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Community-Based Electric Micro-Grids Can Contribute to Rural Development: Evidence from Kenya

CHARLES KIRUBI
University of California, Berkeley, USA

ARNE JACOBSON
Humboldt State University, USA

DANIEL M. KAMMEN and ANDREW MILLS *
University of California, Berkeley, USA

Summary. — In this paper we clarify the mechanisms through which rural electrification can contribute to rural development. Through a detailed case study analysis of a community-based electric micro-grid in rural Kenya, we demonstrate that access to electricity enables the use of electric equipment and tools by small and micro enterprises, resulting in significant improvement in productivity per worker (100–200% depending on the task at hand) and in a corresponding growth in income levels in the order of 20–70%, depending on the product made. Access to electricity simultaneously enables and improves the delivery of social and business services from a wide range of village-level infrastructure (e.g., schools, markets, and water pumps) while improving the productivity of agricultural activities. We find that increased productivity and growth in revenues within the context of better delivery of social and business support services contribute to achieving higher social and economic benefits for rural communities. We also demonstrate that when local electricity users have an ability to charge and enforce cost-reflective tariffs and when electricity consumption is closely linked to productive uses that generate incomes, cost recovery is feasible.

Key words — rural electrification, rural development, Kenya, Africa

1. INTRODUCTION

Past approaches to assessing the relationship between rural electrification and rural development have largely been confined to grid extension by utilities with limited coverage of decentralized electricity options. While a number of studies exist focusing on geographic regions such as South and East Asian and Latin America (Barnes, 1988; Bose, 1993; Chaurey, Ranganathan, & Mohanty, 2004; ESMAP, 2003; Gerger & Gullberg, 1997; Munasinghe, 1988), empirical case studies from sub-Saharan Africa are rare (Khennas & Barnett, 2000; Maher, Smith, & Williams, 2003). This study contributes to filling this research gap by exploring the relationship between rural electrification and rural development in the context of a village-scale community-based electricity project in rural Kenya.

Empirical research on group-based micro-grids is also relevant in view of the current policy shift in favor of off-grid rural electrification options in sub-Saharan Africa. Kenya, for example, has recently passed a law encouraging communities and private investors to generate and distribute electricity in rural areas (Government of Kenya, 2006). As an incentive measure, systems below 3 MW are now permitted to operate with minimal government regulation, and investors can charge tariffs that cover operating costs and yield a return on investment. Similar laws and incentives exist in Tanzania and Uganda (Karekezi & Kithyoma, 2002).

The results presented here are drawn from the experience of the Mpeketoni Electricity Project (MEP), a community-based diesel-powered micro-grid system in rural Kenya. The 13-year history of MEP (1994–2007) permits a village-level exploration of the mechanisms through which access to rural electricity can contribute to rural development in addition to an examination of the circumstances under which cost recovery is feasible.

This paper is organized as follows: It begins with a brief review of debates on rural electrification and rural development. This is followed by a description of the methods used in the study, the project area, and the MEP micro-grid system. The article continues with a discussion of the socio-economic impacts of access to electricity and an analysis of MEP's financial performance. The paper concludes that access to electricity, in conjunction with complementary infrastructure such as markets, roads, and communications, can contribute to increased productivity in two key economic arenas of rural livelihoods: small and micro-enterprises (SMEs) and agriculture. Productive uses of electricity, as reflected by a high load factor,

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appear central to achieving a high degree of cost recovery, hence financial viability of rural electric micro-grids. While this analysis is based on MEP as a case study, this research seeks to show that the development and cost recovery potential demonstrated by MEP is representative of types of outcomes likely to result from similar initiatives where productive uses of electricity are promoted within an integrated rural development framework.

2. RURAL ELECTRIFICATION AND RURAL DEVELOPMENT

The dominant ideas of development economics of 1950s to 1970s largely considered rural electrification as a catalyst for rural development. These ideas have gone through dramatic transformation over the course of the last two decades. The early perception that rural electrification was a ''precondition'' for rural development has given way to the current thinking that under certain circumstances, the development process may indeed lead rather than follow rural electrification.

Centralized grid-based rural electrification in Africa and elsewhere has roots in post-WWII development economics. As part of the import-substitution industrialization (ISI) development strategy, availability of abundant, and cheap electricity was seen as a ''precondition'' for an industrial revolution in Africa (IBRD, 1962). In this view, failure to extend electricity to rural areas meant loss of development potential. Substantial upfront investment in rural infrastructure, including electricity, was central to employment creation in developing countries, argued Mellor (1976). Informed by the foreign experience of ''building ahead of demand,'' electricity, it was assumed, would create its own demand and industrialization would follow (Hirschman, 1970). As an example, consider the statement:

> Power, however produced, represents a small fraction of production costs in any industry, but the replacement of wood by electricity as a source of power over this considerable part of [Jinja] Uganda would probably be followed by many developments which are difficult to foresee. Experience with electricity in other parts of the world has nearly always shown that the most optimistic estimates of consumption have been greatly exceeded soon after the provision of reliable and cheap supply.'' Worthington (1948 cited in Hirschman, 1970, p. 69).

In the efforts to replicate the ''American experience'' in Africa by ''opening up'' rural areas through massive extension of infrastructure (e.g., electricity and railroads), however, important local constraints, such as dispersed rural population, low purchasing power, and limited potential for load growth have been largely overlooked. Long distances and difficult geographic terrain meant greater electricity losses and prohibitive operational, maintenance, and administrative costs. Moreover, for many industries, proximity to main markets (primarily in urban areas) was more decisive because transport costs, not electricity, were a bigger share of production cost (Lury, 1976). Because of these demand-side constraints, effective demand for electricity did not, contrary to initial assumptions, follow supply of power to rural areas.

Consequently, a major re-appraisal of the relationship between rural electrification and rural development has taken place starting in the 1980s (Barnes, 1988; Foley, 1992; Munasinghe, 1987; Pearce & Webb, 1987). These studies consistently concluded that rural electrification was a necessary but not sufficient condition to trigger rural development. Moreover, because of the high initial connection charges and the bureaucracy and politics mediating electricity access, grid-based rural electrification had reached the rich more than the poor. As such, commonly articulated policy objectives of achieving income re-distribution and social-equity through rural electrification have not materialized. A costs and benefits evaluation study by the World Bank (1995) succinctly captured the re-thinking of the impact of rural electrification (RE):

> One of the most persistent claims for RE is that it can induce industrial growth in otherwise lagging low-income rural economies. The evidence from developing countries does not support this claim; RE has not, by itself, triggered industrial growth or regional development. . .The study found that where other prerequisites of sustained development were absent, demand for electricity for productive uses did not grow. . .RE is economically justified only when the emerging uses of electricity are strong enough to ensure sufficient growth in demand to produce a reasonable economic rate of return on the investment (p. 2).

The Bank's view on the economic value of rural electrification continues to evolve, however. In one of its latest cost-benefits analyzes, the Bank asserts: ''the economic case for investments in RE (rural electrification) is proven. . .'' (IEG, 2008, p. 55). This is clearly a re-assessment of the above quoted Bank's position arrived at over a decade ago. The policy shift is in part informed by a growing body of evidence relating to the value of rural electrification: ''the value of RE (rural electrification) benefits to households is above the average long-run supply costs, so cost recovery tariff levels are achievable...'' (p. xvii). An earlier study by ESMAP (2003) carries a similar message, that is, for residential customers, the WTP (willing to pay) for modern energy to power lighting and television is US$0.1–0.40/kWh, respectively, which by far exceeds the average long-run electricity supply costs, typically US$0.05–0.12/kWh.

Analysis of WTP is, however, complicated by the fact that rural households rely on a mix of energy sources such as fuelwood and charcoal for cooking, kerosene and dry-cell batteries for lighting, and auto-type batteries for television (Masera, Saatkamp, & Kammen, 2000). This methodological challenge can be overcome by finding a common metric (e.g., lumens or kWh) for comparing the cost of electricity with the unit cost of energy derived from the mix of energy sources used by a typical household. Conceptually, the process by which access to rural electrification can yield benefits that exceed the average long-run electricity supply costs can be explained by the theory of consumer surplus. Access to electricity lowers the unit cost of energy to the end-user, leading to an increase in consumer surplus (the difference between what the consumers are willing to pay and what they actually do pay). In this context, consumer surplus has two components: one arising from the decrease in the unit cost of current energy consumption, and two, that resulting from incremental consumption due to a drop in unit cost. However, there is a caveat that the magnitude of the benefits depends on the shape of the demand curve used to estimate WTP for different sets of users. [1]

It is interesting that by applying the WTP method, the World Bank, an institution with considerable policy sway and financial leverage in developing countries, finds investments in rural electrification economically favorable and cost recovery possible. This result underscores the importance of cost recovery as a central parameter in assessing the economic viability of rural electrification initiatives, a parameter we address in this paper in the context of MEP (see Section 7).

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A number of energy researchers have sought to understand the value of rural electrification through the lens of multi-dimensional development frameworks that aim to link electricity access with broad rural development and poverty reduction goals (Cabraal, Barnes, & Agarwal, 2005; Cecelski, 2005; Karekezi, Mapako, & Teferra, 2002). The Millennium Development Goals (MDGs) is one such framework and perspective. In addition to supporting income generation as a means of fighting poverty, the MDGs underscore the importance of promoting access to quality education, health, and gender equality. Within the context of MDGs, productive uses of energy should not, these authors suggest, be limited to activities related to income generation, but should also include application of energy to support important development goals such as access to education, health, communication, and women's empowerment. Cabraal *et al.*, for example, cite empirical evidence from rural India and Peru which showed that joint provision of education and electricity was likely to yield higher household income than providing education without electricity. A World Bank's socio-economic impact study in the Philippines established that access to electricity was correlated with significant educational achievement (ESMAP, 2003). Other factors being equal, children from electrified households gained about two years of educational achievement relative to children from non-electrified households. With respect to solar electrification, Jacobson's work in Kenya demonstrated that children in households with larger systems (> 25 W) are more likely to benefit from better lighting for evening study than children in households with smaller systems (<25 W) (2007). This is because in households with smaller systems, a majority of the energy (54%) was allocated to television viewing as opposed to households with larger systems where most of the energy was used for lighting. Better illumination which improved the conditions for evening study is the mechanism through which solar electricity contributed to quality education for children in rural Kenya.

Apart from education, improved health is another desirable millennium development goal whose achievement electricity can play a significant role. Not only does access to electricity increase television viewing, but more importantly television is a useful medium through which women can acquire crucial knowledge related to health and family planning (IEG, 2008). Another study has shown that the number of women's prenatal visits to local health clinics was positively associated with access to mechanical power in Mali (Porcaro, 2005). In this particular case, the increase in prenatal visits was attributable to time savings and reduced drudgery following the installation of multifunctional platforms [2] which are used for milling cereals and dehusking rice, tasks that were otherwise undertaken by women manually. Additionally, electricity can enable deployment of a wide range of information and communication tools such as television, the Internet, and wireless devices to fight pandemics such as HIV/AIDS and malaria (CITRIS, 2008). Other studies in Ghana and Bangladesh demonstrate that not only does access to electricity reduce the probability of absenteeism of workers in rural clinics and schools, but also lack of access to electricity makes it difficult for such remote facilities to attract and retain professional workers (Chaudhury & Hammer, 2003; IEG, 2004). One possible explanation for this finding is that electricity enables professionals (e.g., teachers, nurses, and agricultural officers) working in rural areas to access services (e.g., communication and entertainment from TV) enjoyed by their counterparts in urban settings.

As will be demonstrated in this study, SMEs represent another important link between rural electricity and rural development. There are a number of reasons why SMEs provide a particularly useful lens for illuminating the impact of rural electrification on rural development in sub-Saharan Africa. First, SMEs are an integral player in the African economy (Karekezi & Majoro, 2002; Mead, 1994). In Kenya, this sector accounted for 30% of the GDP and for over 90% (about 500,000) of new jobs created outside agriculture in 2003 (Government of Kenya, 2004a). Second, targeting electrification efforts on SMEs has the double advantage of increasing the value, productivity, and incomes of activities undertaken by this sector while increasing electricity demand in rural areas. Third, the start-up and growth of SMEs for employment creation and poverty reduction is a key and explicit assumption of virtually every rural electrification program on the continent (Government of Kenya, 2004b; Rogerson, 1997; Wamukonya & Davis, 1999).

Rural electrification can be implemented through different approaches. One approach, area coverage, seeks to provide electricity to as many customers as possible within a designated area regardless of their proximity to the central grid. This approach was followed in the United States and has also been adopted in the Philippines (Sathaye, 1987). Grid extension is another method which makes electricity available to customers based on their relative proximity to the existing service networks. A third approach, integrated rural development, delivers electricity as part of a wider package of complementary infrastructure, including but not limited to roads, telecommunication, health, and educational facilities. To increase the prospects for rural development in a selected region, the integrated approach tends to prioritize productive uses such as agricultural, commercial, and institutional activities. In the past, Kenya has pursued this approach (Walubengo & Onyango, 1992), and the trend continues. In 2006/2007 financial year, the Kenya Power & Lighting Company, the national utility, completed nearly 500 rural electrification schemes covering trading centers, secondary schools, health facilities, and community water schemes throughout the country at a cost of Ksh2.2 billion (US$30 million) (KPLC, 2007). India and Indonesia are other countries that have pursued a similar approach to rural electrification (Barnes, 1988; Munasinghe, 1988). No matter what the mode of implementation, rural electrification programs in Africa face formidable challenges. Notable obstacles include low population densities, limited ability to pay, hence low demand, high capital and operating costs, low levels of cost recovery, and political interference. A World Bank study provides a synthesis of factors associated with successful programs in various developing countries (Barnes & Foley, 2004). First and foremost, long-term sustainability and effectiveness of rural electrification programs appear to critically depend on the degree of cost recovery realized by a particular program. From this financial perspective, charging tariffs that at least cover operation and maintenance (O&M) costs is essential. Second, successful programs have an autonomous and effective implementing agency. The exact institutional structure does not seem to matter, however, as different arrangements have worked well in different countries. Successful cases can be found in the context of a separate rural electrification authority (Bangladesh), rural cooperatives (Costa Rica), the rural electrification department of a national utility (Thailand), and regional branches of a national utility (Tunisia). Third, successful programs have developed and enforced criteria and schedules for electrification taking into account the availability of complimentary infrastructure. Finally, community involvement through village organizations is also crucial. This is especially true for successful efforts to leverage local resources and promote increased access to off-grid rural electrification.

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This discussion highlights two important points. First, while access to electricity does not in itself guarantee social progress or economic development, it is an essential element of meaningful rural development. Second, while globally relevant, many of the lessons from studies such as those by Barnes and Foley are drawn largely from rural electrification programs in South and East Asia and Latin America. Empirical case studies of rural electrification programs in sub-Saharan Africa, particularly community-based projects, are limited. Moreover, in a review of data and experiences globally, one of the latest World Bank (IEG, 2008) studies on rural electrification concludes that "the evidence base for the links between RE (rural electrification) and poverty remains thin" (p. 55). This work contributes to this research gap with a particular focus on village-scale off-grid systems in East Africa.

As more group-led electricity projects get underway in East Africa, the 13-year history (1994–2007) of the Mpeketoni Electricity Project provides an excellent learning opportunity about: (a) the socio-economic benefits of rural electrification; (b) the potential for cost recovery; and (c) collective action challenges related to management and governance of community micro-grid systems. This analysis focuses on the first two of these three issues.

3. METHODS AND EVIDENCE

In this study, we draw from both quantitative and qualitative evidence to explore the degree to which community-based electric micro-grids can contribute to rural development. Specifically, we use the experience of the Mpeketoni Electricity Project to illustrate the mechanisms through which access to electricity can generate additional productivity and income opportunities for SMEs and farmers in rural areas. Aside from shedding light on how electricity can fit into an integrated rural development approach, the MEP experience also demonstrates the circumstances under which group-based micro-grids can achieve a high degree of cost recovery.

This work is based on original field research in Mpeketoni Village carried out during June–August 2005.[3] Data were collected through a combination of surveys of SMEs, interviews with key informants, and direct observations of electricity uses. Responses to questions were triangulated by multiple interviews with different sets of individuals and groups (e.g., artisans, traders, and farmers) within Mpeketoni. Primary data were supplemented with secondary data extracted from MEP's management and financial records.

MEP keeps good records of electricity users and their activities. The data from 1994 to 2006 include technical data (units of electricity generated and sold and systems losses) and financial data on income and expenditure based on annual audited accounts. Further, a list of electricity users, supplemented by direct observations, was used to identify the number and diversity of SMEs operational in the small township covered by the micro-grid. SMEs in Mpeketoni are involved in a wide range of activities including food processing, retail and repair shops, grain milling, metal and carpentry workshops, and tailoring. Within this range of SMEs, carpentry and tailoring were selected to assess the effect of access to electricity by comparing productivity of similar enterprises "with" and "without" electricity. As explained below, the "mode of operation" in the two trades allowed the collection of comparative data using direct observations and interview methods.

Data collection was complicated by the fact that supply of electricity from the micro-grid was extremely unreliable. Typically, power outages ranged from a few hours per day to several days per month. Over time, this problem worsened as the poorly maintained diesel generators depreciated. A major break down in early 2005, for example, resulted in total loss of electricity supply in the months of January and February. Consequently, artisans in carpentry and tailoring were constantly switching back and forth between using electricity and manual labor for their production. However, the unreliable power supply permitted a rough comparison between production patterns of the same artisans as they consistently operated on two modes, that is, "with" and "without" electricity. The frequent, often prolonged, outages presented an instructive "experimental" opportunity to observe two distinct production scenarios within the same sample group.[4] In addition to direct observations, individual interviews were later conducted with the same workers to elicit further information relating to possible changes in quality and pricing of goods made with and without access to electricity. All artisans working in carpentry ($n = 12$) and tailoring ($n = 5$) shops in the village were included in the study.

Data on the broader benefits of electrification, including mechanization of agriculture and provision of communication and commercial services, were collected through interviewers with key informants. These interviews focus especially on those who had been in the village since it was established as a settlement scheme in 1972. Within this framework, it was possible to select a sample of 15 farmers who had lived in the village both "before" and "after" MEP was set up. Other key informants included a cross-section of officials (e.g., chiefs, agricultural officers, land surveyors, planners, and social workers) employed by the government and the GTZ[5]/German Assisted Settlement Program (GASP). GTZ/GASP was the primary sponsor of both the Mpeketoni Settlement Scheme and MEP. Particularly useful and comprehensive oral histories came from officials and farmers who played key roles in the establishment of both the settlement scheme in 1972 and MEP in 1994. Data on educational services were collected through interviews with teachers in local primary, secondary, and polytechnic schools.

Additional secondary data were collected from MEP records while one of the authors lived in Mpeketoni and worked as MEP Technical Advisor from September 2006 to March 2007. The data, from 1994 to 2006, include technical data (units of electricity generated and sold and systems losses), and financial data on income and expenditure were based on annual audited accounts. Overall, this broad set of evidence permits an exploration of the linkages between access to rural electrification and socio-economic benefits at Mpeketoni Village as well as of the financial viability of MEP.

4. SURVEY RESULTS

Geographically, Mpeketoni is located on the mainland to the west of Lamu Island in Lamu District, Coast Province of Kenya. With a population of about 30,000 in 2004 and covering approximately 14,000 ha, the Mpeketoni resettlement scheme was initiated in early 1970s with joint support from the GTZ/GASP and the Kenya Government. In conjunction with the Kenya Government and local communities, GTZ/GASP supported many infrastructure projects such as roads, water supply, schools, and health facilities in Mpeketoni. The Mpeketoni township, where the electricity project is located, is a trading center within an extensive agricultural settlement scheme.

As part of an integrated infrastructure package, GTZ/GASP, in partnership with the Mpeketoni community, started

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a diesel-powered micro-grid in 1994 at an initial capital cost of Ksh3.0 million (US$40,000).[6] The local community, including entrepreneurs, farmers, and institutions, contributed about 30% of the initial capital cost in cash and labor, while GTZ/GASP contributed the balance in kind in the form of generators. At the time of the study, the mini-grid operated for 19 h per day (5 am to mid-night) using three Deutz-brand generating sets. Two of the "gensets" (57 kVA and 60 kVA) could be manually synchronized; the third had a capacity of 150 kVA.[7]

Rural trade and commerce at Mpeketoni Village comprises a wide range of SMEs including food processing, retail and repair shops, grain mills, metal and carpentry workshops, tailoring, gas filling stations, and a small cotton ginnery. MEP is central to the local economy, with a diverse customer base as summarized in Table 1 below.

The data given in Table 1, organized by magnitude of monthly consumption, show that SMEs consume the most electricity (8,100 kWh/month). For example, the three grain mills in town consume over a third (2,200 kWh/month) of the electricity consumed by 105 households (6,060 kWh/month). The largest single customer, Mpeketoni Secondary School, consumes nearly 50% of the electricity used by all the households. Load (kW) for various types of customers is estimated using data on monthly consumption (kWh) and average number of hours of operation per day. According to this estimate, the total load is roughly 107 kW. SMEs account for most of the load (51 kW), followed by households (25 kW), and institutions (22 kW). Additionally, SMEs are a vital revenue base for MEP given that they pay higher fixed monthly service charges (US$6.70) than households (US$3.30).

Table 1. *Summary of electricity use at Mpeketoni Village, Kenya*

Customer type	Number of customers	Estimated total load (kW)	Total consumption (kWh/month)
Small and micro-enterprises			
Retail and repair shops	64	15	2,525
Grain mills	3	16	2,200
Petrol station, and welding garages	7	9	1,325
Bars, lodging, and hotels	5	6	1,200
Carpentry workshops	2	4	550
Small tea/food café	20	2	300
Sub/total	101	51	8,100
Households			
High-demand households (>89 kWh/month)	23	14	3,300
Medium-demand households (22–88 kWh/month)	22	6	1,320
Low-demand households (0–21 kWh/month)	60	6	1,440
Sub/total	105	25	6,060
Institutions			
Mpeketoni Sec. School	1	10	2,700
Mpeketoni hospital	1	4	700
Mosque/churches	4	3	495
Cell phone company	1	1	200
Non governmental organizations	2	1	150
Youth polytechnic	1	1	125
Post office	1	1	125
Police station	1	1	90
Commercial bank	1	1	75
District Officer's office	1	1	75
Sub/total	14	22	4,735
Small industry			
Cotton ginnery[a]	1	5	1,125
Sub/total	1	5	1,125
Total	221	107	20,020

Source: MEP Records.
[a] The Ginnery, owned by the TSS Company, had its own generator despite being connected to MEP. Supply was used mainly for lighting and other low-power loads.

Load factor (LF)[8] is a useful parameter in determining the financial viability of rural micro-grids (Fulford, Moseley, & Gill, 2000). In micro-grids lacking productive uses of electricity, electricity consumption is typically concentrated in evening hours, a pattern which can result in LF as low as 20%. In the case of MEP, however, productive uses of electricity had the important effect of enhancing the system's LF, estimated at 43%.[9] The average diurnal load profile (Figure 1) at Mpeketoni presents evidence on the extent to which SMEs enhanced electricity demand in this rural township. The data used to generate Figure 2 were obtained from MEP generator logbooks. The total dataset includes 59 days of MEP's operations for which data were available between June 2005 and April 2006.[10] Results show that peak demand at Mpeketoni occurs in the evening (7–9 pm) with lighting in households and SMEs providing most of the load at this time. During the day, when lighting contributes very little to the load, demand by SMEs accounts for most of MEP's capacity utilization. Moreover, a large number of high-demand inductive loads such as motors and welding machines are responsible for the relatively high-demand variability experienced during the day than during the evening. In addition to improving the system's LF, SMEs, as discussed below, benefited significantly from access to electricity as did the local farmers and schools.

5. IMPACT OF ACCESS TO ELECTRICITY AT MPEKETONI

Results from Mpeketoni contribute to our understanding of the linkages between rural electrification and rural development in sub-Saharan Africa. In addition to enhancing the productivity of SMEs, electricity at Mpeketoni has contributed to mechanization of agriculture, facilitated trade and commerce, and supported improved delivery of services in local schools.

(a) *Impact of access to electricity on small and micro enterprises*

Access to electricity can impact SMEs by enabling the use of electric tools and equipment, thus increasing productivity per worker. Potentially, an increase in productivity (i.e., the quantity and quality of goods made) can result in more sales, thereby boosting business revenues. Using cross-sectional data collected from SMEs, this section presents the analysis of the effects of access to electricity for 12 carpentry and five tailoring businesses in Mpeketoni. In this analysis, the impact of access to electricity on SMEs in the village is evaluated using three indicators: per worker productivity, per unit sale prices, and daily gross revenues.[11]

Even though lack of reliable data made it difficult to determine the cost of electricity per item, detailed interviews with artisans revealed that the volume of production dropped even as the cost of production increased during the long period when there was no electricity (January–February 2005).[12] As a coping strategy, the artisans increased the prices of goods

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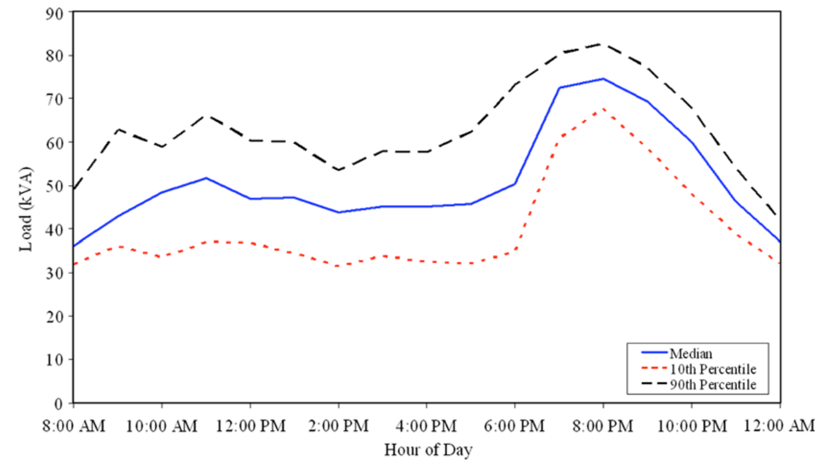

Figure 1. *The average diurnal load profile at Mpeketoni (Source: MEP Records).*

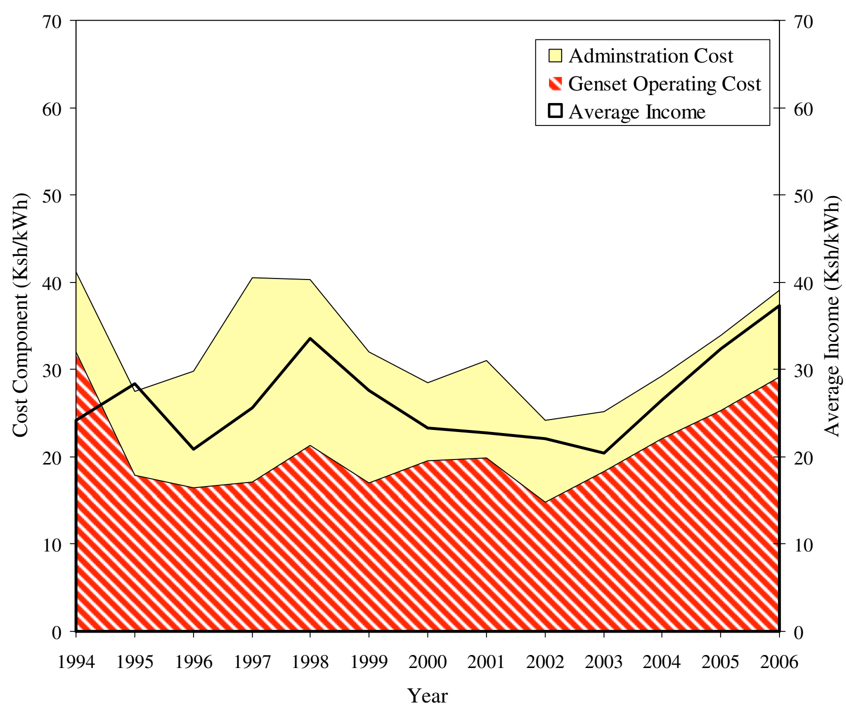

Figure 2. *Comparison of average cost and income for the Mpeketoni Electricity Project: 1994–2006 (Source: MEP Records).*

produced by between 10% and 20% for carpenters (Table 2A) and by 15–25% for tailors (Table 2B). An increase in price was in part possible because, Mpeketoni, like many other rural market centers in different parts of Kenya, is a small and isolated market (65 km and 200 km away from the two major towns of Lamu Island and Malindi, respectively), hence the price of goods produced by SMEs is determined largely by local supply/demand dynamics. As such, a combination of "with and without" observations on the production patterns and the variation in price, which is based on recall data, provides a useful dataset for making "order of magnitude" estimates of the likely impact of access to electricity on SMEs in a rural setting.

As shown in Table 2A, access to electricity enabled the SMEs to use electric tools contributing to an increase in productivity per artisan in the order of 100–200%, depending on the task at hand. Variation in price relative to the period without electricity is one mechanism linking changes in productivity to changes in revenues accruing to the artisans. As the SMEs produced more, thereby increasing the supply of goods entering the local market, the price of goods dropped. As reported by the SMEs, the drop in prices was, however, offset by an increase in the volume of sales made, resulting in significant increase in revenues in the order of 20–80%.

Apart from quantity, the quality and the wider variety of goods produced was another channel through which access to electricity contributed to improved revenues for SMEs. Electric tools enabled the enterprises to make more sophisticated and custom-made products targeting "upmarket" clientele consisting mainly of salaried professionals such as teachers, bank workers, and other civil servants working in the area.

A similar pattern for productivity and price–volume mechanism is observed for the tailoring shops (Table 2B). Use of

Table 2A. *Impact of electricity on carpentry enterprises at Mpeketoni*

Typical carpentry product	Production with electricity		Production without electricity		Impact indicators		
	Average production time per unit per artisan	Average unit price[a] (Ksh)	Average production time per unit per artisan	Average unit price (Ksh)	Increase in productivity per artisan	Price reduction per unit	Increase in gross revenue per day
Stool	3 h	300	63 h	350	100%	14%	70%
Bed (6 × 4 feet)	1 day	4,000	2 days	4500	100%	11%	70%
Sofa set	3 days	7,000	5 days	8500	67%	18%	40%
Door (6 × 3 feet)	1 day	2,000	1.5 days	2300	50%	13%	30%
Window (3 × 3 feet)	1 day	2,000	2 day	2200	100%	9%	20%
Coffee table	1 day	1,500	3 days	1700	200%	12%	20%
Wardrobe	6 days	13,000	N/A[b]	N/A	N/A	N/A	N/A
Wall-unit[c]	12 days	20,000	N/A	N/A	N/A	N/A	N/A

Source: Field data, $n = 12$ artisans.
[a] Price values as at June–August 2005 (Exchange Rate: US$1 = 75 Ksh).
[b] N/A = carpenters indicated that it was "not possible" to make wall-units without electricity because electric machines are necessary to form the "complex" designs demanded by upmarket customers.
[c] In Kenya, a wall-unit is a "custom-made" and "upmarket" wooden furniture typically located in the sitting room of the main living house and used for storage and placement of household items such as cutlery, radio, television, VCR, *etc*.

Table 2B. *Impact of Electricity on Tailoring Enterprises at Mpeketoni*

Typical tailoring product	Production with electricity		Production without electricity		Impact indicators		
	Average production per tailor per day	Average unit price[a] (Ksh)	Average production per tailor/day	Average unit price (Ksh)	Increased productivity per tailor	Price reduction per unit	Increase in gross revenue per day
Men pair of trousers	8 pieces	500	4 pieces	600	170%	17%	70%
Men suit	1.5 piece	1,700	1 piece	2,000	50%	15%	30%
Women dress	6 pieces	200	4 pieces	250	50%	20%	20%
School uniform	10 pieces	150	5 pieces	200	100%	25%	50%

Source: Field data, $n = 5$ artisans.
[a] Price values as at June–August 2005 (Exchange Rate: US$1 = 75 Ksh).

electric sewing and ironing equipment contributed to a 50–170% increase in per worker productivity. But as the supply went up, prices dropped by 15–25%, depending on the item that was being produced. As prices dropped, the volume of sales increased and the corresponding growth in revenues ranged from 20% to 70%. The impact of access to electricity can further be appreciated when one considers the time and effort required to perform a task central to the productivity of a typical rural tailor: ironing a piece of clothing. Roughly, it took 30 min to iron a typical men's coat using an electric iron, but it look 1.5 h to do the same job with a charcoal iron, exclusive of the extra time and effort taken to prepare and light the latter. Put differently, the 1.5 h taken to do a coat with a charcoal iron-box was enough to make one pair of men's trousers using an electric machine. Other factors being equal, this finding implies that for every three coats ironed using charcoal iron, the tailor lost the opportunity to produce two pairs of trousers. At a unit price of Ksh500 (US$6.70) per pair of trousers, this translates to a gross opportunity cost of Ksh1,000 (US$13). The findings from carpentry and tailoring artisans demonstrate that availability of electricity has the potential to transform rural SMEs in ways that enabled increased productivity and value addition, thus boosting income generation. Apart from SMEs, agriculture is another crucial sector that has benefited from access to electricity at Mpeketoni.

(b) *Impact of access to electricity on agriculture*

At the start of the Settlement scheme in 1972, each family was allocated 20 acres of bushland. As narrated by early settlers, farmers relied exclusively on human labor using the traditional hand tools such as axe, hoe, and *panga* (machete). This was because access to tractors to clear and plough the tracts of bushland was quite limited and costly. However, as the early settlers cleared the bushes and the potential for agriculture, particularly cotton and cashew nut farming, became apparent, entrepreneurs from earlier settlements in the region, notably Witu, about 100 km away, introduced tractors for hire at Mpeketoni. The first two tractors, farmers recalled, appeared in 1988, and due to heavy demand for them, farmers had to wait for weeks or months before their land could be cleared and cultivated. Because agriculture in the area is rainfed, such delays made it extremely difficult for farmers to plan, plant, and harvest on time. Before MEP, farmers recalled the experiences of having to make reservations and payment for tractors for as much as one year in advance. Yet, within a few months of commissioning MEP in 1994, there were over a dozen tractors for hire at Mpeketoni. Convenient and timely availability of tractors enabled the farmers who could afford to hire the services to clear and cultivate more land than was previously possible with hand tools.

Clearing more land had other subtle but crucial benefits too. Massive destruction of crops by wild animals, notably elephants and monkeys, was a major challenge early settlers had to grapple with at Mpeketoni. As early farmers recalled, clearing more land contributed to considerable reduction in human/wildlife conflicts. This development freed more time and labor for investment in agriculture, key resources that local households previously expended on round-the-clock surveillance of crop fields against the wildlife menace. Thus, the

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net effect of increased access to tractors at Mpeketoni was improved agricultural productivity, which had a positive effect on the local economy.

But how does electricity relate to diesel-powered tractors? "Without electricity, very few people would dare bring their tractors out here because in the event of a major breakdown, welding repair services could only be obtained in Witu or Mombasa (100 km and 450 km away, respectively)," explained one of the early settler farmers. Thus, local availability of electrical welding services for repairing tractors and other farm tools was the main mechanism through which electricity contributed to better exploitation of the agricultural potential in Mpeketoni. Access to electricity has also benefited farmers and SMEs in other ways. Prior to the arrival of electricity, for example, storage of perishable farm produce, notably meat and milk, was a constant headache for local farmers and traders. Electricity has enabled cold storage for farm produce and other consumer goods (e.g., soft and alcoholic drinks), a non-trivial service in this remote village.

This evidence illustrates the ways in which access to electricity played an important role in developing the agricultural potential in this part of rural Kenya. In addition, the multiple forward and backward linkages between agriculture and SMEs have catalyzed trading, and expanded income opportunities for local farmers. At the time of the survey, a number of shops and hotels in Mpeketoni bought fruits from local farmers and prepared fruit juice for sale in both the local market and Lamu Island (65 km away). This type of enterprise is a valuable income stream for both SMEs and farmers, and has benefited greatly from access to, among other factors, electric tools and cold storage.

Rural areas in Africa are typically poorly equipped with critical infrastructure that can facilitate and promote trade and commerce. Banking and communication services at Mpeketoni provide evidence on the role of electricity in facilitating rural trade and commerce.

(c) *Impact of access to electricity on banking and communication services*

The growth and vibrancy of the local trade and commerce at Mpeketoni are reflected by the presence of a commercial bank and a postal office. These commercial facilities were not only connected to electricity, but were found to use electronic equipment such as computers, printers, and photocopiers which could not operate without electricity. Computer and photocopying services are also readily available in several private shops, reflecting the role of electricity in creating an enabling environment for better business service delivery in rural settings.

Further, at the time of the survey, Internet services were available at the local postal office as part of a countrywide government-sponsored initiative. While intermittent, the Internet services were popular with local youth and other professionals working in the village, access to Internet has also been beneficial to MEP. In February 2005, for example, MEP generators suffered a major breakdown which necessitated importation of critical Deutz-brand spare parts as they were unavailable in Kenya. Access to the Internet, MEP officials explained, enabled a quick online search for availability and comparison of prices for spare parts from different parts of the world. This incident provides an example of the important role electricity can play in facilitating and lowering communication and transaction costs in rural areas. Apart from trade and commerce, education is another key development sector that has benefited from the introduction of electricity at Mpeketoni.

(d) *Impact of electricity on education services*

Availability of quality education is believed to be a crucial factor in determining the economic well-being of rural areas. This is even more critical in a remote rural village like Mpeketoni, where children have to compete in standardized national exams for placement in universities, colleges, and jobs with their counterparts in the urban and more resource-endowed areas of Kenya. Owing to limited electricity capacity available, Mpeketoni Secondary School and Mpeketoni Polytechnic were the only two, of four, educational institutions connected to the MEP grid at the time of the study. The teachers and parents who were interviewed were in agreement that academic performance had measurably improved following electrification of the Secondary School in 1994. However, as many factors are likely to influence academic performance in a typical school, interviews with the Deputy Principal and several teachers helped to carefully probe for the factors that could possibly account for the positive correlation between access to electric power and improved performance as claimed by a wide range of community members. The Deputy Principal, who had been at the school since 1991, recounted:

> "Before we got power, water was an even bigger problem. We had no piped water and students would spend 2–3 hours daily in the evenings hauling water with ropes and buckets from deep boreholes while others walked far way in search of water. Hygiene was very poor at the school." [13]

He added that toilets would seldom be cleaned due to lack of water, while water-borne diseases especially skin infections, typhoid, and cholera were particularly common. The result was rampant absenteeism of both students and teachers from school. What difference did power make? He continued:

> "Obviously our first priority when we got power was water pumping and lighting. The 2–3 hours previously dedicated to gathering water are now dedicated to evening study, with better lighting and huge cost savings in kerosene bills when we switched from hurricane lamps to electricity."

In addition, the use of electricity in the science laboratory had yielded academic improvements, particularly in the science subjects. Mpeketoni is also one of the few schools in Kenya offering computer courses to students. [14] Having their own computers and photocopying machines has, according to the teachers, improved the efficiency of processing information, particularly exams, at the school. This would not have been possible without electricity and one can therefore make a (*prima facie*) plausible connection between access to electricity and improved academic performance at the School.

Further evidence of the impact of electricity on education can be observed at the Mpeketoni Polytechnic. Without electricity, the Polytechnic could offer only very limited vocational trades classes in carpentry, but now it offers a wide variety of courses including engineering, welding, and other metal works. The Polytechnic is an important source of practical know-how and skills for hundreds of youth who find employment in local SMEs. The results of this survey show that over 70% of the youth employed and/or self-employed at the Mpeketoni *Juakali* (open-air) sheds reportedly acquired their training at the Polytechnic.

Access to electric power also enabled schools to use mass media to supplement normal classroom instruction. This opportunity is significant in the context of preparing students to take Kenya's standardized national exams. As currently designed, the standardized examination system is heavily biased against children from rural and remote areas (Daily Nation, 2007). The following quote from the teachers and an Assistant Education Officer at Mpeketoni reflects the degree of disadvantages that rural schools face as well as the role that electricity can play in partially redressing the situation.

> "In national examinations, students get tested about what is assumed to be 'common knowledge' by examiners living in cities like Nairobi. For instance, last year (2004) there was a question on the colors and the workings of traffic lights. How can this be common knowledge in places like Lamu without roads, let alone vehicles? We find TV as the only medium for exposing our students to such ideas."

Yet another advantage of electricity in schools is related to the introduction of electric lighting. Among other benefits, lighting can be instrumental in coping with a severe shortage of teachers in rural and remote locations such as Lamu District. For example, the availability of power at Mpeketoni Secondary School made it possible for teachers to provide extra teaching in early mornings and late evenings to make up for material not adequately covered during normal teaching hours due to lack of teachers.

The preceding discussion has explored the mechanisms through which electricity can positively impact SMEs, agriculture, commerce, and education in rural areas. According to the literature reviewed, however, electricity cannot take all the credit, as other factors are likely to have made an important contribution too. Next is an attempt to situate electricity within a broader integrated rural development strategy adopted by GTZ/GASP at Mpeketoni.

6. ELECTRICITY AND INTEGRATED RURAL DEVELOPMENT AT MPEKETONI

GTZ/GASP's support for an integrated package of complementary infrastructure such as roads, schools, markets, and business services—provided along with electricity—has contributed to a robust and diversified local economy, including better exploitation of the agricultural potential at Mpeketoni.

Central to Mpeketoni's economy is agriculture which is based on a variety of cash crops. Cotton is the highest income earner in the village followed by cashew nuts. The estimated potential for cashew nut production at Mpeketoni is 7,000 tons/year, with a market value of US$5 million (Scottish Power, 2005). Every year, about four to six cashew nut companies (some all the way from India) send representatives to Mpeketoni for up to 8 months to purchase nuts from farmers. Maize, bananas, and vegetables find ready markets in Lamu Island (65 km away) and Mombasa City (450 km away). A conservative figure of income from agriculture alone is US$3.0 million per year. Other cash crops grown on the modestly large farm sizes (10–15 acres/farm) include mangoes and sesame. Scottish Power (2005) reports that interviews with 56 farmers at Mpeketoni indicated that 70% of them grew more than one crop. Such diversification not only boosts farmers' income, but also acts as a vital hedge against multiple risks and vulnerabilities such as the vagaries of weather and commodity price fluctuations.

Road infrastructure is another critical piece of an integrated rural development strategy pursued by GTZ/GASP at Mpeketoni. To improve accessibility and mobility, GTZ/GASP cleared thick bushland and constructed approximately 300 km of all-weather road network (Apindi & Onyango, 2004). Constructed during 1999–2004, the extensive road network comprises three categories of roads: cutlines (9 km), field roads (200 km), and gravel roads (66.4 km). Cutlines are 2 m wide paths cleared by bulldozer in the thick bush to facilitate the demarcation of the settlement scheme and the movement of settlers into their plots. They also serve as fire breaks, thus protecting the farms from fire hazards from the adjacent pockets of natural forests. Field roads are 10 m wide and are bush-cleared, shaped, and compacted while gravel roads have been graveled with 15 cm thick compacted gravel. Importantly, this all-weather road network at Mpeketoni is connected to another major feeder road connecting the two main towns of Lamu and Mombasa.

Communication services are yet another boost to rural trade and commerce at Mpeketoni. Expenditure on information communication services (e.g., telephone) can be an effective proxy for estimating the size and vibrancy of a local market. To estimate this for Mpeketoni, sales of cell phone airtime spanning 10 months were collected from three out of the five airtime retail shops in town at the time of the study. Results show that the size of local cell phone market (approximately US$20,000 per year) is an important source of revenue for local SMEs. Because traders flocking in and out of Mpeketoni purchase the most significant proportion of airtime, these transactions act as vital means of income transfer from outside sources into the village. Road traffic is another indicator of the robustness of a rural market. While most rural markets in small towns in Kenya operate on designated days (often once a week), Mpeketoni markets operate seven days of the week. Despite unpaved roads, the small town is the destination of two to three 60-seat passenger buses per day—one from Lamu Island and two from Mombasa City, exclusive of other smaller-car vehicular traffic.

Access to business support services was another crucial element in the integrated development approach adopted by GTZ/GASP at Mpeketoni. A rapid increase in settler population combined with improvement in agricultural productivity in the village led to a modest but promising emergence of small-scale enterprises. The range of enterprise activities included bars, hotels, retail and repair shops, barber shops, tin smiths, and carpentry, among others. This trend matched well with one of the GTZ/GASP objectives: creation of non-agricultural income generation opportunities in Mpeketoni (Apindi & Onyango, 2004). In 1991, GTZ/GASP commissioned a feasibility study which recommended the establishment of SMEs and support for SMEs as a means of creating local jobs and diversifying the local economy. To this end, GTZ/GASP moved quickly to support the formation of the Mpeketoni Jua Kali[15] Association (MJKA), a self-help group for local SMEs. Officially registered in 1992 with an initial membership of about a hundred business people, MJKA became the institutional mechanism through which GTZ/GASP delivered crucial financial and technical support to SMEs, including setting up a credit fund for artisans, providing training on product design and marketing, book keeping, and self-organizing. An internal review records that in addition to organizing regular seminars and educational tours for the local SMEs, GTZ/GASP produced numerous training materials, handouts, and leaflets for the SMEs in both English and *Swahili*, the local language (Vergroesen, 1995).

Moreover, using membership contributions, supplemented by resources from GTZ/GASP, MJKA built about 20 operating sheds which the organization rented out to its members and other entrepreneurs. As reported by local leaders, GTZ/GASP was also instrumental in facilitating the opening of a

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local branch by the Kenya Commercial Bank, one of the leading financial institutions in Kenya. Importantly, GTZ/GASP hired the services of local SMEs in the implementation of its diverse portfolio of development activities such as making and installing furniture and metal works in local schools, health centers, and community halls. GTZ/GASP's policy of purchasing locally produced goods had a significant effect in growing the local market and boosting revenues for the SMEs. As the results of this study suggest, another important boost to the SMEs and the local economy was access to electricity, efforts toward which MJKA played a central role. Motivated by strong economic interest in accessing electricity, MJKA, as interviews with key informants revealed, played a lead role in mobilizing and organizing collective action which resulted in the setting up and management of MEP as a community-based electric micro-grid.

The foregoing discussion situates the impact of access to electricity within the context an externally funded integrated rural development. The empirical evidence and impact analysis presented here illustrate the possible mechanisms through which rural electrification can contribute to rural development: (i) access to electricity enables use of electric equipment and tools by SMEs, thereby boosting their productivity and revenues; (ii) in parallel, access to electricity enables and improves the delivery of social and business services from an assortment of village infrastructure; and (iii) increased productivity and growth in revenues in combination with improved delivery of social and business support services contribute to achieving higher social and economic benefits for rural communities.

However, the significant development potential of rural electrification on rural development is threatened by the typically dismal levels of cost recovery, hence sustainability, realized by these programs. Thus, attention to cost-recovery measures seems a critical piece of efforts aimed at expanding access to electricity and contribution of electricity to rural development. Indeed, a World Bank study on rural electrification asserts: "cost recovery is probably the single most important factor determining the long-term effectiveness of rural electrification programs" (Barnes & Foley, 2004, p. 4). Consequently, the experience and lessons relating to cost recovery are valuable particularly in sub-Saharan Africa where substantial resources are still required to boost access to electricity as a means of achieving the MDGs.

7. ANALYSIS OF COST RECOVERY AT THE MPEKETONI ELECTRICITY PROJECT

This analysis shows that even though MEP did not achieve profitability, this community initiative is a case study in promising efforts at recovering costs. MEP's management demonstrates an ability to adjust tariffs to reflect changes in donor funding and the cost of diesel fuel.

Figure 2 shows a comparison of MEP's average operating costs and income (Ksh/kWh) over the 12-year (1994–2006) period when financial data are available. The operating cost includes two elements: (i) generator operating costs (costs of diesel fuel and routine maintenance, such as the cost of oil and oil filters), and (ii) administration and miscellaneous costs (wages, management, billing, office supplies, and maintenance of distribution network). These cost elements are plotted cumulatively. The average income per unit (i.e., the average electricity tariff) (Ksh/kWh) is derived from electricity sales and related charges, such as monthly service charges, and connection fees. The degree of operating cost recovery is indicated by the *position* of the income line in Figure 2 relative to the area of each cost element. In 1995, for example, the average income line is marginally above the administration cost area, suggesting full recovery of operating costs incurred that year for both running of the generators and administration.

The average income line in Figure 2 shows that, except in its inaugural year, MEP managed to recover in full the genset operating cost, which made up the lion's share of all the total costs.[16] However, when the genset running costs and administration costs are combined, the average rate of cost recovery over the 12 years drops from 100% to 79%. The operating deficit was covered mainly by subsidy from GTZ/GASP, the primary sponsor. Supplementary revenue to cover the operating deficit came from a grain mill which MEP, with the support from GTZ/GASP, had acquired as an income generating activity. Furthermore, MEP's financial performance trajectory took an appreciably positive turn in 2004. Interestingly, this is the year in which GTZ/GASP completed its phase out from Mpeketoni. Without GTZ/GASP to fall back on, MEP raised tariffs steeply achieving 94% recovery of operating costs during 2004–06. It is noteworthy that the sustained improved financial performance during this period is recorded despite a steep rise in genset operating cost. A corresponding sharp rise in the price of diesel fuel in Kenya and globally was responsible for this increase.

However, the commendable efforts at meeting the operating costs masked an underlying sustainability problem as MEP was progressively running down its capital assets. MEP's revenue was not sufficient to cover 100% of the operating costs (Figure 2) let alone depreciation costs;[17] it is no surprise, therefore, that the net book value (NBV) was declining (Figure 3). Ideally, NBV should not decrease. To achieve this, revenue from electricity sales must be sufficient to allow for savings and re-investment to replace depreciating capital. As such, a declining NBV, as shown in this case, suggests that the capital base was not being replenished at a sustainable rate. As MEP officials explained, the rising cost of fuel had the effect of draining away MEP's revenues, resulting in a situation where maintenance of the generators took place on a "management by crisis" basis rather than on a preventative basis. The result was provision of relatively poor quality service, including power rationing, despite the high tariffs charged.

It would have been interesting to actually see if and when MEP would achieve full cost recovery and what corresponding steps would have made this happen. However, this learning opportunity was lost as the Government took over the generation and distribution of electricity at Mpeketoni on September 30, 2007. Through the Rural Electrification Program (REP), the Kenya Power and Lighting Company (KPLC), the national utility, installed a new and larger (250 MW) diesel-distributed generation system to supply power to Mpeketoni and surrounding villages. Aside from receiving a 24-h/day power supply, the Government's takeover resulted in considerable consumer surplus. This is because, under REP, Mpeketoni customers obtained service at a highly cross-subsidized rate of Ksh8/kWh (US$0.11/kWh) compared to Ksh37/kWh (US$0.53/kWh), the rate MEP customers were willing to pay at the time of the takeover. Conversely, this arrangement yielded a negative producer surplus because the cost of diesel-powered supply by the KPLC (Ksh39/kWh or US$0.56)[18] was nearly five times the REP tariff at the time of the takeover.

Yet, the takeover of MEP by the Government has positive implications for group-based micro-grids as an option for promoting off-grid rural electrification in East Africa. Apart from demonstrating the potential for cost recovery, MEP's operation provided two functions upon which the national utility

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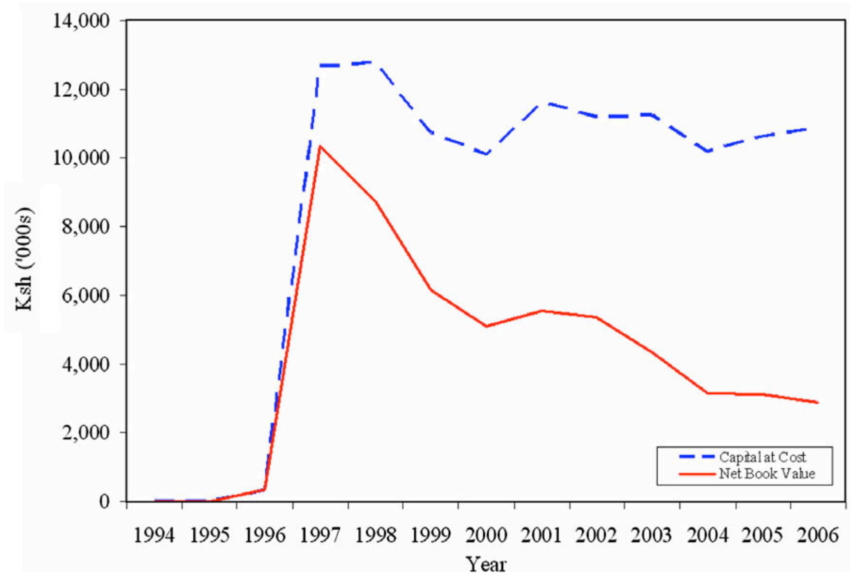

Figure 3. *Comparison of capital at cost with net book value of the Mpeketoni Electricity Project (Source: MEP Records).*

can build and expand: identifying and growing local electricity load; and creating a solid and diverse customer base. Similar community-based electric micro-grids, implemented through a combination of cooperatives and village electrification committees, have made a significant contribution to off-grid rural electrification in South and East Asian countries (Chaurey *et al.*, 2004; Gerger & Gullberg, 1997; Greacen, 2004; Khennas & Barnett, 2000; Pandey, 2004).

8. LESSONS AND POLICY IMPLICATIONS FROM THE MPEKETONI EXPERIENCE

This study helps clarify the mechanisms through which rural electrification can contribute to rural development. Access to electricity enables the use of electric equipment and tools by SMEs, thereby boosting their productivity and revenues in clear and compelling ways. With access to electricity, productivity per worker increased by 100–200%, depending on the task at hand, while increases in gross revenues ranged from 20% to 125%, depending on the product made. Simultaneously, access to electricity enables and improves the delivery of social and business services from a wide range of village-level infrastructure such as schools, financial institutions, and farming tools. Increased productivity and growth in revenues within the context of better delivery of social and business support services contribute to achieving higher social and economic benefits for rural communities.

Another key finding relates to cost recovery. MEP has demonstrated that community-led rural micro-grids have the potential to cover a substantial proportion of the operating costs from internal revenue derived from sales of electricity and other charges. At the time of the takeover by the Government in September 2007, MEP had attained 94% cost recovery, nearly five times that realized by the diesel-powered micro-grids operated by the KPLC, the national utility.

Two factors appear central to the set of circumstances that enabled MEP to realize a reasonably high degree of cost recovery. First, is the ability to charge and enforce cost-reflective tariffs. In this regard, the latest energy legislation in Kenya which permits investors in rural electrification projects to charge tariffs that cover operating costs and yield a return on investment is in the right direction (Government of Kenya, 2006). Second, cost recovery of rural electric micro-grids is closely linked to promoting productive uses so as to generate local revenues and improve the system's LF. In this particular case, the ability of MEP's customers, especially SMEs, to pay cost-reflective tariffs depended on the existence of a range of productive uses of electricity as reflected by the relatively high load factor (43%). By one estimate, micro-grids with low LF (20–25%) tend to require considerable levels of subsidy (60–80%) if only to keep them running (Fulford *et al.*, 2000). Conversely, with a LF of 43%, MEP's level of external subsidy was at most 31% of its operating costs.

The experience at Mpeketoni has four important policy implications for rural electrification programs in Kenya and sub-Saharan Africa. First, while subsidies have drained the resources of public utilities, thus affecting the quality of services delivered to customers and severely constraining the rate of new connections (Karekezi *et al.*, 2002), a World Bank study (Barnes & Foley, 2004) suggests the circumstances under which provision of capital subsidy (in the form of concessionary interest rates or grants) to support rural electrifications programs may be justified: "Provided it is used wisely, and operating costs are covered, having access to such concessionary capital need have no ill-effects on the implementing agency or the rural electrification program. But concessionary capital should never be provided to organizations which are not covering their operating and maintenance costs..." (p. 4). Taking these criteria into account and in view of the positive experience at Mpeketoni, the merits of offering a one-off financial or capital subsidy to support communities and/or private investors setting up DG systems in rural deserve serious consideration. In the Kenyan context, such subsidy could be drawn from the Rural Electrification Fund and/or the Constituency Development Fund (CDF).[19]

Second, rural electrification policy should be coordinated with other infrastructure development efforts to provide a broad set of complimentary infrastructure. Rural areas in sub-Saharan Africa are typically poorly equipped across a number of infrastructure categories, thus it is essential to improve physical infrastructure (e.g., roads and electrification) in tandem with both social and business infrastructure (e.g., schools, health facilities, and markets). Integrated infrastructure development efforts can create substantial multiplier effects, including the reduction of transactions costs, thus making rural SMEs competitive in out-sourcing of business services and products destined for the lucrative urban markets.

Third, to improve the prospects for rural development, the experience at Mpeketoni highlights the need to develop a set of pre-qualification criteria for selecting and prioritizing rural areas and socio-economic facilities to be electrified. To this end, it is encouraging that an autonomous Rural Electrification Agency (REA) has been created in Kenya (Government of Kenya, 2006) as well as in neighboring Tanzania (Marandu, 2002). This study strongly recommends going beyond creation of a REA to designing and publicizing both the criteria and the schedule of areas to be electrified annually. Such a move would raise awareness and provide critical public oversight and accountability. Such oversight is likely to happen because target communities, local elite, and politicians have the motivation and information to ensure that their villages are not short-changed and/or by-passed when their regions fall due for electrification. Similar strategies have been followed in publicizing money allocated toward free-primary education and the Constituency Development Fund in Kenya.

Fourth, the experience at Mpeketoni highlights the potential of an alternative, largely unexplored, way to accelerate rural electrification in Kenya and East Africa. This approach involves the use of group-based micro-grids that are initiated and managed as common property resources (CPRs). The micro-grids can be based on the use of a mix of energy sources (e.g., diesel, micro-hydro, solar, wind, and biomass) to serve small and geographically dispersed villages. As a community-led initiative, MEP's performance begs further research to explore the likely incentives and constraints of initiating and managing electric micro-grids collectively. Understanding the factors likely to make individuals participate and contribute toward collective action for the management of group-based electricity micro-grids would be important. Of particular interest is an empirical inquiry into the ways in which heterogeneity of economic interest (i.e., differences in electricity end-uses) is likely to shape the incentives for collective action, patterns of electricity consumption, equity in access to electricity, and mechanisms for conflicts resolution.

NOTES

1. For details on the advantages and complications of using this approach in measuring the impacts of rural electrification (see IEG, 2008, Appendix H; pp.131–135).

2. A multifunctional platform is a diesel engine (typically 10 hp), mounted on a steel chassis, that powers a variety of end-use equipment such as grinding mills, de-huskers, battery chargers, and water pumps. The engine can also generate electricity for a variety of end-use applications.

3. This research was approved by the Office of the Protection of Human Subjects at the University of California, Berkeley (CPHS # 2005-4-53).

4. One caveat in the assessment of the impact of electricity is that artisans in a "without" electricity situation may not behave like they would if they had no access to electricity at all. They may, for example, shelve specific tedious tasks for the time power gets restored, thereby distorting the observed apparent impact of electricity. Nonetheless, individual interviews with the same artisans helped to minimize possible bias in the reported improvements in productivity.

5. GTZ is Gesellschaft für Technische Zusammenarbeit, a private company owned by the German government (http://www.gtz.de/en/index.htm).

6. Money values are in constant Ksh2007 or constant US$2007. I maintain this conversion throughout the paper unless otherwise stated.

7. The 60 kVA genset was down for overhaul at the time of survey and was not returned to service until November 2006. The 150 kVA genset went out of service in September 2006 and had not been repaired as of March 2007.

8. Load factor is the ratio of average energy consumption to the maximum possible energy consumption.

9. This estimate takes into account that MEP was operating for 19 h per day.

10. While MEP operated from 5 am to mid-night, the generator logbooks did not include data between 5 am and 8 am.

11. A number of factors made it difficult to estimate the cost of production, hence net revenue, for the typical items produced by the sample SMEs at Mpeketoni. Apart from poor record keeping, most SMEs shared electric meters with other activities (e.g., shops and rental houses) and electric bills were shared equally, irrespective of individual consumption. This arrangement made it difficult to estimate the cost of electricity per item produced. Further, the annualized cost of capital investments could not be reliably determined because most of the machines in use at the time of the study had been purchased as second-hand (or used) tools many years before. Additionally, as is typical with SMEs in Kenya (see Kabecha, 1999), most of the machines were quite old while others (e.g., electrical planes) had gone through considerable modification locally. These factors, exacerbated by poor record keeping, made it difficult to accurately assess the original or re-sale value of the end-use equipment and tools used by the sample SMEs at the time of the survey. In light of these challenges, gross rather than net revenue is used as one of the impact indicators, which, for the type of "order of magnitude" estimates being made here, should suffice.

12. The interviewer (the lead author of this paper) held detailed discussions with the artisans to understand not only the benefits of access to electricity but also how the artisans (individually and as a group) coped with the frequent, and in particular the prolonged, loss of electricity supply. Each artisan was asked to indicate the items he/she had made during the two-month period when there was no power supply and, if sold, at what price. This information was further cross-checked with a number of key informants in the village, including the leaders of the Mpeketoni Jua Kali Association, a self-help group for local SMEs.

13. This quotation, as are others that follow, is a paraphrased translation from an unrecorded interview conducted in Swahili or Kikuyu during one of the author's field work.

14. The school has purchased some computers, while others have been donated by various organizations. A number of organizations commonly

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donate computers to schools in Kenya, but eligibility for this opportunity depends on access to electric power.

15. In *Swahili*, *jua kali* literally means ''hot sun.'' Colloquially, the phrase is commonly used to refer to the widespread practice in Kenya of SMEs operating in open-air sheds lacking basic facilities such as shelter, electricity, water, and communication, among others.

16. The inaugural year, 1994, is an anomalous year because MEP started operations in August, selling few units of electricity relative to high costs. This largely explains the peak in unit cost which declined sharply in the following year.

17. Capital subsidy from GTZ/GASP was received in the form of grants, thus MEP was not repaying any loan on this capital. For the sake of financial viability, however, it was essential for MEP to account for depreciation costs, that is, set aside a proportion of its revenue for re-investment to replace its depreciating stock of capital. The depreciation costs data were extracted from MEP's annual audited accounts.

18. According to a Ministry of Energy's Task Force on Rural Energy (2003), the operating cost of the isolated diesel-powered systems managed by KPLC is about Ksh39/kWh, yet the electricity from these systems is sold at a cross-subsidized average rate of Ksh8/kWh (Ministry of Energy, 2003).

19. Created by an Act of Parliament, CDF is a grant from the Kenya Government allocated annually to every constituency represented in Parliament to meet community-driven development projects.

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