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Research Article

Renewable Energy Technologies in Ghana: Opportunities and Threats

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Abstract: In most developing countries, there is a monopoly of electricity generation, transmission and distribution by some governmental agencies, resulting in little or no access to electricity in rural communities where a larger proportion of the population resides. A study of Renewable Energy Technologies (RET) in Ghana is presented in this study. The renewable energy technology discussed is based on solar Photovoltaics (PV). This study addresses some of the vital factors that have prevented the growth of a viable market for RETs using solar PV as a typical example. Adverse policy environment and lack of financing are cited as the main barriers to be surmounted. Recommendations are made for government and all stakeholders to engage the private sector to give the RET industries a boost. The injection of an electrification fund is proposed to support grid extension to areas of proven economic potential using RET.

Keywords: Photovoltaic cell, policy environment, renewable energy technology

INTRODUCTION

With the greenhouse effect and the increase of the price of the energy, new ways to produce energy are intensively developed such as fuel cell, bio-fuel cell, nuclear, biomass, wind power and Photovoltaic (PV). Among all these renewable energies, photovoltaic seem very promising. Indeed, only 0.2% of the solar energy which touches the earth surface is sufficient to produce energy for the whole world (Aartsma *et al.*, 2008; Tao, 2008). A lot of work has already been done in this field in order to improve the efficiency of its supply.

Renewable Energy Technologies provide natural methods of harnessing energy for human use in such a way that the source of energy is not depleted over time. Photovoltaic solar electric generation technology is one of the best means to provide electricity in a clean manner virtually everywhere around the world. PV systems are modular, producing electricity directly from sunlight and do not give rise to harmful emissions. Typical components of the PV systems are shown schematically in Fig. 1.

They (PV systems) can be deployed very rapidly in both rural and urban environments. A PV module rated at 120 W (1 m^2) together with a suitable battery can be installed in a very short time and will provide enough power for several compact fluorescent lights and a radio or TV for 4 to 5 h a day. This can be life-changing for a family in rural Africa, Asia or Latin America, where small levels (quantity or amounts) of electric power could make a significant impact in their standard of living.

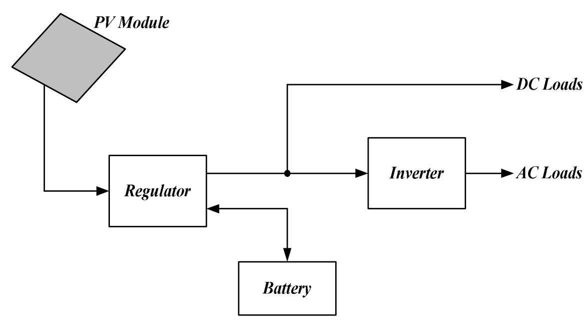

Fig. 1: Typical photovoltaic system showing the major components

Solar PV demand has grown consistently by 20-25% per year over the past 20 years while solar cell prices fell from $27 per watt of capacity in 1982 to less than $4 per watt today (Anon, 2006a and 2006b).

Poverty alleviation is a global concern that has prompted the United Nations to set the Millennium Development Goals. These goals will be fostered partly by ensuring that energy is made available to the rural populations of the world, majority of which are found in developing countries. This has necessitated the need to harness renewable energy resources for electricity generation for the following reasons:

- The resources are abundant.
- They are well dispersed.

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- Electric power from the national grid system has not reached many of the highly populated rural communities.
- Rural dwellers require very little power to meet their basic needs and these levels of power can be met with renewable energy sources.
- Availability of electricity in rural areas will stimulate commercial and small scale industrial development and alleviate poverty.
- Renewable energy resources generate electricity without the pollution of the atmosphere.
- They are easily adaptable to decentralized electricity generation.

This study therefore focuses on the use of solar PVs as an example of an RET that has the potential for commercialization in Ghana. The expectation is that, lessons will be drawn from this industry and will be applicable to other industries.

MATERIALS AND METHODS

The study area is Ghana. By virtue of Ghana's location in the tropics (between latitude 4° and 12° N and longitude 30° W and 1° E), Ghana is well endowed with solar energy resources, receiving daily solar irradiation of between 4 and 6 kWh/m^2 and a corresponding annual sunshine duration of 1800-3000 h. The solar map of Ghana in relation to solar irradiation has been useful for the design and installation of solar systems. The map shows most of the Southern parts of the country having very high diffuse radiation levels (over 45%) with the Northern sector having moderate levels of diffuse radiation (between 32 and 45%) (Edjekumhene *et al.*, 2001).

Recent advances and status of the photovoltaic industry with electrification in Ghana: Much has been achieved in the solar electric industry in recent years. Several countries including the United States, Germany, Japan and South Africa have introduced major programs to boost their local industries by active government participation in the development of solar electricity. This is being pursued through research programs, tax incentives, policy initiatives and financing. In the US, for example, where tax obligations can be high, it has been shown that tax incentives can result in a significant burst of activity in the industry (Gerger, 1998). Their effects, however, last only as long as the incentives exist in the short to medium term and many industries that spring up to take advantage of the tax incentives may no longer be viable when the incentives are removed.

On the technical side, the efficiency of photovoltaic cells has been improved while costs continue to fall. Consolidation in the industry, with the expansion of companies like Kyocera and BP Solar, has meant that more intensive research and development initiatives can result in cheaper and more efficient modules in the near future.

In early 1999, soon after the electricity crisis of 1997, there were an estimated 24 companies primarily involved in the design, installation and sale of photovoltaic systems in Ghana. By the middle of 2000, fewer than half of these companies were actively involved in the industry. The reasons for this decline are varied and include the possibility that the companies involved had not sufficiently developed their business plans. It is telling, however, that the surge in demand created by the energy crisis did not lead to a viable PV industry.

This phenomenon is not restricted to Ghana or developing countries in general. The sharp rise in oil prices during the 1970s led to energy shortages in most parts of the world and created a boom in the number of companies offering renewable energy alternatives. When power stabilized and economies recovered, the number of companies immediately fell.

Table 1 shows the estimated size and growth of PV systems in Ghana, based on information provided by the ministries of Mines and Energy, Health and other institutions (Adanu, 1994; Government of Ghana Data, 1998). The estimates for 1998 are based on installations by solar light companies and other solar system providers. Additional 1,200 domestic rural systems were installed between 1998-99 under a Spanish Government loan.

The benefits of renewable energy in Ghana: Renewable Energy Technologies, particularly PVs, can reduce the country's dependence on centralized power from hydro and fossil fuel sources. In times of domestic shortage, the cost of importing power from neighbouring countries is even higher. Data collected from ECG (first usage) in 1999 showed that domestic users accounted for over 50% of all consumption. In most industrialized countries, domestic consumption accounts for less than about 25% of total consumption and peak periods usually occur during the day.

The challenges: Various reasons have been given for the lack of a viable PV market in Ghana. In some cases, high taxes have been blamed and policy measures have been taken to reduce the import duties on solar PVs (Government of Ghana Data, 1998). In others, it has been argued that the introduction of manufacturing will reduce the cost of solar electric systems and boost the industry. This study argues that the absence of a viable industry is due to the lack of a coherent and coordinated policy on energy that takes RETs into account, coupled with a repressive manufacturing environment.

Each of the above reasons is examined in turn to determine how well they assist the solar PV industry in Ghana to reach a sustainable level. In a review of the industry conducted on behalf of Tse (1999), members of the solar energy industry cited the following reasons among the factors inhibiting their growth and development:

Table 1: Status of photovoltaic electrification in Ghana

Application	1991	1994	1998	2000 (est.)
Lighting	25	67	1,500	2,200
Water pumping	5	n/a	50	80
Vaccine refrigeration	68	56	180	210
Telecommunications	214	500	800	900
Other	25	77	n/a	100
Total	337	700	2,530	3,490
Application	1991/kW	1994/kW	1998/kW	2000 (est.) /kW
Lighting	12	18	100	120
Water pumping	3	n/a	20	25
Vaccine refrigeration	32	14	40	48
Telecommunications	102	292	350	450
Other	11	26	n/a	50
Total	160	350	510	693

Adanu (1994) and Government of Ghana Data (1998)

Table 2: Relative costs of PV system components and opportunities for local manufacture

Component	Cost factor/%	Opportunities for Mfg.
Modules	45	Low
Batteries	25	Medium
Controller	5	High
Inverter	15	Medium
Wiring	5	Low
Frames/supports	5	High

Table 3: Solar technologies in perspective

Solar technology	Status in Ghana	Barriers	Opportunities
Home systems, etc.	Commercialization is underway in both rural and urban areas	High cost, low information & education, lack of standards	Production of components; marketing of systems
Battery charging station	Demonstration and commercialization	Long payback period equipment abuse training required	Production of components; Commercialization
PV refrigeration	Application confined to health sector	High cost, poor user handling, system sizing	
Communication	Institutionally based	High cost	
Water pumping	Community based		Custom designs
PV utility systems	Absent	No investment mechanism	Grid integrated systems; Standardization; utility privatization.
Cooking	Limited activity	Cooking time is dependent on the weather condition and the quantity of food being cooked; cooking has to be done outdoors	Solar ovens could make an impact (as in Uganda etc.) Replacement of wood fuel in domestic and small industrial sectors
Drying	Limited	High costs; poor dissemination; low response from private sector	Promotion of food storage in agric sector; cost reduction measures, commercialization
Evaporative cooling	Widely unknown few past experiments	Ignorance; technological barriers	Promotion of food preservation
Water heating	Very few systems production unit exists	Poor dissemination, low private sector involvement	System could serve several hotels, clinics potent energy saver
Distillation	Few demonstrations	Information barriers	Rural water treatment
Water treatment (UV, pasteurization)	Widely unknown few past experiments	Lack of demonstrative projects	Rural water treatment

Edjekumhene *et al.* (2001)

- High cost of components, leading to high system cost
- Lack of financing for solar energy consumers
- Lack of financing for service providers and installers
- Perception of high cost of solar PV by the public
- Unresponsiveness of potential market groups; e.g., the real estate industry

These and other barriers can be overcome with a concerted effort from the policy, financial and marketing sectors.

Opportunities for local manufacturing: In order to assess the impact of local manufacturing on cost, we must first examine the main cost elements for the manufacture of photovoltaic modules and for a typical solar home system.

The main argument for local manufacturing, other than technology transfer, is that lower labor costs will reduce overall cost. Opportunities have been found in cell stringing as well as module lamination and framing. However, the labor component of module manufacture is less than 10% and reduces further as volumes increase and automation is introduced (Carlson and Wagner, 1993). Thus, a small plant with high labor component will be largely manual and will most likely produce non-uniform parts that will not sell well compared to the nicely finished imported modules from automated plants.

The solar electric system as a whole offers better opportunities for savings through local manufacture. This is mainly because the processes for many balances of system components can be easily adapted to other, non-solar uses. Such a plant could flexibly manufacture components for other uses when demand for solar PV is low. For example, an electrical fabrication plant for manufacturing controllers and inverters can also be used to produce voltage stabilizers and battery chargers for automobiles. Table 2 shows the impacts of local manufacture for various system components.

The above is based on a household PV system delivering AC power with a system cost of about $2,000. Rural solar home systems are usually DC (no inverter) and typically cost less than $1,000 initially. It can be seen from the above that cost reduction should not be the overriding reason to introduce local manufacturing, because it will be a difficult goal to achieve. Other reasons should be taken into account, such as the need to transfer technology, improve manufacturing and strengthen the country's human resources in research and development.

Solar technologies in perspective: Table 3 shows a fisheye view of the features of various solar technologies available or potentially available in Ghana (Edjekumhene *et al.*, 2001).

RESULTS OF IMPLEMENTATION OF RET IN GHANA

Market potential: The Ministry of Mines and Energy in Ghana estimates that the grid reaches only about 30% of the country's population (Ghana Demographic and Health Survey, 1993). Put another way, it is estimated that about 4,000 communities do not have access to electricity (Government of Ghana Data, 1998). In addition to the off-grid households, many institutions such as schools, hospitals and government offices are located in off-grid areas. Finally, many applications in off-grid communities can be served by solar and other renewable energy sources. These include lighting, water pumping, learning centers and streetlights.

Based on the 1998 level of penetration of the national grid, the Ghanaian market for solar electric systems can be classified broadly as shown in Table 4. Most district capitals in Ghana have been connected to the grid and therefore most of the 4,000 off-grid communities are small with populations of less than 10,000. Using 100 households as an average community size, it is further assumed that 5% of the households would be ready and willing to acquire domestic solar electric systems. A penetration level of 20% was used to estimate the number of communities that may be served with community-level applications. It should be noted that the table is merely indicative of the potential market and a detailed demand analysis will be required to determine the market size.

The achievable levels of penetration for each of the market groups will depend on the marketing efforts of solar energy companies as well as incentives provided by government programs and financing schemes. The income levels of most rural communities are well below what is needed to afford a durable solar home system without the assistance from appropriate financing mechanisms.

The opportunities within the Ghanaian market for locally produced systems and components will depend on the willingness of project sponsors and donors to promote local manufacturers. In this regard, projects that involve the wholesale importation of kits should be discouraged in favor of those that allow certain parts or components of the system to be sourced or produced locally. Adequate quality standards can be established and maintained to ensure that the systems perform to expectation.

The policy environment:

Tax and duty exemptions: In the wake of the energy shortage in 1998, the Ghanaian government removed import duties and sales tax on "solar generation systems" as a measure to encourage increase imports of solar electric systems as an alternative source of energy. At the same time, the duties on diesel generators were also reduced. With the introduction of the Value Added Tax (VAT) at the end of 1998, solar electric systems remained exempt from import duties but were charged VAT.

The impact of these policy measures is unclear, but empirical evidence suggests that they have had little impact on the commercial success of the PV industry. Several factors may contribute to this. Firstly, the wording of the exemptions was unclear and the Customs Excise and Preventive Service have often been unable to assign a harmonized system code to imported solar energy equipment. For example, an installation

Table 4: Potential users of solar electric PV systems and their distribution

Market group	Example applications	Estimated size (number of systems)
Households in off-grid and rural areas	Home lighting systems, home power systems, domestic water storage	20,000
Institutions in off-grid and rural areas	Rural telephony, vaccine refrigeration, irrigation, etc.	800
Community-based systems	Water supply, community lighting, street lighting	800
Other applications	Backup systems, communications, etc.	5,000

company that imports various components for assembly would have to pay duties and taxes on all components except the modules themselves. On the other hand, a company that imports complete kits including lights and appliances will enjoy the exemption because the crate is labeled "Solar Generation System".

Secondly, the cost component of the duty exemptions makes very little impact on the affordability of the systems. As discussed above, solar panels constitute less than half of the cost of the entire system. An exemption of 10% duty will result in a 5% price reduction if the savings are passed directly to the consumer. Even at a monthly income of 2 million cedis ($400 at mid-2000 exchange rates), a well-paid Ghanaian worker will have to devote 5 months' salary towards the purchase of a solar electric system for his home.

Finally, the policy of tax and duty exemptions does not recognize the alternatives available to most people when they make energy choices. In most cases, the user can more cheaply meet their needs using grid electricity, even when it is a few kilometers away. At longer distances, diesel generators provide a less expensive short-term solution. Few potential solar customers choose it for environmental reasons.

Rural electrification: The National Electrification Scheme (NES) has been a largely successful government program initiated with donor assistance in 1989 with a goal of extending the grid throughout the country by 2020. To date, all district capitals are on the national grid, as are many communities along the high and medium tension power lines.

With the stated goal of the NES, there is little room for decentralized energy sources such as solar home systems. In addition to the high cost of the systems, people in communities without grid power remain convinced that the grid will be extended to them soon and are not willing to pay substantially more for solar energy in the short term.

It should be noted that, the cost of extending the grid to low-voltage points is estimated at $2,000-$3,000 per connection, a range which is comparable to the cost of a mid-sized solar electric system. This is in addition to the cost of medium and low voltage transmission lines (Government of Ghana Data, 1998).

Under these circumstances, the NES has shut out a large sector of the market for photovoltaic systems. The subsidies enjoyed by users under the NES are also not available to RET users, who are forced to bear the full cost of their power systems in advance.

Impact of pilots, donors and development projects: Many projects have been initiated to test and deploy RETs in Ghana over the years. Most of these projects have not led to commercialization of the technologies, mainly because this was not the primary objective and also because the institutions responsible for developing the projects did not involve the private sector in the process. As historical traders, Ghanaian entrepreneurs are quite efficient at making use of a commercial opportunity when they see one. This positive attribute has hardly been exploited in the projects that have been developed.

Donor projects are usually not necessarily aligned to national interests and can derail the commercial efforts of entrepreneurs. When equipment such as solar PV components is donated, it often serves more as a means to get rid of surplus materials in the donor country or generate employment for the donor country in times of economic downturn.

Development projects that do not take into account the after-effects of their impact end up doing harm to commercialization of RETs. Although many recent projects attempt to include entrepreneurial initiatives, there are still many that focus only on the immediate impact of the project objectives. A vacuum is created when the project winds up, leading to abandoned equipment, lack of ownership and opportunities that are not viable for entrepreneurs. In many cases the assistance would have been offered at highly subsidized rates and an entrepreneur who attempts to charge economic rates for the same service is bound to fail.

For policy measures to be effective, they must be broadly fashioned to provide fair access for a range of energy sources. The current environment heavily favors extension of the grid even to areas where it is not economically justified. The needs of such communities could be easily met with the same level of subsidy enjoyed by grid users if they were given the choice between solar, wind, micro-hydro and other sources.

THREATS ON SOLAR ENERGY IN GHANA

There are technical, economic, social, political and financial constraints to be minimized or overcome before the dissemination of PV systems can reach a level where they make a substantial contribution to the electricity supply mix of Ghana and an impact on the socio-economic life of the rural populations. The threats can be examined as follows:

Economic: Although PV systems may be cost-effective on a life-cycle cost basis, their initial costs are high, usually beyond the reach of the poor rural populations in Ghana. A 50 Wp solar home system costs about $650. The statistics on different technology options for distributed power generation is presented in Table 5. It is noted that while a micro-hydro and wind system can be installed for around $1000/kW (Petrie *et al.*, 2001), a

Table 5: Distributed generation technology options

	Engine generator	Turbine generator	Micro turbine generator	Photovoltaic	Wind turbine	Fuel cell
Fuel	Diesel or gas	Gas	Gas or liquids	Sun	Wind	Gas
Efficiency (%)	35	29-42	27-32	6-19	25	40-57
Energy density (kW/m^2)	50	59	59	0.02	0.01	1-3
Capital cost US$/kW	200-300	450-870	1000	6600	1000	3000-5000
O&M cost US$/kW	0.01	0.005-0.0065	0.005-0.0065	0.001-0.004	0.01	0.0017
Energy storage required	No	No	No	Yes	Yes	No
Technology status	Commercial	Commercial	Commercial	Commercial	Commercial	Soon to be commercial

Petrie *et al.* (2001)

PV system can be installed at $6600/kW. These compare unfavorably with an engine generator system with an initial cost of $200-300/kW. The poverty environment in developing countries like Ghana, constrains consumers to procure goods and services based on the initial cost and PV systems are not exempted from this kind of mindset, despite the fact that they may be cost-effective over 20 to 25 years of the lifespan of the module. It is expected, however, that with module price reduction to about $2/W by (European Photovoltaics Industry Association (2009), Technology Development, EPIA Roadmap), PV will become more cost-competitive. Also, initiatives to provide low interest loans repayable over several years will go a long way to boost the procurement of PV systems by rural dwellers.

Technical: Local manufacture of PV modules and most system components is yet to start in many developing countries. Virtually all PV system components are imported at costs which include the high import duties. Enough technical manpower has not been developed to support the design, installation and monitoring of systems. These deficiencies have often created a wrong impression about the viability of PV systems which have been badly designed, installed and poorly managed.

Social: A vast majority of the Ghanaian population are not aware of the technical viability and commercial availability of PV to meet their electricity needs. The inertia to adopt a new and “untested” technology for electricity supply has prevented the few who can afford to acquire the system from doing so. Also, managers of current conventional electricity generating technologies have often expressed a lack of conviction about the potentials of PV as a viable alternative source of electric power.

Political: For PV and other renewable energy technologies to be widely adopted, governments have to give their political backing through the promulgation of energy policies with the necessary regulatory framework that would encourage the private sector to invest in PV systems for power delivery. Until recently, countries like Ghana, Nigeria etc., have not considered PV for power generation partly because of the abundance of other energy resources such as fossil fuels and hydro power. Others have, because of lack of funds, relied on international donor agencies to provide seed money to stimulate the dissemination of PV systems. Political will is required by governments in developing countries to create the right policy, regulatory and market environment that would attract private investors to adopt renewable energy technologies for power generation in a deregulated electricity industry.

Financial: In Ghana, financing mechanisms for PV are not available at the moment. There are no subsidies and interest rates are very high. Local banks are not willing to give loans to corporate and individual investors in PV because of their lack of conviction on the viability of the technology. Although opportunities for financing exist through facilities such as the World Solar Programme or the Global Environment Facility, the impact of these facilities are yet to be felt in many developing countries including Ghana. Two forms of financing are possible: financing for end-users as a way of making the systems more affordable and financing for retailers and service providers to boost their activities.

CONCLUSION AND RECOMMENDATIONS

Conclusion: For several decades, electricity generation, transmission and distribution in developing countries especially Ghana, have been monopolized by agencies mostly controlled and funded by governments. These agencies, for lack of adequate funding, have not been able to provide adequate and reliable services for most rural areas. Several developing countries have taken bold initiatives to restructure their electric power sector, with remarkable improvements in the availability and quality of electric power supply. The India experience through the Indian Renewable Energy Agency has shown that renewable energy resources and in particular, solar PV, have the potential to meet the electricity needs of developing countries in a deregulated electricity industry. Several constraints exists which hinder the dissemination of PV systems but these can be surmounted through policy, regulatory and financial provisions and the political will to achieve the millennium development goals, through the adoption of environmentally friendly technologies for electricity generation.

Recommendations: Successful implementation of RETs in Ghana is possible, but the current economic and policy conditions are working hard against it. If success is to be achieved, certain fundamental changes would have to be made, starting with a broad policy shift that will be based on energy provision rather than grid extension, as is the case presently. The new policy would need to take into account the various decentralized sources of energy and afford users the choice of the best energy option for all parts of the country.

The following are important steps that will encourage the wider use and market acceptance of photovoltaic products for building applications in Ghana:

- The government must seek Research and Development funding to accelerate the development of PV products for integration into buildings for the purpose of making Ghanaian products available.
- Collaboration amongst architects, building engineers, developers, inspectors and the PV industry must be fostered to establish Ghanaian capacity and experience through demonstrations of grid-connected on-site generation on buildings using PV technology.
- Ghanaian manufacturers must be encouraged to grow and participate in the market for small distributed power systems by removing technical and non-technical barriers to the deployment of PV in buildings, such as barriers to the interconnection of small PV power systems to the electricity grid.
- Ghanaians should be educated on the potential and value of PV in Ghana by raising public awareness through demonstration activities such as building-integrated PV systems on educational facilities.
- Provision of the necessary structures needed to guarantee financing for the users and providers of RETs. This is a good area of intervention for development agencies, where basic objectives such as health improvement, adult education and economic development can be met.

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