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"Potentials, Opportunities and Barriers for the Deployment and Usage of Solar Energy Technologies and Services in West Africa"

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Table of Contents

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TABLE OF FIGURES

TABLE OF TABLES

TABLE OF BOXES

ABBREVIATIONS

AC	ALTERNATING CURRENT
AEEP	AFRICA-EU ENERGY PARTNERSHIP
BMU	BUNDESMINISTERIUMS FÜR UMWELT- FEDERAL MINISTRY FOR THE ENVIRONMENT, NATURE CONSERVATION AND NUCLEAR SAFETY, GERMANY
CER	CERTIFIED EMISSIONS REDUCTION
CF	CAPACITY FACTOR
CILSS:	INTERSTATE COMMITTEE FOR DROUGHT CONTROL IN THE SAHEL
CIM	CONTRUCTION-INSTALLATION-MANUFACTURING
CPV	CONCENTRATING SOLAR PV
C-SI	CRYSTALLINE SILICON
CRES:	REGIONAL CENTRE FOR SOLAR ENERGY (CENTRE REGIONAL D'ÉNERGIE SOLAIRE)
CSP	CONCENTRATED SOLAR POWER
CSR	CLIMATOLOGICAL SOLAR RADIATION
DNI	DIRECT NORMAL IRRADIATION
EBID	ECOWAS BANK FOR INVESTMENT AND DEVELOPMENT
ECOWAS	ECONOMIC COMMUNITY OF WEST AFRICAN STATES
ENDA-TM	ENVIRONMENT ET DEVELOPMENT DU TIERS MONDE
EPIA	EUROPEAN PHOTOVOLTAIC INDUSTRY ASSOCIATION
ERERA	THE ECOWAS REGIONAL ELECTRICITY REGULATORY AUTHORITY
ESMAP	ENERGY SECTOR MANAGEMENT ASSISTANCE PROGRAMME
ESTIF	EUROPEAN SOLAR THERMAL INDUSTRY FEDERATION
EU	EUROPEAN UNION
FIT	FEED-IN-TARIFF
FY	FINANCIAL YEAR
GEF	GLOBAL ENVIRONMENT FACILITY
GHG	GREENHOUSE GAS
GREENFUND	GHANA RENEWABLE ENERGY FUND
GTZ	GESELLSCHAFT FÜR TECHNISCHE ZUSAMMENARBEIT
IEA	INTERNATIONAL ENERGY AGENCY
KW	KILOWATT
KWH	KILOWATT-HOUR
LEDS	LIGHT-EMITTING DIODES
LESEE:	LABORATOIRE D'ENERGIE SOLAIRE ET ECONOMIE D'ENERGIE
LPG	LIQUIFIED PETROLEUM GAS
NGO	NON-GOVERNMENTAL ORGANIZATION
NREL	NATIONAL RENEWABLE ENERGY LABORATORY
NREMP	NATIONAL RENEWABLE ENERGY MASTER PLAN (NIGERIA)
ODA	OVERSEAS DEVELOPMENT ASSISTANCE
OECD	ORGANIZATION FOR ECONOMIC COOPERATION AND DEVELOPMENT
ORC	ORGANIC RANKINE CYCLES
PESGO	PROGRAMME ENERGIE SOLAIRE GRAND-OUAGA
PV	PHOTOVOLTAIC
PVPS	PHOTOVOLTAIC POWER SYSTEMS PROGRAMME
R&D	RESEARCH AND DEVELOPMENT
RE	RENEWABLE ENERGY
REN21	RENEWABLE ENERGY POLICY NETWORK FOR THE 21ST CENTURY
RSP:	REGIONAL SOLAR PROGRAMME
SEESL	SOLAR ENERGY AND ENERGY SAVINGS LABORATORY
SHC	SOLAR HEATING AND COOLING
STREG	STROMEINSPEISUNGSGESETZ
TV	TEVEVISION
UEMOA	UNION ECONOMIQUE ET MONÉTAIRE OUEST AFRICAINE
UNEP-SEFI	UNITED NATIONS ENVIRIONMENT PROGRAMME- SUSTAINABLE ENERGY FINANCE INITIATIVE
USA	UNITED STATES OF AMERICA
WAGP	WEST AFRICAN GAS PIPELINE
WAPP	WEST AFRICAN POWER POOL

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EXECUTIVE SUMMARY

Compared with average continental and global electricity consumption rates of 563 and 2596 kWh/capita respectively, the West African Sub-region remains one of the most energy-poor regions of the world with a per capita electricity consumption of 88kWh; electricity access rate of a little over 20% and household LPG/Kerosene access rate of 5%. The sub-region is endowed with significant renewable and conventional energy resources, with an average daily global radiation of 4-6.5kWh/m^2, the region possesses significant potential for solar energy resource development and utilization. Solar energy technologies have been widely used around the world, particularly in the OECD counties, at the end of 2009 the cumulative global PV deployment was about 24GW most of them, grid-connected systems. The solar thermal collector capacity in operation worldwide amounts to 151.7 GW corresponding to 217 million square meters by the end of 2008. In the ECOWAS sub-region, both on- and off-grid PV applications have the capacity to significantly contribute energy security, poverty reduction and access to other basic services such as water supply, health and education. Solar thermal technology options available include: water heating, distillation and desalination; crop drying, solar cooking, cooling and concentrated solar power. Both grid-connected and off-grid solar Photovoltaic technologies have also been available globally for various applications.

With increasing R&D and market expansion it is expected that the solar-to-electric efficiency of the two main photovoltaic cells would increase as follows: *crystalline silicon* which has a market share of about 78% would improve from current 13-18% to 25% expected by 2030 and thin film from the current 5-9.5% to 18% by 2030 respectively. New and improved solar thermal heat storage systems are also expected, particularly for Concentrated Solar Power (CSP). A number of ECOWAS countries such as Niger, Senegal, Ghana, Cape Verde and Nigeria have policies or strategies that seek to streamline the integration of renewable energy for poverty reduction, energy security and the provision of basic social services. Many other countries also offer tax-exemption. Technical and non-technical barriers that need to be addressed include: lack of skilled manpower for the design, installation and maintenance of solar products, lack of institutional and regulatory framework that support the implementation of solar energy, financing mechanism.

To exploit the solar energy potential of the West African Sub-region for the benefit of its citizenry it is recommended that ECOWAS Regional Centre for Renewable Energy and Energy Efficiency (ECREEE) takes steps to ensure the following:

- Proactive Policy Coordination and Regional Institutional Frameworks (including regional targets and incentives);
- Innovative Financing Mechanisms and Regional Market Creation;
- Technological Capacity Building and Manufacturing for Regional Market;
- That ECOWAS adopts a Short-, Medium-, to Long-term Action Plans.

ENERGY RESOURCES IN WEST AFRICA

a. West African energy context

The energy consumption level is among the lowest in the world with 4 % of the world population, (13 % for Africa) and a 2 % production of world commercial energy (7 % for Africa), ECOWAS accounts for only 1.7 % of world energy consumption (3 % for Africa) (ECOWAS, 2006). The ECOWAS region is characterized by a very low overall access rate to modern energy services, thereby inhibiting prospects of developing economic activities, providing basic social services and fighting poverty. The region has some of the lowest modern energy consumption rates in the world with average electricity consumption of 88 kWh/capita compared to the continental and global averages of 563 and 2596 kWh/capita respectively.

Household access to electricity across the region is about 20 % but wide differences exist between the access rates in urban areas that average 43 % while rates in rural areas range between 6 % and 8 %. There are significant electricity and overall energy pricing inequalities within countries i.e. between rural and urban areas and between countries. Access to modern fuels for motive power and electricity in rural areas is particularly low since there are no decentralized energy systems in place. At household level, access to LPG or kerosene averages a mere 5 %.

The most significant natural gas development project is the West African Gas Pipeline (WAGP) project. The 678 km WAGP links Nigeria's Niger Delta region to the Takoradi thermal power plant in Ghana with gas delivery in Cotonou (Benin), Lome (Togo) and Tema (Ghana). 85 % of the gas is for power generation and the remaining for industrial applications. In order to address the issue of power supply deficiency within West Africa, The West African Power Pool (WAPP) was created. The vision of WAPP is to integrate the national power system operations into a unified regional electricity market - with the expectation that such mechanism would, over the medium to long-term, assure the citizens of ECOWAS Member States a stable and reliable electricity supply at affordable costs.

b. Conventional energy resources

Nigeria alone is endowed with 98% of the proven reserves of crude oil, natural gas and coal , that is 30 % of Africa's total proven crude oil reserves (3,017 million tons), and 31% of Africa's proven natural gas reserves (3,581billion m^3) (ECOWAS, 2006). Smaller oil reserve deposits are located in the Gulf of Guinea (offshore Benin, Côte d'Ivoire and Ghana). West Africa's petroleum refining capacity is concentrated in Nigeria. Nigeria's refining capacity is currently insufficient to meet domestic demand, forcing the country to import petroleum products.

c. Renewable energy resources

Biomass represents one of the main energy resources in West Africa. These resources are mainly concentrated in the humid southern tropical part of the region, and the available quantities vary from one country to another according to the climate. In 2000, ECOWAS total forest area was estimated at some 69 822 000 ha Recent studies (IUCN) reveal that the forest potential in many ECOWAS countries is considerable enough to cater for the overall fuel demand (although there are significant disparities among countries) (ECOWAS, 2006). With a total contribution of 80 %, biomass is currently a vital part of the primary energy consumption within ECOWAS (GTZ, 2009). The **hydroelectricity** potential of the ECOWAS region, mainly concentrated in five of the 15 Member States, is estimated at 25,000 MW out of which only 16 % has been exploited to date (ECOWAS, 2006). The feasible small-hydro power potential is estimated at more than 5,700 MW (UNIDO, 2010). The average **daily global irradiation** in West Africa varies from 4.27 to 6.52 kWh/m^2 while the average daily direct normal irradiation varies from 1 to 6 kwh/m^2. With regard to the utilization of **wind energy**, considerable wind speeds are encountered along the coasts and the desert zones.

d. Challenges and availability of solar energy resources

The West African sub-region receives abundant solar radiation all year round; preliminary solar resource assessment for West Africa was conducted by the Solar Energy and Energy Savings Laboratory (SEEEL, Ouagadougou) and maps were drawn (Figures 1 and 2). The data were obtained using the Climatological Solar Radiation (CSR) Model from the National Renewable Energy Laboratory (NREL, USA).

Figure 1: Annual average daily of Global radiation for West Africa

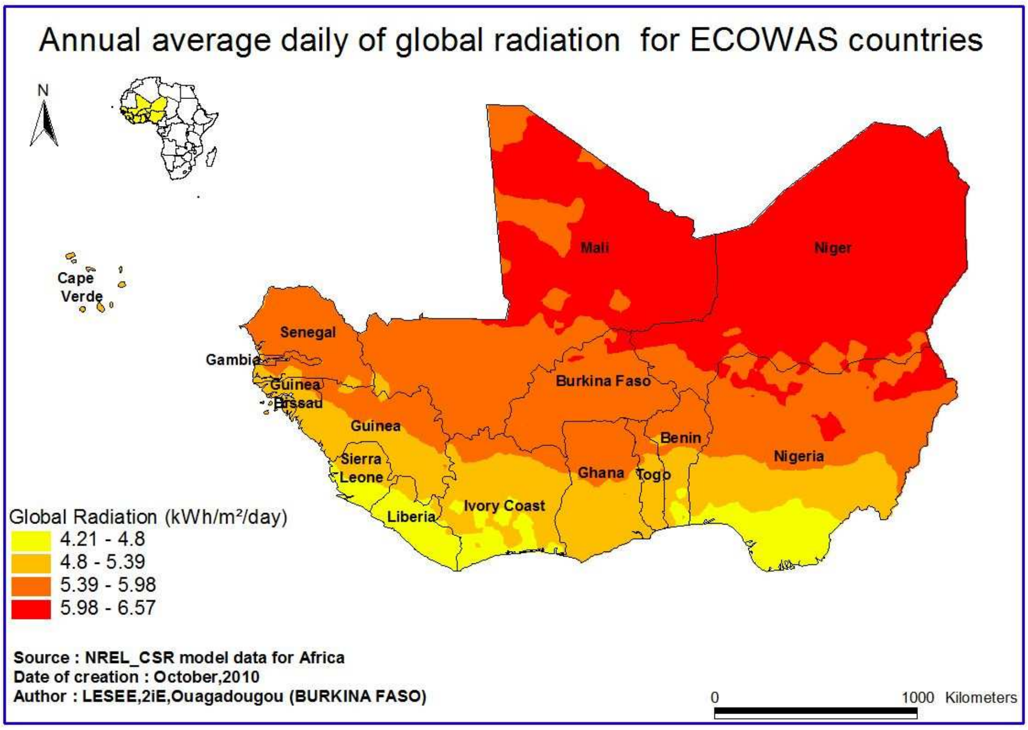
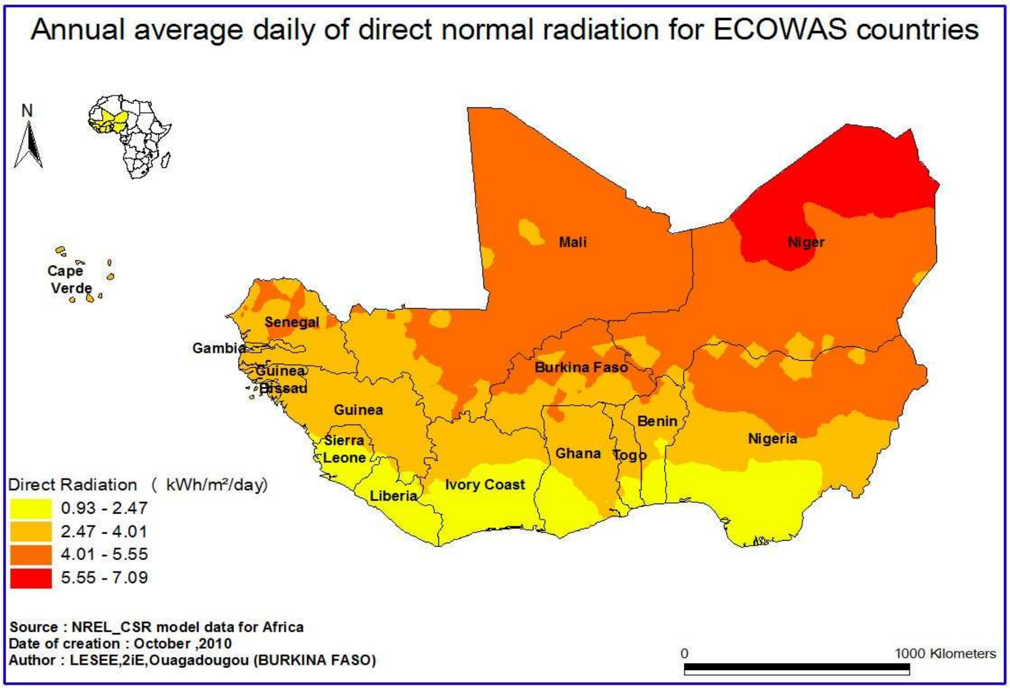


Figure 2: Annual average daily of Direct Normal Irradiation (DNI) for West Africa



The maps show that the average **daily global irradiation** in West Africa varies from 4.27 to 6.52 kWh/m^2 while the average **daily direct normal irradiation** varies from 1 to 6 kwh/m^2. Though, irradiation level is good in the region, modern application of solar energy for lighting, heating, cooking, cooling, drying or thermal power is insignificant.

A challenge in the use of solar energy in the region is lack of comprehensive and accurate solar data especially the direct normal irradiation; this hinders the implementation of solar concentrators for electricity generation. Also, the current cost of PV systems makes it inaccessible to the general population. Although PV finds applications in lighting, water pumping, communication, problems such as theft, lack of standards and certifications, lack of skilled manpower, high ambient temperature are affecting the promotion of solar PVs. institutional mechanisms should be put in place in order to foster entrepreneurial activity and the use of solar energy for activities that can generate income. Comprehensive data on the dissemination of solar technologies is lacking (Brew-Hammond et al., 2008).

SOLAR TECHNOLOGY OPTIONS FOR WEST AFRICA

Solar energy technologies can be divided into two categories: solar thermal systems and solar photovoltaic systems. Solar thermal systems use the sunlight to produce directly usable thermal energy or heat for water or space heating, drying, cooking, cooling or electricity generation while solar photovoltaic is the direct conversion of solar radiation into electricity.

a. Solar Thermal

i. Water Heating

The principle of the system is to heat water, usually in a special collector and store it in a tank until required. The two main types of collectors are: flat plate and evacuated tube. The cheapest technology available and the simplest to install is a thermosiphon system, which uses the natural tendency of heated water to rise and cooler water to fall to perform the heat collection task. To date, solar water heating is the only solar thermal technology that has entered into use on a relatively significant scale. Solar water heating systems may be used in individual homes, in health centres, in schools or in hotels across West Africa. By replacing or complementing electric water heaters, solar water heaters are one effective option to avoid electric shortages and mitigate peak loads. The solar thermal collector capacity in operation worldwide amounts to 151.7 GW corresponding to 217 million square meters by the end of 2008 (IEA-SHC, 2010).

ii. Water Distillation and desalination

Water distillation or desalination is a good option for supplying freshwater to population in West Africa, especially those along the coast. It is a mature but energy-intensive technology used mainly in oil rich countries like Saudi Arabia, Algeria, and Libya. The energy required in the process can be provided by solar thermal energy. However desalination using solar energy remains at the stage of research and development. In general solar distillation/desalination equipment, or stills, is more economically attractive for smaller outputs. Costs increase significantly with increased output, in comparison to other technologies which have considerable economics of scale (UNIDO, 2007).

iii. Crop Drying

Most crops in West Africa are seasonal and perishable; post-harvest and storage losses are even estimated to be between 20 to 25 % in general in Africa. It is therefore imperative to dry them for preservation and utilisation throughout the year. Of the many possible options amongst energy sources, solar drying is a promising source for application in West Africa (Ramde and Forson, 2007). It is the cheapest technique since it uses free, limitless and non-polluting energy with a minimum investment in equipment. Sun drying which consists of

spreading the food directly on the floor or mats openly in the sun is, of course, widely used for preserving agricultural and fishery products in the region; however, in this drying method, dust, airborne moulds and fungi, insects, rodents, and other animals often contaminate the food. Furthermore, open air-drying is often not possible in humid climates, especially in the humid coastal part of region. A solar dryer is most often an enclosed unit, so the crop is safe from damage, birds, insects etc. The crop is dried using solar thermal energy in a cleaner and a healthier way. There are a variety of solar dryers. They can be made in different sizes and designs based on the quantity and type of food to be dried. The size and shape also depends on whether it is to be used on domestic or commercial basis. The cost of a dryer varies with the design, size and materials used. The poor acceptance of solar dryers by farmers is generally related to the cost of the drying system that does not always match the income of the farmers.
Direct mode natural convection solar dryers such as cabinet and tent dryers are relatively cheap, easy to maintain and easy to use. They can be produced from locally available materials, and by local carpenter. They are suitable for small-scale farmers whereas forced convection of any mode (direct, indirect or mixed mode) could be a good option for heavy-duty drying such as timber and cocoa drying.
In general, solar drying is more appropriate when (UNIDO, 2007):

- the value per ton of products dried is high
- the proportion of the product currently spoiled in the open air is high
- the dryer is more often used.

iv. Solar cooking

Solar cooking is using solar energy as fuel to cook food. Experts suggest a minimum daily global solar irradiation of 4 kWh/m^2 for solar cooking application. With regard to that, West Africa has abundant sunshine for solar cooking (Refer to Figure 1). Solar cooking can help alleviate the burden of women and children who must walk for miles to collect wood or spend their meagre income on fuel. Some are of the view that solar cooking cannot entirely replace the use of firewood but can be a complementary technology which can help significantly reduce its use. There are hundreds of different designs of solar cookers; however, they can basically be divided into four types: box types, panel types, parabolic types and indirect types. It is often difficult to produce solar cookers locally. Materials like glass, mirrors, or reflective-coated aluminium is not easily available (Kroon, 2004).

Almost all solar cookers are distributed via NGO's, who partly or fully subsidise the solar cookers. Many early programmes with solar cookers failed. It is believed that Solar cookers have only been able to take a firm hold where there are virtually no alternative fuels available (GTZ, 2007). In 2005, a cheap solar cooking device called CooKit was introduced in Burkina Faso though the 'Programme Energie Solaire Grand-Ouaga (PESGO)'. It was a cardboard panel cooker covered with aluminium foil. The CooKit could not replace firewood entirely, and the use of Jatropha oil as a complement to the CooKit was proposed but further research needed to be pursued. Germany made solar cookers known as the 'papillon' were also introduced in Burkina Faso. These cookers were somewhat a modified version of the parabolic cooker (Ramde et al., 2009). Adaptation to cooking habits have been realized as a problem due to food preparation methodologies and family sizes.

v. Solar cooling

Unlike solar heating, solar cooling benefits from a better time-match between supply and demand. Solar adsorption and absorption cooling are technically mature and commercially available for cooling large administration buildings. They could lead to significant savings in primary energy in West Africa since air conditioning in the administration buildings represents 80 % of the electricity consumed in most countries (Ramde et al., 2009). Solar or hybrid solarbiofuel refrigeration could also be used for keeping vaccine. It should be easy to construct using locally available materials such as charcoal and steel.

vi. Solar Thermal Electric Power

Electricity generation through solar thermal is done either through solar chimney or through Concentrating Solar Power (CSP). Solar Chimney is still at the research and development stage while the first commercial CSP plant has been in operation in California since the mid-1980s. The four main CSP technologies, which have reached commercial or near-commercial stage are parabolic trough collectors, linear Fresnel reflector systems, power towers or central receiver systems and dish sterling systems.

CSP technology could help raise the current low rate access to electricity in West Africa.
Economically viable minimum DNI for Concentrating Solar Power (CSP) plants has been suggested in the literature to be 5 kWh/ m^2 (NREL, 2003; Müller-Steinhagen and Trieb, 2004); with respect to that, Figure 2 shows that the Sahel part of the region is potentially good for CSP projects. Unfortunately, the Sahelian zone is characterized with low water availability and with inadequate high voltage transmission lines. In view of that, dry cooling technology could be adopted when using Rankine cycles and hybrid solar-gas turbines when using Brayton cycles.
Organic Rankine cycles (ORC) are suitable for low temperature applications especially in the coastal belt where DNI values are low. ORC is also a good option for local and small-scale electricity production especially in communities located far from the grid where electricity demand is not high.

b. Solar Photovoltaic Technology (Solar PV)

i. Different PV Technologies, Trends And Prospects

Solar Photovoltaic technology is one of the mature renewable energy technologies for generating electricity, with a cumulative global deployment of 24GW at the end of 2009 (REN21, 2010), it is expected to contribute up to 11% of global electricity generation by 2050 (IEA, 2010). In the West African sub-region, the ECOWAS/UEMOA White Paper on Energy envisages that 66% of the population in the region will have access to electricity by 2015 (up from the estimated regional average electricity access rate of 20%), in achieving this target, renewable energy (including solar PV) is expected to make a significant contribution (ECOWAS/UEMOA, 2005).

The two main categories of PV cell technology are defined by the choice of the semiconductor: either crystalline silicon (c-Si) in a wafer form or thin films of other materials. Crystalline silicon (c-Si) cells have conversion efficiencies of 13-18% with a market share of about 78%, while thin film solar cells have efficiencies of 5-9.5% with approximately 22% market share. With continuing R&D, c-Si cells are expected to improve conversion efficiencies to 23% by 2020 and 25 % by 2030 with thin film cells improving to 15% and 18% within the same time period (pvresources, 2008; IEA, 2010; EPIA, 2010). Under research, development and demonstration are a number of solar PV technologies, among which is the Concentrating Solar PV (CPV) which uses optical systems to focus direct solar radiation on high efficiency silicon solar cells (IEA, 2010).

ii. Off-Grid Solar Home And Battery Charging Systems

Off-grid solar systems comprise mainly of solar modules, Charge controllers, battery storage systems and inverters (where AC loads are used). These systems mainly provide basic energy services such as lighting, powering radios, TVs and other low-power loads. The West African sub-region has moderate experience with these systems, mainly through donor-supported rural solar electrification schemes such as GEDAP (Ghana Energy Development and Access Programme) by the World Bank and RESPRO (Renewable Energy Services Programme) by the Spanish Government.

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iii. Other Off-Grid Applications

Solar PVs have been applied in water supply by powering water pumps systems with over 50,000 such systems installed globally and an estimated 1000 such systems installed in the West African sub-region at the end of 2007 (REN21, 2008), in Nigeria, it constitutes over 52% of PV installations (ESMAP, 2005). Solar pumps work in the range of up to 200m head and with outputs of up to 250m³/day, the technology has improved from a typical solar energy to hydraulic (pumped water) energy efficiency of around 2% in the 1980s with typical photovoltaic array efficiency of 6-8% and the motor pump-set efficiency of around 25%. Currently efficient solar pumps have an average daily solar energy to hydraulic efficiency of more than 9% though lower efficiencies of 2 -3% are still common (Practical Action, 2006). Solar PV systems have over the years also found wide application in the telecommunication sectors where they have powered repeater stations and other installations, over 300 installations had been done in Senegal by end of 2004 (ENDA-TM, 2005). Solar PV technology has also been widely used in a number of off-grid situations including: education for providing lighting and powering computers; in health for vaccine preservation and powering small equipment; street lighting etc, in the social context.

iv. Grid-Connected Solar PV Applications

Grid-connected solar PV systems unlike the off-grid applications deliver their output into the electricity distribution network, though they can be configured to include battery storage systems, they essentially use the utility grid as storage systems. They present interesting opportunities for utility scale solar PV projects and currently represent about 80% of the total global deployment of 24GW, they have been extensively deployed both as centralized and decentralized systems across several regions of the world the world. Though grid-connected systems have great potential to trigger wide usage of the Solar PV technology and increase the share of solar PV in electricity supply, it is also arguably the most demanding in terms of the design of policies and regulations, institutional restructuring and training, monitoring and management, financing mechanisms, etc. The ECOWAS sub-region has not had much experience with these systems due mainly to a number of factors such as the non-availability of RE Laws in most countries. To exploit the huge potential of solar energy in the West Africa, grid-connected solar PV systems must be closely examined. In November 2010 the largest grid-connected PV station in Africa with an installed capacity of 5 MW was inaugurated in Praia, Cape Verde. Another 2,5 MW station was commissioned in October 2010 on the island Sal.

c. Energy Storage

i. Heat-Based Systems

Thermal storage is needed in solar thermal systems and particularly CSPs for:

1. *Smoothening out short-term variation in insolation, a "buffering" capacity;*
2. *Continuous operation of the plant after sunset and also during cloudy days.*

Molten salt is currently the most popular heat storage medium. The extent of storage required for CSPs depend largely on the type of service (load configuration) to which the plant is put: i.e. intermediate load, delayed intermediate load, base load or peak load.
Since the first commercial CSP in California, Research and development (R&D) has led to improved solar field components and new thermal storage concepts (World Bank- GEF, 2006).

ii. Electric Systems

Electricity storage is also needed in Solar PV systems to match time of use and time of solar resource availability- i.e. some system autonomy. This is crucial for off-grid systems; otherwise entire system is almost useless. Available technology options include:

- *Lead Acid Battery (Deep Cycle Solar Batteries and Shallow Cycle Automotive Batteries)*
- *Nickel Cadmium batteries*
- *Nickel-Metal-Hydride batteries*
- *Lithium ion batteries*

Lead acid batteries remain the most mature technology with lowest cost. Key issues proposed for consideration in selection of technology choice include:

- *Cost/Ah (or cost/kWh energy stored)*
- *Environmental- potential for well-structured reclamation and recycling of active materials such as Lead, Cadmium, etc.*

ASSESSMENT OF POLICY FRAMEWORKS AND PROGRAMS FOR SOLAR ENERGY IN WEST AFRICA

a. existing solar policies, strategies and legal frameworks on country and regional levels

Only a few ECOWAS countries have adopted renewable energy support policies. In Senegal a renewable energy law was passed by the Parliament in July 2010. In Ghana a Renewable Energy law is before parliament, and in Niger and Cape Verde a law on renewable energy is currently being formulated. The Gambia is starting with the elaboration of a renewable energy legislation under a UNIDO/GEF programme. Some countries like Niger and Nigeria have formulated a national renewable energy strategy or Renewable Energy Master Plan. However, many countries offer tax exemptions for solar energy products. At the regional level ECOWAS/UEMOA have taken initial steps towards a better integration of Renewable Energy into regional energy policies. The ECOWAS/UEMOA White Paper foresees that at least 20% of new investments in electricity generation in the region will be driven by renewable resources. The Third ECOWAS Business Forum, held from 28 September to 1 October 2010, called for the development of minimum renewable energy targets which member states should adhere to and implement. With Regulation C/REG.23/11/08 of the 61st Session of ECOWAS Council of Ministers in Ouagadougou, Burkina Faso, on November 23, 2008 the ECOWAS Regional Centre for Renewable Energy and Energy Efficiency (ECREEE) was created. On 6 July 2010 the official inauguration of the ECREEE Secretariat took place. The event marked the completion of the six-month preparatory phase, the signing of the headquarters agreement, the nomination of the National Focal Institutions (NFIs), the constitution of the Executive Board and the official launch of the operational phase of the Centre. ECREEE aims at the establishment of regional renewable energy and energy efficiency markets by supporting various activities to mitigate existing barriers on different levels and sectors. The ECREEE activities include policy development and quality assurance, capacity building, the design and usage of tailored financing mechanisms and appraisal tools, awareness raising and the implementation of demonstration projects with potential for regional scaling-up. Most of the activities are implemented in cooperation with the nominated Focal Institutions (NFIs) of ECREEE in each ECOWAS member state, the private sector and civil society. An overview of renewable energy policies and regulations in the sub-region is presented in Appendix A.

b. Existing Solar Markets And Business In West Africa

The manufacturing capacity of solar technology is virtually non-existent in the West African sub-region. There is no structured renewable energy or solar energy market in the region. The business for solar energy, much like the other renewable energy, still appears mainly as informal in many West African countries except in some few countries like Ghana and in Burkina Faso where the solar industry is organized in association.

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c. Existing Solar Capacities On Country And Regional Levels In West Africa

Some initiatives such as the defunct CRES (centre regional de l'energie solaire) were developed in the past. The mission of CRES was to coordinate research on solar energy in West Africa. There are also other centres such as CNES (Centre National de l'energie Solaire) in Niger ; CNESOLER Centre National de l'Energie Solaire et des Energies Renouvelables in Mali. LESEE in Burkina. Also worth mentioning is the Regional Solar Energy Program (PRS); PRS is a region-wide project implemented by the Inter-State Committee to combat draught in the Sahel (CILSS). The extent of renewable energy utilization in general and solar energy in particular remains very small in comparison with global trends and figures. Table 1 summarizes estimates of current solar PV installed capacity in the West African sub-region:

Table 1 Estimation of Sub-regional Solar PV Capacity

Country	Estimated Capacity (PV), kWp	Source/comment
Benin	448	A 2002 figure quoted by GTZ, 2009
Burkina Faso	1368	GTZ, 2009 citing National White Paper
Cape Verde	7500	Estimate at ESEI Regional Forum, Dakar
Cote D'Ivoire	NA	
Gambia	700	A 2006 estimate quoted by GTZ, 2009
Ghana	2500	Estimate of 2.1MW off-grid installation made at ESEI Regional Forum, Dakar plus Authors' approximation of installed grid-connected systems
Guinea	800	A 2008 estimate by GTZ, 2009
Guinea Bissau	450	A 2008 estimate by GTZ, 2009
Liberia	110	Estimate at ESEI Regional Forum, Dakar, up from 90kWp estimated from GTZ, 2009 for 2008
Mali	3395	Estimated from GTZ, 2009[a]
Niger	1170	GTZ, 2009. A 2006 estimate
Nigeria	800	A 2005 estimate by REMP, cited by GTZ, 2009[b]
Senegal	2300	ENDA-TM estimate for 2006 and GTZ-TERNA, 2009
Sierra Leone	25	GTZ, 2009. Citing Sawyer and Sillar, 1999
Togo	25	Martinot E. and Cabraal A. (2000)[c]
TOTAL	**21,591**	This is a very conservative estimate[d]

[a] *700 water pumping systems (100Wp assumed), 50,000SHS (50Wp assumed), 75kWp Kimparana project, plus 750kWp in telecoms*

[b] *Authors believe this figure is significantly understated.*

[c] *Estimated from a 1998 project approved by GEF which distributed 5000 SHS (50Wp per system assumed*

[d] *this is mainly from projects that the government has been formally engaged in and largely does not include installations by private individuals (businesses), NGO and other charitable organizations*

d. main constraints and barriers for deployment and use

The main constraints and barriers for the dissemination of solar technologies can be classified as technical and non-technical. The technical issues are listed as lack skilled manpower for the design, installation and maintenances of solar products; Lack of quality control and warranties, the issue of maintenance and after-sales service, local technical infrastructure development. The non-technical issues are lack of awareness, lack of institutional and regulatory framework that support the implementation of solar energy, financing mechanism, involvement of people in solar projects, etc.

e. Lessons Learnt

A number of solar energy projects have been undertaken across the ECOWAS sub-region over the years, these have however in the opinion of experts not been accompanied by sustainable market and social delivery models and have been largely based on and driven by donations from bilateral and multilateral partners. Although some systems such as those reported by GTZ, 2009 in Guinea are 80% operational after almost 25 years (1984-2008), there has largely not been any systematic, well designed evaluation of these projects across the sub-region with clearly laid-out criteria for assessment. The IEA-PVPS Task 9 undertook case studies of PV systems in a number developing counties including PRS in CILSS member-countries and have identified the following factors inter alia as key to the success of solar energy projects:

- Proper system design and adequate after-sales service by qualified persons to reduce technical failures which negatively affect the reputation of solar energy projects (particularly PVs) as inferior forms of energy.
- Establishing good quality control mechanisms
- Establishing a level of subsidy and payment schemes that are compatible with the financial resources of rural households (in rural PV projects).

"Laboratory test for the Quality Control Approach: 0.25 EUR / Wp (1.3 % of systems cost). By adopting this quality approach, the RSP has contributed to prove the high reliability of the PV technologies: 5 to 10 years after installation, more than 95 % of systems are still providing water; mean time between failure averages at 6 years". IEA-PVPS, 2003 (assessing RSP in CILSS countries- a comment on the benefit of quality control)

These key lessons were also re-iterated by a number of ECREEE country focal persons at the Regional Forum on the ECOWAS Solar Energy Initiative (ESEI) in Dakar in October 2010. The conference documentation is available at: http://esei-forum.ecreee.org/.

COMPARATIVE COST-BENEFIT ANALYSIS OF SOLAR ENERGY SYSTEMS IN WEST AFRICA

a. Competitiveness of solar energy solutions in urban and rural contexts

In off-grid rural areas which are distanced (or inaccessible) from the electricity supply grid and sparsely populated with low daily energy demand, solar energy technologies have sometimes been more cost-effective than grid extension or diesel plants. This is particularly the case in West Africa, where typical poor rural household energy use is estimated around 200-500Wh/day (Ministry of Lands, Mines and Energy - Liberia, 2007) and the Government of Liberia in its National Energy Sector White Paper has made a decision to strongly consider using other means instead of strict grid-extension in providing energy services to rural households. Already, solar water pumping systems have been shown to be cost-competitive in comparison with diesel pumps for water supply and irrigation systems in the Sahel region (Burneya, Wolteringb, Burkec, Naylor, & Pasternakb, 2010). In urban areas which have a sub-regional average of 40% electrification rate, grid-connected systems which have lower costs compared to the off-grid systems because of the absence of electricity storage batteries hold immense potential for raising the share of renewables in the in the sub-region's electricity generation and supply, having already contributed over 80% to global deployment at the end of

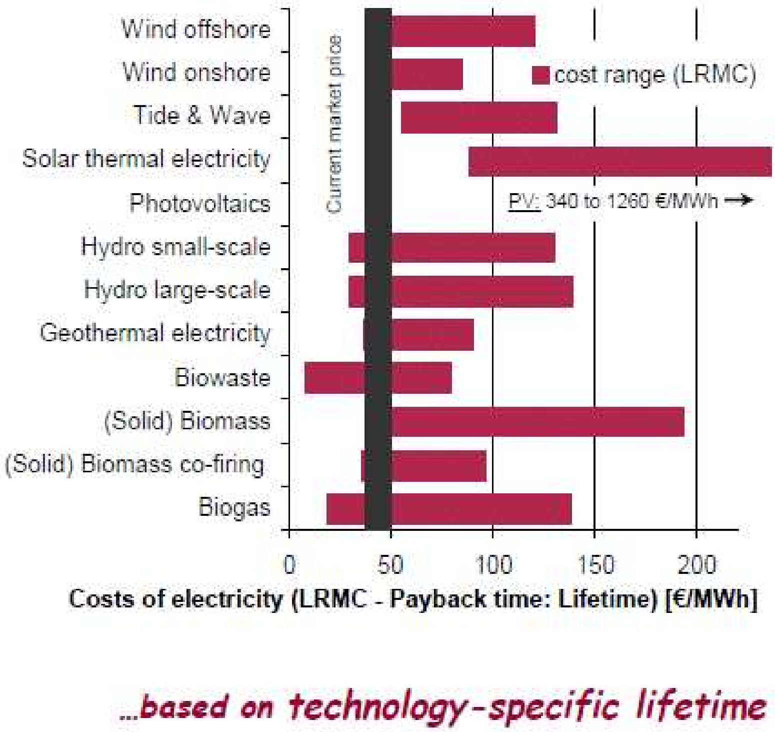
2009 (REN21, 2010). Yet, in spite of these prospects of solar energy technology for rural electrification and urban usage and the fact that they are already cost-competitive in some markets and particular situations, the levelized cost remains high in comparison to other technologies available for meeting energy supply needs and are projected to remain comparatively high for some time (World Future Council, 2007; citing BMU, 2006). A study in Ghana by (Brew-Hammond & KUMI, 2009) on a 4kWp utility grid-connected PV system pointed to poor financial performance, requiring a feed-in-tariff of about 60 US Cents for a payback of 10 years. Feasibility studies for grid-connected PV plants in (1 to 5 MW size) on different islands in Cape Verde assuming a feed in tariff of 30 EUR/Cents per kwh show a pay-back period between 8 to 10 years and a positive NPV. Table 2 and Figures 3 and 4 show comparative cost ranges of power generation from various sources. Such comparisons remains difficult as the cost structure vary from region to region and calculation method.

Table 2 Comparative Cost (US Cents/kWh) Projection for Energy Technologies

TECHNOLOGY OPTION	YEAR	
	2005	2015
Solar PV (25kW, CF=20%), US Cents	43-63	34-52
Wind (100kW, CF=25%), US Cents	17-13	14-21
Biomass Gasifier (100kW CF=80%), US Cents	6- 10	6-9
Diesel generator (100kW, CF=80%), US Cents	17-24	16-25
PV-Wind hybrid(100kW, CF=30%), US Cents	27-34	22-29
biogas (60kW, CF=80%), US Cents	4-5	3.5-5
pico hydro (100kW, CF=30%), US Cents	9-12	8-11

Source: Adapted from (ESMAP, 2007)

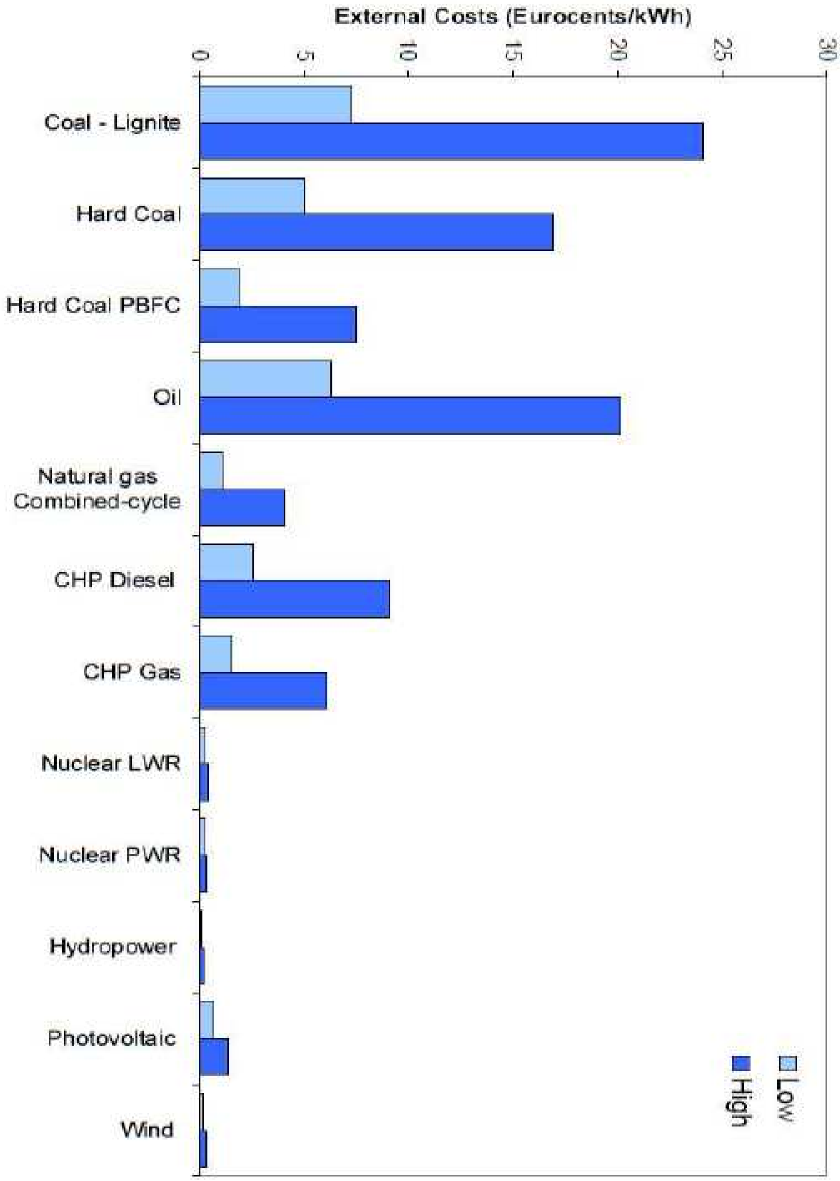
Figure 3 Range of Electricity generation costs of different RE technologies in EU-25



Source: Vienna University of Technology, Energy Economics Group (EEG)

Moreover, these comparative studies do not integrate external costs of conventional power production. For the European Union the following external costs for electricity generation were calculated:

Figure 4 Estimated average EU-25 external costs for electricity generation (EEA, 2005)



Source: Vienna University of Technology, Energy Economics Group (EEG),

Innovative financing schemes, policies and regulations will be needed to ensure that the solar technology is able to compete favourably within the sub-region. This calls for the review, adoption and operationalization of known and emerging strategies for the promotion of solar energy- noting that solar energy is not always the most cost competitive option and may sometimes make more sense when used in a hybrid mode with other technologies.

PV-based rural electrification programmes need to be accompanied by flexible financing and delivery strategies that incorporate lessons from past projects and programmes available financing schemes include:

- Government incentives (*capital subsidies, tax breaks, import duty relief, interest rate buy-down, government guarantees, etc*);

- International Concessionary Financing (ODAs, Multilateral Development Banks, Bilateral Agencies, Funds, Foundations and Charities);
- National Development Financing (budgetary allocations, rural electrification funds, etc);
- Commercial Financing (Foreign Investment, Commercial Loans, Semi-Commercial Loans-subsidized through ODAs). (IEA-PVPS, 2004)

Table 3 summarizes available financing instruments for PV-based rural electrification.

Table 3 Financing instruments for PV-based rural electrification

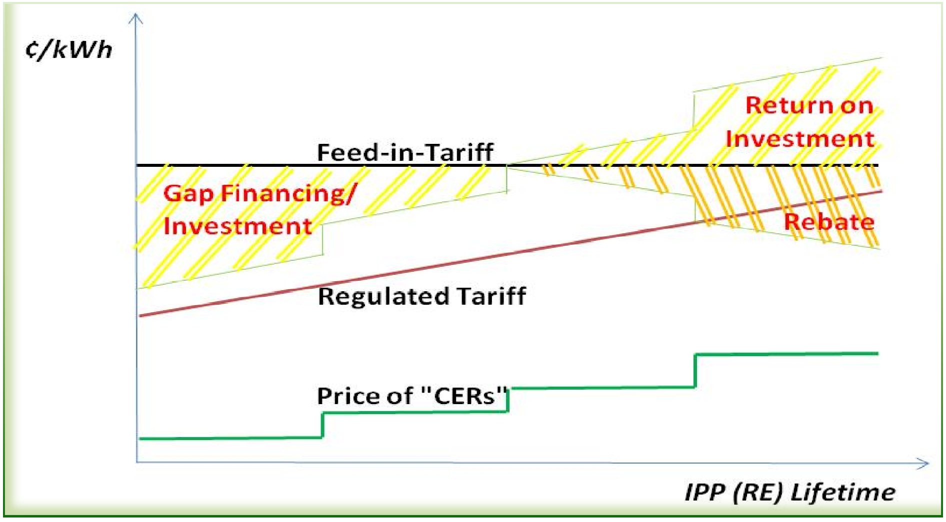
	Market-based Loans	Soft Loans	Grants	Equity investments	Guarantees	Technical Assistance	Other
Multilateral Development Banks	X	X	Some	Some	X	X	
Bilateral Aid	X	X	Some			X	
Funds / Foundations	X	X	X	Some			
Green Investment				X			X
National Development Funds	X	X			X	X	
Commercial Loans & Investment	X			X			

Credit: (IEA-PVPS, 2004)

With over 36% of urban dwellers in the Sub-region having already been connected to the grid or having access through other means, the utilization of solar energy in these localities will be mostly through grid-connected systems, solar water heaters, etc. Financing the gap between the prevailing utility tariffs (largely based on subsidized conventional power generation) and the economic cost of solar energy technology usage will be key to its success or failure. Among the models that have been successfully used in EU is the feed-in-tariff (FiT) system which is designed to offer long-term contracts for electricity sale at prices that incentivize the private sector to invest in its deployment; by the end of 2006 over 40 countries around the world had adopted the feed-in-tariff system (World Future Council , 2007). In his paper *What Works for Renewables in Africa!,* (Karekezi, 2007) advocates a modified form of the German Feed-in law (StrEG) to promote renewables in Africa.

They key question that remains is whether citizens of the sub-region are able to and also willing to pay higher tariffs to fund the gap between the regular tariffs and the economic tariff for solar energy technologies, especially solar PV as shown in Figure 5 and also whether the political courage can be mustered to implement it. Of interest are some new proposals that seek to use a combination of regulated electricity tariff with increasing crude pricing on world market and the sale of CERs over an agreed project life-time.

Figure 5 Some upcoming financing schemes for RETs



Ghana's Draft Renewable Energy Law 2010 envisages the establishment of a feed-in-tariff system as described partly in Box1.

Box 1 Feed-in-Tariff Scheme (Draft RE Law), Ghana

Feed-in-tariff scheme-Ghana (Awaiting Parliamentary approval)

"25. (1) There is established by this Act a feed-in-tariff scheme for the purpose of guaranteeing the sale of electricity generated from renewable energy sources.

(2) The feed-in-tariff scheme consists of

(a) renewable energy purchase obligation

(b) feed- in- tariff rate

(c) connection to transmission and distribution systems"

Source: Energy Commission Ghana

The draft law also seeks to establish a fund to inter alia support the feed-in-tariff scheme, Box The proposed GREENfund concept and others such as the sale of CERs (Certified Emissions Reduction) and other financing schemes in Table 2 could support the "tariff gap" in Figure 3.

b. Economic Social and Environmental Opportunities and Risks for Urban and Rural Areas

The productive use of energy has been argued to be a prerequisite for having successful energy access programmes. Initiatives to expand the use of solar energy technologies must therefore have not only social services such as health and education in mind but also income generation activities. Table 4 presents some income generating activities that solar energy could support

Table 4 Productive Services Supported By Solar Energy Technologies

APPLICATION	EXAMPLES
Food Production and Storage	*Water pumping for crop irrigation, Water pumping for cattle*
	Electric livestock fences, Aeration pumps for fish and shrimp farms
	Egg incubators, etc
Food Processing	*Meat and fish drying (Solar drying)*
	Plant/seaweed drying, Spice drying, Cereal grain processing
	Lighting for processing plants
Cottage Industry	*Bakeries (Solar ovens), Brick making (kilns), Lighting for work places*
	Electronics repair (soldering irons), Sewing (sewing machines), tourism
	Handcraft production (small electric tools)
Drinking Water	*Desalination, solar water distillation, Potable water pumping*
	UV or ozone water purification
Education	*Computer/internet, Video*
	School lighting
Health Care	*Small medical equipment, Vaccine/medicine refrigeration*
	Computer/internet for telemedicine, Clinic lighting
Community/Social services	*Broadcast media, Village cinema, Cellular/satellite telephone/fax*
	Computer/internet e-commerce, Community centers & street lighting

Adapted from: (Martinot, 2004) with authors inclusions.

The job creation potential associated with solar energy technologies is of great importance to national governments and sub-regional bodies like ECOWAS. In addition to the productive uses and the potential impact on small and micro businesses presented in Table 3, TABLE 4 presents a comparative assessment of typical job creation opportunities associated with renewable energy technologies. (Wei & Daniel, 2010) citing Wei, 2010 calculate as shown in TABLE 5, the fraction of jobs available during Construction Installation and Manufacturing (CIM) of various RETs within the United States based on a US national model and then modify it to the fraction of CIM jobs available in California (CIM Manuf fraction) and finally presents total jobs available over the life-time of the technology as person-years/GWh.

Table 5 Job Creation Potential of Various RE Technologies in the US

Work-hrs per year					Employment Components			Average Employment Over Life of Facility						
								Total jobs/MWp		Total jobs/MWa		Total person-yrs/GWh		
Energy Technology	Capacity Factor	Equipment lifetime (years)	CIM Manuf fraction	CA fraction manuf	Adj CIM (person-years/ MWp)	O&M (jobs/ MWp)	Fuel extraction & processing (person-yrs/GWh)	CIM	O&M and fuel process-ing	CIM	O&M and fuel process-ing	CIM	O&M and fuel process-ing	Total
BIOMASS	85%	40	50%	30%	4.16	0.89	0.07	0.10	1.37	0.12	1.61	0.014	0.18	0.20
GEOTHERMAL	90%	40	50%	30%	6.05	1.72	0.00	0.15	1.72	0.17	1.91	0.019	0.218	0.237
LANDFILL GAS	85%	40	50%	35%	8.44	0.24	0.13	0.21	1.21	0.25	1.42	0.028	0.162	0.191
SMALL HYDRO	55%	40	50%	30%	3.71	1.14	0.00	0.09	1.14	0.17	2.07	0.019	0.237	0.256
SOLAR PV	24%	25	30%	25%	19.76	0.17	0.00	0.79	0.17	3.29	0.71	0.376	0.081	0.457
SOLAR THERMAL	28%	25	50%	50%	5.13	0.53	0.00	0.21	0.53	0.73	1.90	0.084	0.217	0.301
WIND	35%	25	75%	15%	2.53	0.24	0.00	0.10	0.24	0.29	0.69	0.033	0.079	0.112

(Wei & Daniel, 2010)

Moving forward with solar energy technologies, it is important to develop sub-regional models that will properly estimate and project more correctly, the number of jobs that citizens of the sub-region can get from such projects. In view of this there is the need to build capacity at the various levels of the supply chain. In spite of these opportunities and the fact that Solar Energy Technologies are environmentally friendly, there are risks that need to be considered in policy design for its promotion these are summarized in Table 6.

Table 6 Economic and Social Risks Associated with Solar Energy Technologies

Parameter	Risks
Economic	- Land acquisition problems for large-scale projects - Disruptions on international financial markets- affecting capital flow - Energy services not being put to productive uses once they are available.
Social	- Unwillingness to pay higher tariffs and rates associated green electricity and non-electricity renewables. - Socio-cultural unfamiliarity with technologies and unwillingness to try new solar technology options. - Local community unrests for job opportunities on large-scale solar projects.

c. Opportunities and Risks for Energy Security

Reliability- Solar energy conversion and utilization technologies have matured over the years to complement a reliable resource- the sun. In solar PVs measurements conducted by (Artur, Sample, & Dunlop, 2009) and many others have confirmed the reliability of solar energy technology for power generation and concluded that that the useful lifetime of solar modules is not limited to the commonly assumed 20 years. BP Solar currently offers 25-year warranty on its crystalline silicon modules (Wohlgemuth, 2008) this followed excellent field results for modules with 10 year warranties and on extensive accelerated testing (Wohlgemuth J. H., 2003; Wohlgemuth, 2008).

Electrical performance measurements were conducted on 204 crystalline silicon-wafer based photovoltaic modules following long-term continuous outdoor exposure. The modules comprise a set of 53 module types originating from 20 different producers, all of which were originally characterized at the European Solar Test Installation (ESTI), over the period 1982-1986. The modules represent diverse generations of PV technologies, different encapsulation and substrate materials. The modules electrical performance was determined according to the standards IEC 60891 and the IEC 60904 series, electrical insulation tests were performed according to the recent IEC 61215 edition 2. Many manufacturers currently give a double power warranty for their products, typically 90% of the initial maximum power after 10 years and 80% of the original maximum power after 25 years. Applying the same criteria (taking into account modules electrical performance only and assuming 2·5% measurement uncertainty of a testing lab) only 17·6% of modules failed (35 modules out of 204 tested). Remarkably even if we consider the initial warranty period i.e. ***10% of Pmax after 10 years, more than 65·7% of modules exposed for 20 years exceed this criteria****. The definition of li****fe time is a difficult task as there does not yet appear to be a fixed catastrophic failure point in module ageing but more of a gradual degradation.*** *Therefore, if a system continues to produce energy which satisfies the user's need it has not yet reached its end of life. If we consider this level arbitrarily to be the 80% of initial power then all indications from the measurements and observations made in this paper are that the useful lifetime of solar modules is not limited to the commonly assumed 20 year.*
(Wohlgemuth, 2008).

Investment costs The high initial cost of renewable energy projects have been widely acknowledged as a major barrier to its increased adoption, particularly in developing countries including the West African Sub-region. Over the past decade however, financing opportunities for renewable energy projects have increased significantly. The World Bank and other multi-lateral funding agencies have significantly increase their portfolio for investment in renewable energy and other climate friendly technologies Table 7 shows increase in World Bank's funding between financial years (FY) 2005 and 2009 in millions of US$ (World Bank, 2009). Commercially, a broad range of financial institutions are now investing or lending money into the renewable energy (RE) sector. Global investment grew exponentially from $22 billion in 2002 to $155 billion in 2008 when, for the first time, investment in new RE power generation capacity (including large hydro) was greater than investment in fossil fuel generation (UNEP-SEFI/Chatham House/New Energy Finance Ltd, 2009).

Table 7 World Bank Group Lending for Renewable Energy and Energy Efficiency

US$ Millions	FY05	FY06	FY07	FY08	FY09	FY05-FY09
New Renewable & Energy Efficiency	463	1,105	682	1,665	3,128	7,043
Large Hydro	538	250	751	1,007	177	2,724
New RE and EE (Bonn Commitment)	251	301	361	433	520	1,866

Source: (World Bank, 2009)

However, there remains particularly a lack of talored grand and loan finance schemes for small- and medium sized renewble energy projects and businesses in the ECOWAS region. Moreover, local banks are hesitant to support such projects or are not able to appraise them.

Carbon financing also provides funding opportunities for solar energy projects, by September 2009, the number of carbon funds and government purchase programmes had risen to 88 (up from 80 the previous year) with a total of $16.1 billion in assets in August the same year (Environmental Finance Magazine, 2009). These offer increased opportunities for the financing of capital investments for national and sub-regional projects in renewable energy in general and solar energy in particular. So far, the West African Countries did not benefit from the opportunities of the Clean Development Mechanism (CDM). The difficult application process and the low subsidy levels to be gained for renewable energy investments makes it unattractive. Pan African financial institutions such as ECOBANK have also indicated their readiness go into carbon financing (GreenBusinessAfrica.com, 2009), in this regard, ECREEE should be resourced and mandated to liaise with national governments and other bodies in the ECOWAS sub-region to develop and properly package eligible projects within the sub-region.

Reduction of fossil fuel import and spending and Potential for Regional Power Trade- About 60% of the Sub-region's power generation is from thermal power plants which are fired by diesel, natural gas with very high import dependence –countries such as The Gambia, Guinea Bissau and Liberia have almost 100% dependence on imported fuels for power generation (ECOWAS/UEMOA, 2005). This raises key questions of sub-regional energy security-exposure to supply disruptions, market price fluctuation and high oil prices as was recorded in 2008.

In the face of increasing power demand in urban and per-urban areas, a subregional approach to reducing the dependence on fossil fuel importation is urgent. In this ECREEE and WAPP should tactically identify locations with the highest solar radiation for regional solar power projects (both PV and CSP)- this opens up the potential for Sub-regional power connectivity and trade. At the first meeting of the Africa-EU Energy Partnership (AEEP) in Vienna, a commitment was made to take joint action to increase both energy efficiency and the use of renewable energy in Africa by inter alia building 500MW of solar energy capacity (Africa-EU Energy Partnership, 2010). An Africa-EU Renewable Energy Cooperation Programme was launched. Such a subregional power project could be packaged along the lines of the DESERTEC[1] intiative.

[1] DESERTEC is an initiative to utilize the deserts of the world to generate clean solar power. http://www.desertec.org/

d. Opportunities and Risks Regarding Provision of Access to Modern Energy Services

The opportunities and risks for providing access to modern, reliable and affordable energy services with solar energy technologies, particularly for peri-urban and rural areas are summarized in Table 8 below.

Table 8 Solar Energy Services- Risks and Opportunities

Energy Service	**Opportunities**	**Risks**
Cooking	Solar stoves and ovens have been developed and are in use- technology exists. Potential to reduce reliance on traditional biomass and related issues with indoor air pollution. Will also free more time for women and girls to do other productive activities.	Major socio-cultural barriers exist and it is unlikely to succeed in displacing other forms of energy considered more convenient. Desert wind, harmattan, even in sunny weather this severely compromises the use of solar cookers because of dust and sand (GTZ, 2007).
Lighting	Solar lanterns (with LEDs) particularly with the Lighting Africa[2] initiative, off-grid PV systems available for life to continue beyond sunset for- kids studying at home, small businesses, health care centres, etc	Low affordability and poorly designed financing mechanisms. Likelihood of over-reliance on donor support
Drying	Modern solar crop dryers are available to reduce duration of drying crops, fish and other agricultural produce and enhancing its quality for higher market value particularly in markets where organic farming products attract premium pricing.	Possibility of problems with socio-cultural adaptation.
Process heating	Solar heating technologies could help displace some kWh of thermally generated electricity and biomass in air and water pre-heating for both industrial and commercial purposes particularly operations requiring temperatures <80^oC[3].	High upfront cost and commercial immaturity of technologies.
Warm water supply	Climate friendly means of supplying domestic hot water needs and also for hotels and other public buildings. Savings on petroleum imports for thermal generation, GHG emissions reduction from avoided electricity generation. Reduction in deforestation from reduced use of biomass for water heating.	High up-front cost, risk of not succeeding without flexible financing.
cooling	Incorporation of passive solar cooling techniques into buildings would reduce thermal load and need for air conditioning. Active cooling for thermally driven absorption chillers for industrial and commercial cooling.	High upfront cost, lack of units with small capacities (expensive where they are available) and also lack of package-solutions for small residential and commercial applications. (ESTIF, 2006)

[2] *Lighting Africa* is a World Bank Group (WBG) initiative which supports the private sector to develop, accelerate, and sustain the market for modern off-grid lighting technologies tailored to the needs of African consumers. http://www.lightingafrica.org/

[3] http://www.iea-shc.org/task33/index.html

e. Opportunities and Risks for the Environment

There are a number of environmental concerns/risks that have been highlighted regarding the use of solar energy technologies both PV and Thermal. These risks include:

- Toxicity of material used in some components such as batteries and PV modules.
- Disruption in ecosystems and land-use patterns with large solar PV and CSP projects.

These notwithstanding solar energy technologies are very environmentally benign on the “balance sheet” and represent a great opportunity for the substitution of fossil-based electricity and heat supply and also the displacement of traditional biomass for heating and in some instances, cooking. Beyond the global environmental benefits of emissions reduction, local benefits such as reduction or complete elimination of pollution (smoke, noise, “dirty-oil” discharge, etc) from diesel-based power and the preservation of local ecosystems could also be enhanced by the wide-scale diffusion of solar energy technologies.

CONCLUSIONS AND RECOMMENDATIONS

a. Key Issues

i. Economies

- High cost of solar compared with larger scale conventional generation systems.
- High upfront costs of solar compared with smaller scale conventional systems even where competitive.
- Lack of large scale projects at regional level to take advantage of higher solar resource endowments and economies of scale.

ii. Policies and Institutions

- Absence of political targets for renewable energy in general and solar in particular, in many countries;
- Non-existent tailored financial schemes for small- and medium sized projects and businesses particularly relevant for peri-urban and rural areas; lack of appraisal capacities of local banks;
- Non-existent or weak policy measures for level playing field for renewable in many countries;
- Weak national agencies with unclear responsibility for solar/renewables in many countries;

iii. Technology

- Inadequate skilled technical manpower in many countries.
- Limited or no local manufacturing due to small national markets.
- Limited R&D with little or no linkages to entrepreneurial/ manufacturing sector.

b. Recommendations To ECREEE

i. Innovative Financing and Regional Markets

- Link up with EBID, AFDB, Donor Agencies and International Carbon-Financing Agencies to develop Regional FIT funds with local arms in more dynamic countries.
- Conduct more in-depth evaluation of past solar energy projects with a clear criteria for determining successful projects and those that are not. It could include visits to selected project locations and interviews with cross-section of project stakeholders (donors, implementing agencies, beneficiary communities, private sector, etc). This would provide more robust and useful lessons that are specific to the ECOWAS sub-region.
- Establish knowledge and experience sharing platforms for national banks involved/interested in financing household/community level solar energy applications.

- Link up with WAPP and ERERA plus local and international private sector to develop solar power plants in solar resource-rich countries.

ii. Proactive Policy Coordination and Regional Institutional Frameworks

- Liaise with ECOWAS Commission for ECOWAS Energy Ministers to adopt RE policies with targets, and with specific provisions for solar energy at sub-regional and national levels.
- Establish information-sharing and peer-training networks among national policy institutions.
- Facilitate twinning arrangements between national policy institutions and counterparts in more advanced countries outside the ECOWAS sub-region.

iii. Technological Capacity Building and Manufacturing for Regional Market

- Establish networks of training institutions and solar/renewable energy entrepreneurs and coordinate/promote information sharing within and across networks.
- Identify solar system components for large-scale manufacture within sub-region by local and/foreign entrepreneurs and liaise with national Ministries of Trade/Industry and Customs agencies to facilitate intra-regional trade.
- Standardization and quality assurance mechanisms for local manufacturing and foreign imports
- Facilitate interaction between R&D institutions and entrepreneurs/manufacturers to define relevant research needs and secure necessary funding.
- Facilitate project finance and carbon finance training for local banks, policy makers and project developers;
- Roll-out programmes along the lines of IEA-PVPS and IEA-SHC to address in phases, barriers specific to solar energy utilization in the Sub-region

c. Proposed Action Plan

i. Short-Term (2010-2012)

- Solar Atlas and Resource Database for West Africa prepared.
- Master plan(s) for solar contribution in rural electrification programmes (similar to JICA Ghana Study) for first five West African Countries prepared.
- Feasibility studies for large scale Solar Electric Power Generation in West Africa undertaken.
- Political targets for renewables and solar in West Africa adopted (e.g. 40%of Africa-EU Energy Partnership target of 500MW solar electricity plus targets for solar heating applications).
- Establishment of planned ECOWAS Renewable Energy Facility for peri-urban and rural areas through ECREEE; first call for proposals;
- Knowledge Networks established and operationalised for:
  - Solar enterprises and manufacturing companies
  - Solar/RE training and research institutions
  - National energy policy and RE promotion institutions
  - Financial institutions involved/interested in financing for RE/solar

- Locations for potential large-scale regional solar power (PV and CSP) projects included in WAPP's regional transmission system interconnectivity project.

ii. *Medium-Term (2013-2015)*

- Commissioning first >10MW Solar Electric Power Plant in West Africa
- Establish systems across the sub-region to (possibly using ECREEE focal persons to obtain reliable information on the existing levels of solar energy systems utilization (PV and Thermal applications) and further structure such systems to automatically capture on an annual or biennial basis, changes that have occurred in installation figures with a brief commentary on market situations and policy developments.
- Extend the finance portfolio of the ECOWAS Renewable Energy Facility in cooperation with banks;

iii. *Long-Term (2016-2020)*

- Commissioning of flagship regional solar projects (>200MW SEPPs and > 50MW of other solar applications)
- Commissioning of regional manufacturing centers for solar energy components and systems for which the sub-region by virtue of its market size and expertise can produce cost-competitively (particularly in relation to imported equivalents).
- Regional strategies for manufacturing and recycling of solar batteries firmly established with already existing efforts at addressing this supported to expand in capacity and quality.

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APPENDIX A: RENEWABLE ENERGY POLICY AND REGULATION STATUS IN ECOWAS MEMBER COUNTRIES

Country	RE Policy Status	Description (including targets)	Source
Benin	No specific RE law and policy. Decrees have however been made regarding biofuels (Decree No 2008-360 and 2008-361 of 13th June 2008)	700kWp solar PV by 2015	GTZ, 2009 Clément Bill AKOUEDENOUDJE Directeur des Energies Nouvelles et Renouvelables Presentation at ESEI forum organized by ECREEE in Dakar
Burkina Faso	No policy exists, though there are projects and support programmes for solar energy utilization for the provision of energy services.	Kouritenga Energy services programme, subsidizes 90 % of equipment costs Activities implemented Jointly (AIJ)/Regional Program for the Traditional Energy Sector (RPTES), subsidizes 100% equipment cost	GTZ, 2009
Cape Verde	No RE policy exists, but there are laws that facilitate solar energy projects (law nº 20/VII/2007); a RE law will be adopted end of 2010;	A target of 50% energy RE by 2020 has been set	GTZ, 2009 Alberto Mendes-General Directorate of Energy, Cape Verde[4]
Cote D'Ivoire	No specific policy on RE, though its role and importance in recognized in the general law guiding energy production and utilization (la loi n°85-583 du 29 Juillet 1985). décret n° 2009-399 of 2009 created the Renewable Energy Directorate within the Ministry of Mines and Energy.	-	GTZ, 2009 GNIGBOGNIMA Siriki N'CHO Pâcome La Direction Générale de l'Energie[4]
Gambia	There is no legislation for the RE sector at the moment. It is however expected to be formulated under the Renewable Energy and Energy Efficiency program of the GEF-UNIDO Energy Program for West Africa. National Energy Policy acknowledges the role of RE and encourages its use.	There has since 2008 been an import duty waiver on RE equipment and energy efficient bulbs	GTZ, 2009 Modou Manneh ECREEE FOCAL POINT The Gambia[4]

[4] Presentation at Regional Forum on ECOWAS Solar Energy Initiative, organized by ECREEE in Dakar Senegal, 18-21st October 2010

Ghana	Strategic National Energy Plan (SNEP), Draft RE Law	10% electricity from RE by 2020 (SNEP). Institutional, policy regulatory and financing mechanisms (Draft RE Law)	Energy Commission, Ghana[4].
Guinea	No specific policy framework for Renewable Energies (RE). Energy sector policy document of 1992 (LPDSE5 92) deemed applicable	-	GTZ, 2009 ECREEE Focal person Guinea[4]
Guinea Bissau	No regulations or specific policies on RE, a draft RE policy in 2004 is yet to be adopted. A strategic RE plan developed for 2004-2008 could not be implemented due to lack of funding.	-	GTZ, 2009
Liberia	Draft Policy on RE and Energy Efficiency exits. National Energy Policy (NEP) advocates RE and acknowledges its potential role	Seeks inter alia to introduce conducive institutional, capacity and investment framework. A target of 30% electricity and 10% overall energy consumption from RE by 2015 has been set by the (NEP)	Ministry of Land, Mines and Energy, Liberia, (2007) GTZ, 2009 Augustus V. Goanue *Rural & Renewable Energy Agency (Liberia)* [4]
Mali	Strategy for Renewable Energy Development has been outlined within the National Energy Policy of March 2006	Tax exemptions on import of RE equipment. Rural Electrification Fund, supporting mainly RE Technologies for rural electricity access, etc	GTZ, 2009 M. Cheick Ahmed SANOGO *Directeur National Adjoint de l'Energie* M. Sékou Oumar TRAORE *Directeur du Centre National de l'Energie Solaire et des Energies Renouvelables*[4]
Niger	Energy Policy of 2004 had a National Renewable Energy Strategy (SNER)[6]	SNER anticipates an increased contribution of RE to the national energy balance; from less than 0.1 % in 2003 to 10 % by 2020.	Ibrahim HASSAN Ibrahim SANI *Ministere des Mines Et De l'energie Niamey (Niger)* [4] GTZ, 2009
Nigeria	No dedicated regulation for developing the renewable energy market. The National Energy Policy of 2003 encourages the optimum utilization of the country's energy resources, including	NREMP envisages electricity demand of 14,000 MW by 2015 of which RE will constitute about 5 % (701 MW); and increasing to 29000MW in 2025 by which time RE will	GTZ, 2009 DR H.N YAHYA Sokoto Energy Research Center Usmanudan Fodiyo University Sokoto ,Nigeria[4] ENGR. P.O. EWESOR

5 LPDSE Lettre de Politique de Développement du Secteur de l'Énergie

6 Stratégie Nationale sur les Énergies Renouvelables (SNER)

	renewable, for sustainable national development with the active participation of the private sector. A National Renewable Energy Master Plan (NREMP) has been developed (2005).	contribute 10% of overall energy demand.	ELECTRICAL Inspectorate Services Department Federal Ministry of Power, Abuja Nigeria[4]
Senegal	The Senegal National Energy Strategy Paper was published in April 2003 (Lettre de Politique de Développement du Secteur de l'Energie) and identifies the role of RE energy diversification and rural electrification.	A targets of 15% electricity production from RE by 2020 has been set.	GTZ-TERNA, 2009
Sierra Leone	National Energy Policy and Strategic Plan (2009) developed.	1% penetration of solar systems in domestic, commercial and agricultural sectors by 2015, increasing to 3-10% in 2020 across these sectors.	Government of Sierra Leone, 2009[7] Ms Yvette Stevens *Ministry of Energy and Water Resources, Sierra Leone*[4]
Togo	No dedicated policies for renewable energy, projects and isolated initiatives exist for RE promotion. Rural electrification by RE is contained in the Poverty Reduction Strategy Paper (PRSP) 2006-2008.	Directive (1998) waiving import duty on energy equipment still in force. Definition of standards for RE rural electrification	GTZ, 2009

[7] NATIONAL ENERGY POLICY AND STRATEGIC PLAN- *ENERGY FOR POVERTY ALLEVIATION AND SOCIO-ECONOMIC DEVELOPMENT*

ECOWAS Regional Centre for Renewable Energy and Energy Efficiency

Centre Régional pour les Energies Renouvelables et l'Efficacité Energétique de la CEDEAO

Centro Regional para Energias Renováveis e Eficiência Energética da CEDEAO

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