A case study on private provision of photovoltaic systems in Kenya

Mark Hankins

Message from the editors

Fewer than 2 percent of Kenya's rural households have access to electricity from the grid. Efforts by the state monopoly to improve that figure by expanding the grid have had little effect, in part because the rural population is so sparse. Some rural households have turned to different suppliers with different technology—private companies providing photovoltaic systems. Since 1990, more than 2.5 megawatts of photovoltaic electricity have been sold in Kenya, mostly to households among the top 25 percent of rural income earners. The photovoltaic market has grown in stages as technological and commercial innovations have brought it within reach of lower-income users. Photovoltaic units have gradually become smaller and cheaper. Just as important, hire purchase and finance agencies have entered the market, enabling lower-income families to buy systems on credit. The government has largely taken a hands-off approach. That, combined with its liberalization of foreign exchange and import regimes, has allowed private entrepreneurship to flourish.

The Kenyan photovoltaic industry should be of interest to other developing countries—in Africa and elsewhere—because it provides a low-cost model for sustainable, private sector–based off-grid rural electrification (box 1). Some 120,000 solar photovoltaic systems for household use (lighting, radio, or television) have been sold in Kenya since 1990, and in 1992–98 the market grew by more than 20 percent a year. (In 1999 sales dropped as a result of a downturn in Kenya's economy.) Most buyers are rural, middle-class households that lack confidence that the power grid will be extended, are knowledgeable about photovoltaic system performance, and want to make existing battery systems less maintenance intensive. Local entrepreneurs have played a key role in the process by aggressively moving photovoltaic systems to market and by downsizing the product to the needs of the lower-income market.

This market has developed in an environment where rural grid electrification had been lagging population growth for years and less than 2 percent of Kenya's 3.7 million rural households have access to grid electricity (box 2). The monopoly utility Kenya Power and Light could not cost-effectively reach most rural customers, who are far from each other and existing distribution systems. By 1999 only about 61,500 households had been connected in the more than fifteen years of Kenya Power and Light's rural electrification program (figure 1). These households consume 153 gigawatt-hours, or 4 percent of the country's demand, in 135 schemes around the country. Even if the annual connection rate more than doubled from its current rate to 10,000 connections a year, it would take almost 400 years to connect the existing rural population. In response to the slow pace of grid expansion, and starting in the mid-1970s, a small portion of salaried rural Kenyans concluded that rural electrification efforts would not reach them and began looking for alternatives.

Three stages of market development

Between 1982 and 1999 the photovoltaic market grew into a US$6 million a year industry in three stages. In the first stage upper-middle-class rural innovators—as well as nongovernmental organizations (NGOs) working off-grid—installed complete photovoltaic systems that generated demand for the technology. In the second stage large numbers of rural people bought small photovoltaic panels and batteries, primarily to power televisions. In the third stage hire purchase and finance agencies began to offer systems, allowing far more rural Kenyans to buy them on credit.

Box 1 Solar home systems

Solar home systems are an increasingly important means of providing lighting in dispersed off-grid areas of developing countries. More than 600,000 solar home systems are installed in rural areas of the developing world, many of them in the Dominican Republic, India, Indonesia, Kenya, Morocco, the Philippines, and Zimbabwe.

These are the main components of solar home systems:

- *Solar cell modules,* which convert sunlight to electricity. Solar home systems use modules that produce between 12 and 60 watts.
- *Lead-acid batteries,* which store the energy collected during the day so that it can power lights, radios, and televisions at night and during cloudy weather. Specially made deep-discharge batteries are preferred. But many people use automotive batteries, which are cheap and readily available.
- *Charge controllers* (also called *regulators*), which manage the electric charge, protect batteries from damage, and show the status of the system.
- *Low-voltage direct current (DC) appliances.* Solar home systems use DC electricity and require efficient lights, radios, and televisions. Local assembly of DC fluorescent lamps is common where solar home systems are sold.
- *Accessories.* Module mounts, wiring and fuses, battery boxes, switches, and other common electrical accessories connect the components of a photovoltaic system. The accessories for alternate current (AC) systems can often be used in solar lighting systems.

Box 2 Demographic and economic indicators for Kenya

Population size	30.5 million
Growth rate	2.7 percent
Rural share	79 percent
GDP, 1999	US$9.6 billion
GDP growth, 1993–99	1.8 percent
Per capita income	US$296
Access to grid electricity, 1999	Less than 2 percent of rural population About 8 percent of total population
Exchange rate, January 2000	70 Kenyan shillings = 1 U.S. dollar

Source: Kenya, Central Bureau of Statistics 1999a, 1999b.

Stage 1: innovators and NGOs

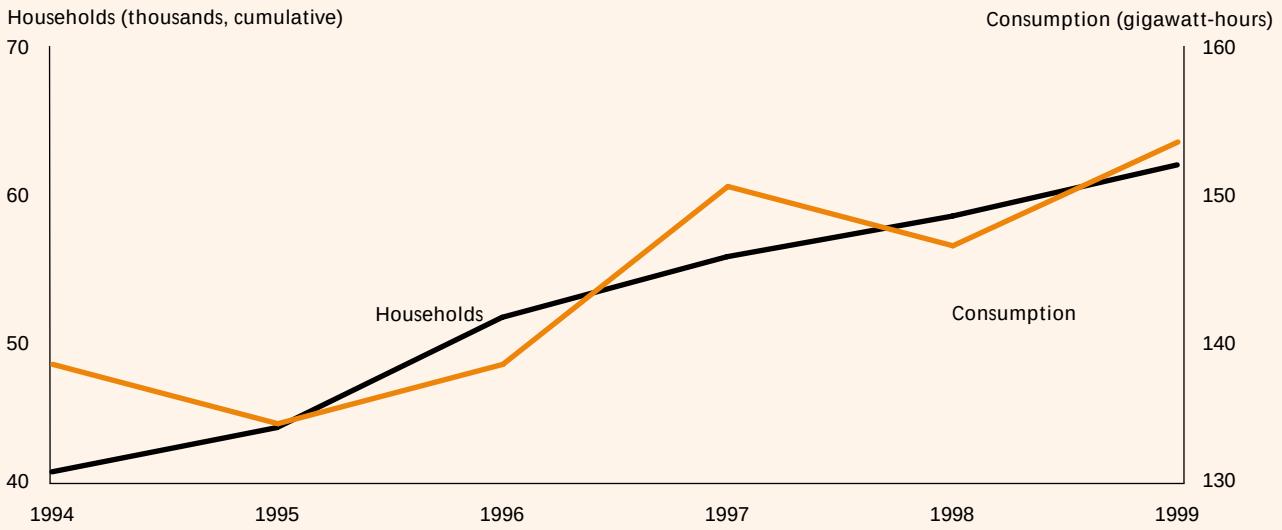
After a significant drop in the price of solar modules, donors and governments began turning to photovoltaic technology for remote power needs in East Africa. In 1982 photovoltaic-powered water pumps came into use in refugee camps in Ethiopia and Somalia. Lighting systems and vaccine refrigerators found applications in missions and clinics in Kenya, Tanzania, and Uganda. In addition, signaling and telecommunications became an immediate market for solar modules. These developments, virtually all donor or government led, initiated East African trade in photovoltaic systems, and Nairobi companies began to stock modules.

It did not take long for the rural market in Kenya to discover that, for lighting and television, photovoltaic systems are superior to generator sets. A small number of donor-initiated projects (church organizations, international NGOs, and small-scale bilateral aid projects) installed demonstration systems in off-grid schools and missions. For example, one project installed four photovoltaic systems in rural boarding schools. Within two years headmasters and scores of other community members had purchased systems for their households. After several initiatives trained rural photovoltaic agents to install and sell systems, local companies went after this household market.

In the early years well-engineered, complete systems were common, typically from 40 to 100 peak watts, with one battery powering five to ten lights and a black and white television. Marketing was easy. During the 1980s coffee boom, any off-grid coffee or tea farmer or businessperson with a permanent stone house was a candidate for a solar home system. Moreover, once a community leader had a photovoltaic lighting system, it did not take long for his middle-income neighbors to buy one too. And once the technology was known in a community, it became common for urban-based Kenyans with disposable income to purchase photovoltaic systems for their rural homes.

By the end of 1990 Kenya had more than 0.5 megawatt of installed photovoltaic capacity and at least 5,000 installed solar home systems. Although donors continued to purchase 20–40 percent of the photovoltaic equipment each year, they became far less important than the household market. Kenya

Figure 1 **Rural electrification in Kenya, 1994–99**



Note: The years refer to fiscal years.
Source: Kenya Power and Light, annual reports for fiscal 1996–99.

had nine importers of photovoltaic modules and scores of agents, mostly serving the Mt. Kenya cash-crop region.

Stage 2: mass-market, battery-based systems

Aggressive marketing quickly saturated the market for buyers of large solar home systems. Less than 0.5 percent of rural Kenyans can afford to spend US$1,000 or more for a 60-peak-watt solar home system, and by the early 1990s this market was quickly "creamed off."

Photovoltaic 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 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. Since 1990, 5–10 percent of rural Kenyan families have bought small Chinese black and white televisions (Musinga and others 1997). In the early 1990s these televisions cost less than US$50 apiece. By the mid-1990s, 10 percent of local battery production—as many as 60,000 units a year—was being sold in the rural television and photovoltaic system market. (Tens of thousands of people use batteries to power televisions without photovoltaic modules.)

With the growth of the television market came smaller, cheaper, and incrementally purchased photovoltaic systems. Rural television buyers are cash-strapped and cannot make large cash outlays. After paying US$50 for a television and US$50 for a battery, most are not interested in a 60-peak-watt photovoltaic system that costs ten times that amount. Photovoltaic panels are still desirable, however, because they eliminate the need to carry a battery to and from a charging station.

Thus it is not surprising that interest soared in smaller, lower-cost photovoltaic modules once they became widely available. The modules were imported from Croatia, France, and Wales. In 1990 only 2,400 12-peak-watt modules were sold, at a retail price of about US$100 each. By 1998 more than 22,000 modules were selling each year, and the retail price had dropped to US$65.

Such small modules do not supply enough electricity to power a family's lighting demand. Still, more and more photovoltaic systems were being purchased a piece at a time, and vital system parts—such as charge regulators, which help protect batteries—were being left out. Yet the poor performance of smaller photovoltaic modules and systems did not slow sales (figure 2). The reason? Many consumers learn to conserve their modules' output by using the television and lights less. In addition, many purchase additional modules later when they can afford them.

Stage 3: financing mechanisms

Growing demand for photovoltaic systems inspired traders to look for ways to generate even higher sales. As noted,

middle-class incomes are not high enough to cover the up-front costs of complete systems. But buying equipment incrementally is only a partial solution because it results in systems that are undersized, incomplete, and short-lived (due to battery failure).

Hire purchase of consumer goods—sewing machines, televisions, stereos, bicycles, sofas—has been common in Kenya for at least twenty years. Under this arrangement a wage employee signs up with a hire purchase company that automatically deducts monthly payments from his or her salary. Interest rates, which run 40 percent a year or more, are factored into the price. In 1996, after at least one failure to market photovoltaic products through hire purchase companies, a leading photovoltaic company tried to build sales through hire purchase agencies. The company offered attractive credit terms to hire purchase retailers and sought a wide base of agents. In 1998 the company sold more than 1,500 systems (and modules) on credit. Today at least four leading photovoltaic importers supply systems to hire purchase agents, and 15 percent of the solar home system business passes through hire purchase.

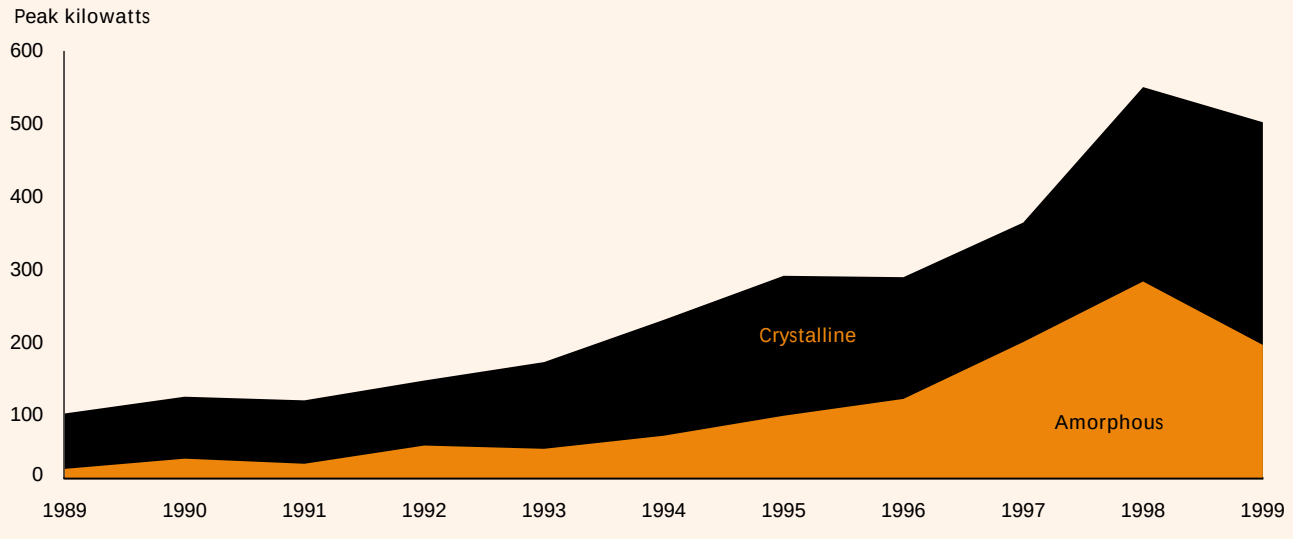
Traditional loans dedicated to solar home systems are still in the early stages, because banks and credit cooperatives are reluctant to enter the photovoltaic business. Certainly, thousands of salaried people have used loans from banks and cooperatives to buy photovoltaic systems. But these ordinary loans are not trackable as solar home system loans.

The World Bank, through the Energy Sector Management Assistance Programme, has tried to stimulate financing for photovoltaic systems. One project worked with two rural banks to develop loan lines dedicated to solar home systems. The demand for the loans was far greater than the supply, repayment rates were high, and installation quality was excellent. Bundling the systems and loans together into one program enabled loans to be priced much lower than regular commercial retail rates. As new products, however, solar home systems required a lot of extra staff time from the two banks. Still, the project underscored the need to educate financial institutions about the demand for and the value and viability of financed solar home systems. As a result of this and a new initiative by the International Finance Corporation, commercial banks and rural savings and credit cooperatives are now more aware of the demand for and viability of finance in providing basic electricity service to rural people through photovoltaic systems. Unfortunately, 1999 was a poor year for the Kenyan economy, undermining efforts to grow lending.

Market prospects

Since 1990 more than 2.5 megawatts of photovoltaic capacity have been sold in Kenya. More than 60 percent of these sales went into solar home systems. By 1999, 3–4 percent of the rural population had acquired a photovoltaic system, and at least 70 percent knew what such a system was. That same year the total photovoltaic market was about 480 peak kilowatts. Of this,

Figure 2 **Estimated photovoltaic sales in Kenya, 1989–99**



Note: Crystalline silicon solar cell modules are manufactured from ingots of very pure silicon. Amorphous solar cell modules are manufactured using a less expensive process. Some amorphous modules have quality problems, but most experts agree that they will eventually be the most common technology.
Source: Energy Alternatives Africa, annual surveys.

more than 250 peak kilowatts came from modules of 20 peak watts or less. This sustained and growing demand is a clear indication of the value rural people place on modern energy.

Data suggest that photovoltaic systems are being bought not by the elite, but mostly by upper-middle-class people—that is, the top quarter of rural income earners. According to a 1997 survey of 1,200 households, the total demand for solar home systems in rural Kenya is about 25 peak megawatts, and the effective demand is 14 peak megawatts (table 1). Market penetration is occurring at about 1 percent a year, and 5–10 percent of the total demand has been satisfied.

But when given a choice between a solar home system and grid power, rural Kenyans universally prefer the grid. If people even hear that electricity service will be supplied in an area, they will wait five years for grid power rather than buy photovoltaic systems. Grid electricity offers more appliance choices and lower costs. But most rural Kenyans do not have a choice. Between 1995 and 1999 the rural electrification program connected fewer than 21,000 households. During the same period more than 80,000 households bought solar modules.

Market players

Today's photovoltaic industry involves an increasing number of players:

- There are ten to twelve photovoltaic equipment importers, many of which have turnovers above US$500,000, and nearly all of which deal in other products related to photovoltaic power. For example, one major photovoltaic importer is a battery manufacturer, another is a television and appliance dealer, and another sells power electronics.
- There are hundreds of retailers—including appliance vendors, automotive parts suppliers, hire purchase agents, and a few dedicated "solar retailers"—selling to customers from urban and small town outlets.
- There is a small but active group of local manufacturers that assemble and sell system components, including 12Vdc (volts of direct current electricity) lights, cables, charge regulators, and batteries.

Consumer benefits

Surveys show that about 60 percent of buyers are satisfied with their photovoltaic systems, and 94 percent would recommend them to a friend (Hankins, Ochieng, and Scherpenzeel 1997).

A dealer's purchase price for a photovoltaic system can be as little as US$150 for a two-light, 12-peak-watt system with batteries and wires (without a charge regulator). In real terms prices for photovoltaic electricity have fallen over the past five years as a growing number of importing companies have increased competition (table 2).

Photovoltaic systems can save consumers more than US$8 a month over more traditional forms of energy, with 80 percent of the savings coming from lower kerosene and dry cell consumption (table 3). Thus a 10- to 15-peak-watt photovoltaic system will pay for itself within 1.5–2.0 years. The smallest systems—that is, 10–15 peak watts—offer the largest incremental savings. Incremental savings are much smaller for larger systems. These savings explain why many rural Kenyans buy small photovoltaic modules and batteries without charge regulators. The first solar home system that a Kenyan buys is likely to be lower quality and less economic. Still, the photovoltaic panel and battery set brings better energy services and cash savings immediately, even if it does not last as long as a well-designed system.

Photovoltaic electricity and 12-volt lead-acid batteries are vastly superior to kerosene and dry cells, mainly because they are more convenient. Electric light is much higher quality than that provided by a kerosene lamp: it provides far more lumens per dollar, it does not smoke, and it can be switched on and off at will (no need to light a lamp). Similarly, a 12-volt battery can run multiple appliances—a television, lights, and a radio—for much longer periods than can a

Table 1 **Breakdown of the demand for solar home systems in rural Kenya**

Type of system consumer could afford	Share of population (percent)	Average monthly energy expenditure (U.S. dollars)	Number of households (millions)
None	40	< 7.4	1.60
One light (5–12 peak watts)	34	7.5	1.36
Two to four lights (15–40 peak watts)	22	7.5–11.0	0.88
Five or more lights (> 40 peak watts)	3	> 11.0	0.12

Source: Musinga and others 1997.

Table 2 Cost and size of average consumer photovoltaic systems in Kenya, 1995–96

System size (watts)	1995 Cost (U.S. dollars)	1995 Watts used	1995 Installed cost per watt (U.S. dollars)	1996 Cost (U.S. dollars)	1996 Watts used	1996 Installed cost per watt (U.S. dollars)
< 16	227	12	18.9	217	12	18.1
16–25	453	22	20.6	399	21	19.0
26–45	734	40	18.4	643	41	15.7
> 45	958	67	14.3	839	56	15.0

Source: Hankins, Ochieng, and Scherpenzeel 1997.

dry cell. And as noted, adding a solar module to a battery system reduces the need to carry the battery back and forth for charging at a distant center. In addition, photovoltaic and battery systems are preferred to generator sets. Photovoltaic systems are cheaper and more convenient for typical rural needs. Even the smallest generator retails for more than US$500, not including installation. Used for four or five hours a day, such a set costs US$64 a month to fuel, plus maintenance. Moreover, to get light in the middle of the night, the household has to start up the machine. Solar systems provide households with round-the-clock electricity.

Still, even in Kenya it is doubtful that the poorest 40 percent of the population—which relies mostly on subsistence farming—would consider photovoltaic power a priority. In terms of megajoules, wood is by far the most important form of energy in East Africa. It is usually a collectable "free" resource. But burning wood does not provide acceptable lighting levels, and neither radios nor televisions can be powered by wood. Most rural Kenyans continue to use kerosene for lighting, dry cell batteries for radios (more than half of rural households own a radio or radio-cassette player; Musinga and others 1997), and wood for cooking. Families pay US$5–10 a month for kerosene and dry cells, while women and children tend to collect wood. Higher-income households use more kerosene and dry cells, while lower-income households limit their purchases to times when they have cash flow (after harvests, at the end of the month, and so on).

Government policy

The demand for electricity in Kenya is growing by about 6 percent a year. Energy policies are primarily targeted to

Table 3 Monthly savings reported by photovoltaic consumers in Kenya, by system size, 1996
(U.S. dollars)

Source of savings	1–15 watts	16–25 watts	26–45 watts	46–200 watts
Battery charging	1.71	1.45	1.75	1.42
Kerosene	2.93	3.87	5.64	6.78
Dry cells	3.89	3.75	5.02	4.24
Other	0.00	0.31	0.27	0.33
Total	8.55	9.40	12.65	12.76

Source: Hankins, Ochieng, and Scherpenzeel 1997.

meet the electric power industry and commercial fuel supplier needs, which have a direct bearing on Kenya's urban infrastructure. Through the 1997 Electric Power Act, Kenya liberalized the power sector and privatized the main power company, Kenya Power and Light—though the government still owns a controlling share. Kenya Power and Light now buys electricity from three new independent power producers, and more independent producers are preparing to enter the market. While Kenya Power and Light retains a monopoly on distribution, privatization has forced the utility to carefully scrutinize programs that are not cost-effective, including its rural program. It has limited generation capacity—about 800 megawatts in 1999—and has made urban and industrial customers a priority.

But the government's hands-off approach to the off-grid private sector has helped the photovoltaic industry flourish. Over the past five years the removal of import, price, and foreign exchange controls has opened markets to competition. The government has reduced duties on photovoltaic modules to 5 percent and removed the value added tax, lowering photovoltaic system prices to consumers by 15–20 percent. The Kenyan shilling is freely convertible. Moreover, after South Africa and Zimbabwe, Kenya has the continent's most thriving secondary capital market: debentures, mortgages, pensions, bonds, and stocks are traded widely. This environment has encouraged international photovoltaic suppliers to establish local bases in Kenya to serve the East African market—modules come to Kenyan vendors from Australia, Croatia, France, India, Japan, Russia, Spain, the United Kingdom, and the United States. The competition has led to more competitive pricing and a wide range of product selection. Still, photovoltaic prices are more competitive in Asian countries such as China and Indonesia.

A final benefit of the government's hands-off policy is that there have been no large projects or government tenders to distort the industry. In other countries (India, South Africa) large projects and unsustainable subsidies for photovoltaic equipment have undermined private sector activity, because big players move in and out of the market at will to take advantage of the handouts. In Kenya the market's commercial base has made it more sustainable.

Still, a number of policy-related hurdles remain:

- Conventional rural electrification equipment and photovoltaic modules are exempt from duties and value added taxes. But batteries, charge regulators, inverters, and efficient appliances are charged duties and value added taxes in excess of 35 percent of their price. (Kenyan manufacturers make more than 90 percent of the batteries used in local solar home systems, 30–50 percent of the lamps, and perhaps 10 percent of the charge regulators.) There is a need to level the playing field for electrification options.
- The industry suffers from erratic equipment and installation standards. Dealers undersize or leave out vital components to win contracts, and there is little incentive for proper engineering. Prevalent sales and installation practices undermine consumer confidence in photovoltaic equipment, especially larger systems. Although many people are satisfied with marginally functioning systems, others will not consider using photovoltaic systems because they view them as inferior. Consumers need to be made aware of what a well-designed system can do. Without consumer awareness, it is hard for companies to promote quality.
- The industry suffers a lack of trained technicians. Without systematic technician training, installation—and hence system quality—will remain poor.
- Financing for photovoltaic systems is the next frontier in making the technology more widely available and functional. Rural residents cannot afford to buy complete systems all at once. But Kenya has a strong rural credit tradition and hire purchase movement and this is fertile ground for more experimentation.

Conclusion

Kenya's experience should be replicable in other countries facing similar conditions. Key among these are:

- Low grid coverage.
- Adequate rural incomes (there is a well-developed middle class) and a large number of rural people who want lights and power for their televisions (television broadcasting reaches deep into rural areas).
- A strong entrepreneurial class. Many components of photovoltaic systems—including batteries, lights, and cables—were already sold by traders before the industry took off. This made it easier for small-scale traders to enter the market. A good flow of customer feedback to importers, wholesalers, and retailers of photovoltaic products has developed. This has helped the industry to respond to new customer demand for smaller, lower-cost systems. And the modular nature of photovoltaic technology has allowed customers to add a module when their energy needs require and budget permits.
- A relatively progressive financial sector that has (albeit slowly) incorporated photovoltaic equipment into its consumer goods portfolio, based on firm demand, not donor projects or government subsidies.

Mark Hankins (energyaf@iconnect.co.ke), Energy Alternatives Africa (Kenya) Ltd.

Note

The Energy Sector Management Assistance Programme has provided about US$500,000 in recent years to analyze the development of the photovoltaic market in Kenya and to test-market equipment.

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