Lighting Rural and Peri-Urban Homes of the Gambia Using Solar Photovoltaics (PV)

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Abstract: The role of energy in development is crucial. Energy fuels economic growth and is therefore of paramount concern for all countries. This was one of the main themes at the world summit on sustainable development (WSSD) held in South Africa in 2002. The Johannesburg plan of implementation highlighted the role of energy service to promote sustainable development and to facilitate the achievement of the MDG's. One of the growing concerns is the persistent energy poverty that is seriously impeding socio-economic development, particularly in sub-Saharan African and in countries of South Asia, but also in many other developing countries. Renewable energy is the solution to the growing energy challenges of developing countries like the Gambia. The heavy reliance on imported fossil fuel coupled with the growing demand for electricity and declining wood fuel supplies call for alternative sources of energy. Finding ways to expand energy services, while addressing the environmental impacts associated with energy use, represents a critical challenge for humanity. Recent developments in countries like China and India, where energy production has increased significantly, demonstrate how difficult it is. The decentralized approach based on power produced with locally available renewable energy resources is, for various reasons, gradually being recognized as a viable alternative in remote places. This research attempts to initiate, from a broad-based socio-economic and environmental point of view, the feasibility of a decentralized solar photovoltaic (SPV) system as a source of power for rural and peri-urban communities of the Gambia.

Keywords: Paramount, sustainability, alternative, decentralized, energy, rural.

INTRODUCTION

Electricity is one of the elements of a country's development and is one of the main infrastructural requirements for agricultural, industrial and socio-economic development. In most parts of the world, areas without electricity are far less developed than those with electricity [1]. PV uses and applications have been justified and strongly recommended for all less-developed countries [2]. A closer look would, however, demonstrate that the nature of the energy sector in Africa offers enormous opportunities for formulating and implementing ambitious renewable energy programmes that will bring an environmentally sound and secure energy future for Africa's poor closer to reality [3].

The Gambia's effort to provide energy services to the rural and peri-urban populace has been very slow. The main energy resources in the country comprise of fuel wood, petroleum products, Liquefied Petroleum Gas (LPG) and renewable Energy (a center exists for research and development on this). The provision of efficient, reliable and affordable energy that is sustainable and environmentally sound is the main objective in the government energy policy framework [4]. The solar energy potential in the Gambia is 5.7kwh/m² in urban areas and 5.1kwh/m² in rural areas [5]. Electricity generation from renewable energy technologies, such as household PV systems, also can be a cost-effective alternative for off-grid rural households with modest electricity needs [6].

Around 30 percent of the world population does not have access to affordable energy sources. However, less than 40% of the African population has access to electricity [7]. The majority of the unelectrified are located in rural and peri-urban areas where access to the grid is financially unviable [8]. Studies have shown that there are links between biomass combustion and respiratory illnesses in women and children [9].

In addition, women and children are the most vulnerable group in terms of energy scarcity and adverse environmental impacts associated with energy production and use [10]. Access to sustainable and green energy is fundamental to health, development and economic growth. Conventional energy sources are harmful to the environment and human health. Most of these unelectrified households in Africa are in rural and peri-urban areas, where the overall level of electrification is less than 15% [11].

According to [12], there is a potential solar home system market of 63 million households in Sub-Saharan Africa. Unlike widely used fossil fuels that emit enormous amounts of greenhouse gases, solar energy is green, clean and limitless. The primary goal of this solar PV-project is to improve the living conditions of communities in areas off the electric grid through the supply of reliable and sustainable electricity. In

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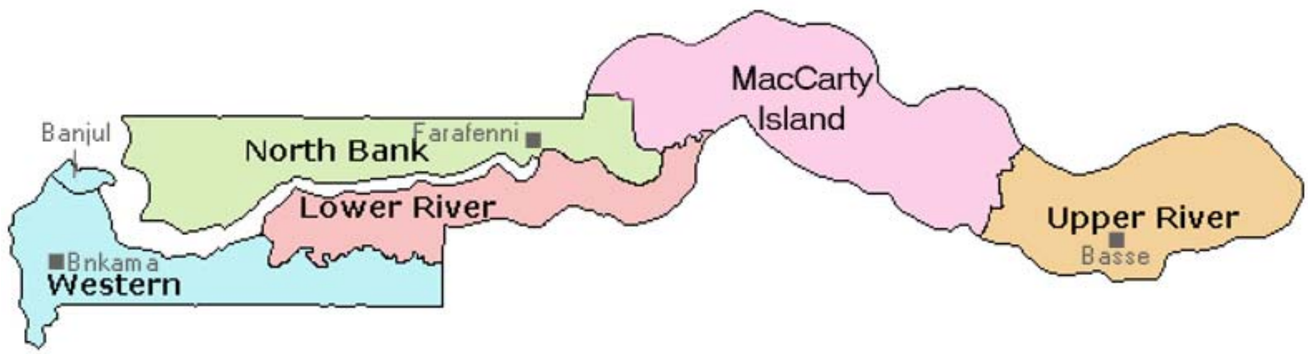

Fig. (1). Administrative divisions of the Gambia.

the long run the project should also provide opportunities to set up local production enterprises, help villagers to cope with harsh living conditions and counteract migration into the cities.

GEOGRAPHY AND ECONOMIC BACK GROUND OF THE GAMBIA

The Gambia is located in the valley of the Gambia River on the west coast of Africa. It is a narrow strip of land, approximately 480km long varying in width from 48km near the estuary of the river to 24km inland. It has a land area of 11,300 sq. km. It is bordered on three sides by Senegal and dissected by the Gambia River into North and South Banks. The current population of 1,688, 659 million (2007 est.) is estimated to be growing at 2.77% annually. The Gambia is divided into seven areas. These includes two municipalities - Banjul City Council and Kanifing Municipal Councils, and five regions -Western Region (WR), North Bank Region (NBR), Lower River Region (LRR), Central River Region (CRR),) and Upper River Region (URR). The capital city is Banjul. Fig. (**1**) presents the location map of The Gambia.

The Gambia's economy continues to be dominated primarily by the service industry and subsistence agriculture, which accounts for 52.3% and 34.9% of the GDP, respectively. Despite positive economic growth, the socioeconomic indicators in the country remain poor. Overall, economic performance in 2004 was very positive as tight macroeconomic policies prevailed throughout the year. This was helped by a remarkable revenue mobilization effort. The fiscal deficit as a percent of GDP (including grants and commitment basis) was 5.1% in 2004 from 5.6% in 2003. The annual inflation rate fell sharply to 8% in December 2004 from 18% a year earlier, mainly as a result of the tight monetary policy implemented. This policy also led to a substantial fall in interest rates. It is evident, therefore, that after the instability of 2001-2003, fiscal and monetary policies have been very effective in stabilizing the macro-economy [40].

In 2002, the United Nations Development Program (UNDP) ranked the Gambia as 155th out of 177 countries according to its Human Development Index [14]. The rating reflects a high rate of malnutrition, lack of access to potable water and widespread poverty. 59.3% of Gambia's population lives on less than $1 per day. Poverty in The Gambia manifests itself in the form of multiple deprivations. The latest Household Poverty Survey in 1998 revealed a high incidence of poverty in the country, with an increasing proportion of the population living below the poverty over the past decade: food poverty increasing from 33 to 37 percent; and overall poverty increasing from 60 to 69 percent.

Though poverty is predominantly a rural phenomenon, urban poverty is rising fast. Women are particularly disadvantaged, while regional disparities are also evident. Income inequality, as measured by the Gini coefficient, is high and increased from 0.180 in 1993 to 0.466 in 1998, indicating that the benefits of increased economic growth have not been distributed evenly, but have gone disproportionately to a small segment of the population [13].

Without infrastructure creation in things like: availability of clean water, electricity, roads, some basic communication and transportation, a genuine development in rural communities is impossible. The provision of electricity to communities would encourage economic activities thereby improving their living standards.

STATUS OF POWER SECTOR IN THE GAMBIA

Commercial electricity production is marked by a number of problems. These include under-capitalization, a rigid tariff system, escalating fuel prices, transmission and distribution losses and non-settlement of electricity bills. This debt is especially owed by institutions and companies. Consequently, the National Water and Electricity Company have great difficulties in meeting its operational costs, replace obsolete equipment and to invest in generation capacity expansion. The electrification rate of the Greater Banjul Area and the provinces averages below 20% except for Banjul where the rate stands at 70%. The electricity tariffs in the country are uniform for both the rural and urban consumers. All conventional electricity is produced mainly by thermal generation. The National Water and Electricity Company (NAWEC), is the sole producer and distributor of commercial electricity throughout the country. It operates a central power station located at Kotu, in the GBA and also runs smaller generation units in the six provincial regions. The gross energy consumption of the Gambia in 1998 was the equivalent of 308,100 tones of oil. This represents 0.28 TOE on a per capita basis. . The net energy demand for the country in 1998 was estimated at 287,100 TOE, which is met by

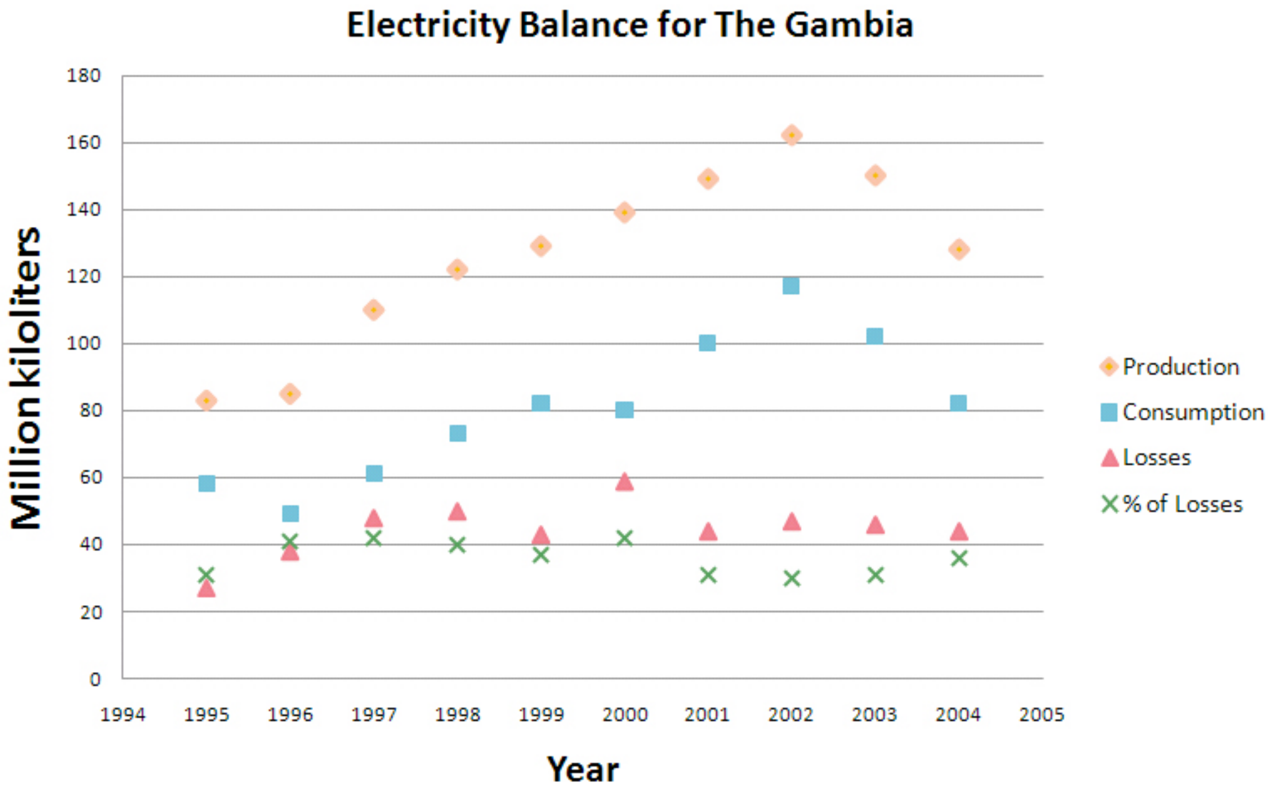

Fig. (2). Petroleum Import (Million Liters).

firewood (225,500 TOE), petroleum products (61,600 TOE) and electricity (6,300 TOE). The two biggest energy consumers are households and the transport sector.

The total consumption of electricity in the year 2005 was 134.9 million kwh. Approximately 60% of this was consumed by residential consumers and small-scale industries. Hotels and larger industries consume approximately 30%. The remaining 10% is consumed by Government and NAWEC. There is now a much larger demand that is being severely suppressed by expansions in the tourism sector, increased commercial activity and settlement patterns in Greater Banjul [15].

In some areas access to electricity is actually declining, as existing systems flounder for lack of maintenance, and extensions of the service fail to keep pace with population growth. In the rural areas, 6 provincial centers were supplied with isolated diesel generating sets that were old and unreliable. Most rural areas have gone unserviced with electricity for almost a year by the national utility. The transmission and distribution network has technical and non-technical losses of over 30% [16].

According to Fig. (**2**), electricity production has increased from 83.9 million Kwh in 1995 to 163.1 million Kwh in 2002 and thereafter declined. The consumption and losses in the system have correspondingly followed the same trend. The core problems and objectives of the government remain the following. Increase of generating capacity which is presently inadequate and unable to meet the demand. Capital investment to improve the poor state of the transmission and distribution system which result in high technical losses and un-metered consumption is estimated at about 40%. It also seeks to improve efficiencies, so as to reduce the extremely high cost of energy estimated at an average of US$0.18 per watt. The Government continues to undertake measures at overcoming these problems through institutional strengthening and other restructuring efforts. In that regard, the Government welcomes local and foreign interest in the sector so as to achieve the following: reduce the cost of electricity, increase the accessibility and reliability of electricity nationwide, and mitigate the environmental impact of the power sector [17].

As the world braces for a looming energy crisis, fueled by skyrocketing oil prices because of increasing demand for energy and fewer resources, solar panels are becoming a more lucrative and attractive solution for powering our energy hungry world. As the price of fossil fuels increase and as the cost to the environment becomes a major concern, solar panels are becoming more affordable and cost effective in the long run [18].

RENEWABLE ENERGY DEVELOPMENT

The government of The Gambia is encouraging renewable forms of energy including solar PV systems. The country enjoys year-round sunshine ideal for tapping solar energy for commercial and domestic purposes. Over the years, a lot of solar PV systems have been installed for applications such as water pumping, refrigeration, telecommunications and community lighting under various projects including the CILSS Regional Solar Programme (RSP) funded by the European Development Fund (EDF). In the past, renewable energy devices, such as wind pumps and solar heaters, were imported and tested locally, but only to a limited extent. Some 20 wind water pumping systems have been installed in various parts of the country. Recent information however indicates that most of them are not operational due to faulty mechanisms [19].

The use of alternative and renewable energy in the country is gaining recognition, especially the use of solar PV. This interest comprises of both individuals and groups. However, the deterring factor in the widespread utilization of renewables is the initial cost of investment, which is beyond the reach of many Gambians. Most Solar PV and wind installations are donor funded. The cost of the systems is tied to foreign exchange fluctuation. Renewable energy provides better alternatives to imported fuels especially for the rural areas. The production and utilization of these fuels have the following positive impacts:

1. Employment creation
2. Increase rural cash incomes and hence reduce poverty
3. Enhances the environment
4. Reduce balance of payment and
5. Ensure a sustainable supply of energy

ENERGY AND SOCIOECONOMIC DEVELOPMENT

There are many factors that can contribute to achieving sustainable development. One of the most important is the requirement of a supply of energy that is fully sustainable [21, 22]. Modern energy services are fundamental to all three pillars of sustainable development: economic, social and environmental [23]. Industries and productive activities (agriculture, commerce) require energy in various forms to fuel machines, power transformation processes and conserve perishable goods [20].

Furthermore, sustainable development within a society demands a sustainable supply of energy that, in the long term, is readily and sustainably available at reasonable cost. As noted in the report by the G8 renewable energy task force (2001), modern energy services are fundamental to all three pillars of sustainable development: economic, social and environmental. The report further states that most energy services must be developed and deployed in concert with all aspects of the development process, e.g. energy and communication and energy and health. This underpins the fact that high-quality energy and electricity services are complimentary factors for social and economic development. It would thus be expected that SHS, if deployed in this context, should provide a service that enables achievement of economic, social and environmental development.

Most social and economic activities require the use of energy in various forms and quantities. Energy is as important to households for basic use as it is to large industries for production. For its development, the world thirst for energy is growing at a faster rate than ever. According to recent BP statistics, energy consumption grew by 4.3% between 2003 and 2004. In some countries, where the availability of energy is limited or where energy is unaffordable for most households or the society in general, development is seriously impaired. In most parts of the world, areas without electricity are far less developed than those with electricity (UNDP; 2002). Energy is thus an essential ingredient for socioeconomic development. Rightfully then, issues of energy supply, access and security, as well as issues related to the impact of the consumption and production patterns of energy on the world sustainability, have been at the core of the world attention for decades [24].

According to United Nations Industrial Development Organization (UNIDO), high levels of income per capita tend to be associated with higher levels of industrialization. Though not specifically referred to in the targets of the Millennium Development Goals (MDGs), energy supply is an underlining requirement to achieve most of the MDGs [26]. Without access to adequate energy services, the majority of rural Gambians will continue to suffer from deep poverty, since energy is required for most basic household needs, such as lighting and heating. According to the World Bank indicators database, there is a strong correlation between modern energy consumption and GNP per capita. The GNP tends to rapidly increase as commercial energy use per capita increases, this applies mainly to low-income countries. When the countries reach a level of per capita energy consumption of around 10.000 TOE, factors such as efficient utilization of energy by industries, energy production and transformation systems and households tend to make the difference for economic growth to continue, so that more energy consumption does no longer imply more income for the country [25].

Nearly two billon people in the world are living without electricity and another billion people are relying on kerosene, candles or batteries. Energy links with other sectors are decisive for the economic growth that reverses poverty. Energy deficiency makes education, health and livelihood extremely difficult in developing countries. Solar energy can be used to empower three billion people in the rural areas and informal urban settlements around the globe. In addition, the solar panel-based outfits can be used to pump ground water for household needs, agriculture, and small industries in remote villages that are very far away from the national power grid. Moreover, computers, printers and telephones in rural areas can be operated by solar power. The governments and development organizations in the Gambia should start to adopt solar energy to bolster energy resources for ICT (information and communication technology) in rural areas. Solar panels can be used very effectively and appropriately in remote areas around the country because the cost of connecting to the conventional power grid by laying cables might be even more expensive. Once a solar PV system is installed one does not need any tools or technicians to maintain it.

The Gambia, like many other developing countries, is heavily dependent on imports to meet its petroleum requirements. Petroleum Products consumed in the Gambia are all imported. It is the second most important source of energy in the country accounting for about 17% of total primary energy needs according to the 2004 energy balance. The petroleum requirements of the country consist of gasoline (premium and regular), diesel oil (gas oil), kerosene, LPG and aviation (jet) fuel. The consumption of liquid products grew from 86,974 metric tons in 2000 to 108,470 metric tons in 2004. Only 5% of imported kerosene is used in households as a source of lighting [25].

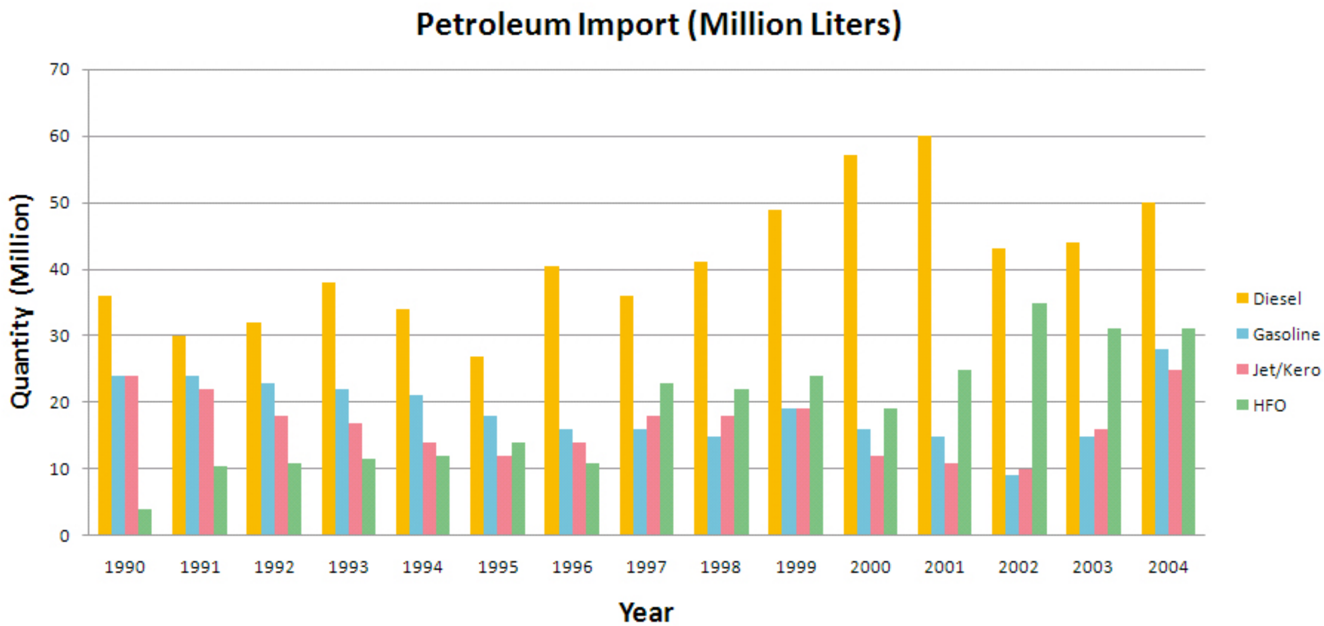

Fig. (3). Petroleum Import (Million Liters).

Fig. (**3**) indicates that The Gambia is heavily dependent on imports to meet its requirements for petroleum products. This includes the importation of diesel fuel for generating electricity. In 2004 The Gambia imported 113 million liters of petroleum products [25].

POTENTIAL BENEFIT OF USING SOLAR PV IN THE GAMBIA

Better access to sustainable energy services is needed at the macro level to foster economic growth and at the micro-level to stimulate businesses and income-generating activities [27]. Small businesses, public buildings and homes need adequate energy for lighting, communication, water supply, heating and cooling. Secondly, sustainable energy is important from an environmental viewpoint. Extending the conventional grid to most rural households has been generally deemed financially unviable since the 1970s [28]. The micro-grid alternative using diesel gensets is also largely unviable due to difficulties in accessing spare parts, technical support and high costs of fuel transportation [29]. Against this background, the World Bank and many governments started considering Solar Home System as the least-costly option for remote rural electrification [30, 31 and 32]. Decentralized systems are hence being advocated and deployed. Solar home systems seem to be the dominant decentralized technology used and promoted in developing countries, often on the justification of cost-effectiveness [33; 34; 35 and 36]. This reflects the general perception that solar-based technologies are in a good position to meet the growing need for energy in the developing countries [37].

Energy emissions represent 80 percent of total GHG emissions, contributing to global warming and making the trend towards natural disasters in many parts of the world worse. Following the Stern Review, and the February 2007 report of The Intergovernmental Panel on Climate Change (IPCC), there is no longer any real doubt that climate change is caused by human activity. World energy demand is expected to rise by some 60 percent by 2030, according to all the latest estimates. The pressure to find alternative and efficient energy sources as well as to save energy will only become greater. As the developing world is forecast to be hit hardest by climate change, it needs to embark upon this common endeavour to minimize the sources of risk [38]. Renewable energy and Solar PV in particular, is a viable option for electrification and has considerable potential to meet the needs of rural populations. The decentralized nature of Solar PV means that it requires local installation, operation and maintenance capabilities, thereby implying the creation of local activities and employment. [39]. Solar Home Systems (SHS) can meet some of the electricity needs of the rural population, generating electricity for a household to provide home lighting and entertainment whilst displacing poor quality kerosene lighting and dry cell battery powered devices.

FINANCING MECHANISMS

There are many barriers to the widespread diffusion of renewable energy technologies in the rural environment. One of the main barriers is financial, as many rural families have little expendable capital and inadequate access to credit. This memorandum outlines schemes that have been utilized to finance solar photovoltaic projects

CASH FINANCING

Direct Sales

Direct sales of PV systems through cash purchases will generally be the means by which a PV retailer first enters a rural market. The technology will generate awareness in the community as a few of the wealthy households purchase systems and people see the advantages of the PV generated light; no fumes, better light and fewer respiratory problems. However, the market for direct purchases is often small. Studies by Enersol have shown that only 5% of rural households can afford to purchase a system directly, whereas other financing methods would allow another 50% of households to purchase PV systems.

Case Study: Kenya

The Solar home systems market has been successful in Kenya without government support or subsidies. 150,000 systems have been installed over the past two decades with 20,000 more going in each year [46]. The Kenyan market for solar home systems has been operating from a base of 100's of small shop owners who sell photovoltaic systems. These shop owners may or may not be trained technicians who can also install and service the systems. Most of the solar systems purchased in Kenya over the last decade have been in the 10-14 Wp range [47].

Lessons Learned

1) Direct sales of systems will often lead to the purchase of the cheapest components and a system that is too small for the required needs. Shop owners are often more concerned with selling the system than assessing household energy requirements.

2) Direct sales are not always properly installed, leading to dissatisfaction from the start due to low system performance

3) Self-installed systems are frequently not properly maintained because the owner/installer is not educated about correct maintenance procedures- this leads to early battery and system failure

CREDIT FINANCING

As stated above the direct sales market for solar systems is rapidly saturated, as there are few families that can afford to purchase systems outright. Financing schemes for solar home systems becomes an important step in facilitating solar system purchases. However, lending to poor rural families with little "collateral" is viewed as a risky venture by most institutions, resulting in very high interest rates or a simple refusal to extend credit. The following schemes are now in use to provide credit for solar system purchases.

Small-Scale Lending Models

Multilateral lenders provide wholesale loans to intermediate, in-country institutions for retail lending at the village level. The multinational lender faces lower risk by lending to a secure institution such as a local bank, an NGO or a large retailer. This model reduces transactions costs for the large institutions by consolidating the loan. Many institutions are attempting to use this model to accelerate photovoltaic dissemination including: U.S. Export-Import Bank, Overseas Private Investment Corporation, USAID, U.S. Trade and Development Agency.

Case Study: Photovoltaic Market Transformation Initiative (PVMTI)

The PVMTI is executed by the International Finance Corporation (IFC) and the Global Environmental Facility (GEF). This project will provide technical assistance and financial capital to the manufacturers and dealers, who sell, install and maintain PV systems in three countries, Kenya, Morocco and India. In Kenya, the PVMTI will provide $5 million in capital to local banks. The local banks will pay retailers for solar home systems on an individual basis and the retailer will install the system. The end-user of the solar system will then pay the local bank over the course of the loan. Systems in the 20 to 60 Wp will be eligible for loan financing [47].

Retailer Provision of Sales/Service/Credit

Credit is not always available from multilateral institutions, in which case a retailer may provide a credit plan on its own. This model may not result in large infusions of capital (such as with PVMTI), but has proven successful in Indonesia.

Revolving Loan Funds

Revolving loan funds are set up by a community to provide low interest loans to individuals. The terms of the loans are often less strict than they would be from a financial institution and people can borrow from the funds without formal types of "collateral". Instead of the financial collateral required by banks, revolving loans utilize the social capital that exists in small communities to enforce loan payment and exert pressure on people who are late on their payments. This model is being used successfully by the Gansu Solar Electric Light Fund for financing solar home systems in China [44].

INSTITUTIONALLY OWNED AND MAINTAINED SYSTEMS

Leasing Solar Systems

A third party buys the systems at bulk rates and then sells them through long term contracts to consumers. This system may or may not include maintenance contracts, though most will include maintenance of some sort.

Government Granted Renewable Energy Concession

When grid extension is not a viable option for a particular population a government my grant a concession to a private institution to serve the community with distributed power. The government may continue to regulate the actions of the company by setting electricity tariffs, overseeing maintenance, mandating service coverage and/or subsidizing renewable energy installations. This system is particularly useful when the service area is deemed to be too dispersed or lightly populated to allow multiple companies to compete for the provision of services within the community.

Energy Service Company (ESCO)

An ESCO sells energy services but retains ownership of the system providing energy. The system is neither sold nor leased to the end-user. Cooperatives, NGO's, electric utilities and private companies can be ESCO's. The ESCO purchases components in bulk to reduce system costs and installs and services the systems. The ESCO is then responsible for financial management and administration. System costs are reduced because of the bulk buy, and the ESCO is seen as a less risky investment to financiers, leading to better interest rates. ESCO's can receive the low interest loans and governments backing that individual rural consumer are not eligible for. These larger loans have less transactions costs than the many small loans that would be required to service the rural population individually, leading to lower costs. Lower costs can then be passed onto the consumer in the form of lower fees. Energy service costs are akin to grid energy services, because the end-user pays for the systems in smaller increments over a longer time frame (10 years or more). It is important to make sure that there is a large enough concentrated demand for electricity, to reduce costs associated with services and repairs.

Financing mechanisms for PV systems is a critical element in the electrification of rural areas. There are several themes that are consistent in successful PV electrification projects. Financing schemes should include installation and maintenance of the systems, if not systems will degrade; people will be dissatisfied with their service and stop paying monthly fees. Financing schemes must also incorporate money for extensive training of technicians and system owners, ensuring proper care for the systems at all levels. Fee collections must be prompt and fee collectors tend to do a better job when they are personally rewarded for high collection rates. The national utility must also be honest about grid extension plans; no financing plan can be successful if people have unrealistic expectations about receiving cheap grid powered electricity. A Summary of financing mechanisms for solar pv projects is shown on Table **1**.

Table 1. Summary of Financing Mechanisms for Solar pv Projects

Cash financing	Credit Financing	Institutionally Owned and Maintained Systems
Direct sales	Small-Scale Lending Models	Leasing Solar Systems
	Retailer Provision of Sales/Service/Credit	Government Granted Renewable Energy Concession
	Revolving Loan Funds	Energy Service Company (ESCO)

METHODOLOGY

Options for energy production and consumption have a direct impact on the world ecosystem, forestry and water resources, air quality, climate change and human health. Currently, energy planners and decision-makers have a larger than ever array of choices of technologies and development paradigms to produce and use the energy required to thrust the development of their countries [14]. The severe economic and environmental implication of the way energy is produced and consumed has propelled energy issues to the top of the political and development agenda worldwide. New notions, such as "clean development", emerged in the international debate on energy, as standards, with constraints and opportunities for developing the energy sector. One such notion is the concept of sustainable energy. Even though there are some differences in the understanding of this concept, for most stakeholders, sustainable energy implies either renewable energy sources or/and the use of technologies that ensure a minimum or no damage to the environment. People at the base of the pyramid are the key to commercializing tomorrow's clean technology, because they so often are poorly served and exploited. They pay a lot of money for bad service. There is a huge opportunity to create new technologies. There is no question that people in many countries are paying more in one year for kerosene or candles than the one-time cost of a system.

Access to electricity is a fundamental component of economic and social development and therefore of great importance to these populations. The lack of electricity deprives people of basic necessities such as refrigeration, lighting, and communications. This study discusses the possible proposals that would enhance the provision of Solar PV that is affordable to the average Gambian. That being the case, a model that will suit the Gambian communities was developed. Fig. (**4**) shows the required capacity of a Solar PV that can light an average rural home.

Most households in the rural Gambia have no access to modern energy services. Therefore, Solar PV's are seen as an excellent alternative to grid extension and existing power supply systems. The population is in need of such solutions. As stated earlier, this study is largely focused on rural and peri-urban populations that do not (and will not in the medium or long term) have access to electricity via a power grid. Because of weakness of the distribution, some households in urban regions will purchase solar PV, either because they are not connected or because they want to be sure to have electricity 24 hours a day, 7 days a week. Fig. (**5**) shows a PV module that would be able to provide energy to a standard Gambian urban home.

With cash purchase out of the question, most rural families will have to resort to some form of financing. If one is a member of a credit union, or a rural-based civil servant, such as a teacher, one can enter an agreement to have a monthly deduction from the pay slip. If they are a member of a cooperative organization, they can take out a loan at lower interest rates (than those normally charged by banks). The author hopes that the Solar PV programme will be financed by donors. The method that will be used for the distribution of the solar PV is shown in Fig. (**6**).

While reliable information on ability to pay does not really exist, some rough estimates can be made based on the income level of the 'average' rural household. The Strategy for poverty alleviation coordinating office (SPACO,2000) survey, for example, estimates the income level of non-groundnut farmers, groundnut farmers, non-farming workers and non-workers at US$ 330, US$ 228-254, US$ 338 and US$ 727 respectively [40], implying an average income of US$ 387 per household annually. With average expenditure of US$ 234 on food and non-food items this would imply cash savings of the average rural households of around US$ 150 annually. This is not very much indeed. Although the figures in the above example should be interpreted with care, they show the magnitude of earnings in The Gambian rural areas. It becomes clear that only a few rural households would be able to cash purchase a PV system. However, wealthier and non-farming households (or farming house-

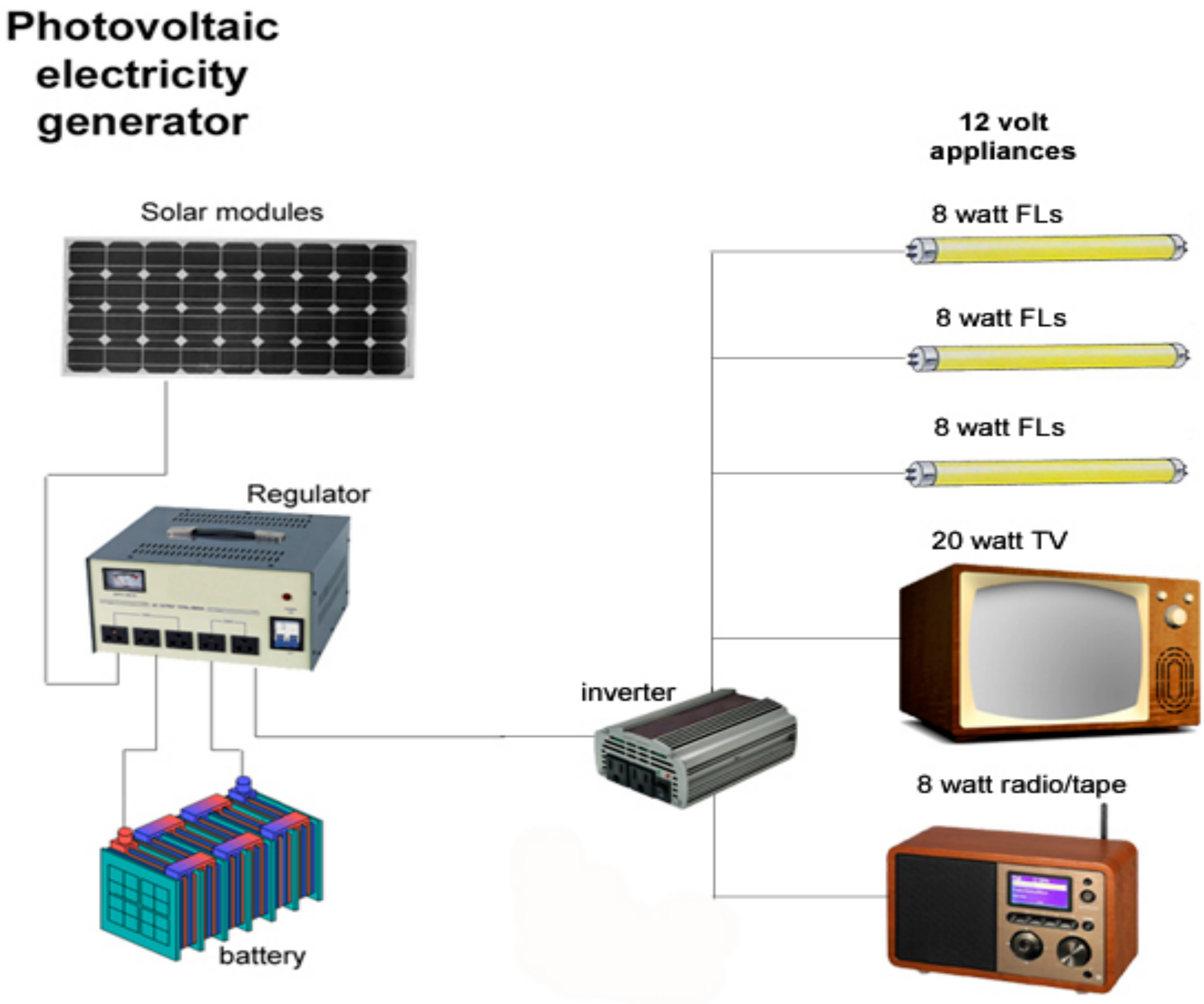

Fig. (4). Solar PV module that will be ideal for a rural Gambian home.

holds that have additional sources of income) will be more interested in acquiring a solar PV system if credit is offered.

A pilot project would be first conducted to evaluate the suitability of solar PV usage as a domestic source of energy. It will be launched in a peri-urban area in the Gambia where studies have shown electricity to be highest in demand.

Pilot Project

The Government of the Gambia is committed to addressing the energy needs of the majority of its citizens who live in rural areas. The government has realized it needs to shift emphasis to alternative approaches to enable a greater portion of the population to attain energy security and an improved standard of living. One of the objectives of this project is the establishment of a scheme suitable for the household purchasing of the product. This will act as a pilot project for installations in other villages.

This project, upon implementation will lay the basis for sustainable dissemination and use of solar photovoltaic systems in rural areas that cannot access the national electric grid. At the same time, this project will help curb greenhouse gas emissions from kerosene and diesel generators as well as the burning of fuel wood. Specifically, the project will work to overcome the financial, social, and institutional barriers to widespread dissemination of solar technology in the Gambia. Rapid scaling up of photovoltaic-based rural electrification activities will begin on completion of this pilot project.

Willingness to Pay

The Energy Affairs Division of the Ministry will determine the acceptability of PV lighting systems to the rural population and whether they are willing and able to pay for PV installations. Proposed funding for the initial phase of the PV rural electrification scheme will be through a donor funding. More funds will be required if the scheme is to become a countrywide project.

Tasks

1. Identify Credit Funds involved with local financial institutions to look at the possibility of their collaboration

2. Evaluate technicians on system installation and maintenance to work for commercial photovoltaic suppliers

3. Raise awareness of rural residents on photovoltaic alternatives

4. Establish appropriate community-level, solar dissemination model for rural electrification

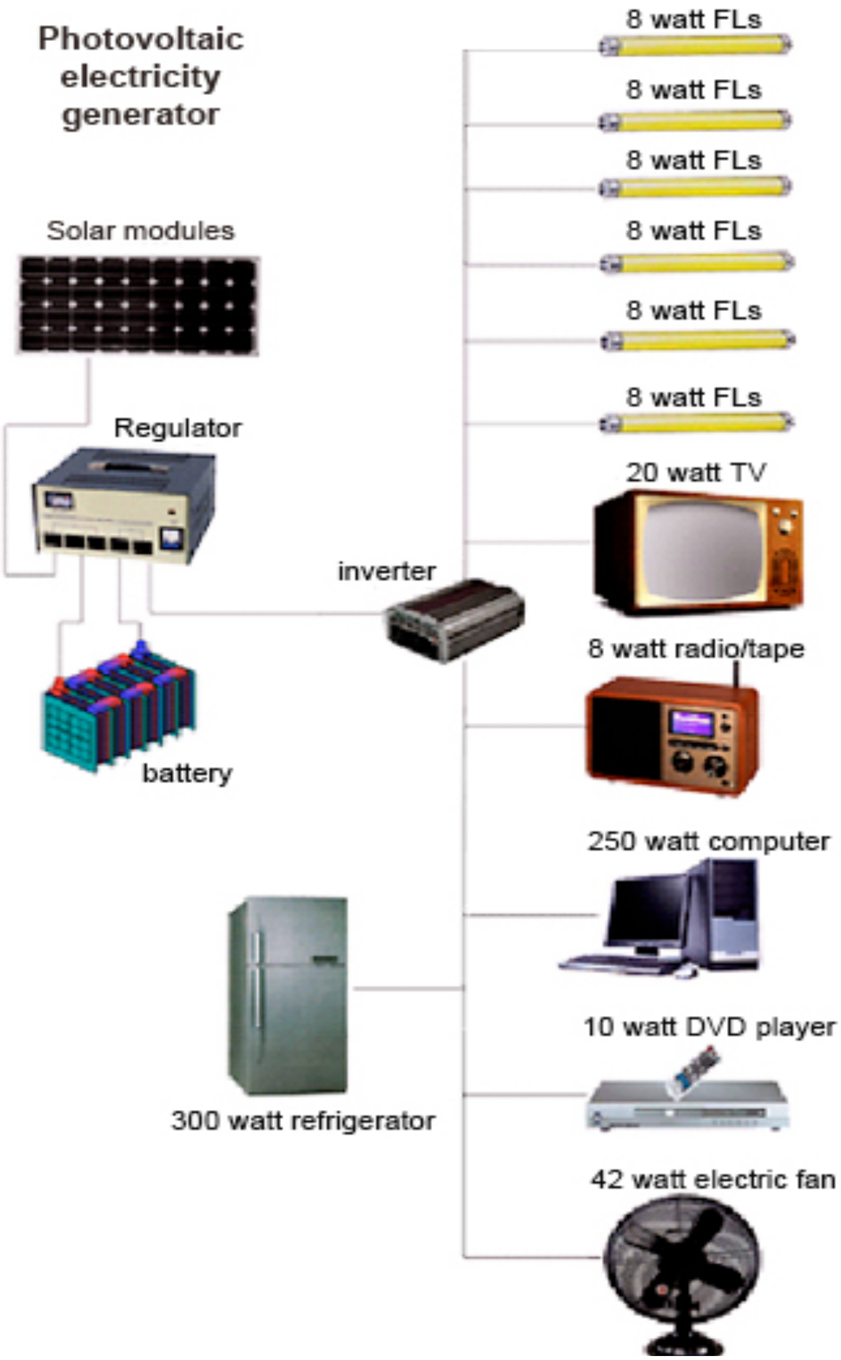

Fig. (5). PV module that would be ideal for an urban Gambian home.

FINANCING THE PROJECT

In developing countries where total rural electrification is not yet realized, PV programmes for rural electrification have been typically donor- and or government-subsidized with aims to benefit the rural population including the poor [43]. Donors have long supported this market, particularly with projects to promote SHS systems. This was primarily done to promote poverty alleviation and increase environmentally friendly solutions. SHSs are often perceived as the only choice for rural households to get access to modern electricity services (poverty alleviation), and in addition SHSs are considered by some organizations a cost-effective way to reduce greenhouse gas emissions [43]. This project intends to seek funding from international agencies and governments of developed nations. In the event that donor funding is not enough, individuals with better economic status would be asked to make some payment with subsidy from government. The project will work to overcome the financial, social and institutional barriers to widespread dissemination of solar PV in the Gambia. Most rural communities won't be able to cash purchase solar modules. With micro credit financing, most communities would be able to afford it. Also the income disparities would need initiating a mode of financing that would enhance access. Studies have shown that first cost barriers are the obstacles to widespread dis-

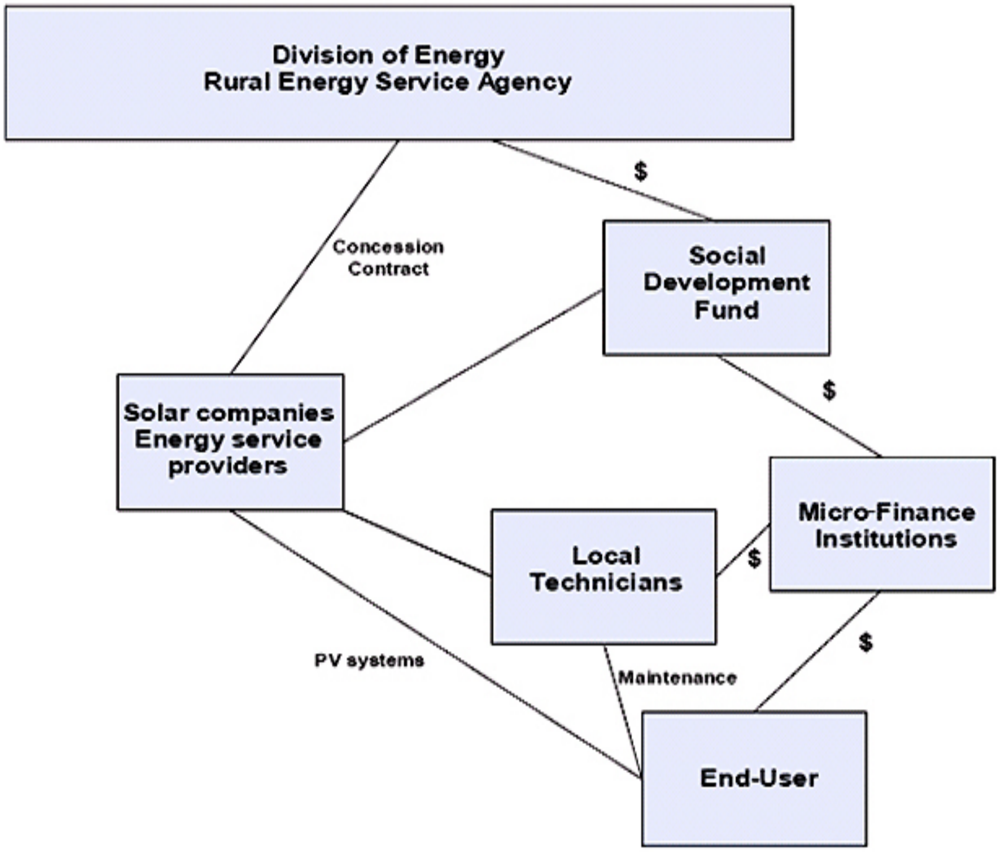

Fig. (6). Possible PV system delivery scheme

semination of solar PV.Through this method, individuals can select the type of financing that suit them most economically.

- ✓ Module 1**:** Customer pays only 15% of the total price of the SHS during installation and the remaining 85% of the cost is paid by monthly instalments within 60 months, including the 12% service charge.
- ✓ Module 2: Customer pays 25% of the total price of the SHS as down payment and the remaining 75% of the cost is paid by monthly instalments within 48 months, including the 8 % Service Charge.
- ✓ Module 3**:** Customer pays 10% of the total price of the SHS during installation and the remaining 90% of the cost, including 10% service charge in 60 months
- ✓ Module 4**:** 4 % discount is allowed for cash purchase

DISCUSSIONS

This research is conducted in collaboration with solar manufacturing company in Taiwan. Arrangements are made for the design of solar modules that would be affordable to Gambians. A Feasibility study report on renewable energy potentials in the Gambia conducted by the department of state for energy was being used as a source of reference. Also the Bottom of the Pyramid (BOP) concept is being incorporated for the author believes that upon successful implementation, it would have an impact on poverty alleviation.

Grid-based electricity is more expensive in rural than in urban areas due to lower load densities, lower capacity utilization rates and often higher energy losses. Rural customers increase the costs of generating electricity disproportionately, since rural areas add to the evening system peak, when power is more expensive. The costs of grid-based rural electrification extensions have ranged from US$230 to US$1,800 and more per connection, with a median cost of about US$600 per connection (excluding the cost of basic generating equipment and high-voltage transmission lines). Since these costs rise considerably in areas with small loads and low load densities (i.e., areas with low population density), alternative approaches are necessary in order to meet rural electricity needs in the least expensive way. Table **2** shows the electricity coverage by the National Water and Electricity Company. It is hoped that the introduction of solar pv for rural households would increase the electricity coverage.

The higher cost of inefficient energy-using devices and the lack of access to modern energy sources such as electricity become part of the BOP penalty, an added cost of being poor [41]. Unlike other power generating systems such as diesel gensets, SHS do not require any fuel; they require maintenance and spare parts. This part of a SHS Program is very important as it will determine the viability of a Program. If the targeted populations do not have enough income or the willingness to perform adequate maintenance, the installations will fail within a short period of time. Therefore, widespread use of solar PV systems should go hand-in-hand with a recycling system for batteries to prevent battery chemi-

Table 2. National Water and Electricity Company (NAWEC) Electrification Rate

Region	Population	Estimated number of Households	Official number of domestic meters	Coverage by NAWEC
Banjul + Kanifing Western Division	357'796	56'395	22'202	39%
Entire division	389'594	44'781	3'716	8%
Part Covered by NAWER's grid	294'972	33'905	3'716	11%

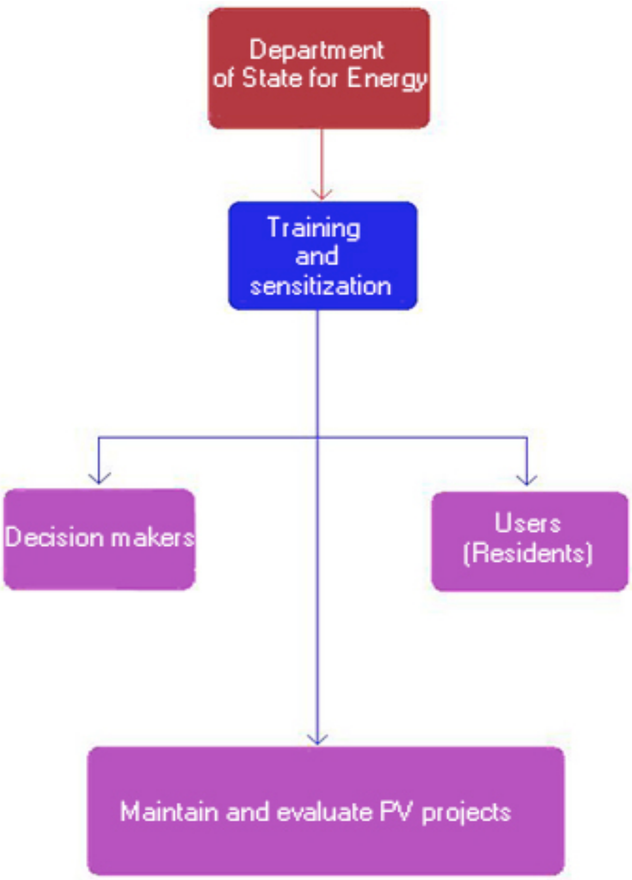

Fig. (7). Dissemination of PV modules.

cals being dumped into the environment. Current practice in The Gambia with the management of waste car batteries is by dumping them in municipal dumps.

The use of solar PV by rural households and services will lead to reduced CO_2 emissions by means of the avoided use of kerosene for lighting in households and the avoided use of diesel in generators that would be the alternative in rural communities. The targeted settlements in the SHS Programme consume about 71,365 kWh per year. Assuming this energy would otherwise need to be generated using a diesel generator, this implies a greenhouse emission avoidance of 90 tCO_2 annually. In the case of households, the solar home system will replace the use of paraffin lamps. Assuming a paraffin consumption of 118 liters a year per household, this implies a CO_2 reduction of 3,835 tCO_2 annually for the 10,186 targeted in the SHS programme. The over-reliance of the city and major urban centers on fuel wood and charcoal is destroying the country's forest resources and natural vegetation cover at an alarming rate, causing general environmental degradation [5].

CONCLUSION

We live in a world dominated by a "center-periphery" consciousness. Access to energy, is concentrated in urban areas that are connected to centralized power grids. Remote villages are deprived of basic energy services. Four out of five people without access to electricity live in rural areas of the developing world, mainly in South Asia and Sub-Saharan Africa. In Sub-Saharan Africa only 8 percent of the rural population has access to electricity, compared with 51 percent of the urban population. Likewise in South Asia, only 30 percent of the rural population has access compared with 68 percent of the urban population. Moreover, under today's policies and investment trends in energy infrastructure, 1.5 billion people will still lack access to electricity in 2030. Hence a major expansion of electricity supply is needed in both the urban and rural areas of these regions. Rural communities in developing countries have very few financing possibilities to buy PV panels. Innovating financial schemes would help people access them

Future research would focus on the integration of a hybrid system at power plants. Installation of solar panels at the National Water and Electricity Company's power generation stations where they will be connected to the grid would boost energy generation and supply. Also further studies on solar photovoltaic equipment standards and installation codes in the Gambia would be conducted to have uniformity.

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