WWS 402f
Sustainable Development: Can We Do It?

Professor Denise Mauzerall

The Development of Photovoltaic Markets in Rural Africa

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May 2, 2003

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Executive Summary
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Ashley Collins

Africa is the least electrified region of the world with up to 98% of the population without electricity. The inhabitants of the rural areas of Africa are very dispersed and lack the necessary infrastructure to allow them to connect to urban electricity grids without high transmission and distribution costs. This is especially true in the Eastern and Southern regions of Africa, which do not have the village settlement patterns common in Western Africa. These characteristics make Africa and highly viable location for the implementation photovoltaic technology programs.

Currently, energy in rural areas of Africa is derived from biomass and is used mainly for household, agricultural and rural enterprise purposes. The burning of biomass indoors is extremely harmful to one's health due to particulate emissions. PV technology can improve indoor air quality primarily by replacing lamps and candles, which produce the harmful particulates. In addition, the technology improves living conditions by providing a light source after the sun sets, which extends the number of potentially productive hours in the day. A PV unit can also be used to power a radio, which can serve as a very useful educational tool and can connect the dispersed population to the rest of the region. Lastly, solar energy can be used to aid in agricultural and business activities by powering a water pump or a water heater, for example. This facilitates the retrieval and distribution of water in the home or business area, reducing the time and human energy spent on such activities.

The most significant lesson that should be taken from current and past efforts to develop photovoltaic markets is the importance of barrier assessment in each individual

country and region. Demand for PV technology must be assessed, along with the resources available and needed for market development. The most suitable options to overcoming market barriers must then be determined and applied. Five main categories of market barriers exist to block development: technical, governmental, financial, institutional and consumer confidence. Technical barriers spring from a dire need for further research and development to tailor products to the needs of consumers. Governmental policy can be used to promote or inhibit growth of the market, depending on how taxes, tariffs, duties, and regulations are designed. The industry, individual companies and consumers all face financial barriers, including high start-up costs, low levels of investment and high prices of the technology. The industry as a whole also needs many capacity building efforts in terms of resources, capital and infrastructure. These institutional barriers need to be address by the players to help distribute the technology. Lastly, the consumers of the products have to be convinced that photovoltaic technology meets their energy needs.

All stakeholders in the PV industry – producers, distributors, consumers, donors and governments – should be involved in this process so that no elements are overlooked. The United Nations Division on Sustainable Development uses the term "Type II partnership" to describe this relationships among the players. These partnerships allow the players to work together to overcome all market barriers through specializing in the ones each player is most fit to address. Most importantly, the relationship provides a self-monitoring systems; each player has a vested interest in the success of the program and will watch the progress of all aspects carefully to ensure that everyone is doing their job and the goals of the program are being address. The recommendations offered by this paper are applicable given the conditions of African countries. In an attempt to develop these third world nations while at the same time considering the environmental needs of the Earth as expressed through global warming from greenhouse gases, it is advisable for the players involved to adopt some of these recommendations with an eye to the future needs of their nations and of the environment.

ABSTRACT

Continental Africa faces many obstacles in its path to sustainable development. The growth of the energy sector has been problematic due to the low incomes of the highly dispersed rural populations. Extremely high percentages of these populations are not connected to any electricity grid and rely on burning mostly biomass for energy, resulting in devastatingly poor indoor air pollution, greenhouse gas emissions, and limited productivity. Given these challenges and the goals of international organizations to couple economic growth with environmental conservation, this paper will support the use of solar energy in rural Africa. Current energy trends and demands in rural Africa will be examined along with case studies to determine the most effective methods of program implementation and market development for photovoltaic technology. Recommendations will be directed to the formation of Type II partnerships to address market barriers.

I. INTRODUCTION

Great attention is being devoted to the scientific research done over the past few decades concerning global warming trends. Many of these studies seem to suggest that the earth has been warming since the industrial revolution, and that human-produced carbon dioxide is the primary cause. The Intergovernment Panel on Climate Change (IPCC) claims that climate change will affect water resources, agriculture and food security, terrestrial and freshwater ecosystems, coastal zones and marine ecosystems, and human health and industry.[1] Due to these potential effects of global climate change, this issue has been integrated into political agendas internationally.

One solution to troublesome emissions is renewable energy technology (RET). Such sources produce no emissions while operating and require little during their production. Many industrialized and developing nations are in a position to implement RET and support the movement toward cleaner energy practices. Developing nations are located in areas of high solar incidence and have large percentages of their populations unconnected to any electricity grid system. These characteristics make such areas well suited to the use of photovoltaic (PV) energy technology, such as solar home systems, solar water pumps and solar water heaters. However, many barriers exist that prevent the success of PV markets and must be addressed.

This paper will focus on the potential of rural Africa to be powered by PV technology in an effort to improve the standard of living in these areas while acknowledging the need for cleaner energy sources. Current sources and uses of energy will first be examined to establish a comparison for RET. Section II will provide information on solar energy as the most promising source for rural Africa. Following this, Section III will examine three country case studies to identify successes and failures. Lessons drawn from these studies will be discussed in Section IV. Lastly, recommendations to facilitate the development of PV markets in rural Africa will be offered.

[1] Intergovernmental Panel on Climate Change Working Group II, "Climate Change 2001: Impacts, Adaptation andVulnerability," IPCC, 2001, http://www.grida.no/climate/ipcc_tar/wg2/index.htm.

Current Energy Consumption Patterns in Rural Africa

Africa is the least electrified region of the world with up to 98% of the population without electricity.[2] The inhabitants of the rural areas of Africa are very dispersed and lack the necessary infrastructure to allow them to connect to urban electricity grids without high transmission and distribution costs. This is especially true in the Eastern and Southern regions of Africa, which do not have the village settlement patterns common in Western Africa.

Currently, energy in rural areas of Africa is derived from biomass and is used mainly for household, agricultural and rural enterprise purposes.[3] Biomass energy sources are the most readily available to rural Africans; 70% of the national energy sources of Kenya are from biomass and an even higher 95% is used in Uganda, for example.[4]

In the household, at least 90% of energy consumed is used for cooking, while the rest serves for lighting and space heating. Wood fuel, kerosene lamps and candles are used for the latter purposes based on availability and cost. Lower income houses rely heavily on biomass fuels for cooking, while the less numerous, higher income families are able to use kerosene (see Figure 1). Firewood is the most used source because it can often be collected rather that bought.

[2] Karekezi, Stephen and Waeni Kithyoma, "Renewable energy strategies for rural Africa: is a PV-led renewable energy strategy the right approach for providing modern energy to the rural poor of sub-Saharan Africa?" *Energy Policy*, Vol. 30, No. 15 (Dec. 2002), 1072.
[3] Ibid, 1073.
[4] World Energy Council, *World Energy Council Journal*, Dec. 1992.

End use	Rural household income		
	Low	Medium	High
Cooking	Wood, residues, dung	Wood, residues, dung, kerosene and biogas	Wood, kerosene, biogas, LPG and coal
Lighting	Candles, kerosene (Sometimes none)	Candles, kerosene	Kerosene, electricity
Space heating	Wood, residues and dung	Wood, residues and dung	Wood, residues, dung and coal
Other appliances	None	Grid or genset-based electricity and batteries	Grid or genset-based electricity and batteries

Figure 1[5] As income increases, more efficient fuel sources are available. This will help reduce pollution but will not eliminate it, thus preserving the importance of renewable energy.

Improving the Standard of Living through PV Technology

Energy produced from solar radiation can improve the standard of living in rural Africa in three main ways: the reduction of indoor air pollution, the provision of an electricity source within the household, and the provision of appliances to reduce labor demands. The burning of biomass indoors is extremely harmful to one's health due to particulate emissions. PV technology can improve indoor air quality primarily by replacing lamps and candles, which produce the harmful particulates. In addition, the technology improves living conditions by providing a light source after the sun sets, which extends the number of potentially productive hours in the day. A PV unit can also be used to power a radio, which can serve as a very useful educational tool and can connect the dispersed population to the rest of the region. Lastly, solar energy can be used to aid in agricultural and business activities; by powering a water pump or a water heater, for example. This facilitates the retrieval and distribution of water in the home or business area, reducing the time and human energy spent on such activities.

[5] AFREPREN/FWD, "Renewables and Energy for Rural Development Theme Group: Data and Statistics and Methodology Handbook," *AFREPREN/FWD Secretariat*, 1999.

III. PHOTOVOLTAIC TECHNOLOGY OVERVIEW

Edmond Becquerel discovered the photoelectric effect in 1839 through his observations of certain materials that appeared to produce a small current when exposed to light.[6] Since this development, solar energy technology has been applied internationally to individual homes, businesses, and even satellites.

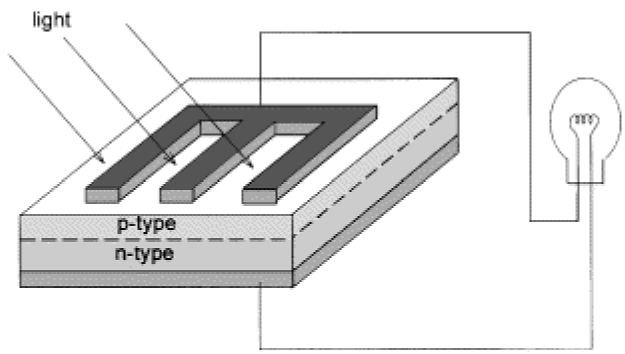

Figure 2[7] This diagram represents a simplified diagram of a photovoltaic cell.

When solar rays enter a PV cell through gaps in the top contact metal (Figure 2), energy is transferred, temporarily releasing electrons from the covalent bonds holding together the semiconductor. The circuit can be completed through a light bulb or other appliances. Efficiency is lost when sunlight is reflected off the device or the incoming photons do not have enough energy to excite the electrons and initiate a current.[8] These losses and others (to be discussed later) result in efficiency levels of between about 10%

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[6] Acker, Richard H., "The quiet (energy) revolution: Analyzing the dissemination of photovoltaic power systems in Kenya," *Energy Policy*, Vol. 24, No. 1 (Jan. 1996), 82.
[7] Green, M.A., "Photovoltaics: technology overview," *Energy Policy*, Vol. 28, No. 14 (Nov. 2000), 990.
[8] Ibid.

and 25%, depending on the maintenance and solar incidence.[9] However, many elements of a PV panel are being further developed to increase this efficiency level.

In a PV unit, the silicon wafer serves as the bed for the metal contact layer. The silicon must be extracted from quartz, highly refined and melted, molded into large blocks, sawed into smaller ingots and finally sliced into thin sheets. A metal contact sheet is added below, and a phosphorus layer and another metal contact sheet above. The cells are laid in a matrix, interconnected and encapsulated by a glass front plate, a lamination foil and a back cover foil. This method leaves much room for improvement: the saws, frames and wafers are being made thinner to reduce lost material; frameless models are being experimented with; and more efficient materials are being tested to replace silicon. These advancements will help to decrease the costs of PV units by decreasing the amount of energy and materials needed to produce them.[10,11] Currently, a PV unit has a lifetime expectancy of about 25-30 years and a payback time of about 3-4 years, depending on the model and level of solar radiation and maintenance attention.[12] This indicates that savings from PV use in a 3-4 year period can equal or exceed the initial purchase costs of the product.

Benefits of Photovoltaic over Biomass

A tradeoff is evident in the current state of technology between cost and emissions. Technological advances in each industry can reduce the levels of both cost

[9] Green, M.A., Emery, K., King, D.L., Igari, S., and Warta, W., "Solar Cell Efficiency Tables (Version 21)," *Progress in Photovoltaics: Research and Applications*, Vol. 11, No. 1 (Jan. 2003), 39-45.
[10] Alsema, E.A., and Nieuwlaar, E., "Energy viability of photovoltaic systems," *Energy Policy*, Vol. 28, No. 14 (Nov. 2000), 1001.
[11] Green et al., 991.
[12] Alsema and Nieuwlaar, 1004.

and emissions; however, only renewable energy can assure zero emissions post-production. Below are comparisons of carbon dioxide emissions and costs of PV systems and conventional electricity supply. Figure 3 makes a compelling case for the high benefits received from the emission reductions of PV systems. The potential for the cost of PV systems to become more economical for consumers, depending on the market growth is seen in Figure 4. Lastly, Figure 5 reveals the savings reported each month from the replacement of traditional energy sources.

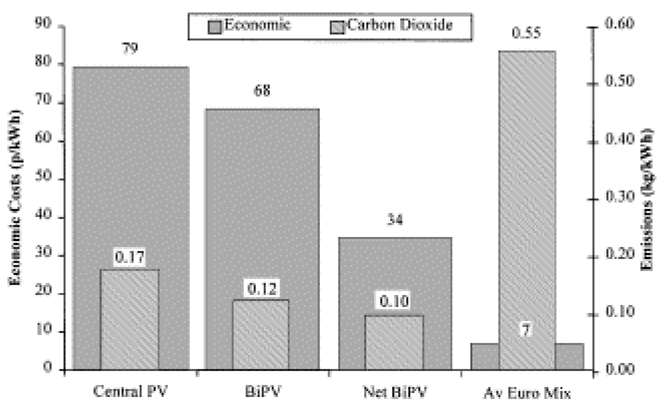

Figure 3[13] Three PV systems are compared to the Euro Mix of fossil fuels and biomass. While the mix has a current cost advantage, PV systems release far less carbon dioxide.

[13] Oliver, M. and T. Jackson, "The evolution of economic and environmental cost for crystalline silicon photovoltaics," *Energy Policy*, Vol. 28, No. 14 (Nov. 2000), 1011-1021.

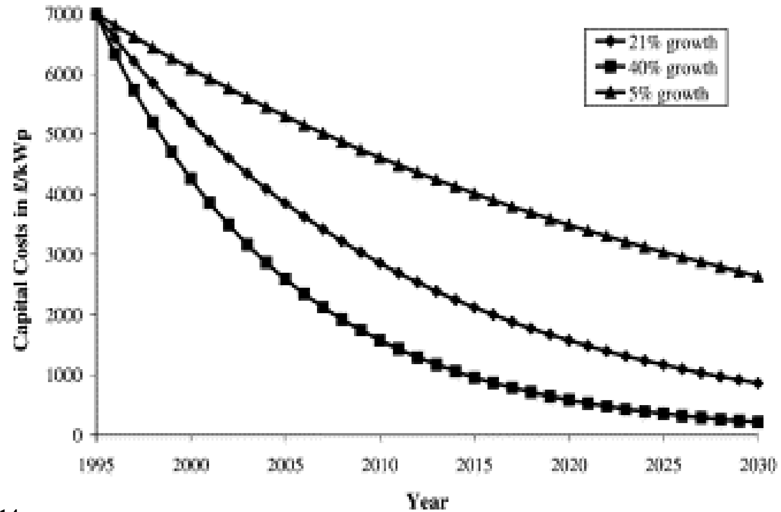

Figure 4[14] Projected cost decreases in PC technology over 35 years range from becoming about half as expensive as present day products, to costing one-seventh the price.

	Size of PV system				Row total
Ksh/month (KSh55/US $)	1–15 W	16–25 W	26–45 W	46–200 W	(W
Battery charging savings	94	80	96	78	90
Kerosene savings	161	213	310	373	230
Drycell savings	214	206	276	233	230
Other savings	0	17	15	18	9
Total in sample	470	517	696	702	559

Figure 5[15] Savings from PV use are from the replacement of 3 previous needs – battery charging, kerosene use, and drycell use – and range from about $8.50 per month to over $12 per month.

IV. HURDLES IN THE PHOTOVOLTAIC MARKET

Photovoltaic technology has proven to be a promising technology in the pursuit of new energy sources for rural areas. However, the PV market encounters many obstacles in its pursuit of sustainability. The following barriers must be addressed properly when designing a program for market development: technical, governmental, fiscal,

[14] Ibid.
[15] Ibid.

institutional and consumer confidence. The case studies examined later will illustrate the successes and failures of various policies' attempts to negotiate the hurdles.

Technological Barriers

Cost and efficiency levels hinder the popularity of PV technology. The energy output of PV units compared to the input they receive from the sun is miniscule. Beside module inefficiencies, dirt and high temperature induced voltage drops of around 10%.[16] Addressing the areas of inefficiency, both in production methods and output, will help reduce the costs of PV systems and increase their viability as the main energy sources for rural Africa. This will further accelerate the markets by "buying down" the market: costs will be eliminated in production, distribution, transactions and other aspects of the market as production levels increase. Figure 6 shows the projected escalation of market size; when this is considered along side the estimations for the decreases in production costs, the promise of PV becomes clearer.

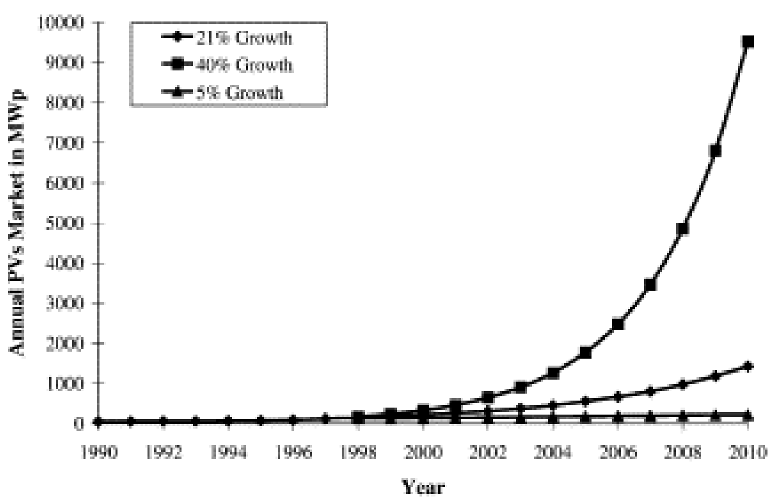

Figure 6[17] PV Market growth may vary depending on the achieved rates, however, projections may encourage investors to strive toward maximum growth and participation.

[16] Ibid.
[17] Oliver, M., and Jackson, T., "The market for solar photovoltaics," *Energy Policy,* Vol. 27, No. 7 (July 1999), 371-385.

Governmental Barriers

The case studies will show how the policies of a government can determine the success of renewable energy markets. Government intervention efforts include subsidies, tariffs, domestic taxes, value added taxes, regulations of the utility grid connection, and standards of safety and quality. Governments are also a sound source of investment in research and development and in the establishment of product manufacturers and producers.

Fiscal Barriers

There are many facets to this barrier: the industry, the individual firm or entrepreuneur, and the consumer. The industry is challenged by the present costs of production, advertisement, distribution and follow-up maintenance, as well as the governmental regulations and restraints (taxes, standards, etc.). Entrepreneurs have difficulties attaining start-up funding and competing with donated technology and larger firms. Lastly, many individuals cannot afford to buy solar home systems in a cash-only system where the entire cost must be paid at once, many end up not buying or purchasing a product that provides insufficient energy.

Institutional Barriers

The institutional infrastructure of the energy industry has many characteristics that inhibit the sales growth of SHSs. Established utility companies are often unwilling to adopt innovative approaches to energy service delivery and they may refuse to decentralize to help rural areas. Urban headquarters have limited access to the dispersed rural populations and have difficulty serving them. Rigid industrial infrastructure also results in low stock turnover, impeding changes in energy supply, and lacks service structures for promotion, distribution, sales, technical assistance and maintenance. Individual firms must be willing to change business structures and practices and realize the potential for profit in the emerging PV market.

Consumer Confidence Barriers

Rural customers lack the necessary knowledge of the technology behind solar energy and of what products are of the highest quality. There is a need for standardization in the market and dissemination of information to customers. Enforcing standards will ensure a minimum quality in all products and increase the confidence in purchases and in PV units as reliable energy sources. Information will also help customers maximize the returns they can receive from their purchases.

V. CASE STUDIES OF SOLAR ENERGY PROGRAMS

KENYA: A privatized market example

History of the market development

First introduced in the late 1970s for government-funded telecommunications projects, use of PV systems quickly increased in the 1980s and 1990s spurred by private interests and international donor programs. The 1980s were also a time of increased research and investment in renewable resources, spurring a further decrease in prices.

These factors prompted several large international companies, such as Siemens and BP, to open regional offices in Nairobi, and other Kenya businesses to enter the solar sector. However, these larger firms focused on the urban markets that were still donor-reliant and ignored the smaller, rural markets.[18]

The turning point in the PV industry with the insight of Harold Burris, an ex-U.S. Peace Corps volunteer, to go against the preconceived notion that rural Africans could not afford to buy PV systems. Burris set up a small PV business in 1984 called Solar Shamba in Embu, a coffee growing region near Mt. Kenya. By 1990, he had sold approximately 500 PV systems. In 1985, Burris and a partner, Mark Hankins, received funding from the US Agency for International Development (USAID) to set up a workshop to train rural technicians in Kenya to install and maintain products. Many of the trainees eventually established PV businesses of their own, thus initiating the mushrooming of the PV industry in Kenya. The effects Burris had on the PV market can be seen in Figures 7 and 8. Increases in the slopes of the PV market experience curve and the PV market graph occur at the same time Burris enters the market, indicating his dramatic contributions. Burris showed that the PV market could survive without heavy, continual reliance on donor aid through regionally established PV businesses focused on not only sales, but service as well.[19]

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[18] Acker and Kammen, 87.

[19] Duke, R.D., Jacobson, A., and Kammen, D.M., "Photovoltaic module quality in the Kenya solar home systems market," *Energy Policy,* Vol. 30, No. 6 (May 2002), 481.

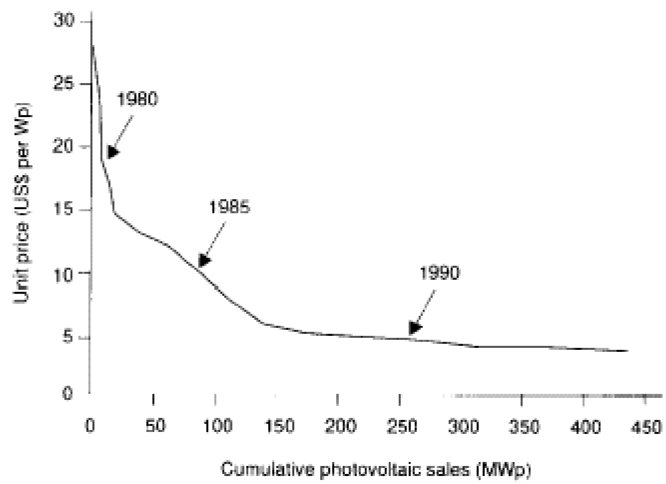

Figure 7[20] As sales increase, unit price decreases; this relationship is known as an experience curve.

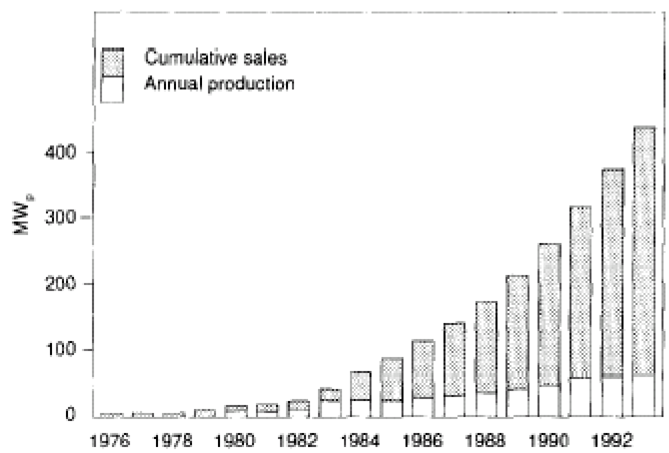

Figure 8[21] **Annual Production of PV technologies** has grown steadily while cumulative sales have exploded.

Factors promoting the acceleration of market development

Many forces combined to accelerate market growth, beginning with increased international investment in technology and the lowering of PV prices. Burris's contributions included the creation of local awareness of PV and a skilled group of electricians and entrepreneurs. The local demand in Kenya for solar home units

[20] Acker and Kammen, 89.
[21] Ibid, 88.

continued to increase as the market took-off.[22] Not only did the number of vendors and distributors increase in Kenya, but component manufacturers also established factories in the country, which served to eliminate transaction costs. There are now more than ten major PV import and manufacturing companies and hundreds of rural vendors in Kenya selling a range of brands. Regional town vendors sell at least 50% of SHSs, while the rest are bought directly from distributors in major cities.[23] Development of local production capacity is critical to support the growth of the PV market.

Factors hindering the acceleration of market development

The main factor hindering market growth in Kenya was governmental instability. Governmental problems contributed to economic difficulties, causing a decreasing currency value, rising inflation, and therefore rising prices relative to the rest of the world.[24] Import duties and value added taxes were used differently by different leaders, but always served to increase prices. In addition to these impediments, the market was missing credit lines to increase the number of clients from those with the ability to pay cash up front, to those who needed financing schedules to distribute the costs. Consumer confidence has been undermined by a large variance in product quality. There are no standards in place in Kenya to protect the inhabitants and to keep them aware and knowledgeable.[25] Despite these factors, the Kenyan PV market is a leader in Africa and a good example of the success commercialization can have.

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[22] Ibid, 87.
[23] Duke et al., 481.
[24] Acker and Kammen, 90-2.
[25] Agumba, M. and Osawa, B., "Kenya's PV market: a showcase for commercial development," found in "Experience with PV systems in Africa," ed. N. Wamukonya, UNEP. www.unep.org

ZIMBABWE: A Cooperative Effort

Access to electricity in Zimbabwe is limited to only 20% of the population. Extension efforts have been restricted due to a lack of financial and technical resources. Currently, about 50% of energy used comes from biomass, 13% from coal and 12% from electricity.[26] However, projects are in place to increase energy provision through renewable sources, namely solar and hydroelectric. Before the early 1990s, solar companies already established in Zimbabwe focused mainly on the more affluent customers and ignored the majority of rural inhabitants. The poorest of Zimbabwe were left behind, assumed to lack profitability. The Global Environmental Fund (GEF) had a project in Zimbabwe that focused on supplying energy to the poor. Zimbabwe attracted the GEF because it was a founder of the fund and one of the first countries to sign and ratify the UN Framework Convention on Climate Change. In addition, Zimbabwe was the host nation of the 1996 World Solar Congress; therefore it was an appealing site for the GEF Solar Project to begin in 1992.[27]

The GEF Solar Project

The GEF began its Zimbabwe project with many goals in mind to enhance the long-term sustainability of the PV industry and improve the standards of living. Some of the particular goals included: enhancing and upgrading the PV industry infrastructure, developing the commercial market in rural areas with low-interest financing mechanisms,

[26] Painuly, J.P., and Fenhann, J.V., "Implementation of Renewable Energy Technologies – Opportunities and Barriers," (UNEP Collaborating Center on Energy and Environment: Denmark, 2002), 28.
[27] Mulugetta, Y., Nhete, T., and Jackson, T., "Photovoltaics in Zimbabwe: lessons from the GEF Solar project," *Energy Policy*, Vol. 28, No. 14 (Nov. 2000), 1069-1070.

establishing credit tools for low-income rural households, and integrating solar lighting of other programs already active in Zimbabwe. To attain these goals, the GEF worked with the Government of Zimbabwe (GoZ) to supply US$7 million and US$400,000, respectively, during 1993 to 1997.[28]

In addition to these goals, the GEF formulated its program to address many barriers of the PV market. The market was lacking in local production capability, private sector capacity for servicing the market, data for design, adequate financing programs, experienced personnel, public awareness of the technology, institutional structures for renewable energy, and clear government policy. A medium for foreign exchange of technology was needed, along with appropriate taxes and duties to encourage growth.[29]

These barriers were to be overcome through the interaction of the many "players" the GEF introduced and involved. The main administrative player was the Project Management Unit (PMU) set up by the Department of Energy. The PMU oversaw the daily duties of the project, explored the prospects for alternative funding assistance, and set national standards for solar components. The creditor was the Agricultural Finance Corporation, who agreed to a low 15% interest rate upon assurance that the UNDP would provide a starting donation of US$250,000 for their proposed Credit Support Facility and its revolving fund concept. The Standards Association of Zimbabwe (SAZ) and the Solar Energy Industries Association of Zimbabwe (SEIAZ) developed the standards for installation and components and also registered companies who wished to be involved in the project. In this manner, manufacturers, distributors, and installers could be assessed

[28] Ibid, 1070.
[29] The Southern Centre for Energy and Environment, "Implementation of Renewable Energy Technologies – Opportunities and Barriers" (UNEP Collaborating Centre on Energy and Environment: Denmark, 2001), 23.

and a level of quality maintained, theoretically. The people of Zimbabwe completed the player list; the project sought to provide them with clean and high-quality lighting and replace kerosene lanterns and paraffin candles, and reduce indoor emissions.[30]

Results of the Project

Motivated by the aforementioned goals, the five-year effort resulted in about 10,000 households and service centers lit by PV sources and about 60 companies registered with the SEIAZ. However, one year after the GEF project ended, this number of companies dropped to about 30, and questions began to surface concerning the number of PV systems still operating well. It was found that many companies entered the market under the GEF regime enticed by its support, but pulled out with the GEF, having only short term survival in mind and left PV systems unmaintained. Those companies that remained were under considerable financial and resource strain, especially those dependent on "handouts" from the GEF. By early 2000, only 15 PV companies had survived the high inflation rates of Zimbabwe and the depreciation of the currency.[31]

GHANA: A Governmental Initiative

Ghana is located in an area of high solar incidence; most of the Southern parts of Ghana have very high diffuse radiation levels, while the Northern areas have moderate

[30] Mulugetta et al., 1070-2.
[31] Mulugetta et al., 1078 and Wamukonya et al., 16.

levels.[32] Photovoltaic technologies to harness this energy are presently being implemented, including water heaters, crop dryers, water pumps, refrigerators and lighting. The government of Ghana has held a central role in the progress of the PV markets in Ghana through two main policy regimes: the Energy Sector Development Programme (ESDP) and the Ghana Renewable Energy Services Project (RESPRO).[33]

The Energy Sector Development Programme (ESDP)

Passed in 1983, PNDC Law 62 established the National Energy Board (NEB) to direct the development of renewable energy projects and to create and monitor projects in electricity, petroleum, energy conservation and demand management. The Ministry of Mine and Energy (MME) dethroned this past regime in 1996 with the ESDP. Under the ESDP, the Renewable Energy Development Programme (REDP) evaluated, supported and demonstrated the potential of RETs, as well as promoted the renewable energy industries and an information database.

Still another energy policy regime has emerged: the National Renewable Energy Strategy (NRES), as upheld by the Renewable Energy Component (REC) of the DANDIDA Energy Sector Programme Support (ESPS). With this tool, the Energy Commission, the Public Utilities Regulatory Commission and the Energy Fund were set up to facilitate the growth of RET markets. However, these organizations met various barriers and limited success. One of the most problematic barriers found were high initial costs to starting the market. There was also a general lack of information as to what was

[32] Edjekumhene, I., Atakora, S.B., Atta-Konadu, R., and Grew-Hammond, A., "Implementation of Renewable Energy Technologies – Opportunities and Barriers," (UNEP Collaborating Centre on Energy and Environment: Denmark, 2001), 48.
[33] Painuly et al., 20-1.

needed in the market, for both long and short-term success. The test markets for the technology were weakened by a lack of financing mechanisms to allow the customers to met the costs and repay in full.[34] Other programs in Ghana have met similar obstacles that have retarded the growth of renewable energy markets in general.

The Ghana Renewable Energy Services Project (RESPRO)

In 1999, the Ministry of Mines and Energy established RESPRO with funding from the Global Environmental Facility (GEF) and technical support from the National Renewable Energy Laboratory of the US Department of Energy. The project was designed for a three-year period, followed by an assessment, which will be available to the private sector as a learning tool. The goals of the project were to find sustainable energy solutions for social and economic development by providing electricity and fuel supply technologies to replace fossil fuels while striving to reach the government's goal of nationwide electrification by 2020.

Studies show RESPRO's success in building technical capability in the design, installation and maintenance of products is a result of a commitment to training a technical staff in these areas at Kwama Nkrumah University of Science and Technology in Kumasi as well as in each district of operations. In addition to the training program, a financing plan was set up based on the fee-for-service method on the individual level, while community and health clinic products are installed and owned by RESPRO. An individual customer can apply for one of two sizes of home systems, 50Wp and 100Wp, each costing US$630 and US$950, respectively. A US$100 installation fee is charged,

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[34] Painuly et al., 23.

along with a monthly rate of US$3 and US$5, but the program is being expanded to include a purchase option.

Like the previous case study, this one had encountered difficulties. Under the system, the government does not support the cost of PV technology to the extent that fossil fuel electrification is, and therefore much of the cost falls upon the customer. Affordability is a large issue, also due to instable economic conditions and a low willingness to pay on the part of the customer, given the above prices and inflexible financing program. A lack of public education has begun to be addressed to gain support for the technology and, hopefully, to aid in the growth of the market.[35]

VI. LESSONS LEARNED FROM CASE STUDIES

Based on a study completed in 2002 by the World Bank, many solar energy projects in Africa have had rather limited success. Figure 9 below reveals the percentages of six African nations. The highest percentage of population with SHSs by 2000 was 3.42% in Zimbabwe, and the lowest was 0.05% in Nepal. In addition, many solar homes systems in this study were found to be partly or wholly non-operational, as seen in Figure 10. Therefore, attempts made must be reassessed to determine why such limited penetration of solar energy was achieved.

[35] Wamukonya, 52-54.

Country	Number of SHS installed by early 2000(in thousands)	Total Population in million in 1998	Share of total pop with SHS
Kenya	150	29.3	2.56
Zimbabwe	80	11.7	3.42
South Africa	60	41.4	0.72
Morocco	50	27.8	0.90
Nepal	2.5	22.9	0.05
Swaziland	1.2	1	0.60
Other developing countries	366.8	1634	0.10

Figure 9[36] Actual percentages of the total population of these nations with SHSs is startlingly low, revealing the difficulty of penetrating this market.

Country	Good	Partly non-operational	Non-operational	Year of Publication
Kenya	69	12	19	1998
Kenya	60	30	10	1996
Kenya	77	2	21	2000
Tunisia	38	37	25	1999
Swaziland	73	17	10	2001
Nepal	60	40	-	1995
Total	377	158	85	

Figure 10[37] The results of six projects in Africa are listed above and show the potential for dissatisfaction among customers as to the quality degradation of the products once the programs are over.

According to previous experiences, the success of any program depends on the ability of the organizing parties to overcome the many variables present. Some of the most formidable barriers have included: high capital costs, high tariffs and taxes, a lack of information about technology, technical problems, and a lack of institutional structures to promote the growth of the PV markets, to name a few. Many projects have had success in the PV markets, but none have sustained growth. Simple adjustments in their design can be made to overcome the barriers they encounter.

[36] Nieuwenhout, F.D.J., van Dijk, A., Lasschuit, P.E., van Roekel, G., van Dijk, V.A.P., Hirsch, D., Arriaza, H., Hankins, M., Sharma, B.D., and Wade, H., "Experience with Solar Home Systems in Developing Countries: A Review," *Progress in Photovoltaics*, Vol. 9, No. 6 (Nov./Dec. 2001), 461.
[37] Ibid, 466.

VII. RECOMMENDATIONS FOR THE DEVELOPMENT AND ACCELERATION OF PHOTOVOLTAIC MARKETS

The most significant lesson that should be taken from all case studies is the importance of barrier assessment in each individual country and region. Many recommendations are offered below, however not all may be applicable universally. Demand for PV technology must be assessed, along with the resources available and needed for market development. The most suitable options to overcoming market barriers must then be determined and applied. All stakeholders in the PV industry – producers, distributors, consumers, donors and governments – should be involved in this process so that no elements are overlooked. This may be done through stakeholders meetings in the program development stage, as well as in the monitoring process.

Technical Barriers

The efficiency of technology and production methods must be improved to make PV technology a more appealing alternative to fossil fuels and biomass. Therefore, investments must be directed to research and development of PV; the government, international donors or the private sector must raise funds to further research and development. The international renewable energy market is relatively young and unsophisticated; this leaves room for African governments and businesses to establish themselves without being crowded out.

Technology must not only be progressed, but also distributed to a wide variety of beneficiaries to promote income generation, increase participation in the PV markets and enterprise development, and improve standards of living. Some argue that if producers and distributors are able to turn a profit in RET markets, the users will become more involved in the market and sustainability will be reached sooner. Dissemination of RETs may be incorporated into existing technology systems to reduce costs associated with transactions and distribution. Some solar and wind energy technology programs have relied on existing agricultural networks to provide low-cost dissemination.[38]

Governmental Barriers

The primary roles of governments are to provide monetary support in the initial stages, to monitor the needs of the markets (including the needs of the industry and the consumer) and to establish incentives for private sector participation and commercialization. In most cases, the initial start-up costs are very high, and therefore the government should act as the donor agency in the absence or in addition to international support. However, donors should be wary of a program growing dependent on aid because this will make sustainability impossible. Growth of the industry should spur a decrease in donation dependence. In addition, governments can provide further incentives for businesses to enter the market through protective legislation and by reducing barrier legislation. Subsidies, tax credits and tariffs can be used to promote domestic growth. Renewable energy technology can be given subsidies or tax credits to level the playing field of RETs and conventional energy sources; tariffs will promote the growth of domestic producers of components needed. The more the PV industry can be

[38] Karekezi, 1067.

contained and sustained within a country's borders, the more the growth of the markets will accelerate. Lastly, the government is best suited to monitor all the players involved in the PV industry to ascertain whether the consumers' interests are being protected and that the producers and distributors are functioning properly without undue barriers. Governments should monitor producers and distributors for decreases in dependency on the incentive system. As this occurs, subsidies and tax benefits should be reduced to allow the market to reflect the true prices of PV technology and to open competition. Governments should be careful not to set initial import duties on new technology too high or they may restrict technology transfer. A reduction in import duties should coincide with domestic market growth, allowing it to be more able to compete internationally.

Financial Barriers

Photovoltaic companies will not enter if there is no profit in the business, and people will not buy PV products if they cannot afford them. Many companies have run into a wall because there is a limited market in cash-only payment methods. Financing programs must be more flexible with payment schedules to permit the distribution of costs over longer time periods. As discussed above, governments and international donors should be relied upon for initial funds to establish a market and promote its growth because the ability of the industry to produce a profit will depend on the affordability of the products.

There are three viable financing mechanisms that can be implemented: cash payments, renting, or microfinance programs. In some regions, the incomes of the inhabitants will be sufficient to pay for the PV system in cash; however, this is not the case in most areas. Renting, or "fee-for-service" programs have been experimented with in many countries, as seen in Zimbabwe and Ghana. However, microfinance institutions (MFIs) are gaining a strong presence in Africa and present a highly appealing alternative. Solar energy programs can include a partnership with a MFI to allow customers with lower incomes to pay for the PV systems in smaller allotments at low interest rates. If there are no MFIs present in the region and the prospects of enticing one to join a partnership are bleak, the government may include a financing program in their budget, as was done in Mexico with its Programa Nacional de Solidaridad scheme to aid the poor through rural electrification.[39]

Institutional Barriers

Photovoltaic programs will need to include capacity building components and market infrastructure designs to promote growth and increase demand for products. Research must be done on market and customer demographics and to determine the most appropriate methods of product design, delivery and support. Programs will encounter difficulties in performing these tasks if they lack access to rural customers due to the increase costs of delivering and servicing products. Training programs for technical and sales staff will help to ensure that a system of sales and post-sales services will be carried out properly.

Capacity building is also a crucial element to PV programs. Presently, most PV markets lack the capital, investment and demand to become sustainable. Already, it can be seen that producers of the technology must be supported in the early stages. Rural markets are very dispersed, therefore it is advisable for producers and distributors to have

[39] Acker and Kammen, 106.

regional departments to aid in dissemination of products. Financing programs will also build market capacity by increasing the client base and the payment rates, thus bringing more money into the market. Domestic markets can be enhanced through technology transfer from international sources of research and development by decreasing product costs and thus increasing the client base. All three countries showed that, overall, to increase market capacity and the success rates of programs, they must be designed for long-term goals; this will prevent a replacement of the Zimbabwe experience of fly-by-night operations that destroyed the market.

Consumer Confidence Barriers

The most productive action the government and producers can take to increase the demand for products is to increase the consumer confidence in the technology. Confidence in PV technology has been eroded by its lower efficiency levels relative to other energy sources and by inconsistencies in product performance. This effect can be reversed with awareness building through reputation signaling, warranties, performance testing and disclosure, certification and labeling, and/or minimum quality standards.

The public needs to learn and be made aware of the potential that PV systems hold to improve the standard of living. People will only buy a product if they are assured of its value to their lifestyle. Governments can assure this through market standards, mandatory performance testing and disclosure, certification processes, and labeling of products that meet these requirements. Businesses can attract customers with warranties and by advertising the fact that their products meet government standards and requirements. Below are two examples of labels used to attract customers to the promises of higher quality. Figure 11 is an advertisement by Sollatek, a Kenyan company, for a product offered with a warrantee. Figure 12 is a bumper sticker distributed in Kenya by Free Energy Europe in 2000 to show that the product has been tested and has shown superior performance.

Figure 11[40] This product boasts the cheapest cost per watt and a five year warrantee on this product label.

Figure 12[41] Free Energy Europe claims to have the best tested product in Kenya with this bumper sticker.

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[40] Duke et al., 2002, 484.
[41] Ibid, 485.

VIII. CONCLUSION: THE ROLE OF TYPE II PARTNERSHIPS IN THE PHOTOVOLTAIC MARKET

Rural Africa relies heavily on biomass fuel sources to heat, cook and light their homes, manage their farms, and run their small home businesses. With over 90% of the continent unconnected to an electricity grid and widely dispersed, solar home systems will benefit the inhabitants through the provision of enough electricity to run a few lights, a television, or other small appliances, based on the system size. This will help better the current standards of living, and slightly increase health conditions through replacing kerosene lamps, where used. As seen in the Zimbabwe and Ghana case studies, joint efforts by governments, non-governmental organizations and the private sector have the potential for success. The United Nations Division on Sustainable Development uses the term "Type II partnership" to describe this relationships among the players. Following the World Summit on Sustainable Development in Johannesburg, many such partnerships were formed, including the African Energy Legacy Project, the Alliance for Rural Energy in Africa, the Energy Integration of Western Africa, and The Johannesburg Climate Legacy.[42] These partnerships allow the players to work together to overcome all market barriers through specializing in the ones each player is most fit to address. Most importantly, the relationship provides a self-monitoring systems; each player has a vested interest in the success of the program and will watch the progress of all aspects carefully

[42] United Nations Division for Sustainable Development, "List of Partnerships: Sustainable Development Initiatives for Africa," http://www.un.org/esa/sustdev/partnerships/AFRICA.htm#top.

to ensure that everyone is doing their job and the goals of the program are being address. The recommendations offered by this paper are applicable given the conditions of African countries. In an attempt to develop these third world nations while at the same time considering the environmental needs of the Earth as expressed through global warming from greenhouse gases, it is advisable for the players involved to adopt some of these recommendations with an eye to the future needs of their nations and of the environment.

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