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GIS-BASED SUPPORT FOR IMPLEMENTING POLICIES AND PLANS TO INCREASE ACCESS TO ENERGY SERVICES IN GHANA

Appendix 4 – Template for Developing a GIS Based Decision Support System for Increasing Access to Energy in ECOWAS Countries

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1 Introduction

1.1 Background

In sub-Saharan Africa and for that matter ECOWAS, energy policies are aimed at ensuring reliable and cost-effective supply of high quality energy services for households, businesses, industries and the transport sector nationwide. The need to secure future electricity and modern fuel supplies has been touted as the pivot of the Millennium Development Goals (MDGs). However, in spite of the popular notion underpinning energy access-poverty reduction nexus, policies and plans intended to create enabling environment for an improved energy access are seldom evaluated in most ECOWAS countries. The case of Ghana is no exception. For the people who lack access to electricity and who depend on traditional biomass (wood, charcoal, coconut husk, etc.) for cooking; their hope is to have sustainable access to modern energy services. This is particularly important because without modern energy, services such as lighting, cooking, refrigeration, pumping, transport, communication, etc. would be overloaded with drudgery. The energy access targets set by ECOWAS which aims to provide a useful guide for an improved access to modern energy services to at least half of the West African population by 2015 is very timely.

Effective assessment of energy access most often requires the use of Geographic Information System (GIS) as a planning tool. This is necessary for a timely analysis and review of population and service distribution (such as improved heating/drying systems and cook stoves, Liquefied Petroleum Gas (LPG) distribution and mechanical power), grid-extension, mini-grid and off-grid plans. Using a GIS-based system is useful because it seeks to provide data and analysis to enable policy makers, private sector and development partners like EU Energy Initiative, UNDP, the World Bank, and regional organizations such as ECOWAS to determine the additional measures or adaptations that will be needed to achieve the energy access targets in the sub- region.

In Ghana, this assessment was undertaken by The Energy Center (TEC) of the Kwame Nkrumah University of Science and Technology, Kumasi. The assessment sought to employ and complement existing policies, strategies, plans and recommendations in the energy sector such as the Energy for Poverty Reduction Action Plan (EPRAP) and the Ghana Energy Development and Access Project (GEDAP) to achieve national goals and the MDGs.

This template is a document that describes the project implementation of the GIS-based Energy Access Project (GIS-EAP) in TEC. It provides needs, roles and responsibilities, prerequisites and steps involved in implementation of such projects.

Editorial Note: The focus of this section is to give a brief background about the project

1.2 The role of GIS in Energy Access Projects

Improving energy access at all levels will demand the use of modern technological tools like the use of Geographical Information System (GIS) to make intelligent and comprehensive decisions for energy planning, management and monitoring. GIS has been defined in so many ways by people from diverse professional backgrounds. As per the definition given by the United States Geological Survey, GIS can be defined as “a system of hardware, software and procedures designed to support the capture, management, manipulation, analysis, modelling, and display of spatially referenced data (i.e. data identified by their positional coordinates) for complex planning and management problems

A GIS program has the ability to combine variety of datasets from different sources (such as wind, solar, geothermal, biomass, substations, MV lines, LPG, hydro-dams, biogas plants sites), process them and integrate the processed datasets into thematic project maps. Most GIS programs are designed to perform sophisticated calculations to locate least-cost path for siting linear features such as transmission and distribution lines and so on. GIS gives people the geographic advantage to become more productive, more aware, and more responsive to use of resources; natural or manmade.

Editorial Note: This section introduces the need for using GIS for energy access projects

2 Overview of GIS-EAP Implementation

2.1 Project Objectives

The general objective of the GIS-EAP was to contribute towards effective implementation of policies and plans for achieving energy access targets by 2020 through continuous review and adaptation.

The specific objectives were, to:

1. Review existing energy policies, strategies and plans for increasing energy access in Ghana with reference to the targets set in the Government's policy statements/documents, the ECOWAS White Paper and the MDGs.
2. Use GIS to collate and analyze national level data and provide timely information on population distribution, services, economic activities, and status of energy access programs.
3. Identify the gaps in energy policies and plans for achieving expected energy access targets by 2020 and proffer timely mitigation measures.
4. Develop methods and tools to facilitate business models, investment plans and capacity development to complement current planned activities to achieve the energy access targets by 2015.
5. Facilitate project identification, planning implementation and impact assessment for the Energy Commission of Ghana, the Ghana Ministry of Energy and the ECOWAS Commission for timely development, implementation and monitoring of energy access strategies.

Editorial Note: A **clea**r set of objectives is needed to keep the project in focus

2.2 Intended Audience

The project intended audience include:

- Government Ministries particularly Energy Ministry
- Utility Companies
- National Statistical Services
- National Petroleum Authorities/Agencies
- Project Implementers /Managers
- ECOWAS Commission
- International Organisations
- NGOs etc.

Editorial Note: The focus of this section is to highlight project stakeholders and key beneficiaries

3 Project Approach

3.1 Human Resources and Expertise

- The GIS-EAP team of experts comprising the following:
- One (1) **Project Director** who is the administrative head of the project and is responsible for the successful implementation of the project.
- One (1) **Project coordinator** who will oversee the project and coordinate the project team members.
- Two(2) to Three (3) **GIS experts** who will be responsible for processing and analysing geospatial data
- **Energy access experts**. Their number will depend on the sectors of energy to be tackled and their various specialisations. Their tasks will be to review existing energy policies, strategies and come up with plans for increasing energy access.
- **Computer Programmer** who will develop a toolkit for collating, storing, and analysing and viewing results
- **Field staffs**: The number of field staff to be used depends on how wide and sparse the data collection points in the study area are and the amount of data to be collected. It also largely depends on the timeframe allocated for data collection. The duty of the field staff will be to collect all primary and secondary data needed for the project. About three (3) to five (5) people should be sufficient.
- One (1) to two(2) **Data entry staffs** who will be responsible for entering field data and organising it in the correct formats for easy processing.
- One (1) **Accountant**: Due to the nature of the project, there should be an accountant to manage the financial matters of the project.

Editorial Note: A project team is needed for the execution of projects of such nature. This team could comprise but not limited to above mentioned experts. Clearly defining the roles and responsibilities for each team member is essential for successful implementation

3.2 Technical Infrastructure

Technical infrastructure refers to the necessary physical, organizational, administrative and cultural environments that are needed for the successful implementation of the project. The detailed technical infrastructure requirements for executing this kind of project are enumerated below:

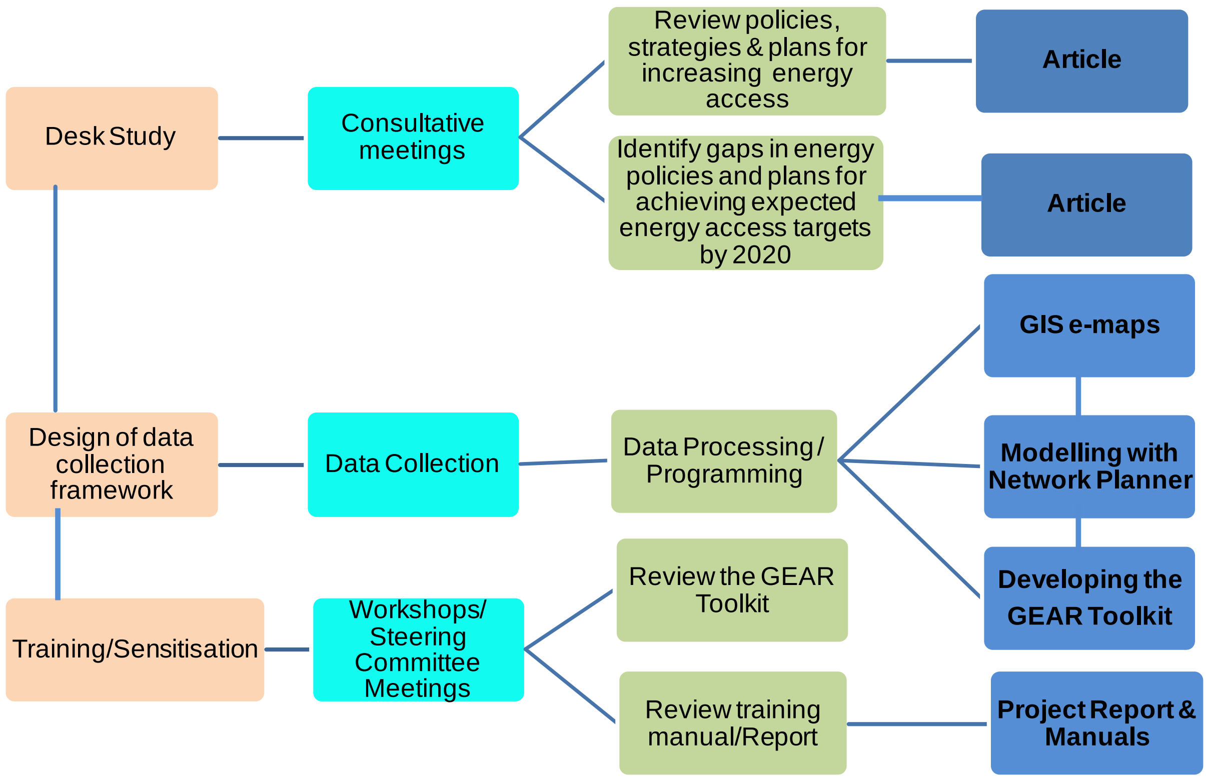
- The hardware system comprises of the computers with its accompanying peripherals such as system units, high resolution monitors for display, keyboard for entering attribute data, digitizers or scanners for capturing spatial data input, printers and plotters for hardcopy data outputs and hand-held GPS devices for field data capturing.

- The GIS software includes the programs for driving the hardware. Notable GIS software that can be used to execute this project includes ArcGIS, IDRISI, MapInfo, MapWindow, Quantum GIS and GeoMedia.
- Reliable data in the correct formats (georeferenced) are needed
- Due to the nature of this kind of project and the large number of human resources needed, there should be a large working space available to accommodate these working professionals to execute their tasks effectively.

> **Editorial Note**: For a Geographical Information System to function effectively, it will require the four components namely hardware (computer system), GIS software, data and human resources (technical-know-how) listed above.

3.3 Project Methodology

The project methodology is summarised in the flow chart below:



> **Editorial Note**: This section gives the flowchart of the methodology to be employed to achieve the set objectives

3.3.1 Desk Study

The project should first begin with a desk study to investigate the policies, strategies and plans for increasing energy access. Through this study, gaps in energy policies and plans for achieving expected energy access targets can be revealed. Moreover, desk study can reveal what has been done and additional tasks to be done to increase energy access in a country. There should also be consultation meetings with relevant agencies such as Energy Ministries, Utility companies, Statistical services etc. to discuss the data needs for the completion of the project.

Editorial Note: Desk study is very important to address gaps in previous research and to save resources especially time and money (i.e. with regards to the collection of primary and/or secondary data which may already have been collected)

3.3.2 Data Acquisition

One of the vital components of every project is the data requirements for the successful execution of the project. Table 1 shows the possible data requirements for the project. These datasets can be obtained from the various relevant institutions in a country; some have been listed but are country specific. Some of the locational datasets (wind sites, mini hydro sites, LPG stations) that could not be acquired from secondary sources or can be collected on the field using hand-held GPS devices.

Editorial Note: A data framework is essential for the collection of data. It helps with the prioritisation of data needs

Table 1: Summarised Data Requirements for The Project

DATA TYPE	SOURCE	DESCRIPTION	FORMAT
1.0 Base Maps			
1.1 Population	National Statistical Service (NSS).	District level data with projections up to the year of interest	preferably soft cop in excel, access, word etc
1.2 Regional/ District/Province Boundaries	National Survey Department (NSD)		preferably soft copy as shapefiles or hardcopies to be scanned
1.3 Towns	NSS and NSD	Names of Communities, their districts/provinces etc with their geolocations if possible	preferably soft copy in e-map, excel, access or as shapefiles
1.4 Road Network	NSD / Dept. of Urban and Feeder roads/ Highway Authorities/Ministries of Roads and Transportation	Road network (rural/urban), foot paths etc	preferably soft copy as shapefiles
1.5 River Systems	NSD and Hydrological Services department (HSD)	Major rivers that has/can be dammed	preferably soft copy as shapefiles
2.0 Social Services			
2.1 Health	Ministry of Health/National Statistical Services	Hospitals and clinics with and without access to electricity	preferably soft copy in e-map, excel, access, word, shapefile etc
2.2 Education	Ministry of Education/ National Statistical Services	Basic & Secondary schools with and without access to electricity	preferably soft copy in e-map, excel, access, word, shapefile etc

2.3 Water supply	Ministry of Water Resources; Water Resources Agencies, NGOs	Towns/communities with and without access to potable water	preferably soft copy in e-map, excel, access, word, shapefile etc
3.0 Economic Activities			
3.1 Access to Thermal energy /mechanical power (Animal, engine)	Ministries, Food and Agriculture (MOFA). Organisations, District/ Province Assemblies, NGOs, etc.	Towns/communities with access to thermal energy (e.g. Ovens, stoves, boilers)/mechanical power (e.g. diesel engines for grinding mills)	preferably soft copy in e-map, excel, access, word, shapefile etc
3.2 Access to irrigation facilities	Ministry of Food and Agriculture, Irrigation Development Authority, Water Boards, etc	Towns/communities with access to irrigation facilities	preferably soft copy in e-map, excel, access, word, shapefile etc
3.3 Enterprises with access to modern forms of energy	Ministry of Trade and Industry; NSS/ NBSSI/AGI	rural micro and small enterprises (MSEs) with and without electricity	preferably soft copy in e-map, excel, access, word, shapefile etc
3.4 ICT	Ministry of Communication (MOC), Telecommunication service providers, National Communication Authority, NGOs	Availability and powering of telecommunication systems at community levels (e.g. e-care, repeater stations)	preferably soft copy in e-map, excel, access, word, shapefiles etc
4.0 Access to electricity			
4.1 Grid, Substations	MOE; Energy distribution/ Transmissions companies (EDTC), Energy Commissions (EC), NSS.	Network map and National level access by Communities/Households	preferably soft copy in e-map, excel, access, shapefiles etc
4.2 Generators	EDTC; MOE, EC	Households/Towns/ Communities that rely on electricity from Diesel/Petrol powered Generators	preferably soft copy in e-map, excel, access, shapefile etc
5.0 Access to cooking Fuels/ technology		*This excludes Electricity*	

5.1 Improved cook stoves			
5.1.1. Number & Location of manufacturing shops	MOE; UNDP; EC; NSS	Number & Locations of manufacturing shops	preferably soft copy in e-map, excel, access, word, shapefile etc
5.1.2 Household level access	MOE; UNDP; EC; NSS	Household level data	preferably soft copy in e-map, excel, access, word, shapefile etc
5.2 LPG			
5.2.1. Number & Location of filling stations	National Petroleum Agencies (NPA), MOE, EC., Environmental Protection Agencies	Number and Location of Retail Stations	preferably soft copy in e-map, excel, access, word, shapefile etc
5.2.2 Household level access	MOE; UNDP; EC; NSS	Households using LPG	preferably soft copy in e-map, excel, access, word, shapefile etc
6.0 Renewable energy			
6.1 Solar PV	MOE; EDTC; EC	household level access	preferably soft copy in e-map, excel, access, word, shapefile etc
6.1.1 Home Systems	MOE; EDTC; EC	household level access	preferably soft copy in e-map, excel, access, word, shapefile etc
6.1.2 Water Pumping	MOE; EDTC; EC		preferably soft copy in e-map, excel, access, word, shapefile etc

6.1.3 Other (e.g. grid connected systems)	MOE; EDTC; EC		preferably soft copy in e-map, excel, access, word, shapefile etc
6.2 Solar Thermal	MOE; EDTC; EC	household level access	preferably soft copy in e-map, excel, access, word, shapefile etc
6.2.1 Water heating	MOE; EDTC; EC	household level access	preferably soft copy in e-map, excel, access, word, shapefile etc
6.2.2. Crop drying	MOE; EDTC; EC	household level access	preferably soft copy in e-map, excel, access, word, shapefile etc
6.2.3. Other (e.g Solar still)	MOE; EDTC; EC	Household level access	preferably soft copy in e-map, excel, access, word, shapefile etc
6.3 Wind energy	MOE; EDTC; EC	Town/community level access (no large-scale development project is implemented)	preferably soft copy in e-map, excel, access, word, shapefile etc
6.4 Mini-hydro	MOE; EDTC; EC	Locations and number of mini-hydro plants	preferably soft copy in e-map, excel, access, word, shapefile
6.5 Biogas			
6.5.1 *Household*	MOE; UNDP; EC;	Households with access to biogas	preferably soft copy in e-map, excel, access, word, shapefile
6.5.2 Community	MOE; UNDP; EC;	Communities with access to biogas	preferably soft copy in e-map, excel, access, word, shapefile

6.5.3 Industrial	MOE; UNDP; EC;	Industries with access to biogas	preferably soft copy in e-map, excel, access, word, shapefile
6.6 Biofuels			
6.6.1 Plantations	MOE; EC;	Town/community with access and possibly area of plantations	preferably soft copy in e-map, excel, access, word, shapefile
6.6.2 Bio-refinery/ Processing	MOE; EC;	Town/community with refinery/processing facilities	preferably soft copy in e-map, excel, access, word, shapefile

3.3.3 Data Processing

The data processing should be carried out in three (3) phases namely:

Phase1 - Publishing GIS e-maps: Datasets are cleaned to remove errors which will be costly when left undetected. The datasets should then be edited from its crude formats to a data formats that will be recognised by the GIS software used for the analyses of data. A geo-database is then created from the collection of all the datasets including all the attribute information of the data requirements. Spatial analysis is then performed on the created shapefiles data formats generated from these datasets. The resultant outputs from this spatial analysis are the generation of the various GIS e-maps which includes the following:

- Map showing locations of electricity substations.
- Map showing locations of mini-hydro dams.
- Map of Towns/Communities with access to irrigation facilities by district and region.
- Map of Towns/Communities with and without access to potable water
- Map of Basic Schools with and without access to Electricity
- Map of Communities with access to biogas
- Map showing locations of LPG stations
- Map showing locations of micro and small scale enterprises with & without access to electricity
- Map of Communities with Clinics and Hospitals and their electrification status by district and region

Phase2 - Modelling with Network Planner: This model is developed by Modi Research Group based at the Earth Institute, Columbia University. This is an open sourced web-based model (www.october.meach.columbia.edu) used to explore detailed estimation cost of electrification technology options (Grid and other decentralised options) for un-electrified communities. The key inputs needed to be used by this model are summarised in Table 2.

Table 2: Data Needs for the Network Planner Software

SN	DATA CATEGORY	DATA REQUIRED	SOURCE(S)
1	Low voltage Lines	Cost per meter or kilometer of lines	Ministry of Energy (MOE), Electricity Distribution Companies (EDC)
		Equipment costs (per connection)	
		Equipment O&M cost	
		Line lifetime	
		Line O&M cost per year	
2	Grid Extension	Transformer Capacities Available (kW)	MOE, EDC
		Distribution loss	
		Installation cost per connection	
		Medium Voltage Line cost per meter	
		Medium Voltage Line lifetime	

		Medium Voltage Lines O&M costs per year Cost of transformers Transformer lifetime Transformer O&M costs	
3	Diesel Generator	Available System Capacities (kW) Diesel fuel (litres) consumed per kWh Diesel generator cost per kWh of energy produced Diesel generator installation cost (as fraction of generator cost) Diesel generator lifetime Diesel generator O&M cost per year (as fraction of generator cost) Distribution Loss	Diesel Generator companies, EDC.
4	Solar System	Available System Capacities (kW) PV balance (other accessories, excluding battery) cost as fraction of panel cost PV panel lifetime PV balance (other accessories, excluding battery) life time PV battery cost per kWh PV battery lifetime PV battery kWh per PV component kW PV component effieiciency loss PV component O&M cost per year as fraction of component cost PV panel cost per PV component kilowatt	MOE – Renewable Energy Directorate, Solar Energy Companies; Solar Laboratories
5	Social, Economic and Finance metrics	Economic Growth Rate Population Growth Rates Electricity Demand Growth Elasticity of Electricity Demand Interest Rate	National Statistical Service (NSS); Country's central banks; EDC
6	Electricity demand and/or consumption data (in kW and kWh)	Residential Social infrastructure (schools, health facilities, government offices, etc Commercial and industry Public uses (such as street lighting)	EDC, NSS, Ministries of Health and Education
7	Price/cost data for both Grid and off-grid (solar, diesel) technologies	Materials for grid extension (poles, wire, transformers, etc.), and for off-grid (solar and diesel generation equipment) Recurring costs (operations & maintenance), and "soft costs" such as system design and installation Electricity connection fees for households, businesses (single-phase and three-phase)	EDC, MOE
8	Geo-spatial location data	Coordinates of Communities and locations of existing grid networks plus the population data for those communities.	EDC, MOE

Some of these datasets should be computed upon consultations with the various energy agencies and experts. Once all the data requirements are entered in the model and run, a map of proposed system of electrification option for each community size coupled with its proposed MV- line networks are shown. In addition, a detailed cost of each electrification technology option (initial and recurring costs) is estimated coupled with its desired capacity for each technology options for meeting such projected electricity demands of the communities. The levelised cost of each electrification technology option is also provided for investment purposes.

It is worth noting that to equip the project team with all the necessary understanding about the model, a team/ an expert from Modi Research Group may be invited to introduce the project team to this model.

Phase3 - GIS-Based Energy Access Review (GEAR) toolkit development: A GIS programmer is needed to develop a comprehensive energy toolkit that will compile, analyse and present data for energy planning, management and monitoring. A visual studio programming language coupled with MapWindow plug-in could be used to create this toolkit. This toolkit should be developed with its main input datasets from the results obtained from the Network Planner and the shapefile datasets generated from the spatial analyses performed earlier. Frequent workshops and seminars should be organized to review the GEAR toolkit for improvement and updates.

Editorial Note: This section focuses on the various phases involved in the implementation of the project

4 Key Deliverables/Outputs

The listed items below are expected from this kind of project:

1. Existing energy policies, strategies, planning tools reviewed for energy access needs.
2. Assessment of Energy gaps using GIS tools, national level data on population distribution with information on social services, economic activities, and planned energy services.
3. A report on the energy gaps with targets set in the Government's policy statements/documents, the ECOWAS White Paper and the MDGs.
4. GIS e-maps developed for showing locations of energy infrastructure and services that will guide policy makers for better managerial purposes.
5. Network Planner outputs including project household count, projected demand for the communities, projected education, health, enterprise facility counts and electricity demand, LV-line operations and maintenance cost per year, available system size, capacity, proposed electrification technologies for the communities, etc
6. A toolkit developed to facilitate energy planning and monitoring.
7. Workshops organised to sensitise relevant energy and other public institutions on the outcomes of the project to assist them in decision making.

Editorial Note: This section highlights the deliverables for the project

5 Challenges

Challenges that are expected to be encountered in this kind of project may include the following:

- **Data acquisition** –unavailability of data and the unwillingness by institutions to give out data freely. In addition a high hierarchy of bureaucratic system to follow in order to acquire data for the project is tiresome. To solve this challenge, the project team should include budget on data acquisition and pay for data acquisition. This will fast-track the process of data collections.
- **Data format** - The format of the datasets are normally in its crude format and therefore there is the need to convert them to the desired and acceptable format compatible with the software being used. Some of the datasets acquired will be without geographical reference and capturing them in GIS software will become difficult.
- **Bulk datasets** – Due to the large datasets involved, organisation of data becomes a problem. When working with bulky datasets there is the tendency of disorganising the project data. There should be a way of organising the project data in order to smoothly and easily locate data when needed.
- **Accounting system** – Looking at the nature of the project and the financial involvement, there should be a proper accounting system to manage the inflows and outflows of money in the system. A proper book and record keeping should be employed to avoid any financial problems.

Editorial Note: There are bound to be challenges in the implementation of every project but turning them into opportunities demands great creativity. It must be emphasised that the challenges should not bring the project to a premature end: there should always be a way around the challenges.

6 Project communication strategies

A project like this will require an effective way of communicating to the intended audience. The question of how to contact your audience can be answered through organising meetings and workshops with them to discuss the project and the way forward from where the project has reached. Online mailing service is one effective approach of sending and receiving messages.

Editorial Note: In addition to these strategies, the use of tele/video conference facilities such as Skype and Webinar calling can be employed to communicate to your intended audiences, not necessarily bringing them to one place which is costly in some cases. Online social networks such as Facebook, Twitter, yahoo messenger and others can be employed for communicating purposes.

7 Conclusions

To conclude, the GIS-Based Energy Access project has been successfully implemented in Ghana. It is doable and can be replicated in any country in the sub-region. It can be realised that the project is quiet intensive and will require special group of expertise such as Energy Policy and Planning, GIS and Computer programming. Considering the volume of data, expertise needed, technical infrastructure requirement, communication etc., funding is key for successful implementation of the project. The use of GIS and the development of GIS-Based Energy Access Review (GEAR) toolkit would guide and support policy makers and energy planners to make informed and effective energy planning and policy decisions.

Editorial Note: GIS-Based Energy Access projects can easily be replicated in all the ECOWAS Countries. What is needed is funding and the required expertise.

The Final report of the GIS-Based Energy Access Project (GIS-EAP) implementation in Ghana can be obtained from The Energy Centre (TEC), College of Engineering, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana.

For further information please visit the website of TEC: energycenter.knust.edu.gh