RENEWABLE ENERGY POLICY FRAMEWORK FOR CLIMATE CHANGE MITIGATION IN GHANA

Review of Existing Renewable Energy Resource Data, Energy Policies, Strategies, Plans and Projects

ENERGY COMMISSION, GHANA

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The goal of the project is to develop tools for decision making and to stimulate policy initiatives designed to attract public and private investment into the renewable energy sector. It lead to the development of GIS-based toolkits to be used for a more accurate techno-economic analysis that will result in realistic cost-benefit projections, and the outlining of financial incentives and energy development policies.

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1 INTRODUCTION

The Energy Commission in collaboration with the Renewable Energy and Energy Efficiency Partnership are undertaking a project that would see the development of a Renewable Energy Policy Framework for Climate Change Mitigation in Ghana. The ultimate goal of the project is to develop tools for decision making and to stimulate policy initiatives designed to attract public and private investment in the renewable energy sector. This will require the development of GIS-based toolkits which will be used to create a more accurate techno-economic analysis that will result in realistic cost-benefit projections, and the outlining of financial incentives and energy development policies. As a first step, a review of the renewable energy resources, strategies, plans and policies has been conducted and compiled into a report. This document presents an overview of renewable energy resources of the country, the current renewable energy technology utilisation, renewable energy policies, strategies and plans, and profiles of renewable energy projects that have been implemented in Ghana.

Fig. 1: Map of Ghana

Ghana is located latitudes 4° 44'N and 11°11'N and longitude 3° 15W and 1° 12'E. It shares boundaries with Burkina Faso in the north, Tog in the East and Cote d'Ivoire in the West and the Gulf of Guinea in the South. See Fig. 1. It has a total surface land area of 238,539 km^2. Extensive water bodies (including the Volta and Bosomtwe lakes) occupy 3,275 square kilometres. The coastline is about 539 km long.

The climate is tropical with the southern part comparatively warm and humid and the northern part hot and dry. The country experiences two major seasons (dry and wet) with an average daily temperature of about 30°C. The annual rainfall varies between 2200mm in the south, 900mm in the north and about 700mm along the eastern coastal belt.

2 OVERVIEW OF RENEWABLE ENERGY RESOURCES

2.1 Solar Energy

Solar radiation and sunshine duration data has been collected by the Ghana Meteorological Services Agency (MSA) for over 50 years. The daily irradiation data has a probable error of 15%. Currently the Mechanical Engineering Department at Kwame Nkrumah University of Science and Technology (KNUST) is measuring hourly global and diffuse irradiance using standard instruments that have a probable error of 5%. The average duration of sunshine varies from a minimum of 5.3 hours per day at Kumasi, which is in the cloudy semi-deciduous forest region, to 7.7 hours per day at Wa, which is in the dry savannah region. The monthly average solar irradiation in different parts of the country ranges between 4.4 and 5.6kWh/m^2/day (16-20 MJ/m^2/day). See Table 1.

Table 1: Monthly Averages of Solar Radiation (kWh/m2/day) at 19 Synoptic Stations

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	**AV.**
Kumasi	4.8	5.3	5.3	5.4	4.7	4.0	4.0	3.8	4.0	4.7	5.0	4.6	**4.6**
Accra	4.7	5.2	5.3	5.7	5.4	4.6	4.2	4.5	5.1	5.6	5.5	4.9	**5.1**
Axim	4.9	5.4	5.6	5.6	5.1	3.9	4.2	4.2	4.4	5.2	5.5	5.0	**4.9**
Navrongo	5.4	5.4	5.8	6.0	5.9	5.7	5.3	5.1	5.3	5.7	5.6	4.8	**5.5**
Saltpond	4.9	5.6	5.5	5.7	5.4	4.4	4.7	4.5	5.0	5.7	5.7	5.2	**5.2**
Ada	5.0	5.4	5.6	5.9	5.6	5.0	5.1	5.1	5.5	5.9	5.5	5.4	**5.4**
Koforidua	4.7	5.1`	5.3	5.4	5.3	4.6	4.1	3.8	4.4	5.2	5.2	4.9	**4.8**
Wenchi	5.2	5.5	5.5	5.7	5.5	5.0	4.4	4.1	4.4	4.9	5.1	4.9	**5.0**
Tamale	5.1	5.5	5.6	5.9	5.9	5.5	5.0	4.8	5.0	5.5	5.7	5.2	**5.4**
Bekwai	4.7	5.1	5.3	5.5	5.3	4.6	4.1	3.8	4.1	5.0	5.0	4.4	**4.7**
Ho	4.9	5.2	5.5	5.7	5.6	4.9	4.6	4.2	4.7	5.5	5.6	5.1	**5.1**
Wa	5.5	5.8	5.8	5.9	5.9	5.6	5.1	4.9	5.1	5.6	5.6	5.4	**5.5**
Akim Oda	4.5	4.8	4.9	5.2	4.9	4.3	4.0	3.8	4.2	4.8	4.9	4.5	**4.6**
Krachi	5.1	5.4	5.7	6.0	5.9	5.2	4.7	4.5	4.8	5.3	5.7	5.1	**5.3**
Yendi	5.2	5.5	5.6	5.9	5.9	5.4	5.0	4.6	5.0	5.6	5.7	5.2	**5.4**
Takoradi	4.8	5.4	5.5	5.7	5.2	4.4	4.4	4.2	4.6	5.5	5.6	5.0	**5.0**
Bole	5.4	5.8	5.8	5.8	5.7	5.1	4.6	4.5	4.8	5.5	5.5	5.3	**5.3**
Abetifi	5.0	5.5	5.6	5.6	5.4	4.8	4.8	4.6	4.7	5.2	5.6	5.1	**5.2**
Akuse	4.6	5.1	5.2	5.0	5.3	4.6	4.3	4.1	4.7	5.3	4.8	4.8	**4.8**
Average	**5.0**	**5.4**	**5.5**	**5.6**	**5.5**	**4.8**	**4.6**	**4.4**	**4.7**	**5.4**	**5.4**	**5.0**	**5.1**

Source: Energy Commission, Ghana

The northern regions and the northern parts of Brong-Ahafo and Volta Regions receive very high radiation levels with monthly average of between 4.0 and 6.5kWh/m^2/day. The area experiences one major rainy season between July and September. The Harmattan is prevalent between November and February. Ashanti, parts of Brong-Ahafo, Eastern, Western and parts of Central and Volta regions have monthly average radiation level of 3.1 - 5.8 kWh/m^2/day. The water vapour in the atmosphere causes greater absorption and scattering producing high levels of diffuse radiation. Greater Accra, and the coastal regions of Central and Volta Regions have monthly average radiation levels ranging from 4.0 – 6.0 kWh/m^2-day. See Fig 2.

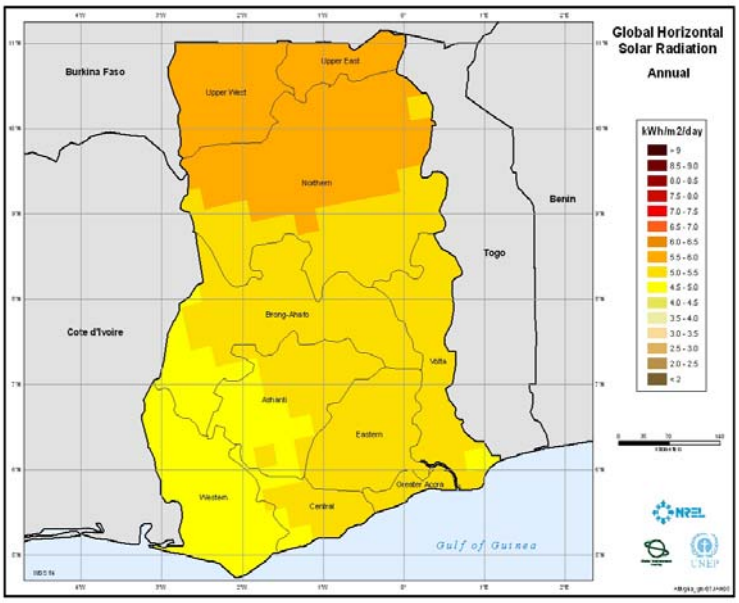

Fig 2: Global Horizontal Radiation Annual (Source: SWERA)

The humidity is low and rainfall is bimodal in these regions. Throughout the country, diffuse radiation constitutes more than 30% of the total solar radiation and this does not augur well for concentrating collectors used in solar thermal power plants. This device uses the direct component of the solar radiation. The direct solar radiation is highest in the small part of the Upper West region as depicted in Fig 3. Flat plate solar collectors and PV modules are not affected by the diffuse fraction, and thus may be used effectively anywhere in the country.

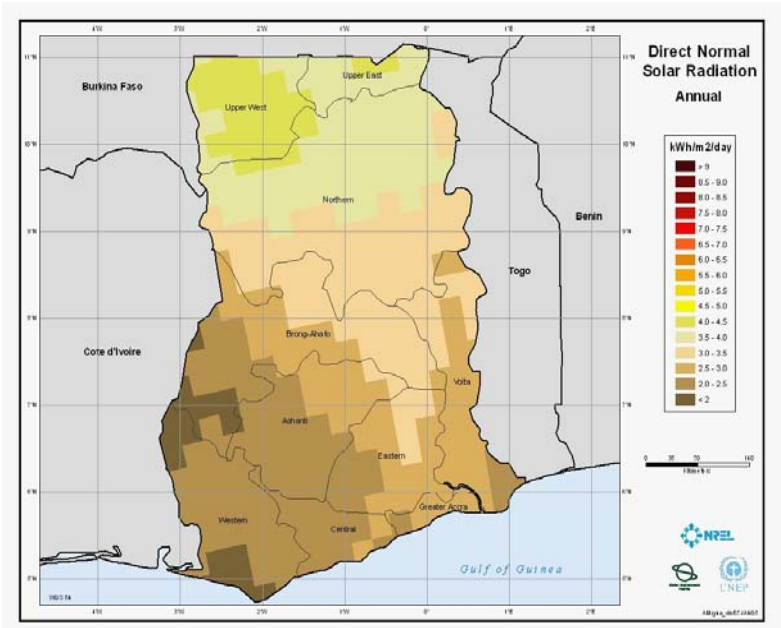

Fig 3: Direct Normal Solar Radiation Annual (Source: SWERA)

The total solar energy used in drying of major cash crops in 2008 has been estimated to be 17,821 tonnes of oil equivalents. The crops included over 700,000 tonnes of cocoa which earned the country the bulk of its foreign exchange in 2004. In conclusion, the potential for using solar thermal energy for hot water production in the commercial/service sector is very high. It could reduce the use of electric water heaters in the sector. The potential for use of solar energy in agro-industrial and wood processing is also very high.

2.2 Bioenergy

Bioenergy resources that are available in Ghana include woodfuels, sawmill residues, agro-fuels and municipal waste. Biomass resources cover about 20.8 million hectares of the land mass of Ghana (23.8 million hectares) and is the source of supply of about 60% of total energy consumed in the country annually.

2.2.1 Woodfuels

Direct woodfuels have a total stock of about 832[1] million tonnes whilst the potential annual production is estimated to be about 30 million tonnes. However, not all of this production is available. Actual logging cut is 2.0 - 2.7 million m^3 per annum. This generates as much as 1.0 to 1.4 million m^3 of logging residues on an annual basis. Fig 4 shows an example of logging residue. In addition to logging there are several other potential reserves of biomass. Total land area under tree plantation is estimated at 75,000 ha. Trees of poor form, which will not be suitable for commercial sale, that are removed from these plantations together with the residues from the harvesting of lumber grade trees could also be reckoned as potential sources of energy.

Fig. 4: Logging residues *(Source: Energy Commission, Ghana)*

Diseased coconut trees as well as, over-matured coconut and oil palm trees could be very good fuel sources for the production of energy. Wood processing residues from sawmills are estimated to be 1.0[1] million m^3 per annum. This includes slabs, edgings, off cuttings, sawdust, peeler cores and residues from plywood manufacturing. See Fig. 5. Sawmill and ply-mill residues are most concentrated in the Kumasi area and large-scale furniture mills are in Accra, with several smaller-scale furniture producers distributed throughout the country. There is also potential of wood residues from construction of roads and skidding trails in the forest for the haulage of harvested timber, wood residues from forest clearings for agriculture and wood from surface mining sites.

Fig. 5: Wood processing residues *(Source: Energy Commission, Ghana)*

Analysis of the physical characteristics of trees reveals that woodfuel from the savannah zone have higher calorific values than those in the closed high forest zone of central Ghana. Thus, the trees from the savannah zone which are not suitable for processing into lumber or veneer are very suitable for energy use in the form of charcoal or fuelwood. Woodfuel consumption in 2005 was between 14.6 – 17.3 million tonnes. Over 7.0 million tonnes of the wood is converted to charcoal by traditional earth mound method which has an efficiency of about 12.5%[3] as in Fig. 6.

Fig. 6: Charcoal production by traditional earth mound *(Source: Energy Commission, Ghana)*

2.2.2 Agro-fuels

There are two types of agro-fuels: crop residues and animal waste. Agriculture is a major industry in Ghana, and consequently, large amounts of by-products/residues that can be used for energy production are generated. It has been estimated that there is 553,000[3] tonnes of maize cob and stalk produced with a potential energy of 17.65 - 18.77 MJ/kg and 19 tonnes of paddy rice husks with a potential

energy of 16.14 MJ/kg. As well, 193,000 tonnes of oil palm shells, 136,000 tonnes of sorghum stalks, 150,000 tons of millet stalk and 56,000 tonnes of groundnut shells are also produced. As a result, the estimated energy that could be harvested from various products in the year 2000 are: maize 32,513.7 TJ/kg, rice 7,076.6 TJ/kg, cassava 5,7720.1 TJ/kg, yam 23,943.9 TJ/kg, groundnuts 1,045.3 TJ/kg and cocoyam 11,570.6 TJ/kg.

2.2.3 Municipal Waste

Municipal waste is generated in large quantities. For example, Kumasi and its suburbs generate up to 1,600 tonnes daily while Accra and its environs generate up to 2,500 tonnes. In general, municipal waste generation in the metropolitan centres varies from 600-800 tonnes per day.

2.3 Wind Energy

Ghana has about 2,000MW of raw potential for wind energy as shown in the Wind Energy Resource Map of Ghana in Fig 7. Satellite data provided by the National Renewable Energy Laboratory of USA under the UNEP SWERA Project indicates that the annual average wind speed along the Ghana-Togo border is above 8 m/s. It is currently reliably projected that over 300 MW installed capacity of wind farm could be established at the coastal part to generate over 500 GWh to supplement the nation's energy supply. The wind direction in the country is predominately southwest.

Wind resource measurement activities in Ghana dates back to 1921 when the Meteorological Service Agency (MSA) started collecting wind direction data in its Accra station. In 1936, the Agency installed an anemometer to measure wind speed and direction at 2 metres above ground level in 22 synoptic stations located all over the country. The data was collected for agro-meteorological purposes and not for wind energy application. The wind data indicated an average wind speed of approximately 1.4m/s with the highest average speed of 3m/s experienced along the eastern coastline of the country. Wind speed data collection for energy purposes was initiated in 1999. From this period wind resource measurements have been undertaken at 13 sites along the coast at 12 metres or more above ground level as shown in Fig 8.

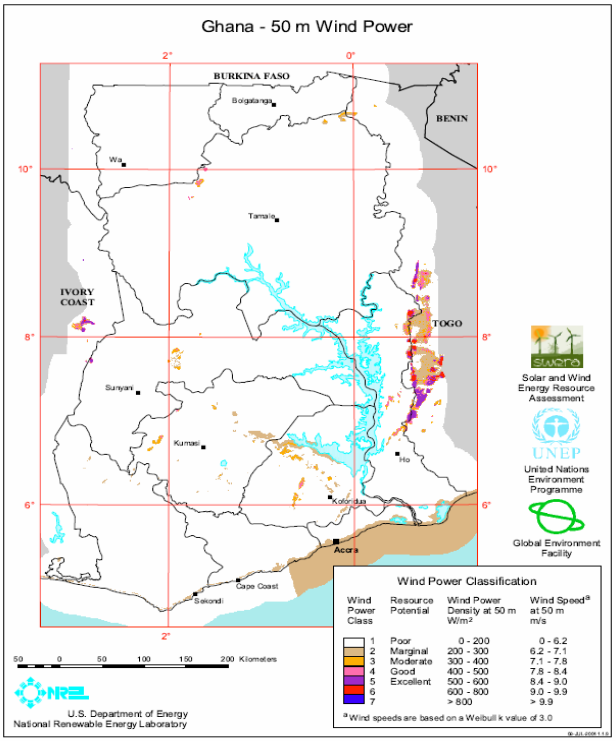

Fig 7: Wind Energy Resource Map of Ghana (Source: SWERA)

Fig. 8: Installed wind measurement mast *(Source: Energy Commission, Ghana)*

Analysis of the data indicates that the annual average wind speed ranges from 2.9 to 5.5 m/s at 12 metres high. Wind speeds extrapolated at 50 metres high (using WASP) range from 3.4 to 7.4 m/s. See Table 2.

Table 2: Wind Measurement along the coast by Energy Commission

Site	Position		Altitude (m)	Height (m)	Annual Mean Wind Speed at 12m (m/s)	Predicted Wind Speed at 50m (m/s)
	Latitude (°N)	Longitude				
Adafoah	5.79	0.55°E		12	5.3	
Aplaku	5.32	0.20°W	50	12	5.2	6.92
Asemkow	5.21	3.27°W	10	12	3.7	5.16
Kpone	5.68	0.07°E	96	12	4.9	7.18
Lolonya	5.79	0.44°E	40	12	5.4	7.15
Pute	5.79	0.52°E	3	12	5.5	7.37
Tema	5.62	0.07°W	50	12	5.0	6.66
Warabeba	5.22	0.35°W	50	12	3.9	5.38
Anloga	5.47	0.55°E	-7	20	5.4	6.80
Amedzofe	6.50	0.25°E	740	20	3.9	5.00
Kue	8.30	0.35°E	327	30	2.9	3.40
Nkwanta	8.15	0.30°E	295	30	3.5	4.00

Source: Energy Commission, Ghana

2.4 Small Hydro

There are 22 exploitable mini-hydro sites in the country with total potential between 5.6MW – 24.5MW as indicated in Table 3. The mini-hydro sites are shown in Fig 9.

Ghana has two large hydroelectric plants, Akosomobo and Kpong, on the Volta River with a total installed generation capacity of 1,180 MW. Currently the Bui hydroelectric plant of capacity 400MW is being developed on the Black Volta.

Hydroelectric plants of over 10 MW are possible on 17 sites on the Black Volta, White Volta, Oti River, Tano River, Pra River and Ankobra River as found in Table 4.

Fig 9: Mini Hydro Sites in Ghana ***(Source: Energy Foundation, Ghana)***

Table 3: Total Potential of Mini Hydro Resource by Region

Region	Potential (kW)
Volta	3117 - 12,065
Eastern	226 - 1.150
Brong Ahafo	364 - 1,900
Central and Western	472 - 2,150
Ashanti	720
Northern	913 - 4,420
Upper East and West	499 - 2,100
TOTAL	**5591 - 24,505**

Source: Hydrological Service Department Ministry of Works and Housing

Table 4: Medium Hydro Sites

RIVER BASIN	POTENTIAL (MW)	ANNUAL ENERGY (GWH)
Black Volta		
Koulbi	68	393
Ntereso	64	257
Lanka	95	319
Jambito	55	180
	Total: 282	**1,148**
White Volta		
Pwalugu	48	184
Kulpawn	36	166
Daboya	43	194
	Total: 127	**544**
Oti River		
Juale	90	405
	Total: 90	**405**
River Tano		
Asuaso	25	129
Sedukrom	17	67
Jomoro	20	85
Tanoso	56	256
	Total: 118	**537**
Pra River		
Awiasam	50	205
Hemang	90	336
Abatumesu	50	233
Kojokrom	30	136
Total	**Total: 220**	**910**
Ankobra		
Nsueam	25	33
Breman	25	41
Mehami	50	63
	Total: 100	**137**
TOTAL POTENTIAL	**937**	**3,681**

Source: Volta River Authority, 1997

3 CURRENT RENEWABLE ENERGY TECHNOLOGY UTILISATION

3.1 Solar PV

Over 4,500 solar systems have been installed in over 89 communities throughout the country. This systems include: Solar Home System for basic house lighting, radio and TV operation; Solar Hospital System for vaccine refrigeration and lighting; Solar School System for classroom lighting and television for Presidential Special Initiative on distance education; Solar Streetlight System for lighting general meeting points, such as markets, lorry stations, water supply points and important busy paths/roads requiring visibility; Solar Water Pumping System for the provision of water and irrigation; Solar Battery Charging System for charging automotive batteries for operating TV and radios in rural communities; Solar System for communication and centralized solar system for providing AC power into the grid. See Fig 10.

Fig 10: Solar System for Communication *(Source: Energy Commission, Ghana)*

Three grid connected solar panels have been deployed at Energy Commission (4.25 kW), Ministry of Energy (50.0 kW) and Kwame Nkrumah University of Science and Technology (4.25kW). See Figs. 11 and 12 show the two installations at the Energy Commission and Ministry of Energy.

Fig. 11: Grid Connected solar system at the Energy Commission ***(Source: Energy Commission, Ghana)***

Fig. 12: Grid Connected solar system at the Ministry of Energy ***(Source: Energy Commission, Ghana)***

The total installed capacity of solar PV is about 1.0 MW and generates approximately 1.8GWh of electricity per annum. See Table 5.

There have been three major projects that have sought to electrify rural communities with solar energy. There are the Renewable Energy services Project which provided stand alone solar PV systems for thirteen communities in the East Mamprusi district and Tenzu;

the Ministry of Energy off-grid solar project that electrified 24 rural communities with assistance from the Spanish Government; and the Renewable Energy Development project that was financed by the Danish International Development Agency.

Table 5: Solar PV Installations in Ghana

SOLAR PV SYSTEMS	INSTALLED CAPACITY	GENERATION
Rural home system	450	0.70 – 0.90
Urban home system	20	0.05 – 0.06
School system	15	0.01 – 0,02
System for lighting health centres	6	0.01 -0.10
Vaccine refrigeration	42	0.08 – 0,09
Water pumping	120	0,24 – 0.25
Telecommunication	100	0.10 – 0.20
Battery charging system	10	0.01 – 0.02
Grid connected systtem	60	0.10 – 0.12
Solar streetlights	10	0.04 – 0.06
TOTAL	**853**	**1.34 – 1.82**

Source: Energy Commission, Ghana

3.2 Solar Water Heaters

Solar Water Heaters are assembled by a local company, Deng Ghana Ltd. They are currently installed in residential dwellings, health institutions, hotels, restaurants and laundries. The majority are in rural health posts. In recent times the use of solar water heaters in hotels are increasing rapidly with the African Regent Hotel, a 4 star hotel in Accra, meeting its hot water requirement from this system. Over 95% of the solar water heaters that have been deployed in the country are imported. Fig 13 shows a sample of solar water heaters sold in Ghana.

Fig 13: Solar Water Heater sold on the market *(Source: Energy Commission, Ghana)*

3.3 Co-generation

There is potential for co-generation use in many sectors especially in the wood processing and vegetable oil industries. Some biomass-fired co-generation projects were implemented in the past. Two key factors have hindered the exploitation of co-generation especially in the wood processing industry. First, most of the potential co-generators have access to cheaper power supply from the grid. Second, there are virtually no financial or fiscal incentives neither are there regulatory requirements that would encourage them to generate and sell electricity to the grid. Table 6 shows biomass-fired co-generation plants in Ghana.

Table 6: Biomass-fired co-generation plants in Ghana

Plant Location	Installed Capacity (kW)	Average annual production (GWh)
Kwae Oil Palm	420	1.50
Juaben Oil Palm	424	1.50
Benso Oil Mill	500	1.90
Twifo Oil Palm	610	2.10

Source: Energy Commission, Ghana

3.4 Biogas technology

The biogas technology has been used in Ghana for cooking in households, direct lighting, small power generation, and bio-sanitation. Figs 14 and 15 show examples of biogas installations. The use of biogas technology for cooking in households and small power generation has not been successful. Most of the household biogas plants built in the country have been abandoned. The average cost of electricity generated from biogas is about 51cents/kWh compared to other sources such as diesel and other petroleum based generation. A very interesting development in the use of biogas technology however has been in the area of bio-sanitation for schools, slaughter-houses, hospitals etc.

Fig. 14: Biogas/diesel generator and mini-grid at Appolonia *(Source: Energy Commission, Ghana)*

Fig. 15: Bio-sanitation project at Ejura Slaughter-house *(Source: Energy Commission, Ghana)*

3.5 Barriers to Renewable Energy Development in Ghana

Besides the fact that renewable energy technologies (RETs), are not cost competitive with other alternative energy sources in most applications, other factors have posed as important barriers to the development of RETs in the country. These barriers are:

- Absence of comprehensive RET Policies;
- Absence of regulatory framework;
- High initial cost of RETs;
- Inadequate financing schemes for RETs;
- Lack of favourable pricing policies;
- Inadequate public awareness to the benefits of RETs;
- Uncoordinated R&D

Unless they are adequately addressed, these barriers would continue to constrain the contribution of renewable energy to national energy supply.

4 RENEWABLE ENERGY POLICIES, STRATEGIES AND PLANS

4.1 Energy for the Demand Sectors

The Strategic National Energy Plan completed in 2006 encourages renewable energy use in three sectors: residential, commercial and service, and agriculture and fisheries. It is expected that in the residential sector, 15% of rural electrification will be by decentralised renewable energy by 2015, increasing to 30% by 2020. Decentralised renewable energy is currently less than 1%. Woodfuels comprise 90% of cooking fuels used by urban households. A strategic target has been set to reduce woodfuel energy intensity by 30% by 2015 and a further 20% by 2020. The strategic target for rural households is to reduce firewood intensity by 10% by 2020. In the commercial sector, a strategic target has been set to have solar water heaters comprise 1% of overall electricity use in hotels, restaurants and institutional kitchens by 2015 and 5% by 2020. Currently solar energy is not used in the commercial sector. Woodfuel comprises the largest portion of cooking fuel used in the commercial sector. Strategic targets have been set to reduce woodfuel's share to 50% by 2015 and to 40% by 2020. In addition, biogas should increase its share to 1% by 2015 and 2% by 2020. Biogas will be limited to hotels, restaurants and institutional kitchens. In the agriculture and fisheries sector, the use of solar energy and biodiesel will be promoted. The two strategic targets set for this sector are: i) to increase biofuel to 2% of overall energy use by 2015 and 10% by 2020 and ii) to have the share of solar energy use rise to 20% by 2020.

The plan is being implemented using a variety of policies and specific measures. In the residential sector, solar electric systems are being proposed for areas with population less than 1,000 who are currently off grid. Minigrid systems will also be provided in large populated areas that are remotely located, using biomass plants, wind farms and small hydro. While communal facilities such as schools and health centres will be electrified using distributed power systems. To decrease woodfuel use in residential cooking, the use of LPG will be encouraged. This will require the National Petroleum Authority to grant licenses for more LPG filling plants to be opened in the country, increase LPG production at the refinery, expand production of domestic LPG cylinders and design financial packages to support fabrication of single and double LPG burners. In addition, the Energy Commission, jointly with the Energy Foundation, will manage woodstove efficiency promotion programs. In the commercial sector, several policies and measures will be implemented to reduce woodfuel use for cooking. These policies include the regulation of the use of firewood and charcoal in restaurants, chop bars, canteens in the regional capitals and the assurance that LPG is fairly accessible throughout the country. This will require more LPG filling stations to be opened in the regional and district capitals and more Oil Marketing Companies to operate LPG stations. Efficient woodfuel stoves will also be promoted. Two additional policies in this area include the promotion of biogas for heating in institutions such as hospitals, barracks, laboratories, boarding schools and institutional kitchens, as well as, the development of biodiesel as a substitute for diesel for running grain mills and other cottage industries in rural areas. In addition, the use of solar water heaters in hospitals, hotels and restaurants will be promoted.

In the agriculture and fisheries sector, the Government will encourage commercial agricultural projects to produce a proportion of their own electricity. This will be accomplished by providing them incentives to develop appropriate alternatives in order to promote decentralised energy and minigrids countrywide. In addition, the Public Utilities Regulatory Commission (PURC) will develop a feed-in-tariff for decentralized power generation and set up an attractive tariff. Feed-in-tariffs will also be developed for the industrial sector to encourage industries capable of generating own or part of their energy especially from renewable sources such as biomass or wastes to do so.

4.2 Energy for Supply Sectors

4.2.1 Electricity

The two strategic targets for this area are to increase the share of renewables in the energy mix to 10% by 2020 (excluding large scale hydro) and to increase the use of renewables for electricity use in rural areas to 30% by 2020. Implementation measures include the creation of incentives to attract private sector investment, unbundling of the power sector, issuing licenses for the operation of large scale renewable energy power plants, and the creation of feed-in-tariffs for embedded generation to allow existing biomass co-generation plants to be connected to the grid. For rural electrification, the Government will establish a Rural Electrification Agency with a Rural Electrification Fund to manage and coordinate efforts. It will also support local agencies to solicit funding from international donor facilities such as the Global Environment Facility and the Clean Development Mechanism.

4.2.2 Woodfuels

Two strategic targets have been earmarked for this sub sector. The first target is to reduce the wood intensity of charcoal production from an existing ratio of wood input to charcoal of 4:1 in the Savannah zone and 5-6:1 in the Forest zone to 3:1 and 4:1, respectively, by 2015. The second target tackles the large share of traditional biomass (woodfuels) in the energy mix which currently stands at over 60%. This should be reduced to 50% by 2015 and to 40% by 2020.

To ensure sustainable production, marketing and consumption of woodfuels, effort be made to survey, map, register and gazette all sustainably managed woodfuel areas outside of forest reserves. Then the woodfuel trade will be standardised. To manage woodfuel production, the Government will encourage and assist local community groups or individual entrepreneurs to establish woodlots or plantations to ensure sustainable supply of wood, define rights and responsibilities of landowning communities on the fringes of forest reserves, introduce woodfuel production contracts, establish standards and registration requirements for woodfuel producers and registration of all commercial woodfuel producers to be given trading rights; and investigate ways to salvage wood from large scale Government construction works. To improve technology and efficiency, all traditional and commercial charcoal producers will be registered and trained in modern carbonisation process. Regulation of the woodfuel transportation, marketing, and export system will be streamlined and strengthened. Furthermore, the current woodfuel taxation system will be revised in order that a portion of the tax revenues will be used for reforestation and support of sustainable management of woodland and ensure that those taxes from sustainably managed areas are less than those from unsustainably managed areas. To build capacity, assistance will be provided to tertiary institutions to establish curriculum on Woodfuel technology and technical and vocational institutions to develop courses in modern woodfuel technologies.

4.2.3 Renewables

In order for the target of 10% of renewables in the energy mix to be achieved, several policies have been developed. A Renewable Energy Regulatory Framework is being developed, as well as, technical regulations and a system of certification and standardisation for and equipment and technicians. A permitting manual which provides guidelines for the issue of permits to service providers to conduct business in the renewable energy industry has already been created. To overcome the high initial cost of renewable energy, the Government will investigate innovative capital subsidy arrangements to assist rural communities, rationalise the fiscal regime regarding import duty and VAT on renewable energy technology (RET) and equipment, expand the current tax exemption regime for RETs to

include import duty and VAT exemption for non-solar, non-wind renewables and support the promotion of local manufacturing of renewable energy devices and equipment in the medium to long term.

4.3 The National Energy Policy

Within the Power Sub-Sector the Government is committed to providing an adequate, reliable and cost effective electricity supply through timely capacity additions and modernization of transmission and distribution infrastructure as well as ensuring universal access to electricity by 2020. This would require increasing generating capacity from the current 1,986 MW to over 4,000 MW by 2015. The Government will also seek to complete the Bui Hydro Power Project and smaller hydro project on the River Oti. Moreover, it will support the development of small and medium scale hydro power projects on other rivers such as the White Volta and a group of rivers in the western part of the country.

The policy paper contains a section on Biomass Energy Policy which has the policy goal of sustaining the supply of woodfuels while ensuring that their exploitation does not lead to deforestation. To this end, the Government will support sustained regeneration of woody biomass resources through legislation and fiscal incentives; promote the establishment of woodlots for charcoal production for export; promote the production and use of improved and more efficient biomass utilisation technologies; promote the use of alternative fuels such as LPG by addressing institutional and market constraints; and promote the use of modern biomass energy resources through creation of favourable regulatory and fiscal regimes and attractive pricing incentives.

Since Ghana is well endowed with solar and wind resources, the Government is committed to the exploitation of renewable and waste energy to enhance energy supplies. The Renewable Energy Policy will proceed in three areas: solar and wind, alternative fuels for transportation and biomass pricing. In the area of solar and wind, the Government will improve the cost effectiveness of these technologies by addressing technological difficulties, institutional barriers and market constraints. Specifically, the Government will promote exploitation and use through the creation of a favourable regulatory and fiscal regimes and attractive pricing; provide tax exemptions for the importation of all equipment; support the use of decentralized off-grid alternative technologies where competitive; and engage Ghanaian engineers and scientists to undertake research and development aimed at bringing down the cost. Policy geared to the development of alternative transportation fuels will entail supporting the development of an indigenous alternative transportation fuel industry based on bio-energy resources (bio-fuels). Keeping in mind that biofuel development will be balanced against food security. In addition, legislation will also be enacted with the goal of creating a demand for biofuels and financial and tax incentives will be brought in to support private sector investments in cultivation, extraction, and refining.

5. RENEWABLE ENERGY PROJECTS

Several projects have been implemented in the past with varying degrees of success. The following are the examples of such projects:

5.1 CIDA-University of Regina/Kwame Nkrumah University of Science and Technology (KNUST) Renewable Energy Project

Objective of Project

The objective of the project was to ensure educational, research and infrastructural development, manpower and skill training, technology development and transfer and information exchange in renewable energy technologies.

The CIDA-University of Regina, Canada/KNUST Renewable Energy project was a combined effort implemented as a pilot project in three rural communities where solar service centres were installed in March 1995. The project was implemented over a six year period. The total cost of the project was CN$1.24 million with CIDA contributing CN$ 900,000 and the remaining amount contributed by the participating universities, in kind.

Output of Project

The project designed and installed solar battery charging systems including distilled water plants at the solar service centres in three communities. Small solar home lighting systems and battery operated home systems were sold under a hire purchased scheme to persons in the pilot areas.

The project also designed, manufactured and sold nearly 100, 18W fluorescent lamps, 100 battery cut-outs (LVD) and 60, 5W halogen lamps. The traditional kerosene lantern was modified to operate on solar charged batteries (K-Electric Lanterns)
The project spilled over to other sectors and communities. The Ministry of Mines and Energy, in support of the solar service centres strategy, contracted the project to build two solar service centres at Appolonia in the Greater Accra Region and a 2.1kW solar service centre at Wechiau in the Upper West Region of Ghana.

The project with funding from the Ministry of Mines and Energy, and in collaboration with other NGOs organised training workshop for technicians, engineers, entrepreneurs and solar enthusiasts.

5.2 Wechiau Solar Battery Charging Project

Objective of Project

The project objective was to demonstrate and evaluate the concept of an integrated solar power village.

Description of Project

Under the off-grid electrification programme, the Ministry of Mines and Energy built a 2.1kW solar PV powered battery charging centre at Wechiau, in the Upper West Region as in Fig. 16. The Wechiau centre has ten battery charging lines. At the onset of the project, 23

batteries were given to the beneficiaries to be serviced and charged at the centre whenever any one of them ran down. Two solar water distillation units were also installed to support the battery charging operation at the centre. A total of 38 solar home systems comprising nineteen 50Wp and nineteen 100Wp panel were distributed throughout Wechiau on fee-for-service basis.

Fig 16: Solar battery charging centre at Wechiau *(Source: Energy Commission, Ghana)*

Forty-one households were provided with 12V, 100Ah deep cycle lead acid batteries together with the following items on credit basis:

- Two 5W halogen lamps and one 18W fluorescent lamp.
- The 5W lamp was used as study and bedside lamp while the 18W lamp was used for lighting the compound.
- Low voltage disconnect.
- A 12V socket for 12V television set, sound system and radio.

5.3 Off grid Solar PV Rural Electrification Project

Objective of Project

The objective of the project was to demonstrate the viability of solar PV for rural electrification on the basis of fee-for-service and also to establish the conditions necessary for the integration of solar PV technology into the national electrification scheme.

Description of Project

The project commenced in July 1998. It was financed through a mixed credit facility of US$ 5.0 million made of 50% concessionary loan and 50% official export credit from the Spanish Government. The project was executed by the Ministry of Energy and implemented by Isofoton S. A. of Spain with Wilkins Engineering Ltd. as local counterpart.

Output of Project

A total of 10 villages benefited from the project. Solar PV services provided under the project included the power for home lighting, televisions and radio sets, vaccine refrigeration and lighting in Health Centers, and solar streetlights for public places and street illumination, solar battery charging centres and water pumping. See Fig. 17, 18, 19 & 20. Table 7 shows the type systems installed under the project. The homes systems were provided to the beneficiaries on fee-for- service basis.

Fig. 17: Solar PV installation for rural school
(Source: Energy Commission, Ghana)

Fig. 18: Solar PV installation at Durbar ground
(Source: Energy Commission, Ghana)

Fig. 19: Solar pumping systems
(Source: Energy Commission, Ghana)

Fig. 20: Solar PV system installed in a rural home
(Source: Energy Commission, Ghana)

The project closely collaborated with District Councils and the communities in their operational areas. A solar committee was established in each of the 10 beneficiary communities. Training was offered to enable the committees undertake basic repairs and maintenance of the solar systems. The committees were also mandated to collect tariffs on behalf of the MOE.

Under the project, a 50 kW solar PV grid connect system was installed at the Ministry of Energy premises as backup to the grid power.

Table 7: Types of systems installed

Solar system	Quantity of systems	Total capacity
Home system	1,923	154,300
Hospital	14	8,400
Streetlight	200	30,000
School & community	48	12,000
Water pumping (drinking & irrigation)	2	7,200
Battery charging centre	6	3,000
Centralised station	1	50,000

(Source: Energy Commission, Ghana)

5.4 UNDP/GEF Project on Renewable Energy Service Project (RESPRO)

Objective of Project

The project aimed at: (i) facilitating the development of a national capacity in the large scale application of renewable energy technologies, especially solar PV and PV/diesel hybrid power systems in the provision of sustainable electric power services; (ii) providing government of Ghana with the true cost of extending electricity service to rural and remote communities so that a decision can be taken on the integration of RETs into the National Electrification Scheme; and (iii) serving as model and catalyst for the emergence of a commercial market for solar PV and other RETs in Ghana.

Description of Project

In 1999 the UNDP/GEF and the Government of Ghana, through the Renewable Energy Service Project (RESPRO) of the Ministry of Energy, selected the East Mamprusi District as the site for a pilot study for solar home systems of two types (50W and 100W). These systems were installed in 283 households in 13 communities in 2001. Fig. 21is an example of a solar home system installed. All the communities selected for this project were more than 20km away from the national grid, the criterion for selecting the sites for the solar home systems. Permanent staff on monthly salary were employed to handle the project. The project operated fee-for service mode of payment and the systems were owned by the project and not the beneficiaries just like the MoE/Spanish project.

Fig. 21: Solar home system *(Source: Energy Commission, Ghana)*

5.5 Renewable Energy Development Project

Description of Project

The Renewable Energy Development Project (REDP) was funded by the Danish Aid Development Agency (DANIDA). It was implemented from 2000 to 2002. The project installed eleven new Renewable Energy Service Centres (RESCs) and rehabilitated and upgraded three existing ones. See Fig 22. These centres are located at Asuhyiae, Asekye, Dromakese, Alipe, Sankpala, Wulugu, Nabari, Yibile, Kadoli, Guadayiri, Yaru, Manwe, Gorlipie, and Kwamoso. Six of these centres are in Upper West and four are in Northern region. Over 300 customers have been provided with solar PV systems within the concession areas of 14 RESCs. The RESCs at Dromankese, Asuhyiae, and Kwamoso have all been equipped with PV based telecommunications centres which are operating on a commercial basis. Three health centres have been equipped with solar systems for lighting and vaccine refrigeration. Six schools in Ashanti and Volta regions have been equipped with solar systems for lighting to facilitate studies at night. These have been implemented as demonstration projects for the District Assemblies. Under the project six Rural Banks are providing financial services to the entrepreneurs, customers and the project as a whole. The primary focus of the rural banks is to deal with the issue of sustainability of the project by providing the necessary financial intermediation that will enable beneficiaries to replace major components of their solar home systems when they are due to be replaced. In that regard, the Rural Banks are responsible for managing a "Seed Fund" set up under the project for a fee. The "Seed Fund" is generated from payments made regularly by beneficiaries towards the cost of systems they have acquired from the project.

Lessons Learnt

In undertaking these activities, several lessons were learned. In the establishment of RESC and the delivery model, it is important to provide flexibility in project design, particularly, in terms of developing a successful delivery model and technical specifications about size and nature of systems supported. There are several issues that need to be addressed in developing a sustainable PV delivery model for rural communities. Firstly, there is a need to reduce the initial costs for consumers but ensure full coverage of recurrent costs. Secondly, there is a need to introduce systems of various sizes, so that consumers have a choice of model and costs. Thirdly, adequate

after sales service needs to be provided. The involvement of financial intermediation is crucial, as well as, consumer credit. Finally, business focus applications are more sustainable than social services. It is also critical that components of PV be of high quality, but moderately priced.

Fig 22: Solar Battery Charging Station *(Source: Energy Commission, Ghana)*

5.6 Solar Streetlighting Project

Description of Project

The Ministry of Energy financed the installation of 46 solar street lights to determine the feasibility of the replacement of the conventional street lights at the following places: (i) the University of Ghana, Legon, (ii) the University of Cape Coast, Cape Coast and (iii) the Army Recruit Training School, Shai Hills.

Lessons Learnt

The project established that in the short to medium terms the feasibility for the widespread deployment of solar street lights to replace conventional street lights on the country's roads is not favourable. There are however some essential sectors such as military installations, police check points, custom's outposts where they could be installed for security considerations.

Fig. 23: Solar street lights *(Source: Energy Commission, Ghana)*

5.7 UNEP SWERA Project

Objective of Project

The goal of the SWERA project is to develop adequate, accurate and reliable solar and wind energy resources data and information and evaluation tools for energy planning and policy.

Description of Project

The Solar and Wind Energy Resource Assessment (SWERA) was a UNEP project with co-financing from Global Environment Facility (GEF). It was implemented to promote the utilisation of renewable forms of solar and wind energy by: (i) removing barriers created by the lack of information; (ii) supporting more informed decision-making, science and technology based policy that would ultimately increase investors interest in renewable energy

In August 2002 the Energy Commission signed a contract with the United Nations Environment Programme (UNEP) for the execution of the SWERA project in Ghana. Under the contract, UNEP provided the Energy Commission with a grant of US$80,000.00 to implement the project. The project which commenced in September 2002 was completed at the end of 2005.

Outputs of Project

The project produced the following outputs:

- Direct, diffuse, global and latitude tilt data from satellite data at 40km resolution.
- Solar radiation maps (direct, global and latitude tilt).
- Wind map of Ghana (drawn from EC wind data and satellite data).
- Four wind measuring equipment for collecting wind speed data at the eastern corridor of the country

5.8 Appolonia Model Biogas Village Project

Objective of Project

The objective of the project was to develop biogas technology for lighting and cooking at Appolonia as a full demonstration project with a view to extend to other rural communities.

Project Description

The Integrated Rural Energy and Environment Project at Apollonia was established as part of the Renewable Energy Development programme of the Ministry of Energy. It started in December 1987 and was formally commissioned in June 1992 At the beginning of the project ten (10) household biogas digesters were constructed to provide biogas for cooking in ten (10) households. Later, the generation of electricity from biogas for use in the community was added. For this purpose, ten (10) 50m3 capacity biogas plants was constructed to supply biogas to run an internal combustion engine of capacity 10 kW to generate electricity for distribution to the whole village. The feed materials were obtained from human wastes fed directly from two KVIP toilet facilities and from cow dung collected by paid caretakers using power tillers.

Another component of the project involves the use of the effluent from the digesters as organic fertilizer in the cultivation of various crops.

Outputs of Project

The project is a very interesting concept and has greatly helped to unearth several issues concerning the factors that influence the development of biogas technology in Ghana. For example, the project has clearly demonstrated the following:

At current non-economic pricing of grid electricity, power generation from biogas technology is not cost-effective. However, it is likely that as electricity pricing approaches economic levels electricity from biogas may become more competitive.

Under current pricing environment, the sanitation aspect of biogas system is more attractive for community use than the energy aspect. Indeed, the system is becoming very popular with the District Assemblies and Educational institutions for human waste management. Already over 50 of such systems have been constructed across the country.

So long as there is abundance of fuelwood, in a given community, the traditional use of firewood for cooking is preferable to the rural dweller than shifting to biogas. In other words, biogas technology in Ghana may be cost-effective and thus stand a better chance of success only in geographic areas of the country where fuelwood is deficient.

5.9 Household Energy Programme

Objective of Project

The objectives of the project were to: create policy environment to regulate the woodfuel sector; encourage the efficient utilization of charcoal & firewood through improved woodstoves; encourage the use of efficient charcoal production techniques; encourage shift to alternate cooking fuels such as LPG; promote the establishment of woodfuel plantations; and educate the public on effects of woodfuel smoke on the health.

Description of Project

An Annual Work Programme was signed between UNDP and Ministry of Energy in June 2006 for the implementation of the Household Energy Project. Energy Commission was the main implementing partner. The other partners included WFP, CSIR-IIR, GEF/SGP, NewEnergy and CASLID.

Outputs of Project

The project was completed in 2008 and the following were accomplished:

1. Woodfuel policy developed and incorporated in the Strategic National Energy Plan of Government
2. Safety standards for LPG use in the household and commercial sector in Ghana developed and gazatted.
3. Establishment of Woodfuel plantations and introduction of improved institutional woodstoves in selected basic schools benefiting from the school feeding programme in the Northern and Upper East regions. See Fig 24 and 25.
4. Men and women in three communities within the millennium village cluster trained on improved mud stoves.
5. Awareness creation on negative health impact of woodfuel.

Fig 24: Woodfuel Plantation ***(Source: Energy Commission, Ghana)***

Fig 25: Training of Women in the construction of Improved Wood Burning Stoves ***(Source: Energy Commission, Ghana)***

CONCLUSIONS

Ghana's known renewable energy resources are solar, biomass[i], wind and small hydro. The endowment of the country's renewable energy resources suggests that it has some prospects to contribute to the country's energy needs. Besides the resources being indigenous, they have the potential to meet critical energy policy concerns of security of supply and negative environmental impacts, if exploited.

Ghana receives an average solar radiation of about 4 – 6 kWh/m^2/day and sunshine duration of 1,800 hours to 3,000 hours per annum. Solar radiation in Ghana shows strong geographical variations with the highest level of solar radiation found in the northern regions of the country. Diffuse radiation is between 41 percent and 53 percent, with the lowest occurring in the northern parts of the country and the highest across the western part of the country. Generally, solar radiation levels are good enough to be exploited for electricity generation and direct thermal applications.

Solar PV installations in Ghana numbering over 4,500 with capacity of about 1.0MW are being used for lighting, telecommunication, water pumping, vaccine refrigeration, battery charging, streetlighting, etc. Included are 3 grid connected solar PV systems of total capacity of 58.5kW that have been deployed at Energy Commission, Ministry of Energy and Kwame Nkrumah University of Science and Technology as pilot projects.

Solar Water Heaters could be promoted as an electricity demand management tool in urban residential dwellings, hotels, hospitals and other commercial activities that require hot water owing to the fact that they would displace electric power loads. Solar water heaters are financially viable options for water heating because they have reasonable short payback periods.

Wind energy resource assessment studies conducted in Ghana have shown that the annual average wind speeds along the coast range between 4.0m/s and 6.0m/s.

Biomass resources can be converted into electricity, heat, transport fuels, etc through a number of technologies – co-generation (combined heat and power), gasification, anaerobic digestion, fermentation and distillation. Biomass resources that are available in Ghana include sawmill residues, agricultural wastes, animal waste, municipal wastes and energy crops. Of these, sawmill residue and energy crops are the most promising for energy purposes. In Ghana, the well-tested applications of biomass-based technologies are co-generation, biogas production from anaerobic digestion, and very recently bio-diesel production. The use of biogas technology has been in the area of bio-sanitation projects for schools, slaughter-houses and hospitals.

Studies conducted in the 1970s, on mini-hydro potential, concluded that the country has about 70 mini-hydro sites in six of the 10 regions in Ghana with a total minimum and maximum capacities of 5.59MW and 24.5 MW respectively.

Besides the fact that renewable energy technologies (RETs), are not cost competitive with other alternative energy sources in most applications, other factors have posed as important barriers to the development of RETs in the country. They are: i) absence of comprehensive RET Policies; ii) absence of regulatory framework; iii) high initial cost of RETs; iv) inadequate financing schemes for RETs; v) lack of favourable pricing policies; vi) inadequate public awareness to the benefits of RETs; and vii) uncoordinated R&D

The Government of Ghana is committed to the development of the country's renewable energy sources. To this effect, the Renewable Energy Policy will proceed in three areas: solar and wind, alternative fuels for transportation and biomass pricing. The Government will promote exploitation and use of renewable energy through the creation of a favourable regulatory and fiscal regimes and attractive pricing; provide tax exemptions for the importation of all renewable energy equipment; support the use of decentralized off-grid alternative technologies where competitive; and engage Ghanaian engineers and scientists to undertake research and development aimed at bringing down the cost of RETs.

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