assumption that household members will collectively allocate resources to reach a condition in which no further improvement of any one person's total utility can be achieved without reducing the utility of someone else.

largely separate, and they often have distinct responsibilities *vis a vis* the welfare of different family members [e.g. Guyer, 1981].

The households that I studied in Kenya appeared to manage income and negotiate resource allocation in a way that is roughly consistent with this separate spheres conception of the household.[255] In the context of solar electrification in Kenya, separate spheres budgeting can have important implications, as the money to buy solar systems often - but certainly not always - comes from income streams that are controlled primarily by men. This gendered purchasing pattern can influence not only the decisions related to what components are included in the system (and where lights are installed in the home, etc.), but also the degrees of access that each family member has to the electricity generated by the system. That is, when men buy and "own" the solar system, they may maintain greater authority - at least in principle - over the ways that the electricity is allocated among different uses within the home.

However, as a number of authors in anthropology and geography have pointed out, economic models of the household - including the separate spheres model - are by definition an overly structural view of how households operate. Models must operate based on fixed bargaining rules, while the reality within the household is much more fluid. The "rules" in any household governing resource allocation can - and frequently are - stretched, bent, broken, and renegotiated on an ongoing basis [e.g. Carney and Watts, 1990; Berry, 1993; Hart, 1995; Hart, 1997; and others]. This does not mean that

[255] However, while the separate spheres approach may have been common, there was considerable variation from family to family in actual budgeting and allocation processes. These variations among households in Kenya are consistent with findings reported in the literature. For example, see Guyer and Peters [1987], Wilk [1989], and Hart [1995].

models are not useful conceptual tools, but it does indicate that their utility for predicting future behavior may be highly limited.

Thus, while I work from the separate spheres *conception* of the household, I do not take the step of using this framework as a predictive model with fixed rules of allocation and negotiation. As Ghanadan notes in this regard, it is important to recognize that "…the spheres of the household are themselves negotiated and cannot be mapped simply onto (statically defined) male and female spaces…" [2004; see also Hart, 1995].

Given these limitations of the modeling approach, Hart advocates the use of ethnographic research to understand the "…relations within and among households…" to unpack the processes through which decisions are made and resources are allocated or deployed [Hart, 1995, p. 52]. While a complete understanding of household relationships and the processes that govern intra-household energy allocation is beyond the scope of my current work, this chapter is intended to contribute to an understanding of the "terrain" on which the allocation of small amounts of electricity from solar systems takes place. It is only by describing these processes that we can begin to understand how and why certain social uses of solar electricity become prevalent while others appear marginalized.

In addition to power relationships and negotiation dynamics within the family, technical issues related to the size, performance, and use of the solar system are important. The Macharia's solar system included a 20 Watt solar module which provided barely enough electricity for a few hours of TV and light in the sitting room during sunny periods, and much less during the long cloudy months of June, July, and

August. A larger - and costlier - system would deliver more electricity and, though it certainly would not eliminate the intra-household energy allocation issues, it would perhaps reduce the level of competition over the various possible uses. In Kenya's unsubsidized solar market, the importance of system size links energy allocation to household wealth, as wealthier families are in a better position to buy a larger solar system.

Once the system is in place, allocation of the energy can be a less than scientifically managed process, as it is often difficult for any one member of the household to regulate the use of the electricity by others. Thus, although one member of the household may be considered the "owner" of the system and strict "rules" about the use of the energy may be in place, other household members may, and often do, choose to surreptitiously use energy when the "owner" is not around.[256]

To complicate matters still further, solar systems in Kenya almost never include a voltage meter or any other indicator that would allow household members to estimate how much energy is stored in the battery. People know when the battery is empty because appliances no longer function, but given variations in solar input from day to day and the lack of feedback from any type of meter, it is extremely difficult to estimate energy availability at any given time. In addition, most rural Kenyans have only a rough sense of the electric power consumption rates for each appliance when it is on. Therefore, processes of energy allocation take place in the context of substantial

[256] Note that in many households the guidelines for energy use were substantially less rigid than is suggested in this brief description. The point I am making here is not that all households have strict rules about energy use, but rather that even in cases where such rules are in place it is often difficult to enforce them.

uncertainty about how much of the resource is actually available and how the use of a given appliance will influence this availability.

These technical realities provide insight into John Macharia's decision to remove the kitchen light, which he viewed as a key contributing factor to the lack of energy available for television viewing and the sitting room light. He knew that there often was not enough energy to power the television and sitting room light for as long as he wanted, and he guessed that the kitchen light - the light in a room where he rarely spent much time himself - was the main reason for the deficit. His wife Miriam promised to reduce her usage, but he had no reliable way to verify if her efforts were effective. All he saw was that the situation with the television set was not improving in any noticeable way. Thus, he decided that removing the light was the only sure way to ensure that the kitchen light was not contributing to the problem. Intra-household power relationships and gendered energy allocation dynamics are clearly central to this story, but the uncertainties associated with managing energy in the solar system are also important. In other words, the process may have unfolded differently if the Macharia's had had better information with which to make decisions about and negotiate allocation of the energy from the solar system.[257]

Finally, as I describe below, the geography of the home - including the physical layout of the rooms as well as everyday socio-cultural practices associated with the use of each space - also influences the social use dynamics of solar electricity in important ways.

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[257] The inclusion of meters or other feedback devices in the system does not, of course, guarantee that all household members will have equal access to the information that these devices provide.

The work in this chapter and its focus on intra-household dynamics can be understood as another dimension of the access question, where access is defined, following Ribot and Peluso [2003], as the *ability* of different household members to use electricity.[258] As I discussed in Chapter 5, access is determined in part by household purchasing power as well as factors that influence the performance of the system. The interaction between intra-household allocation dynamics, family wealth, the geography of the home, and technical issues associated with solar system use provide an additional and critical set of processes through which energy access is negotiated.

Gendered energy allocation and lighting in the kitchen[259]

Although solar advocates frequently claim that women are among the main beneficiaries of solar electrification, gendered household energy allocation dynamics limit women's access to the electricity in many homes. This does not mean that women do not benefit from solar power. Rather, evidence from Kenya indicates large variations from one household to the next in women's access to and control over the use of solar electricity for key household tasks. These access dynamics are shaped by a combination of gendered power relationships among family members, household wealth, and the spatial layout of the home.

In this section I use an analysis of the use of solar lighting in the kitchen in order to unpack important energy allocation dynamics that influence women's access to solar electricity. This focus on the kitchen provides only a partial view of women's level of

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[258] See Chapter 1 for further discussion.
[259] The analysis in this section is based heavily on collaborative work that I conducted with Rebecca Ghanadan in Kenya beginning in 2002. I thank Rebecca for generously allowing me to include this material here, as well as for countless insights into these and other issues. Any errors or omissions are, of course, my own.

access. Women's use of the electricity is not, of course, confined to the kitchen nor to housework related tasks alone. Moreover, women (as well as men) are a highly heterogeneous group, and there are important differences from household to household as well as for different women within a given household with respect to these issues. Nonetheless, rural Kenyan kitchens are unquestionably a key site of housework that is usually - with a few exceptions - done by women. As such, an analysis of solar lighting in rural kitchens provides useful insights into the role that gendered power relationships within the home play in shaping the possibilities for and limits of women's access to solar electricity for housework related activities.

I began this chapter with the story about the Macharia's, where a conflict over electricity allocation between Miriam and her husband John led to the removal of the kitchen light. Evidence that I present below suggests that this dynamic may be common, but it is not universal. For example, I was present when Francisca Wambui was talking with an electrician about re-wiring some electrical connections and adding a second light to the small solar system installed in her and her husband's home. Francisca, who is a primary school teacher, briefly contemplated where to put the light and then decided - without consulting with her husband who was away for the day - that the light should go in the kitchen since, "that is where it will help me the most." When I asked her about the decision later, she said that it was her salary that had paid for the system, and that she considered it to be more her property than her husbands. This ownership dynamic appears to be considerably less common than the opposite dynamic in which men are the primary decision makers for issues related to the system, but it

appears to be present especially in homes where women have significant incomes through professional salaried jobs or small business earnings.

In presenting these observations I do not mean to imply a binary set of arrangements in which either a man or a woman unilaterally makes the main decisions about the solar system. In many homes I observed considerable negotiation between men and women on these issues. Nonetheless, in the majority of "solar" homes that I visited men appeared to have primary - though often not exclusive - decision making authority when it came to issues related to the solar system.

In total, 37% of "solar" homes in a 2003 survey[260] had an electric light in the kitchen. Data on the placement of lights in households from this survey reveals that electric lighting in the kitchen becomes common only in homes that have five or more lights (see Figure 34). In other words, for small systems that include relatively few lights, other rooms are given priority over the kitchen. In most cases, it is only when a system has a relatively large number of lighting points that the kitchen is considered for lighting.

The sitting room - or *mezani* in Swahili - is almost always the first priority for lighting in rural solar homes for both men and women. Figure 35 shows that almost all solar systems in Kenya that include at least one light have a light in the sitting room. This is unsurprising, as the *mezani* is the social center of the household. In most homes the *mezani* is the main space for eating and socializing. Families who can afford to do so often invest considerable sums of money in the sitting room, filling it with couches,

[260] This survey included interviews with 76 "solar" households in three districts of Kenya. See Appendix B for additional information.

chairs, and coffee tables for relaxing and entertaining guests, and those who have a television set nearly always put it in the *mezani*. This room can also be an important space for evening time work or study. The sitting room is generally the primary study room for school children, and if there is accounting or school teacher related work to be done at home in the evening this is usually the place for it. Thus, the high priority given to the *mezani* when it comes to lighting is both social, as it is an area for receiving guests, and practical, as it is a heavily used space for many evening time activities that can benefit from electric lighting. All of this makes it no surprise that both men and women nearly always prioritize the sitting room over all other rooms, including the kitchen, when it comes to light placement.

What may seem initially surprising, though, is the low priority given to the kitchen in comparison to some of the other rooms in the house. Lights are usually installed in the master bedroom and a second bedroom (often a children's room) before the kitchen. According to the data in Figures 34 to 39, lights are installed in the kitchen only slightly more often than in the third bedroom (when there is one) or on the porch.[261]

[261] The porch light is an outdoor light - often to light the walkway near the front door. It is often referred to as an outdoor "security" light, but unlike security lights on many grid connected homes which are left on all night these solar powered porch lights are rarely used for more than a few minutes a day.

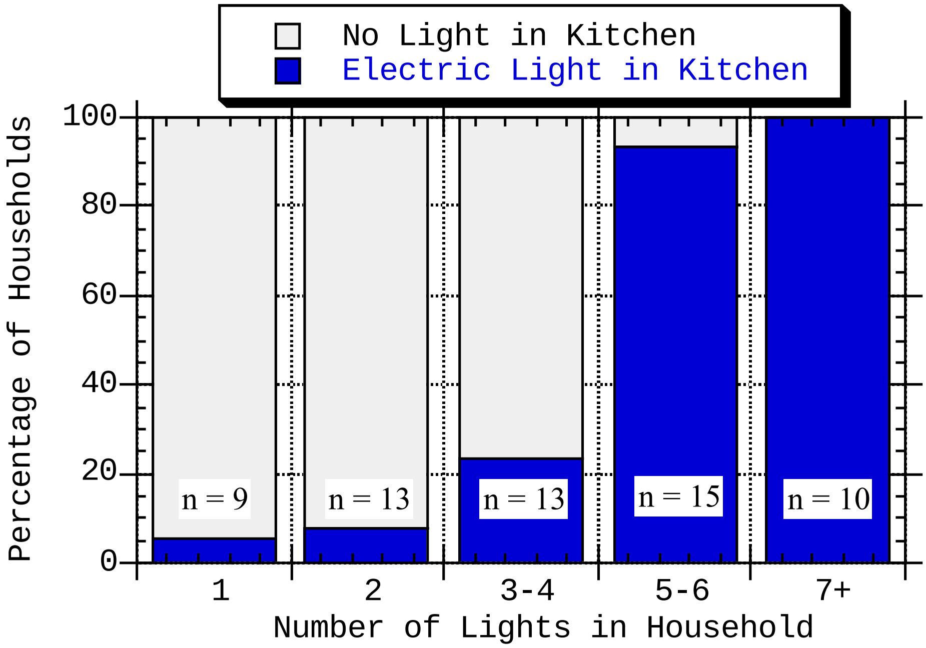

Figure 34: **Kitchen Lighting in "Solar" Households in Rural Kenya**
Source: 2003 survey of "solar" households, n = 76 solar homes in rural Kenya (note that 13 of the 76 households had no lights at all and are not included in the graph)

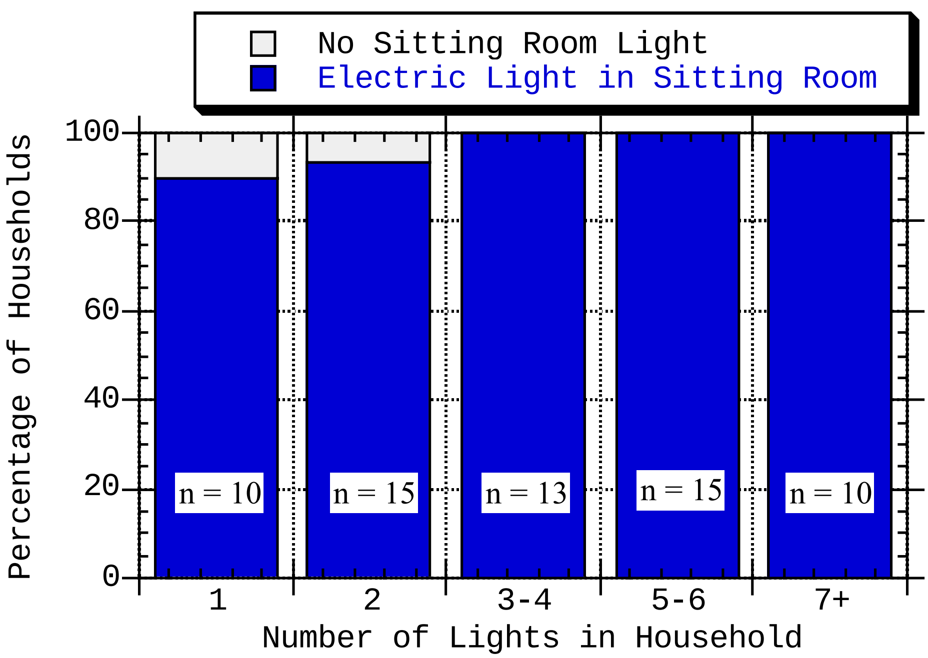

Figure 35: **Sitting Room Lighting in "Solar" Households in Rural Kenya**
Source: 2003 survey of "solar" households, n = 76 solar homes in rural Kenya

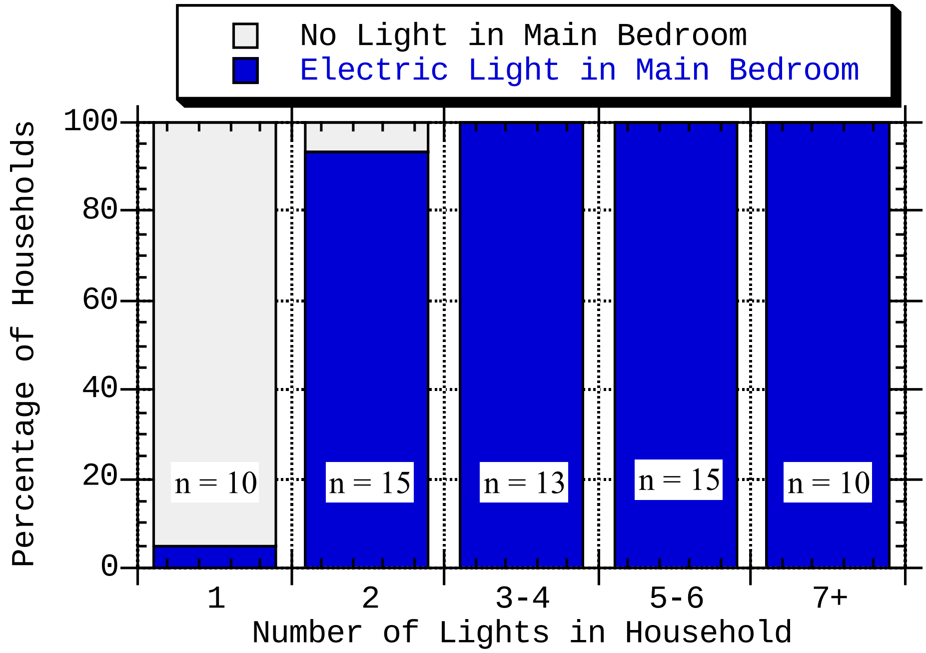

Figure 36: **Master Bedroom Lighting in "Solar" Households in Rural Kenya**
Source: 2003 survey of "solar" households, n = 76 solar homes in rural Kenya

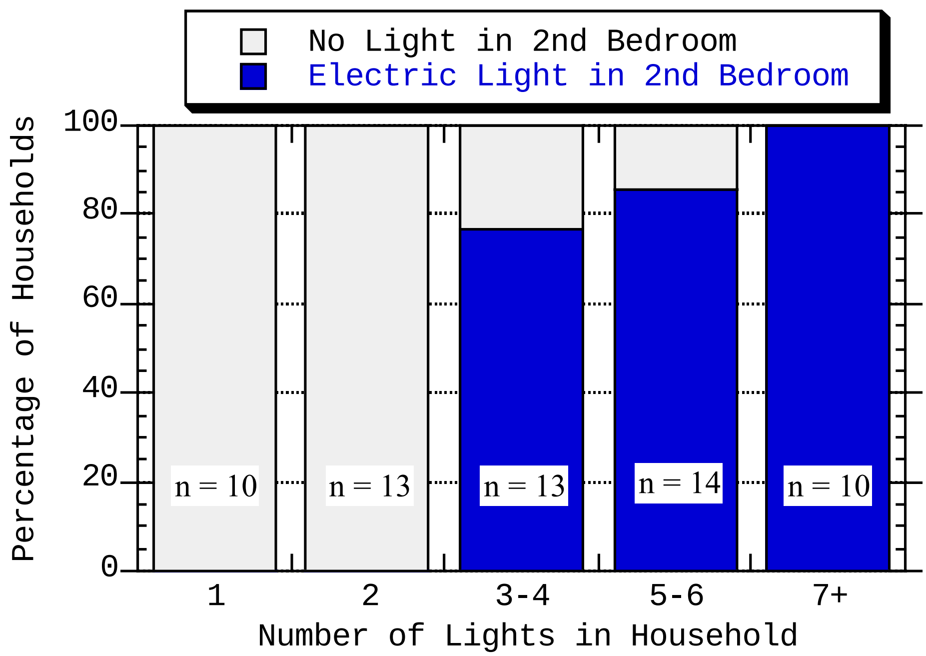

Figure 37: **Second Bedroom Lighting in "Solar" Households in Rural Kenya**
Source: 2003 survey of "solar" households, n = 76 solar homes in rural Kenya

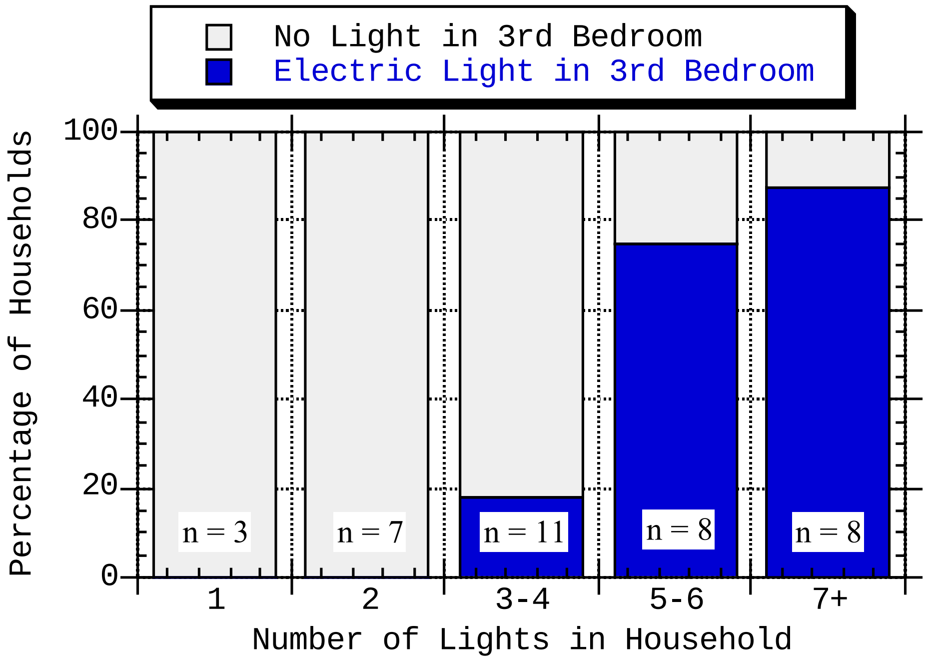

Figure 38: **Third Bedroom Lighting in "Solar" Households in Rural Kenya**
Source: 2003 survey of "solar" households, n = 76 solar homes in rural Kenya

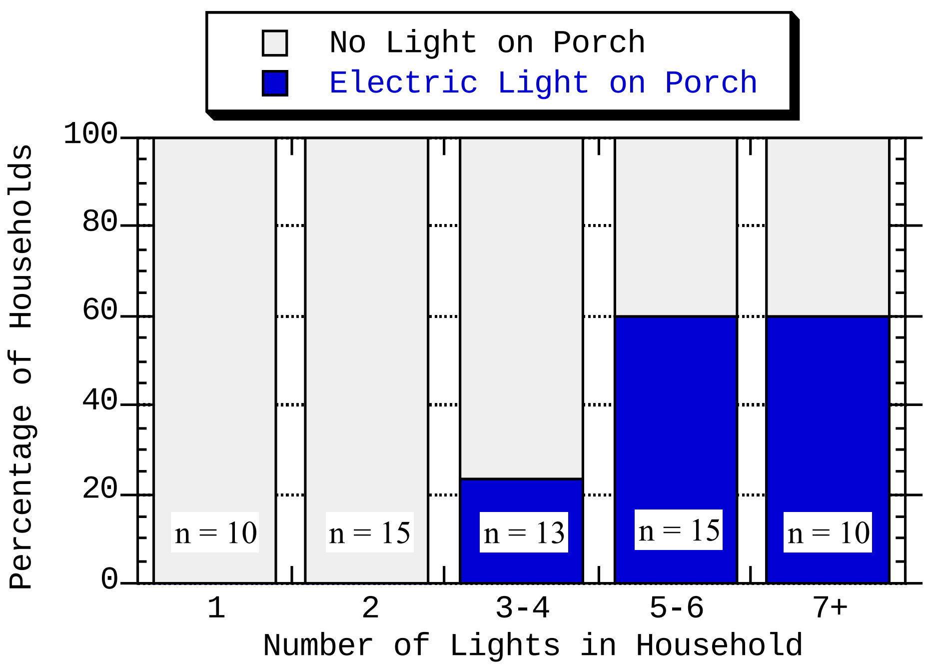

Figure 39: **Porch Lights in "Solar" Households in Rural Kenya**
Source: 2003 survey of "solar" households, n = 76 solar homes in rural Kenya

Although further research is needed to fully establish the processes and factors that influence women's access to lighting in the kitchen, the survey data from 2003 and detailed energy allocation measurements in a sub-set of 15 households combined with interviews and observations in a number of homes provide some key insights.

In the Macharia home, the kitchen light was eliminated in an attempt to save energy for other "higher priority" uses. Given their utility for kitchen based tasks in the evening and pre-dawn hours, kitchen lights - if present - are often in high demand. In households where sufficient quantities of electrical energy are available, kitchen lights are frequently used for several hours per day. This suggests a link between solar system size and kitchen lighting. That is, women may be in a better position to negotiate access to electricity for kitchen lighting when more energy is available.

Two sets of data support this relationship between system size and women's access to electricity in the kitchen. First, larger systems in the 2003 survey were more likely to have a kitchen light than smaller systems, where "large" can be measured in terms of the size of the solar module or the number of lights installed with the system.[262]

Second, data from a detailed energy allocation study in 15 rural Kenyan homes[263] indicates that the fraction of energy allocated to kitchen lighting appears to grow disproportionately in larger solar systems. Figure 40 shows the distribution of solar electricity among various household appliances in four systems with a solar module that was larger than 25 Watts. These data show that, in these homes, 60% of all energy was

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[262] In the 2003 survey the median system size for homes with a kitchen light was 28 Watts, while the median for those without was 14 Watts. The different is statistically significant (p = 0.002) according to a non-parametric "median test."

[263] These energy allocation data were collected over a period of 6 months in 2003 and 2004. See Chapter 2 as well as Appendix B for more information about this data set.

allocated to lighting, with the sitting room light alone accounting for 25% of the energy. The kitchen light accounted for the second largest fraction of energy among lighting uses, with 15% of the total. It was followed by the bedrooms, which are divided in the figure between the "master" bedroom (7%), the other bedrooms (4% combined among all other bedrooms), and several other uses.

The distribution of energy differed substantially for the 11 systems smaller than 25 Watts included in the study (see Figure 41). As noted in Chapter 2, TV and radio accounted for a much larger fraction of the total energy in small systems, with 54% and 12% respectively.[264] The sitting room light was the most used among the lights, with 23% of the energy. However, the kitchen was reduced to a paltry 0.4%, well below the use of lighting in the master bedroom (5%), the other bedrooms (1%), and even for the porch light (1%). Figure 42, which presents the same findings as Figures 40 and 41 in a different format, clearly shows the large percentage increase in energy allocated to kitchen lighting as well as the decline for TV and radio in the larger solar systems.

The low usage level in the kitchen among the smaller systems is due largely to an absence of kitchen lights in these systems. Only three of the 11 in the sample had a kitchen light.[265] Nonetheless, the energy allocated to kitchen lights was small, 2% of the total, even for the three small system households that *did* have a kitchen light. This compares to 35% of energy to the sitting room light, 8% to the master bedroom, 3% for the other bedrooms, and 3% for the porch light in these three systems. In other words,

[264] In the larger (> 25 Watt) systems 33% of the energy was allocated to TV and 5% to radio.
[265] This is roughly consistent with the presence of kitchen lights in small systems in the 2003 survey of "solar" households, where nine of the 48 systems smaller than 25 Watts (19%) had a kitchen light.

in the small systems in the sample, the energy allocated to kitchen lighting was greatly reduced compared to other uses even in those households that did have a kitchen light.

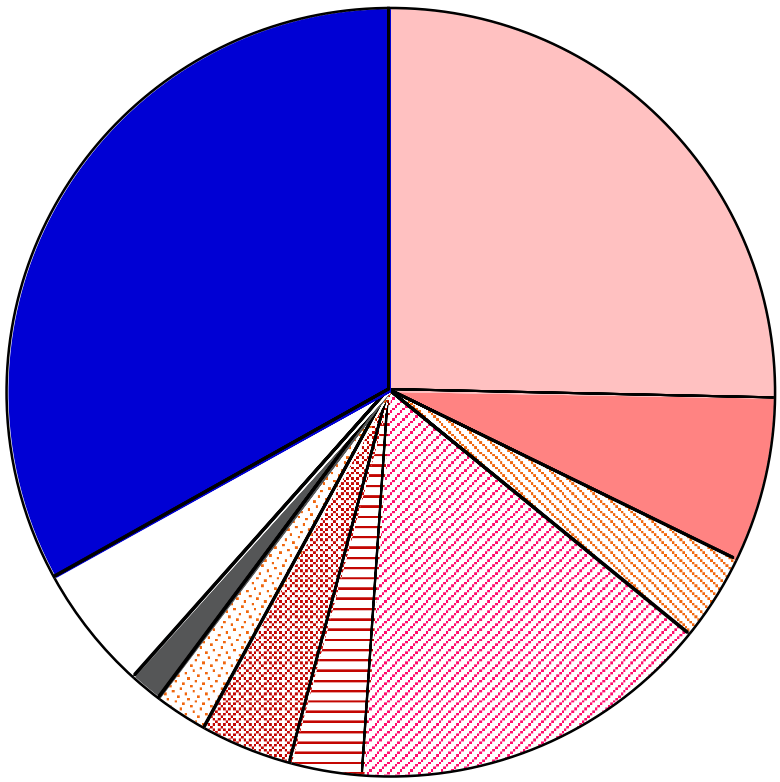

Figure 40: **Electricity Allocation in Solar Systems Larger than 25 Watts** (see Figure 41 below for legend) Source: Data monitoring in four solar homes in Kenya over six months in 2003-04

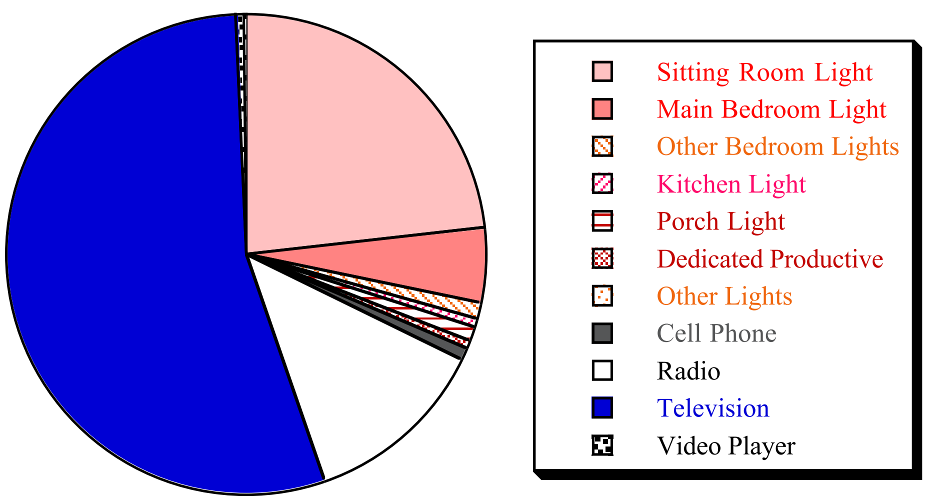

Figure 41: **Electricity Allocation in Solar Systems Smaller than 25 Watts**[266]

[266] Figures 40 and 41 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

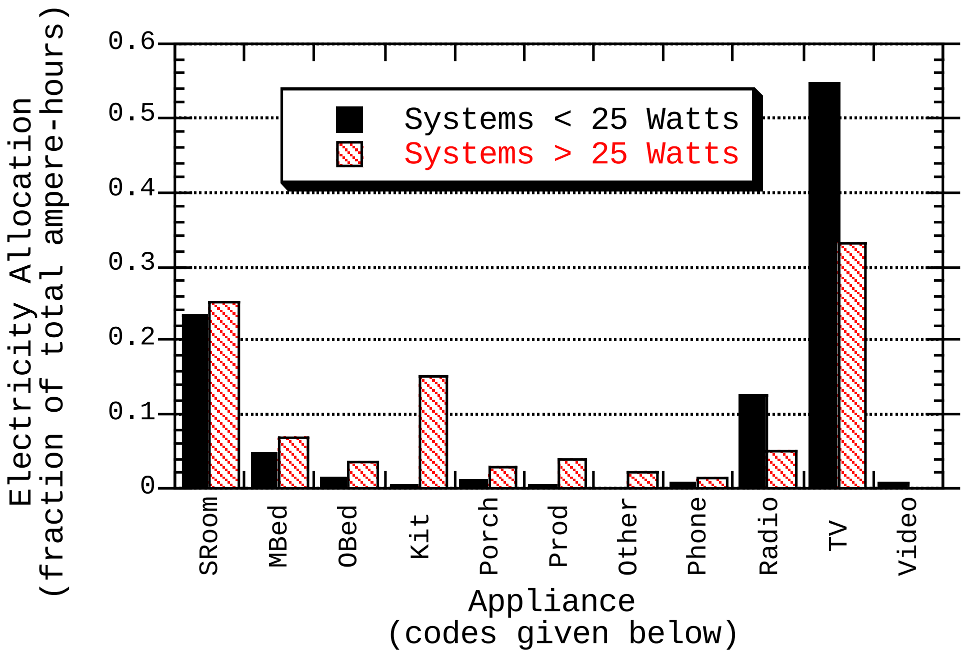

Figure 42: **Electricity Allocation for Small and Large Solar Systems in Kenya**
Codes for Appliances: SRoom = Sitting Room Light; MBed = Main Bedroom Light; OBed = Other Bedroom Lights; Kit = Kitchen Light; Porch = Porch Light; Prod = Dedicated Productive Uses of Electric Light; Other = Other Lights; Phone = Cellular Telephone Charging; Radio = Radio & Radio/Cassette Players; TV = Television; Video = Video Players (i.e. VCRs).

While this detailed analysis of energy allocation is based on a modest number of households, it strongly suggests that when sufficient energy is available and the allocation dynamics are favorable, kitchen lighting can expand to become one of the largest lighting uses of energy in the home. However, when energy is "tight," kitchen lighting is reduced disproportionately compared to many of the other uses. This supports the idea that gendered energy allocation dynamics play a strong role in limiting women's access to electricity in the kitchen.

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sets of systems. The average solar module size for the larger (> 25 W) systems was 40 Watts, while the average size for the smaller systems (< 25 W) was 16 Watts. Thus, the ratio in the area between the two pie graphs is roughly 2.5.

The spatial layout of households also influences the possibilities for lighting in the kitchen. By far the most common type of kitchen - or *jiko* in Swahili[267] - in rural Kenya is a small one room structure that is separate from the main house. Often these "traditional" *jikos* are located quite close to the house - within a few meters - though in some cases they are further away. See Figure 43 for a photograph of a rural Kenyan house with a separate kitchen structure.

The walls in traditional kitchens, whether made of wood, stone, or thatch, are generally covered with black soot from wood smoke from the three-stone fire that is used as the main cooking fire, and often the rafters are filled with stacked fuel wood. See Figure 44 for an image of a young woman cooking with a three-stone fire in a traditional kitchen. During meal preparation the kitchen is thick with smoke that fills the room before escaping through vent holes in the roof, as well as with the warmth of a crackling, or sometimes smouldering, fire. In most rural Kenyan homes the evening meal, which is usually prepared after dark, is cooked by the faint light of a kerosene lantern as well as the dim glow of the fire.

[267] The word *jiko* is used in Swahili both for the actual stove or cooking device (e.g. a three stone fire is called a *jiko*) as well as for the place (the room) where the cooking occurs. The word *jikoni* is also used to refer to the kitchen room, but the meaning of this word is best translated as "in the kitchen" rather than the place itself.

Figure 43: **Rural Kenyan House with a Separate Kitchen** (the kitchen is on the right)

Figure 44: **Cooking with a Three-Stone Wood Fire in Rural Kenya**

Less common than traditional *jikos* are indoor kitchens, which are used by some wealthy rural families[268] as well as many peri-urban middle class households.[269] Indoor

[268] Note that many wealthy rural families have both an indoor kitchen *and* a traditional kitchen. 18% of the "solar" households in the 2003 survey had both types of kitchens. The use of both types of kitchens is consistent with the "eclectic energy" hypothesis by Masera, et al. [2000], which indicates that wealthier families diversify their cooking energy use by adding new technologies and fuels such as charcoal,

kitchens are almost always cleaner and much less smoke filled than "traditional" kitchens, as indoor kitchen cooking is generally done with cleaner burning fuels such as charcoal, kerosene, or LPG[270] (see Figure 45).

Figure 45: **An LPG Stove in an Indoor Kitchen in Rural Kenya** (the LPG cylinder is to the immediate right of the table).

Electric light can improve conditions for cooking and other kitchen based tasks in both types of *jikos*, but they are somewhat more common in indoor kitchens. In the 2003 survey, 44% of "solar" households with an indoor kitchen equipped them with an electric light, while just 30% of "traditional" *jikos* had electric lighting.[271]

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kerosene, and LPG based cooking systems while *also* continuing to use traditional wood based cooking methods.

[269] Peri-urban households often do not have access to land on which to gather firewood. As a result, they must buy cooking fuel. Many use kerosene or charcoal to cook, and LPG is also sometimes used by the better off among this group.

[270] LPG stands for Liquified Petroleum Gas. Another common name for LPG is propane gas.

[271] This is based on all of the kitchens in the survey, including both of the kitchens from households with two kitchens. Note also that two of the households in the survey did not have a kitchen at all. In both of these cases the families ate at the home of nearby relatives.

Practical considerations and economic costs influence this pattern of kitchen lighting use, as it is easier and somewhat less expensive to install electrical wires to rooms that are part of the main house structure than it is to run them to a separate building. The cost of the extra wire to install a light in a "traditional" kitchen, combined with the additional labor time if an electrician is hired to do the job, is usually on the order of $5 to $10 more than the cost to install the same light in a room that in the main house, although the cost differential can be higher if the kitchen is located far away. However, even a modest cost increase can be a major obstacle if the person paying for the installation - often but not always a man - sees relatively little value in having a kitchen light, perhaps because he rarely uses the space himself or perhaps because he views kitchen lighting as competition for other "more important" uses of the electricity.[272]

The terrain on which women and men negotiate the allocation of energy to kitchen lighting and other uses is heavily defined by the amount of energy available from the solar system and the layout and social uses of spaces within the home. Also important are family specific understandings about the "ownership" of the system with corresponding ideas about the "rights" of different household members to claim access to the electricity. Several of these factors are closely tied to wealth, as higher income people are in a better position to invest in a larger solar system or indoor kitchen.

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[272] In addition, perceptions of the "compatibility" between electric light and traditional kitchens can play a role in the decision to install a light. Some men that I interviewed expressed a reluctance to install a light in the "traditional" kitchen at their home because those *jikos* were "too dirty" for a modern high tech device like an electric light. One man suggested that the smoke might damage the electronics of a fluorescent tube light, and several said that the light would be "wasted" and "ineffective" in such a smoky room. My experience is that the smoke residue does build up on light bulbs and fluorescent tubes over time in "traditional" kitchens, with a corresponding reduction in light output. However, this does not damage the lights, and periodic cleaning can correct the problem.

Women with a significant and independent source of income from a salary job or a business venture are often in a better position to negotiate access to electricity for uses such as kitchen lighting, as was illustrated by the story about Francisca Wambui. Nonetheless, while an independent income can be extremely important, women's power within the home and their relative influence on energy allocation processes cannot be reduced to economic factors alone, as a number of other issues influence relationships between women and men.

It is also important not to essentialize women's (or men's) preferences when it comes to energy allocation decisions. For instance, several households where I conducted interviews in 2003 had female wage earners with significant incomes who reported that they did not cook on a regular basis. Instead, a younger woman - usually either a daughter or a hired servant - was responsible for the majority of the cooking. These households appeared to be even less likely to have a light in the kitchen than the other households in the survey, although the results are not statistically significant due to the small number of households in this category.[273] This may indicate that the prioritization of the kitchen light is highest for those who use the kitchen on a regular basis rather than for "women in general."

Moreover, several women that I spoke with - including some in cases where their salary was the main source of income used to purchase the system - indicated that they placed a higher priority on the sitting room light and the television than on the kitchen light. Thus while these women may give a higher priority to the kitchen light than their

[273] Seven households fit into this category, and none of them had a kitchen light, despite a respectable median system size of 24 Watts. Even the relatively large systems - two with 40 Watt solar modules and one with an 80 Watt module, lacked kitchen lighting.

male counterparts, it was not their top priority. This suggests a gendered energy allocation dynamic, but not one that can be reduced to simple stereotypes in which men mainly prefer entertainment through TV and radio, while women are primarily interested in lighting for domestic tasks and the like. Instead, the dynamic often appears to result in an energy allocation pattern in which uses of solar electricity that may be favored by women alone, such as kitchen lighting, are often marginalized, while uses favored by *men only* or by *men and women* alike generally receive higher priority.

Solar advocates often claim that women are among the main beneficiaries of solar electrification, in large part due to the utility of electric light for domestic tasks such as housework. These claims appear to be consistent with an understanding of energy allocation based on the unitary model of the household, since one might expect use of energy to facilitate housework - for example in the kitchen - to be a higher priority than television viewing or bedroom lighting in the context of allocation processes based on improving the overall "collective interests" of the family.

In this section I have presented an analysis based on evidence from rural Kenya that indicates that kitchen lighting is often marginalized compared to other uses, and these findings challenge both the claims of the solar advocates and the expected results from the unitary conception of the household. The gendered separate spheres conception - in contrast - has proved to be a useful lens for understanding intra-household energy allocation dynamics for "solar" homes in rural Kenya.

I use this framework in combination with an analysis of the geography of the home, an understanding of the importance of family wealth, and insights about the technical aspects of solar system performance and use to begin to define the "terrain" on which

the allocation of the small amounts of electricity available from solar systems are negotiated among household members. I will now turn to a second case of energy allocation within "solar" households. Here I examine the role of intra-household dynamics in the use of solar electricity to facilitate evening time studying by children.

Solar electricity and children's education in Kenyan homes

I know from personal experience that it is much easier to read by the light of a solar powered fluorescent lamp - or even the dimmer glow of a 15 Watt incandescent bulb - than it is to read using a kerosene lantern or a candle. Reading with electric light is easier on the eyes,[274] it is safer (kerosene lamps and candles are significant fire hazards), and it can be healthier as there are no kerosene fumes to inhale. In rural homes that do not have grid electricity, solar power has a strong potential to facilitate evening time studying by children.

As I noted in Chapter 3, education has long been viewed in rural Kenya as an important investment in socio-economic advancement. Moreover, nearly one-third of solar system sales are to households that include a school teacher. Given the great potential utility of solar electricity for evening time studying and the high levels of use by teachers (many of whom are also parents), it is no surprise that in many solar households electric lighting is used by children to facilitate evening time studying.

Nonetheless, evidence from Kenya indicates that education related uses are far from universal among "solar" households. In a significant number of homes energy

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[274] Electric lights generally provide brighter light than kerosene lanterns or candles. Perhaps more importantly, electric lights generally provide a steady light that is much easier to read by than the flickering flame of kerosene or candles. The constant eye adjustments required with a flickering light sources are a major source of eye strain [Mills, 2000; Versak, 2004].

allocation dynamics favor other uses, and, despite the presence of solar electricity, children continue to study by the light of a kerosene lamp. 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.[275] In others (34%) electric lights were present, but the energy from the solar system was allocated to other uses.[276] 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.

In addition, the ever-present television can be a major distraction from studying in "solar" homes, and in a few cases the presence of solar electricity actually appears to contribute to a deterioration in children's study habits. In the 2003 survey, 40% of parents indicated that television was a major distraction 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.[277]

These findings complicate conventional framings of the role of household solar electrification in supporting children's education. Education related uses of household solar electricity - and especially evening time studying by children - are centrally

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[275] i.e. the household used solar electricity to power a television and/or a radio, but not lights. This was true in 19% of homes with school age children.
[276] 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.
[277] 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.

important in international discourses about the social benefits of developing country solar electrification, and the solar policy literature is filled with references to the role of solar lighting in improving children's educational opportunities [e.g. see Cabraal, et al., 1996; Khan and Huque, 1998; Stone, et al., 1998; Kaufmann, et al., 2000; Greenpeace, 2001; and many others]. Powerful images of children studying by solar light are also common. See Figure 46 for an example.

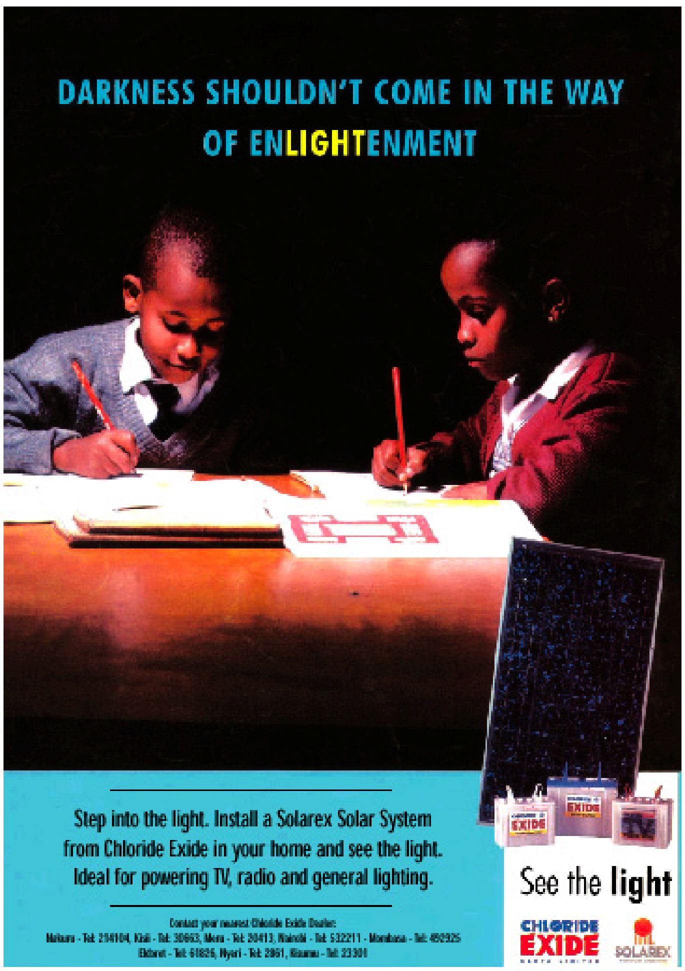

Figure 46: **Magazine Advertisement for Solar Electricity that Highlights Education Related Uses**. Source: Solarnet, 2000

In many cases, the references to education related uses of solar power in the literature are anecdotal, so that it is impossible to evaluate the extent of the use.

However, a few studies do provide household level survey data on education related uses of solar electricity by school children.

Schweitzer, et al. [1995] report that "…the study time and learning of the children increased (noticeably)" following the introduction of 35 Watt household solar systems in a rural Nepali village. The study included visits to 46 households in the village with solar systems, and detailed interviews with 21 of these families. However, the reported increase in children's studying appears to have been based on a single interview with the village school teacher, and there is no discussion of differences from one family to another with respect to education related uses of solar electricity.

Gustavsson and Ellegård [2004], in a study of 100 homes using 50 Watt systems in Zambia, reports that children studied in the evening in 89% of solar households, while only 42% of their counterparts in unelectrified households were able to study at night.[278] This suggests a measurable increase in children's studying due to the presence of solar light.

It is unclear if Wamukonya and Davis's [2001] findings from a study of 63 solar households - each of which has a 50 Watt system - in Namibia is consistent with these first two studies. They report that 15% of the families said that improved conditions for studying were the most important benefit from the use of the system, but they do not indicate the total fraction of households in which solar lighting was used for evening time studying.

[278] According to Gustavsson and Ellegård, the children in the 'solar' homes use electric lights to study in the evening, while those in the unelectrified homes use kerosene lighting or candles. They do not specify what fraction of the households in the study did not have school age children.

In any case, at least two of the three available studies report solar lighting use levels for evening time studying by children that exceed the levels that I found in Kenya. A key difference between the Nepal, Zambia, and Namibia cases, on the one hand, and Kenya, on the other, is the size of the systems in the groups of households included in the studies. The systems in Nepal were 35 Watts, and those in Zambia and Nambia were 50 Watts. Moreover, in each of these cases the systems were installed through programs that involved substantial subsidy support, which played a critical role in making the systems affordable to the beneficiary households.[279]

In contrast, solar electrification in Kenya is based on unsubsidized free market sales, and the systems tend to be significantly smaller; several studies, including my 2003 survey, have documented that the median solar system size in Kenya is between 20 and 25 Watts [van der Plas and Hankins, 1998; Jacobson, 2004c]. Thus, what appear to be lower reported levels of evening time studying in the smaller systems found in Kenya suggest a linkage between solar system size and the use of solar lighting for evening time studying.

Indeed, small system size appears to be a major factor restricting children's access to electric lighting in those solar households where a kerosene lamp was the main study

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[279] In Nepal households purchasing a solar system in the village received subsidies that covered 25-50% of the sytsem cost, depending on whether they purchased the systems with a single payment (50% subsidy) or in installments over 3 years (25% subsidy) [Schweitzer, et al., 1995]. In Zambia the systems were installed through a pilot project Fee-for-Service arrangement. This effort has been heavily subsidized, and the Energy Service Company received all of the equipment on donation with no requirement for repayment. It is unclear if the monthly payment amount that the company is charging each household ($US7 per month) is a commercially viable rate for an unsubsidized venture [see Ellegård, et al., 2004]. In Namibia the solar systems were sold through a revolving micro-credit loan fund with a five year repayment period at heavily subsidized interest rates (the nominal rate was 5%; this indicates a negative real interest rate after adjustment for inflation). Even at these concessional rates, the Namibian loans were restricted to families with an annual income of at least $2,500 (i.e. relatively wealthy compared to most rural families in Sub-Saharan Africa) [Wamukonya and Davis, 2001].

light. As I noted above, in 19% of the solar households with school age children in the 2003 survey, evening time studying was restricted to kerosene because the system did not include an electric light. Nearly all of these cases were small systems (< 20 Watts) where the electricity was used exclusively to power a television and a radio.

Another 34% of the households in the survey had at least one electric light, but kerosene remained the primary study light. In half of these homes the solar system was small (< 20 Watts), and many of the parents interviewed cited a lack of energy as the reason that evening time studying could not be supported. An additional one quarter of the families had larger systems, but cited technical problems with the system - in some cases problems with the battery and in others with the lights - as the main impediment. The remaining one quarter - or about 9% of all of the solar households with school age children in the survey - had a larger system (25 - 50 Watts or more) with no apparent technical problems, but electric lighting remained unavailable for children's studies.

In many of these homes, and especially those with a small system, an increase in solar system size would likely improve children's access to solar electricity for studying. In some homes, investments in higher quality (and more efficient) lights might also help to improve children's access levels. For example, a 6 Watt fluorescent tube light provides better (brighter) lighting while using only 40% of the electricity used by a 15 Watt incandescent bulb. For homes that do not already have fluorescent lights in the sitting room (true in 31% of the households in the survey with school age children), this increase in efficiency has the *potential* to make an important difference as long as the extra energy that becomes available through the efficiency savings is allocated towards education related uses.

Investing in a larger solar system or a fluorescent light costs money,[280] and in Kenya's unsubsidized market this puts children in wealthier families at a distinct advantage relative to their less wealthy neighbors when it comes to evening time studying. Thus, while it may come as no surprise that children in households that can afford a solar system may have an advantage over those in families that cannot,[281] this discussion indicates that there are also important differences among those in homes that *do* have solar electricity.

System size is not the only important factor influencing children's access to electric light for studying in "solar" homes. Intra-household energy allocation dynamics are critically important. For instance, while over half of the solar systems in homes where children did not study with electric light were small (< 20 Watts), a significant fraction (37%) of the systems where children *did* use the lights to study were also less than 20 Watts in size. This highlights the importance of intra-household dynamics around energy allocation and education, as it suggests that some families may prioritize education uses of solar electricity more than others.

Unlike the case of kitchen lighting, the energy allocation dynamics related to children's studying are not gendered in any direct way. Nonetheless, a number of studies indicate that women often allocate household resources under their control

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[280] The price for a 14 Watt solar module in Kenya is about $50, while fluorescent tube lights generally cost $10-15. An incandescent bulb - including the fixture - costs about $2. These costs do not include installation.

[281] Children in unelectrified households can have trouble studying in the evening not only because kerosene lamps give lower quality illumination than electric lights, but also because for many families the cost of kerosene is prohibitive. As a result, for many children there are times when even kerosene and candles may be unavailable for studying.

differently than men do. In her review of the household literature Hart[282] cites a number of studies which indicate that "…women typically (spend) a higher portion of their income on food, health, and other forms of child welfare, and men often (retain) discretionary control over a higher portion of their income for commodities such as alcohol, tobacco, and sometimes 'female companionship'" [Hart, 1995, pp. 47-48].

If these patterns extend to electricity allocation in solar homes, then the tendency for men to have a greater degree of control over this allocation may play a role in restricting children's access for education related uses in some homes. I was not able to document any definitive trend in this regard through my work in Kenya, perhaps in part because women exerted greater degrees of control over electricity allocation in only a few of the households in the study. As a result, this remains an important area for future research.

While the role of gender dynamics remains unresolved in relation to education uses of solar power, elder-junior relationships clearly play an important role in the shaping the degree to which solar electricity is used to support evening time studying by children. The best case scenario for education related uses of solar energy was in homes where parents were strongly supportive of their children's studying (as well as fairly strict about maintaining a regular study regime) *and* children were motivated to study.[283] I observed this dynamic in a significant minority of families, and especially in homes where at least one of the parents was a school teacher.

[282] Hart also emphasizes the importance of not essentializing women's behavior patterns. Thus, while studies may indicate gendered tendencies in allocation patterns, these results do not indicate that women (or men) will always or even usually behave in a particular way [Hart, 1997].

[283] As I noted above, solar system size is also important for creating a "best case scenario" for children's use of solar electricity for studying.

In many of the solar households where kerosene remained the primary study light, allocation of energy to television appeared to be a central reason for the "energy deficit" that constrained the use of electricity for evening time studying. In a few cases the father appeared to be the main person responsible for this allocation pattern, but it should come as no surprise that children were often equally - if not more - active in advocating the use of TV. A number of parents, including Titus Murungi who is quoted in the Introduction, bemoaned their "inability to control" their children's TV viewing habits. This was particularly true in households that had teenaged children. In many cases when children exercised significant agency with regard to the allocation of solar electricity, the result was more TV viewing and less studying rather than the reverse. Thus, in most homes children's use of solar electricity for evening time studying had at least as much to do with their parents motivation and ability to set a regular homework routine and to restrict TV viewing as it did with the children's own interest to study.

In many ways these observations are unremarkable, as they could describe interactions between parents and children around school work in nearly any country in the world. However, these "mundane" dynamics gain heightened significance when a key resource for facilitating children's studies (namely, electricity for lighting) is available but in extremely short supply. For example, in households with a 14 Watt solar system, a decision by either the parents or the children to watch an hour or two of television before the children start their homework can result in the children studying by kerosene rather than electric light, as there may be insufficient energy left over to power the light for any significant length of time. Thus, while many families do make education a top priority, in some households energy allocation dynamics that give even

a modest priority to other uses such as television viewing can greatly reduce children's ability to use electricity for evening time studying.

The spatial patterns of sitting room use - combined with the high priority that is often given to television - also influence children's study habits. The sitting room is the most commonly used room for studying by children,[284] and it is also nearly always the room where the television is kept. As I noted earlier in this section, this overlapping use of space for evening time activities can distract children from their studies. See Figure 47 for an artist's depiction of a scene that I observed a number of times in rural Kenyan homes.

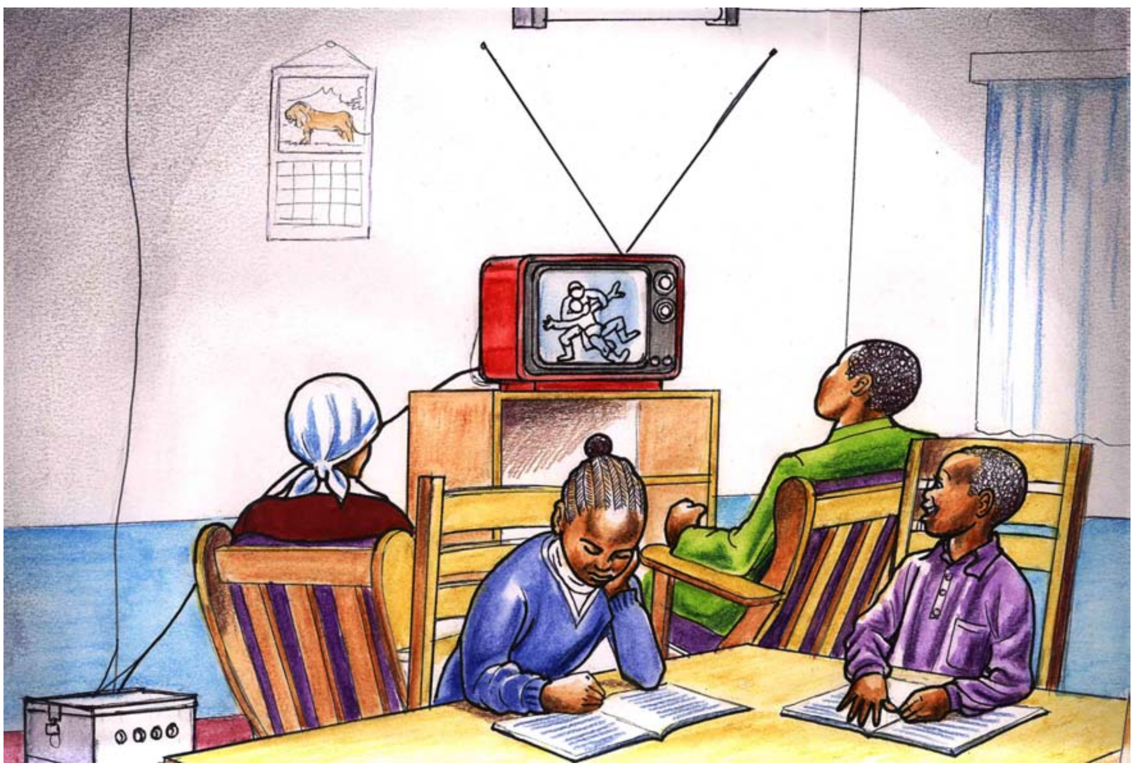

Figure 47: **The sitting room is often used simultaneously for television viewing and evening time studying by children**. (image by Mike Okendo)

[284] In the 2003 survey, parents in 71% of households indicated that the *mezani* was the main room that the children used for studying. 19% indicated other rooms, while 10% said that their children did not study at home in the evening.

And while children's access to solar lighting for evening time studying may decrease with increasing system size, the potential for television to serve as a distraction from studying may not. In fact, as parents in grid connected households around the world are only too aware, the possibilities for distraction may increase as more energy - and hence an ability to watch TV for longer hours - becomes available [e.g. see Barnes et al., 2002].

As with energy allocation dynamics, the potential for television to act as a distraction is closely tied to family relationships, priorities, and motivations around education. In some households - for example the Kariuki family described in the Introduction - both parents and their children make the children's studies a top priority. In these homes the use of solar electricity can greatly facilitate children's ability to study. In other households the family "rules" around television viewing by children were considerably more "relaxed," and this appeared to play a strong role in the degree to which television served as a distraction. In a few homes that I observed, the presence of solar electricity and the corresponding use of television actually appeared to have an overall negative influence on children's study habits. One parent even commented that a few months after they bought the solar system, a teacher sent home a note warning of a sharp decline in the children's school performance. These observations indicate the important role that family dynamics play in shaping the social use of solar electricity for education and other socially beneficial uses of solar electricity.

And of course, the relationship between television and education can have a positive dimension as well. Parents in 54% of the surveyed homes cited modest educational

benefits to television viewing, particularly in relation to news, nature, and technology related programs. Some noted in particular the important role of television in giving their children - not to mention themselves - a window to a wider world. Others said that television viewing was useful for learning English. And many cited the informational benefits of having access to the nightly news.

At the same time, parents in 42% of the households in the 2003 survey expressed concern about some of the images and messages available to their children through television. The most common complaint - that certain TV programs promote "romance and bad values" - resonates with the strongly held Christian values of many rural Kenyans.

This analysis suggests multiple possibilities in the relationship between solar electrification and children's education. They include the potential for the electricity to be used in a way that enhances children's education opportunities, but the possibilities for these benefits to be realized depend heavily on family dynamics around education and household energy allocation.

Conclusion

These two case studies demonstrate conclusively that the social significance of solar electric systems is not pre-given by the environmental characteristics nor the small scale nature of the technology. Nor are the social uses determined through household energy allocation processes that maximize the "common interests" of the family as a whole, as would be suggested by the unitary model of the household. Instead, the social uses are negotiated among family members on a terrain that is defined by the size and

performance of the solar system (with corresponding linkages to family wealth), the geography of the home, and - perhaps most importantly - intra-household relationships.

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 kitchen lighting and 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.

In the context of Kenya's unsubsidized free market, this suggests a tension between the market dynamics of access at the household level and the intra-household dynamics of access within the home. The market dynamics that I described in Chapter 5 indicate that access to solar electricity is deepening slowly to less wealthy families through the sales of the very smallest solar systems. At the same time, the access dynamics within the home indicate that certain important social uses of the solar electricity - e.g. for lighting in the kitchen or evening time studying by children - are often marginalized in small systems due in large part to gender and elder-junior power relationships within the home. These two sets of access dynamics, taken together, suggest that substantial subsidies that target lower income families may be needed if women and children are to derive substantial benefits from solar electrification in the decades to come.

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. My work in this chapter indicates that women who have a significant, independent income from a salary job or a business enterprise are often better situated to negotiate access to solar electricity. And while my results are

inconclusive on the gender dimensions of energy allocation for children's studying, considerable research on the allocation of other goods suggests that women may often be better advocates for the use of the electricity for studying by their children than men are. Although these findings are not definitive and it is important not to essentialize women's (or men's) behavior, the relative power of women in the home does appear to play a key role in influencing the use of solar electricity for important social uses.

The geography of the home - including the spatial layout of the house as well as the social use of the rooms - also influences the possibilities for the social use of the energy. These overlapping elements - intra-household dynamics, family wealth, solar system size and performance, and the geography of the home - come together to create the "terrain" on which the allocation of solar electricity is negotiated. 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. In the next - and final - chapter I argue that it is also necessary to go "beyond the household" in order to understand the full significance of solar electrification in Kenya.

Chapter 7

Solar Electrification and the Political Economy of Rural-Urban Connectivity in Kenya

Solar electricity in Kenya is connective power for the rural middle class. Wireless broadcast and telecommunications technologies, powered primarily by a micro-electricity "infrastructure" that includes solar electricity as well as lead-acid batteries and dry cells, are being used by rural Kenyans 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."

While there are a number of dimensions to this technology-mediated rural-urban connectivity, a highly significant aspect has been a substantial increase in the ability of business advertisers - including especially multi-national corporations such as Coca-cola, Unilever, and Colgate-Palmolive - to reach rural Kenyans who live beyond the main urban centers. This finding links solar electrification strongly to a particular aspect of the deepening of capitalism in rural areas of developing countries; namely, the ongoing integration of the rural middle class into international consumer goods markets.

Although it may seem tempting to therefore view solar PV - as well as televisions and radios - as "neo-liberal tools" in a process of "globalization" that is steadily

increasing the degrees of connection between us all, this characterization is problematic. First, as I discussed in Chapter 1, the significance of a technology cannot be controlled by any one group. Rather, technologies are developed and deployed on complex and contested ground, and the implications of their use are constructed through social action in multiple arenas. Thus, while events in Kenya have produced a media scene that is increasingly favorable for advertisers, this configuration came about only after bitter and protracted struggles, the outcomes of which (as well as its future directions) were far from pre-ordained.

Second, as Cooper and Hart note, this line of thinking assumes a necessary linkage between "connectivity" and the set of processes that are often referred to as "globalization." Globalization is often conceived of as a single, unified process of integration that is driven by "core" interests in "the West" and is moving to envelope more and more elements at "the periphery." Under this conception people and countries at the "periphery" are either "on" or "off" the globalization train, and being "on" the train implies joining a single western version of modernity [Cooper, 2001; Hart, 2002].

This conception of globalization is misleading, as it does not recognize the roles that the particular histories of places or the agency of people in the "periphery" play - in combination with external forces - in shaping their continuously changing realities [Sayer, 1991; Massey, 1994; Hart, 2002]. The result is not a move towards a single western modernity, but rather the simultaneous construction of multiple, interconnected modern societies through the actions of people and groups in local places in combination with "…forces at play in other places, and in wider regional, national, and transnational arenas" [Hart, 2002].

Increased interconnection is not, therefore, just a process of reducing the distance between town and country or a simple incorporation of people in one place into a broader process of "globalization." Rather, it is a "stretching" of certain social relations over space in which some connections are made between some people, but other connections do not get made, and still others are actively contested by opposing people or groups [Massey, 1994; Cooper, 2001; Hart, 2002]. In other words, connectivity is both a social and a political category, and the implications of the use of a particular "connective" technology are powerfully shaped by historically situated social, economic, and political processes.

In this chapter I explore the linkages between solar electrification and the use of wireless broadcast and telecommunications technologies in rural Kenya through two cases, arguing that the significance of solar PV is strongly influenced by the social and political dynamics of rural-urban connectivity. Thus, in addition to going "inside the household" as I did in Chapter 6, understanding the full significance of solar electrification also requires going "beyond the household" to analyze the social and political geographies of rural-urban connectivity. A key element of this analysis is the recognition that rural and urban places are not separate spheres, but rather they are deeply interconnected and mutually constituted through long term socio-spatial relationships [Williams, 1973; Hart, 2002]. The technology mediated forms of interconnection that I discuss here are deeply embedded in social, economic, and political processes associated with the rural-urban relationship in Kenya.

The first case involves linkages between solar electrification and the politics of media broadcasting. The expansion of television and radio broadcasting into rural areas

of Kenya over the past two decades has been heavily influenced by two processes. On the one hand, the political economy of media broadcasting - which was dominated by government investments in TV and radio broadcasting in the 1970s and 80s, and an intense political struggle over broadcast liberalization in the 1990s - has resulted in a broadcast infrastructure that reaches nearly every populated corner of the country. On the other, the expanded use of micro-electricity technologies over the past 15 years - including especially solar PV and lead-acid battery systems - has allowed rural Kenyans to power televisions and radios in off-grid areas. The resulting configuration has important implications for Kenyan politics, as well as cultural and social significance. Nonetheless, business advertisers are among the biggest beneficiaries, as their ability to reach a wider audience of potential consumers has increased considerably.

More recently, cellular telephones have emerged as another important "connective" technology that is supported in rural areas by the use of decentralized solar PV and lead-acid battery systems. In this second case I argue that the main social significance of cell phone use is related to extended family structures that are stretched across rural and urban spaces. In Kenya, many families lead a dual urban/rural existence due to decades old patterns of rural-to-urban migration, with urban family members retaining close connections to the rural "home place." Mobile phones are being used by the rural elite and the rural middle class especially to facilitate long distance family communication. Business related uses of mobile telephones are also important, especially in the merchant and service sectors in rural areas. Farm related uses of cell phones appear to be less common. These findings, which suggest that some professions have a differential ability to benefit from the phones, indicate that their increasing use in

rural Kenya may contribute to particular forms of economic differentiation and middle class formation. Thus, the significance of rural mobile telephones can only be understood by situating their use in relation to long term socio-economic processes.

Solar Electrification and Broadcast Media Politics

The social implications of solar electrification in Kenya are strongly tied to the history and politics of television and radio broadcasting. Likewise, the rural use of televisions and radios has depended on the availability of micro-electricity technologies, including solar PV as well as lead-acid battery systems and dry cells. The current broadcast configuration, which is proving to be increasingly beneficial for business advertisers, is the result of an interplay between these sets of dynamics. I discussed the emergence of solar electrification in previous chapters, and will add only a few key remarks about micro-electricity here. I then proceed to an analysis of the history of broadcasting in Kenya, with an emphasis on the struggle over broadcast liberalization during the 1990s.

Micro-electricity and Rural Broadcasting in Kenya

Radio and television have long been recognized as technologies with important political and socio-economic dimensions [e.g. Williams, 1974; Mosco, 1996; Tomaselli and Dunn, 2001]. Williams [1974] and others have noted that the potential significance of broadcast technologies is linked to the political economy of broadcasting in a

particular context,[285] as well as the dynamics that determine access to receiver sets (i.e. TVs and radios) within a population.[286]

Data for Kenya from 2000 presented in Figure 48 indicate that the distribution of TV ownership is skewed towards the wealthier segments of rural society, with 55% of the TVs being owned by the top 20%, and 84% by the top 40%, by wealth. The data further indicate that lead-acid battery and solar PV systems provide power for the large majority (75%) of rural TV sets. Thus, the rural middle class in Kenya accounts for a substantial fraction of rural TV ownership, and in most rural TV owning homes, solar and battery systems provide the electrical "infrastructure" that enables television use.

Radio ownership is more evenly distributed across the population, with the wealthiest households being only moderately more likely to have a radio than the poorest ones (see Figure 49). The fact that radios can be powered with dry cell batteries is an important factor - along with the low cost of radios - that allows for this broad distribution of access. However, while dry cell batteries are inexpensive enough to allow some use by low income households, the cost per hour to operate a radio with dry cells is much higher than with a lead-acid battery, a solar system, or the grid.[287]

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[285] Including the political economies of media ownership, broadcast licensing and regulation, programming content, and others.

[286] The availability of electricity to power radio and TV sets is, of course, one factor influencing the access dynamics. Transistor radios use very small amounts of power (e.g. < 2 Watts), and they can be operated - if necessary - using dry cell batteries. Television sets require substantially more electricity (e.g. 10 - 20 Watts for a black and white set, and 50 Watts or more for a colored TV), and as a result they were relatively rare in areas beyond the reach of electrical grids until the 1970s. Portable TV sets that could be powered with automotive style batteries - which were developed (i.e. the TV sets) in the 1950s and 60s but became widely available only in the 1970s and 80s [e.g. see Nakashima and Fuchida, 1992] - contributed to the expanded use of television in off-grid areas. In addition, as I describe in Chapter 4, solar PV technology entered the scene in the 1980s and 90s to become an increasingly important technology for enabling the use of television in off-grid rural areas.

[287] In other words, while the capital cost to use dry cell batteries is low, the operating costs are relatively high. In contrast, lead-acid batteries, solar systems, and grid connections require a greater initial investment, but thereafter the operating costs are substantially lower. See Table 5.

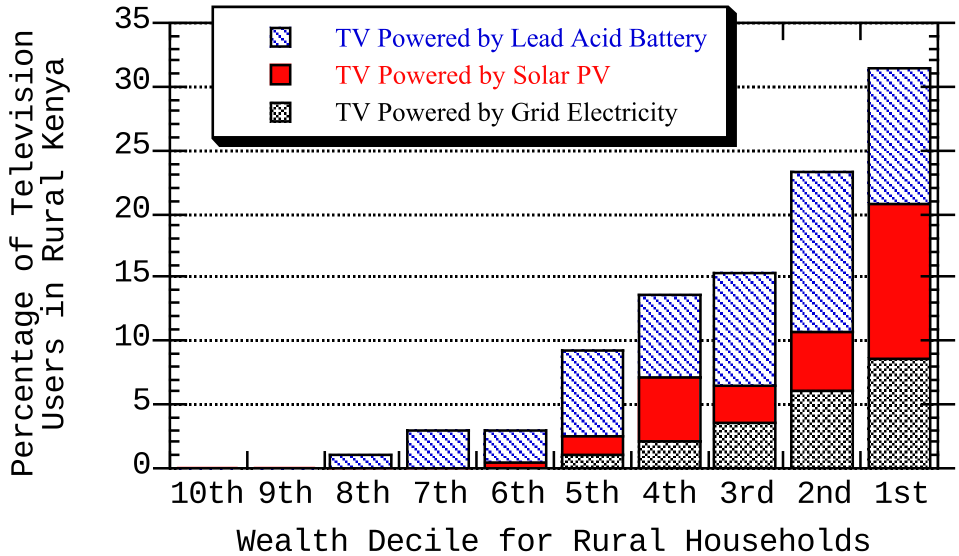

Figure 48: **Distribution of Television Ownership in Rural Kenya with Information about the Source of Electricity Used to Power the Sets** (the combined total of the values listed in the columns represents 100% of the television owning households in rural Kenya)
Source: Tegemeo 2000 data set

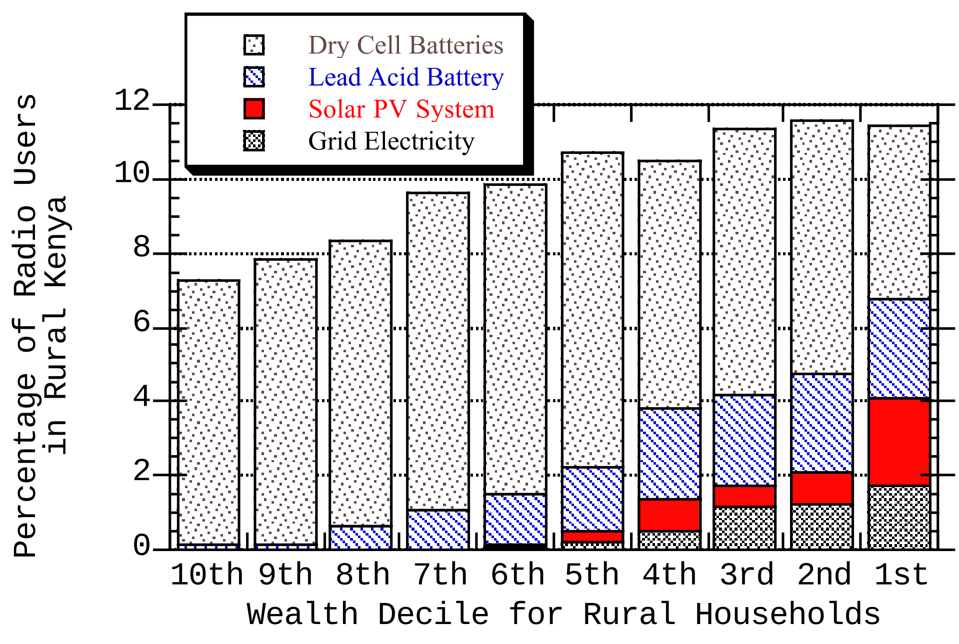

Figure 49: **Distribution of Radio Ownership in Rural Kenya with Information about the Source of Electricity Used to Power the Radios**. (the combined total of the values listed in the columns represents 100% of the radio owning households in rural Kenya)
Source: Tegemeo 2000 data set

Table 22 includes estimates of the monthly cost to operate a typical radio for two hours per day with each of the four main household rural electricity technologies used in rural Kenyan households. These data show that it is over than 20 times more expensive to operate a radio with dry cells than with the other three technologies. In practice, this means that many people in households that have access to a lead-acid battery, a solar system, or the grid listen to the radio for many more hours per day than people who are restricted to dry cells alone.[288] Thus, while radio ownership is widely distributed, radio listening patterns may vary in important ways according to electricity access patterns. These variations, in which people in wealthier households are often in a position to listen for longer hours than those in poorer ones, appears to be especially significant in the context of radio advertising, and I explore this issue in greater depth later in the chapter.

Table 22: **Monthly Cost to Operate a Typical Radio for Two Hours Daily**[289]

Electricity Technology	Approximate Monthly Cost to Power Radio for 2 Hours per Day
Dry Cell Batteries	$2.00
Lead-Acid Battery System	$0.07
Solar PV System (12 Watts)	$0.06
Solar PV System (40 Watts)	$0.02
Electrical Grid	$0.006

[288] Observations from Kenya suggest that in households where the radio is powered with dry cells, the radio is often used only when there is a specific program that a wage earner (i.e. someone who can afford to buy dry cell batteries) wants to hear. In contrast, in households with solar, lead-acid battery, or grid electricity the radio is often used for many hours each day (in some such homes the radio is often on whenever someone is at home). Data collected over six months during 2003 and 2004 indicate that radios were used, on average, for 4.4. hours per day in 15 rural Kenyan "solar" households. Although detailed data are unavailable for the number of radio listening hours in households that power the radio with dry cells, field observations suggest that in most "dry cell" cases radios are used for fewer hours each day.
[289] The comparison presented here is for a radio that draws one Watt of electricity. The cost data are from Table 5. This comparison does not include the initial capital cost of any necessary equipment (e.g. the solar system components).

The close connection between solar PV and lead acid battery systems, on the one hand, and television and (to a lesser degree) radio, on the other, links the social significance of solar electrification to the political economy of media broadcasting. In other words, given that powering TVs and radios are among the primary uses of household solar and battery systems, the implications of solar and battery use in a particular time and place depend in part on the character of the television and radio broadcasting that is available in that location. Moreover, as I describe below through an examination of broadcasting in Kenya, as the character of broadcasting shifts over time, the significance of solar and battery electrification may also change in subtle but important ways.

Broadcast Politics and State Monopoly in Kenya

Radio and television broadcasting were originally established in Kenya to serve the European settlers during the British colonial period.[290] After independence, which was gained in 1963, the ruling KANU party[291] nationalized the KBC[292] and shifted the

[290] Radio broadcasting was initiated in Kenya in 1928 as part of a commercial venture intended to serve the European settler community. During World War II the colonial government established a second radio network to broadcast news and events related to the war effort. These two services were merged into the Kenya Broadcasting Service (KBS) in 1959, which operated from within the colonial administration's Ministry of Information and Broadcasting. In 1961, just before Kenyan independence, the KBS was converted into the privately operated Kenya Broadcasting Corporation (KBC), which had a governing structure similar to the British Broadcasting Corporation (BBC) [Heath, 1986]. Heath notes that "…the conventional wisdom [for the privatization of the KBS in 1961] is that with independence at hand the colonial government thought it essential to take broadcasting out of the hands of subsequent (African) governments which might *misuse* it." [Heath, 1986, p.161, emphasis added]. Heath uses the term "misuse" ironically, and notes that the colonial authorities had long used radio as a political tool during their term of rule. She indicates that the idea that the subsequent African led government might use the broadcast media as a political tool can be understood as a recognition on the part of the colonial authorities that the post-independence government would likely use the broadcast media in a way that was similar to common practices under British rule [Heath, 1986].

[291] KANU is the Kenya African National Union political party. KANU ruled Kenya continuously from independence in 1963 until 2002, when it was defeated by the NARC coalition (National Alliance for Renewal and Change). For much of its time in power KANU ruled with no legal opposition, as Kenya was a *de facto* one-party state from 1968 until 1991 [Miller and Yeager, 1994].

agenda away from serving the settler community and towards one of nation building and consolidation of their political rule [Heath, 1986; Mak'Ochieng, 1996; Makali, 2003]. The government maintained a formal monopoly on broadcasting from nationalization in 1964 until 1989, when the first private broadcaster - the Kenya Television Network (KTN) - was licensed.[293] The broadcast media scene diversified considerably in the late 1990s as the result of a bitter struggle over media liberalization, but state run TV and radio continued to dominate in much of the country up through the 2002 elections [Moggi and Tessier, 2001; Makali, 2003].

Kenyan government investments in the expansion of television broadcasting can be understood as part of a broader strategy by the ruling KANU party to maintain political control. The state established a monopoly on both television and radio broadcasting shortly after independence in 1963, and the expansion of these networks gave the government immense control over news and information in the country [Heath, 1986; Mak'Ochieng, 1996; Moggi and Tessier, 2001; Makali, 2003; and others]. This was especially true in rural areas, where access to print media and other forms of news were limited. Thus, by providing electricity for television in rural areas, solar energy may have contributed - albeit in a small way - to the ability of the ruling KANU party to retain its grip on state power.[294]

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[292] The KBC is the Kenya Broadcasting Corporation. In 1964 the Kenyan government nationalized the KBC and changed its name to the Voice of Kenya (VoK). In 1989 the VoK was changed from a fully government operated agency to a semi-autonomous parastatal company, and its name was changed back to the KBC [Heath, 1986; Makali, 2003].

[293] KTN was licensed in 1989, and began broadcasting early in 1990 [Kariuki, 1990; Media Institute, 2002a]

[294] Significantly, KANU's main base of political strength has traditionally come from rural areas. Opposition groups have tended to have significantly greater success in mobilizing support in the main urban centers.

Although radio broadcasting had a significantly larger reach than television during the 1960s and 70s, neither medium had extensive coverage until the 1980s.[295] During the 1980s the Kenyan government made substantial investments in expanding coverage for both radio and television.[296] By the early 1990s, radio reached nearly every corner of the country, and television expanded from being a largely urban medium to one that covered a substantial fraction of the high population density rural areas [e.g. Xinhua, 1994].

From the government's perspective radio was the more valuable of the two media because of its greater broadcast reach, the relatively low cost of transistor radio sets, and the fact that rural people in off-grid areas could power their radios with dry cell batteries (i.e. grid electricity was not a requirement). In fact, given the limited influence of print media outside of the main urban centers,[297] radio was (and continues to be) widely acknowledged to be the most powerful form of mass media in the country.

Television was also viewed as important in the 1970s and early 1980s, but its influence was seen to be limited outside of the cities by its smaller broadcast range, the high cost of TVs, and a relative absence of rural grid electricity to power the sets [e.g.

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[295] See Heath, 1986 for information about radio broadcast signal range in the early 1980s (especially Map 3, p. 205). See also Inter Press Services, 1989 and Xinhua, 1994 for information about radio coverage. See Figures 26 and 27 for information about the expansion of television broadcasting.

[296] See chapter 4 for further discussion of Kenyan Government investments in the broadcast sector.

[297] Kenya's record on press freedom has been mixed, and journalists and publishers alike have often come under pressure (and worse) to refrain from criticizing the state. However, in the years following the re-establishment of multi-party elections (i.e. beginning in 1991) the situation improved markedly, and during the 1990s media watch groups described the Kenya print media as "vibrant," "dynamic," and "independent" [e.g. see U.S. Department of State, 2002; Moggi and Tessier, 2001; Wedell and Tudesq, 1996]. This contrasts sharply with descriptions of the broadcast sector during the 1990s, where Moggi and Tessier say that "…in comparison with print media, broadcast media in Kenya are still tightly under Government control." However, they also note that "…freedom of expression…is still largely restricted to the print media whose outreach remains limited by distribution problems in remote areas and illiteracy…" [Moggi and Tessier, 2001, p. 6]. The limited reach of the print media made radio an especially powerful and important tool for reaching a rural and small town audience in Kenya.

see BBC, 1980b; BBC, 1981] As I outline in Chapter 4, these factors began to change in the 1980s and 1990s, and television has become an increasingly important medium for reaching rural and small town audiences. As noted previously, lead-acid batteries and solar systems have played an important role in supporting the rural use of television.[298] In other words, although government officials expressed concern in the early 1980s that their efforts to reach rural households with TV broadcasting would be hampered by the slow expansion of the rural power grid, by the end of the decade battery and solar systems were beginning to provide the necessary electricity "infrastructure" to enable the expanded use of television in off-grid areas.[299]

Thus, during the 1980s and most of the 1990s, solar PV systems and lead-acid batteries were used increasingly to enable the use of television in rural Kenya, while dry cell batteries power most rural radios. Throughout this period the VoK (and after 1989 the KBC) had exclusive radio and television broadcasting rights for nearly all rural areas in Kenya. Therefore, the micro-electricity "infrastructure" helped many rural people to increase their access to broadcast media, but in almost all cases their listening and viewing options were limited to VoK/KBC stations alone due to the government monopoly on broadcasting.[300] Seen from a different perspective, the increasing use of micro-electricity technologies, including solar PV, can be understood as an important

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[298] Solar and battery sales grew rapidly starting in the late 1980s (see Figure 24 for historical estimates of television and solar module sales). This growth corresponded with an increase in the use of television in rural areas, and lead-acid batteries and solar systems together now provide electricity for approximately 75% of all rural TV sets (see Table 7).

[299] It is unclear if anyone in the Kenya Government recognized the important role of solar and battery systems in enabling the use of rural TV. Government policies and official statements related to solar electrification over the past two decades do not appear to reflect any recognition of the connection.

[300] As I will describe below, one private television station went on air in the Nairobi area beginning in 1990, but this development did not influence the KBC monopoly beyond the capital.

component of the ruling KANU party's exclusive ability to reach rural Kenyans through the broadcast media. However, with media liberalization the significance of solar PV and the other micro-electricity technologies has shifted in subtle but important ways, as the government monopoly has slowly given way to a semi-pluralistic broadcasting scene which includes a number of privately owned stations.

Liberalization of the Broadcast Sector in Kenya

> Kenya's print media may be among the most liberalized in Africa, but the process of freeing the country's airwaves has been long and often painful. The government is often seen as reluctant to free up the broadcast media, especially outside the capital Nairobi.
>
> Adrian Blomfield, 1998, writing for Reuters

The liberalization of broadcasting during the 1990s in Kenya began haltingly at the beginning of the decade with the licensing of a private television station, and it ended with a deluge of privately owned commercial radio and television stations going on air beginning in 1998. In the interim very few new broadcasters entered the arena, but the politics of the broadcast sector were characterized by bitter struggles between the ruling KANU government - which resisted broadcast liberalization at every turn - and a loose coalition of would-be private broadcasters, opposition politicians, private sector businesses, and foreign donor groups ranging from the World Bank to the U.S. Government, all of whom were pushing for an increased role for private broadcasters.

The battle over broadcast licensing in Kenya during the 1990s was a political struggle about connectivity. That is, it was a struggle over determining who would be able to communicate with whom. At stake, from the KANU perspective, was monopoly control over a set of increasingly powerful tools for reaching, and perhaps influencing, the Kenyan populace. Those in opposition to this monopoly had a variety of economic

and political agendas, and the confluence of their interests appears to have contributed to their ability to break the government monopoly. By the end of the decade liberalization was well underway, and the increasing presence of private radio and television stations appears to have contributed in a modest way to KANU's electoral defeat - its first since independence in 1963 - in December of 2002. Nonetheless, while some segments of the political opposition certainly gained from broadcast liberalization, corporate advertisers - who are now able to reach a much wider audience with their TV and radio commercials - may have been the biggest beneficiaries of the changes that have taken place in Kenya's broadcast scene since 1990.

Understanding these changes, including the politics behind them as well as the significance of the emerging reconfigurations, requires situating broadcast media politics in relation to wider economic and political shifts that took place in Kenya during the 1980s and 90s. In particular, broadcast liberalization must be viewed in relation to and as part of the wider process of economic liberalization in Kenya, which had its roots in the early 1980s but which began to emerge fully only in the mid-1990s. Also of great significance was the move in the early 1990s from single party rule towards a multi-party system that led to national multi-party elections in 1992, 1997, and 2002.

Struggles Over Economic and Political Reform in the 1980s and 1990s

Although Kenya has often been held up as a "model of African capitalism," patronage politics and crony capitalism have long played central roles in the functioning

of the economy[301] [Mosley, 1991; Miller and Yeager, 1994]. The resulting economy has been described as a combination of "…decentralized private enterprise and highly centralized state capitalism…" [Miller and Yeager, 1994, p. 125]. In addition, from 1968 to 1991 Kenya operated in practice as a one party state, with elections but no legal opposition to challenge KANU rule [Miller and Yeager, 1994].

This configuration was propped up by substantial assistance from Western donor nations as well as the World Bank and IMF, and its economy was further supported by relatively large (for East Africa) infusions of private foreign investment [Miller and Yeager, 1994; Duncan, 1997].

While many of the donors did not endorse the patronage and authoritarianism of KANU rule, they did appear - to varying degrees - to tolerate it. For example, between 1975 and 1989 the Kenya government negotiated no fewer than four structural adjustment related plans with the World Bank and nine additional agreements with the IMF. These arrangements involved a significant set of conditions related to economic liberalization and reductions in government spending.[302] However, although the Kenya government failed to comply with a substantial fraction of the conditions, the World Bank and IMF continued to come back to the table to negotiate new aid packages [Mosley, 1991; Duncan, 1997; World Bank, 2003]. Thus, while Mosley notes that "…few country lending experiences have given the Bank so much cause for

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[301] Patronage and cronyism as practiced in Kenya was common during the colonial period under British rule as well as under the post-Independence Kenyatta and Moi presidencies [e.g. see Mosley, 1991; Miller and Yeager, 1994]. In other words, these practices have a long history.

[302] In other words, many of the conditions - if observed - would have limited the ability of key members of the KANU government to engage in patronage based politics. This is true because limits on government spending and liberalization of some of the specified sectors (e.g. sales of maize) would have curtailed their ability to use their political positions to influence economic activities [e.g. see Miller and Yeager, 1994].

frustration…" [1991, p. 270], the fact that the Kenyan Government was continually able to renegotiate despite frequent non-compliance indicates a certain type of tolerance, albeit grudging, on the part of the World Bank and the IMF.

Although a number of conditions and factors influenced these dynamics, Kenya's position as a strategic Cold War ally to the United States and Great Britain almost certainly played an important role [e.g. see Gavshon, 1981; Miller and Yeager, 1994]. In East Africa, which is important in global geo-politics especially given its proximity to the Persian Gulf, Kenya was a relatively stable and consistently pro-Western country in a region full of civil conflicts and socialist leaning governments.[303]

However, by the end of the 1980s the Cold War was drawing to a close, and the Moi administration came under increasing pressure to reform. The first major change came in the form of a move to multi-party politics in 1991, which occurred only after a bitter fight involving, on the one hand, the KANU government, and, on the other, a coalition of opposition groups from within Kenya as well as donor nations and institutions. Miller and Yeager note that

> During 1990, the (KANU) regime had come under intense international pressure to liberalize its economic policies, to reinstate a *de jure* multiparty system, and to halt its abuse of civil liberties and rights. … Pressures for change rose to a crescendo toward the end of 1991, when key donors met in Paris and announced that Kenya's foreign aid would be held in abeyance for six months pending the initiation of political and economic reforms. Moi capitulated in December, asking parliament to authorize multiparty competition… [Miller and Yeager, 1994, p. 108].

[303] During the 1970s and 1980s Ethiopia, Somalia, and Tanzania all, at times, practiced varying forms of socialism, and Uganda was beset by civil war and the rule of Idi Amin [e.g. see Gavshon, 1981; Miller and Yeager, 1994].

The shift towards multiparty elections - which Moi managed to win in 1992 over a badly fractured opposition with a mere 36% of the vote - was followed by significant steps towards economic liberalization beginning especially in 1994 [Miller and Yeager, 1994; World Bank, 2003].

Broadcast Liberalization in Kenya During the 1990s

It was in the context of these struggles over economic and political reform that the battle over broadcast liberalization took place. The first tentative steps in 1989 involved the reorganization of the Voice of Kenya (VoK) into the semi-autonomous Kenya Broadcasting Corporation (KBC) and the licensing of the Kenya Television Network (KTN), a privately owned company.

The reorganization of the VoK into the KBC did not confer any substantial changes in the ruling party's nearly complete ability to control the editorial content of radio and television broadcasts, but it did shift the financial structure of the organization towards substantially greater reliance on paid advertising [Mak'Ochieng, 1996]. This move appears to have been motivated largely by the government's increasing need to reduce spending [Odhiambo, 2001]. Nonetheless, as I will outline below, these changes had important implications for corporate advertisers.

In the same year (1989), the government granted permission for the establishment of a private television station, and KTN went on air in 1990 with a broadcast range covering an area in a 40 mile radius in the greater Nairobi area [Xinhua, 1989; Moggi and Tessier, 2001]. Although the government framed the establishment of KTN as an important step towards media liberalization, the fact that the station was owned by the

Kenya Times Media Trust, a fully owned subsidiary of the KANU ruling party, belied this claim[304] [Xinhua, 1989; Moggi and Tessier, 2001; The Media Institute, 2002a].

In the years following 1990 an intense struggle over broadcast liberalization ensued, with KANU resisting at every step and with much of the effective pressure to liberalize coming from international groups such as the U.S. Government and the multilateral donor agencies.[305] During this process the ruling party relied on a set of arbitrary licensing policies to restrict broadcasting rights to companies considered friendly to the regime, and to confine the range of private broadcasters to the area around the capital city of Nairobi .[306] Through these tactics the government managed to largely contain broadcast liberalization, despite intense domestic and international pressure, until after the 1997 national elections.[307] Moi won these elections, again with a plurality (of 41%)

[304] KTN's ownership changed hands several times over the 1990s, but in practice it remained under the control of President Moi and his close allies [Moggi and Tessier, 2001].
[305] For example, Cyrille Nabutola, the managing director of privately owned "Nation TV," says that while a number of groups opposed the KANU government's broadcast policies, international pressure from the U.S. Government and other donor groups was decisive in forcing the Kenya government to take concrete steps towards broadcast liberalization [Nabutola, 2002]. Much of the politicking appears to have occurred behind closed doors. Nonetheless, there were moments - for example a set of exchanges between U.S. Ambassador Aurelia Brazeal and Kenyan Minister for Information and Broadcasting Johnstone Makau that played out in the Kenyan press for several weeks in 1995 - when the debate spilled over into the public realm [e.g. see Daily Nation 1995a, 1995b, 1995c, and 1995d].
[306] David Makali notes that under the 1989 law governing broadcasting licenses, the Minister of Information had complete discretion over the licensing process. In his words, "…there were no clear guidelines or principles applied in granting or refusing to grant such licenses." [Makali, 2003, p.327]. The government used this arbitrary approach to broadcast law on a number of occasions to deny, revoke, or restrict licenses for those considered critical of the KANU regime [e.g. see Makali, 2003, pp.326-339; Moggi and Tessier, 2001, p. 13].
[307] Two new broadcasters went on air in 1996, allowing the government to claim further steps toward liberalization. These were STV (also known as Stellavision), a TV station owned by KANU loyalists, and Capital FM, a radio station "…owned and managed by expatriates (that) was allegedly set up to serve the white 'expatriates'" [Moggi and Tessier, 2001, pp. 11-12]. Neither station posed a threat to KBC's near monopoly on news and information. STV did not include domestic news in its programming (though they did rebroadcast segments of Sky News, an international cable news company owned by Rupert Murdoch [BBC, 1996]), and Capital FM focused initially on a limited audience in the Nairobi area [Nduru, 1997]. In addition, Linda Holt, then the managing director of Capital FM, indicated that the station "…was awarded a license on the understanding that it did not broadcast news…" [Blomfield, 1998].

over a divided opposition, and the KBC's near monopoly on radio and television broadcasting again played an important role [Kanyongolo and Lunn, 1998].

It was only in 1998 that liberalization began in earnest, with 12 new FM radio stations and three TV stations going on air between 1998 and 2000.[308] There are now (as of 2003) more than 20 radio stations and a total of seven TV stations operating in Kenya, including government (i.e. KBC), private business, religious affiliated, and international (e.g. BBC, VoA) broadcasters[309] [Media Institute, 2002a; Steadman, 2002; Daily Nation, 2003b].

Nonetheless, despite the rapid increase in the number of broadcasters, KBC continues to dominate the airwaves throughout much of the country. This was especially true prior to the 2002 elections, as the government effectively managed to contain the signal range of many broadcasters to the area around Nairobi through the use of licensing rules and restrictions.[310]

KBC's dominance is especially prevalent among TV broadcasters. Survey data from 2002 presented in Table 23 indicate that for 72% of TV viewers nationwide, KBC was

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[308] Most of the new FM radio stations were owned by private companies, but several were also owned by religious organizations. In addition, the BBC began broadcasting its "Network Africa" programs through an FM station in Nairobi in 1998, and the Voice of America (VoA) went on air in 2001. The three new TV stations included two private corporate stations (Nation TV and Citizen TV) and one religious (Christian) station (Family TV) [The Media Institute, 2002a].

[309] In addition to the stations listed here, Kenya also has several paid subscription satellite channels, including the privately owned DSTV (Digital Satellite TV) and "KBC 2," which is owned by the KBC. These paid subscription channels are limited to a relatively small and wealthy audience, mostly in urban areas [Media Institute, 2002a; Moggi and Tessier, 2001].

[310] Notably, the KANU led government worked especially hard to contain the expansion of stations considered critical of its rule. Thus, while STV (which did not broadcast an Kenyan news programs) and KTN (which was owned by associates of President Moi) gained permission to expand their TV broadcasts beyond the capital, Nation TV, which was considered critical of the government, won the right to broadcast only after a long lawsuit. Even then, its broadcast rights were confined to the Nairobi metropolitan area until after NARC's 2002 election victory [Africa News Service, 1998; Media Institute, 2002b; Makali, 2003; Daily Nation, 2003c].

the station that they watched most often.[311] KBC's next closest rival, KTN, was a distant second with 12% of the viewership. In rural areas the differences were even more stark, with 85% of viewers watching KBC most often. For the large majority of rural viewers this pattern was not by choice, as the KBC was the only channel available in their area.

Table 23: **Most Watched Television Stations Among TV Viewers, 2002**

	Most Watched TV Channel (% of Viewers)[312]						
Area	KBC	KTN	STV	Nation TV	Metro TV	Family TV	Citizen TV
Overall	72	12	2	6	1	1	0
Urban	58	21	4	9	3	2	0
Rural	85	5	0	3	0	0	0

Source: Research International and Steadman Research Services, 2002 media survey in Kenya (n = 2,000 adult respondents, 66% rural, 34% urban)

The radio scene is more diverse than TV, but KBC is still by far the dominant player among radio broadcasters. In 2002 the KBC national service in Swahili had the highest listenership with 63% of adults tuning in daily and 87% listening on at least a monthly basis.[313] The data in Table 24 further indicate that KBC's preeminence extends considerably beyond this, with four of the five top stations falling under its ownership. The top privately owned station - KISS FM - garnered just 13% of the daily listeners in 2002, and no other private station topped 10%. Nonetheless, while KBC remains dominant, the proliferation of FM radio stations has led to some significant changes. Of

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311 Nationwide 43% of adults surveyed in 2002 indicated that they watched television on a daily basis. Daily TV viewing was substantially more common in urban areas (68%) than in rural areas (27%) [Steadman, 2002].

312 The totals for the different categories do not add up to 100% because some viewers were unsure or declined to state which station they watched most often. The remainders (i.e. 6% of the overall population, 3% of the urban population, and 7% of the rural population) fall into this "decline to state" category.

313 Survey data from 2002 indicate that 95% of Kenyans listen to the radio on a daily basis, with little difference between rural and urban audiences [Steadman, 2002].

particular note is the high number of regionally oriented stations, including both private broadcasters as well as those in the KBC network.[314] This "regionalization" of radio has been especially significant for advertisers, and I return to this trend in the next section.

Table 24: **Radio Listening Trends for Selected Stations in Kenya (2002)**

		Listened to Station…	
Radio Station	**Ownership**	**Yesterday (%)**	**In Past 4 Weeks (%)**
KBC Swahili	KBC (national service)	63	87
KBC English	KBC (national service)	22	56
Metro FM	KBC (regional)	13	30
KISS FM	Private Commercial	13	21
KBC Western	KBC (regional)	6	18
Citizen FM	Private Commercial	9	17
BBC	BBC (UK)	3	10
CORO	KBC (regional)	9	14
Nation FM	Private Commercial	5	12
Kameme FM	Private Commercial	5	12
KBC Central	KBC (regional)	2	8
Sayare FM	Private Religious	5	9
Capital FM	Private Commercial	2	7
Baraka FM	Private Religious	4	7
Metro East FM	Private Commercial	1	4
Family FM	Private Religious	1	4
Pwani FM	KBC (regional)	2	4
Pulse FM	Private Commercial	2	3
Voice of America (VOA)	VOA (USA)	0	2
Deutsche Welle (DW)	DW (Germany)	0	2

Source: Research International and Steadman Research Services, 2002 media survey in Kenya (n = 2,000)

[314] Among the private commercial broadcasters listed in Table 24, KISS FM, Citizen FM, and Nation FM are seeking to develop national broadcasting reach, but have yet to fully expand their networks. Kameme FM is a regional station focused on the Kikuyu community in Nairobi and the Central Province, Capital FM and Pulse FM are commercial stations geared towards a Nairobi audience, and Family FM (Nairobi), Sayare FM (Eldoret), and Baraka FM (Coastal region) are regionally oriented religious stations. KBC now has six regionally oriented broadcasts (Metro FM for Nairobi, KBC Western, KBC Central, KBC Eastern, CORO for the Kikuyu community in Nairobi and the Central Province, and Pwani FM for the Coast region).

The 2002 elections, which the opposition NARC coalition won in a landslide,[315] were a major victory for the private broadcast companies. After the election, the new NARC led government proceeded to honor its promise to allow the previously restricted private broadcasters to expand their signals beyond the capital, and two of the major TV stations - KTN and Nation TV - have greatly increased their reach [e.g. see Daily Nation, 2003a; BBC, 2003; and Kithi, 2004].

Observers of broadcast media trends from elsewhere on the continent indicate that Kenya's shift towards an increasing role for private broadcasters is common throughout Sub Saharan Africa [e.g. see Tomaselli and Dunn, 2001]. These studies suggest that while an end to government monopolies in broadcasting may be a positive trend, the new media configurations - which are dominated by a few corporate broadcasters in many countries - leave much to be desired in terms of the diversity of viewpoints that are presented on air. John Barker, working from an analysis of broadcasting in several Southern African countries, argues that…

> …with the transformation of media organizations into large scale commercial organizations, freedom of expression has been confronted by a new threat, a threat stemming not from excessive use of State power, but rather from the unhindered growth of media organizations as commercial concerns. This view does not

[315] The main opposition party to KANU in the 2002 elections - the National Alliance for Renewal and Change (NARC) - made broadcast media reform a key plank in their platform [Njeru and Ochieng, 2002], but in the context of the campaign KANU maintained a decisive - although no longer overwhelming - advantage with respect to their ability to reach voters through the broadcast media. The result of this advantage is described in a study of TV and radio election coverage [Media Institute, 2002b]. However, KANU does not appear to have been able to use their advantage in the broadcasting realm effectively in the 2002 elections. This may have been due in part to an increasing skepticism among many Kenyans about the reliability of KBC as a source of information about politics. One 2002 nationwide media study indicated that KBC was ranked last among TV broadcasters in terms of viewers perceptions of the "objectivity" of the information presented on its news programs [Steadman, 2002]. This indicates the key role of viewer agency in determining the political significance of broadcast media content. In the end NARC's landslide victory in 2002 - Kibaki won the presidential race with 62% of the vote to Kenyatta's 31% - appears to have been due more to the ability of the opposition unite around a single candidate than any other factor. Nonetheless, broadcast liberalization likely played a role in the process, as KANU's dominance over the airwaves was loosened, if only in a modest way.

> presuppose that the free market approach to economic activity is the best guarantor of freedom of expression (in the broadcast media), since an unregulated market may develop in a way which effectively reduces diversity and limits the capacity of most individuals to make their views heard [Barker, 2001, p.16].

The concern is that the commercial pressures of broadcasting in what are often only marginally profitable media markets can lead to a concentration of private media ownership into a few hands, a high level of dependence on imported programming, and a marginalization of voices deemed to be outside of the "mainstream." These concerns are especially large in the case of television, given its higher investment and operating costs relative to radio.

Despite the openings associated with the recent liberalization, this trend towards media ownership concentration appears to be evident in Kenya. The two largest players in private broadcasting are the Nation Media Group (NMG) and the Standard, Ltd. NMG, in addition to owning the rapidly growing Nation TV and Nation FM radio stations, is the long time owner of Kenya's leading newspaper, the Daily Nation.[316] Likewise, KTN TV is owned by the Standard, Ltd., which also owns Kenya's second largest newspaper (The East African Standard)[317] as well as Capital FM radio. In other words, the mass media scene in Kenya is increasingly dominated, along with the KBC, by two large corporate media companies with holdings that span newsprint, television,

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[316] The Daily Nation has the largest readership of any newspaper in Kenya, with a daily circulation of over 200,000. In a 2002 survey 26% of Kenyan adults reported reading the paper on a daily basis. The Nation Media Group also owns Kenya's third largest newspaper, the Taifa Leo, which is published daily in Swahili, has a daily circulation of 35,000, and an estimated daily readership that totals 5% of Kenyan adults. The Nation Media Group is a stockholder owned company quoted on the Nairobi stock exchange. The principle owner is HH the Aga Khan, who holds a 43% ownership share [Steadman, 2002; www.nationaudio.com/kenyapolitics/info/nationmedia.html].

[317] The East African Standard has a daily circulation of 80,000, and 5% of Kenyan adults report reading it on a daily basis [Steadman, 2002; www.eastandard.net]. The ownership of the Standard Group has been shrouded in mystery over the last decade, but former President Daniel Arap Moi and his family appear to be major stakeholders [Media Institute, 2004].

and radio. Thus, while the end of the KBC monopoly may be welcome, the issue of media diversity remains an important concern.

Africanist media scholars have argued that reforms of public broadcasting that combine significant levels of public funding with political autonomy from the government in power are critical components of media diversification [e.g. see Barker, 2001; Tomaselli and Dunn, 2001; Barnett, 2001]. The current Kenyan government is in a position to enact such reforms, but to date it appears to be under little effective pressure to do so. The main forces behind the push for media liberalization in the 1990s - including international interests such as the U.S. Government as well as private media concerns and corporate advertisers - appear to have little interest in this agenda. This may indicate that the top priorities of these groups in their struggle for media liberalization in Kenya over the past 20 years were more closely linked to opening the airwaves to business interests than to ensuring media diversity. This has important implications for the significance of solar and battery electric systems, as it indicates that their role in enabling the use of television (and to a lesser degree radio) is closely associated with the ability of corporate media broadcasters and media advertisers to expand their reach into rural areas of Kenya.

The Significance of Broadcast Liberalization for Business Advertisers

While the recent changes in the broadcasting sector have had political implications, their importance for business advertisers has been perhaps even more significant. Advertising on radio and television in Kenya has increased substantially since 1989 when the KBC began relying on advertising revenue to meet its operating costs, and

these two media now receive more than 60% of all commercial sector advertising expenditures in Kenya [WARC, 2004].

Growth in radio advertising has been particularly rapid, with total expenditures increasing at 16.3% annually from 1994 to 2002[318] [WARC, 1994]. Television advertising sales, while initially higher than radio in the early 1990s, remained relatively constant over the mid to late 1990s. In recent years following the significant expansion in the number of broadcasters in the late 1990s, however, TV advertising revenues have grown sharply.[319] As shown in Figure 50, all of this advertising growth happened during a period when the overall economy was relatively stagnant. This suggests that increased spending on advertising is due not to economic growth, but may instead be related to processes of economic liberalization in general and broadcast media liberalization in particular that have opened up new opportunities, respectively, for the expansion of consumer goods markets on the one hand and media advertising on the other.

Radio is widely acknowledged as the most important medium for reaching a rural and small town audience, but the significance of television is growing given recent increases in viewership [Miriti, 2003; Waruhiu, 2003; Waititu, 2003]. See Figure 51 for a summary of recent media use trends in rural Kenya. These data indicate that radio use

[318] Detailed advertising expenditure data are not available for the years prior to 1994.

[319] Although 1998 is often cited as the year in which widespread broadcast media liberalization began, Nation TV did not begin broadcasting until December of 1999 [Daily Nation, 1999], and the two main private stations (KTN and Nation TV) did not begin to expand their reach beyond Nairobi until 2003 [Daily Nation, 2003a; BBC, 2003]. Thus, it is perhaps unsurprising that TV advertising revenue appears to increase sharply beginning in 2000. Nonetheless, it will take several additional years of observation to determine if the increase in TV advertising from 2000-2002 is the beginning of a long term trend.

is widespread, television viewing is growing rapidly, and that newspaper reading has declined somewhat in rural areas over the past few years.

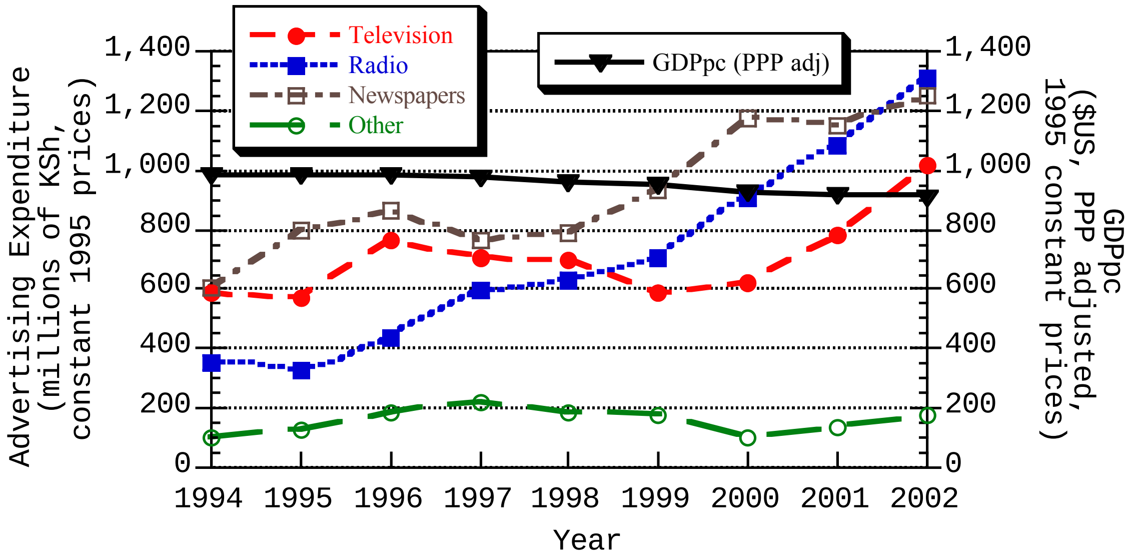

Figure 50: **Advertising Expenditure in the Kenyan Media, 1994 to 2002**
Source: Advertising expenditure data from WARC, 2004; GDPpc data from World Bank online database (devdata.worldbank.org).

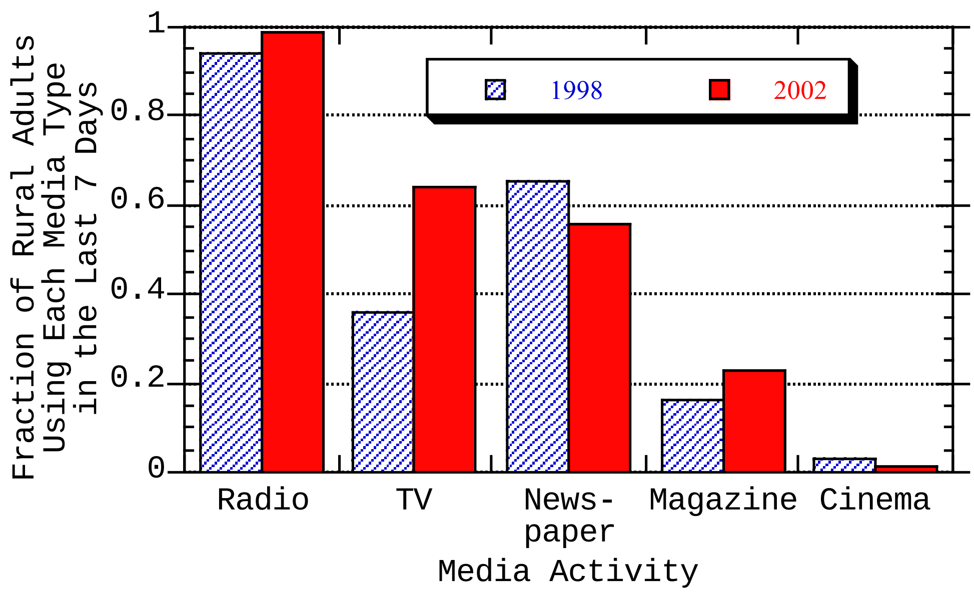

Figure 51: **Weekly Media Use Trends for Rural Kenyan Adults**[320]
Source: Research International and Steadman Research Services, 1998 and 2002 media surveys in Kenya (1998 survey, n = 1,660 (77% rural); 2002 survey n = 2,000 (66% rural); only the rural respondents are included in this figure).

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[320] In the survey people were asked about their use of media in the seven days prior to the interview [Steadman, 2002].

The broad reach of radio has made it a valuable medium for advertisers, and the recent liberalization and the proliferation of regionally oriented stations has further increased its significance. Liberalization has led to competition among radio broadcasters with a corresponding decline in advertising rates [Miriti, 2003; Warihiu, 2003], and the smaller regional stations often sell ad space at particularly low prices.[321] Moreover, many of the regionally oriented stations broadcast in area specific vernacular languages rather than in English or Swahili, which allows advertisers to tailor their messages for the people living in each region.[322] According to prominent Kenyan advertising professionals, this targeting can greatly enhance the effectiveness of an ad campaign [Miriti, 2003; Waruhiu, 2003; Waititu, 2003].

In addition to targeting, the frequency with which people hear an advertisement plays a critical role in the development of brand recognition. The low cost of radio advertising relative to other media allows for repeated broadcasts of the ad spot, and this contributes to the value of this medium. The number of hours that people listen to the radio is also centrally important, since those who listen longer are likely to hear a given ad more often. This last point links the interests of radio advertisers to solar,

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321 For example, in 2002 the advertising rate during prime time hours for KBC's national FM radio service in Swahili was 16,500 KSh for a 30 second spot, while the cost for the same ad on one of its regional FM stations was 2,400 KSh (and the cost for Metro FM, the KBC station for Nairobi was 4,960 KSh). The cost to put a prime time advertisement on each of the 5 KBC regional stations plus Metro FM (16,960 KSh in total) is therefore more or less equal to the cost to put a single advertisement on the national KBC service in Swahili. Several marketing specialists indicated that they consider the regional radio ad spots to be a particularly good bargain [Miriti, 2003; Warihiu, 2003].

322 There are more than 40 ethnic groups in Kenya, and most people's "first" language is the one associated with their ethnic group. Swahili is used by most people as a "second" language to communicate with people from other ethnic groups, and English is common mainly among the well educated urban population. A number of radio stations now broadcast in "ethnic" (or vernacular) languages. These include 5 KBC regional stations as well as several of the small private stations. For example KBC Central broadcasts in the Kimeru, Kiembu, Kikamba, and Kimaasai languages, while Coro FM (KBC) and Kameme FM (privately owned) are in the Kikuyu language [KBC, 2004; Media Institute, 2002a].

battery, and grid based electrification, as rural Kenyans who power their radios with these power sources may tend to use the radio for more hours each day than those who power their radios with dry cell batteries.[323] Thus, while radio is already the most powerful medium for reaching rural Kenyans, its value to advertisers will further increase as more families gain access to electricity sources such as lead-acid batteries and solar PV that allow for lower cost listening.

Television is cited as the second most important medium, behind radio, for reaching a rural audience.[324] As rural TV ownership levels grow, advertising professionals expect it to eventually overtake radio [Miriti, 2003; Warihiu, 2003; Waititu, 2003]. As discussed previously, solar and battery systems already play a central role in supporting the rural use of TV, and continued growth is likely to depend heavily on these two micro-electricity technologies.

In addition to radio and television, advertising strategies to reach rural Kenyans also include "postering," "mobile cinema," "road shows," newspaper advertisements, corporate calendars, and others.[325] These media are often used complementarily with

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[323] See Table 22 and footnote 288.

[324] Leading advertising professionals indicate that TV is considered the most important medium for reaching potential urban consumers [Miriti, 2003; Warihiu, 2003; Waititu, 2003].

[325] The following descriptions are based on interviews with Lisa Miriti [2003] and Evah Warihiu [2003]. "Postering" involves distributing brand oriented posters and signs to vendors throughout the supply chain for a product. The posters are typically hung near the entrance to the business where the goods are sold (this practice is also sometimes called "wall branding"). "Mobile cinemas" are movie shows that travel from town to town. Advertisements are shown before and in between movies, and these help finance the cost of the mobile cinema companies. One marketing specialist noted that this venue is particularly well suited for advertisements targeted at men, as the audience for the action movies that are commonly shown in mobile cinemas is usually largely male [Miriti, 2003]. "Road shows" are sometimes used to launch new products in rural and small town markets. These involve a team of marketers who travel from town to town giving out product samples and advertising the brand through public speeches and short theater skits. The idea is to generate a carnival atmosphere that draws many people over to watch the 'show', where they will therefore hear about the new product. In addition to these marketing approaches, billboards and other large signs are also used, but they are much more common in cities and large towns than in small towns and rural areas.

radio and television in a multi-pronged approach to reach rural and small town audiences.[326]

Multinational corporations account for a large fraction of advertising expenditures in Kenya, and this is particularly true in the broadcast media. A 2003 survey of television advertisements on two of Kenya's leading TV stations indicates that over 60% of prime time ads are purchased by multinational corporations (see Table 25). This result is supported by other studies of media advertising in Kenya, which indicate that "… multinational companies tend to support their brands more than local firms…" [Maina, 2001]. While products marketed by multinationals have a particularly large presence on television, they also make up a substantial fraction of radio advertising [e.g. see Maina, 2000]. Several advertising professionals noted that large multinationals, including Unilever, Coca-Cola, Colgate-Palmolive, and several others, have been especially well positioned to take advantage of the advertising opportunities presented by the decentralization and regionalization of radio that has taken place in recent years [Miriti, 2003; Warihiu, 2003]. These findings indicate that multinational corporations are among the important beneficiaries of broadcast media liberalization in Kenya.

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[326] For example, a campaign for a particular brand might include frequent radio spots on several regionally oriented stations, a smaller number of TV ads on KBC (i.e. the station with the widest broadcast reach), and the distribution of posters to shops throughout the product supply chain. The radio and TV ads are used in this example to generate brand recognition through repeated broadcasts to people in their homes and work places, while the posters - which are generally displayed around the entrance of shops that carry the brand - are used to attempt to draw potential customers who recognize the brand name into the shop for a purchase [Miriti, 2003].

Table 25: **Ownership Status of Advertisers on Two Television Stations in Kenya**

Description of Advertiser (Primary Ownership)	**KBC TV (% of Ads)**	**Nation TV (% of Ads)**
Multinational Corporation[327]	68%	64%
Kenyan Owned Company	24%	19%
Advertisement for TV Program	4%	7%
Other (e.g. Religious, NGO, or Gov't Sponsored Ads)	5%	9%

Source: Original survey of advertisements on KBC TV and Nation TV channels during prime time hours (7 pm to 9 pm) over 13 days in 2003. There were a total of 206 ads in the sample (KBC TV, n = 111; Nation TV, n = 95).

The results presented in this section indicate that television and radio advertisers, including especially large multinational corporations, are among the biggest beneficiaries of broadcast media liberalization in Kenya. In rural areas solar and battery systems are a key component - along with dry cell batteries - of the decentralized micro-electricity infrastructure that enables most of the television and radio use, and solar PV and lead-acid batteries are especially important for powering rural TV sets. These findings shed new light on the political economy of rural-urban connectivity, and its relationship to decentralized approaches to rural electrification with solar PV and other micro-electricity technologies.

In Kenya the combination of broadcast media liberalization and micro-electricity technologies - including solar PV - have created new possibilities for linkages between rural people and markets, people, and ideas in national and international urban centers. However, as I describe in this chapter, this is not a case of shortening the distance between rural and urban spaces for everyone. Rather, certain connections get made while others do not. In the case of television and radio in Kenya, the politics of

[327] Products from five multi-national corporations have a particularly large presence on Kenyan television. Products marketed by 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 in the 2003 survey.

broadcasting have played a central role in determining who gets to deliver messages across the airwaves, while the dynamics of access to televisions, radios, and the electricity to power them have been a central component of determining who is able to receive the messages.

On the broadcasting side, the dynamic has shifted from one in which a government monopoly, in the form of the KBC, dominated the airwaves, to a scene in which private corporate broadcasters have an increasingly large presence. This shift has had important implications for electoral politics, but business advertisers are among the largest beneficiaries. These changes must be understood in relation to the dynamics of access to rural electricity through technologies ranging from dry cell batteries to lead-acid batteries, solar PV, and the grid, where the rural elite and middle class are generally in a much better position to own the necessary equipment.

The significance of solar electrification, then, must be understood not only through the processes that influence its use, but also in relation to socio-political and socio-economic processes that take place well beyond the households where the energy is used, including the struggles over broadcasting that I describe in this chapter.

In the preceding pages I have described how the significance of solar PV as a key technology for enabling rural television - and to a lesser degree radio - has shifted over time with changes that have occurred in the broadcasting sector. I will now turn to another "connective" use of solar PV and battery based systems, the emerging use of cellular telephones in rural Kenya. As with the case of television and radio, the significance of solar PV in relation to rural cell phone use must be understood in the

broader context of Kenyan society. In this case, long term processes of rural-urban migration play a central role.

Solar Electrification and Mobile Telephones in Rural Kenya

Since their introduction in the late 1990s, cellular telephones have become increasingly common in Kenya. According to the data presented in Figure 52, mobile phone sales have grown at an astronomical 107% annual rate, and their use now dwarfs that of conventional land line telephones.

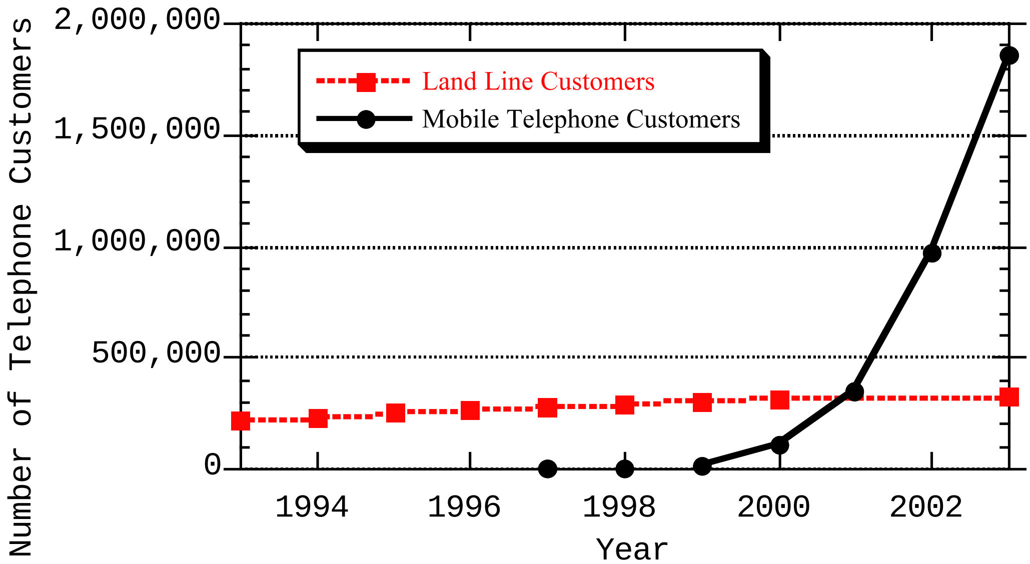

Figure 52: **Number of Land Line and Mobile Telephone Customers in Kenya, 1993-2003**[328] Sources: CCK, 2001; Balancing Act, 2002; Kisero, 2003; CCK, 2003

[328] Two companies provide mobile telephone service in Kenya. These are (1) Safaricom, which is owned jointly by the Kenya government through Telkom Kenya Ltd. (60%) and the British telecommunications giant Vodafone (40%) [www.safaricom.com], and (2) Kencell, which is owned privately by the Kenya based Sameer Group of Companies (40%) and Celtel International (60%) [www.kencell.com]. Celtel International is an Dutch headquartered multinational company with cellular telephone operations in 13 African countries [www.celtel.com]. The numbers listed in Figure 52 are the combined totals for both Safaricom and Kencell. A third mobile telephone company, Econet Wireless Kenya, was licensed to operate in 2003 but has yet to start operations in Kenya [Wahome, 2003; Epipisu, 2004]. Land line service in Kenya is provided by the state owned Telkom Kenya.

The majority of mobile telephone owners live in urban areas, but as the cellular networks expanded beyond the cities beginning in 2001, some people in small towns and rural areas also started to purchase the phones.[329] Although countrywide data on rural cell phone use remain unavailable, it is clear that in the last two years their use has grown rapidly, especially among the rural elite and middle class.[330] However, while the telephones themselves are new, the rural-urban connections that they facilitate are not.

In Kenya the dynamics of mobile telephone mediated rural-urban connectivity are historically rooted in decades old social, economic, and political processes. Rural areas have often been conceptualized as "satellites" to urban centers, with money, resources, and people "flowing" primarily from rural to urban spaces [e.g. Frank, 1966; Lipton,1977; Kitching, 1989]. However, in Kenya and elsewhere on the African continent many of these flows have been bi-directional and cyclical rather than unidirectional towards the city. For example, a significant fraction of capital investment monies for small family farms in Kenya have come historically from urban income streams [Kitching, 1980; Cowen and Shenton, 1996]. These money flows are the result of tightly knit extended family structures that are stretched over rural and urban spaces. And while rural to urban migration is the dominant trend, many "migrants" actually lead a dual urban-rural existence. For some this means returning to the rural farm regularly, while others live more or less full time in the city for years or decades before moving back to the farm to retire or during hard economic times [Berry, 1993]. Cell phone use

[329] See www.safaricom.com and www.kencell.com for information about their respective coverage levels.
[330] For example, a survey of 76 rural "solar" homes conducted in 2003 indicated that 50% included at least one person who owned a cellular telephone. This suggests a potentially high level of cell phone use among the rural middle class.

in rural Kenya is deeply embedded in these rural-urban social patterns, and a significant fraction of cell phone use is for long distance family communication. These extended family connections combine with free market technology access dynamics as well as differential opportunities for productive uses - both of which favor the rural elite and middle class over the mass of rural poor - to link the social use of cell phones with decades old migration patterns as well as particular forms of economic differentiation and middle class formation.

In other words, mobile telephones are facilitating rural-urban communication, but as with television and radio, the linkages are far from universal and they must be understood by situating them in the broader context of Kenyan society. I leave a full analysis of the significance of rural cellular telephone use for future research, but some preliminary observations are warranted based on current information.

Cellular Telephone Ownership Patterns in Rural Kenya

Although national data are unavailable, preliminary survey results and price data indicate that most mobile telephones in rural areas are owned by members of the rural elite and middle class. Data from a survey of 79 rural cellular telephone owners from 2003[331] indicate that 77% live in a household where the main source of income is from a professional salary or business earnings, while only 18% depend primarily on farming.[332] Moreover, current prices for cellular telephones suggest that they may

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[331] The results presented here should be interpreted with some caution, as these preliminary results are based on a "snowball" sampling technique for a limited sample in three regions of Kenya rather than through a large national survey with true random sampling. Further research is needed to establish the wealth and class dimensions of cellular telephone ownership among rural Kenyans. See footnote 91 and Appendix B for more information about the 2003 survey.

[332] These are results for the "most important" source of income for the household where the person owning the cell phone lives. The remaining 5% of the people surveyed indicated other sources as their main income (e.g. daily wage labor). Many people indicated that their household depended on multiple

remain too expensive for the majority of lower income rural Kenyans. The median price paid to purchase a phone combined with an initial fee to set up service among rural cell phone owners in the 2003 survey was approximately $80, and the minimum price to gain access was $50. These amounts are affordable - if expensive - for many members of the rural middle class, but they indicate that cell phones likely remain beyond the reach of most rural Kenyans.[333] These preliminary findings support the conclusion that the main beneficiaries of cell phone mediated rural-urban connectivity are members of the rural middle class.

Cellular Telephone Charging in Rural Kenya

Solar PV and battery systems play an important role in supporting the rural use of cellular telephones, but the rural grid appears to play an even more significant role. Data presented in Table 7 indicate that the electrical grid accounts for an estimated 58% of rural cell phone charging, while solar PV accounts for 24%, lead-acid battery systems account for 11%, and the remaining 7% of charging is done with generators or in vehicles. The high prevalence of grid based charging is largely related to the mobility of the phones as well as the fact that most people live near a town or market center that has grid electricity.[334] In other words, while very few of the rural cell phone owners had grid electricity at home, many were able to charge their phones in a nearby town at a workplace, at a business that charges cell phones for a fee, or at another grid

sources of income. The most common configurations combined professional salaries and/or business earnings with farm income (57% reported mixed incomes that included farming). Others (35%) reported business or professional salary incomes, but no farm related earnings. Only 8% indicated that they depended on farming alone. These results suggest that most rural cellular telephone owners fall into the hybrid rural middle class category described in Chapter 3.

[333]Nearly all of those surveyed reported purchasing the phones with their own income (89%). Most of the remainder (10%) said that a family member purchased the phone for them.

[334] See Figure 15 for more information about the geography of the rural electrical grid.

connected location.[335] Thus, while the decentralized solar and lead-acid battery electricity "infrastructure" is used by some, the rural electrical grid is the main source of electricity supporting the rural use of cellular telephones.

This indicates a key difference between the relationship of solar electrification with rural television and radio use on the one hand, and rural cellular telephone use on the other. In the case of television and radio, future growth in rural use is likely to be closely linked to solar and battery based electrification. In contrast, rural cellular telephone use is much less dependent on solar and lead-acid batteries, as the existing grid network provides a reasonably convenient source of charging for many users.[336]

Social Uses of Cellular Telephones in Rural Kenya

Long distance rural-urban family communication appear to be the leading driver behind the demand for cellular telephones in rural Kenya, while business related uses appear to be the second most important motivation for purchasing a phone. In the 2003 survey, 61% of rural cell phone owners reported that they purchased the phone mainly to communicate with family and friends, while 39% reported that business or professional uses were their main motivation.

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[335] See Table 7 as well as footnote 93.

[336] A technical issue related to cell phone charging may contribute to the relatively large fraction of grid charging relative to solar and battery based systems. The AC electricity chargers that are used for grid charging of cellular telephones are, in general, of much higher quality that the DC chargers that are used with solar and battery systems (the DC chargers are the type that plug into an automotive cigarette lighter). The AC devices generally charge the cell phone battery completely, while many of the DC chargers often appear to give an incomplete charge. The DC chargers also fail frequently: one rural cell phone user told me that he replaced his DC cell phone charger four times over a period of six months. Several others said that the battery on their cell phone had failed because of problems associated with DC charging. These technical problems with the types of DC chargers that are commonly available to rural Kenyans may be an important limitation on the role of solar and battery electricity for supporting rural cell phone use.

Data on recent phone calls further support the conclusion that long distance family communication is the leading use of the phones. Results from the 2003 cell phone survey indicated that 81% of recent calls were long distance rural to urban calls, while the remainder were local "rural to rural" calls.[337] 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.[338]

Information presented in Chapter 3 from this same rural "cell phone" survey indicate that business related uses are also significant. This is especially true for people with certain work occupations, including service and trade related businesses as well as shopkeepers. Cell phone use in businesses appears to be especially common among businesses that depend heavily on ordering from distant suppliers (e.g. shopkeepers) or where being available to calls from customers is important (e.g. auto mechanic, veterinarian, electrician, etc.). At the same time, farm related uses were rarely reported as a key benefit of the use of the cell phones.

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[337] I asked each cell phone user for information about the most recent call that she or he made as well as the most recent call received. The data reported here are the combined results for these two sets of calls.
[338] The survey respondents indicated that they typically made and received a total of 3-4 calls per day (the median number of calls made on the previous day was 1 call, while the median received was 2; the respective averages were 1.5 calls made and 2.8 calls received). This result combined wit the data on long distance family calls cited in the text above indicates that many rural cell phone owners are communicating with urban relatives on the order of once or twice daily. While the conversations are usually quite short (72% of recent calls made and received were less than 2 minutes long) due to the high cost of cellular service in Kenya (calls within Kenya cost from $0.15 to $0.70 per minute depending on the cellular telephone company, the plan that is being used, and the time of day that the call is made), this nonetheless represents a substantial increase in intra-family communication for people who formerly often had to travel 5 km or more to reach a public telephone to make a long distance call.

These results indicate that the use of mobile telephones in rural Kenya is deeply rooted in and shaped by two important socio-economic trends. First, patterns of rural-urban migration and the desire for increased communication among family members provide a strong motivation to purchase the phones. For those who can afford them, they provide a important means to strengthen and maintain intra-family connections. Given the linkages between farm investment and urban income streams reported in the literature on agrarian change in Kenya [e.g. see Kitching, 1980; Cowen and Shenton, 1996], this increased communication is likely to have important economic dimensions. Thus, the fact that the rural elite and middle class are better positioned to gain access to cell phones may have important implications for processes of economic differentiation. However, the family communication cannot be viewed strictly in economic terms, as there are, of course, important non-economic dimensions to the these long distance family ties.

Second, as Cowen and Shenton [1996] note, the small farm economy in Kenya has generated a dynamic entrepreneurial sector in a number of regions in Kenya. These small businesses, which provide products and services within local small town economies, revolve especially around food products, transport, the distribution of consumer goods, agricultural services (e.g. veterinarians), and the like. Much of the business related use of cell phones in rural Kenya is tied to this entrepreneurial sector, while directly farm related uses of the phones appear to be less common. Thus, the differential ability of rural middle class entrepreneurs to use this newly available technology to increase their productivity is likely to deepen particular processes of economic differentiation and middle class formation.

Further research, which I intend to pursue, is needed to fully explore and analyze the relationships between mobile telephone use, rural to urban migration, and economic differentiation. Nonetheless, these preliminary findings indicate the importance of situating the proliferation of rural cellular telephones in the broader context of long term socio-economic and socio-spatial processes within Kenya that influence and shape the social use possibilities of the technology.

Conclusion

The analysis in this chapter as well as findings presented elsewhere in this dissertation establish a strong linkage between solar electrification and increasing interconnection between rural Kenyans and people, markets, and ideas in national and international urban centers. Televisions, radios, and cellular telephones are key elements of this technology mediated rural-urban connectivity, and decentralized micro-electricity technologies, including solar PV as well as lead-acid batteries and dry cells, form the backbone of the electricity "infrastructure" to power these "connective" devices in rural areas.

However, while the growing connectivity is very real, it is far from universal. Rural television and cellular telephone ownership is most common among the rural middle class. Radio ownership is much more widespread, but the wealthier segments of the population - that is, those who are able to afford a lead-acid battery, a solar PV system, or who are fortunate enough to have a grid connection - are generally in a better position to listen more often than their lower income neighbors. These distributional dimensions of technology mediated connectivity are important in shaping the social

significance not only of the connective technologies themselves, but also of the sources of electricity that enable their use.

In addition, the types of connections that can be made through the use of these technologies depend on specific sets of social, economic, and political processes. In Kenya the political economy of broadcasting has played a central role in defining the realm of possibilities for interconnection over the airwaves. For example, the VoK/KBC dominance in broadcasting up through the 2002 elections (and especially prior to 1998) limited the images and information that could be transmitted to most Kenyans - including nearly all of the rural population - mainly to those messages that were sanctioned by the ruling KANU party.

The move towards broadcast liberalization, which occurred over more than a decade through hotly contested political struggles, has shifted the dynamic towards greater participation by private broadcasters. This has resulted in some diversification relative to the previous government monopoly, but current trends indicate that a broad opening that would provide broadcast access to a wide range of voices and viewpoints is unlikely. Instead, two large media companies appear poised to dominate the Kenyan media, along with the government controlled KBC. In this new configuration corporate business advertisers are among the biggest beneficiaries, as their ability to reach wide segments of the Kenyan population through radio and TV advertising has improved markedly. Meanwhile, key reforms that could open the airwaves to a wider set of perspectives - namely reforms that would increase KBC's independence from ruling party editorial control while reducing its dependence on advertising revenues - appear to have fallen by the wayside.

Thus, the types of connections - i.e. who gets to communicate with whom - that can be made through micro-electricity supported television and radio in rural Kenya are closely linked to the political economy of broadcasting. The social significance of solar electrification, which is a crucial part of the micro-electricity infrastructure and which is especially important in the context of enabling rural television, is therefore strongly tied to the politics of broadcasting.

The results from the analysis of cellular telephones are more preliminary, but these initial observations nonetheless indicate that mobile telephone use in rural Kenya is deeply rooted in two long term socio-economic processes. First, cell phones are being used especially by the rural middle class to facilitate long distance communication with urban based family members. This links cell phone use to decades old processes of rural to urban migration. Second, business related uses of cell phones are also increasingly common, and the differential ability of certain professions - including shopkeepers as well as some rural entrepreneurs and professionals - to gain economic benefits from cell phone use may contribute to particular forms of economic differentiation and middle class formation. Thus, like television and radio, the significance of rural mobile telephones can only be understood by situating their use in relation to social processes within Kenyan society.

On the energy side of the equation, solar PV and lead-acid battery systems play a role in supporting the use of rural cell phones, but various grid based charging strategies appear to be more common. Thus, the link between solar electrification and rural mobile telephone use is somewhat less pronounced - at least to date - than the connection between solar PV and rural television.

The analysis in this chapter indicates that the technology mediated rural-urban connectivity that is facilitated by the use of solar PV and the other micro-electricity technologies is more closely linked to neo-liberal goals of economic integration than to neo-populist ideas about building small scale alternatives to global capitalism. This is especially true in the case of television and radio, where the recent shift towards broadcast liberalization has helped business advertisers - including especially multinational corporations - to expand their ability to deliver advertising messages to Kenyans in both rural and urban areas.

However, while these results challenge conceptions of household solar electric systems as "small as beautiful" appropriate technologies in the Schumacherian tradition, they should not be interpreted to mean that solar PV is a "neo-liberal technology" in a broader process of globalization. This latter framing would suggest that solar electrification is always and inevitably associated with increasing economic integration, which is an interpretation that is unsupported by evidence from Kenya as well as from solar electrification efforts elsewhere around the world.

In particular, the political struggles over broadcasting in Kenya and the associated shifts that have taken place over time in this realm indicate that the forms that technology mediated interconnection take are far from pre-given. Instead, connectivity must be viewed as a political category in which the types of connections that get made, as well as those that do not, are shaped by a combination of long term social processes as well as political struggles and everyday practices.

Thus, neither the future forms of rural-urban connectivity nor the social significance of solar electrification are fixed, but instead can be influenced by actions in a number of

arenas. Nonetheless, to paraphrase Gillian Hart, while multiple trajectories are possible, not all paths are open [2002]. In the case of solar electrification, my analysis in this chapter indicates that the social significance of the technology is closely linked to the political, economic, and social dimensions of rural-urban connectivity. As a result, attempts to shape the future directions of the use of this technology in places like Kenya should occur with a firm understanding of its relationship to processes ranging from the politics of television and radio broadcasting to long term rural to urban migration patterns.

Chapter 8: Conclusion

In Chapter 1 I demonstrated that while solar electrification is often framed as a "small is beautiful" technology for poverty alleviation and sustainable development, the environmental climate change mitigation benefits of the technology are quite modest, and mainstream policy approaches for solar market development in countries like Kenya have little in common with E.F. Schumacher's classic neo-populist vision of increasing local self-reliance and creating small scale, more egalitarian alternatives to world capitalism. Instead, my analysis indicates that developing country solar electrification is more closely associated with neo-liberal goals of achieving market-based service provision and a increasing the integration of rural people into global capitalist markets. In this sense, the mainstream of solar electrification discourse fits with Prahalad and Hart's vision of a multinational corporation led program for poverty alleviation and sustainable development through the creation of a "…more inclusive capitalism" [2002; p. 14].

These findings raise two important sets of questions, with corresponding sets of political stakes. First, how does solar electrification relate to capitalist development and processes of social change in places like Kenya? In what sense might solar PV be linked to a move towards a more "inclusive capitalism," and, if it is, who is to be included, on what terms, and to what effect? Second, what is the political significance of discursive framings that appear to draw simultaneously from neo-populist and neo-liberal lines of thinking, despite the contradictions between their visions for

development?[339] My work from Kenya provides key insights into these issues. I begin here with the first set of questions, and I return to the second set later in this concluding chapter.

Solar Electrification and the Access Question

Prahalad and Hart argue that the key to achieving a capitalism that is "inclusive" of the world's poor is closely associated with efforts by multinational corporations to market products and services to what they call the "Tier 4" market. They define this group as the 4 billion people worldwide who live in a household that has a purchasing power parity adjusted annual income of less than $1,500 per capita[340] [Prahalad and Hart, 2002, p. 2]. By this definition, a little more than half of the "solar" households in Kenya "qualify" as being among the world's poor, while the remainder live in households with earnings that exceed this amount.[341] Prahalad and Hart's definition of the "tier 4" market therefore suggests that solar PV systems do, indeed, provide electricity services to the rural poor in Kenya.

The solar market in Kenya has grown at an impressive rate over the past two decades, and it has allowed rural people in an estimated 200,000 families to improve their access to electricity. To be sure, this is no small accomplishment. However, this does not mean that this market has delivered electricity to a substantial fraction of the

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[339] In asking these questions, I draw from Mohan and Stokke, who call for greater attention to the politics of 'the local' (i.e. "…to the hegemonic production of and representation of 'the local' and the use of 'the local' in counter-hegemonic collective mobilisation…") as well as to local politics (i.e. "…local social inequities and power relations…"). At the same time, they note that it is also critical to identify and analyze interconnections between 'local' social processes and "…broader economic and political structures…" [Mohan and Stokke, 2000, p.249].

[340] The authors refer to this group as the "bottom of the (economic) pyramid" [Prahalad and Hart, 2002].

[341] According to data from the 2000 Tegemeo survey, 57% of "solar" households in Kenya fall below the ppp adjusted $1,500 per capita annual income level, while 43% are above this line.

rural poor. Such a characterization is misleading, as it treats people who fall below the $1,500 per capita income level as a relatively undifferentiated mass of poor people. As I discussed in Chapters 3 and 5, the distribution of solar system ownership in Kenya's unsubsidized market is, unsurprisingly, skewed strongly towards the wealthier segment of the rural population. Most solar systems are owned by households that can be described as belonging to the rural upper or middle classes,[342] and electricity access options for the majority of rural Kenyans remain sharply limited. Thus, while most solar system owners in rural Kenya may not be wealthy by international standards, they are considerably better off than the large majority of their rural neighbors. These distinctions are important not because the rural middle class in Kenya is undeserving of electrical service or support (on the contrary), but because the distribution of electricity access has important implications for the equity dimensions of policy choices as well as the development significance of solar electrification. Before turning to a discussion of the relationship between solar PV and processes of rural development, however, there are two additional dimensions of the access question that require further consideration. First, within the household allocation dynamics play a central role in determining how and by whom the electricity is used. Second, interactions between solar PV and the grid are centrally important for understanding the significance of market-based solar electrification for rural electricity access.

Solar Electricity Access and Intra-household Allocation

I started this dissertation with two contrasting accounts of solar system use in the Murungi and Kariuki households. In the Murungi home much of the electricity was

[342] See chapter three for definition of the rural middle class.

used for television and radio, and the father complained that there was never enough energy left over for lighting. The Kariuki's experience with solar PV was quite different. While they also used the system for TV and radio - not to mention cellular telephone charging - their system produced sufficient energy for a number of lighting related uses as well. The children in the Kariuki home studied by solar light on practically every school night, and their mother, a school teacher, used the light regularly to grade papers and plan lessons. In addition, they used solar lighting regularly to facilitate housework, entertain guests, and to generally make it easier and more pleasant to do everyday tasks in the evening and early morning hours.

The differences between the social uses of solar energy in the Murungi and Kariuki homes can be attributed in part to differences in wealth between the families, as well as differences in the technical capacity of the respective systems. The larger and more expensive 50 Watt solar system at the wealthier Kariuki home produces more than twice as much energy as the 20 Watt Murungi system, and, with more energy to go around, the allocation conflicts between competing uses such as television viewing and lighting are fewer. However, system size alone cannot account for all of the differences, such as the divergent dynamics around television viewing, solar lighting, and evening time study habits. In addition to wealth and system size, personal priorities, family relationships, and the household dynamics of energy allocation also all play central roles in creating the diverging social use patterns. This highlights the need to go "inside the household" in order to understand the spectrum of development possibilities associated with solar electrification in Kenya.

My work in Chapter 6 shows clearly that, while there are important variations in allocation patterns from one home to another, in many "solar" households key social uses - including lighting in the kitchen and evening time studying by children - are marginalized in the context of household energy allocation dynamics. This marginalization is especially common in the most affordable solar systems (< 25 Watts), as the majority of the energy from these small systems is often allocated to television viewing. Social use patterns cannot, of course, be reduced to system size alone, as gender and elder-junior relationships within households play important roles in both smaller and larger systems. Nonetheless, the linkage between system size and energy allocation connects issues of household wealth with social use possibilities, as wealthier families are in a much better position to own a larger system.

From the perspective of policy makers who are reluctant or unable to allocate significantly greater levels of subsidy support for solar electrification, this indicates a key tension between promoting access for lower income households, on the one hand, and supporting the dissemination of the "larger" solar systems (e.g. 40 Watts) that appear more likely to allow for the widespread use of solar electricity for social uses such as evening time studying by children, on the other.

Importantly, the main programs aimed at expanding developing country solar markets - many of which are funded by the GEF and the World Bank - are unlikely to produce any significant deepening of access relative to the current ownership pattern in Kenya. As I explain in Chapter 5, consumer finance based programs such as the GEF sponsored and World Bank implemented PVMTI project may, if successful, help rural middle class families to purchase a larger system than they could otherwise afford. This

could result in increased solar sales, but in the absence of significant subsidies these consumer finance approaches are unlikely to deepen ownership levels beyond the current status quo established through cash sales in Kenya anytime soon.

However, the modular cash sales approach, while modestly successful in terms of making solar PV affordable beyond the rural middle class, is no panacea. This dissemination approach relies on the sales of the smallest (e.g. 14 Watt) systems to deepen access. These small systems provide only tiny amounts of electricity, and it is in this context that the marginalization of key social uses of the electricity is the most likely.[343] Thus, in the absence of significant subsidies, including both "soft" subsidies for building institutional capacity as well as "hard" subsidies on the cost of equipment, solar electricity from high quality systems is likely to remain beyond the reach of the large majority of rural poor in countries like Kenya for a long time to come.[344]

Some have argued that such subsidies are not warranted, as financial resources for development are limited and other priorities are more pressing than solar electrification [e.g. Covell and Hansen, 1995; Karekezi and Kithyoma, 2002; Morgenstern, 2002]. This is certainly a valid point, as education, health, job creation, water, sanitation, and a host of other concerns remain widely under-funded. Nonetheless, subsidies for rural electricity - including possibly solar PV - should not necessarily be taken off the table. Instead, if poverty alleviation is to be taken seriously, there is a broad need for

[343] Quality and performance problems with solar systems sold through the modular cash sales approach are also an important concern.
[344] I will explore key socio-economic and political dimensions of rural electrification subsidies in a future article.

increased development funding on a number of fronts, including substantial redistributive wealth transfers.

Such an increase in funding is, of course, unlikely in the absence of compelling political pressure. Ongoing efforts to increase redistributive funding for a variety of programs can play a small role in this larger project. In this context, one key issue at stake is whether services such as electricity (as well as water, health, and others) should be treated as entitlements that should be delivered - to the degree practical - to all in society, or whether they are commodities that are to be available only to those who can afford to buy them in unsubsidized markets. Understanding the connection between solar PV and this "entitlement versus commodity" question requires an examination of the relationship between solar and grid based electrification.

Solar Markets and Grid Based Rural Electrification

Market-based solar electrification emerged as an important alternative to grid based rural electrification at a time when the electricity sectors in many developing countries were undergoing processes of privatization and restructuring. These reform programs, many of which were initiated in response to financial difficulties and World Bank conditionality, have often involved sharp cutbacks in cross subsidies, rural electrification programs, and other redistributive measures associated with the goal of achieving universal electricity access [Dubash, 2003; Karekezi, et al., 2004; Williams and Dubash, 2004]. In this context, market-based solar electrification, because it is generally much less expensive on a per household basis than rural grid electrification, offers policy makers the possibility of unsubsidized rural electrification for at least a portion of the unelectrified population in countries like Kenya. Thus, the current trend

in mainstream policy towards market-based solar electrification under full cost recovery business models can be understood as a component of a broader shift towards treating electricity less like an entitlement and more like a commodity that is available only to those who can afford it.

The immediate practical effect of this shift varies from country to country, but several lessons are readily apparent. In Kenya, grid based electrification for rural households has moved at a snail's pace. This is due in part to scarce financial resources as well as justifiable policy decisions that have prioritized electrical service for small towns, market centers, and rural enterprises over households. Nonetheless, corruption and inefficiency have also contributed to the slow pace.[345] In the wake of the restructuring of Kenya's electricity sector in the late 1990s, the pace of rural electrification has - perhaps unsurprisingly - slowed still further [Karekezi, et al., 2004], but few rural people had much hope of receiving service anytime soon with or without the reforms.

Thus, one possible interpretation of unsubsidized, market-based solar electrification in Kenya is that it provides at least the possibility of delivering small amounts of electric service to those who can afford it, without doing any obvious harm to those who cannot (since they were unlikely to have been in a position to get electric service in any case) [e.g. van der Plas and Hankins, 1998]. By contrast, in South Africa, where universal grid electrification is viewed by many people as a right won through years of anti-apartheid struggle as well as a real possibility, solar PV systems are often seen as a poor substitute for the "real thing" [Duke and Anderson, 2001; Annecke, 2002].

[345] See chapter four for further discussion.

However, while solar electrification may be viewed in a more positive light by rural Kenyans than by many rural South Africans, the move towards unsubsidized electrification - whether with solar PV or other technologies - represents a problematic trend in terms of equity and access for low income people over the long term in both countries (as well as elsewhere). As noted above, the key issue at stake is whether services like electricity are to be treated in principle as an entitlement, or whether they are commodities like any other to be purchased only by those who can afford it. Here the question is not one of technology choice or even whether market or centrally planned distribution is to be used. Rather, the issue is related to equity and the distributional dimensions of public policy choices.

The practical effect of the sharp reduction in support for grid based rural electrification in many countries, in combination with the move towards market-based solar electrification with full cost recovery, is that access to rural electricity - i.e. "inclusion" - is defined increasingly in terms of purchasing power alone. This trend has problematic implications for distributional equity as well as access for low income groups. In the end, re-distributive subsidies remain critical if the poor are to gain access to high quality electricity services in the coming decades. There are, of course, substantial challenges associated with making subsidies work effectively to deliver services to low income segments of society [e.g. see Barnes and Halpern, 2000]. Nonetheless, these challenges should not be used as a reason to opt for no subsidies at all, as leaving access to market forces alone always puts low income families at a steep disadvantage.

Questions of equity and access are important dimensions of solar electrification policy, and the corresponding distributions of access play an important role in shaping the social significance of the technology. However, the implications of solar PV go well beyond the access question alone. In the next section I draw from my work in this dissertation to discuss the relationship between solar electrification and broader processes of rural development in Kenya.

Solar Electrification and Rural Development

Solar electrification in Kenya is deeply rooted in long term processes of rural development and social change. My analysis in Chapter 3 indicates that the emergence of solar electrification in Kenya is closely tied to a particular history of capitalist development in the country. That is, solar sales are driven largely by rural middle class purchasing power, which is in turn the result of a particular history of middle class formation based on land redistribution, small holder cash cropping, a thriving small business service economy, and education policies that have resulted in large numbers of rural school teachers.

In addition to the development of the rural middle class, several other processes and factors were instrumental in creating the conditions for solar market growth. In Chapter 4, I use an historical-conjunctural analysis to discuss five additional key processes, including: (1) declining solar equipment prices, (2) the slow pace of grid based household rural electrification, (3) relatively close connections between Kenya and "the West", (4) the distribution of solar equipment through pre-existing supply chains, and (5) government investments in the expansion of TV broadcasting to rural areas.

My analysis in Chapter 4 goes beyond many conventional framings of solar market development, which often emphasize the role of entrepreneurial initiative, economics, and market institutional development. While these elements are important, I demonstrate the additional key - if indirect - role that the Kenyan Government played in setting the stage for solar market growth. Important government contributions have included re-distributive land reform and education policies that have resulted in large numbers of rural school teachers, both of which were key elements of the subsequent development of the rural middle class. In addition, government investments in the expansion of TV broadcasting to rural areas was a necessary condition for market growth, as television has been a central driver for demand for solar PV. At the same time, the Kenyan Government has been notable by its absence, as quality problems in the market are due in part to a lack of effective regulation by the state. These findings highlight the key role of government action in creating the conditions for solar market development, even as they also indicate the important linkages and interconnections that exist between long term historical processes and the use of solar PV. This work has important implications for efforts to transfer lessons from the Kenya solar electrification experience to other contexts, as the combination of conditions that enabled solar market development in Kenya are far from universal.

Returning to the relationship between solar electrification and rural development, my work shows that while rural middle class incomes provide the purchasing power behind solar sales in Kenya, the income and work related uses of the technology are, to date, relatively modest. This finding, in combination with a broader analysis of the social use of household solar electricity (which is dominated by TV viewing in many

homes), indicates 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 combination with lead-acid batteries and dry cells - in supporting the use of television and radio in rural Kenya facilitates the ability of business advertisers to reach a wider audience. The link between rural television use and solar PV, which is barely acknowledged in much of the literature,[346] is centrally important. Substantial evidence supports the conclusion that television is the main driver for demand in the Kenya solar home systems 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 marginalized in some homes, in many "solar" households 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 the process of rural to urban migration. As I discuss in Chapter 3, investments in education have long been viewed

[346] Key exceptions include Acker and Kammen [1996], Hankins [1997b; 2000a; 2004], and Hammami, et al., [1998].

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, the children of rural middle class families are generally in the best position of any to do so. Solar lighting, to the degree that it is used to facilitate studying, can play an important role in supporting children's studies. Given that most solar systems - and nearly all of the larger (> 25 Watts) 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. As I note in Chapter 7, 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 electrification may contribute in a small way to the deepening of middle class formation in rural Kenya.[347]

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[347] It is important not to overstate solar PV's role in these processes, as it is only one of several electricity sources that is used to support the various activities. Solar PV does play a key role - along with the electrical grid - in supporting rural electric lighting and the associated uses. For rural television, solar PV and lead-acid battery systems combine to provide the main base of support. Given the close relationship between battery and solar PV use, it makes sense to view them as two parts of a single, decentralized electricity "infrastructure." In the case of cellular telephones, however, the rural grid appears be a much more important source of electricity than solar, while dry cells are the most important power source for rural radio. Nonetheless, while solar electricity is only one of several electricity sources, it is an increasingly important element of the rural electricity "infrastructure" in Kenya.

Notably, all three of the preceding relationships between solar electrification and development involve a socio-spatial rural-urban dynamic. This highlights the importance of looking beyond the household as a unit of analysis when studying the social significance of rural technologies such as solar PV. The multiple arenas approach that I use in this dissertation is a powerful tool for situating locally based processes - in this case the social use of solar electricity - into the broader context of development and social change. In my current research, this methodological framework quickly and decisively eliminates any notion of technological determinism or other forms of simple causality. Thus, the social implications of even a technology with solar PV's "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.

The multiple arenas framework is particularly valuable because of its explicit inclusion of both historical and socio-spatial analysis. Importantly, this approach facilitates an integrated analysis that includes simultaneous attention to processes at the "local level" (e.g. intra-household dynamics; long term processes of agrarian change), as well as processes in geographically distant arenas that nevertheless influence the possibilities for the use of the technology (e.g. broadcast media politics; policy debates about energy and infrastructure development; solar market dynamics; etc.).

Although the relationship between solar electrification and broader processes of rural development and social change is always crucially shaped by national and local dynamics, evidence from elsewhere suggests that the social significance of solar PV in Kenya is far from unique. For example, studies from China, Thailand, Sri Lanka,

Tunisia, Zimbabwe, and elsewhere indicate that the use of solar PV to power television sets is common in many countries [Hankins, 1993; Hammami, 1998; Nieuwenhout, 2000; Greacen, 2004; Kapadia, 2004b]. This strongly suggests that the linkage between solar electrification and the expansion of consumer goods markets may be present not only in Kenya, but in many places where solar PV is used for household electricity.[348] Moreover, although solar advocates at the World Bank and elsewhere have worked hard to encourage the use of solar PV for economically productive applications [e.g. see Kapadia, 2004a], with the possible exception of rural school teachers and the emerging use of cellular telephones, there is little evidence of any widespread trend towards substantial income generation or work related uses of the electricity [e.g. see Nieuwenhout, 2000]. This does not indicate that solar electrification is necessarily unimportant from a productivity standpoint, but it does support the idea that in many cases solar systems are purchased more as a consumer good than as a productive investment.

The role of solar electricity in supporting activities related to education in rural areas may be the main exception to this trend, as children's education - to the degree that it eventually leads to better employment opportunities - can be linked to economic productivity over the long term. Here, several studies indicate a potentially important connection between solar electrification and education [e.g. Gustavsson and Ellegård, 2004; Wamukonya and Davis, 2001; Schweitzer, et al., 1995], but in all of the cases cited (Zambia, Namibia, and Nepal, respectively) the systems were subsidized to some

[348] This linkage is also, of course, a component of grid electrification. However, a grid connection provides sufficient power - at least in principle - for many more additional uses beyond television and radio, whereas with solar power only a few other applications are possible.

degree and, as a result, they were larger (35-50 Watts) than the majority of the systems sold in the unsubsidized Kenya market. Given the potential linkage between larger system size and children's access to solar electricity for studying, this further supports my claim that significant subsidies are needed to support the widespread use of solar PV for key social uses such as evening time studying by children. Thus, while detailed studies from other countries that seek to situate solar electrification in the broader context of rural development will help to clarify and extend many of the findings that I present here, the information that is currently available in the literature indicates a number of commonalities between Kenya and the other cases.

Returning to the question at the beginning of this chapter about the relationship between solar electrification and the development of a more "inclusive" capitalism, my findings from Kenya and similar use patterns from elsewhere suggest that one of the main dimensions of this "inclusion" is in the realm of greater integration into international consumer goods markets. Meanwhile, solar PV's links to productive activities are more tenuous, especially in the case of the more affordable systems (< 25 Watts) that are common in unsubsidized cash-based solar markets like Kenya. In other words, while solar PV systems may provide power for TV sets that allow business advertisers to encourage the purchase of consumer goods, they appear to play a smaller role in supporting activities related to generating the income required to participate in those markets.[349]

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[349] While larger solar systems may help create more possibilities for certain social uses (e.g. kitchen lighting and education related applications), there is no guarantee that increased system size would necessarily result in proportionately greater levels of economic productivity. As many studies have indicated, the relationship between electricity and rural productivity is complex, with a number of processes and factors influencing the degree to which electricity is used to increase productivity [e.g. Barnes, et al., 2002; Kapadia, 2004a]. Further research is needed on this topic, and the multiple arenas

The Ghost of Schumacher in an Era of Market Triumphalism

Solar PV is, in many respects, a remarkable technology. It generates electricity directly from the sun without producing any pollution[350] or noise. In addition, for applications with small to medium sized power requirements, solar PV systems can be installed near the place where electricity is needed, thereby avoiding the need to run power lines to the site. The technology can be used for a wide variety of applications, ranging from emissions free grid-connected electricity generation (increasingly common in Europe, Japan, and the United States) to powering vaccine refrigeration at remote health clinics in developing countries to the small household solar PV systems that I discuss in this dissertation. Given the pressing realities of global climate change as well as the eventual limits of fossil fuel resources, solar PV as well as a host of other renewable energy and energy efficiency technologies are undoubtedly a critical element of an environmentally sustainable future.

Nonetheless, neither the environmental benefits nor the decentralized, small scale characteristics of solar PV technology provide any guarantees about the social outcomes that can be expected from its use. Instead, like any technology, the social significance of solar PV is shaped by a number of processes and factors, including socio-economic, socio-political, and socio-cultural dynamics in the local contexts where the technology is used, as well as forces from afar that stretch across space to influence the possibilities

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framework that I use in this dissertation provides an important tool for this work. The multiple arenas approach will also prove useful for analyzing the social significance of the emerging use of other key technologies, such as the rural use of cellular telephones and the internet.

[350] There is, of course, some pollution associated with the manufacture of solar electric equipment. There are also important environmental concerns associated with the disposal lead-acid batteries that are widely used in off-grid solar PV systems. Nonetheless, the environmental issues associated with solar electric systems are far smaller than the concerns associated with fossil fuel based energy systems. See Fthenakis and Moskowitz [2000] for further discussion.

for its use. Thus, as I have argued at length, understanding the social significance of solar electrification requires situating the use of the technology in the broader setting of development and process of social change.

Over the past two decades, household solar electrification has emerged to become one of the main alternatives to grid based rural electrification in Kenya as well as a number of other developing countries. During this period, international support for the technology has grown, with the GEF and the World Bank together having leveraged over $2 billion for solar electrification in developing countries [International Resources Group, 2003]. In this dissertation I argue that the increasing level of support for solar PV can be understood as a confluence between environmental concerns about climate change, neo-populist views about poverty alleviation and rural development, and neo-liberal market-oriented strategies for rural service provision. In this configuration, environmental and neo-populist arguments are used to justify international donor aid support for solar electrification, while dissemination strategies are increasingly implemented using neo-liberal market-based approaches.

The confluence between "small is beautiful" neo-populism and market-oriented neo-liberalism suggests a complex picture of two distinct but sometimes overlapping discourses surrounding the development dimensions of rural electrification with solar PV. Solar electrification is perhaps most commonly associated with the "small is beautiful" neo-populist perspective, which emphasizes decentralized development as a means of building small-scale, more egalitarian alternatives to world capitalism. This contrasts with the neo-liberal perspective on solar PV, where economic efficiency is

valued over equity and where economic integration and the expansion of global capitalism are the central goals.

The largest and most influential developing country solar electrification programs are funded by the GEF and the World Bank, where the neo-liberal perspective is decidedly dominant. It should come as no surprise, then, that neo-liberal concerns about economic efficiency and market-based approaches are central elements of international solar electrification policy and implementation efforts. The linkages between solar electrification and classic neo-populist ideas are considerably more tenuous. While neo-populist style *claims* about the significance of solar electrification for poverty alleviation, small-scale development, and rural productivity through small-scale production abound in the discourse, the classic neo-populist concerns about equity and building small-scale alternatives to large-scale capitalism are less present in the actual policies and implementation efforts.

The disconnect between the neo-populist style framing of solar electrification and the policy approaches used to disseminate the technology can be linked to a political ambivalence that has long been an element of populism. Peet and Watts note that "…a distinctive feature of populism - which perhaps explains its current appeal - is its flexible ability to draw on liberalism, nationalism, and socialism in fashioning its pragmatic, rather than political, agenda…" [1993, p. 237]. Here the argument is not that particular theorists, e.g. E.F. Schumacher, Julius Nyerere, or Michael Lipton, did not have strong political convictions. Rather, it is that there is no inherent political affiliation associated with small scale approaches that invoke the importance of putting "ordinary people" at the center of development. As a result, elements of populism can

be found in a variety of discourses, often with diverging social and political goals [Laclau, 1977; Kitching, 1989; Peet and Watts, 1993; Mohan and Stokke, 2000].

The danger in the case of solar PV is that the chameleon-like appeal of neo-populist “small is beautiful” style discursive framings of the technology have effectively reduced the level of critical attention given to the social and political dimensions of the market-oriented approaches that currently dominate mainstream solar electrification policy. The prevalence of market-oriented policies does not, of course, indicate that solar PV is merely a "neo-liberal technology" in the broader process of "globalization", as the social significance of a technology cannot be controlled by any one agenda or group. Rather, it indicates that it is not enough to simply push for the deployment of renewable energy technologies - including solar PV - as there are a number of key policy choices, often with diverging implications, that influence the equity dimensions of access as well as the social use possibilities of the technologies.

My findings from Kenya challenge the idea that socially equitable climate change solutions are primarily a matter of picking the right technologies (i.e. switching from fossil fuels to renewable energy), then using market channels to disseminate them. Implicit in this line of thinking is the technologically determinist idea that equitable social outcomes can be read from technology choice. In other words, some advocates seem to suggest that solar PV's reputation as a "small is beautiful" technology mean that its use will necessarily go hand in hand with progressive social outcomes. This framing serves to marginalize social justice issues, as it suggests that socially just "sustainable development" is a matter of using the "right" environmental technologies in the context of status quo social arrangements.

My work in Kenya indicates that while solar electrification *can* be associated with some of the social uses claimed by its advocates, including especially education related uses by children, these outcomes are far from guaranteed. Rather, the social implications of solar electrification are determined through social actions in multiple, overlapping arenas, including processes ranging from rural development and middle class formation over a number of decades to everyday intra-household dynamics of energy allocation to national level broadcast media politics, as well as socio-technical factors, public policy choices, and market prices. This highlights the need to avoid framing "sustainable development" and associated climate change mitigation policies in terms of technology choice alone. If concerns about social equity and poverty alleviation are to remain a central element of efforts to achieve sustainable development, it is critical to avoid looking primarily to technology and markets to address issues that are strongly shaped by social and political processes.

Appendix A:
Common Components Used in Household Solar Systems in Kenya

Solar Modules[351]

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,[352] 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[353] 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.[354] See Figure A1 for images of mono-crystalline and amorphous silicon solar modules.

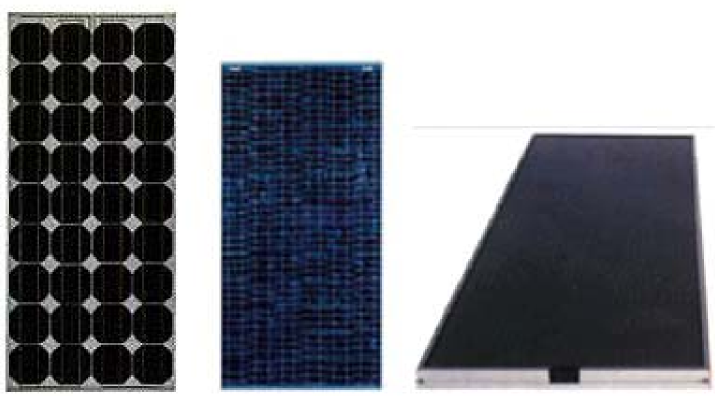

Figure A1: **Monocrystalline, Polycrystalline, and Amorphous Silicon Solar Modules**. The mono-crystalline and polycrystalline images are for modules that are rated at approximately 60 watts, while the amorphous silicon module is rated at 12 watts (images are not to scale).

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[351] See Jacobson, 2002c for further discussion of the different types of solar modules used in Kenya.

[352] 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 Laboratories, 1991].

[353] 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.

[354] 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].

Lead-Acid Batteries[355]

There are four main types of lead-acid storage batteries used in Kenya. These are (1) automotive starter batteries, (2) "solar" batteries, (3) "true deep cycle" batteries, and (4) sealed lead acid batteries. The first three types are all "wet cell" batteries, which means that their acid electrolyte is a liquid. The fourth type, the sealed batteries, have a gel type acid electrolyte that will not spill if the battery is tipped over. These are sometimes called "gel-cell" batteries. See Table A1 for a brief summary of these four types of lead acid batteries.

Table A1: Common Lead Acid Battery Types

Battery Type	Typical Lifetime for Solar Use	Recommended Maximum Depth of Discharge	Notes
Automotive starter	Short (about 1 year)	20%	NOT for solar uses
Solar battery	Medium (2 to 3 years)	50%	Best for small solar PV systems
True deep cycle	Long (4 to 6 years)	80%	Best for larger solar PV systems
Sealed	Medium (2 to 3 years)	40%	Best for lanterns and other movable PV systems

Although they are often used in household solar and battery systems, the automotive starter type batteries are poorly designed for these applications. The lead plates that are used in these "starter" batteries are very thin in order to deliver lots of quick power (amps) when starting an engine. While this is appropriate for vehicle applications, this design does not work well in solar and battery systems where slow charging and slow, deep discharging are normal. As a result of their thin plate design, "starter" batteries that are used in household solar and battery systems generally have a relatively short operating lifetime.

Several Kenyan companies manufacture lead-acid batteries that are similar to automotive starter batteries, but which have several design modifications - including thicker lead plates - that make them more appropriate for household applications. These batteries are often marketed as "solar" batteries in Kenya.

However, while "solar" batteries perform better than automotive starter batteries in household applications, they are not as good as the "true deep cycle" batteries that are often used in industrialized countries for solar systems and similar applications. True deep cycle batteries include "tubular plate" type batteries and "flat plate" batteries that have very thick plates. These are the type of battery that lasts the longest in solar uses, but they are also expensive and they are often not available in small sizes (they generally are 100 amp-hours or larger) so they usually cannot be used with small solar PV systems. True deep cycle batteries are sometimes used in Kenya for large

[355] See Jacobson, 2002d for further discussion of lead-acid batteries used in Kenya.

commercial or donor financed solar systems (e.g. solar systems > 100 Watts), but they are rare in household solar systems.

Finally, a fourth type of battery that is sometimes used in solar systems is the "sealed" lead acid battery. These batteries are *not* true deep cycle batteries, and they generally last about as long as the "solar" batteries for solar applications. However, they are more expensive than "solar" batteries, and they are considerably less common in Kenya. The main advantage of the sealed batteries is that the acid inside them will not spill out, so they are good for use in solar lanterns or other uses where the battery is moved frequently.

Appendix B: Survey Data and Methods

Table B1: **Summary Information on Primary Data Sets** (see below for additional notes on data sets)

Data Set	When Collected	Who Collected	Where Collected	Sample Size	Selection Method	Data Collection Methods
1) Tegemeo Rural Household Survey	2000	Tegemeo Project	24 districts (national)	1,512	Stratified random sample of rural households	Household Survey
2) Kamfor Household Energy Survey	2001	Kamfor, Ltd.	15 districts (national)	1,755	Stratified random sample of rural households	Household Survey
3) Solar Technician Survey	2000/01	Original	48 towns (national)	366	Snowball sample of solar technicians in randomly selected towns	Technician Survey
4) Solar Equipment Vendor Survey	2000/01	Original	45 towns (national)	312	Visited all solar vendors in randomly selected towns	Vendor Survey
5) Solar Household Survey	2003	Original	3 districts	76	Snowball sample of solar households	Household Survey
6) Energy Allocation and Appliance Use in "Solar" Households	2003/04	Original	Households in Nyeri and Nakuru Districts	15	Sub-sample of solar households from 2003 survey; selected based on system size and consent	Electronic Data Monitoring & Ethnographic Observation
7) Rural Cellular Telephone Users	2003	Original	4 districts	79	Snowball sample of rural cell phone users	Cell Phone User Survey
8) Newspaper Advertisements by Solar Companies	2002/03	Original	Daily Nation newspaper	391 ads	Clipped all ads for solar products from May 6, 2002 to December 31, 2003	Content analysis of solar ads
9) Television Advertisements During Prime Time	2003	Original	KBC & Nation TV	206 ads	Recorded TV broadcasts from 7 pm to 9 pm on 13 randomly selected days	Identified brand & parent company for each ad

Data Set Notes:

1) **Tegemeo Household Survey** (2000): This survey was conducted by the Tegemeo Project, which is a joint program of Egerton University (Kenya) and Michigan State University (USA). See Appendix C for further information about this data set.

2) **Kamfor Household Energy Survey** (2001): This survey was conducted by Kamfor, Ltd., a Kenya based consulting firm, under a contract with the Kenyan Ministry of Energy. This full sample size for this survey was 2,270 households (1,755 rural and 515 urban). I used information from the rural portion of the survey in this dissertation. The rural households were located in 15 randomly selected districts (Busia, Kajiado, Kakamega, Kiambu, Kilifi, Kisii, Kisumu, Kitui, Kwale, Laikipia, Meru, Nakuru, Nyeri, Taita Taveta, Uasin Gishu). The urban households were located in the five cities of Nairobi, Mombasa, Eldoret, Nakuru and Kisumu. All of the households were selected randomly based on lists of households from the 1999 Kenyan census. See Kamfor, 2002 for additional information on this data set.

   Differences between the Tegemeo and Kamfor data sets: Although both were collected through stratified random sampling designs, there are importance differences between the two data sets. One major difference in the sample designs involves the definition of "rural" that is used in each case. In the Kamfor survey all households outside of the major urban centers (i.e. Nairobi, Mombasa, Kisumu, Eldoret, and Nakuru) were counted as "rural." This means that in some cases households in towns with populations over 100,000 were counted as being "rural." In contrast, in the Tegemeo survey the population of "rural" households was defined as only those lying outside of town boundaries. In practice, this means that as many as 25% of the households in the Kamfor survey may fall outside of the definition of "rural" that was used in the Tegemeo survey.

   There are also differences in the content of the data collected. The Tegemeo survey is part of an program directed by academic researchers to analyze economic and policy dimensions of Kenyan agriculture and rural development. As such, the data set includes high quality information about agricultural production, use of farm inputs, farm and non-farm sources of income, household assets, along with other information. The Kamfor study was conducted by a private consulting firm as part of a Kenyan Government study of energy use patterns in Kenya. This data set includes considerable detail about energy use patterns in households, but much less economic data on the households than the Tegemeo study.

3) **Solar Technician Survey**: This original survey was carried out in 2000 and 2001 under the direction of the author. Maina Mumbi and Henry Watitwa conducted the majority of the survey interviews. Shannon Graham provided crucial assistance in the design survey as well as in the implementation of the effort. See Appendix D for additional information. Results from this work were published in Jacobson, 2002.

4) **Solar Equipment Vendor Survey**: Like the solar technician survey, this work was carried out in 2000 and 2001 with critical participation from Maina Mumbi, Henry Watitwa, and Shannon Graham. See Appendix D for further information.]

5) **Solar Household Survey**: The solar household survey involved detailed survey interviews with 76 "solar" households in three districts (Nyeri District in the Central Province, Nakuru District in the Rift Valley Province, and Bungoma District in the Western Province) during 2003. The survey interviews were carried out by the author, Maina Mumbi, and Henry Watitwa. Rebecca Ghanadan played a central role in designing and field testing the survey and in 2002.

   The participating households were selected through a "snowball" sampling approach. Initial contacts with "solar" households in each region were made through solar technicians (i.e. electricians who install systems). After respondents in household were interviewed, we asked them for introductions to other households with solar systems in the area.

   Although a random sample of solar households would have been preferable, it was not practical to generate such a sample given the budget and time constraints of the project.[356] Nonetheless, the resulting sample from the "snowball" approach resulted in a set of households that shared a number of similarities with the 63 households in the 2000 Tegemeo project survey that owned a solar system[357] (see Table B2). The households in the Tegemeo survey were selected through a stratified random design, so the 63 households that had a solar PV system represent a random sample of "solar" households in Kenya.

   The data in Table B2 indicate that the distribution of solar system sizes in my 2003 survey was similar to the distribution from the 2000 Tegemeo survey. The data on appliance ownership are insufficient to make a definitive comparison, although the television ownership levels are strong in both cases. However, the appliance ownership patterns for TV, lights, and radios in the 2003 survey are similar to the results of a 1997 survey of 410 solar systems. The 1997 survey indicated that 89% of solar households had a television, 84% had at least one light, and 75% had a radio that was powered by solar [Hankins, et al., 1997].

[356] There is no census of "solar households" in Kenya from which to generate a random sample. Other methods of randomization exist, but require significantly more field time to select households than the snowball method used in the study. The snowball method is also practical from the standpoint of gaining consent to conduct the interviews. In my experience, rural household members are much more willing to participate in an interview if the initial introduction is made through the solar technician who installed their system or by a trusted neighbor.

[357] Note that while I had access to the data from the Tegemeo household survey, the identities of the households remained anonymous to me. It was therefore not possible to interview the "solar" households from the Tegemeo survey for the purposes of my 2003 survey.

Table B2: Comparison of "Solar" Households in the Author's 2003 Survey and the 2000 Tegemeo Survey

Data Set Characteristic	2003 "solar" household survey (n = 76)	"solar" households in Tegemeo survey (n = 63)
Solar System Size		
Average System Size	27 Watts	25 Watts[358]
Median System Size	20 Watts	18 Watts
Systems < 25 Watts (%)	68%	70%
Appliance Ownership		
Television Set	95%	86%
Electric Light (at least 1)	83%	No information[359]
Radio (powered by solar)	84%	No information[360]
Cellular Telephone	50%[361]	0%[362]
Main Source of Income (1st)		
Farming or Livestock	30%	49%
Professional Salary	45%	37%
Business Earnings	18%	14%
Other[363]	7%	0%
Income Sources (additional information)		
Salary or Business Earnings as 1st or 2nd most important income source	77%	80%
Teacher in Household	34%	30%

A comparison of income sources for the two data sets indicates that households where farming or livestock earnings are the largest source of income appear to be somewhat under-represented in the 2003 sample, while those where salary or business earnings were the largest source were slightly over-represented.[364]

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[358] The data for the average and median solar system size for the Tegemeo "solar" households is an estimate based on the reported monetary value of the solar modules owned by the household.

[359] Information about lighting is not included in the Tegemeo survey. However, data from a 1997 survey of 410 "solar" households in Kenya indicated that 84% had at least one light. See Hankins, et al., 1997.

[360] 94% of the solar households owned a radio, but it is not possible from the data in the Tegemeo set to determine how many of these households used solar electricity (as opposed to dry cell batteries) to power their radios.

[361] 39% of the household reported that they charge their mobile phone regularly with solar electricity, while 11% used other sources (e.g. grid electricity in a workplace) to charge the phones.

[362] Cellular telephone signals were not available in rural areas of Kenya prior to 2001.

[363] Several households in the 2003 survey indicated that remittances or non-farm day labor were their main sources of income.

[364] These patterns are likely due to the fact that on of the three main field sites for the surveys was located near the town of Maai Mahiu in the Nakuru District. Maai Mahiu is a small "truck stop town" on one of the main routes between Nairobi and Nakuru, and many households in the area depend on small business

However, the distribution of households were salary or business earnings were either the 1st or 2nd most important source of income was very similar for the two data sets, as was the fraction where a school teacher was a member of the household. These results indicate a number of important similarities as well as some modest differences between the households in the 2003 survey and the random sample of "solar" households in the 2000 Tegemeo survey.

6) **Energy Allocation and Appliance Use in "Solar" Households**: This portion of my research involved a detailed electricity allocation study in 15 "solar" households in rural Kenya. Maina Mumbi played a central role in implementing this study. His contributions included directing the installation of many of the data monitoring systems, making electronic components (e.g. voltage divider circuits), collecting data from the homes, compiling the data files onto a computer, and - for the periods that I was out of Kenya - sending the files to me via email. Others that provided critical assistance include Scott Rommel (designed and built current switch circuits), Peter Ndegwa Thuo (system wiring and data collection in Nyeri District), Paul Philip Chaura (system wiring in Nyeri District), and Christopher Ongeri Adundo (system wiring in Nakuru District).

Seven of the households in the study were located in a tea growing area in the Nyeri District, and eight were located near a small road-side town in a semi-arid in the Nakuru District. The households in this study are a subset of those interviewed in the 2003 solar household survey (#5, above). Each of the participating families agreed to take part in the study following detailed conversations with adult members of the respective households in which I explained the nature and goals of the study. In selecting the households I sought to include a range of small and large systems. See Table B3 for summary information about the households included in the study.

The average system size for the 15 households included in the study was 22 Watts, the median system was 20 Watts, and 73% of the systems were smaller than 25 Watts. These summary statistics indicate that the distribution of system sizes in this study is roughly similar to the distribution in the larger 2003 survey and the 2000 Tegemeo survey. The appliance ownership patterns are also roughly similar. All of the 15 households had a television, 87% had a radio that they powered with solar electricity, 80% had at least one light, and 40% had a cellular telephone. Most of the households appeared to fall within the "rural middle class" category in terms of their wealth, and 80% reported a professional salary or business earnings as their 1st or 2nd main source of income (see Chapter 3 for a discussion of the "rural middle class" in Kenya). The data in Table B3 indicate that households that rely on a professional salary were somewhat over-represented, while households that rely on farming as their 1st source of income were under-represented. The primary income source

earnings related to road traffic. In addition, there are several boarding schools in the town, and a number of school teachers own solar systems. Relatively few families in the Maai Mahiu area depend on farming as a source of income.

reported by 67% of households was a professional salary, while 27% reported farming income, and 7% reported business earnings.

In each of the participating households I used electronic data monitoring to record appliance use patterns over a number of months.[365] The battery voltage for each system was also recorded. The quantitative energy allocation results presented in this dissertation are based on four to six months of monitoring - including at least two months of wet season and two months of dry season observations - for each household. Data on appliance use were recorded every five minutes.

I complimented the quantitative electricity allocation study with ethnographic observations of appliance use and related household dynamics. I visited each of the households a number of times over the course of the study. My observations and interactions with household members focused on understanding family relationships (including gender and elder-junior dynamics), energy allocation patterns, and the social use of electric appliances.

[365] I used inexpensive data loggers ("Hobo" H8 brand; see www.onsetcomputers.com) to record whether each of the appliances used with the solar system was "on" or "off." I used a combination of voltage dividers and current switches to send data signals to the Hobo data loggers. The voltage dividers (which reduced the voltage signal from nominal 12 volt system voltage to a 0-2.5 volts signal as required by the Hobo data logger) were used to monitor appliances that were wired to a wall switch (e.g. permanently installed lights). Custom built current switches were used with appliances that did not have a permanent wall switch (e.g. TVs, radios, cell phone chargers). The current switches sent a 0.5 volt signal to the Hobo logger when the appliance was "off," and a 0.05 volt signal when the current in the circuit exceeded a pre-set "threshold" current (the threshold current for radios and cell phone chargers was 40 mA; for TVs it was 0.2 amps). At the time that we installed the data monitoring systems, we (Maina Mumbi or I) measured the amount of current that each appliance used when turned "on." We then checked the current draw periodically under a range of different operating conditions over the months that the systems were monitored. In nearly all cases the variations in current consumption from the appliances were relatively modest over the range of operating conditions for the systems. I used the information about typical current draw for each appliance along with the usage patterns over the months of electronic monitoring to estimate the electricity allocation patterns reported in this dissertation.

Table B3: **Information about "Solar" Households Included in the Household Electricity Allocation Study**

#	District	Solar PV Size (W)	Energy Use (Whr/day)	Lights (#)	Appliances	Household Members	Income Source #1	Income Source #2	Income Source #3	Notes
1	Nakuru	12	41	0	B&W TV, radio	2 adults, 2 children	School headmaster	School teacher	Corn farming	
2	Nakuru	12	50	0	B&W TV, radio	2 adults, 1 child	School teacher	Carpentry business	Corn farming	
3	Nakuru	12	38	1	B&W TV, radio, phone	2 adults, 1 child	School teacher	Petrol station employee	None	Single mother, adult daughter
4	Nakuru	12	68	1	B&W TV, radio, VCR	2 adults, 2 children	School teacher	Taxi driver	None	Charge batt. in taxi
5	Nyeri	12	30	2	B&W TV, 2 radios	3 adults, 3 children	Tea farming	None	None	
6	Nyeri	12	22	1	B&W TV, phone	2 adults, 2 children	Veterinarian business	Tea farming	None	Cell phone, Vet Business
7	Nyeri	20	50	5	B&W TV, radio	2 adults, 3 children	Prison guard salary (city)	Tea farming	None	Father home weekends
8	Nyeri	20	36	4	B&W TV, radio	2 adults, 2 children	Tea farming	Retail shop at homesite	None	Prod. Use: light in shop
9	Nyeri	20	32	5	B&W TV, 2 radios	3 adults, no children	Tea farming	None	None	18 year adult son at home
10	Nyeri	20	40	5	B&W TV, radio, phone	2 adults, 2 children	Tea farming	None	None	
11	Nakuru	22	30	0	B&W TV, radio	2 adults, no children	School teacher	Clothing shop (town)	Cow & goat milk sales	
12	Nakuru	28	96	6	B&W TV, phone	2 adults, 4 children	Nurse (hospital)	Rental house	Goat milk sales	
13	Nakuru	39	104	10	B&W TV, radio	5 adults, no children	Pastor	Orphanage admin.	Vegetable & corn farming	2.5 kW generator
14	Nakuru	42	91	8	B&W TV, radio, phone	3 adults, no children	Truck driver (lorry)	Egg business	None	Prod. Use: egg business
15	Nyeri	50	145	3	Color TV, radio, phone	2 adults, 2 children	Health clinic officer	School teacher	Tea farming	Inverter for TV (200 W)

Table B3 notes:

Energy Use: Energy use is given in Watt-hours per day (Wh/day). This value is estimated by multiplying average electricity consumption data in ampere-hours by 12 volts (the nominal voltage of the solar systems). Factors that influence energy use include solar system size, location (Nakuru is sunnier than Nyeri), the condition of the battery used in the system, and appliance use patterns.

Household #4: In this household they supplement the electricity from their solar system by charging a battery in the father's taxi. They use two different batteries with the system. One is connected to the solar system, while the other is charged in the taxi on a regular basis. When the solar system battery is discharged, they operate their light and appliances using the battery that is charged in the taxi.

Household #6: In this household the cellular telephone, which is charged with solar electricity, is a key tool used by the father in his veterinary business.

Household #8: The family has a small retail shop where they sell general merchandise (e.g. sugar, flour, eggs, dry cell batteries, and others) from their homesite in a rural tea farming area in the Nyeri District. They use solar electricity to power a 15 Watt incandescent light bulb in the shop for an average of 1.6 hours per day. This facilitates business transactions in the evening hours.

Household #13: This family has a 2.5 kW petrol powered generator that they use to pump water from a well. When the generator is on, some of the excess electricity is used to charge the solar system battery. The generator is used infrequently, and it charges the solar battery at a rate of approximately 10 amps for 3.8 hours per month on average.

Household #14: This household was in the process of starting a home based egg business at the time that I began monitoring their electric appliance use. Their business has 250 chickens, and they produce approximately 150-200 eggs per day. When they were starting their business they used a 6 Watt fluorescent solar light for an average of 14.5 hours per day in the chick brooder over a three month period. This was done in order to ensure that the chick brooder room had light 24 hours per day (the room was also heated using a charcoal brazier). After the chicks grew to maturity they stopped using the solar electricity for the egg business, but they plan to use it again in a similar fashion within a year or two when they raise another group of chicks. They continue to use the solar electricity in their home.

Household #15: This family has a color TV that draws 65 Watts of electric power when it is on. They use a 200 Watt inverter to convert the 12 volt DC electricity from the solar system battery into the 240 volt AC electricity required by the television set.

7) **Rural Cellular Telephone Users**: The cellular telephone survey involved survey interviews with 79 rural cell phone owners in four districts (Nyeri District in the Central Province, Nakuru District in the Rift Valley Province, and Bungoma & Lugari Districts in the Western Province) during 2003. The survey interviews were carried out by the author, Maina Mumbi, and Henry Watitwa. Rebecca Ghanadan provided valuable advice related to the design of the survey.

The respondents were selected through an approach that utilized contact people in each area with a snowball sampling method. We asked our contacts to introduce us to a few people who owned cellular telephones in their area. We then asked each person that we interviewed to introduce us to another rural telephone owner. This approach did not generate a true random sample, but it did provide a practical approach for interviewing a reasonable number of rural cellular telephone users within the time and budgetary constraints of the project.

The data in Table B4 provide some information about the characteristics of the cellular telephone owners included in the sample. The majority of the rural cell phone owners that we interviewed were men, but we did find a number of women who owned phones. Most cell phone owners were young adults, and the large majority appeared to belong to the "rural middle class" (see Chapter 3 for a discussion of the definition of this social group).

Table B4: **Information About Rural Cellular Telephone Users in 2003 Survey**

Category	**Result**[366]
Gender of Cell Phone Owners	
Men (%)	70%
Women (%)	30%
Age of Cell Phone Owners	
Median Age (years)	35 years
Percentage Between 20 and 40 years (%)	71%
Cellular Telephone Company Used	
Safaricom	57%
Kencell	41%
Both (i.e. person used both services)	3%
Primary Source of Income in Household of Cell Phone User	
Professional salary	41%
Business earnings	37%
Farming	18%
Other	5%
Professional salary or business earnings as 1st or 2nd most important source of household income	92%

366 In some cases the results do not add up to 100% due to rounding errors.

8) **Newspaper Advertisements by Solar Companies**: This survey involved systematically clipping all advertisements for solar PV products in the Daily Nation, Kenya's largest circulating daily newspaper, from May 6, 2002 to December 31, 2003. A total of 391 ads were included in the survey. The content of each advertisement was analyzed to determine the main emphasis of the ad. For example, in some ads solar systems were framed primarily as a technology for powering TV sets, while in others lights or cellular telephone charging was the main emphasis. Still other ads focused on the solar modules alone, without mentioning potential applications. Maina Mumbi assisted me in this survey by purchasing the newspapers daily over the period of the survey, as well as by clipping a portion of the advertisements.

9) **Television Advertisements During Prime Time**: In this study Maina Mumbi and I recorded information about television advertisements during the period from 7 pm to 9 pm on 13 randomly selected days. I chose the 7 to 9 pm time slot because this was the period during which most TV viewing took place in the 15 "solar" households observed during 2003 and 2004 (see information about the " Solar Household Appliance Use Observation" study described in item #6, above).

   On seven of the 13 days we monitored commercials on KBC TV (111 total advertisements), and on the remaining six days we monitored Nation TV (95 total advertisements). For each evening we recorded the programs during the period onto a video tape. We then worked from the video recording to collect information about each advertisement shown during the time period. We noted the type of product advertised and its brand name (e.g. Colgate Herbal toothpaste, Tusker beer, BlueBand margarine). I then used this information to determine the parent company for each brand (e.g. Colgate-Palmolive, Kenya Breweries, Ltd., Unilever), and the ownership structure for that company (i.e. multinational corporation, Kenya owned company, etc.). These data were used to estimate the fraction of the prime time TV commercials that correspond to each type of company or organization (in addition to the various types of private businesses, some advertisements were placed by non-profit institutions and the Kenya Government).

Appendix C: Estimating Wealth for Rural Kenyan Households

I estimated the wealth characteristics of rural households based on asset ownership and livestock value data from a stratified random sample of 1,512 rural households in 24 districts of Kenya.[367] These survey data were collected in 2000 through the "Tegemeo Project" of Michigan State University (USA) and Egerton University (Kenya).[368]

In order to rank the households according to wealth, I combined the estimated monetary value of the livestock owned[369] by each household at the time of the survey with the overall estimated monetary value of 46 possible household property assets.[370] This assets based approach to estimating household wealth effectively captures the value of wealth accumulated by a family over a number of years. As such, it provides a better estimate of wealth ranking than the household income information in the data set for a single year (i.e. 2000), as agricultural and livestock related incomes for many households vary widely from year to year.

It is important to note that several important types of assets are not included in my wealth estimate. These include financial assets (e.g. savings accounts), land ownership, and human capacity assets (e.g. education). These assets are missing either because the data were not available in the Tegemeo data set (e.g. financial savings) or because it

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[367]Sampling for this data set occurred in the following districts of Kenya: Kilifi, Kwale, Taita Taveta, Garrisa, Kitui, Machakos, Makueni, Meru, Mwingi, Kisii, Kisumu, Siaya, Bungoma, Kakamega, Vihiga, Muranga, Nyeri, Bomet, Nakuru, Narok, Trans Nzoia, Uasin Gishu, Laikipia, and Turkana. For the purposes of the wealth ranking estimates reported in this paper, I chose to eliminate data from two of these districts (Garrisa and Turkana) due to insufficient information about livestock values in these districts. As a result, the results reported here are from a sample of 1,446 households, while the original sample included 1,540 households.

[368] 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 a copy of the year 2000 original survey questionnaire), as well as more information about the Tegemeo Project see http://www.aec.msu.edu/agecon/fs2/kenya/.

[369] The Tegemeo 2000 data set included livestock ownership data for 18 different classes of livestock, including sheep, goats, pigs, poultry, nine different grades of cattle, and several others. The Tegemeo team carried out a separate survey of livestock sale prices (in Kenyan Shillings) in districts where households were surveyed in order to estimate a standard value for animal types in each district. I combined the household livestock ownership data with these standard prices to estimate the total value of livestock owned by each family. Note that standardized livestock price data were not available for Garissa and Turkana districts. See footnote 367.

[370] The Tegemeo 2000 data set included information about the ownership of 46 possible household assets ranging from buildings (e.g. houses) to farm equipment (e.g. ploughs) to consumer goods (e.g. TV sets). For each possible asset the survey enumerators noted whether or not the household owned the item, how many were present, and the estimated resale value (in Kenyan Shillings) of the item(s) as reported by the respondent household member(s). I used the sum total value of all of the reported items – along with the value of livestock owned – as an indicator of household wealth. Note that solar PV modules and batteries were included in the list of possible household assets. I excluded the value of these items in my estimates of the wealth ranking of households owning solar and battery systems, respectively. See the end of this appendix for a complete list of the assets included in the Tegemeo survey.

was not possible to make a reliable estimate of the monetary value of the assets based on the available data (e.g. land ownership and education). These exclusions notwithstanding, the assets based approach that I present here should provide a relatively robust estimate of wealth *ranking* among rural Kenyan households, as one would expect substantial positive correlation between the value of livestock and key property assets on the one hand and the value of these missing assets on the other.

List of Household Assets Included in Tegemeo Household Survey

1 animal traction plough
2 battery (automotive, truck, or solar type lead-acid battery)
3 beehive
4 bicycle
5 boom sprayer
6 borehole (well for water)
7 cane crusher (sugar cane crusher)
8 car
9 cart
10 cattle dip / cattle crush
11 chaf cutter
12 coffee churner
13 combine harvester
14 dam
15 donkey
16 generator (power for irrigation)
17 grinder
18 harrow/tiller
19 houses
20 irrigation equipment
21 jaggery unit
22 motorcycle
23 pestle & mortar
24 piggery houses
25 planter
26 ploughs for tractor
27 poultry houses/rabbit sheep pen
28 power saw
29 radio
30 ridger/weeder
31 sheller
32 solar panels
33 spray pump
34 stores
35 telephone
36 tractor
37 trailer
38 truck
39 TV
40 water pump
41 water tanks
42 water trough
43 weighing machine
44 well
45 wheel barrow
46 zero-grazing assets

Appendix D: Solar Vendors and Technicians in Kenyan Towns

Table D1: **Solar Vendors and Technicians in Kenyan Towns, 2001**

#	Town Name (alphabetical listing)	Province	Town Group (i.e. Main Town in Area)	Solar Technician Interviews (#)	Solar Business Surveys (#)
1	Bungoma	Western	Bungoma ‡	n/a	14
2	Busia	Western	Busia ‡	n/a	5
3	Chogoria	Eastern	Meru §	14	n/a
4	Chuka	Eastern	Meru §	13	5
5	Eldoret	Rift Valley	Eldoret ‡	n/a	20
6	Embu	Eastern	Embu ‡	n/a	12
7	Endebbes	Rift Valley	Kitale §	1	n/a
8	Engineer	Rift Valley	Naivasha ‡	4	n/a
9	Gilgil	Rift Valley	Nakuru ‡	n/a	3
10	Homabay	Nyanza	Kisii §	n/a	6
11	Iten	Rift Valley	Kitale §	2	n/a
12	Kabarnet	Rift Valley	Kitale §	1	n/a
13	Kakamega	Western	Kakamega ‡	n/a	9
14	Kangema	Central	Murang’a §	7	1
15	Kangundo	Eastern	Machakos §	8	n/a
16	Kanyakine*	Eastern	Meru §	1	n/a
17	Kapenguria	Rift Valley	Kitale §	n/a	1
18	Kapsabet	Rift Valley	Eldoret ‡	n/a	6
19	Karatina	Central	Nyeri ‡	n/a	6
20	Kericho	Rift Valley	Kericho §	15	11
21	Keroka	Nyanza	Kisii §	1	2
22	Kerugoya	Central	Kerugoya §	15	11
23	Kilifi	Coast	Malindi §	4	2
24	Kiminini*	Rift Valley	Kitale §	1	n/a
25	Kinamba	Rift Valley	Nyahururu §	5	3
26	Kisii	Nyanza	Kisii §	13	12
27	Kisumu	Nyanza	Kisumu ‡	n/a	18
28	Kitale	Rift Valley	Kitale §	22	14
29	Kutus	Central	Kerugoya §	8	2
30	Lodwar*	Rift Valley	N. Kenya ‡	1	n/a
31	Lunga-Lunga	Coast	Mombasa §	1	n/a
32	Machakos	Eastern	Machakos §	12	12
33	Makutano	Rift Valley	Kitale §	2	n/a
34	Malindi	Coast	Malindi §	4	4
35	Maragua	Central	Murang’a §	8	n/a
36	Matunda	Rift Valley	Kitale §	2	2
37	Maua	Eastern	Meru §	7	2
38	Meru	Eastern	Meru §	23	12
39	Migori	Nyanza	Kisii §	5	6
40	Mikunduri*	Eastern	Meru §	1	n/a
41	Moi's Bridge	Rift Valley	Kitale §	2	1
42	Mombasa	Coast	Mombasa §	8	10
43	Murang’a	Central	Murang’a §	22	6
44	Nairobi	Nairobi	Nairobi ‡	25	31**
45	Naivasha	Rift Valley	Naivasha ‡	21	14
46	Nakuru	Rift Valley	Nakuru ‡	32	19
47	Nanyuki	Rift Valley	Nyeri ‡	n/a	8
48	Njoro	Rift Valley	Nakuru ‡	7	1
49	Nkubu	Eastern	Meru §	19	n/a
50	North Kinangop	Rift Valley	Naivasha ‡	n/a	1

Table D1 (Continued) Solar Vendors and Technicians in Kenyan Towns, 2001

#	Town Name (alphabetical listing)	Province	Town Group (i.e. Main Town in Area)	Solar Technician Interviews (#)	Solar Business Surveys (#)
51	Nyahururu	Rift Valley	Nyahururu §	9	11
52	Nyamira	Nyanza	Kisii §	1	n/a
53	Nyeri	Central	Nyeri ‡	n/a	12
54	Ol Kalau	Rift Valley	Nyahururu §	5	3
55	Rumuruti	Rift Valley	Nyahururu §	2	n/a
56	Sagana	Central	Kerugoya §	6	1
57	Sibanga	Rift Valley	Kitale §	1	1
58	Sotik	Rift Valley	Kericho §	1	4
59	Soy	Rift Valley	Kitale §	1	n/a
60	Subukia	Rift Valley	Nakuru	6	n/a
61	Tala	Eastern	Machakos §	9	2
62	Thika	Central	Thika ‡	n/a	11
63	Ukunda	Coast	Mombasa §	9	1
64	Webuye	Western	Bungoma ‡	n/a	4
65	Wote	Eastern	Machakos §	4	n/a

*Interviewed one technician from here, but did not visit the town.
§ These town groups selected randomly for technician interview and business survey data collection.
‡ These town groups selected deliberately (not randomly) for technician and/or business data collection
** Unlike the other towns, this number is not an estimate of the total number of solar businesses in Nairobi.

Table D2: **Solar PV Module Vendors in Kenyan Towns by Shop Type, 2001**

Shop Type	**Percentage of Total (%)***			
	All towns** (45)	Towns < 20K pop.	Towns 20K to 100K pop.	Towns > 100K pop.**
	n = 311 shops	n = 77	n = 155	n = 79
Hire Purchase Credit	41%	43%	45%	29%
Electronics	16%	12%	15%	22%
Electrical Hardware	13%	13%	10%	20%
Automotive Spare & Tire	11%	9%	12%	10%
General Hardware	6%	5%	8%	4%
Solar & Battery Specialists	5%	4%	3%	11%
Other[371]	7%	14%	7%	4%

*Total does not add up to 100% in some cases due to rounding errors.
** All towns included in the survey, excluding Nairobi.

[371] "Other" includes categories such as supermarkets, general merchandise shops, petrol stations, and bicycle shops.

Table D3: **Products & Services Offered by PV Vendors Listed by Shop Type, 2001**

	Percentage of Total (%)*						
Products and Services Offered	Hire Purchase Credit	Electronics	Electrical Hardware	Auto Spares & Tire	General Hardware	Solar & Battery	Other
	n = 126	n = 50	n = 41	n = 34	n = 19	n = 17	n = 24
Electrical Hardware	1%	94%	93%	3%	95%	53%	74%
DC Electrical Equip.	33%	96%	90%	65%	95%	76%	75%
PV Installation Services	6%	45%	76%	21%	22%	82%	26%

*Total does not add up to 100% in some cases due to rounding errors.
** Excluding Nairobi; n refers to number of shops.

Table D4: **Main Source of Income for "Solar Technicians" by Town Size, 2001**

	Percentage of Total*				
Category	Solar Techs, All Towns**	Solar Techs, Towns < 20,000	Solar Techs, Towns 20,000 to 100,000	Solar Techs, Towns > 100,000**	Nairobi Solar Specialists
	n = 366	n = 160	n = 154	n = 52	n = 25
a) Electrician	52%	34%	65%	67%	0%
b) Electronics Tech.	14%	18%	10%	12%	4%
c) Both (a) & (b)	24%	34%	19%	8%	0%
d) Solar PV	9%	11%	5%	12%	96%
e) Other	2%	3%	1%	2%	0%

*Total does not add up to 100% in some cases due to rounding errors.
** Excluding Nairobi; n refers to number of technicians.

Table D5: **Years of Experience Working with Solar PV for Solar Technicians**

	Percentage of Total*				
Years of Experience with Solar Energy	Solar Techs, All Towns**	Solar Techs, Towns < 20,000	Solar Techs, Towns 20,000 to 100,000	Solar Techs, Towns > 100,000**	Nairobi Solar Specialists
	n = 366	n = 160	n = 154	n = 52	n = 25
3 years or less	39%	37%	39%	43%	25%
4 to 7 years	37%	34%	40%	41%	50%
8 to 10 years	10%	10%	12%	6%	4%
more than 10 years	14%	19%	10%	10%	21%

*Total does not add up to 100% due to rounding error.
** Excluding Nairobi; n refers to number of technicians.

Table D6: Number of Solar PV Systems Installed by Solar Technicians, 2001

	Percentage of Total*				
Number of Solar PV Systems Installed	Solar Techs, All Towns**	Solar Techs, Towns < 20,000	Solar Techs, Towns 20,000 to 100,000	Solar Techs, Towns > 100,000**	Nairobi Solar Specialists
	n = 366	n = 160	n = 154	n = 52	n = 25
Fewer than 5	24%	18%	31%	20%	4%
5 to 10	29%	25%	29%	37%	12%
11 to 20	23%	25%	22%	18%	4%
21 to 50	16%	21%	11%	12%	32%
51 to 100	4%	6%	3%	6%	16%
More than 100	5%	5%	3%	8%	32%

*Total does not add up to 100% due to rounding error.
** Excluding Nairobi; n refers to number of technicians.

Table D7: Educational Backgrounds for Solar Technicians, 2001

	Percentage of Total*				
Education Completed	Solar Techs, All Towns**	Solar Techs, Towns < 20,000	Solar Techs, Towns 20,000 to 100,000	Solar Techs, Towns > 100,000**	Nairobi Solar Specialists
	n = 366	n = 160	n = 154	n = 52	n = 25
a) Primary School	98%	99%	97%	100%	100%
b) Secondary School[372]	83%	82%	85%	80%	100%
c) "Youth" Polytechnic	14%	21%	8%	12%	0%
d) Worked Under Exp Tech[373]	93%	90%	96%	92%	100%
e) Tech. Training Institute	41%	42%	42%	35%	40%
f) Nat'l Level Polytechnic	14%	11%	14%	25%	20%
g) University	1%	1%	1%	2%	16%
i) Specialized Solar Training	6%	7%	6%	12%	52%

*Total does not add up to 100% because categories are overlapping.
** Excluding Nairobi; n refers to number of technicians.

[372] This indicates that the technician completed at least 2 years of secondary school.
[373] This category includes all technicians who reported that they had learned by working under a more experienced technician (i.e. both formal and informal apprenticeship arrangements).

Appendix E:
Terms, Acronyms, and Abbreviations

AC	Alternating Current (alternating electrical current)
Ahr	Ampere-hours
a-Si	Amorphous Silicon solar photovoltaic technology
BBC	British Broadcasting Corporation
B&W	Black and White television
°C	Degrees Celcius
CDM	Clean Development Mechanism of the Kyoto Protocol on climate change
CO_2	Carbon Dioxide
c-Si	Crystalline Silicon solar photovoltaic technology
DC	Direct Current (direct electrical current)
ESMAP	Energy Sector Management Assistance Program; a joint program of the World Bank and the UNDP
f.o.b.	Free on board (term used in import/export; see footnote 4)
G-8	Group of Eight countries[374]
GDP	Gross Domestic Product
GDPpc	Per Capita Gross Domestic Product
GHG	Greenhouse Gas (i.e. gases such as CO_2 and methane that contribute to global warming)
GNP	Gross National Product
GEF	Global Environmental Facility (see also footnote 5 in the Introduction)
GTZ	German based development agency (*Deutsche Gesellschaft für Technische Zusammenarbeit*)
HH	His Holiness (as in "His Holiness, the Aga Khan")
IFC	International Finance Corporation (a member of the World Bank Group)
IMF	International Monetary Fund
KANU	Kenya African National Union (Kenyan political party)
KBC	Kenya Broadcasting Corporation (1962-1964; 1989-present; radio and television broadcaster affiliated with the Kenya Government)
K£	Kenyan Pound (monetary unit; 1 K£ = 20 KSh)
km	kilometers
KSh	Kenyan Shilling (main monetary unit used in Kenya)
KTN	Kenya Television Network (privately owned television station in Kenya)
kW	Kilowatt
kWh	Kilowatt-hours
kWp	Peak Kilowatts (measure of solar module output; see Wp)

[374] The G-8 countries include the United States, the United Kingdom, France, Germany, Italy, Japan, Canada, and Russia.

LPG	Liquid Petroleum Gas (also known as propane gas)
m	meters
MNC	Multinational corporation
MW	Megawatts
MWp	Peak Megawatts (measure of solar module output, see Wp)
NARC	National Alliance for Renewal and Change (coalition of 14 Kenyan political parties formed to present a unified opposition to KANU during the 2002 elections)
NATO	North Atlantic Treaty Organization[375]
NMG	Nation Media Group (privately owned media company in Kenya)
OECD	Organization of Economic Cooperation and Development[376]
O&M	Operations and Maintenance
PPP	Purchasing Power Parity (the PPP method is used to make income comparisons between different countries)
PV	Photovoltaic (abbreviation for solar photovoltaic technology)
PVMTI	Photovoltaic Market Transformation Initiative ($30 million GEF program initiated in 1998 to fund solar PV market activities in India, Morocco, and Kenya).
REP	Rural Electrification Program (of Kenya)
SHS	Solar Home System (common shorthand for household solar electric system)
SSA	Sub-Saharan Africa
STV	Stellavision (privately owned television station in Kenya)
TV	Television
UK	United Kingdom
UNCED	United Nations Conference on Environment and Development (held in Rio de Janeiro, Brazil in 1992)
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
$US	United States dollars (monetary unit)
US	United States of America
US-AID	United States Agency for International Development
VAT	Value Added Tax
VoK	Voice of Kenya (1964-1989; radio and television broadcasting network that was fully owned by the Kenya Government)
W	Watts
Wh	Watt-hours

[375] As of 1990, NATO member countries included Belgium, Canada, Denmark, France, Germany, Greece, Iceland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Turkey, the United Kingdom, and the United States.

[376] As of August, 2004 OECD had 31 member countries, including Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Japan, Korea (South), Luxemburg, Mexico, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom, and the United States. OECD member states include most of the world's strongest economies.

W/m^2	Watts per square meter, a common measure of solar radiation
Wp	Watts, peak (common abbreviation used in the power ratings for solar photovoltaic modules; it refers to the maximum power that can be produced by the modules under standard test conditions of 1000 W/m^2 and 25° C)

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