THE GHANA RENEWABLE ENERGY MASTER PLAN

Draft

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ACRONYMS AND ABBREVIATONS

3SIL	Strategic Security Systems International Limited
AEG	Accelerated Economic Growth
AESD	Agricultural Engineering Services Directorate
AfDB	African Development Bank
ARB	Assessment Resource Bank
AU	African Union
BAU	Business-as-Usual
BOST	Bulk Oil Storage and Transportation Company
DC	Direct Current
DFID	Department for International Development
EC	Energy Commission
ECG	Electricity Company of Ghana
ECOWAS	Economic Community of West African States
EnDeV	Energising Development
EPA	Environmental Protection Agency
ESPS	Energy Sector Programme Support
ESSDP	Energy Sector Strategy and Development Plan
EU	European Union
FiT	Feed-in-Tariff
GDP	Gross Domestic Product
GEDAP	Ghana Energy Development and Access Project
GEF	Global Environment Facility
GHS	Ghana Cedi
GHG	Greenhouse Gas
GHp	Ghana Pesewa
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GOPDC	Ghana Oil Palm Development Company
GPRS	Ghana Poverty Reduction Strategy
GRIDCo	Ghana Grid Company Limited
GSA	Ghana Standards Authority
GSGDA	Ghana Shared Growth Development Agenda
INDCs	Intended Nationally Determined Contributions
IPP	Independent Power Producer
LPG	Liquefied Petroleum Gas
MoEn	Ministry of Energy
MOFA	Ministry of Food and Agriculture
NDPC	National Development Planning Commission
NEB	National Energy Board
NEDCo	Northern Electricity Distribution Company
NES	National Electrification Scheme
NGOs	Non-Governmental Organisations
NG	Natural Gas
NITS	National Interconnected Transmission System
NPA	National Petroleum Authority
NRES	National Renewable Energy Strategy
OMCs	Oil Marketing Companies
PPP	Public Private Partnership
PSP	Private Sector Participation
PURC	Public Utilities Regulatory Commission
PV	Photovoltaic
R&D	Research and Development

RE	Renewable Energy
REDP	Renewable Energy Development and Management Programme
REMP	Renewable Energy Masterplan
REPF	Renewable Energy Project Financing
REPO	Renewable Energy Purchase Obligation
RESPRO	Renewable Energy Services Project
RETs	Renewable Energy Technologies
RETT	Renewable Energy Technology Transfer
SEforALL	Sustainable Energy for All
SHS	Solar Home Systems
SLAPP	Solar Lantern Promotion Programme
SNEP	Strategic National Energy Plan
SWH	Solar Water Heater
UEMOA	Union Économique et Monétaire Ouest-Africaine
UN	United Nations
UNDP	United Nations Development Programme
USAID	United States Agency for International Development
VRA	Volta River Authority

UNITS

MW	Megawatt
MWe	Megawatt Electricity Equivalent
MWp	Megawatt Peak
kWh	Kilowatt hour
kWp	Kilowatt Peak
t	Tonne
ha	Hectare

EXECUTIVE SUMMARY

Introduction

Globally, renewable energy is going through exciting times with increasing investment in many countries. Solar PV capacity increased from 3.1 GW in 2005 to 227 GW in 2015. Within the same period, wind power capacity increased from 59 GW to 433 GW. Large hydropower has remained at very high annual market volumes as well. Bio-power partly operated as co-generation plants quadrupled to a total global generation capacity of 106.4 GW over the same time period. Other renewable energy technologies have made significant progress as well, with total annual biofuels production increasing from 37 billion litres in 2005 to 128 billion litres in 2015. As production levels have soared, costs have dropped significantly for most of the technologies.

In view of the global trends, the Government of Ghana has identified renewable energy as one of the options that could contribute to the overall energy supply mix and minimise the adverse effects of energy production on the environment. Indeed, renewable energy programmes and projects implemented in recent years have demonstrated that renewable energy interventions have enormous potential to reduce poverty and improve the socio-economic development of the country, particularly, in rural communities.

Renewable energy in the form of hydro power already accounts for 43.2 % of total installed electricity generation capacity as at 2015. Utility scale solar also accounted for 0.6 % of total installed capacity (this excludes standalone solar systems).

At the moment, most of the renewable energy interventions in the country are either being carried out as pilot projects or on short term planning cycle basis. Thus, no clear integrated roadmap exists for the long-term development and promotion of the different renewable energy resources in the country.

To address the attendant effects of such short-term planning of the overall development of the renewable energy sector, the Renewable Energy Master Plan has been developed with the goal to provide investment-focussed framework for the promotion and development of the country's rich renewable energy resources for sustainable economic growth, contribute to improved social life and reduce adverse climate change effects.

The REMP aims to achieve the following by 2030:

- Increase the proportion of renewable energy[1] in the national energy generation mix from 38 MW in 2016 to 2,567 MW;
- Reduce the dependence on biomass as main fuel for thermal energy applications;
- Provide renewable energy-based decentralised electrification options in 1,000 off-grid communities;
- Promote local content and local participation in the renewable energy industry.

Targets and Actions

Existing policies, strategies and resource potentials were taken into consideration to establish the targets and actions required for each of the renewable energy technologies.

The implementation of the REMP starts from the year 2018 and run through to the year 2030. The scope of the targets and plan of action are based on a thorough stakeholder consultation

[1] Renewable energy as defined by the Renewable Energy Act 2011 (Act 832). In the Act, hydropower capacity up to 100 MW is considered renewable.

and analysis of the renewable energy resources and applications, economics and financial implications. The set targets are presented in Table E1.

The REMP also prescribe action plans for all the Renewable Energy Technologies (RETs). For each of the RET areas (solar, wind, hydro, biomass, etc.), the action plan analysed the resource availability, opportunities in developing the resource, and recommends interventions for their promotion and development. Further details and actions are provided for each of the technologies/ interventions under each resource with specific considerations given to the challenges and strategies to promote it.

The broad strategies proposed for the successful implementation of the REMP are as follows:

- Boost and sustain local assembly and manufacture of RETs through a systematic phasing out of import duty exemptions on RETs where the country has a competitive advantage;
- Strategically recommend consideration for tax exemptions on components and materials for assembly and manufacture to make RETs competitive on the local and sub-regional markets;
- Provide support to existing RET assembling/manufacturing companies including preferential procurements under public financed projects;
- Guarantee local market through local content and local participation actions;
- Support the private sector through concessional financing and government on-lending facilities to RE investments;
- Institutionalise competitive procurement to achieve cost reduction in tariff for utility scale renewable energy projects;
- Continuously provide investment support for the upgrading of the National Interconnected Transmission System to accommodate the planned renewable energy power targets;
- Incorporate land requirements for renewable energy projects in the national spatial planning framework;
- Develop legislation to ensure that increased development of renewable energy projects does not become detrimental to the environment;
- Intensify awareness creation;
- Build capacity in various aspects of renewable energy development; and
- Support research and development.

In line with the Renewable Energy Act, 2011 (Act 832), the Ministry of Energy will implement the plan through the REMP Coordinating Unit (REMP-CU). The REMP-CU shall be responsible for the overall procurement and fiscal management, coordination with key REMP Components Implementation Entities and Beneficiaries (CIEB[2]) and reporting obligation. The Ministry of Energy will from time to time designate relevant entities to implement key components of the REMP.

A National Steering Committee (NSC) made up of experts drawn from all relevant institutions will be established to provide overall guidance to the REMP and will among other responsibilities review progress made at the end of each cycle. Members of the NSC will serve for not more than two terms aligned with the REMP implementation cycles. The NSC will hold quarterly meetings and as and when necessary.

[2] Public and private sector actors implementing aspects and or whose actions are aligned with the REMP.

The REMP-CU will be staffed with competent personnel. The REMP-CU arrangements, assets and liabilities shall be given to the Renewable Energy Authority when it is established and operational.

Economic, Social and Environmental Impacts

The REMP is an US$ 8 billion investment master plan. On annual basis, the REMP translates into an estimated US$ 620 million investment. The plan shall be implemented over a 13-year time-space, from 2018 to 2030.

The successful implementation of the plan would lead to an installed capacity of 2567 MW, 225,000 jobs[3], and carbon savings of about 20.6 million tonnes of CO_2 by 2030.

The REMP proposes strategies to minimize the adverse impact of the various renewable energy technologies and targets on land use through spatial planning.

Enabling Environment

Government shall continue to provide an enabling business environment and work to remove the bottlenecks that hinder growth in the private sector. Manufacturing and assembling shall be consciously promoted.

Incentives proposed for renewable energy manufacturing and assembling firms include:

- Substantial tax reduction;
- Exemption of materials, components, equipment and machinery (that cannot be obtained locally) for manufacturing or assembling, from import duty and VAT, up to the year 2025; and
- Exemption of Import duty on plants and plant parts for electricity generation from renewable energy resources.

With regards to infrastructural development, government would dedicate significant budgetary allocations to fund detailed technical studies at national level, and assist GRIDCo to invest in modern weather forecasting equipment and stations synchronised with weather stations at various utility scale renewable electricity installations for proper and timely planning of the sub-sector and evacuation of renewable electricity. In view of this, all variable renewable electricity generation plants shall be required to install weather stations on site.

To boost mini-grid development, government would facilitate an efficient and cost-effective water transportation system to support mini-grid activities in island and lakeside communities.

Government would team up with well-equipped training centres to provide technical and entrepreneurial training programmes to interested groups and individuals on renewable energy technologies. Technical capacity development will target areas such as solar PV system design and installation, construction of biogas digesters, design and construction of gasifiers, improvements in the design and construction of improved household and institutional cookstoves, design and construction of small-scale biomass briquetting and pelleting machines, repair and maintenance of aforementioned systems, among others.

Implementation plan

The REMP will be implemented in three (3) cycles with the first cycle (or transition phase) running from 2018 to 2020. Subsequent cycles will run from 2021 to 2025 and 2026 to 2030

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[3] Jobs include farmers who will benefit from solar irrigation projects and cultivate all year round

respectively (see Table E1). Each cycle will be reviewed in the last year of implementation and the outcome used to improve the implementation of the next cycle.

The utilities will play key roles, especially in relation to utility scale projects. The Volta River Authority, Bui Power Authority and the Renewable Energy Authority (yet to be established) will be encouraged to grow and expand the renewable energy electricity space through public sector led investments and or through public private partnerships.

GRIDCo will drive strategic investments and expansion of the National Interconnected Transmission System (NITS) in line with provisions defined in the 'Renewable Energy Sub-Code and the National Grid Code' to accelerate the interconnection of utility renewable energy projects.

The Renewable Energy Purchase Obligation (REPO) will be implemented to ensure that the distribution companies, ECG, NEDCo, and Enclave Power Company (EPC), and all other bulk customers integrate electricity generated from renewable resources in their distribution and consumption mix.

ECG, NEDCo and EPC will also ensure that net-metered systems have access to the distribution grid, in line with the 'Net-Metering Code'.

Private sector investment is at the centre of the REMP. In addition to government and donor-led programmes, the private sector investments toward achieving the targets in the REMP, especially, utility scale projects, will be given priority. The REMP will continue to create opportunities through the RE-FiTs, Competitive Procurement of RE projects (Tenders) and Purchase Obligations to increase investment in the sector.

The government will give significant financial incentives and procurement preferences to private sector actors engaged in the local assembly and manufacturing of renewable energy technologies and related services.

Manufacturing and assembling of renewable energy technologies is pivotal to the overall success of the REMP. This will not only stimulate sustainable growth of the sector, but also contribute to the overall development of the West African renewable energy market. Manufacturing and assembling along strategic links in the renewable energy value chain in the REMP would be fully implemented

In accordance with the Local Content Policy for the sector and to boost local production, both state sponsored and private sector renewable energy projects would source a minimum 20 % of goods from the local market (where applicable) in the medium term. The scope and content of local sourcing of goods will be broadened as the local production market matures.

The REMP would strengthen the GSA to ensure that local production of renewable energy technologies meet national/ international standards.

Table E1: REMP Implementation Schedule 2018 to 2030

REMP IMPLEMENTATION PLAN - RE TARGETS UP TO 2030										
Renewable Energy Technologies	Reference 2015		Cycle I (2018-2020)		Cycle II (2021-2025)		Cycle III (2026-2030)		Cumulative in 2030	
	No. of units	MWp	No. of Units	MWp	No. of Units	MWp	No. of Units	MWp	No. of Units	MWp
Solar Energy										
Solar Utility Scale	-	23	-	270	-	202	-	378	-	873
Distributed Solar PV (Net Metering)		2	20000	18	100000	100	80000	80	200000	200
Solar Home Systems	-	3	-	1.5	-	3.5	-	6	-	14
Solar Street/Community lighting	-	3	-	4	-	4	-	14	-	25
Solar Traffic signals (% of total traffic signals installed in the country)	14	3	11	-	15	-	20	-	60	-
Solar Lanterns	72,000	-	128000	-	300000	-	500000	-	1000000	-
Solar irrigation	150	2	4250	6.8	22000	44	22400	44.8	48800	97.6
Solar Crop Dryers	70	-	80	-	250	-	300	-	700	-
Solar Water Heaters	4,700	-	15300	-	50000	-	65000	-	135000	-
Wind Energy										
Wind Utility Scale	-	0	-	125	-	275	-	250	-	650
Standalone Wind Systems	-	0	-	0.1	-	0.9	-	1	-	2
Wind Irrigation/Water Pumping	10	0	25	-	30	-	35	-	100	-
Biomass / Waste-to-Energy										
Biomass Utility-Scale/ standalone	-	10	-	58.5	-	106.5	-	125	-	300
Waste-to-Energy Utility Scale	-	0.1	-	1	-	3	-	5.9	-	10
Landfill Gas to Energy (LFGTE)	-	0	-	1.5	-	8.5	-	10	-	20
Biogas (Agricultural/Industrial Organic Waste)	10	-	20	-	70	-	100	-	200	-
Biogas (Institutional)	100	-	80	-	140	-	180	-	500	-
Biogas (Domestic)	50	-	30	-	50	-	70	-	200	-
Woodlot Cultivation (ha)	190,000	-	60000	-	100000	-	78000	-	428000	-
Charcoal (Local Demand)	1,551,282	-	94017	-	93947	-	100877	-	1840123	-
Charcoal (Export)	190,450	-	59550	-	100000	-	78000	-	428000	-
Briquetting/Pelleting	19,700	-	20300	-	25000	-	35000	-	100000	-
Biofuel (tonnes)	0	-	100	-	4900	-	15000	-	20000	-
Hydro / Wave Power										
Small/Medium Hydro Plants	-	4.00[1]	-	2.03	-	108	-	232	-	346.03
Wave Power	-	0	-	10	-	15	-	90	-	115
Hybrid Mini-Grids										
Mini/Micro-grids	7	-	73	-	120	4.8	100	4	300	-
End User Technologies										
Improved Biomass Cookstove (Domestic)	800,000	-	500000	-	500000	-	1200000	-	3000000	-
Improved Biomass Cookstove (Institutional/Commercial)	1,800	-	1200	-	7000	-	8000	-	18000	-
Total Installed RE Electricity Capacity		***46.1***		***503.53***		***875.2***		***1239.8***	0	***2664.63***

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1 INTRODUCTION

1.1 Background

Fossil fuel price volatility coupled with its increasing cost and climate change, as well as efforts to reduce pollution, have led to an unprecedented investment in renewable energy (RE) sources in recent times globally. Generally, life-cycle global warming emissions associated with renewable energy – including manufacturing, installation, operation and maintenance, and dismantling and decommissioning – are minimal, compared to fossil fuels. Generating electricity from renewable energy rather than fossil fuels offers significant public health benefits. The air and water pollution emitted by fossil-fuel powered plants is linked to breathing problems, neurological damage, heart attacks, and cancer (Machol, 2013). Replacing fossil fuels with renewable energy has been found to reduce premature mortality and lost workdays, and it reduces overall healthcare costs. Ghana, like many other countries, is focused on the integration of RE into the national energy mix to ensure security of energy supply, ensure a cleaner environment, and help mitigate climate change.

Interest in RE dates to the first oil crisis that occurred in the early 1970s. Following from the oil crisis, the development and reliance on indigenous energy resources became the cornerstone of Government policies as a measure to ensure security of energy supply. Efforts by the Government of Ghana to promote indigenous energy resources culminated in the establishment of the National Energy Board (NEB) under PNDC Law 62, 1983. The primary responsibility of the NEB was to promote the exploitation and development of the country's energy resources, particularly RE resources. The creation of the NEB led to pioneering efforts to consolidate and further develop Government plans and programmes on RE. The NEB supported a number of research and development works in various aspects of RE. Lessons learnt over the years provided a sound basis for formulating appropriate policies and strategies for the development of the country's renewable energy resources **besides hydropower.**

Ghana is signatory to several international conventions, treaties and regional programmes such as UN Sustainable Energy for All (SEforALL) Initiative, Sustainable Development Goals (SDGs), Paris Agreement on the Intended Nationally Determined Contributions (INDCs), AU Agenda 2063, Economic Community of West African States (ECOWAS) White Paper on Energy Access, ECOWAS Renewable Energy and Energy Efficiency Policies, among others aimed at promoting sustainable energy development.

The aforementioned conventions, treaties, and regional programmes all aim at vigorously promoting renewable energy and thereby reduce the incidence and effects of climate change, to ensure a future that is conducive enough for its generation. In view of this, developed countries and transition economies such as China have taken the giant step towards pushing renewables forward with huge investment coming up every year. According to the 2017 version of the Renewable Global Futures Report (REN21, 2017), renewable power generation technologies have developed rapidly over the past decade, dominated by wind and solar.

Solar PV capacity increased from 3.1 GW in 2005 to 227 GW in 2015, beating expectations from the solar photovoltaic industry itself, which in a publication in 2001, estimated a total installed capacity of 100 GW by 2015; wind power capacity increased from 59 GW in 2005 to 433 GW in 2015; large hydropower has remained at very high annual market volumes – mainly in China – as well. Bio-power partly operated as co-generation plants quadrupled to a total global generation capacity of 106.4 GW – equal to around 140 coal power plants with an average capacity of 750 MW – over the same time period. Other renewable energy technologies have equally made significant progress. Total annual biofuels production increased from 37 billion litres in 2005 to 128 billion litres in 2015.

Over the years, costs have dropped significantly for most of the technologies. For example, costs for off-shore wind have dropped from 12-15 Euro cents per kWh for projects in the North Sea area in 2012, to a record low of 5.45 Euro cents per kWh for recent projects in the Netherlands. Data from NREL (2015) indicate that since 1998, reported PV system prices have fallen by roughly $0.50/W per year on average. Overall, reported system prices of residential and commercial PV systems declined by 6 %-7 % per year, on average, from 1998-2013, and by 12 %-15 % from 2012-2013, depending on system size.

As costs have reduced, investments have risen in several parts of the world. Annual investments in new renewable energy capacity increased from about US$ 65 billion in 2005 to US$ 286 billion in 2015. As of 2015, 173 countries have policy targets for renewable energy. Interviews conducted of global experts by REN21 (2017) showed an overwhelming consensus among all experts across all regions that renewable power will dominate in the future. Over 85 % of the experts interviewed said they expect the share of renewable power will at least double by 2050, and more than half estimated a share of 80 % or higher.

Even though Ghana's energy mix is currently clean, with about 43.2 % installed capacity coming from hydropower in 2015, and a corresponding grid emission factor of 0.33 tCO_2/MWh in the year, it is prudent that Ghana begins to develop its renewable energy resources to continue to keep it clean, reduce dependence on imported fuels for power generation, while at the same time, contribute power towards the energy needs of the country for accelerated economic development. A well-developed renewable energy sector will also create 'home grown' jobs. If and when manufacturing of basic components is able to take root, this could also help reduce the trade balance deficit. In view of this, efforts towards the creation of a clear regulatory framework for the RE sector have been ongoing, with the formulation of policies, strategy documents and enactment of laws. A major milestone for the RE industry was the enactment of Renewable Energy Act (Act 832) in 2011. These policies and strategies have helped in increasing investments from both the public and private sectors.

On the solar front in RE, some successes have been made in the small-scale solar PV (for rooftop and lantern applications), grid-connected systems, and to some extent solar water heating systems in the hospitality industry. About 22.5 MW utility scale solar PV systems have been connected to the national grid. A few biomass-based industries have installed combustion technologies for the generation of heat and power from biomass waste and some biogas installations exist, albeit with varying levels of success. There is scope to expand solar PV and solar thermal installations. A lot more biomass-based industries stand to benefit from utilising their resources to generate heat and electricity. Significant data has been collected and feasibility studies are advanced to assess economic potential of wind and remaining hydro resources. Prospects for tidal energy exploration are exciting.

Government, and indeed the private sector, has implemented different renewable energy projects over the years with results that demonstrated the impact of RE in poverty reduction and socio-economic development in Ghana. Going forward, there is the need for a targeted plan with clear roadmap for the long-term development and promotion of the different energy forms of renewable energy sources.

1.2 Vision, Goal and Objectives of the Renewable Energy Master Plan

1.2.1 Vision

The vision of the Renewable Energy Masterplan is to 'develop the renewable energy sector with the capacity to sustainably utilise resources and transform Ghana into a country with expertise in renewable energy research, production, and services.'

1.2.2 Goal

The goal of the Renewable Energy Masterplan (REMP) is to provide investment-focussed framework for the promotion and development of renewable energy resources for economic growth, improved social life and minimise the adverse effects of climate change.

1.2.3 Specific objectives

The specific objectives of the REMP are to achieve the following by 2030:

- Increase the supply of renewable energy[4] in the national interconnected grid electricity supply system from 40 MW in 2015 to 2664 MW;
- Reduce the dependence on biomass as main fuel for thermal energy applications;
- Provide renewable energy-based decentralised electrification options in 1000 off-grid communities;
- Promote local content and local participation in the renewable energy industry.

1.3 Definition of Renewable Energy

In line with Section 2 of the Renewable Energy Act, 2011 (Act 832), Renewable Energy is defined as energy obtained from non-depleting sources including:

a) wind;
b) solar
c) hydro;
d) biomass;
e) biofuel;
f) landfill gas;
g) sewage gas;
h) geothermal energy;
i) ocean energy; and
j) any other energy source designated in writing by the Minister.

1.4 Overview of Energy Demand and Supply

1.4.1 Primary Energy Supply

Ghana's primary energy supply[5] is largely dependent on petroleum, biomass and hydro. In 2015, oil contributed 44.48 % to primary energy supply, followed by biomass (37.87 %), hydroelectricity (5.27 %) and natural gas (12.38 %). As shown in Figure 1, there has been an overall 65% increase in the total primary energy supply between 2005 and 2015. This growth

[4] Renewable energy as defined by the Renewable Energy Act 2011 (Act 832). In the Act, hydropower capacity up to 100 MW is considered renewable.

[5] Primary energy supply is defined as energy production plus energy imports, minus energy exports, then plus or minus stock changes.

was led by oil, which doubled between the period, followed by natural gas. Biomass supply remained practically the same over the period, and hydro saw a slight dip.

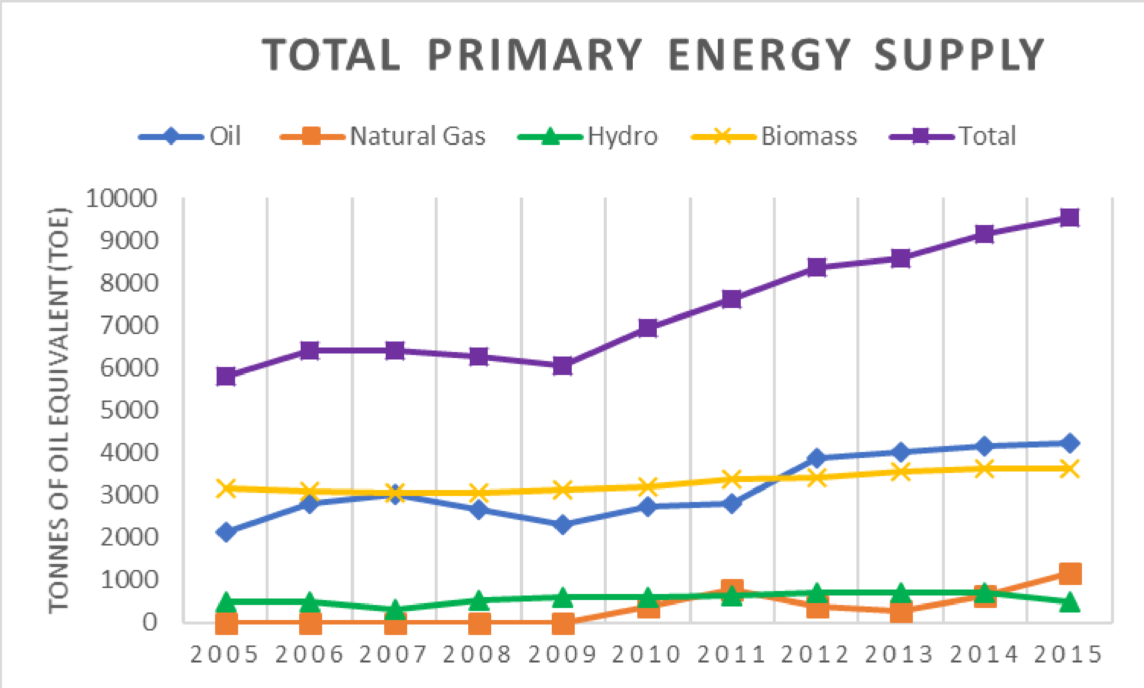

Figure 1: Total primary energy supply in Ghana, 2005-2015

Source: Energy Commission, 2016

1.4.2 Final Energy Consumed

Final energy[6] consumed in Ghana is dominated by petroleum products and biomass. Petroleum products, including gasoline, diesel, LPG and jet fuel accounted for 47 % (of about 7 million toe) of final energy consumed in 2015. Biomass, in the form of firewood, charcoal and agricultural residue contributed 40 %. Electricity accounted for only 13 %. As shown in Figure 2, there was an 81 % increase in the total final energy consumed between 2005 and 2015. This growth was led mainly by petroleum products, which saw a 77 % growth over the period. Biomass consumption was fairly stable, with electricity consumption growing at 62 % beyond the 2005 level.

[6] Final energy consumption is the total energy consumed by end users, such as households, industry and agriculture. It is the energy which reaches the final consumer's door and excludes that which is used by the energy sector itself.

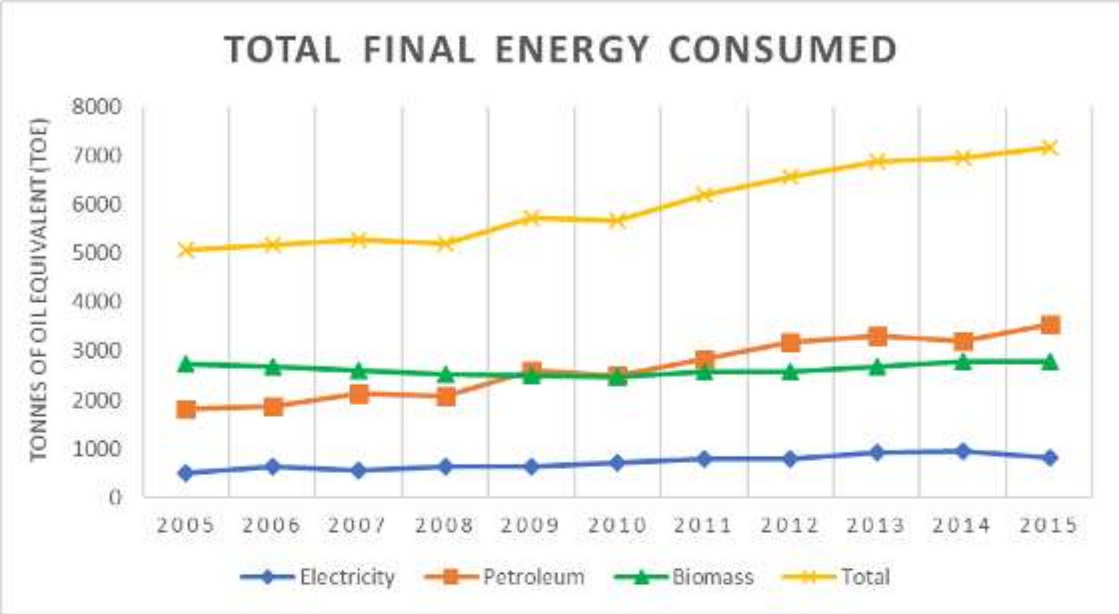

Figure 2: Total final energy consumed, 2005-2015
Source: Energy Commission, 2016

1.4.3 Electricity Generation Sources

Until the early 2000s, Ghana's electricity generation was dominated by large hydro. In recent times however, thermal generation increased from 1,159 GWh in 2005 to 5,644 GWh by 2015. Thermal sources for electricity generation in Ghana include Light Crude Oil, Natural Gas and Diesel. Total installed renewable energy capacity (electricity) at the end of 2015 was about 1,602 MW, contributing approximately 43.8 % of the total national installed electricity out of which Hydropower accounted for 43.2 %. Electricity generation from hydropower reduced significantly in the year 2007 and 2015 due to low rainfall in the Volta basin (see Figure 3).

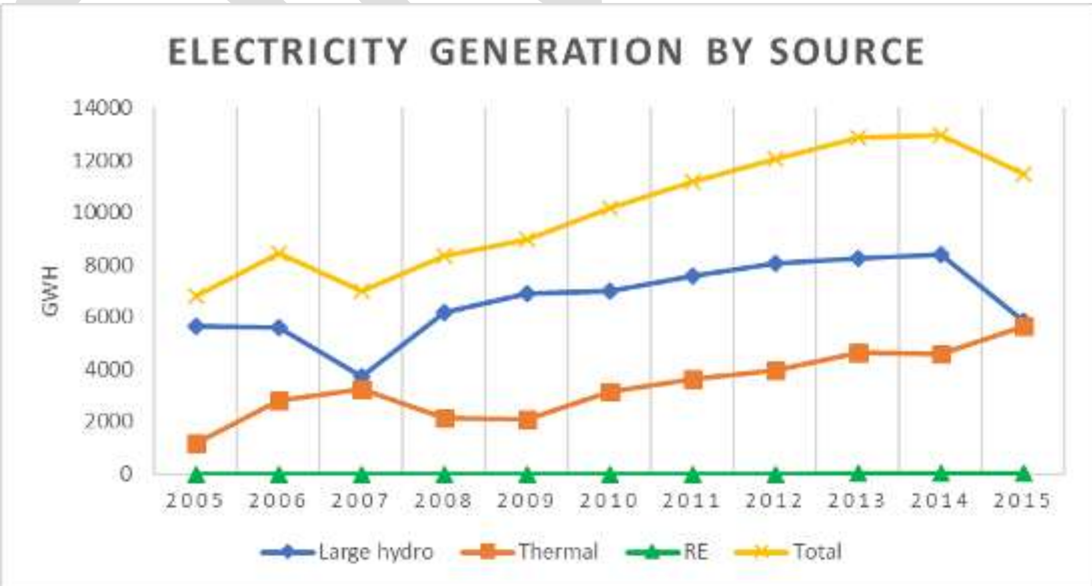

Figure 3: Electricity generation by fuel source, 2005-2015
Source: Energy Commission, 2016

1.4.4 Sectoral Electricity Consumption

Electricity consumption in Ghana is disaggregated into residential, non-residential, industrial and public lighting sectors. The industrial sector is the highest consumer of electricity in Ghana followed by residential and non-residential sectors. As shown in Figure 4, there was an 84 % increase in industrial electricity consumption between 2005 and 2014, before dropping marginally in 2015 due to supply challenges. Consumption in all the other sectors also increased during the period as follows: residential (46 %), non-residential (126 %) and street lighting (980 %).

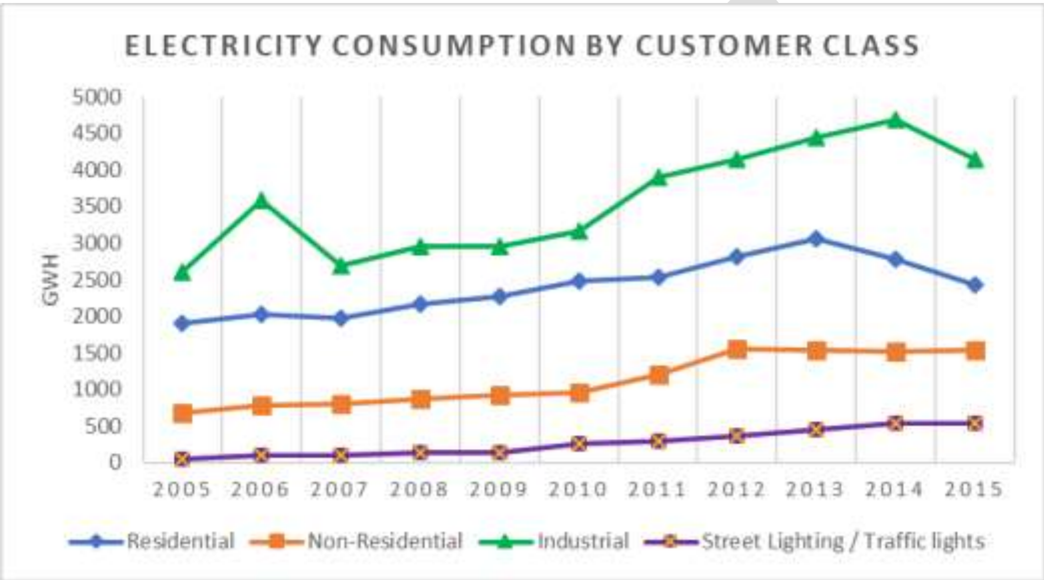

Figure 4: Electricity consumption by customer class

Source: Energy Commission, 2016

1.4.5 Cooking Fuel Sources

Firewood dominate Ghana's cooking fuel landscape. In the year 2013, firewood was the main source of cooking fuel to more than 40 % of households in Ghana, followed by charcoal and gas (see Figure 5). In rural communities, about 75 % of households used firewood as main cooking fuel, whereas in urban communities, charcoal dominates, used by almost 44 % as main cooking fuel. Liquefied Petroleum Gas (LPG) is used as main cooking fuel in 36 % of urban households, and only 5.5 % in rural households. Cookstoves are dominated by traditional firewood and charcoal stoves.

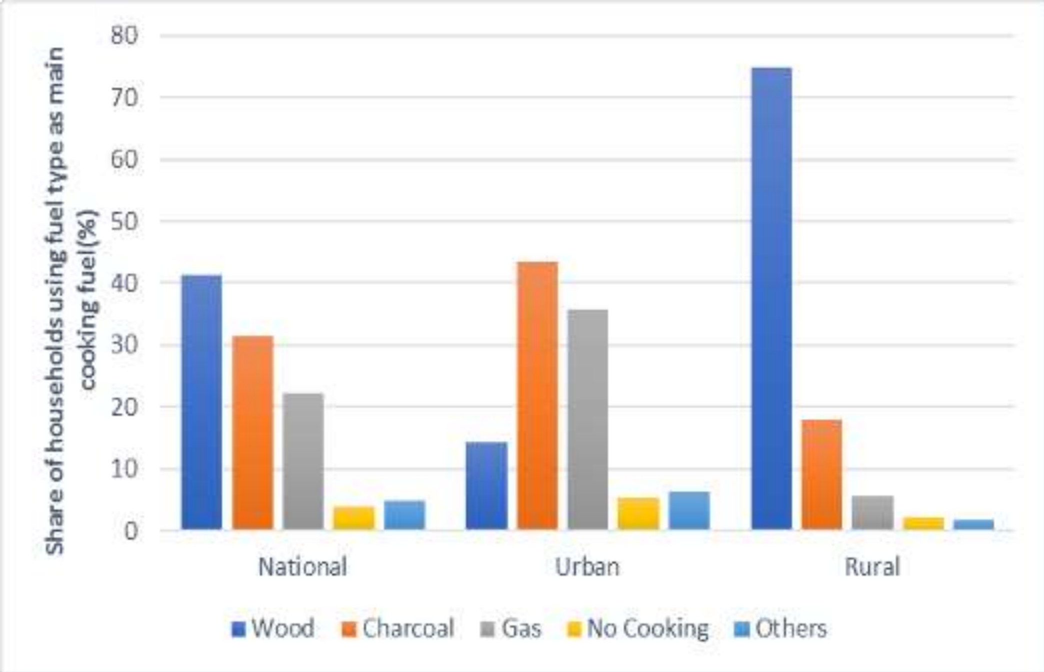

Figure 5: Cooking fuel sources in 2013

Source: Ghana Statistical Services (2014)

1.4.6 Energy Demand Projections

Annual electricity demand growth is estimated at about 10 %. Energy Commission estimates that a capacity addition of about 200 MW per annum is required to catch up with the increasing demand in the medium to long term. It is projected that electricity demand would reach about 23,000 GWh by 2020, rising to about 40,000 GWh by 2030 (Figure 6). Demand for petroleum products is expected to increase by about 300 % from 2800 ktoe in 2015 to 11,240 ktoe in 2030 (Figure 7). Growth in petroleum products demand will be driven largely by expected increases in demand for diesel, gasoline, and LPG. In line with government efforts to promote modern fuels for cooking, demand for woodfuel on the other hand, will increase by only 21 % from 3,460 ktoe in 2015 to 4200 ktoe in 2030 (Figure 8). Woodfuel demand is driven almost entirely by the household and small industry sector.

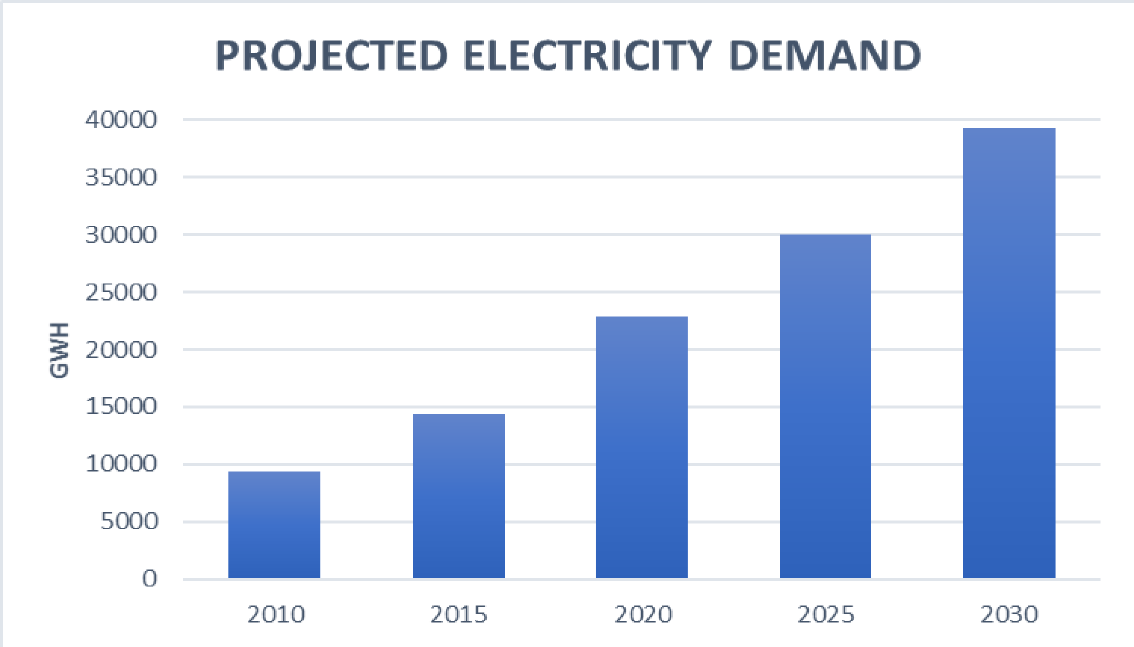

Figure 6: Electricity demand projection to 2030[7]

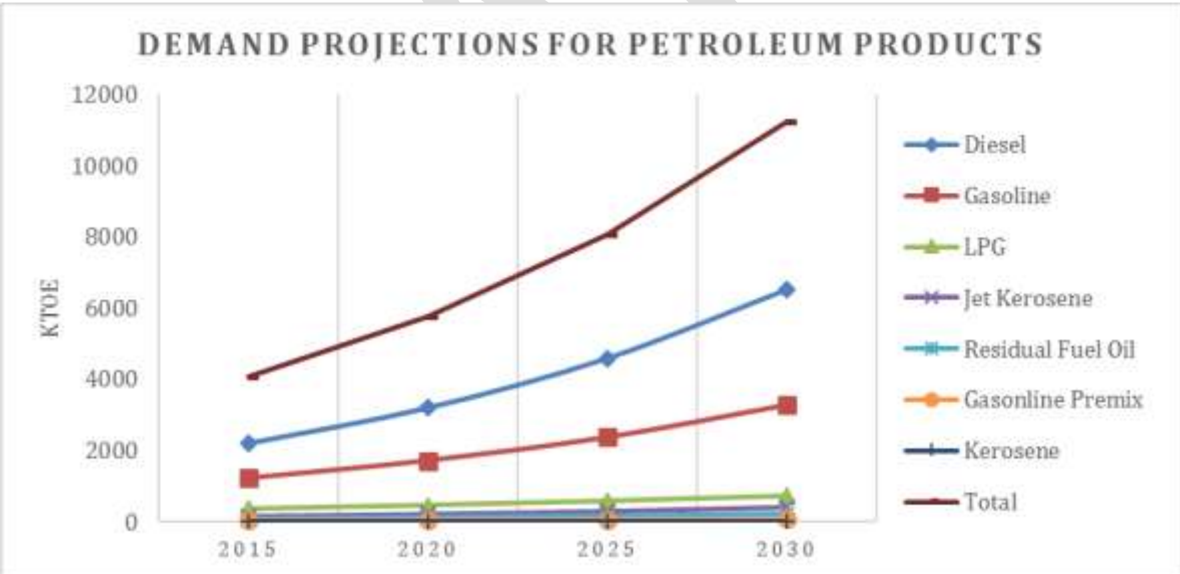

Figure 7: Final petroleum demand projections

Source: Energy Commission, 2016

[7] Data obtained from the draft Strategic National Energy Plan 2016-2030

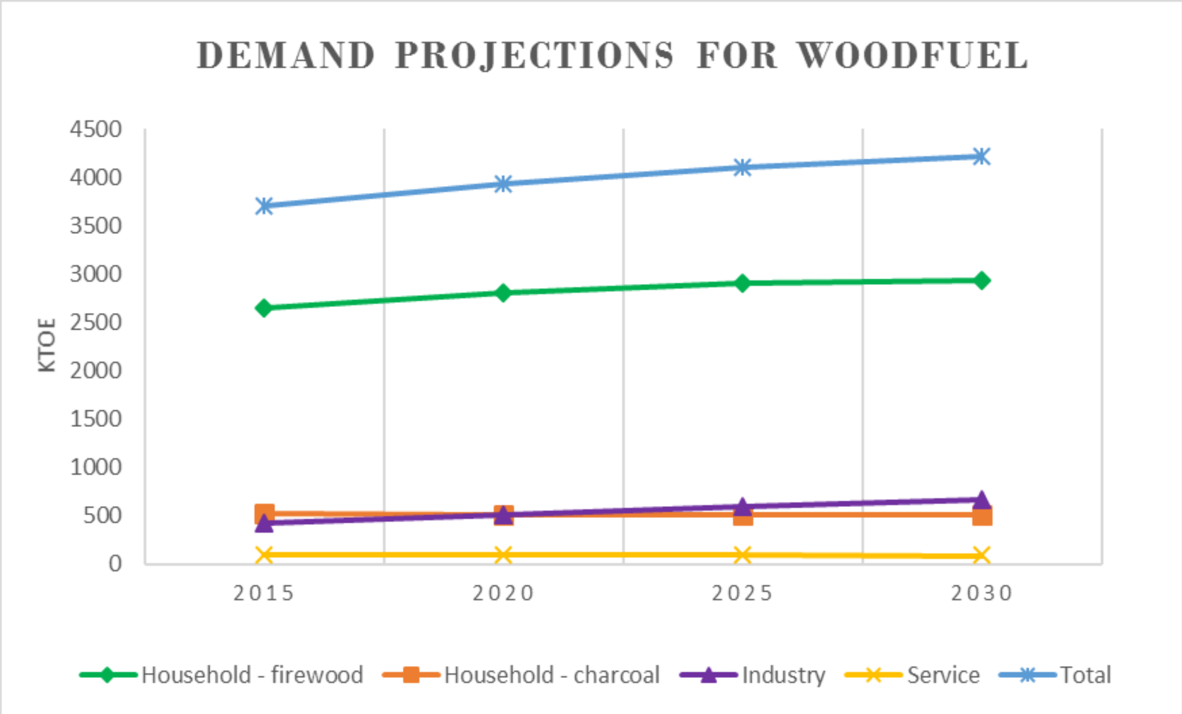

Figure 8: Woodfuel demand projections

Source: Energy Commission, 2016

1.5 Status of Renewable Energy Technology Developments in Ghana

Table 1 presents an estimate of RE installations deployed up to December 2015 by technology type and capacity.

Table 1: Estimated installed capacity of RE systems in Ghana

Technology type	**Installed capacity/No. of Units (estimated)**	**Unit**
Utility scale grid-connected renewables	23	MWp
Other grid-connected renewables (distributed generation)	15	MWp
Mini-grid (hybrid systems)	0.2	MWp
Off-grid solar (including street/community lighting)	> 5	MWp
Solar Lanterns	> 72,000	No. of units
Biogas	9,000	m^3
Biomass/Biogas	5.6	MW
Solar dryers	50	Tonnes

1.5.1 Thermal and Mechanical Renewable Energy Technologies

Thermal and Mechanical RETs in this context refer to technologies that provide end-use services not related to electricity. These include solar water heaters, solar and wind for water supply (for consumption and irrigation), biogas systems (for cooking and heating), biofuels (transportation and heating), solar dryers, etc.

Solar PV systems installed for water supply and irrigation are located mainly in the northern parts of the country. These systems use DC pump technology to provide clean water for community water supply and irrigation water to ensure all year cropping. Many of the water supply systems do not require batteries and/or inverters, and have low operational costs. Close to 30 systems have been installed for water supply and irrigation under various donor funded and government assisted projects in rural communities.

Currently, GIZ (with support from other development partners such as DFID) under the irrigation component of Energising Development (EnDev) programme is assisting farmers to change from the use of diesel generators to grid electricity or solar PV powered systems. In the solar PV component, 30 farmers are to be supported to procure solar irrigation equipment. EnDev provides 40 % of the cost of up to 2 kW complete solar pumping system. The farmer is responsible for covering the remaining 60 % of the cost together with the additional cost of installing/creating the necessary water flow facilities/channels on the farm.

There is growing interest in solar water heating systems and indeed a number of installations have been completed, mainly in the hospitability industry. The total installed capacity of solar water heating systems in 2015 was estimated to be 1018.48 kW_{th} (1454.97 m^2) (ECREEE, 2015). With rising electricity tariffs, the hospitability industry is adopting solar water heaters as a cost saving measure to supplement electric water heaters.

Traditional sun drying exposes grain crops to rainfall and poor hygienic conditions. Modern solar dryers, often in the form of transparent tents with shelves, help minimise these challenges. Modern solar dryers have been piloted in Ghana but existing installations are few. The Agricultural Engineering Services Directorate (AESD) of the Ministry of Food and Agriculture (MOFA) has piloted and installed about 25 solar dryers nationwide. The structure of the solar dryer is based on the green house model, using acrylic sheet to trap heat, with side vents for natural air flow, thereby employing no mechanical power for airflow. However, acrylic materials used for constructing the dryers are imported and expensive, stalling the solar dryer programme.

Poldaw wind pumps for irrigation have also been piloted by MOFA. In 2002, MOFA through AESD commenced activities aimed at promoting the use of groundwater for agricultural purposes and identified wind power as an alternative energy source to lift groundwater. The Village Infrastructure Project assisted MOFA to acquire a franchise from NEALE Consulting Engineers, UK to produce poldaw windpumps in Ghana. Local engineers and technicians were trained and supervised to produce component parts for installation. At the end of the training period, about 20 Poldaw wind-pumps were fabricated and installed in the Northern, Western and Greater Accra regions. The windpumps were designed with start-up speed of as low as 3 m/s and could withstand high wind-speeds up to 50m/s. They could draw water from boreholes up to a depth of 30 m. The technology could not be promoted widely because of high initial costs, limited expertise and lack of equipment for maintenance.

Efforts by Government to develop biogas systems started as far back as 1987 with the construction of household biogas digesters for cooking and lighting. Later on in 1992 the technology was developed to establish the technical and economic viability for decentralised rural electrification. The Appolonia Biogas Project commissioned in 1992, provided useful lessons for the sustainable use of biogas development. The Appolonia project faced a number of challenges which were related to sustainable feedstock supply for digesters owing to drudgery involved in collecting dung from kraals that were about half to three-quarters of a mile from the plant, maintenance, and uncooperative attitude of some of the inhabitants. In addition, there were socio-cultural challenges with the collection and use of digested faecal material from the plant for agricultural activities. Also, operation and maintenance costs did not match the revenue inflow to ensure sustainability, leading to discontinuation of the project and extension of grid electricity to Appolonia under the rural electrification programme in the late 2000s. These challenges showed clearly that in the case of Ghana, biogas technology is not sustainable to provide community based electrification, but may be an ideal technology for sanitation management in relevant institutions.

Recent activities have sought to introduce more modern technologies. A notable example is the Upflow Anaerobic Sludge Blanket plant built at Guinness Ghana Ltd. in Kumasi, intended for sanitation purposes only. Other systems have been installed at Ghana Oil Palm Development Company (GOPDC) and HPW Fresh and Dry (at Adeiso in the Eastern Region), which also include units for power generation.

1.5.2 Decentralized Renewable Energy Systems

At the end of 2015, about 10 MWp of stand-alone solar PV systems have been installed in Ghana. These are being used for inter alia, lighting, water pumping, powering of computers for the teaching and learning of ICT and vaccine refrigeration across the country. Over 70,000 solar lanterns have been disseminated.

Stand-alone solar PV systems are market driven in Ghana, spurred by government and donor supported community projects in the past. There has been several of these government projects but a few cases stand out for enjoying several years of success. Notable community cases implemented include the Weichau project, Isofoton project – funded by the Spanish government, Renewable Energy Services Project (RESPRO) – funded by UNDP and GEF, and the ARB Apex Bank project. The objectives of these projects were to provide lighting solutions and other services to these communities, and many of them worked successfully until grid extension reached the community. All these projects were based on the fee-for-service model and community ownership was key to their success.

The **Weichau Project,** initiated in 1997, provided a battery bank where community members could go to recharge solar batteries. The scheme was managed by a community solar committee that was jointly chaired by the local Assemblyman, the Chief and one representative from the community. In addition to household and school lighting, the project additionally provided portable water to the community and refrigeration for vaccines in the clinic. Due to the weight of the batteries, it was laborious for households to transport them for charging. The 'to and fro' movement also reduced the lifespan of the units. These challenges became lessons for subsequent solar PV projects, such as the **ISOFOTON** and **RESPRO projects, which** provided individual panels to interested households under a fee-for-service subsidized scheme. Unfortunately, the revenue generated was not adequate to replace the system components. The three projects described above were public sector-led.

The **ARB Apex Bank Project** was initiated to involve the private sector. The project supported the formation of the Association of Ghana Solar Industries to enhance the participation of private sector in providing maintenance and system supply. Under this project, the ARB Apex Bank provided low-interest loans to rural communities to obtain solar systems and lanterns.

Government supported beneficiaries with 50 % grant subsidy. Whilst this project was successful in increasing access to solar systems and lanterns, battery replacement also became an issue.

Some of the general challenges encountered in all these projects include:

- Difficulty in moving batteries for the central charging schemes;
- Security of systems;
- Political interference;
- High cost of systems, despite the subsidies;
- Instability of the local currency negatively affected battery replacement;
- Beneficiaries with seasonal income had difficulty making payments; and
- Lack of coordination between national grid extension and off-grid interventions.

One key lesson from all these projects is the need to initiate local assembly / manufacture of components for solar systems in Ghana. With a growing interest in solar PV off-grid systems, there is a growing market for components in the country. Another important lesson, which is currently informing government policy on rural off-grid projects, is to target remote and island communities where it is not economical and accessible to extend the national electricity grid.

Other decentralised lighting systems that have been disseminated in the country include street and community lighting systems and traffic signals. More than 5 MW capacity of solar PV has been installed for street and community lighting. Many of the solar street lights and traffic signals are championed by the Urban Roads Department of the Ministry of Roads and Highways. There is presently no financing model for the replacement of system components once installed.

There are several solar systems installers in Ghana today, even though many of them are located in Accra, with very little representation in other parts of the country. Over 100 businesses have been licensed by the Energy Commission to carry out installation and maintenance of RE systems, mainly solar, in Ghana.

1.5.3 Grid-integrated Renewable Energy

As of December 2015, about 23 MW of solar PV grid-connected systems existed in Ghana. Of this total, 22.5 MW is from two utility-scale projects: a 20 MW plant by BXC Company Ltd. and another 2.5 MW by VRA. The remaining systems are mainly household and institutional grid-connected systems, either self-funded, donor funded, or with government support. Grid connected systems also face challenges including:

- High cost of capital;
- Lack of access to capital from the local market;
- Lack of indigenous investors; and
- Uncertainties in FiT rates beyond the guaranteed period of ten years.

1.5.4 Manufacturing / Assembly Capacity

There is the potential to manufacture all renewable energy components in Ghana. Government has put in place incentives and created the enabling environment for local manufacturing and / or assembly of RETs. Four companies are taking advantage of these market incentives to locally manufacture and assemble PV modules with details as follows:

- Strategic Security Systems International Limited (3SiL), has begun solar PV module assembly in Ghana since 2015 with capacity of up to 30 MW of modules per year;

- Halo International has also completed a solar PV module plant in 2016 with production capacity of 15 MW per year;
- Tradeworks Ghana Ltd., is in the process of completing a solar PV module assembly plant with 12 MW per year capacity; and
- Atlas Business and Energy Systems (ABES) has had a smaller scale solar PV module assembly plant in place since 2012.
- Africano Electro Ltd, PowerWings Company Ltd, Pamasonic and Deng Ghana Ltd, among others are at various stages setting up manufacturing/assembly plants for RE components.

1.6 Structure of the Masterplan

The masterplan is structured into ten (10) chapters. Following this introductory chapter, the next chapter highlights existing policies and the institutional framework in Ghana's renewable energy sector. Thereafter, targets for each of the proposed interventions are presented, together with actions and strategies to promote their implementation. The remaining chapters address issues such as the implementation plan, economic impacts, environmental impacts and the creation of an enabling environment. The concluding chapters discuss cross-cutting issues such as gender and energy efficiency, risk analysis, as well as monitoring and evaluation.

2 POLICIES AND INSTITUTIONAL FRAMEWORK

From the 1980s to date, the promotion of RETs in Ghana have been supported by government and development partners. Records are found in various policy and strategy documents. Below is a list of the major policies, plans and strategy documents that have been developed since 1986.

a) Issues and Options in the Energy Sector (1986)
b) National Electrification Scheme (1989)
c) Vision 2020 (1995)
d) Ghana Poverty Reduction Strategy (2003)
e) Growth and Poverty Reduction Strategy (2006)
f) National Renewable Energy Strategy (2003)
g) ECOWAS White Paper on Access to Energy Services (2006)
h) Strategic National Energy Plan (2006/2020)
i) Ghana Shared Growth and Development Agenda I & II (2009/2014))
j) National Energy Policy (2010)
k) Energy Sector Strategy and Development Plan (2010)
l) Renewable Energy Act, 2011 (Act 832)
m) Sustainable Energy for All Action Plan / Agenda of Ghana (2012/2016)
n) Mini-grid Electrification Policy (2016)
o) Bioenergy Policy (Draft)

2.1 Issues and Options in the Energy Sector (1986)

The aim of the 'Issues and Options in the Energy Sector' was to rehabilitate the productive installations in the petroleum and electricity subsectors, reduce the dependence on petroleum imports and manage forestry resources such that their productivity is raised and they provide sustainable quantities of woodfuel over the longer term. The strategic targets in the RE sector, were to:

- Ensure efficient dissemination of potentially viable options, relying increasingly on the private sector; and
- Coordinate studies and demonstrate projects on RE, analysing proven technologies prior to dissemination, evaluating potentially viable projects, and ensuring the wider application of appropriate technologies.

2.2 National Electrification Scheme (1989)

In the National Electrification Scheme (NES), government first laid out its plans for the electrification of the country with the aim to reach universal electrification by 2020. The overall aim of the NES include:

- Increasing the overall socio-economic development of the nation and creating wealth to alleviate poverty, especially in the rural areas;
- Increasing people's standard of living, especially those in the rural areas;
- Creating small-to-medium scale industries in rural areas;
- Enhancing activities in other sectors of the economy, such as agriculture, health, education and tourism; and
- Creating jobs in rural areas and thereby reducing the rate of rural-urban migration.

2.3 Vision 2020 (1995)

In 1995, government launched the Vision 2020 document that was put together by the National Development Planning Commission (NDPC) as Ghana's blue print for sustainable socio-economic development. The aim of Vision 2020 was to lay strong foundations for accelerated growth and development. Strategic targets for the RE sector were to:

- Encourage research into solar energy as well as pursuing a vigorous programme in biogas technology by setting up models at the village level to further reduce pressure on forest for woodfuel;
- Expand electricity supply using natural gas, solar energy, biogas, domestic and industrial wastes; and
- Expand and rehabilitate existing renewable energy technologies.

2.4 Ghana Poverty Reduction Strategy (2003)

The Ghana Poverty Reduction Strategy (GPRS) came up with comprehensive policies, strategies, programmes and projects to support growth and poverty reduction. GPRS spanned the period 2003 to 2005. Strategic targets with regards to RE were to:

- Promote and encourage private sector participation in the energy sector;
- Diversify the national energy mix by implementing programmes to support renewable energy sources in Ghana (i.e. hydro, wind, solar PV, etc.);
- Implement rural energy programme involving renewable energy in areas where it is economically feasible; and
- Fund the development of renewable energy using the national budget.

2.5 Growth and Poverty Reduction Strategy (2006)

The Growth and Poverty Reduction Strategy covered the period 2006 to 2009. The GPRS emphasised on poverty reduction using social interventions while the Growth and Poverty Reduction Strategy focused on poverty reduction through induced growth by developing the private sector; diversifying the export base; and increasing agricultural productivity, processing and rural income.

Strategic targets with regards to RE were to:

- Diversify the national energy mix by implementing programmes to support RE sources in Ghana (i.e. hydro, wind, solar PV, etc.); and
- Minimise environmental impacts of energy supply and consumption through increased RE and energy efficiency (EE) technologies.

2.6 National Energy Strategy (2003)

The development of the National Energy Strategy began in 2001 when the Government of Denmark agreed with the Government of Ghana to provide technical and funding support to the energy sector under the Energy Sector Programme Support (ESPS). The support covered three areas, namely:

a) Renewable Energy Development and Management Programme (REDP);
b) Traditional Energy Development and Management Programme; and
c) Strategic National Energy Plan (SNEP).

2.7 Renewable Energy Development and Management Programme (REDP)

The REDP aimed to accelerate the development and utilisation of renewable energy and energy efficiency technologies to achieve 10 percent penetration of national electricity and petroleum demand mix by 2020. A key output from the REDP was the preparation of a National Renewable Energy Strategy (NRES) which identified major barriers hindering RE development and proposed the following actions, among others:

1. Establishing comprehensive RET policies;
2. Creating RET friendly regulatory framework;
3. Establishing favourable pricing policies for RETs;
4. Intensifying Energy Research and Development (R&D); and
5. Establishing database on RES.

2.8 Strategic National Energy Plan

The broad objective of the Strategic National Energy Plan (SNEP) was to develop a medium- to long-term plan for the entire energy sector to ensure that reasonable demand for energy is met in a sustainable manner. A key output of SNEP was the development of energy demand and supply scenarios.

2.9 ECOWAS White Paper on Access to Energy Services (2006)

Ghana is party to ECOWAS and subscribes to its energy policies and plans. There are two principal documents that spell out RE programmes for the ECOWAS region. The first is the 'ECOWAS/UEMOA White Paper on Energy Access' which was developed in 2006. The White Paper proposes that at least 20 % of new investments in electricity generation in rural and peri-urban areas should originate from renewable sources. The second document, 'ECOWAS Renewable Energy Policy', is much more elaborate on issues concerning RE. The ECOWAS RE Policy envisions universal access to electricity for all ECOWAS citizens by 2030, with 75 % of the population connected to the grid. The remaining 25 % of the ECOWAS population living in smaller localities in remote rural areas will enjoy electricity services from mini-grids providing high quality services at competitive prices, or will be supplied by highly reliable stand-alone systems. Renewable energy is projected to reach a share of about 48 % of the overall installed electricity capacity in the ECOWAS region (incl. medium and large hydro) by 2030.

2.10 ECOWAS Regional Bioenergy Strategy

The ECOWAS Regional Bioenergy Strategy aims to increase food and energy security in the ECOWAS Region through sustainable production and utilisation of bioenergy resources. The objectives are to:

- Promote a modern, sustainable and vibrant bioenergy sector in ECOWAS region by creating an enabling environment that can unlock the potential by removing the institutional, legal, financial, social, environmental and capacity gaps and barriers;

- Address the needs and constraints of governments, the private sector and the local communities in using existing resources such as household and agro-processing wastes and residues; and
- Encourage the utilisation of the bioenergy resources to provide sustainable energy access to its population prior to any attempt to export the resources.

2.11 Ghana Shared Growth and Development Agenda I & II (2009/2014)

The Ghana Shared Growth Development Agenda (GSGDA) was prepared by the National Development Planning Commission to provide a consistent set of development policy objectives and strategies to advance a better Ghana agenda. GSGDA I spanned the period 2010 to 2013 and GSGDA II, from 2014 to 2017. Strategic targets with regards to RE were to:

- Increase the proportion of renewable energy, in the national energy supply mix;
- Promote the use and design of energy efficient and renewable energy technologies in public and private buildings;
- Create appropriate fiscal and regulatory framework to encourage renewable energy from mini-hydropower projects; and
- Support the development of small and medium scale hydro power projects on rivers, including the Western Rivers (Ankobra, Tano and Pra), River Oti and the White Volta.

2.12 National Energy Policy (2010)

The objective of the National Energy Policy (NEP) is to create a conducive environment for increased investment in the energy sector. The policy also seeks to put in place a framework for the efficient management of the country's energy resources as well as revenues accruing. The NEP seeks to increase the proportion of renewable energy in the total national energy mix and ensure its efficient production and use. The policy identifies high cost of RETs as one of the major challenges to their adoption. The policy direction is to improve the cost-effectiveness of solar and wind technologies. The policy also seeks to:

- Improve the production and promote the efficient use of biomass in the short term, while increasing regeneration, switching from the use of biomass to alternative sources of energy; and
- Create fiscal and pricing incentives to enhance the development and use of renewable energy.

2.13 Energy Sector Strategy and Development Plan (2010)

The Energy Sector Strategy and Development Plan (ESSDP) emphasises 'increasing the renewable energy supply in national energy mix to 10 % by 2020', echoing a similar statement from the SNEP. The strategies are to:

- Promote the establishment of dedicated woodlots for woodfuel production;
- Promote the production and use of improved cookstoves;
- Support development of biofuels as a transportation fuel as well as job creation initiative by creating appropriate financial and tax incentives;
- Promote the exploitation and use of mini hydro, solar and wind energy resources; and

- Provide tax incentives for the importation of all equipment used in the development of renewable and waste-to-energy projects.

2.14 Renewable Energy Act, 2011 (Act 832)

The Renewable Energy Act (RE Act) aims to create an enabling regulatory environment to attract private sector involvement in the development, management and utilisation of renewable energy in an efficient and environmentally sustainable manner.

The key provisions in the RE Act include:

- Feed-in-Tariff Scheme under which electricity generated from renewable energy sources is offered a guaranteed price;
- Renewable Energy Purchase obligations under which power distribution utilities and bulk electricity consumers must purchase some percentage of their electricity from electricity generated from renewable energy sources;
- Designating biofuel blend as a petroleum product;
- Licensing regime for Commercial Renewable Energy Service Providers, among others, to ensure transparency of operations in the renewable energy industry;
- The establishment of the Renewable Energy Fund to provide incentives for the promotion, development and utilisation of renewable energy resources; and
- Establishment of a Renewable Energy Authority.

The RE Act defines the roles and responsibilities of key institutions to facilitate the implementation of the provisions of the Act.

The following have been achieved under the RE Act:

- FiTs have been developed and gazetted;
- Framework for the RE Fund has been developed;
- Net metering code and renewable energy sub-codes for transmission and distribution systems have been developed;
- Licensing manual developed for RE service providers; and
- Guidelines for the Renewable Energy Purchase Obligation have been drafted.

2.15 Sustainable Energy for All (2012/2016)

The Sustainable Energy for All (SEforALL) initiative is a global initiative to mobilise the UN system, governments, the private sector and civil society to take concrete action toward three critical objectives to be achieved by 2030 namely:

- Ensuring universal access to modern energy services;
- Doubling the global rate of improvement in energy efficiency; and
- Doubling the share of renewable energy in the global energy mix.

The Ghana SEforALL Action Plan developed in 2012 sought to address three key areas:

- Provision of Off-Grid Renewable Energy-Based Power Solutions for Remote Communities;
- Access to Modern Energy for Cooking; and
- Productive Use of Energy.

Ghana's SEforALL Action Plan has been updated into an action agenda which encompasses all energy related actions needed to achieve the three global SEforALL goals.

2.16 Mini-Grid Electrification Policy (2016)

A mini-grid policy was approved in January 2016 to mainstream mini-grid electrification into the National Electrification Scheme. Under the policy, mini-grids are public sector led investment with VRA and ECG/NEDCo responsible for generation and distribution, respectively. Customers on mini-grids would enjoy the same pricing policy as those on the main electricity grid under the rural electrification arrangement.

2.17 Bioenergy Policy (Draft)

The goal of the Bioenergy Policy is to develop and promote the sustainable supply and utilisation of bioenergy to enhance energy security for Ghana whilst ensuring food security. Key objectives of the policy are to:

- Promote increased supply of woodfuel;
- Support sustainable production and supply of woodfuel;
- Promote alternative fuel sources;
- Promote alternative fuel and efficient end-use technologies;
- Facilitate the development of biofuel for local consumption and export;
- Promote market for biofuel and its consumption in the country;
- Promote the utilisation of biomass waste for the generation of electricity and heat; and
- Promote bioenergy research, development and commercialisation.

2.18 Institutional Framework

The Ministry of Energy is the policy making body for RE, with a primary responsibility of ensuring policy development, coordination and implementation as well as supervision of operations and activities of sector institutions in the country. The Renewable Energy Directorate of the Ministry is mandated to perform key functions under section 53 of the RE Act.

The Energy Commission is mandated to:

- Provide technical regulation for the energy sector;
- Advise the Minister responsible for Energy on RE matters;
- Promote public education and awareness on RE technologies;
- Recommend for exemptions from customs, levies and other duties on RE equipment and machinery;
- Promote the local manufacture of components to facilitate the rapid growth of RE sources;
- Promote plans for training and supporting local experts;
- Set targets for the development and utilization of RE sources; and
- Implement the provisions of the RE Act.

The PURC is mandated to approve:

- Rates chargeable for the purchase of electricity from RE by public utilities;
- Charges for grid connection; and
- Rates chargeable for wheeling electricity from RE.

Other institutions that should collaborate with the Energy Commission in the development, promotion, management and utilisation of renewable energy include:

- Ghana Standards Authority;
- Forestry Commission;
- Lands Commission;
- Environmental Protection Agency;
- Ministry of Food and Agriculture;
- Metropolitan, Municipal & District Assemblies;
- National Petroleum Authority;
- Water Resources Commission;
- Ghana Cocoa Board;
- Ministry of Environment, Science, Technology & Innovation; and
- Ghana Revenue Authority.

Other key stakeholders that play a role in RE electricity generation, evacuation, and distribution, include the Volta River Authority (VRA), Independent Power Producers (IPP), Ghana Grid Company Limited (GRIDCo), Electricity Company of Ghana (ECG) and Northern Electricity Distribution Company (NEDCo). The National Petroleum Authority is responsible for pricing biofuel blend in accordance with NPA Act, 2005 (Act 691).

A Renewable Energy Authority is to be established under the RE Act to perform the following functions:

- Oversee the implementation of renewable energy activities in the country;
- Execute renewable energy projects initiated by the State or in which the State has an interest; and
- Manage the assets in the renewable energy sector on behalf of the State.

A summary of the key institutions in Ghana's renewable energy sector and their responsibilities are shown in Table 2.

Table 2: Institutional Framework in the Renewable Energy Sector

MINISTRY/AGENCY	**RESPONSIBILITIES**
Ministry of Energy	Policy formulation, monitoring and evaluation, and implementation of government programmes
Utilities	
• Volta River Authority (VRA)	Power generation
• Bui Power Authority	Power generation
• Independent Power Producers (IPPs)	Power generation
• Ghana Grid Company (GRIDCo)	`Power transmission
• Electricity Company of Ghana (ECG)	Power distribution in Southern Ghana
• Northern Electricity Distribution Company (NEDCo)	Power distribution in Northern Ghana
• Enclave Power Company	Power distribution in parts of Southern Ghana
Bioenergy Sector	
• Bulk Oil Storage and Transportation Company (BOST)	Biofuel transportation and storage
• Oil Marketing Companies (OMCs)	Biofuel distribution

Regulatory agencies	
• Public Utilities Regulatory Commission (PURC)	Approval of electricity tariffs; monitoring of quality of service and consumer protection
• Energy Commission (EC)	Licensing of operators in the renewable energy sector and setting technical standards for their performance, sector planning and policy advice to Minister of Energy
• National Petroleum Authority (NPA)	Determine the proportion and price of biofuel in biofuel blend in accordance with the prescribed petroleum pricing formula
• Ghana Standards Authority	Develop standards for renewable energy technologies and biofuel
• Forestry Commission	Assist in the development and implementation of programmes to sustain woodfuel production and consumption

2.19 Barriers to Renewable Energy Development

The Government of Ghana has demonstrated strong policy commitments towards the development and promotion of renewable energy. However, investment in the renewable energy sector has been limited due to the following:

- Challenging investment climate;
- Uncertainty of available resources;
- Limited technological capacity;
- Insufficient experience in renewable energy development;
- Human and socio-cultural challenges; and
- Information and awareness barriers.

Challenging investment climate: Investment in RE in Ghana faces considerable challenges including macroeconomic situation, perceived risk by the financial sector, financing terms and conditions - high commercial interest rates, limited tenor loans, high inflation, and currency depreciation.

Uncertainty of available resources: While solar resource data can be said to be somewhat adequate and efforts underway to improve on wind and biomass resource data, there remains some gaps in the data for hydro (existing data for most potential sites is outdated) and tidal.

Limited technological capacity: There is limited availability of experienced personnel to undertake technology and feasibility assessments, as well as to construct, operate and manage renewable energy initiatives.

Insufficient experience in renewable energy development: Power sector entities, regulators, financiers, domestic investors, and national technology and service providers appear to have limited knowledge and experience in the development and deployment of RE technologies. For some technologies, there is difficulty in obtaining equipment and spare parts, poor operations and maintenance of facilities, and a lack of infrastructure to support usage.

Human and socio-cultural challenges: People have a tendency to resist changes when new technologies and practices are introduced due to the fear of the unknown.

Information and awareness barriers: Low understanding of RE technologies by the public and media is not doing much in its promotion.

2.20 Mainstreaming Development of RE Sector

The REMP will be mainstreamed into the National Infrastructure Plan (NIP) of the Long Term National Development Plan to ensure political buy-in and adequate financial support for effective implementation.

3 TARGETS AND ACTION PLAN

This section presents targets and plan of action for RE development in Ghana, up to the year 2030. The 13-year targets shall be implemented in three cycles or phases. The scope of the targets and plan of action were based on a thorough stakeholder consultation and analysis of the renewable energy resources and applications and ranked in the order of most promising and scalable options. The section also analyses the challenges facing renewable energy development at the Metropolitan, Municipal and District Assemblies (MMDAs) and proposes strategies to address them.

3.1 Key Assumptions for setting the targets

The targets and action plans are prepared to cover the period 2018 to 2030, and are to be reviewed periodically. The review is necessary in order to maintain focus on the choice of priority in connection with the realization of the effort areas; deal with future developments in renewable energy technology; and be aligned to policy reviews in the energy sector. Specific targets may be revised upwards or downwards during the review period. The review process may include appendices describing possible necessary changes in the individual effort areas, the reasons for the changes and what corrective actions should be taken to ensure that Ghana's efforts within renewable energy as a growth area can be maintained continuously and reflected in this masterplan.

Following the Lomé African Ministers Conference in 2017, large hydropower installations have been adopted and included in the renewable energy mix. As a result, the renewable energy capacity forecast over the next 13 years included the three main large hydropower installations (Akosombo, Kpong and Bui) as part of the 2015 renewable energy baseline. The year-on-year target over the baseline averaged approximately 10 % over the next 13 years, thus starting from 2018 through to 2030.

The ongoing review of the RE Act 2011 (Act 832), would include amendment of the hydropower capacity to now include large hydropower installations in line with the Lomé Declaration, 2017. The targets set forth in the REMP would be reviewed over the three (3) implementation cycles to reflect the overall growth trajectory and performance of the economy.

The targets concluded in the REMP also took into account other key assumptions and factors such as:

1. The 40-year long term National Infrastructure Plan of the NDPC's projection for electricity demand for accelerated development, which estimated approximately 22,000 MW of installed capacity by 2030;
2. Targets put forth in the Strategic National Energy Plan (SNEP) 2016-2030
3. Targets put forth by the regional bloc and Ghana's SEforALL Agenda for 2030;
4. The industrialization agenda of government and other new growth poles in the economy; and
5. Environmental and social-cultural obligations.

3.2 Targets and Action Plan for Solar Energy

3.2.1 Resource

Ghana's geographical location gives it a good exposure to solar radiation which is ideal for both electricity and thermal energy applications. The country 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, with the highest occurring in the northern belt (see Appendix 1A).

3.2.2 Opportunities

Several opportunities exist to develop solar energy in Ghana and includes the following:

- increase generation capacity – through utility scale projects, mini-grids, standalone applications for street lighting, traffic controls, aviation signals, telecommunication, light electronic devices, etc.;
- demand side management (net-metering) – integration of solar PV and solar water heaters into existing and new buildings, and captive power due to increasing cost of conventional power;
- applications in agriculture – irrigation and crop drying;
- assembling / manufacturing – principally in the areas of solar PV module and balance of systems, including inverters, batteries, solar water heaters, etc. to service both the domestic and the fast-growing ECOWAS market;
- increase research, development, demonstration and commercialisation of solar energy technologies;
- opportunities exist to develop a market and production hub for electric vehicles; and
- Solar Water Heaters have the potential to contribute 2GWh of savings from energy demand (ECREEE, 2015).

3.2.3 Description of interventions

Interventions considered under solar are water heaters, lanterns, crop dryers, utility scale systems, solar home systems (lanterns and rooftop standalone / net metering), street / community lighting, traffic signals and irrigation / water supply systems.

3.2.4 Targets

Targets for the various solar energy technologies or interventions are shown in Table 3.

Table 3: Targets for solar technologies

TECHNOLOGY / INTERVENTION	UNIT	REFERENCE (2015)	2020	2025	2030
1. Solar Water Heaters	Units	4700	20,000	70,000	135,000
2. Solar Lanterns	Units	72,000	200,000	500,000	1,000,000
3. Utility scale Solar	MW	22.5	293	495	873
4. Solar Crop Dryers	Units	70	150	400	700
5. Distributed Solar PV (net metering)	MW	1.7	20	120	200
6. Standalone Solar PV Systems	MW	2.5	4.5	8	14
7. Street/Community lighting	MW	5	7	11	25
8. Solar Traffic signals	%*	14	25	40	60
9. Solar Irrigation	ha	150	4,400	26,400	48,800

*Percentage of total installed traffic signals. Targets are cumulative

3.2.5 Actions

Solar Water Heaters (SWHs)

Challenges in mass usage of Solar Water Heaters

The main challenges that have been encountered in the mass adoption and usage of solar water heaters in the country are outlined below:

- High cost of maintenance because of high level of chlorine on copper pipes in the SWH;
- Low water pressure and irregular supply often renders many systems non-functional;
- High import duty on solar water heaters;
- High initial cost of systems in the market;
- Low cost alternatives for heating water; and
- Low patronage or use of hot water in hot weather.

Strategies to promote Solar Water Heaters

To promote the use of solar water heaters, the following strategies are proposed.

- Create awareness on the benefits of SWHs, targeting households, real estate developers, hotels and commercial facilities that require hot water;
- Develop regulation to encourage existing commercial properties such as hotels to install SWHs;
- Promote hybrid (electric-solar) water heating systems;
- Provide tax incentives to support local assembly / manufacturing;
- Incorporate SWHs in the National Building Code; and
- Remove import duties on SWH components and impose higher import duties on electric water heaters.

Solar lanterns

Challenges in adoption of Solar Lanterns

The main challenges in the adoption of solar lanterns has been:

- High import duty and VAT/NHIL;
- Relatively higher cost, especially for rural communities; and
- Influx of inferior products.

Strategies to promote Solar Lanterns

The off-grid market in Ghana has dwindled due to the high electrification rate, however, solar lanterns remain a priority intervention for isolated areas where the grid would not reach in the foreseeable future. The key strategy is to make Ghana the manufacturing hub for solar lanterns in the sub-region. It is therefore proposed that at least one company in the free-zones enclave should be established by 2018 to manufacture solar lanterns. This would be expected to create jobs and develop local skills.

Key Actions to create enabling environment are as follows:

- Ensure compliance of local content and local participation for solar lantern procurements;
- Provide incentives for local assembly/manufacturing; and
- Strengthen relevant regulatory institutions to implement quality compliance.

Solar Crop Dryers

Challenges in adoption of solar crop dryers

Whereas solar drying is an exciting concept for both minimising post-harvest losses and ensuring quality of dried produce, its use has been low in Ghana principally because of:

- High capital cost;
- Little knowledge of improvements in quality of some special crops after drying in solar dryers (e.g. cocoa beans);
- Low awareness among smallholder and commercial farmers;
- Lack of quality requirements of dried foods / produce; and
- Cheaper alternative drying methods.

Strategies to promote Solar Crop Dryers

- MOFA/MoEn to develop policies to adopt and promote solar crop dryers for crop and food processing;
- Establish quality requirements of dried farm produce on health grounds;
- Create awareness of the financial, economic and health benefits of using solar crop dryers;
- Organise training for farmers, buyers, exporters, and cooperatives on sustainable models for financing and operating solar dryers;
- Support research and development of models using locally available materials to reduce cost of installations;
- Support research into use of solar crop dryers for non-traditional and cash crops such as cocoa, coffee, pepper, fruits, cassava, etc.; and
- Indigenise solar drying technology.

Utility Scale Solar

Challenges in adoption of utility scale solar power projects

Based on provisional licences granted by the Energy Commission for solar utility scale projects, it appears investors perceive solar utility projects as the least challenging among the utility scale projects. However, the industry faces a set of unique challenges with regards to funding and grid integration. These challenges include:

- Variable nature of solar power;
- High cost of solar power;
- High cost of capital and limited access to long term financing;
- Inadequate reserve margin limits integration of larger utility scale solar plant; and
- Land requirement (2.5 to 4 acres/MWp) is significant and could compete with other land use options.

Strategies to promote utility scale solar power systems

In view of the above, the following strategies will be used to promote the utility scale solar market:

- Mobilize funds domestically (e.g., bonds, shares, etc.) to finance major RE projects;
- Provide government on-lending facilities to RE investments;
- Institutionalise competitive procurement to achieve price reduction in tariff;
- Upgrade the National Interconnected Transmission System to make the grid robust for RET integration (system control centre, weather forecasting systems, etc.);
- Drive developments onto lands that does not compete with other uses;
- Encourage contribution of land as equity in RET projects;
- Institute reward schemes for outstanding RE projects/initiatives;
- Promote mixed use of land for solar power and agriculture; and
- Incorporate land requirement for renewable energy projects in the national spatial planning.

Solar Home Systems (standalone and grid interactive)

Challenges in adoption of SHS

The principal challenges encountered with the SHS market are outlined below.

- High cost of inverters and batteries, making systems expensive.
- Households with seasonal income have difficulty making payment for fee-for-service installations; and
- Difficulty in finding the perfect business model to implement SHS in rural communities.

Strategies to promote SHS

Solar home systems already receive a lot of government support. Government sees this sector as a strategic sector in which Ghana could develop competitive advantage, and provide manufacturing service to its neighbours. To further promote the sector, the following strategies will be adopted.

- Continue providing incentives through the energy levy;
- Intensify awareness creation and capacity development for stakeholders;
- Continue to develop and implement innovative market-driven policy instruments, e.g. matching grants, subsidies, revenue generation models, etc.;
- Support the implementation of the 200,000 rooftop solar programme;
- Support the private sector to facilitate the establishment and growth of a local solar components manufacturing industry (details are provided under enabling environment in Chapter Six);
- Encourage local assembling/manufacturers to supply solar systems and components for GoG funded-projects in line with the Local Content and Local Participation Policy; and
- Remove import duty and taxes on raw materials and components for the production of RE systems.

Solar Street / Public Lighting

Challenges in implementing solar street / community lighting schemes

- High capital cost;

- Incorrect sizing of components that make up a complete working solar energy generation, storage and supply system;
- Poor maintenance of systems by MMDAs;
- Theft and vandalism; and
- Damage through vehicular accidents.

Strategies to promote solar streetlight / public lighting systems

- Increase public sector investment in solar street and community lighting systems for off-grid rural electrification;
- Enforce the implementation of insurance cover for solar streetlights that are damaged through accidents;
- Promote local assembly and manufacture;
- Encourage CSR support for off-grid installations and maintenance; and
- Build capacities of utilities, MMDAs and host communities in the maintenance of RE installations.

Solar Traffic signals

Challenges in implementing solar traffic signals

- High capital cost;
- Incorrect sizing of components that make up a complete working solar energy generation, storage and supply system;
- Theft and vandalism; and
- Damage through vehicular accidents.

Strategies to promote solar traffic signals

The following strategies would be adopted:

- Collaborate with Ministry of Roads and Highways to ensure that all new traffic signals are solar powered;
- Dedicate a portion of the road fund to support financing of solar traffic signals;
- Enforce the implementation of insurance cover for solar traffic signals;
- Collaborate with the Ministry of Road and Highways to ensure adherence to technical standards;
- Support local production of components; and
- Introduce anti-theft and anti-temper systems including applications for monitoring and tracking.

Solar Irrigation Systems

Solar PV water pumping is the right choice for water pumping from a bore-hole or a river for irrigation purposes in remote areas where utility power is unavailable or unreliable. It would help to transition small farmers to affordable and renewable technologies that are easy to maintain, use and sell on local markets. Adopting solar powered irrigation pumps instead of diesel on small farms would cut carbon dioxide emissions. Solar irrigation systems are fairly easy to operate with very minimal training. Modern systems have control panels that relay real time information to supervisors/technicians and help with monitoring and the provision of early support.

Challenges in adoption of solar irrigation systems

The main challenges encountered so far with a few piloted systems have been:

- High capital cost of systems, even with subsidy, making solar irrigation systems unattractive to small-scale farmers;
- Poor security, sometimes resulting in theft of systems due to remoteness of installations;
- Pump spare parts and service providers are not readily available; and
- Low public awareness of the technology, its availability in Ghana and benefits.

Strategies to promote solar irrigation systems

- Partner with and incentivise financial institutions to develop cost-effective financing packages to promote solar irrigation;
- Intensify awareness creation, especially for medium to large-scale famers who can afford systems;
- Support subsistence farmers to expand farms and provide ready market for farm produce;
- Undertake studies to ascertain the economic impacts of solar irrigation;
- Build capacities of utilities, MMDAs and farmers in the installation, operations and maintenance of solar irrigation facilities; and
- Introduce anti-theft and anti-temper systems including applications for monitoring and tracking.

3.3 Targets and Action Plan for Wind Energy

3.3.1 Resource

Wind resource in Ghana is highest along the coast east of the Greenwich Meridian. Average wind speeds measured at sixteen (16) locations in the country, at 60 m and 80 m heights, range between 4.0 m/s and 7.0 m/s (See Appendix 1B). Appendix 1C is a map of Ghana showing wind speeds in the country. With current technology, this level of wind speed is adequate to generate electricity and for direct use in water pumping.

3.3.2 Opportunities

Several opportunities exist to develop wind energy schemes in Ghana:

- Undertake wind measurements in other areas with potential to establish the true size of the market;
- Increase generation capacity – like solar, utility scale wind projects and standalone systems can be relied upon to increase generation capacity;
- Applications in irrigation – poldaw wind pumps requiring low operating wind speeds can be used for irrigation and community water provision, particularly in off-grid applications;
- scale-up manufacturing – principally in the areas of standalone wind turbines; and

- increase research, development, demonstration and commercialisation of wind energy technologies.

3.3.3 Description of interventions

Interventions considered under wind energy are water pumping and / or irrigation, standalone and utility scale grid connected wind power systems.

3.3.4 Targets

Targets for wind energy technologies are summarised in Table 4.

Table 4: Targets for wind energy technologies

TECHNOLOGY / INTERVENTION	UNITS	REFERENCE (2015)	2020	2025	2030
1. Wind Irrigation/water pumping	Units	<20	35	65	100
2. Standalone systems (including net-metered)	MW	0.01	0.1	1	2
3. Utility scale	MW	0	125	400	650

3.3.5 Actions

Wind Irrigation Systems

Challenges in implementing wind irrigation systems

The general challenges include:

- Absence of niche market for farm produce that can commercially be produced with water pumping systems;
- High capital costs;
- Low efficiency;
- Low operation and maintenance skill;
- Non-availability of spare parts; and
- Lack of research and inadequate data on technical and economic performance.

Strategies to promote wind irrigation systems are outlined below:

- Review the status of the existing installations;
- Conduct studies to identify potential areas and niche markets for implementation;
- Train manpower in local manufacturing, installations, operation and maintenance; and
- Promote research and development on the technology.

Standalone wind systems

Challenges in implementing standalone wind systems

- High capital cost;
- Variable wind speed, requiring stabilizer;

- Limited local expertise;
- Moving parts require regular maintenance; and
- Height risks for maintenance personnel.

Strategies to promote standalone wind systems

- Train manpower in design, fabrication, repair, installations, operations and maintenance of small scale wind turbines; and
- Promote research and development of small wind turbines;
- Encourage local production/manufacture; and
- Build capacities of MMDAs and farmers in the installation, operations and maintenance of solar irrigation facilities.

Utility scale wind

Challenges in implementing utility scale wind power projects

The challenges are as follows:

- Requires huge capital investments;
- High cost of electricity generated by wind power systems;
- Inadequate cranes available locally to lift large wind turbines, requiring importation of specialised cranes;
- Road network constraints to transport long equipment /blades of wind turbine;
- Distance of potential sites to existing sub-stations is long, requiring more capital investment into the grid network; and
- Competing use of potential wind sites for fishing, salt production, eco-tourism, hospitality and entertainment.

Strategies to promote utility scale wind

The proposed strategies are as follows:

- Continue with the wind resource assessment in other potential sites;
- Explore and implement innovative de-risking instruments for project developers and off-takers;
- Encourage take and pay PPAs for RET projects;
- Promote installation of smaller systems that local infrastructure can support;
- Identify and encourage high businesses along the coastal areas to go into wind-power captive generation;
- Demarcate and secure potential wind sites for project development;
- Explore capacity building opportunities for skills development;
- Promote the leasing of land for utility scale projects, and discourage outright sale;
- Encourage the use of land as equity in wind power investments;
- Institute reward schemes for outstanding RE projects/initiatives; and
- Ensure that utility scale developers include Corporate Social Responsibility plans in their operation.

3.4 Targets and Action Plan for Hydropower

3.4.1 Resource

Hydro has been a dominant power source in Ghana, providing cheap power for industrial development in the post-independence era. Currently, all of Ghana's large hydro resources have been exploited. Each of the remaining sites have potential capacity below 100 MW. Future electricity generation potential from hydro is estimated at about 800 MW. Ghana's Renewable Energy Act passed in 2011 considers hydro projects that generate up to 100 MW for Feed-in-Tariffs (FiTs).

3.4.2 Opportunities

Opportunities for small and medium hydropower development includes the following:

- increase generation capacity using less variable hydro power;
- export power to neighbouring countries;
- develop irrigation projects and water supply schemes as co-benefits;
- develop river transportation as co-benefit
- create jobs; and
- build capacity in small and medium hydro project management.

3.4.3 Description of interventions

Interventions considered here relate to the development of hydropower systems for power generation and irrigation. Government has plans to develop some of the remaining hydro potentials. These include Pwalugu (50 MW), Juale (90 MW), Daboya (40 MW), Jambito (55 MW), Hemang (60 MW), Tsatsadu (60 kW), and numerous small hydro power plants.

3.4.4 Targets

Targets for hydropower are shown in Table 5.

Table 5: Targets for hydropower

TECHNOLOGY / INTERVENTION	UNITS	REFERENCE (2015)	2020	2025	2030
Small / Medium Hydropower	MW	-	0.03	108	340

3.4.5 Actions

Challenges in implementing hydropower schemes

- Hydropower development may flood farmlands and communities;
- Inadequate framework and model for the promotion and development of hydropower;
- Medium sized hydro projects have longer lead time and therefore not very attractive to investors;

- Deforestation along water bodies is causing drying up of rivers and affecting hydro potential over time;
- Impact of illegal small-scale mining (galamsey) is fast changing the characteristics of the river bodies and reducing the potential in the Western, Central and Eastern parts of the country; and
- Unit cost of power from remaining hydro sites is high.

Strategies to promote hydropower

- Fast track and deploy innovative financing instruments (e.g. bonds, shares, etc.) to develop hydropower projects for peaking (flexible capacity);
- Develop a clear framework / model and legislation for medium/ small hydropower development;
- Provide incentives including GoG funded feasibility studies, public private partnerships arrangements (BOOT or BOT) to accelerate project development;
- Collaborate with relevant stakeholders to create buffer zones and undertake reforestation along river bodies, and prevent mining, farming and logging activities;
- Encourage and support the development of all new hydropower projects as hybrids and multipurpose (fisheries, transportation, irrigation, etc.); and
- Build capacities of utilities, MMDAs and R&D institutions in the installation, operations and maintenance of hydro facilities; and
- Explore the opportunity of desilting reservoirs and other river bodies and make sand available for the construction industry.

3.5 Targets and Action Plan for Wave/Tidal Energy

3.5.1 Resource

Preliminary assessment has shown that the waves in the sea east of the meridian are strong, indicating strong potential for wave energy development.

3.5.2 Opportunities

There is opportunity to develop wave resource with higher capacity factor than wind and solar, which would complement generation capacity.

3.5.3 Description of interventions

Wave energy will be harnessed from viable sites for power generation. Wave/tidal energy or wave power is essentially power drawn from waves. When wind blows across the sea surface, it transfers the energy to the waves. The energy output is measured by wave/tidal speed, wave height, wavelength and water density.

3.5.4 Targets

Targets for wave/tidal energy is shown in Table 6.

Table 6: Targets for wave energy

TECHNOLOGY / INTERVENTION	UNITS	REFERENCE (2015)	2020	2025	2030
Wave Energy	MW	-	10	25	115

3.5.5 Actions

Challenges

- Wave energy technology is still evolving, hence investment and maintenance costs remain high.

Strategies to promote wave/tidal power

- Undertake studies to identify key constraints facing the development of wave/tidal energy;
- Pilot and scale up wave/tidal energy development;
- Provide incentives for investors to manage high start-up costs and long lead time;
- Install robust and safe technologies;
- Support the development of legislation to regulate the wave/tidal space;
- Ensure that proper environmental and social impact assessments are carried out;
- Undertake resource assessment, research and development; and
- Build capacities of relevant institutions in the installation, operations and maintenance of wave/tidal facilities.

3.6 Targets and Action Plan for Solid Biomass

3.6.1 Resource

At present, solid biomass contributes approximately 40 % of Ghana's primary energy supply. Besides its use as fuelwood and charcoal for cooking and heating, biomass can also be converted into electricity and transport fuel. Ghana is well endowed with abundant biomass resources. Available biomass resources include dedicated plantations, wood waste, forest cuttings, crop residues, etc. A study conducted by the Ministry of Energy under GEDAP (see Appendix 1D), has shown that there is potential for electricity generation from solid biomass waste (sawmill and agro-residues) of between 600 kWp and 5 MWp per site, in more than 15 wood and agro-processing sites in Ghana.

3.6.2 Opportunities

- increase generation capacity using less variable biomass conversion technologies;
- captive power for industrial use;
- reduce deforestation by using dedicated woodlots;
- diversify cooking fuel mix;
- create jobs;
- build capacity in solid biomass technologies;
- develop knowledge through research and development of biomass technologies; and
- empower women businesses / entrepreneurs.

3.6.3 Description of interventions

This plan focuses on solid biomass technologies for heat and power generation, and production of solid fuels, such as sustainable charcoal, pellets and briquettes. Proposed interventions will also cover promotion of energy efficient conversion (improved kilns, pelleting & briquetting equipment) and end-use devices (improved cookstoves, efficient boilers, etc.) and sustainable feedstock cultivation.

3.6.4 Targets

Targets for the solid biomass technologies are shown in Table 7.

Table 7: Targets for solid biomass technologies

TECHNOLOGY / INTERVENTION	UNITS	REFERENCE (2015)	2020	2025	2030
1. Utility-scale power generation	MWe	<10	70	175	300
2. Charcoal (export)	1000 t	190	250	350	428
3. Charcoal (local demand)	1000 t	1,551	1,645	1,739	1,840
4. Improved Cookstove (Domestic)	Million Units	0.80	1.3	1.8	3
5. Improved Cookstove (Institutional/commercial)	Thousand Units	1.8	3	10	18
6. Woodlot Cultivation	1000 ha	190	250	350	428
7. Briquetting/Pelleting	1000 t	19.7	40	65	100

3.6.5 Actions

Utility scale power generation

Challenges in implementing utility scale biomass power generation

- High capital cost;
- Long lead time for feedstock cultivation;
- Difficulty in land acquisition for plantation based projects;
- Price and availability risk of feedstock; and
- Inadequate research available.

Strategies to promote utility scale biomass electricity generation projects

- Collaborate with relevant stakeholders to secure land for woodlot plantations;
- Implement projects in modular units to address capital cost challenges; and
- Strengthen research and development institutions to undertake R&D along the value chain; and
- Build capacities of private sector, utilities and MMDAs in the installation, operations and maintenance of biomass fired electricity generation facilities.

Charcoal Production (local consumption and export)

Challenges in charcoal production

- Inefficient carbonisation technologies;
- Dwindling and unsustainable feedstocks;
- Productions centres are far from the feedstock – transportation is a bottleneck that makes it expensive to transfer feedstock to efficient kilns; and
- High cost of charcoal production kilns.

Strategies to promote improvements in charcoal production

- Develop mobile kiln technologies and promote artisanal interest in improved kiln development;
- Organise training in design, construction, operation and maintenance; and
- Promote sustainable woodlot plantations.

Woodlot Cultivation

Challenges in woodlot cultivation

- Land requirements, cost and tenure systems;
- High cost of seedlings;
- Lack of incentive for the planting of woodlots;
- Difficulty in getting water during the dry season, especially in arid areas, makes woodlots unattractive;
- Poor financing opportunities;
- Low knowledge of the benefits of woodlots; and
- Long lead time for feedstock cultivation.

Strategies to promote woodlot cultivation

- Collaborate with relevant stakeholders to implement a national programme for woodlot cultivation;
- Collaborate with Ministry of Lands and Natural Resources to make seedlings widely accessible and affordable for afforestation and reforestation;
- Provide adequate incentives for own-plantation based biomass power plants;
- Support MMDAs to earmark land banks for afforestation and reforestation;
- Promote fast-growing, water resistant and multi-purpose species (power generation, poles for distribution networking, etc.); and
- Facilitate establishment of woodlot clubs in basic, secondary and tertiary schools to enhance the programme.

Briquetting and Pelleting

Challenges in briquetting and pelleting

- Low awareness about the use of pellets and briquettes, hence a low demand as an alternative fuel;
- Carbonised briquettes are not readily available for purchase;

- Cookstoves for pellets and briquettes not available on the market;
- High cost of electricity reduces the net energy derived from pellets and briquettes; and
- High capital cost for initial setup and maintenance.

Strategies to promote briquetting and pelleting

- Promote the use of pellets/briquettes and alternative fuels such as LPG, NG, etc for cooking, use in industries (industrial boilers) and other commercial interventions such as bakeries, gasifiers, etc.;
- Encourage local production/assembly of stoves that use pellets and briquettes;
- Remove import duty and taxes on equipment for production and local use of pellets/briquettes; and
- Promote an export market.

Energy Efficient (Improved) Domestic cookstoves

Challenges in adoption of improved domestic cookstoves

- Low awareness of improved cookstoves;
- Lack of standards and labelling for the local cookstove industry;
- Local manufacture relies more on manual techniques, with some semi-automation; and
- High cost of improved cookstoves.

Strategies to promote domestic cookstoves

- Provide Business Development Supports (BDS) to artisans for improved cookstove manufacture;
- Fast-track the development of standards and labelling which are currently under preparation;
- Explore the automation of cook stove production processes;
- Raise awareness among households; and
- Promote research and development if improved local stoves.

Energy Efficient (Improved) Institutional Cookstoves

Challenges in implementing institutional Cookstoves

- High cost of improved institutional stoves;
- Poor designs with excessive heat generation or smoke emission;
- Some users have issue with permanent position of the stove;
- Low level of skilled personnel; and
- Regular maintenance requirements.

Strategies to promote Institutional cookstoves

- Provide subsidies for construction of improved cookstoves in public institutions such as hospitals, schools and prisons;

- Provide support for research and development into improved designs that provides easy mobility for the units;
- Build capacity of local artisans to assemble/manufacture and maintain the units;
- Facilitate partnerships between local and foreign stove manufacturers and research institutions to improve the quality of stoves on the local market; and
- Introduce innovative financing schemes through collaboration with financial institutions.

3.7 Targets and Action Plan for Mini-grids

3.7.1 Resource

Mini-grid development would be based mainly on available renewable energy resources such as solar, wind, biomass, biofuels, hydro, etc., in the target communities. Mini-grids in this context may also refer to micro-grids in some literature, as several of them would be in the order of tens of kW.

3.7.2 Opportunities

- Contribute towards universal access to electricity in remote and island communities;
- Improve socio-economic condition of remote and island households;
- Provide access to cheaper and reliable power supply;
- Integration of mini-grids into national grid in line with NES and the mini-grid policy;
- Promote productive uses of electricity;
- Development of mini-grids enhanced; and
- Distributed generation using local resources.

3.7.3 Description of interventions

Islands and lakeside communities with population 500 and above which cannot be connected to the national grid for economic reasons, would be electrified using renewable based mini-grid systems. Smaller communities elsewhere that have not been connected to the grid would also benefit from mini-grids.

3.7.4 Targets

Targets for mini-grids are shown in Table 8.

Table 8: Mini-grid targets

Year	Reference / Target (Units)
Reference (2015)	13
2020	80
2025	200
2030	300

3.7.5 Actions

Challenges in adoption of mini-grids

- Inadequate local technical expertise;

- Higher cost of generation, distribution and operation;
- Resource availability limitations in some locations;
- Access to community, especially with equipment, using existing modes of transport is difficult due to poor geographical accessibility;
- High illiteracy rate could influence adoption; and
- Potential to out crowd of stand-alone RE businesses.

Strategies to promote mini-grids

- Create special funding envelope (GoG budgets, loans, grants, rural electrification levy, etc.) dedicated for mini-grid development;
- Promote energy efficiency (EE), demand side management, and productive use interventions in all mini-grid projects;
- Support integration of existing stand-alone systems into mini-grids under net metering scheme;
- Ensure proper sizing of mini-grids (with approximately 500 W per capita); and
- Provide water transportation facilities for mini-grid development on islands and lakeside communities.

3.8 Targets and Action Plan for Waste-to-Energy Technologies

3.8.1 Resource

The residential, agriculture, manufacturing, and industrial sectors of Ghana generate a lot of organic and inorganic waste which could be converted into energy. It is estimated that 3 million tonnes of municipal waste are generated or collected per annum. The potential energy in waste generated in the agriculture sector (crop residue and livestock manure) is estimated to be about 90 PJ per annum. The wood industry (timber, saw mills, etc.) generates about 200,000 tonnes of waste per annum (Kemausuor *et al*., 2014). A crop residue density map is shown in Appendix 1E.

3.8.2 Opportunities

Opportunities to develop waste-to-energy technologies are presented below:

- Increase generation capacity using less variable waste-to-energy conversion technologies;
- Captive power for industrial use;
- Potential to generate a local market for organic manure/compost;
- Production of briquettes and pellets for domestic and export market;
- Heat generation for industrial use;
- Create jobs; and
- Increase research, development, demonstration and commercialisation of waste-to-energy technologies.

3.8.3 Description of interventions

Interventions under waste-to-energy include technologies for heat and power using domestic and industrial solid and liquid wastes as well as agro and forest residues.

3.8.4 Targets

Targets for waste-to-energy technologies are shown in Table 9.

Table 9: Targets for waste-to-energy technologies

TECHNOLOGY / INTERVENTION		UNITS	REFERENCE (2015)	2020	2025	2030
1.Utility scale power	MSW + Biogas	MW	1	2	5	10
2.Biogas	Agricultural/Industrial organic waste	Units	10	30	100	200
	Institutional	Units	< 100	180	320	500
	Domestic	Units	< 50	80	130	200
3.Landfill	Municipal Waste	Units	0	1.5	10	20

3.8.5 Actions

Municipal Waste

Challenges in adoption of Municipal Waste to Energy Projects

- Negative attitudes of the general public towards waste handling;
- Non-segregation of waste at source;
- Lack of proper understanding of the composition of waste and hence appropriate technology and cost;
- Lack of adequate infrastructure such as waste collection and transfer points; and
- Inadequate incentives for private sector investment.

Strategies to improve Municipal Waste to Energy Projects

- Collaborate with relevant sector Ministry to formulate and enforce regulations on waste management (e.g. tipping fee, sorting at source, transportation, etc.);
- Increase public awareness on proper waste management and attitudinal change towards waste sorting, collection and disposal;
- Provide incentives (training, transfer points, financial supports, etc.) for private sector to invest in waste transfer infrastructure to energy projects;
- Enforce existing environmental instruments - e.g., polluter-pays principle; and
- Implement waste-to-energy under PPP arrangements.
- Collaborate with relevant stakeholders (e.g. Health, Education) to promote efficient incineration in public and private facilities which incorporate heat exchangers in incinerators for hot water production and other heat application; and
- Promote use of biogas for institutional cooking.

Biogas from Agricultural / Industrial Organic Waste

Challenges in adoption of agro and industrial waste biogas systems

- Sparse nature of agro-waste with its cost implications on collection and processing; and
- High installation costs compared to conventional waste management systems;
- Little awareness on environmental benefits; and

- Inadequate data on quantities of biogas units and their current state in Ghana.

Strategies to promote agricultural / industrial waste biogas systems

- Collaborate with relevant stakeholders to enforce and promote waste sorting, treatment and material recovery, i.e. waste reduction, reuse and recycling;
- Collaborate with relevant stakeholders to implement environmental instruments for waste management – e.g., polluter-pays principle;
- Collaborate with relevant institutions to integrate biogas technologies into waste management of agro-industries;
- Provide financial incentives to promote biogas as a waste management option to address sanitation and climate change related issues; and
- Build capacities of private sector in the installation, operations and maintenance of biogas facilities.

Domestic and institutional biogas

Challenges in domestic and institutional biogas development

- Low level of awareness on the benefits;
- Lack of regulations and standards for service providers;
- Poor operation and maintenance culture rendering large number of installations non-operational;
- Non-availability of spare parts on the local market for the maintenance of biogas installations; and
- Inadequate data on quantities of biogas units and their current state in Ghana.

Strategies to promote domestic and institutional biogas

- Promote biogas systems as waste treatment facility with energy spill over;
- Increase awareness on the benefits of domestic and institutional biogas systems;
- Develop and enforce regulations and standards;
- Collaborate with relevant institutions to promote biogas systems for management of domestic and industrial waste;
- Promote biogas systems in estates and commercial facilities;
- Build capacity of local artisans in design, construction, operation and maintenance of biogas systems; and
- Provide incentives to promote prefabricated digesters which have relatively lower cost and are quicker to install and maintain.

Landfill

Challenges in Landfill Technology

- Not-in-my-backyard (NIMBY) syndrome. Residential areas refusal to have landfills constructed in their communities due to bad odour, pest and other related issues;
- Difficulty in acquiring land for landfills;
- Waste received at landfills are not segregated;
- Lack of incentives to attract private sector investments;
- Weak enforcement of regulations on waste management by local authorities; and
- High cost of investment for power generation.

Strategies to promote Landfill Technology

- Collaborate with relevant institutions such as EPA and MMDAs to formulate and enforce regulations on waste management (e.g. tipping fee, sorting at source, transportation, development of engineered landfill sites, etc.);
- Provide incentives and support Public-Private-Partnerships between district assemblies and private entities in the development of landfill gas projects; and
- Encourage railways transportation of waste from waste transfer points to waste-to-energy sites.

3.9 Targets and Action Plan for Biofuels

3.9.1 Resource

More than 60 % of Ghana's agricultural lands are still uncultivated. Portion of the uncultivated lands should be earmarked to produce biofuel feedstock that address the food-energy nexus. Multi-purpose crops such as oil palm, coconut, cassava, sugar cane, etc. could be promoted on a large scale to support food and biofuel industry.

The following immediate benefits can be derived:

- reduced reliance on fossil fuels; and
- job creation prospect through local content; and
- support industrialisation and foreign earnings through export.

3.9.2 Description of interventions

Production of liquid biofuels for blending and export.

3.9.3 Targets

Targets for biofuels development are shown in Table 10.

Table 10: Targets for biofuels development

Year	Reference / Target (tonnes)
Reference (2015)	0
2020	100

2025	5,000
2030	20,000

Actions

Challenges

- Lack of clear policy on biofuel
- The perception of biofuels competing with food production;
- Land tenure system makes it difficult for investors to have access to large parcels of land at specific locations for investments; and
- Unavailability of logistics for feedstock sourcing.

Strategies to promote biofuel

- Promote the use of multipurpose crops and trees for biofuel production, e.g. oil palm, sunflower, neem tree, etc.;
- Develop clear procedures and regulations;
- Support relevant institutions to research into second and third generation biofuels;
- Collaborate with relevant institutions (MMDAs, NDPC, MLNR, CSIR) to prepare land use plans;
- Promote the use of SVOs and PPOs for agricultural machinery; and
- Create market for unrefined biodiesel, which is cost competitive with ordinary diesel, for tractors and other mechanised agricultural equipment.

3.10 Others

Other possible technologies that could be explored include concentrated solar power (CSP) and geothermal energy.

A study conducted under Solar and Wind Energy Resource Assessment (SWERA) in 2002 indicated that direct solar radiation is limited to the upper western part of the country. Further studies are required to fully establish the resource potential for CSP application. See Appendix 1F.

At present, Ghana is not known to have any geothermal resources. Following Ghana's recent oil exploration activities, it may be possible to discover some geothermal resource in the future.

3.11 Decentralisation of RE development

Resource

All MMDAs are endowed with one or the other renewable energy resources that remain untapped for socio-economic development. At the national level, significant advances have been made in the development and promotion of renewable energy, however not much focus has been placed in decentralizing the planning and development process. To ensure the sustainability of RE development it is important to identify the contraints at the MMDAs levels and propose specifics strategies that will promote RE development at the local government level.

Challenges

The following challenges have been identified at the MMDA levels:

1. Limited awareness on renewable energy potential and opportunities at the local level;
2. Inadequate human and institutional capacity;
3. Limited financing for RET deployment;
4. No clear initiatives to integrate renewable energy into development plans;
5. Limited incentives to attract investment particularly for rural districts;
6. Inadequate modular RE technology to support small scale projects at the rural level;

Strategies

In order to address the above challenges, the following strategies have been outlined:

1. Map out RE resource potentials of the various MMDAs and promote them for investment;
2. Prioritize MMDAs based on their RE potential and willingness to actively participate in the promotion and development of these resources;
3. Incorporate RE opportunities into district development plans;
4. Create energy desk with focus on renewable energy at the MMDAs to facilitate and enhance RE planning and implementation;
5. Promote human and institutional capacity building in RE at the MMDA levels;
6. Identify and promote incentives that will attract RE investments in the districts;
7. Support awareness creation of the opportunities and benefits through investment fora;
8. Government and donor funded renewable energy projects should make adequate budgetary provisions to support the RE decentralization drive.
9. Identify, develop and support the promotion of indigenous RET innovations to address the peculiar needs of MMDAs.

4 IMPLEMENTATION ARRANGEMENTS

The implementation of the REMP requires a concerted effort by all stakeholders including public and private sector actors, academia and research institutions, civil society organisations and development partners.

To ensure effective implementation of the plan, MMDAs should incorporate the strategies into their overall development plans. Furthermore, investments would be made to map out renewable energy resources at the MMDAs and promoted in accordance with plan.

4.1 Implementation schedule

The REMP will be implemented in three (3) cycles with the first cycle, or a 'transition phase', running from 2018 to 2020. The subsequent cycles will run from 2021 to 2025, and 2026 to 2030 (see Table 11). Each cycle will be reviewed in the last year of implementation and the outcome used to improve the implementation of the next cycle. Electricity generation capacity from renewables is projected to reach 2567 MW by 2030. Of this total, utility scale generation comprises 2308 MW (or 90 %), with the remaining 253 MW (comprising 10 %) coming from distributed generation. Distributed generation sources will include solar home systems (both standalone and net-metering systems), solar street and community lighting systems, standalone wind systems, and mini-grids (which could be made of single or hybrid technologies). Detailed planned generation is shown in Table 12.

Cycle I will serve as the preparatory stage of the implementation process, even as installation of some major projects begin. Activities to be undertaken in Cycle I includes:

- Establishment of REMP-Coordinating Unit;
- Awareness creation and marketing of the REMP;
- Preparation of outstanding regulations, e.g. integration of SWH into buildings;
- Development of outstanding Standards, Codes and Labels;
- Establishment of a Renewable Energy Demonstration Centre at Appolonia;
- Capacity building for technicians, entrepreneurs and local enterprises;
- Studies to identify areas for local assembly and manufacture of RETs; and
- Establishment of the Renewable Energy Authority.

In addition to the activities outlines above, major installations that are expected to take place in Cycle I include the following, with detailed timelines shown in Table 13:

- Development of the 30 kW Tsatsadu hydropower project by Bui Power Authority;
- Development of about 70 MW biomass utility scale projects by three companies: African Plantations for Sustainable Development (APSD), Kwamoka Group, and Ghana Oil Palm Development Company (GOPDC);
- Development of a total 125 MW wind utility scale projects by the Volta River Authority and Ayitepa;
- Development of 290 MW of solar utility scale projects by Bui Power Authority and Volta River Authority; and
- Development of about 10 MW wave / tidal power by TC's Energy.

In addition, solar home systems projects would be promoted through the Energy Commission's Solar Rooftop Programme and other private initiatives. Solar irrigation projects would play a significant role towards the achievement of government's policy on agriculture and industrialization.

Outcome of activities in Cycle I will inform activities to be implemented in Cycle II and III, as well possible revision of the targets should the need arise. Preparation of detailed activities to be performed in Cycle II will form part of the review of Cycle I activities towards the end of 2020.

Table 11: REMP Implementation Schedule 2018 to 2030

REMP IMPLEMENTATION PLAN - RE TARGETS UP TO 2030										
Renewable Energy Technologies	Reference 2015		Cycle I (2018-2020)		Cycle II (2021-2025)		Cycle III (2026-2030)		Cumulative in 2030	
	No. of units	MWp	No. of Units	MWp	No. of Units	MWp	No. of Units	MWp	No. of Units	MWp
Solar Energy										
Solar Utility Scale	-	23	-	270	-	202	-	378	-	873
Distributed Solar PV (Net Metering)		2	20000	18	100000	100	80000	80	200000	200
Solar Home Systems	-	3	-	1.5	-	3.5	-	6	-	14
Solar Street/Community lighting	-	3	-	4	-	4	-	14	-	25
Solar Traffic signals (% of total traffic signals installed in the country)	14	3	11	-	15	-	20	-	60	-
Solar Lanterns	72,000	-	128000	-	300000	-	500000	-	1000000	-
Solar irrigation	150	2	4250	6.8	22000	44	22400	44.8	48800	97.6
Solar Crop Dryers	70	-	80	-	250	-	300	-	700	-
Solar Water Heaters	4,700	-	15300	-	50000	-	65000	-	135000	-
Wind Energy										
Wind Utility Scale	-	0	-	125	-	275	-	250	-	650
Standalone Wind Systems	-	0	-	0.1	-	0.9	-	1	-	2
Wind Irrigation/Water Pumping	10	0	25	-	30	-	35	-	100	-
Biomass / Waste-to-Energy										
Biomass Utility-Scale/ standalone	-	10	-	58.5	-	106.5	-	125	-	300
Waste-to-Energy Utility Scale	-	0.1	-	1	-	3	-	5.9	-	10
Landfill Gas to Energy (LFGTE)	-	0	-	1.5	-	8.5	-	10	-	20
Biogas (Agricultural/Industrial Organic Waste)	10	-	20	-	70	-	100	-	200	-
Biogas (Institutional)	100	-	80	-	140	-	180	-	500	-
Biogas (Domestic)	50	-	30	-	50	-	70	-	200	-
Woodlot Cultivation (ha)	190,000	-	60000	-	100000	-	78000	-	428000	-
Charcoal (Local Demand)	1,551,282	-	94017	-	93947	-	100877	-	1840123	-
Charcoal (Export)	190,450	-	59550	-	100000	-	78000	-	428000	-
Briquetting/Pelleting	19,700	-	20300	-	25000	-	35000	-	100000	-
Biofuel (tonnes)	0	-	100	-	4900	-	15000	-	20000	-
Hydro / Wave Power										
Small/Medium Hydro Plants	-	4.00[1]	-	2.03	-	108	-	232	-	346.03
Wave Power	-	0	-	10	-	15	-	90	-	115
Hybrid Mini-Grids										
Mini/Micro-grids	7	-	73	-	120	4.8	100	4	300	-
End User Technologies										
Improved Biomass Cookstove (Domestic)	800,000	-	500000	-	500000	-	1200000	-	3000000	-
Improved Biomass Cookstove (Institutional/Commercial)	1,800	-	1200	-	7000	-	8000	-	18000	-
Total Installed RE Electricity Capacity		***46.1***		***503.53***		***875.2***		***1239.8***	0	***2664.63***

Table 12: Detailed renewable electricity installation plan*

RET	Ref	COMMULATIVE INSTALLED CAPACITY [MW]												
		Cycle I			Cycle II					Cycle III				
	2015	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Large Hydro	1,580.00	1,580.00	1,580.00	1,580.00	1,580.00	1,580.00	1,580.00	1,580.00	1,580.00	1,580.00	1,580.00	1,580.00	1,580.00	1,580.00
Small Hydro	6.00	-	-	6.03	6.03	54.03	54.03	114.03	114.03	114.03	201.03	251.03	291.03	346.03
Waste-to-energy	-	-	2.00	2.00	2.00	2.00	2.00	2.00	5.00	5.00	5.00	10.00	10.00	10.00
Biomass	-	-	8.50	68.50	68.50	68.50	120.00	120.00	175.00	200.00	200.00	250.00	250.00	300.00
LFGTE/Biogas	-	0.10	0.10	1.50	4.00	4.00	7.00	7.00	10.00	13.00	13.00	17.00	17.00	20.00
Wave	-	-	5.00	10.00	10.00	10.00	15.00	20.00	25.00	45.00	80.00	80.00	100.00	115.00
Wind	-	-	-	125.00	125.00	270.00	270.00	350.00	400.00	450.00	500.00	550.00	600.00	650.00
Solar PV	23.00	88.00	176.00	313.00	373.40	433.80	494.20	554.60	615.00	706.60	798.20	889.80	981.40	1,073.00
Total (Incl. L Hydro)	1,609.00	1,668.10	1,771.60	2,106.03	2,168.93	2,422.33	2,542.23	2,747.63	2,924.03	3,113.63	3,377.23	3,627.83	3,829.43	4,094.03
Total (Exc. L Hydro)	**29.00**	**88.10**	**191.60**	**526.03**	**588.93**	**842.33**	**962.23**	**1,167.63**	**1,344.03**	**1,533.63**	**1,797.23**	**2,047.83**	**2,249.43**	**2,514.03**

*Capacity is mainly grid connected systems and excludes mini/micro grids, solar home systems, stand-alone wind systems, and solar street/community lighting systems

Table 13: Institutional and Human Capacity Development Plan for Cycle I

Activities	2018	2019	2020	Responsibility
Formation of REMP-Coordinating Unit	■			MoEN
Development of comprehensive strategy for the implementation of the REMP	■			MoEN, EC, REA
Awareness creation on targeted renewable energy technologies	■	■	■	REA
Development of standards, codes and labels for biogas plants, SWH, solar dryers, etc.	■			GSA, EC, REA
Amendment of LI on standards, codes and labels to include newly developed ones		■	■	EC, GSA
Establishment of the Appolonia Renewable Energy Demonstration Centre	■	■	■	MoEN, REA
Capacity building programme of key research/training institutions in targeted areas	■	■	■	REA
Preparation of training materials for capacity building of technicians, entrepreneurs and local enterprises		■		REA
Capacity building programmes for entrepreneurs and local enterprises		■	■	REA

4.2 Roles and responsibilities of institutions

In line with the Renewable Energy Act, 2011 (Act 832), the Ministry of Energy will implement the plan through the REMP Coordinating Unit (REMP-CU). The REMP-CU shall be responsible for the overall procurement and financial management, coordination with key REMP Components Implementation Entities and Beneficiaries (CIEB[8]) and reporting obligation. The Ministry of Energy will from time to time designate relevant entities to implement key components of the REMP. The REMP-CU will perform the following specific functions, among others;

a. Ensuring prompt and efficient coordination and supervision of REMP activities by CIEBs;
b. Maintaining, updating and reconciling REMP Designated Accounts on regular basis;
c. Developing, approving and submitting proposals/funding applications to funding institutions;
d. Ensuring timely preparation, consolidation and submission of progress reports and publications;
e. Ensuring effective communication, and providing overall guidance to REMP activities;
f. Championing the establishment of strategic Public Private Partnerships (PPPs) and providing technical, financial and procurement support for such establishments;
g. Ensuring that procurement procedures are strictly followed;
h. Managing the funds of the REMP (strategies, programs, projects and tasks) and ensuring that they are used only for the intended purposes, with due consideration to economy and efficiency;
i. Ensuring environmental safeguard compliance;
j. Consolidating Annual Work Plans and Budgets of the CIEBs;
k. Monitoring and controlling progress and evaluating REMP activities;
l. Organising REMP-NSTC meetings to discuss progress and validate implementing strategies, and approve/disapprove annual work plans and budgets;
m. Holding events and coordinating Ghana's participation in national and international events (summits, conferences, forums, etc.) relevant to the success of the REMP;
n. Organising meetings and presenting reports on status of REMP implementation, challenges confronting the REMP and planned activities; and
o. Coordinating human and institutional capacity building programmes under the plan.

A National Steering Committee (NSC) made up of experts drawn from all relevant institutions will be established to provide overall guidance to the REMP and will among other responsibilities review progress made at the end of each cycle. Members of the NSC will serve for not more than two terms aligned with the REMP implementation cycles. The NSC will hold quarterly meetings and as and when necessary.

The REMP-CU will be staffed with competent personnel. The REMP-CU arrangements, assets and liabilities shall be given to the Renewable Energy Authority when it is established and operational.

[8] Public and private sector actors implementing aspects and or whose actions are aligned with the REMP.

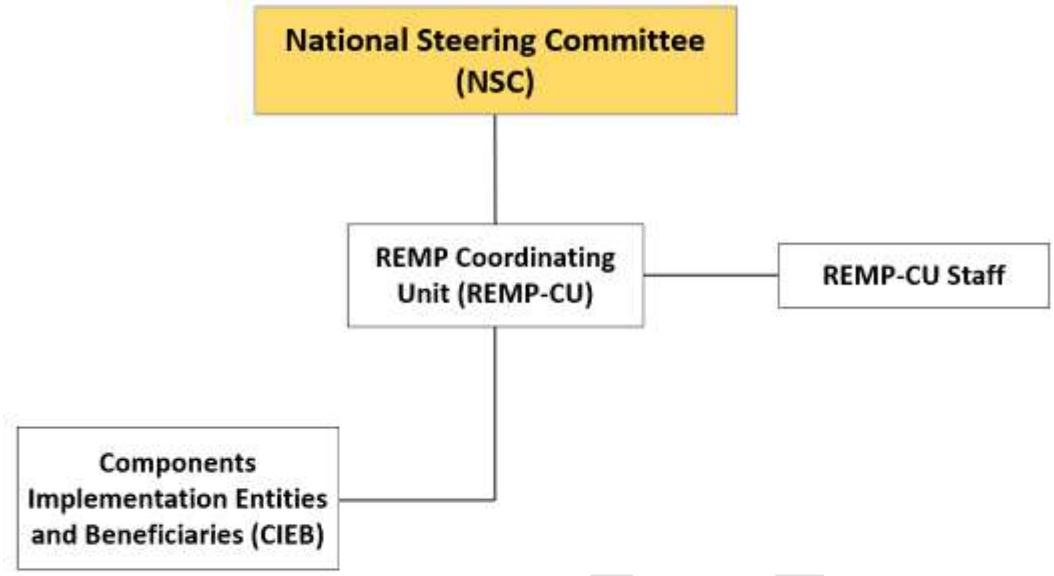

Figure 9: The REMP implementation governance structure

4.3 Roles and Responsibilities of CIEBs

Aspects of the REMP shall be implemented by the CIEB. The CIEBs shall include but not limited to the following; Energy Commission, Public Utilities Regulatory Commission, National Petroleum Authority, Forestry Commission, Ministry of Food & Agriculture, Ghana Irrigation Development Authority, Ghana Grid Company, Training & Research Institutions, Electricity Distribution Companies, Public Electricity Generation Companies, Renewable Energy Private Sector Companies, Civil Society Organizations, etc.

Their roles and responsibilities shall be determined and defined by the REMP-CU in consultation with the NSC, and aligned with their statutory mandates as defined in the Renewable Energy Act, 2011 (Act 832).

The utilities shall play key roles, especially in relation to utility scale projects. The Volta River Authority, Bui Power Authority and the Renewable Energy Authority (yet to be established) will be encouraged to grow and expand the renewable energy electricity space through public sector led investments and or through public private partnerships.

GRIDCo will drive strategic investments and expansion of the National Interconnected Transmission System (NITS) in line with provisions defined in the Renewable Energy Sub-Code and the National Grid Code to accelerate the interconnection of utility renewable energy projects.

Distribution companies and bulk customers would be required under the Renewable Energy Purchase Obligation (REPO) to integrate RE electricity in their distribution and consumption mix. Distribution companies will supply on request bi-directional meters to customer generators and give access to the distribution system, in line with the Net-Metering Code.

The NPA in consultation with all relevant actors shall implement the biofuel obligations under the REMP and in line with the RE Act.

The Energy Commission in consultation with all relevant actors shall intensify and expand woodfuel and related activities under the REMP and in line with the RE Act. The Energy Commission through the Ministry of Energy will continue to engage government revenue agencies including the Ghana Revenue Authority to facilitate access to import duty waivers by importers, in line with provisions in the RE Act, until such a time that a local renewable energy manufacturing industry evolves.

4.4 Role of Government of Ghana

The Government shall continue to create the enabling environment for private and public-sector investments in the renewable energy space. Particularly, government will continue to invest in strategic social interventions including cookstoves and alternative fuels, renewable energy mini-grids, solar community lighting and rural/urban solar traffic signals and street lights, and explore PPPs where viable.

The Ministry of Energy and sector agencies such as the Energy Commission shall continue to scale-up already existing projects to increase the overall renewable energy capacity in the country.

Within the framework of the government's mini-grid policy, the state-owned utilities will be strengthened technically and financially to play leading roles in the implementation of mini-grids in remote and island communities.

4.5 Private Sector Participation (PSP)

Private sector investment is at the centre of the REMP, hence, government would continue to provide the enabling business environment and pursue policies and strategies to address bottlenecks that hinder private sector participation and growth in the renewable energy space. Incentives would be given to private sector actors engaged in the local assembly and manufacturing of renewable energy technologies and related services to increase their competitiveness. Local RE companies would be given priority in procurement for government supported programmes or projects.

4.6 Opportunities for Local Manufacture

Manufacturing and assembling of renewable energy technologies is pivotal to the overall growth of the industry. This will not only stimulate sustainable growth of the sector, but also contribute to the overall development of the West African renewable energy market.

The REMP-CU would facilitate and provide technical and investment support to innovative private sector initiatives directly and through recognisable professional bodies. The targets would be delivered within the three (3) cycles which would cover the local assembly and manufacturing of renewable energy powered-household gadgets, batteries, inverters, wind turbine components, water pumping, biogas reactors, waste-to-energy plants, small hydropower turbines, improved cookstoves and fuel, etc.

In accordance with the Local Content and Local Participation (Electricity Supply Industry) Regulations, 2017, LI 2354, for the sector and to boost local production, both state sponsored and private sector renewable energy projects would source a minimum 30 % of goods from the local market (where available) in the medium-term. The scope and content of local sourcing of goods will be broadened as the local production market matures.

All necessary support would be given to the private sector to ensure that local manufacturing and or assembling of RETs such as batteries, inverters, controllers, PV modules, efficient cookstoves and alternative fuel like briquettes, pellets and gel fuels commence under circle II implementation.

4.7 Resource assessment and research into new technologies

The Ministry of Energy and Energy Commission will continue to undertake RE resource assessments to increase data credibility and readiness for project planning and development. Activities to be undertaken will include: (a) assessing and mapping out of proven technologies such as solar, wind, hydropower, waste-to-energy, biomass and improved cookstoves; and (b) exploring potentials in new RE frontiers such as tidal wave, fuel cells, etc.

Existing funds that support research in institutions would be further supported to prioritise RETs research and demonstration projects to showcase the technical performance or financial viability of these technologies. The REMP-CU in consultation with the NSC shall identify and define new areas for R&D, provide support to notable and emerging RE R&D institutions and help bring the results to the market place.

4.8 Awareness creation and communication strategy

A communication strategy would be developed during the inception phase and implemented throughout the life span of the REMP. The REMP-CU will engage stakeholders in the conception and development of programmes, projects and activities to promote widespread support for implementing the REMP.

The goal of the awareness and communication strategy to be developed is to improve public awareness on and understanding of renewable energy issues and initiatives under the REMP. The goal would be achieved through a number of strategic objectives as follows:

- Build awareness, understanding and support for the implementation of the REMP;
- Promote understanding of issues related to the development and utilisation of renewable energy;
- Increase awareness and commitment among public and private sector organisations, NGOs and agencies on the importance of implementing the REMP;
- Provide general information to the public about the REMP and how people can actively contribute;
- Build new partnerships between government and civil society including local communities, indigenous people, women groups, the private sector and the general public; and
- Identify potential conflicts amongst stakeholders for possible resolution.

Key activities would include the development of communications and awareness creation materials, placing of media advertisements and tracking of the effectiveness of the strategy. A mix of communication channels, including: radio, television, social media, local community workshops, leaflets and dedicated web pages will be used to create awareness about the REMP in particular, and benefits of renewable energy technologies in general.

5 ECONOMIC, SOCIAL AND ENVIRONMENTAL IMPACTS

5.1 Economic Impacts

This section covers the investment and jobs to be created resulting from the implementation of the REMP[9]. Effective implementation of the REMP will cost an estimated US$ 8 billion over the period from 2018 to 2030. On annual basis, this translates into an estimated US$ 620 million investment. The successful implementation of the plan would lead to an estimated 225,000 jobs[10].

Investment cost and job prospects for the first cycle of implementation (Cycle I) is shown in Table 14. An estimated US$ 1.453 billion will be required for the activities and investments in Cycle I. Close to a third of the estimated investment (approximately 72.24 %) is expected to be provided by the private sector. Private sector is expected to invest mainly in the utility scale projects and other sectors such as solar water heaters, biofuels, and industrial biogas systems. Government will be expected to provide approximately 27.40 % of the funding, with the remaining 0.36 % coming from research institutions through the application of external research grants to support renewable energy research. It is expected that research institutions through their usual grant applications will provide a minimum 20 % of the estimated cost for research, development, and demonstration. Government's funding will partly support sectors such as street / community lighting, distributed solar PV, development of mini-grids, provision of solar lanterns, solar irrigation, solar crop dryers, capacity building, infrastructural development, implementation costs, and the like.

Job creation in Cycle 1 will amount to some 27,000 jobs along the value chains of the various interventions. Benefits expected to be derived from the implementation of the REMP include:

- Boost industrialisation in areas such as manufacturing, assembling, etc.;
- Contribute to national energy security;
- Increased productivity in sectors such as agriculture and small-scale industries;
- Increased foreign exchange earnings and improved balance of trade;
- Enhanced security and improved quality of life of rural and urban people using indigenous resources;
- Improved public service delivery particularly in the areas of health and education;
- Reduction in household air pollution;
- Creation of a sustainable market for RETs;
- Improved regulatory and fiscal regime to facilitate ease of doing business in the RE sector;
- Increased renewable energy penetration;
- Increased access to modern energy services to unserved and underserved communities;
- Increased energy efficiency (co-benefit – economic and environmental);
- Increased human capacity in the RE sector; and
- R&D enhanced to spur on innovation, adaptation and localisation of RE technologies.

[9] costs and jobs prospects are indicative figures only

[10] Jobs include farmers who will benefit from solar irrigation projects and cultivate all year round

Co-benefits identified include:

- Compost and bio-char for the agriculture sector;
- Inputs for the production of organic cosmetic;
- Improved soil fertility and bio-diversity for well-developed woodlot plantation;
- Activated charcoal for the mining sector;
- Tar as a by-product from improved charcoal production for construction sector;
- Successful implementation of the REMP will serve as a learning curve towards improving activities in other sectors of the economy; and
- Improved socio-economic status of women through increased use of modern energy.

Table 14: Investment costs and job prospects for Cycle 1

Technology	**Unit**	**2020 Target**		**Estimated Investment Required (US$)**	**Job Prospects***
		No. of Units	**MWp**		
Solar Utility Scale	MW	-	293	351,650,000	2,489
Wind Utility Scale	MW	-	125	227,500,000	340
Biomass Utility-Scale	MW	-	70	204,000,000	930
Waste-to-Energy Utility Scale	MW	-	2	4,800,000	16
Wave Power	MW	-	10	45,000,000	93
Landfill (LGTE)	MW	-	1.5	2,100,000	20
Small/Medium Hydro Plants	MW	-	0.03	72,000	5
Distributed Solar PV (Net Metering)	MW	20,000	200	51,240,000	168
Solar Home Systems	MW	7,000	14	5,600,000	20
Standalone Wind Systems	MW	-	0.1	630,000	0
Solar Street/Community lighting	MW	-	7	9,400,000	20
Mini/Micro-grids	Unit	80	3.2	52,260,000	281
Solar Lanterns	Unit	200,000	-	5,760,000	2,176
Solar Water Heaters	Unit	20,000	-	45,900,000	4,590
Solar irrigation	ha	4,400	8.8	85,000,000	25,500
Solar Crop Dryers	tonnes	150	-	400,000	56
Solar Traffic signals (% of total traffic signals installed in the country)	%	25	-	8,550,000	6
Wind Irrigation/Water Pumping	Unit	35	-	875,000	165
Woodlot Cultivation	ha	250,000	-	180,000,000	2,664
Charcoal (Local Demand)	tonnes	1,645,299	-	200,000	1,000
Charcoal (Export)	tonnes	250,000	-	200,000	600
Briquetting/Pelleting	tonnes	40,000	-	304,500	2,030
Improved Biomass Cookstove (Domestic)	Unit	1,300,000	-	4,000,000	2,500
Improved Biomass Cookstove (Institutional/Commercial)	Unit	3,000	-	1,560,000	35
Biofuel	tonnes	100	-	90,000	50
Biogas (Agricultural/Industrial Organic	Unit	30	-	20,000,000	100

Waste)					
Biogas (Institutional)	Unit	180	-	8,000,000	400
Biogas (Domestic)	Unit	80	-	90,000	150
SUB-TOTAL				*1,315,181,500*	*46,400*
Capacity Building				20,000,000	30
Infrastructural Development				30,000,000	30
Development of Standards and Codes				2,000,000	10
Demonstration Centre				20,000,000	40
#Implementation costs (3 %)				39,455,445	10
Research and Development (2 %)				26,303,630	30
TOTAL				**1,452,940,575**	**46,550**

* Data drawn largely from REN21 (2017). Renewables Global Status Report
#Implementation costs cover cost of funding the agency to oversee the REMP implementation process

5.2 Environmental impacts

The success of the REMP will lead to significant carbon dioxide emission reduction and contribute to the reduction of Ghana's carbon footprint. Generating electricity from renewables will result in fuel savings and therefore reduction in carbon emissions as a result of the displacement of fuel for thermal generation. An estimated 2567 MW of additional renewable energy installed capacity would be realised which would translate into a straight-line carbon savings of about 20.6 million tonnes of CO_2 by 2030. Other technologies such as improved cookstoves would result in health benefits arising from the use of less wood fuel, and hence lower emissions. Notwithstanding the positive benefits, some of the renewable energy technologies, such as solar, wind and plantation based schemes have higher land requirements. There would also be issues with hazardous materials resulting from the increased use of batteries for power storage in household systems.

5.2.1 Land use

Renewable energy technologies such as utility scale solar and wind, and plantation based schemes require appreciable land mass for development with its attendant effect on other land uses. For instance, the land requirement for solar PV installations is about 2.5 acres (1 hectare) per MW. Land required for wind farms is about 35 hectares per MW which could still be used for perennial cropping. In the case of solar however there is less opportunity to share land with other economic uses such as agriculture, although a significant breakthrough has been achieved in China.

Development of the remaining small hydropower resources will lead to minimal land displacement and resettlement. Opportunities however exist to develop irrigation schemes from some of the hydropower developments.

With respect to biomass fuels, economic and multipurpose energy crops and tree species for electricity generation and liquid biofuels would be promoted for optimal land use. Further gains envisaged are listed below;

- Reduction of adverse climate change effects;
- Increased forest cover as a result of afforestation and reforestation; and

- Boost eco-tourism.

In all, about 1.123 million acres of land will be required to meet the renewable energy targets for 2030, with woodlot plantations alone requiring approximately 1 million acres.

Through spatial planning, the impacts of utility-scale renewable energy systems could be minimized by siting them at locations where there is less competition for land use, for example; degraded lands, abandoned mining sites, transportation and transmission corridors, etc.

The use of roof space in commercial, industrial, public and private facilities for solar installations would be strongly encouraged and promoted.

Due to the site-specific nature of renewable energy resources, the Implementing Authority for the REMP will secure potential areas where the resource abounds for development. This is to avoid losing such sites particularly areas along the coastal belts to other competing needs.

Several models would be deployed, such as land acquisition through executive instruments or contribution of land as equity by owners in the development of renewable energy projects.

5.2.2 Hazardous Materials

In the manufacturing process, materials used for solar PV cells could be hazardous. For example, industrial chemicals such as hydrochloric acid, sulfuric acid, nitric acid, hydrogen fluoride, 1,1,1-trichloroethane, and acetone are used to clean and purify the semiconductor surfaces. The indiscriminate disposal of batteries could also result in serious environmental and public health issues.

As the country industrialises, the volume of these waste materials will increase significantly and would therefore require an improved and aggressive approach to handling and managing their disposal. This could present economic opportunities particularly in the areas of reuse and recycling. The REMP would support the expansion of the existing e-waste disposal and recycling plants in the country and the construction of new ones in strategic locations to turn the voluminous waste into usable materials and proper disposal.

6 ENABLING ENVIRONMENT

The Government of Ghana continues to create an enabling environment for the energy sector.

6.1 Regulatory Framework

The main enabling instruments comprise:

- The Renewable Energy Act, 2011 (Act 832);
- Renewable Energy Sub-Code for National Interconnected Transmission System connected Variable Renewable Energy Power Plants in Ghana;
- Renewable Energy Sub-Code for Distribution Network connected Variable Renewable Energy Power Plants in Ghana;
- Net Metering Sub-Code for Connecting Renewable Energy Generating Systems to the Distribution Network in Ghana;
- Feed-in-tariff for electricity generated from RE sources;
- Guidelines and modalities for the Renewable Energy Purchase Obligation (REPO); and
- Standardised Power Purchase Agreement Template.

In addition to these instruments, licensing manuals have been developed that detail the license application process for utility scale projects and other non-electricity renewables. These include:

- Importation Licence;
- Wholesale Electricity Supply Licence;
- Installation and Maintenance Licence;
- Bulk Charcoal Production Licence for Export;
- Bulk Charcoal Transportation Licence;
- Charcoal Export Permit;
- Briquette/Pellet Production Licence;
- Briquette/Pellet Export Licence;
- Biofuel Production Licence;
- Bulk Biofuel Storage Licence; and
- Biofuel Export Licence.

6.2 Support / Incentive for Manufacturing / Assembly Centres

In order to reduce the over reliance on imported RETs, government shall support local manufacturing / assembly initiatives by providing incentives such as tax breaks, capital subsidies, loan guarantees, etc.

Specific incentives for renewable energy manufacturing and assembling would be as follows:

- Local content requirements under the Local Content and Local Participation regulations, LI 2354, 2018;
- Substantial tax reduction for manufacturing and assembling;
- Materials, components, equipment and machinery (that cannot be obtained locally) for manufacturing or assembling, shall be exempted from import duty and VAT, up to the year 2025;
- Materials, components, equipment and machinery that Ghana has competitive advantage over, shall attract the relevant import duty and other applicable taxes to promote the local industry;
- Import of plant and plant parts for electricity generation from renewable energy resources, shall be exempted from import duty and VAT;

- Allocation of a quota for local industries in all Government projects to facilitate expansion of the existing market; and
- Government shall provide a vehicle through existing facilities such as the Venture Capital Trust Fund to provide soft loans to local industries.

6.3 Local Content

A Local Content and Local Participation (Electricity Supply Industry) Regulations, 2018 including electricity from renewable energy resources has been enacted. The Government of Ghana is committed to the implementation of an effective Local Content and Local Participation Policy as the platform for achieving the goals for the power sector with full local participation in all aspects of the ESI value chain of at least 60 % by 2025.

The following shall be in line with the Local Content Policy:

i. Ownership;
ii. Engineering, Procurement and Construction contracts;
iii. Construction and Installations Works;
iv. Post Construction Works Supplies;
v. Services;
vi. Management;
vii. Operations & Maintenance Staff; and
viii. Operation and Maintenance Contract.

The above requirements shall apply to all the other renewable energy initiatives under the REMP.

6.4 Infrastructure Development

One of the prerequisites to a successful integration of renewable energy electricity into the national grid is a robust National Interconnected Transmission System (NITS) that is able to manage variable loads from wind and solar facilities. GRIDCo has conducted some preliminary technical impact studies for projects that were seeking to connect to the NITS.

A detailed technical study to ascertain the status of the current infrastructure and the level of investment is required to achieve the RETs targets.

As part of the infrastructure development, GRIDCo shall modernise its operations to synchronise with weather forecasting stations in all utility scale variable RE installations.

Government would support GRIDCo to obtain financing to develop evacuation infrastructure, such as substations and switchyards to accelerate the development of utility scale RETs.

On mini-grids, government would invest, as well as provide opportunities for the private sector to invest in generation and distribution infrastructure. Government would explore opportunities to provide sustainable water transportation system to support transportation of mini-grid facilities to islands and lakeside communities.

Government would support the Bulk Oil Storage and Transportation Company (BOST) and also encourage PPP to construct biofuel storage facilities.

6.5 Technical Capacity Development

Sustainable human and institutional capacity building is required for the effective implementation of the REMP. Government shall identify and collaborate with relevant training institutions and industries to develop tailor-made technical and entrepreneurial programmes for targeted groups and individuals along the entire renewable energy value chain. Focus will be placed on areas such as assembling, manufacturing and installation of RETs; design, construction and maintenance of biogas digesters, gasifiers, kilns, improved household and institutional cookstoves; and biomass briquetting and pelleting. The private sector shall be the major beneficiary of this intervention.

The Appolonia Renewable Energy Demonstration Centre is being upgraded and expanded into a centre of excellence to coordinate and build capacity in renewable energy and energy efficiency, and host the Renewable Energy Authority to be established. Government would secure land for this purpose.

6.6 Research and Development

There is limited capacity and technical know-how in renewable energy research and development (R&D) in Ghanaian universities and research institutions. In addition, funding of R&D activities has not been properly streamlined, and this has led to a lack of focus and duplication of resources. Currently, total government budgetary support in terms of GDP for R&D in all sectors is about 0.25 % (World Bank, 2016) as opposed to over 4 % in Israel and South Korea. It is therefore imperative that sufficient financial resource is allocated to boost R&D.

Government would provide adequate support to existing universities, research institutions and incubation centres such as the Ghana Climate Innovation Centre (GCIC), The Brew-Hammond Energy Centre, Centre for Renewable Energy and Energy Efficiency at Kumasi Technical University, Department of Energy Systems Engineering at Koforidua Technical University, Council for Scientific and Industrial Research (CSIR), etc., to deliver on their core mandates.

The Appolonia Renewable Energy Demonstration Centre would serve as a link between government and research institutions to promote and drive research that is targeted at national development priorities and bridge the gap between researchers, private sector and government. The Centre shall coordinate research dissemination, working closely with the existing universities and research centres.

The key areas for R&D in the renewable energy sector would include:

- Existing and new materials for production of the components of RETs;
- Improvement of the technical characteristics of indigenous RETs (cookstoves, kilns, inverters, controllers, etc.);
- Advanced assembling and manufacturing techniques and processes for the components of RETs;
- Innovations in RET solutions; and
- Policies and socio-economic issues for effective planning and development of the renewable energy and energy efficiency (REEE) sectors.

In consultation with industry, renewable energy R&D priorities would be established and implemented in partnership with the relevant stakeholders. In this regard, efforts would be made to strengthen individual and institutional research capabilities, increase cost sharing in financing proposals, and upgrade equipment and instrumentation.

6.7 Development of Standards and Codes

Standards and technical codes are needed to ensure that optimal benefits are derived from the utilisation of RETs. The Ghana Standards Authority (GSA) has adopted standards for solar modules, batteries, inverters, solar lanterns, liquid biofuel and selected electrical appliances and is also in the process of completing the minimum performance requirements for biomass cookstoves.

The Energy Commission (EC) in collaboration with relevant institutions has developed technical codes for connecting renewable energy generating systems to the transmission and distribution systems.

In order to be abreast with emerging trends in the sector, GSA shall continue to update these standards. The existing laboratory for testing solar systems at the GSA must also be upgraded to provide full range testing services for all RETs as defined in the RE Act. Standards shall also be adopted for mini-grid development in Ghana.

Testing laboratories have also been established at the Technology Consultancy Centre (TCC) of the Kwame Nkrumah University of Science and Technology (KNUST) and the Institute of Industrial Research of CSIR for testing of cookstoves and fuel.

6.8 Financing

Limited access to long-term financing and high cost of capital are a major constraint to the growth of the renewable energy sector. At the moment, local banks are unable to offer long-term lending for infrastructural projects including RE projects.

Investment and commercial banks in the country would be encouraged to develop long term financing portfolios for renewable energy projects.

Having attained lower middle-income status, concessional funding facilities from development partners have dwindled. There is therefore the need to develop and explore innovative funding mechanisms to support renewable energy projects.

In this regard, the following sources of funding shall be explored:

i. Petroleum Fund;
ii. Ghana Infrastructure Investment Fund (GIIF);
iii. Multilateral Development Banks;
iv. Green Climate Funds;
v. Global Environment Facility (GEF);
vi. Sustainable Energy Fund for Africa (SEFA);
vii. Abu Dhabi Fund;
viii. Africa Renewable Energy Fund;
ix. African Catalytic Fund;
x. Rural Electrification Levy for mini-grid development;
xi. Loans and grants negotiated for rural electrification;
xii. Grants and matching funds; and
xiii. Renewable Energy Fund (when operational).

Utility-scale renewable energy projects shall be supported with risk mitigation instruments (e.g. Renewable Energy Put Call Option Agreement (PCOAs), liquidity support, insurance, etc.).

7 CROSS-CUTTING ISSUES

7.1 Gender mainstreaming

The development of policies and strategies should always seek to ensure equity in participation and delivery of energy services to men, women, children and the vulnerable. Unfortunately, lack of energy sector gender based data has made it difficult to establish the active role of gender in the development of policy support for the energy value chain. This has led to a situation where the concerns of gender are not factored in the decision-making process which has presented a situation where the vulnerable are marginalised in the design, development and promotion of clean energy products.

This situation could be attributed to the inadequate personnel and gender experts in management positions within the energy sector. A major reason could be the lack of interest in pursuing energy related academic programmes and limited access to financial resource for capacity building.

The income generating activities of women particularly in the areas of industrial and agro-processing tends to rely on high quality sources of energy. Recent experiences in Ghana has however shown the important role played by women in the energy development agenda at the decision-making level.

Efforts have been made to mainstreaming gender into all government institutions, policies, programmes and projects. Building on this initiative, the REMP places special focus on gender inclusion to improve the wellbeing of women and children, especially.

Gender shall be farther mainstreamed into the implementation of the REMP to:

- Build a strong gender based database within the energy sector to establish the individual involvement of gender in the entire energy value chain;
- strengthen coordination mechanisms and promote initiatives that ensure gender equality;
- provide equal opportunity for women to work in the renewable energy sector;
- increase awareness on the benefits of energy and gender;
- create financing opportunities for women entrepreneurs; and
  Support end-use consumer and gender disaggregated data assessment to inform policies on women, children, vulnerable groups and persons with disability.

With the right enabling environment, women can be empowered to play a more active role in decision-making in the energy space and contribute in areas such as:

- engineering, procurement and construction;
- operations and management of renewable energy installations;
- maintenance and repair works;
- customer services such as meter reading;
- management of corporate entities; and
- cutting-edge research and development.

7.2 Energy efficiency

The major consumers of electricity in Ghana are the industrial, residential and non-residential (commercial users) sectors. Energy efficiency could be improved by adopting energy conservation practices and promoting the use of energy efficient technologies. Significant reduction of the total energy consumed can be achieved through an aggressive and sustainable energy efficiency programmes and strategies. Accordingly, the Government of Ghana has over the past years implemented programmes to raise public awareness on energy conservation and management in both the industrial and residential sectors and promoted the use of energy efficient appliances. Standards and labelling schemes are currently being implemented for lighting devices, air-conditioners and refrigerators.

The government has implemented the following energy efficiency programmes:

a) Replacement of incandescent lamps with Compact Fluorescent Lamp (CFL);
b) Replacement of inefficient refrigerators with new energy efficient ones in homes under a rebate scheme;
c) Power factor correction in about 32 public institutions;
d) Energy efficiency training and capacity building for energy managers in Ministries, Departments and Agencies (MDAs) and Metropolitan, Municipal and District Assemblies (MMDAs);
e) Nationwide public education and capacity building for members of Ghana Hoteliers Association; and
f) Promotion of energy efficient lighting and electrical appliances as part of the National Rooftop Solar Programme.

Work is currently underway done to incorporate energy efficiency requirements into the National Building Code. The government also intends to develop and implement standard and labelling schemes for other electrical appliances such as motors, fans, televisions, etc.

Energy efficiency will continue to play a key role in the implementation of RE interventions. The following strategies will be used:

- Enforce mandatory energy audits in any commercial building that is applying for RE solution that covers more than 40 % of the total energy consumption needs;
- Reduce consumption through energy efficiency, to lower the size and investments needed for RE Systems;
- Build capacity for energy auditors and institute certification for auditors;
- Provision of incentives for real estate developers and other construction designers to incorporate energy efficiency and conservation into buildings;
- Sustained and intensive public education and awareness-raising campaign on the benefits of energy efficiency and conservation;
- Development and implementation of programmes and measures to help consumers to optimize their use of energy;
- Promotion of LED lights for community and street lighting and traffic signals;
- Facilitation of access to finance by industry and commercial entities to implement energy efficiency interventions; and
- Provision of support to private energy service providers to actively promote energy efficiency and conservation in residential, public, commercial and industrial facilities.

8 RISK ANALYSIS AND MITIGATION MEASURES

Many factors may hinder the realization of the objectives and targets of the Renewable Energy Master Plan. The risk factors include, funding, poor infrastructure, policy changes, a change in government, instability in the macroeconomic framework, international setbacks, operational risks, environmental and climate related risks, disaster risks and risks associated with R&D.

The identification and analysis of these risks will allow for stakeholders and relevant regulatory institutions in the renewable energy sector to factor in the risks during programme implementation, as well as seek alternative approaches to achieving the targets and objectives set out in the REMP, and monitor them within an MVR framework.

Table 15 present risks that have been identified, as well as proposed mitigation actions to address these risks.

Table 15: Identified risks and proposed mitigation actions

Risk	Sub-risk	Description	Proposed mitigation actions
Funding and Infrastructure Risks	Inadequate access to investment capital	There is difficulty in assessing investment capital in Ghana, with attendant high interest rates. Several promising projects, especially in new areas like renewable energy investments suffer setbacks due to the inability to secure funds from commercial banks and other financial institutions.	Project developers may access funding from international funding bodies, as well as existing local funding structures like the Ghana Infrastructure Fund. Details of financing support is presented in Section 6.8.
	Poor infrastructure	Poor infrastructure increases transaction costs and reduces the profitability of businesses. Roads, distance from transmission points, telecommunication and above all, access to energy are important for local manufacturing of renewable energy systems and components.	As much as practicable, renewable energy projects should target locations that provide the maximum infrastructure needed for inter alia, construction, grid connection and operation, using appropriate tools such as GIS.
Policy and Political Risks	Outlined policies may not be adopted	Certain policies developed by past governments may not be adopted by future governments, or may not be implemented to significant levels.	Involvement of relevant government agencies in the design and implementation of project activities, outlining concrete activities to address risks and securing the political will to reach set targets.
	Policy inconsistency, instability and contending interests within Government	Risks may prevail when sections of the REMP are not properly aligned to the overall economic policy direction of the government or are contradicting broader energy policy objectives. This may result in policy inconsistencies and the poor performance of the REMP. These inconsistencies may also result from frequent changes in policy direction. Other inconsistent government policies, particularly in the application of tariffs and exemptions, transaction costs at ports, customs clearance procedures, and the use of import bans on goods, merchandise, products, equipment and	It is important to meet the concerns and interests of all relevant stakeholders so that potential conflicts are reduced. Once stakeholders are fully involved and implementation agencies are properly equipped, success will be achieved.

Risk	Sub-risk	Description	Proposed mitigation actions
		production machinery; tariff and non-tariff barriers pose great risk on investments in the renewable energy sector.	
	Lack of continuity in Government policies	Governments over the years have embarked on several reforms to make the energy market less strict, thereby creating opportunities for investors in the renewable energy sector. Uncertainties cast shadows over policy direction whenever there is change of government. In an atmosphere where continuity of policy is lacking, the risk of a new government making significant changes in implementation of the REMP is a reality.	Institutionalizing the activities of the REMP will assist in imbedding the key activities and achieving the objectives.
International Development Risks		The global market for RETs and the actions of other governments and international agencies are of great importance to the success of the REMP. This global risk may affect renewable energy development in Ghana. Multilateral agencies such as the World Bank, UNDP, EU and AfDB as well as bilateral agencies such as USAID and GIZ have contributed to renewable energy development. Many of the planned activities of the REMP are expected to be financed from international sources. This constitutes a major risk factor that must be managed to prevent the collapse of the main pillars of the REMP	Managing other related issues such as democracy, economic reforms and good governance is important in securing international support.
Standards and Quality Control Risks	Non-conformity of manufacturers and importers to set standards	Presently, there may be products on the Ghanaian market that are not conforming to the standards set by the GSA and EC which is because of regulation not being enforced. This results in influx of sub-standard technologies that dampen market confidence.	The REMP recommends the strengthening of agencies responsible for quality control and standards for renewable energy products entering the Ghanaian market.

Risk	Sub-risk	Description	Proposed mitigation actions
	Entry of unqualified institutions into the sector	The lack of strong entrepreneurship framework for emerging renewable energy businesses result in the entrance of institutions without the relevant professional background in the renewable energy sector. These can create and spread bad publicity for the sector and make market growth stagnant.	Institutions mandated to grant licenses should ensure that businesses have the requisite qualification, or is prepared to undergo relevant training before granting licenses to operate.
Research and Development Risks	R&D capacity risk	Achieving the targets of the REMP will depend on the identification of suited resource centres and professionals to lead long-term R&D programmes. The conditions of Ghana's R&D institutions fall short of expectations in several respects, including funding, infrastructure, etc. Achieving set targets and milestones are therefore difficult under these conditions.	Establishing many thriving resource centres can go a long way in easing R&D capacity risks. Such a long term and collaborative programme should be overseen by the Energy Commission.
	R&D funding risk	Funding for R&D is an issue. Influencing financial resources to kick-start and sustain R&D programmes may be a challenge. Another reason why financial resources cannot be raised for R&D activities in Ghana is the over-dependence on public budgets.	An alleviating strategy will focus on expanding the scope for funding by actively engaging international agencies and the private sector, and developing international collaborations among R&D centres.
Environmental and Climate Change Risks	Adverse impact on the environment	Hydro plants can have impacts on aquatic life. Utility scale solar is land intensive. Wind turbines may cause noise pollution. Poorly managed biofuel crop cultivation may also result in deforestation. Disposal of used acid batteries can be an environmental headache and recycling must be encouraged. Other equipment equally damaging to the environment when disposed include wind turbines, solar panels and inverters.	Several environmental tools could be useful in addressing these concerns, and they include environmental impact assessment (EIA), environmental audits and environmental management planning. Legislation of the management of these components and other e-waste should be enforced. To use less land for solar, installations will be encouraged along car parks, residential roofs, and degraded lands.

Risk	Sub-risk	Description	Proposed mitigation actions
	Aesthetics	Some renewable energy forms unfortunately might not be so pleasant to behold. Wind farms, for instance arouse significant resentment by environmentalists, as they seem to deface natural environments. Large PV farms may also invoke such concerns. The handling of conventional and domestic waste such as excreta for biogas generation may cause some problems	There should be due diligence when selecting sites for renewable energy installations.

9 MONITORING, EVALUATION AND REPORTING

The objectives of the monitoring, evaluation and reporting framework for the REMP is to gather the needed information on the planned activities (including resource inputs and outputs, impacts and assumptions), analyse and synthesise them and use the results to measure the achievements/impacts in relation to the targets and actions. The information to be generated from the monitoring and evaluation activities would be used as a basis for reviewing the plan.

9.1 Monitoring

The implementing agency shall continuously assess the progress of various target areas in the REMP. In the monitoring process, they would collect and analyse data which serve as a guide to either continue the pace and direction of the implementation of the masterplan, or set up corrective measures if it has diverted from the original path. It is therefore necessary that the MoEn coordinates all the activities within the sector to ensure that various departments and agencies share information, experiences and above all work towards the common vision of the REMP.

9.1.1 Data collection

Data to be collected for monitoring purposes would include the following:

- Baseline information;
- Broad information on installations done during the period under review;
- Extent to which targets are being achieved;
- Renewable energy contribution to energy access;
- Avoided GHG emissions;
- Job creation;
- Trend in cost of technologies;
- Effectiveness of adopted strategies;
- Effectiveness of subsidies;
- Technological successes and failures;
- Implementation challenges; and
- Research and development activities, among others.

9.1.2 Data analysis

The data to be collected and analysed would be for two reasons:

1. to progressively monitor progress at activity level. This will be done to monitor the progress of the achievements of targets; and
2. to monitor and evaluate outcomes and impact of various operations: data will mainly come from external services such as project, community, and national surveys. Monitoring will be based on the assessment of what has been achieved as compared to the planned. Analysed and verified field data will be used in analysing plans and achievements. It is on this basis that technical reports will be prepared.

9.2 Evaluation

Based on the data to be collected, evaluations will be conducted to know outcomes of actions. This is important to know whether the REMP is achieving its goals. The key outcomes to be evaluated include:

- Installations – one of the key outcomes will be installations done over the period, compared to set target. Installations will be evaluated for energy generated, economic gains and environmental benefits. The simplest, and often most relevant, way to evaluate economic gains is to compare the amount of money invested to the number of jobs directly created. Environmental gains will be evaluated based on avoided GHG emissions, compared to a business-as-usual energy investment programmes.

- Market transformation and technology transfer – some of the interventions proposed in the REMP aim not only to increase the number of installations but to transform the renewable energy market. The goal is to create a market that will ultimately sustain itself without continued financial support from government. Such market transformation programmes need to be evaluated differently than installation programmes, although the number of installations can be an important indicator of whether the market is on track to being permanently changed. Many of the strategic actions are aimed at boosting the local economy with a vibrant local manufacturing industry. This will be evaluated to look at achievements especially in relation to dates proposed to achieve specific manufacturing targets.

- Research, development, demonstration and diffusion – it is expected that state energy funds and funds from the donor community will carry out a wide range of different types of research and technology demonstration programmes. For successful evaluation of the outcomes of research and demonstration programmes – and indeed for successful design of such programmes – it is important to have a clear understanding of what the specific outcomes of the programme are supposed to be. The Appolonia Renewable Energy Demonstration Centre will assist in this evaluation.

The evaluation will be coordinated by the implementing agency. External and independent organisations and consultants will be engaged to evaluate progress of implementation.

9.3 Reporting

The implementing agency shall organize annual review meetings to review performance of the REMP implementation. This will allow them to make the necessary adjustments in the plan. The progress report on activities would be compiled by the monitoring and evaluation staff. Outcomes from the annual review meetings will be instrumental in the periodic review of the targets. The cost of monitoring should form part of the operating budget of the implementing entity.

An annual report shall be prepared to showcase activities for the calendar year under review. In addition to capturing key statistics as standalone and also in the annual National Energy Statistics, descriptive reports shall be prepared, which will be disseminated on key websites, including that of the Energy Commission.

The following stakeholders would use the monitoring and evaluation information:

- Ministry of Finance;
- Ministry of Energy;
- National Development Planning Commission;
- Ghana Statistical Service;
- Development partners;
- Energy Commission;
- PURC;
- Utilities;
- Civil Society Organizations;
- Primary beneficiaries: the private sector and decentralized entities; and
- Research Institutions.

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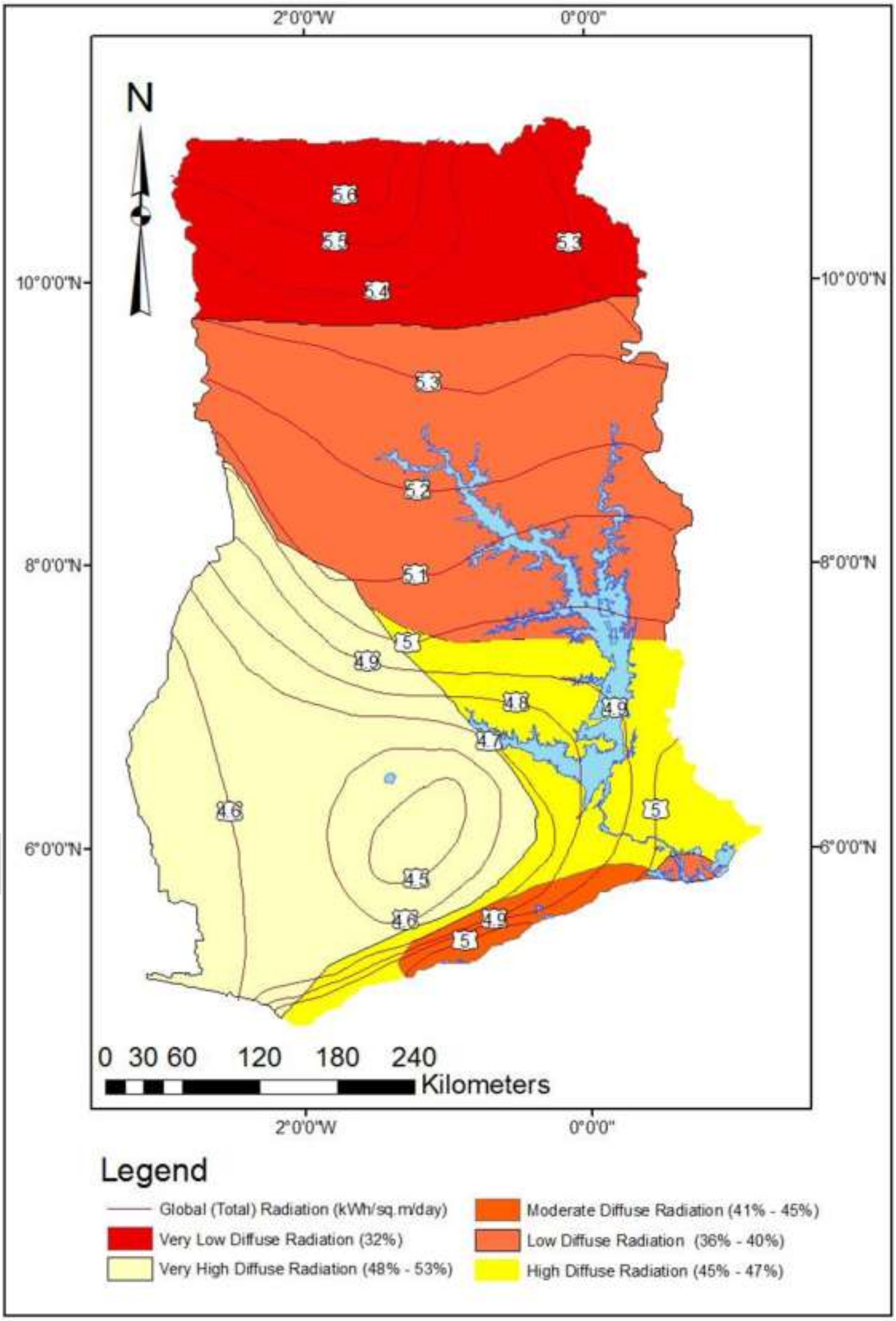
APPENDIX 1 – RESOURCE MAPS

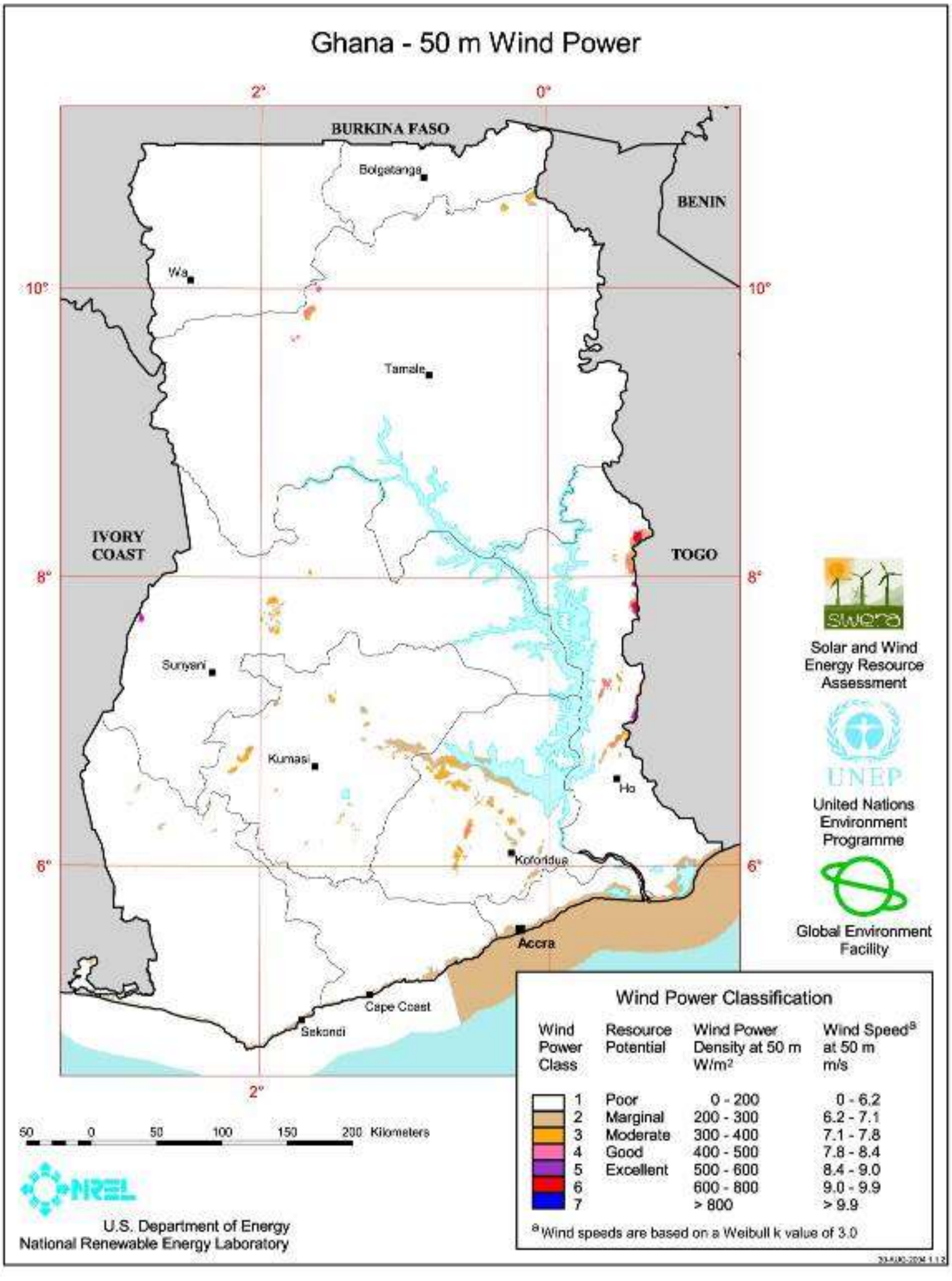


Appendix 1A: Global horizontal solar radiation map of Ghana

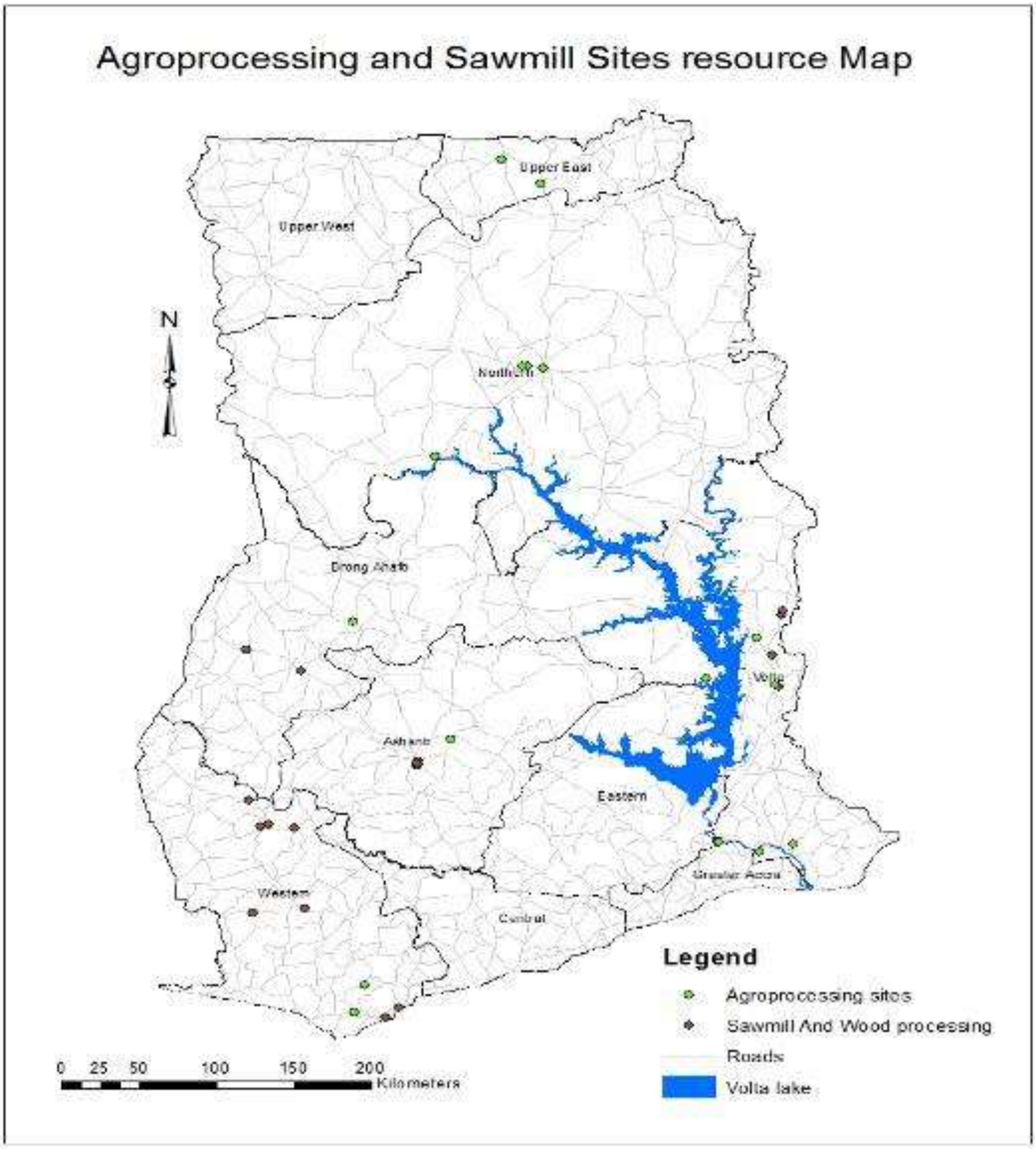
Appendix 1B: Wind measurements carried out by Energy Commission

Start Date of measurement	Site	Geographical coordinates		Elevation (m asl)	Tower Height (m asl)	Kind of Tower	Annual Mean Wind Speed(m/s)
		Latitude (ºN/ºS)	Longitude (ºW/ºE)				
June, 1999	Adafoah	5.79 ºN	0.55 ºE	N/A	12	Tubular mast	5.3
	Apiaku	5.32 ºN	0.20 ºW	50	12	-do-	5.2
	Asemkow	5.21 ºN	3.27 ºW	10	12	-do-	3.7
	Kpone	5.68ºN	0.07 ºE	96	12	-do-	4.9
	Lolonya	5.79 ºN	0.44 ºE	40	12	-do-	5.4
	Oshiyie	5.30 ºN	0.22 ºW	73	12	-do-	3.9
	Pute	5.79 ºN	0.52 ºE	3	12	-do-	5.5
	Mankoadze	5.19 ºN	0.41 ºW	13	12	-do-	6.08
	Tema	5.62 ºN	0.07 ºW	50	12	-do-	5.0
	Warabeba	5.22 ºN	0.35 ºW	50	12	-do-	3.9
	Bortiano	N/A	N/A	N/A	12	-do-	4.8 to 5.5
	Gomoa Fetteh	5.25 ºN	0.28 ºW	44	12	-do-	4.8 to 5.5
May,2006	Anloga	5.47 ºN	0.55 ºE	-7	20	Tubular mast	5.5
	Amedzofe	6.50 ºN	0.25 ºE	740	20	GBC pylon	3.5
	Kue Nkwanta	8.30 ºN	0.35 ºE	327	30	Tubular mast	3.0
	Areeba Nkwanta	8.15 ºN	0.30 ºE	295	30	MTN mast	3.3

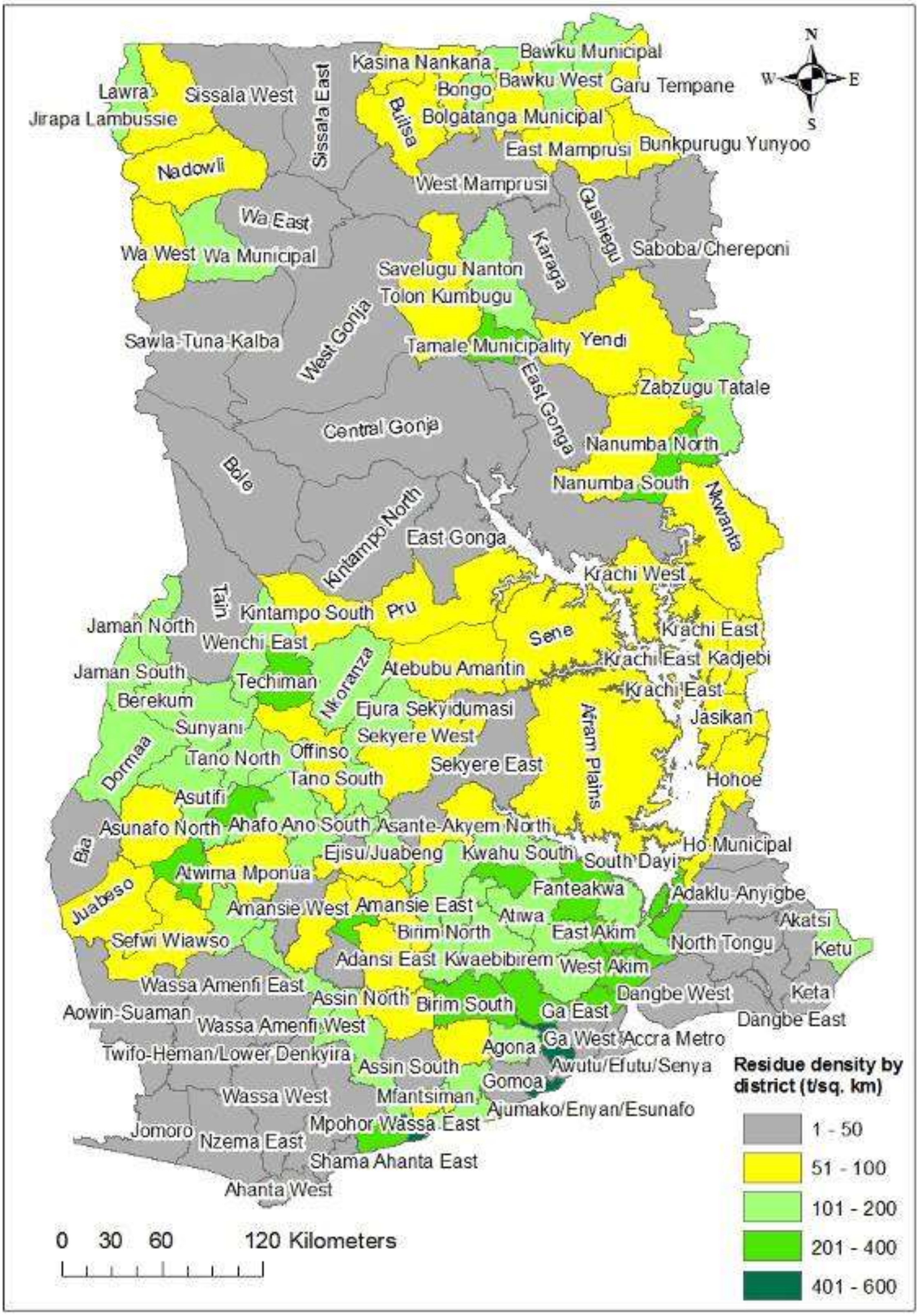
Start- Date	End-Date	Site	Tower Height(m)	Annual Mean Wind Speed(m/s)
Dec., 2011	Nov., 2012	Ekumfi Edumata	60 m	4.67
Dec., 2011	Nov., 2012	Gomoa Fetteh	60 m	4.53
Jan., 2012	Dec., 2012	Sege Ningo	60 m	5.47
Jan., 2012	Dec., 2012	Atiteti	60 m	5.97
Dec., 2011	Nov., 2012	Avata	60 m	5.01



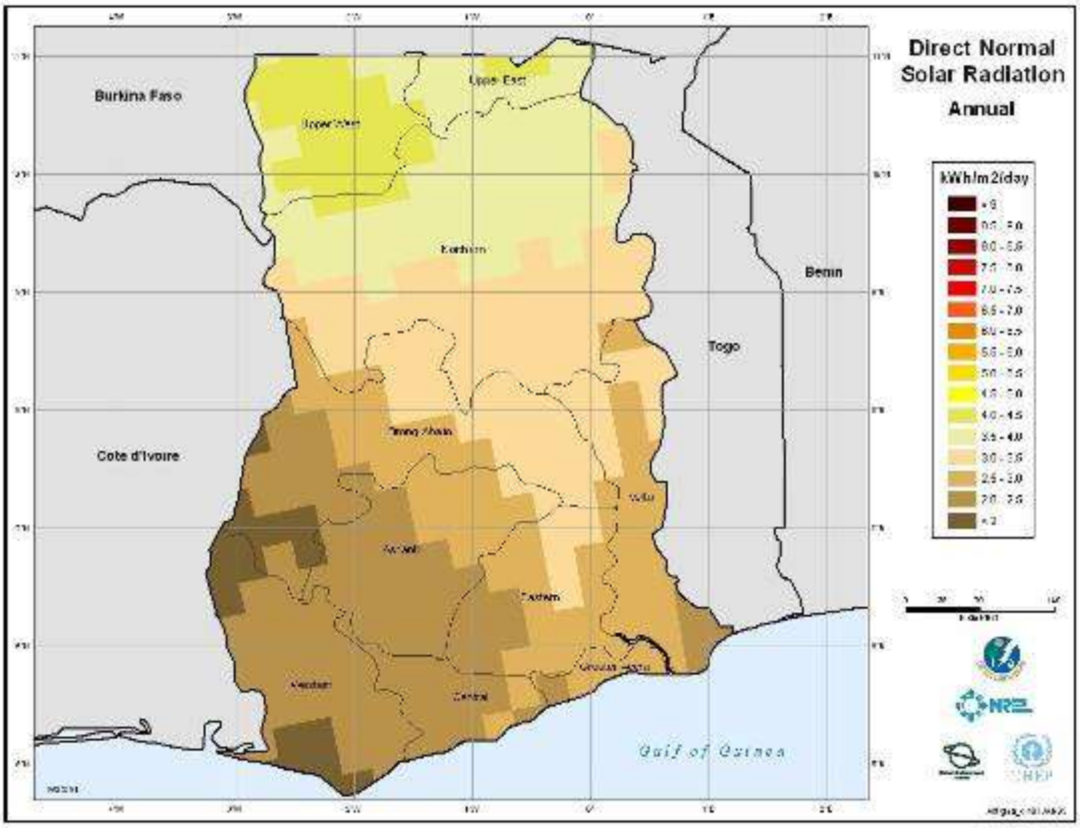
Appendix 1C: Wind resource map of Ghana



Appendix 1D: Location of selected agro-processing and sawmill residue sites in Ghana



Appendix 1E: Residue generation density at district level using 2011 crop production data



Appendix 1F: Direct Normal Solar Radiation for Ghana

APPENDIX 2 – ASSUMPTIONS USED IN SETTING TARGETS

The targets are set on the assumption that private sector would drive development of renewable energy interventions in Ghana given suitable regulatory and fiscal conditions. The baseline is set at 2015. Below are specific interventions and developments considered in setting proposed targets:

Biomass Utility Scale Projects

Currently there is no utility scale biomass power plant operational in Ghana, however, companies like APSD and Kwamoka have plans to install 60 MW and 6 MW biomass plants, respectively by 2020. The assumption is that these projects would be operational by 2020 giving a total of 66 MW, spurring further development by other Independent Power Producers (IPPs). Some projects have already been granted provisional licences by the Energy Commission.

Woodlot cultivation

Baseline was set based on current woodlot planted by the government (Energy Commission) and three known private companies. Targets are based on projections in the Ghana Forestry Development Masterplan published by the Ministry of Lands and Natural Resources (2016).

Charcoal production for export

The local market for charcoal is currently unregulated and does not come from a sustainable feedstock. Hence, baseline was set based on amount of charcoal produced for the export market by 10 licensed charcoal exporters using feedstock from a sustainable feedstock. Projections for are based on anticipated growth in the charcoal subsector.

Briquettes and pellets

Baseline was set based on amount of briquettes and pellets being produced by four (4) companies. Projections are based on expected increase in production capacity of these companies. It is also assumed that as the market develops for briquettes and pellets, and demand increases, production would also increase.

Institutional and domestic cookstoves

Baselines were set based on number of stoves disseminated from 2012 to 2015. The assumed lifespan of the stoves is 3 years. Projections for domestic cookstoves were made based on projected number of households by the set times and SEforALL target to have 2 million households using improved cookstoves by 2020. The assumption is that by 2030, half the total number of households would adopt LPG as primary cooking fuel and the remaining half, an improved biomass cookstove.

For institutional and commercial cooking, there is clearly demand for improved stoves but the barrier is low awareness of the availability of improved technologies and limited number of commercial stove builders. It is therefore assumed that when planned capacity building interventions are implemented, public awareness created and business models developed to remove any financing barrier to adoption, the number of improved biomass institutional stoves adopted or disseminated would increase.

APPENDIX 3 – CASE STUDIES

This chapter presents case studies of existing renewable energy projects which were assessed as part of the masterplan preparation and within the larger Renewable Energy Technology Transfer project.

Biogas for educational institutions – KITA [Source: RETT Project]

Located at Apromase in the Ashanti Region, KITA (Kumasi Institute of Tropical Agriculture) is a non-governmental institution providing vocational technical training and consultancy in general tropical agriculture to practising and prospective farmers. The 40m^3 biogas plant built at KITA was funded by SNV-Ghana. A local consulting body, Centre for Energy, Environment and Sustainable Development (CEESD) was recruited to work with an international SNV senior biogas expert. The project was geared towards developing local capacity to properly design, construct and maintain biogas plants.

KITA has a student population of about 250. This in addition to a pig population of 120, makes available a lot of fermentable biomass in the form of human faeces and pig dung. In addition, food waste from student hostels is also used as feedstock for the digester. The digester is fed with 2 wheel barrows (about 100 litres) of feedstock on week days when school is in session. This reduces during the holidays.

The digester produces about 10 m^3 of biogas daily. The gas line is fitted with a dehydrator for moisture removal and a hydrogen sulphide (H_2S) scrubber. The gas is piped to the kitchen where some students use it as their main source of cooking fuel, replacing wood fuel and charcoal. Part of the gas is piped to a biogas generator for the generation of 10.5 kWh per day. This has contributed to reducing power consumption from the grid and downtimes for administrative staff during power outages.

Presently, the system is self-maintaining. However, some minor maintenance had been carried out on some of the biogas burners in the kitchen. To balance the excreta-to-water ratio, water content in the digester feed is reduced to balance out the water used for flushing toilet. The local consultant from CEESD is regularly invited by the school for maintenance and also to orient new students on how to use the system. There are also guidelines posted on the toilet facility to educate users on the usage of the facility.

Factsheet

Type of digester: Fixed dome
Feedstock composition: Faecal matter, pig dung, kitchen waste
Capacity: 40 m3
Daily gas production: 10m3
Electricity output: 10.5 kWh per day
Project Cost: 70,000 Euros
Other uses of the gas: Cooking

Electricity from forest plantations – APSD, Kwame Danso [Source: RETT Project]

The African Plantations for Sustainable Development (APSD) is developing the largest purpose-built biomass plantation in the West-African sub region. The Norwegian company is also developing a biomass fired power station which will use the biomass plantation as source of feedstock. Since October 2009, African Plantations for Sustainable Development has been developing an 80,000-hectare site near Atebubu, in central part of Ghana and on the Western shores of the Lake Volta. The project is growing Eucalyptus as a biomass feedstock for an initial phase of 60MW of baseload power generation. Eucalyptus was selected because it is drought resistant and grows faster. The project has a nursery with capacity of 20-25 million seedlings per year. The trees do not require irrigation and are rain fed only, but are adaptable to periods of drought.

A 60 MW power plant is planned for the first phase, generating about 426 GWh of baseload power to the grid. The plant will require 700,000 m^3 of timber per year (or about 4,500 hectares). The trees take 5 years to reach 25 m at maturity, and are then harvested on a rotation basis, with the new seedlings being planted in the furrows between harvested stumps. The ash produced after firing the wood in the plant will be used as fertilizer in the plantations. Harvesting is planned to take place all year and will be mostly mechanical.

APSD strives to develop the project in accordance with best practices, preserving the remaining natural forest together with the riparian belts close to permanent or seasonal water sources. According to APSD, most fertile lands are retained by local farmers to grow food whiles less fertile areas are planted with Eucalyptus. Completion of the first stage is expected to provide a permanent sink for about 2 million tonnes of CO_2. The company has a strict policy to not relocate any settlements within its operational area. In cases where farmers are willing to relocate their farms, APSD assists them in identifying a suitable replacement area and assist with land clearing and preparation. The project has already employed over 1,000 people, planting 40,000 trees per day and has planted 12-13 million trees on about 8,000 hectares of land as of July 2016.

<u>Factsheet</u>

Plantation size: 8,000 ha (July 2016)

Number of trees: 12-13 million

Capacity: 60 MW (first phase)

Annual output: 426 GWh

Total savings: 2 million tonnes CO_{2e}

© RETT Project

Biomass Cogeneration – GOPDC [Source: RETT Project]

The Ghana Oil Palm Development Company (GOPDC) is located at Kwae in the Eastern region of Ghana. The company, previously owned by the Government of Ghana, is now wholly owned by Societe d'Investissement pour l'Agriculture Tropicale of Belgium. It has about 22,500 hectares of oil palm plantations at its Kwae and Okumaning estates in the Eastern region which spreads over a radius of about 23 km. The processing plant produces 210,000 tonnes of oil per year.

GOPDC supplies the Kwae community with power generated from a biomass-fired cogeneration plant. Biomass solid waste (palm fruit fibre and kernel shell) from the processing plant is fired to run a steam turbine generator. The company has the potential to generate 4MW but currently generates 2.5 MW, with a spare 1.5 MW turbine generator. The company also has a 2 x 1000 m^3 biogas plant which produces biogas for heat and steam generation for the refinery plant processes. The methane and carbon dioxide content of the biogas are 56-60 % and 30 % respectively.

The installation of the biogas plant was completed in September, 2014, by contractors from South America and funded by GOPDC. The cost of the biogas and biomass power plants are 4.5 million euros and 3.5 million euros with a payback period of 11 and 9 years respectively. The biogas plant produces 18000 m^3/day of biogas for the plant. This has displaced the 615,000 litres of diesel that was previously consumed by the plant per year.

GOPDC is prepared to sell excess power of 1.5 MW provided there is a good proposal for off-take. They depend solely on energy from renewable sources. Power from the national grid is used only during emergency situations such as shut down and maintenance of the biogas/biomass cogeneration plant.

<u>**Factsheet**</u>

Solid biomass plant capacity: 4 MW

Biogas plant capacity: 2000 m^3

Methane content: 56-60 %

Savings: 615,000 litres of diesel per year

1000m^3 biogas reactor
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Ejura solar-biomass hybrid dryer [Source: RETT Project]

The Ejura solar biomass hybrid dryer is managed and operated by Pens Food Bank Enterprise in Ejura in the Ashanti region of Ghana. Pens Food Bank was initially using a mechanical dryer for drying grains but could not sustain its operation due to the high running cost. The solar biomass hybrid dryer has proven to be a clean, less expensive and more efficient means of drying even in the wet major season.

The solar biomass hybrid dryer was built by Pens Food Bank in collaboration with the Agricultural Engineering Department of KNUST in July 2015. The total cost of the facility is USD 18,000. The project was funded by Pens Food Bank (20 %) and a UK based organization (80 %). The dryer can be used for drying 5 tons of produce per batch (2 batches/day) for 8 hours. It achieves a 100 % destruction of insects and larvae. The biomass furnace uses 30 kilos of corn husk for drying harvests per batch during the major season. The biomass furnace pump and the air circulation fans in the dryer are powered by solar PVs. The cost of drying using the solar biomass dryer is GHC 4 per bag which is cheaper than the GHC 20 that was initially charged for drying with the mechanical dryer. Farmers patronize the facility because it is cheap and provides additional premium of dry grains over wet grains.

<u>**Factsheet:** Capacity of dryer – 5 tonnes; Total cost – USD 18,000.</u>

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Solar Irrigation System – Tamalugu [Source: RETT Project]

The solar irrigation system at Tamalugu is equipped with a 15kW DC pump capable of delivering a maximum 166,000 litres of water per hour. The system currently irrigates 28 acres under furrow irrigation and about 3 acres of drip irrigation. Water for irrigation is from a tributary of the White Volta, whose level reduces during the dry season. Key project information includes the following:

- Prior to the installation farmers invested most of their earnings on fuelling and servicing petrol pumps for irrigation;
- The farmers have formed a co-operative made up of 17 men and 20 women;
- Each farmer pays GHC100 to water per acre for the whole season;
- Previously, Iddrisu Abubakari (a farmer), could produce 5 bags of onions from 5 acres of land in the wet season, but with the solar irrigation system he is able to produce more than 5 bags of onions from a quarter acre of land in the dry season;
- Among the maintenance practices are plumbing works and periodic cleaning of the panels.

Factsheet: Module capacity – 15 kW; Pump capacity – 15 kW DC; Discharge – 166,000 l/h; Total cost – USD 80,000. Total land size – 30 acres

© RETT Project

Mini-grids – Pediatorkope [Source: RETT Project]

The southeastern island of Pediatorkope is located in the Dangme East District Ghana. The community has a population of about 1,500 people with mussels farming on the Volta River as their main occupation. A solar/wind hybrid power plant has been installed to provide power for the communities on the island as part of the outputs of the Ghana Energy Access and Development Project (GEDAP). This USD 800,000 project was constructed by the Spanish company, Trama Techno Ambiental (TTA), with a five-year warranty agreement. The system was completed in April 2015 and provides power to 110 households and a clinic and 3 businesses in the communities. It also includes 120 poles mounted with LED streetlight.

Factsheet: The system comprises a 39.5kWp Solar PV generator, 11kW wind turbine, 30kVA genset with 48x3528Ah battery bank and 6x48kVA inverter systems with a three-phase AC backbone distribution infrastructure.

Top left: solar panels mounted on high metallic structures. Top right: battery bank for storage. Bottom left: 30kVA diesel generator. Bottom right: transmission lines with LED streetlight