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Project: Support to SE4ALL Country Actions processes in Ghana, Kenya and Tanzania

-Ghana-

Identification of Technology Transfer, Business Model Understanding, Risk Identification and Receptivity Capacities of Selected Public and Private Institutions in Ghana

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EXECUTIVE SUMMARY

Scientific and technical capabilities that exist in government and private sector institutions in a country drives industrial development and helps raise living standards. Ghana is home to a large number of institutions that are known internationally for their research capabilities in sustainable energy issues and have contributed in varying degrees to the SE4ALL initiative in Ghana. Developing, augmenting and strengthening capabilities of these institutions is important to achieve as well as sustain these achievements in the three SE4ALL objectives of Ghana: universal energy access, increase in the renewable energy production and increase in energy efficiency. Technology development capabilities and ability to absorb transferred technologies are an important element of these capabilities. Energy access and clean energy development also requires capabilities to develop and implement appropriate business models to deliver energy services. Also important are the capabilities to assess the risks associated with technology and business model innovations and to put in place measures including regulations to manage these risks.

This report was written as part of the consultancy work carried out by the consultants under the project "Support to SE4ALL Country Actions processes in Ghana, Kenya and Tanzania", which is financed by the African Climate Technology Finance Centre and Network (ACTFCN) as part of a UNFCCC/GEF initiative conducted with regional multilateral development banks, in this case, the African Development Bank (AfDB). The objective of ACTFCN is to support Sub-Saharan African (SSA) member countries in scaling-up the deployment of low-carbon and climate resilient technologies for climate change mitigation and adaptation. On the mitigation side, the project supports the implementation of the Sustainable Energy for All (SE4ALL) initiative in Africa. The project contributes to advancing the SE4ALL initiative in three countries, and this evaluation and technical assistance scoping effort is to support the implementation of SE4ALL initiative in Ghana with an emphasis on climate technology deployment. It is envisaged that the proposed technical assistance for development and augmentation of technological and business capabilities will result in achieving the SE4ALL objectives of Ghana and in institutionalizing national capabilities that will sustain national efforts on clean energy and climate change.

In line with the objectives of the assignment "Support to SE4ALL Country Actions processes in Ghana, Kenya and Tanzania" this report focuses on Ghana and presents the Ghanaian context regarding technology transfer activities, i.e. who the key players are and what capabilities they have. It also provides an assessment of the technology transfer and institutional capacity building needs based on the results of a survey of the institutional capacities in Ghana.

The outcomes of this assessment provide the basis for designing a technical assistance programme to further develop and implement technology transfer activities as part of the SE4ALL initiative for Ghana.

ABBREVIATIONS

AA	Action Agenda
AC	Alternating Current
AESD	Agricultural Engineering Services Directorate
AfDB	African Development Bank
ARC	Aprovecho Research Centre
AU	African Union
BSc	Bachelor of Science
CAP	Country Action Plan
CFL	Compact Fluorescent Lamp
CFP	Country Focal Point
CSIR	Council for Scientific and Industrial Research
CTCN	Climate Technology Centre and Network
DC	Direct Current
DSTC	Deng Solar Training Centre
EC	Energy Commission
EF	Energy Foundation
EPC	Engineering, Procurement and Construction
GCIC	Ghana Climate Innovation Centre
GDP	Gross Domestic Product
GEF	Global Environment Facility
GIZ	Gesellschaft für Internationale Zusammenarbeit
GoG	Government of Ghana
GSES	Global Sustainable Energy Solutions
HND	Higher National Diplomas
IDRC	International Development Research Centre
IFC	International Finance Corporation
IWAD	Integrated Water and Agricultural Development Ghana Ltd
JICA	Japanese International Cooperation Agency
KITE	Kumasi Institute of Technology, Energy and Environment
KNUST	Kwame Nkrumah University of Science and Technology
LED	Light Emitting Diode
MEST	Ministry of Environment, Science and Technology
MESTI	Ministry of Environment, Science, Technology and Innovation
MIT	Massachusetts Institute of Technology
MoP	Ministry of Power
NE	New Energy
NGO	Non-Governmental Organisation
NRD-UNISS	Nucleo Ricerca Desertificazione, University of Sassari-Sardinia
NVTI	National Vocational Training Institute

O&M	Operation and maintenance
PV	Photovoltaic
PwC	Price waterhouse Coopers
R&D	Research and development
SE4ALL	Sustainable Energy for All
SHS	Solar Home Systems
SLS	Street Lighting Systems
STI	Science, Technology and Innovation
TNA	Technology Needs Assessment
UNDP	United Nations Development Programme
UNEP-DTU	United Nations Environment Programme - Technical University of Denmark
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
VSD	Variable Speed Drive
WE	Wilkins Engineering
WEG	Wind Electric Generators

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1 BACKGROUND

1.1 Science, Technology and Innovation Capabilities

A good human resource base of researchers or professionals engaged in the conception or creation of new knowledge, products, processes, methods, or systems and in the management of projects is important for advancing science, technology and innovation capabilities. Ghana has a relatively strong education system both in the public and private sector. It has 16 research and development (R&D) institutes, 7 public universities, about 40 private universities and 10 public polytechnics[1]. The Council of Scientific and Industrial Research (CSIR) has 13 research institutes under its aegis which carry out applied R&D. In terms of general science, technology and innovation capabilities, Ghana only spends about 0.38% of its Gross Domestic Product (GDP[2]) on research and development[3] well below the 1% of GDP target set by African Union (AU). On this measure Ghana also lags behind that of industrialised and emerging economies but is comparable to other developing countries in Sub-Saharan Africa. In terms of the human resource base, in 2010, Ghana only had 39 researchers/million[4] and 30 technicians/million[5] which are relatively low ratios[6]. The number of scientific and engineering/technical journal articles[7] from Ghanaian researchers was only 121[8] in 2011[9].

The World Economic Forum's Global Competitiveness Index also indicates relatively low levels of scientific and technical capabilities in Ghana. Ghana was ranked at 100 out of 144 countries in technological readiness, and 106 in higher education and training[10]. However Ghana does better in Innovation and Sophistication by being ranked at 63 out of 144 in innovation and 70 in Business Sophistication[10]. It may be noted that Ghana has been steadily increasing its competitiveness ratings over the past years and particularly on innovation and business sophistication.

1.2 National Science, Technology and Innovation Policy

The Ministry of Environment Science and Technology, in 2011, promulgated the National Science Technology and Innovation (STI) Policy which has also been integrated into development planning[11].This policy framework is expected to drive enhanced scientific and technical capabilities in Ghana in the future.

The STI policy also articulates sector-specific policy strategies in 20 sectors including energy[12]. The STI policy envisages development of a strong Science, Technology and Innovation capacity to develop Ghana into a middle-income country. The priorities of the sectoral energy science, technology and innovation policy are to provide sustainable, affordable, safe and reliable energy

[1] UNCTAD, 2011, Science, Technology and Innovation Policy Review: Ghana
[2] Compared to 0.98% for Kenya, 0.52 % for Tanzania and 0.76 % for South Africa
[3] World Bank, data.worldbank.org accessed in June 2015
[4] Compared to 227 for Kenya, 36 for Tanzania and 364 for South Africa
[5] Compared to 645 for Kenya, 10 for Tanzania and 105 for South Africa
[6] World Bank, data.worldbank.org accessed in June 2015
[7] Journal articles in physics, biology, chemistry, mathematics, clinical medicine, biomedical research, engineering and technology, and earth and space sciences
[8] Compared to 290 for Kenya, 121 for Tanzania and 3,125 for South Africa
[9] World Bank, data.worldbank.org accessed in June 2015
[10] World Economic Forum, 2014, Global Competitiveness Report 2014-15
[11] UNCTAD, 2011, Science, Technology and Innovation Policy Review: Ghana
[12] Ministry of Environment, Science and Technology, 2011, National Science Technology and Innovation Policy

for homes and industries. The science, technology and innovation in the energy sector will be driven by policy initiatives to:

I. Promote a research and development programme relating to alternate energy sources such as solar energy, biomass, wind and other renewable energy sources to supplement the current traditional energy sources;
II. Facilitate efforts to acquire and adapt sustainable, safe and economical energy technologies for national development;
III. Support research aimed at upgrading hydropower energy production technology;
IV. Promote R&D efforts aimed at popularizing and disseminating energy technology for rural development;
V. Promote public support for energy conservation and encourage private investment in energy technologies;
VI. Encourage community investment and ownership of energy systems, e.g. solar farms, windmills and biomass plants;
VII. Exploit the utilization of nuclear energy resources for domestic and industrial use; and
VIII. Develop an integrated petrochemical industry to respond to the oil and gas industry.

2 KEY INSTITUTIONS

A total of 16 Ghanaian institutions[13] were identified in consultation with the SE4ALL Country Focal Point (CFP) from the private, public, civil society and academia. One-to-one meetings as well as a questionnaire survey was carried out to gather information on institutional capabilities of these 16 institutions during the period March-June 2015 by the consultants, coordinated by the CFP. A total of 10 responses were received as a result of this institutional survey and an additional response was also received following the workshops in July 2015. The list of institutions surveyed and the questionnaire used for the survey are available at Annexes A and B respectively.

2.1 Public Institutions

The only public institution which responded to the questionnaire survey was Agricultural Engineering Services Directorate (AESD) of Ministry of Food and Agriculture. An additional response was also received from Ghana Irrigation Development Authority (GIDA) in July 2015. The institutional profile of AESD and GIDA are given below:

Agricultural Engineering Services Directorate (AESD) is one of the 7 technical Directorates of the Ministry of Food and Agriculture. It was established in 1966 and currently has the mandate to ensure the availability of farm power and other engineering technologies with sound and sustainable environmental practices for all the categories of farmers, fishermen and agro-processors in Ghana for agricultural production and related activities. AESD employs 60 people with qualifications ranging from BSc, HND, NVTI certificates etc. AESD has technical capabilities in wind energy and productive use of energy. The two specific productive uses where AESD has capabilities are irrigation and food processing. AESD has also collaborated with Neal Consulting Engineers, UK, in production of Poldaw wind pumps.

Ghana Irrigation Development Authority (GIDA) is an authority which operates under the Ministry of Food and Agriculture. It was established in 1977 and the main functions of GIDA are to formulate, develop and implement Irrigation and drainage plans for all year round agricultural production in Ghana. GIDA employs 135 people with qualifications ranging from PhDs, Masters, bachelors and HND. As the name indicates GIDA's capabilities are focussed on the productive use area of irrigation and its staff have the capability to undertake design and construction supervision

[13] Including Ghanaian operations of an international management consulting company.

of dams/irrigation facilities, tube wells and fish ponds and project management. In addition GIDA provides services in irrigation scheme operational management and irrigation extension services on several irrigation schemes across the country. GIDA does not have publications, patents or international collaborations relating to sustainable energy, however is interested in the use of solar pumping systems to displace petrol and diesel pump sets in Ghana.

2.2 Private Institutions

There were 5 private sector institutions which responded to the questionnaire survey. The institutional profiles of all the 5 institutions are described below:

Integrated Water and Agricultural Development Ghana Ltd (IWAD) is a private company established in April 2014, to promote sustainable commercial irrigation for agriculture. IWAD is a subsidiary of Wienco, a Dutch-Ghanaian agricultural company active in agricultural inputs[14]. IWAD plans to bring sustainable commercial irrigation to over 10,000 Ha of land area over the next 10 years. IWAD operates in the Sisili Kulpawn basin in Yagaba, Northern Region. IWAD currently employs 40 people including 8 people with post graduate and 15 people with graduate level qualifications. IWAD is currently constructing a model farm of 400 Ha which also includes a 500 kWp solar power plant which are expected to be completed in September and August 2015 respectively. IWAD has capabilities in productive use of irrigation but lack the capacity to manage the solar energy plant being commissioned as well as other clean energy sources that are relevant to irrigation and agriculture.

Energy Foundation (EF) is a non-profit, private sector institution, devoted to the promotion of energy efficiency and renewable energy. The Energy Foundation Ghana was established in 1997 and, as suggested by the name, is active on energy efficiency issues. EF undertakes energy audits in industries and promotes awareness and public education on energy conservation. EF carries out projects that involve power factor improvements in industries as well as lighting retrofits. EF has managed programmes such as the Energy Demand Management Programme and the national Compact Fluorescent Lamp (CFL) Exchange programme at the national level. EF employs 9 people with post graduate and bachelor degree qualifications.

Deng Solar Training Centre (DSTC) is a private training and capacity building institution which is a subsidiary of Deng Ltd. DSTC was established in 2007 by Deng in collaboration with Global Sustainable Energy Solutions (GSES), Australia. DSTC training programmes focus on solar energy with varying end-uses such as lighting, vaccine refrigeration, battery charging, water pumps as well as grid connected systems. From October 2015, DSTC will be extending its training programmes to include energy efficiency. DSTC employs 6 full-time staff, all of whom have engineering qualifications. DSTC has collaborated with Japanese International Cooperation Agency (JICA) and the German International Cooperation Agency - Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). Apart from its plans in energy efficiency, DSTC plans to offer training courses in Nigeria and also in French to Francophone West African countries.

Wilkins Engineering (WE) is a Ghanaian private Engineering, Procurement and Construction (EPC) company specialising in electricity networks and clean energy. The company was established in 1993 and employs 76 people and has a national presence. WE has capabilities in Solar Home Systems (SHS), Mini-grid solutions for energy access, energy efficiency, solar and wind energy technologies. WE staff have masters, bachelor degrees and diplomas and the company has partnered with private international partners such as Elecnor, Phillips and Huawei to execute solar energy projects in Ghana. WE plans to offer solar solutions totalling 70 MW to institutional clients

[14] Seeds, supplements, insecticides, sprayers etc.

that will result in a similar size demand reduction on the national grid. Apart from Ghana, WE has also been active in Liberia.

Price waterhouse Coopers Ghana (PwC Ghana) is the Ghanaian member of the PwC network and has an energy sector practice in addition to financial, government and industry practices. PwC Ghana established in 1998 is also responsible for services in Liberia, Sierra Leone and Gambia. PwC Ghana employs 300 people mostly with financial and accounting qualifications. While the work with PwC Ghana is primarily on transaction advisory and sustainability strategies, through its local staff and global network, PwC Ghana has access to capabilities in business case planning, business models and risk assessment. PwC also organises events and courses on sustainable energy for corporates under the umbrella of PwC Ghana Business School.

2.3 Academic Institutions

Two academic institutions responded to the questionnaire survey. The institutional profiles of these organisations are given below:

Kwame Nkrumah University of Science and Technology (KNUST), located in Kumasi, was established in 1952 as the second Public University in Ghana. KNUST's Technology Consultancy Centre was established in 1972 and currently employs 6 people with doctoral and masters qualifications. KNUST has capabilities in clean cookstoves, biomass gasifier based power generation, solar thermal, photovoltaics and biogas. KNUST also has business model development capabilities in the context of rural energy and enterprise development. KNUST has two labs: A-Lab, the applied industrial ceramic-rural energy and enterprise development and C-Lab, a cookstoves testing and expertise laboratory. KNUST researchers have published papers in areas relevant to SE4ALL and are also patenting two technologies on institutional cookstoves and plastic to fuel. KNUST also has international collaborations with Netherlands Development Organization, Aprovecho Research Centre (ARC), Massachusetts Institute of Technology (MIT), Orleans College, International Development and Design Network, Arizona State University and the Global Alliance for Clean Cookstoves and fuels.

Ashesi University's Ghana Climate Innovation Centre (GCIC) is being established with support from World Bank's Infodev Climate Technology Programme and the Government of Denmark. GCIC plans to provide financial and advisory support to local Ghanaian enterprises on climate technologies. Ashesi University is a private non-profit university founded in 2002 near Accra with support from IFC of the World Bank group. Ashesi University focuses on business administration, management information systems and computer science and plans to offer courses in engineering in 2015. GCIC's climate technology enterprise development support will feature five service lines – Entrepreneurship and Venture Acceleration, Access to Finance, Market Growth and Access, Technology and Product Development and Policy and Regulatory Support. GCIC has identified areas such as off-grid renewable energy and energy-efficient manufacturing that have direct relevance to SE4ALL as well as climate-smart agriculture and wastewater treatment which may have relevance to the productive end-use element in Ghana's SE4ALL initiative.

2.4 Non-Governmental Organisations

Two Non-Governmental Organisations (NGOs) have responded to the questionnaire survey. The institutional profiles of these organisations are given below:

Kumasi Institute of Technology, Energy and Environment (KITE) is a non-governmental research institution that was established in 1996 and has a presence in Kumasi and Accra. KITE currently employs 13 staff with masters, bachelors and diploma qualifications. KITE has expertise in clean cooking, SHS and mini-grids, solar, biomass and mini-hydro renewable energy technologies and energy efficiency. KITE also has expertise on irrigation and food processing as productive end-uses of electrification. KITE also has expertise on business case planning including development of innovative and sustainable business models. KITE has had a number of international collaborations including with IDRC Canada, UNEP-DTU Centre, etc.

New Energy (NE) is a non-governmental organisation established in 1994 and located in Tamale in Ghana. NE has expertise on clean cooking, renewable energy mini-grids and energy audits. NE also has expertise in using solar photovoltaics for irrigation. NE is also active on management issues such as supply chains, enterprise and end-user credit as well as market research on clean energy and energy access. NE researchers have also published on energy access and clean energy issues and have also had international collaboration with Nucleo Ricerca Desertificazione, University of Sassari-Sardinia (NRD-UNISS), Italy, on energy access projects involving Jatropha based biofuels.

3 PRIORITY TECHNOLOGIES FOR SE4ALL IN GHANA

During the stakeholder consultations held in December 2014 by the consultants, specific off-grid and mini-grid electrification technologies and energy efficiency technologies were identified as key technologies that are relevant to the SE4ALL Country Action Plan (CAP) and future Action Agenda (AA) for Ghana. A brief description of these technologies follow.

3.1 Off-grid electrification technologies

The off-grid electrification technologies are also termed as stand-alone systems and these either power homes or institutions that are not served by national electricity grids. All renewable energy sources i.e. wind, solar photovoltaics, biomass and hydro power can be used to power these systems. The home systems are relatively smaller systems that provide electricity for lighting, mobile phone charging and optionally for radios or televisions. The institutional systems are larger systems that are used in public or private institutions in un-electrified areas. The possible off-grid electrification technology options are:

Pico hydro: Such systems consist of a small Peltric set or a pump used as turbine and sometimes slightly larger cross-flow turbines. Sizes could range from 50 W to 5 kW[15] or so with the smaller sizes powering homes and the larger ones for institutions. These systems are often bought off the shelf like irrigation pumps and installed by local plumbers or masons. Hydraulic efficiencies are often low and power quality is also generally poor. Such systems do not have energy storage as the turbo-generator is only operated when needed by diverting the water. These are popular in Asia, parts of Latin America and parts of Sub-Saharan Africa such as in Kenya.

Small wind: small wind off-grid systems are also called aero generators consisting of small wind turbine combined with an electrical generator, which is mounted on the rooftop or on a pole. The size ranges could be from 30 W to 1 kW with a battery storage. Larger systems are intended for institutional and off-grid enterprise use with smaller systems for homes. Such systems are popular in North America, Asia and Europe.

Small bio-energy systems: Such systems combust biogas in a combustion engine[16] or a gas engine coupled with an electrical generator. The size of the systems are less than 5 kW and are often used at the institutional level than individual houses. The biogas is either produced using the biological route in a biogas digester or the thermo-chemical route in a gasifier. The producer gas that is produced in a gasifier can often be used in a diesel engine generator in a 'dual fuel' mode with both diesel and the biogas. Because the biomass feedstock or the biogas can be stored, such systems do not have a battery storage.

[15] University of Nottingham http://www.eee.nottingham.ac.uk/picohydro/index.html accessed June 2015
[16] Both internal and external combustion engines.

Photovoltaic (PV) stand-alone systems: such systems consist of one or more PV panels and an electro-chemical energy storage[17] to store solar energy for use during periods of non-availability. The size of such systems can range from as low as 5 Wp to tens of kWps or from portable solar lanterns, SHS, Street Lighting Systems (SLS) to larger institutional systems for schools or hospitals. The off-grid electrification technologies generally offer Direct Current (DC) typically at 12 or 24 V but some larger institutional systems in the kW scale may have an inverter which offers 110 V or 220 V Alternating Current (AC). PV off-grid systems are popular across the world as an off-grid electrification option.

Typical configuration of off-grid electrification technologies is shown in Figure 1.

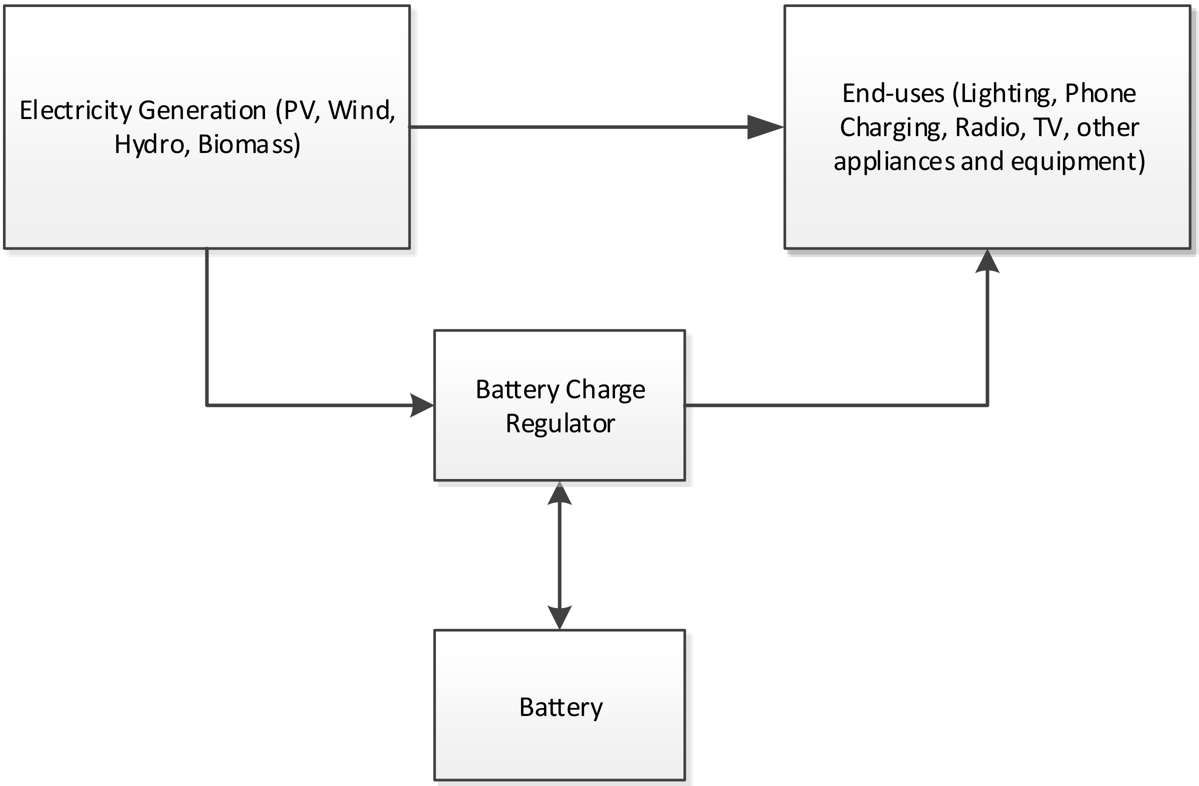

Figure 1: Off-grid electrification System Configuration[18]

In the Ghanaian context the most relevant off-grid electrification technology is PV stand-alone systems. Government of Ghana (GoG) and donor programmes have supported SHS, SLS as well as larger institutional systems private initiatives have resulted in major contributions in SHS as well. Over 21,600 SHS, 20 SLS and 62 institutional PV systems[19] have been installed in Ghana[20]. Other technologies such as hydro, wind and biomass have also been used in Ghana at a larger scale than at the household level. Ghanaian companies do not manufacture these systems and most of the components are imported. However considerable local capability exists for integration, installation and operation and maintenance (O&M) of these systems, especially for PV SHS, SLS and institutional

[17] Typically lead-acid batteries and sometimes Nickel-Cadmium batteries.
[18] Battery storage is used for variable renewable energy sources such as solar and wind and not used for energy resources that can be stored or have regular availability such as hydro or biomass.
[19] 48 hospital systems and 14 school systems.
[20] ECREEE, 2014: Baseline Report for Ghana, Within the Process and Strategy on the development of Sustainable Energy for all (SE4ALL) Action Agendas, National Renewable Energy Action Plans (NREAPs) and National Energy Efficiency Action Plans (NEEAPs) in the ECOWAS Member States

systems. There is also one company that manufactures LED lamps in Ghana, which are used in lighting systems. Post implementation evaluations of small-scale renewable energy systems in developing countries indicate that energy systems based on hydro and PV electricity technologies are more sustainable in the long run compared to biomass and wind electricity technologies[21]. This is illustrated in Figure 2 below.

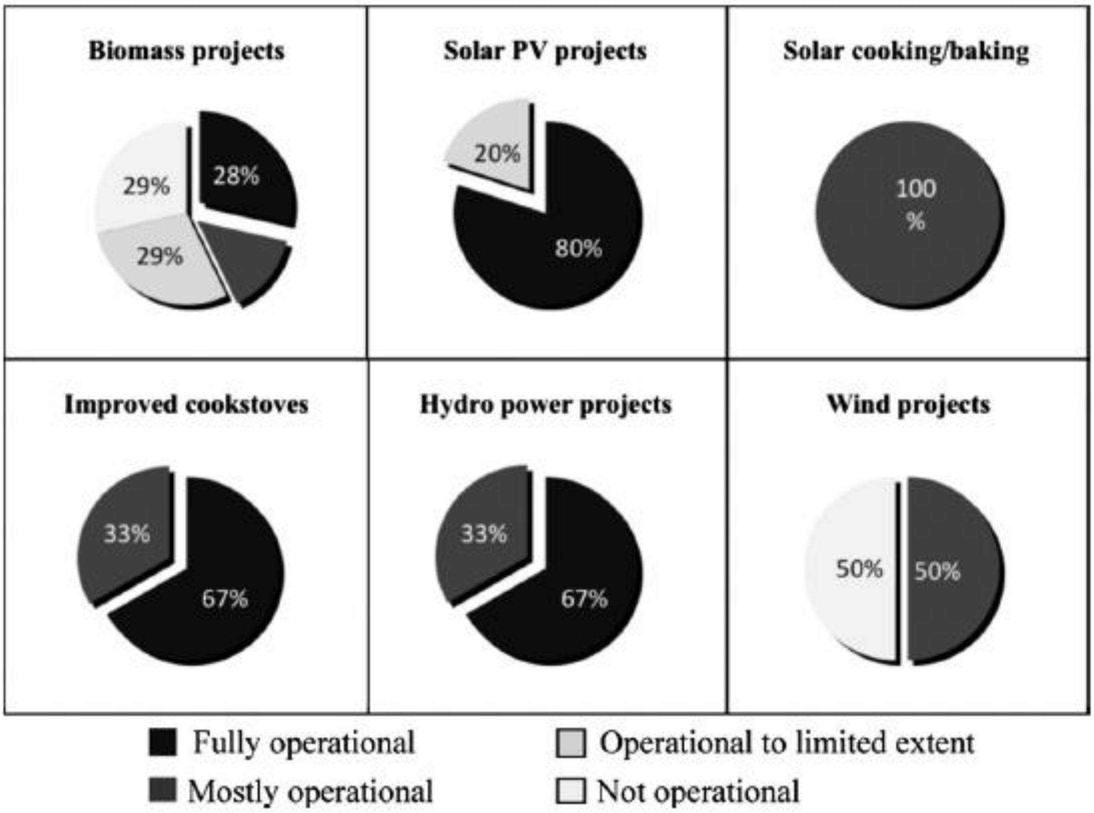

Figure 2: Sustainability of small scale renewable energy systems (including off-grid systems) [21]

3.2 Mini-grid electrification technologies

Mini-grids are the next level of electrification from isolated off-grid discussed in the previous section which power individual homes or institutions. Mini-grids are deployed in locations where there is a critical mass of households, private enterprises and public institutions which justify investments in the service infrastructure. Mini-grids are also deployed in locations where the distance from the electricity network is too large or the geographical features are complex[22] to justify investment in grid extension. The feature of mini-grids is that they are electrical distribution networks that are not connected to the main electrical grid and are able to operate autonomously[23]. While range of system sizes exist within mini-grids, a generally accepted threshold is that systems that are larger than 10 kW and less than 10 MW size[24]. The mini-grids provide electricity supply at low-voltage (typically 110 or 220 V) Alternating Current which allows the use

[21] Terrapon-Pfaff et al, 2014, How Effective are small-scale energy interventions in developing countries? Results from a post-evaluation on project- level, Applied Energy 135, 809-814
[22] Such as mountainous regions, islands, forests etc.
[23] SE4ALL, 2014, High Impact Opportunity: Clean Energy Mini-grids
[24] Essentially following the definitions of mini-hydro power plants which have been developed as isolated grids and extending this classification to other renewable energy and hybrid technologies.

of regular equipment available in the market rated for AC service. The mini-grid technologies that are relevant in the Ghanaian context are:

Solar mini-grids. These are powered by PV arrays of hundreds of kW with an inverter and often with a battery bank which stores energy for use during periods when solar insolation is not available. A battery charge regulator is used to regulate the charge and discharge cycles of the battery storage. An inverter is used to convert the DC power input from the solar array or the battery bank into AC power and feed into the electrical service network. In a large number of systems the battery charge regulator and the inverter are integrated into a single unit often called as the power conditioning unit.

Wind mini-grids are configured in a similar manner as the solar mini-grids and have one or more Wind Electric Generators (WEGs) that generate electricity during periods when wind resources are available. The nacelle assembly of these WEGs consisting of the generator, mechanical parts and the blades are mounted high from the ground on a tubular or lattice tower. Similar to solar mini-grids, wind powered mini-grids also often have a battery bank sized to meet energy needs during periods when wind is not available and an associated battery charge regulator. Similarly, there is also an inverter to convert the DC current from the battery to AC to supply the end-uses. In some wind mini-grids, the WEGs generate AC power and a rectifier is used to convert the AC power generated to DC for charging the Battery Bank. Power Conditioning Units that integrate the inverter, rectifier and the battery regulator are also used in many wind mini-grids.

Hydro mini-grids typically divert water from streams and rivers as a run-off for a short distance and return the water to the source after power generation. Such mini-grids do not have dams and storage reservoirs. A hydro mini-grid consists of civil, hydro-mechanical and electro-mechanical components. The civil component consists of the intake for water, canal or closed conduit for transporting water, the desilting tank and the penstocks which direct the water to the hydro-mechanical equipment. The hydro-mechanical equipment consists of the hydraulic valves, the hydro turbine and the tailrace pipes. The electromechanical components consist of the gear box, electrical generator, the power and load controller, the circuit breaker as well as the electrical network. Battery storage is not associated with hydro mini-grids as the streams used for hydro mini-grids have perennial water supply. The hydro and electro-mechanical components are generally housed in a power house in most hydro mini-grids.

Hybrid mini-grids are used to combine different energy sources and storage to achieve mini-grid electrification solutions that are more reliable and economical. Solar and wind energy is hybridised as part of mini-grids in locations where the solar and wind resources complement each other[25], with a battery storage to address the variability of these resources. Diesel generators are also hybridised with solar and or wind energy generators where such complementarity of resources is not evident. In hybrid systems the size and investment in the battery bank is considerably reduced lowering energy generation and supply costs. Similar to solar and wind mini-grids, the hybrid systems also have an inverter, a battery charge regulator and often a rectifier or a bi-directional inverter[26]. Additionally a switching system is included in hybrid mini-grids where a diesel genset exists, for the purpose of starting and stopping the diesel generation. Similar to solar and wind mini-grids all these electronic and electro-mechanical systems are often integrated into a single power conditioning unit.

In Asia and Africa mini-grids are playing an increasingly important role in Rural Electrification. China is currently the leader in mini-grids with over 1,000 mini-grids powered by solar, hydro and

[25] Locations such as valleys and sea-shores where there are strong winds during evenings that compliment solar insolation available during daylight hours.
[26] When there is AC electricity generation from a WEG or diesel genset.

hybrids. India has over 500 solar, biomass and hydro mini-grids with government and private ownership[27] models. Nepal has over 300 hydro powered mini-grids mostly operated by village communities and the private sector. In Africa, there are large numbers of diesel mini-grids in countries like Kenya, Mali, Senegal etc. and countries like Zimbabwe have about 400 solar and hydro mini-grids. Hydro and solar mini-grids also exist in Malawi and Zambia.

In Ghana several mini-grids using solar, wind and hybrid configurations are currently being implemented by GoG. The technology is understood in Ghana and capabilities for assessment, sourcing, integration and O&M exist in the country. The mini-grid system configuration is shown in Figure 3 below:

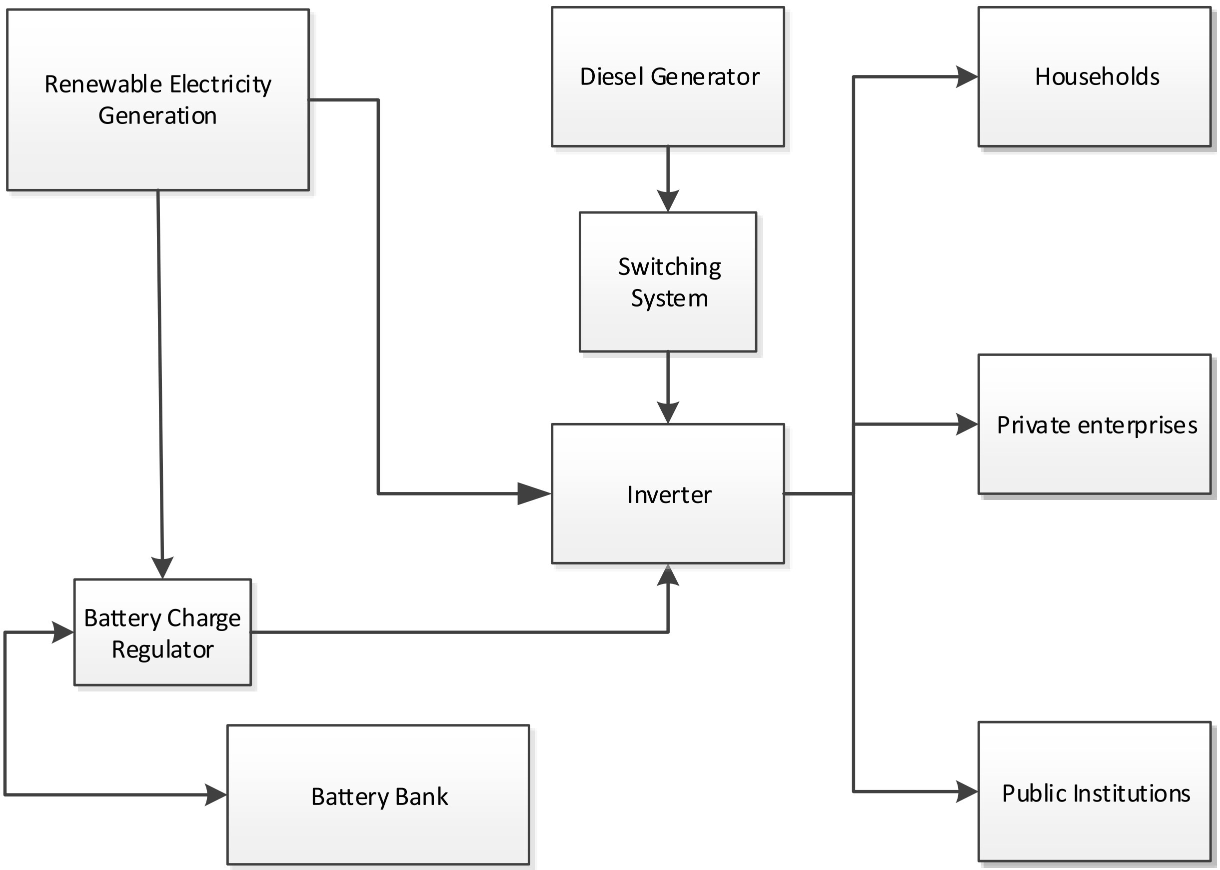

Figure 3: Mini-grid electrification System Configuration[28]

3.3 Energy efficiency technologies

Energy efficiency technologies that were relevant to the Ghanaian SE4ALL objectives were identified as electrical equipment that was relevant to productive end-use. End-use efficiency of productive use equipment for such as electrical pumps for irrigation, is relevant to the Ghanaian situation. Agriculture is an important sector in Ghana which accounts for 65% of the workforce, 40% of GDP and 40% of exports[29]. The agriculture primarily relies on rain-fed irrigation and only less than 2% of the cultivable area is irrigated[29].

[27] Companies like Husk Power, MeraGaoPower, OMC Power and Desi Power operate biomass and solar mini-grids
[28] Battery storage is not relevant for hydro mini-grids and a rectifier or a bi-directional inverter is also added for AC generation such as WEGs and diesel genset.
[29] IFPRI, 2011, Irrigation Development in Ghana: Past Experiences, Emerging Opportunities and Future Directions.

Agriculture in Ghana is predominantly small-holder, family owned farms involving more than 2.74 million families, each with less than 2 Ha land but produces 80% of total agricultural output[29]. Most of these small farms use diesel or petrol pumps to irrigate their farms. Most pumps are petrol pumps and pumps are either owned by the farmer, owned by the farmer collective or rented on a daily basis by the farmer[29]. The GoG had also deployed 120 solar water pumping systems in the country as part of a national effort[30]. Once there is electricity access through mini-grid systems or grid extensions, many of these family-owned farms will be able to use electrical pumps which offer significant advantages over the petrol and diesel pumps that are being used predominantly in Ghana.

Efficiency of diesel and petrol pumps are in the range of 30-40% whereas the efficiency of electric pumps are in the range of 45-80%. The switch to electric pump sets has the potential to reduce the operating costs of the irrigation system by almost half providing benefits to the farmer and the agricultural sector. In addition to higher efficiency and cost savings, electric pumps also have low labour and maintenance costs and low levels of environmental impacts. However the electric pumps need to be matched to available head and required discharge to ensure that the pumps operate at the highest possible efficiency. In situations where the head and the required discharge varies, a Variable Speed Drive (VSD) can be added to ensure that the electric pump continues to operate at high efficiency. However, the additional cost of VSD needs to be considered against loss of efficiency due to variations in head and/or discharge.

However the challenge in Ghana and many other developing countries is that often the agricultural pump sets available in the market have low efficiencies in the range of 45-55% rather than 70-80%, which is only a slight efficiency improvement over petrol and diesel pumps that are being replaced. Most farmers are likely to purchase electric pumps with lowest upfront costs which are most likely to be inefficient. Therefore a simple and understandable mechanism to promote energy efficiency such as an energy efficiency label for agricultural pump sets would be helpful to the farmers to identify and purchase efficient pump sets. Since Ghana already has energy efficiency labels for air-conditioners and lighting systems, it may be relatively easier to add an energy efficiency label for electric agricultural pump sets.

4 INSTITUTIONAL CAPACITIES IN GHANA

4.1 Technology development

Technology research and development capabilities are emerging in Ghana and indicators such as investments in R&D, number of researchers and technicians involved in R&D have all lagged behind African and other developing country peers. Consequently the outputs of R&D as manifested in research publications and patents[31] have also lagged behind comparable nations.

This overall situation with R&D in the country is also reflected in the sustainable energy space where a limited number of researchers are active and only limited publications and patent applications have been made by Ghanaian researchers. The questionnaire assessment by the consultants have indicated that at least 226 technical and scientific personnel have been active in sustainable energy issues, only 4 papers on sustainable energy issues have been published in peer-reviewed journals and 2 patent applications have been made by Ghanaian institutions.

[30] ECREEE, 2014: Baseline Report for Ghana, Within the Process and Strategy on the development of Sustainable Energy for all (SE4ALL) Action Agendas, National Renewable Energy Action Plans (NREAPs) and National Energy Efficiency Action Plans (NEEAPs) in the ECOWAS Member States

[31] Reliable information on patent applications on Ghana not publicly available

4.2 Business model understanding

Increasingly, the importance of a business model for sustainable energy investments and enterprises is becoming as critical as technology development. Business models are important in government led interventions to ensure that the sustainable energy projects and programmes are financially sustainable in the long run. Understanding of business models is important to the policy makers to ensure that the fiscal incentive frameworks are designed to ensure that sustainable energy investments are attractive enough to leverage private investments. The private sector and civil society practitioners in energy access and sustainable energy should also be capable of understanding and adapting the business models used in other countries to national circumstances in Ghana. Also important are the financing and service models for market development of off-grid and mini-grid based electrification and energy efficiency finance models.

During the questionnaire assessment carried out by the consultants, it was found that 63% of organisations have the understanding and capabilities around business models, financing and service models relevant to sustainable energy. The capabilities existing in Ghanaian institutions have included enterprise development, supply chains, finance models, feasibility evaluation, business case planning, etc.

4.3 Risk identification

Early identification of risks associated to sustainable energy programmes and projects and putting in place that risk management measures are important for successful implementation and achieving the intended outcomes. Typical risks associated to sustainable energy projects could be either operational, financial or political. It is important to identify the specific risks, classify them, and assess the possible impact and probability of occurrence. Various countermeasures and responses to be made if the risk materialises should also be identified upfront and the responsibility for risk management should also be specified.

During the questionnaire assessment not many organisations demonstrated capabilities in risk identification and management. While some of the covered management consulting companies may have such capabilities and it is possible that such capabilities may also exist with other management, accounting and rating agencies based in Ghana who were not surveyed. However, it appears that ability to identify and manage risk is a shortcoming for the current set of organisations involved in sustainable energy issues in Ghana.

4.4 Receptivity capacity

Receptivity capacity in the sustainable energy technology context in Ghana is the ability of Ghanaian institutions to assimilate technology know-how that is transferred to them and to apply this know-how in supporting the SE4ALL objectives of GoG. This capacity is important to ensure that considerable local institutional capacity is built during sustainable energy technology transfer projects and programmes that can be leveraged by the Ghanaian stakeholders to sustain efforts after the completion of the technology transfer initiatives.

Such an ongoing initiative is the Danish Government supported project on South-South renewable energy technology transfer between China and Ghana being coordinated by UNDP and implemented by the Energy Commission. This 4 year $2.7 million project which started in 2015 will focus on building receptivity capacity in Ghana for absorption of renewable energy technology transfer. This project will also contribute to the sustainability of Ghana's SE4ALL achievements.

Of the institutions that responded to the survey, 63% of the organisations have had technology collaborations with international partners. The technologies in which collaborations have taken place include solar energy, cookstoves, biofuels, etc. The international organisations which have had technology collaborations with Ghanaian institutions include JICA, GIZ, UNEP, USAID, ARC, MIT, GSES, NRD-UNISS, Elecnor, Philips, Huawei, etc.

5 ASSESSMENT OF TECHNOLOGY TRANSFER AND INSTITUTIONAL CAPACITY BUILDING NEEDS

The results of the questionnaire survey on technology transfer and institutional capacity assessments is presented in Table 1 below:

Table 1: Ghanaian Institutional Capabilities relating to technology transfer

Organisation	Priority SE4ALL Technologies of Competence	Year of Establishment	Employee Strength	Technology Development	Business Model understanding	Risk Identification	Receptivity Capacity
AESD	Wind mechanical energy, End-use energy efficiency - agriculture and food processing	1966	60	N	N	N	Y
IWAD	Solar energy, End-use energy efficiency - water pumping	2014	40	N	Y	N	N
Energy Foundation	End-use Energy Efficiency - lighting, industries	1997	9	N	Y	N	Y
DSTC	Solar PV, off-grid end - use energy efficiency, in agriculture, health	2007	6	N	N	N	Y
Wilkins	Solar, wind, off-grid and mini-grid and end-use energy efficiency	1993	76	N	N	N	Y
PwC Ghana	Generic	1998	300[32]	N	Y	Y	N
KNUST	Solar PV, Biomass power, Clean cook stoves, end use of food processing	1972	6	Y	Y	N	Y
GCIC[33]	Generic	2015	N	N	Y	N	N
KITE	Solar PV, biomass, hydro, clean cookstoves, off-grid and mini-grid systems	1996	13	N	Y	N	Y
New Energy	Solar PV, Clean cookstoves, mini-grids, end-use energy efficiency	1994	16	Y	Y	N	Y
GIDA	Irrigation	1977	135	N	N	N	N

[32] Mostly with financing and accounting qualifications and hence not included as technology experts or researchers.
[33] GCIC is under establishment and the data inputs indicate GCIC plans rather than achievements.

The following inferences can be made from the results of the institutional survey:

- Institutions involved in sustainable energy technologies range from private, public, academia and NGO sectors, with more recent institutions being established in the private sector;

- Most organisations are small or medium sized and the majority, 54% of institutions, are small. The average staff strength for the institutions is 37;

- The SE4ALL technologies where high levels of capacity exists are off-grid and on-grid renewables such as PV, wind, biomass and end-use energy efficiency of productive uses such as agriculture and food processing.

- There is a high level of capability on business models among Ghanaian institutions engaged in sustainable energy issues with 63% of organisations reporting capabilities. The type of business and financial models and management issues that have been managed by the institutions are considered to be relevant to Ghana's SE4ALL agenda;

- There is also high level of international collaboration between Ghanaian institutions and international partners with 63% of the institutions having had collaboration with one or more international partners. While the development of receptivity capacity as a result of such international collaboration depends on the institutions themselves as well as national frameworks, level of current activities by many of the institutions surveyed indicate a high level of technology know-how absorption;

- One technology where Ghanaian institutions do not seem to have high levels of capabilities is hydro-power both Pico and mini hydro for off-grid and on-grid systems. A second area of improvement could be energy efficiency of priority end-use applications for productive use such as agriculture – both pre and post-harvest, where institutions are actively engaged. It is not evident from the survey that the energy efficiency aspects are being adequately emphasized;

- Another aspect of concern is technology development by local institutions, only 18% of the institutions surveyed are engaged in technology development activities with one outstanding institution. While this result is consistent with lower levels of technology development in science and technology in Ghana, it may need to be addressed to sustain Ghanaian efforts on SE4ALL;

- Other area of concern is the low level of ability of surveyed institutions in risk identification and management. While this is an important aspect, it does not seem to have been emphasised much in past national and international efforts on sustainable energy. Only 9% of the organisations surveyed have risk identification and management capabilities.

6 TECHNICAL ASSISTANCE PROGRAMME

No similar technical assistance efforts to build capacity on sustainable energy technologies, business models or risk management have been implemented in Ghana so far. A UNDP supported project which has started in 2015 will be supporting south-south technology transfer between China and Ghana. Since this project has only begun implementation, the evidence base is only emerging to draw any early lessons. Therefore based on the assessed institutional capabilities and the gaps identified, the following technical assistance programme has been developed.

6.1 Output 1: Developing technology development capability

6.1.1 Baseline

Only 18% of the institutions surveyed are engaged in technology development on sustainable energy technologies which is consistent with the national profile on science, technology and innovation activities. The GoG, in 2011, put in place the Science, Technology and Innovation Policy targeting 20 sectors including energy. The STI policy is expected to provide a framework for developing sustainable energy development capability in Ghana. Of the organisations that have technology development capabilities, KNUST is the major institution making contributions.

6.1.2 Implementation

Capabilities of the target institutions will be strengthened through a series of activities which will help institutions in Ghana develop and enhance their technology development capabilities. The activities to be implemented include:

Sustainable Energy Research Grants Programme: Energy Commission (EC) and GoG will establish an open annual competitive research grants programme which will be targeting all Ghanaian institutions. This programme will be coordinated by the SE4ALL CFP. The Research priorities for each year will be determined on the basis of the state of achievement of SE4ALL CAP. A mechanism for independent reviews of the proposals from Ghanaian research institutions on pre-determined criteria would be established and research grants would be made available to the winning organisations. Technology development will be the objective and desired outcomes will include peer-reviewed publications and patent applications. It is proposed that a five year research programme will be developed and implemented providing 5 research grants every year for a two year period each, each valued at US$ 50,000[34];

Sustainable Energy Research Collaboration Programme: EC and the GoG will establish a research collaboration and exchange programme between Ghanaian research institutes and reputed international research institutions in developing countries. As an initial step the SE4ALL CFP will identify a group of research establishments in developing countries with high levels of renewable energy research activity (e.g. China, South Africa, India, Brazil, Kenya, etc.). Exchange programmes will be established where 2-3 months residency of researchers from the Ghanaian and collaborating institutes will be financed and supported. The exchange programmes will be output oriented and should result in publications or research outputs that support Ghana's SE4ALL objectives. Balancing of the research across research themes is suggested. It is suggested that at least 3 residency grants each be given every year to international researchers for residency in Ghana and a similar number for Ghanaian researchers in external research institutions. The grants should be enough to cover travel, living and research costs and the costs of time for the researchers will be paid by the employer.

The estimated budget for this output is US$ 2 million. The activities, targets and the budget are detailed in Annex C.

6.2 Output 2: Developing risk identification and management capabilities

6.2.1 Baseline

Existing sustainable energy research institutions do not carry out risk assessments of projects and programmes in sustainable energy. The capacity of institutions active in sustainable energy to carry out such risk assessments and to propose management systems is also limited. The risk assessment

[34] US$ 25,000/year/institution

framework for sustainable energy projects also does not exist. Therefore risk identification and management remains an area which is underdeveloped.

6.2.2 Implementation

Development of a Risk Assessment Framework: A framework for carrying out a risk assessment for sustainable energy projects and programmes that contribute to Ghana's SE4ALL objectives will be developed and implemented. All sustainable energy projects including nationally and internationally promoted above a specific value[35] could include a risk assessment and management component. Explore the possibility of integrating the risk assessment and management into the energy regulatory framework. A Ghanaian management or risk consulting organisation such as PwC Ghana or Ashesi University or others may be able to carry out this framework development. The course material will be available online for those who wish to do self-paced learning.

Development of a Risk Management Training Programme: The curriculum for a risk management training programme of 3 to 5 day duration will be developed and implemented on-line and as classroom modules. The programme will be targeting researchers, programme and project managers, policy makers, regulators, banks, private enterprises, etc. The courses can be developed and implemented by Ghanaian education and training institutions like Ashesi University, PwC Ghana, DSTC, etc. The training institute will continue to offer this training programme beyond the Technical Assistance period.

Implementation of Risk Management Training Programme: Full and partial fee scholarships will be given for the initial few years for participants from key stakeholder institutions that wish to attend the training programmes. Emphasis to be placed on training of teachers in business management institutes as training of trainers. The training scholarships and sponsorships are to be phased out during the Technical Assistance period. The on-line training modules will continue to be available indefinitely and will be periodically updated by the institute.

The estimated budget for this output is US$ 300,000. The activities, targets and the budget are detailed in Annex C.

6.3 Output 3: Developing priority technology capabilities

6.3.1 Baseline

Ghanaian institutions surveyed do have capabilities in off-grid and mini-grid technologies such as solar, wind and biomass. The Ghanaian institutions also have capabilities in the productive end-use technologies including agriculture. Capabilities of Ghanaian institutions are rather limited in hydro-power and pump set energy efficiency.

6.3.2 Implementation

Electrical Pump labelling programme: the EC will develop a labelling programme suitable to the electrical pumps being used for irrigation in Ghana. The programme will follow the existing framework used for air-conditioning and efficient lighting programmes in Ghana. Once the labelling programme has been developed and implemented in a voluntary mode, a multi-media promotion campaign[36] should be carried out to create awareness among farmers on the energy label.

South-South Exchange programmes on priority technologies: group study tours will be supported for Ghanaian stakeholders from government, research/academia, private and NGO institutions to visit countries with successful hydro and biomass based power programmes (e.g. Kenya, Zimbabwe,

[35] Such as US$ 1 million or an appropriate value relevant to national circumstances.
[36] Print and electronic media including radio broadcasts

Nepal, Peru, etc. for hydro and Brazil, China, India, Ethiopia, Kenya, Mauritius, etc. for biomass power) and electrical pump set labelling programmes (e.g. India). The members attending the study tour will develop a report on key outcomes and lessons which are relevant for Ghana's SE4ALL objectives along with an action plan. It is proposed that two such study tours be organised on hydro power and biomass based power and one study tour be organised on efficient pump set labelling programmes.

The estimated budget for this output is US$ 700,000. The activities, targets and the budget are detailed in Annex C.

6.4 Output 4: Augmenting business and financial model capabilities

6.4.1 Baseline

Ghanaian research institutions do have capabilities in business and management issues relating to sustainable energy projects, financing models and enterprises. These capabilities have been acquired through a number of national and international initiatives and continue to be utilised in sustainable energy projects. While the Ghanaian capabilities are strong, there may be benefits through South-South exchange focused on business and financial models.

6.4.2 Implementation

South-South Exchange Visits: Group study tours will be supported to countries in Sub-Saharan Africa and South Asia (e.g. Kenya, Bangladesh etc.) where innovative business models for rural electrification, renewable energy and energy efficiency are being implemented. Particular efforts will be made to emphasize financing models that are relevant to off-grid and mini-grid systems. The members attending the study tour will develop a report on the key outcomes and what lessons are relevant for Ghana's SE4ALL objectives along with an action plan. It is proposed that 3 such study tours be organised for rural electrification stakeholders in Ghana over a 5 year period.

Expert visits and lectures: It is suggested to invite international experts for visits and lectures on business and financing models for rural electrification. In this activity, an international expert will visit Ghana for a week to provide lectures and updates on new developments relating to business and financial models in rural electrification. The experts will visit key institutions and will also hold public presentations for key stakeholder groups during the visit. It is proposed that two such expert visits be organised during a 5 year period. It is suggested that the visits be of 1 week duration and the professional fees of the expert on preparation and delivery of the lecture and the costs of local lecture organisation and other expenses be covered.

The estimated budget for this output is US$ 350,000. The activities, targets and the budget are detailed in Annex C.

6.5 Output 5: Augmenting technology absorption capabilities

6.5.1 Baseline

Ghanaian institutions do have high levels of collaboration with international organisations and have been able to apply the technical know-how and expertise transferred through such collaborations to sustainable energy projects in Ghana. These collaborations have been on a range of technologies and also with multiple organisations from public, private and civil society backgrounds. Such capabilities will be further strengthened and augmented through collaborations that will be supported under the output 1 on developing technology development capabilities. However a follow-on support mechanism is probably required to sustain research collaborations.

6.5.2 Implementation

Small Grant Scheme for Ghanaian researchers on technology absorption: Small grants will be provided to Ghanaian researchers who have benefited from a research collaboration programme under the output 1. These small grants as a special window of the sustainable energy research programme under output 1, could finance Ghanaian researchers who have participated in exchange visits to develop collaborative research proposals with the host institution for international collaboration where the researcher was associated during the initial collaboration.. Such grants could finance development of new research collaboration proposals or expansion and augmentation of existing research collaborations. These small grants can also be used to finance visit and presentation by Ghanaian researchers in international academic and research sustainable energy conferences of repute which will be helpful in raising the international profile of the Ghanaian research institution leading to more collaborative research opportunities. It is proposed that 20 such small grant be made to those that have benefitted from the research collaboration activity. The grants will be in the range of US$ 3000 to 5000 and will be made to the affiliated research institution. Researchers working in Public institutions, academia and NGOs will benefit from this small grant scheme. This small grant scheme will also use the same institutional mechanism established for managing output 1 on technology development capabilities.

The estimated budget for this output is US$ 150,000. The activities, targets and the budget are detailed in Annex C.

6.6 Budget and financing

The technical assistance programme as presented in this section and detailed at Annex C is aimed at developing and augmenting existing sustainable energy technology capabilities in Ghana. These are aimed to be achieved through international collaboration with institutions from both industrialised and developing countries.

Detailed budgetary estimates have been made for each activity and the total budget for all the 5 technical assistance outputs is estimated to be US$ 3.6 million over a period of 5 years. The technical assistance programmes have been designed to be self-sustaining and generic so that these can be developed further and customised to requirements of interested donor agencies.

Since energy technologies were identified as a priority climate change mitigation technology need under Ghana's first Technology Needs Assessment (TNAs) under the UNFCCC, there could be justification for support under the technology strand of the UNFCCC. Possible sources of financing for the Technical Assistance could be African Development Bank, Global Environment Facility (GEF) under its technology transfer window, Climate Technology Centre and Network (CTCN) as well as UN systems entities such as UNDP or UNEP and bilateral governments that support technology transfer activities such as US, Denmark, Germany, etc.

7 CONCLUSIONS AND THE WAY FORWARD

7.1 Conclusions

The conclusions that can be drawn from the assessment and evaluation of technology and institutional capabilities in the sustainable energy environment in Ghana are:

- While Ghana has a relatively well developed educational system, it lags behind its peers in science, technology and innovation capabilities.

- Technological and business capabilities relating to sustainable energy exist in the Ghanaian institutions surveyed. Capabilities exist in most priority sustainable energy technologies, business models and capacity to absorb technologies.

- Opportunities to strengthen capacities exist in technologies such as hydro and end-use energy efficiency. Scope for capacity building also exists in technology development and risk identification and management.

- A technical assistance programme targeting Ghanaian institutions active in sustainable energy has been developed and presented. Implementation of this technical assistance as a stand-alone project or as part of planned future projects and programmes is recommended.

- This technical assistance which require a funding of US$ 3.6 million over a 5 year period is expected to strengthen the existing institutional base for science and technology capabilities in sustainable energy and anchor it on a sustainable footing.

7.2 Outlook

Despite the absence of a science, technology and innovation ecosystem in Ghana, capabilities in sustainable energy do exist in technology collaborations & absorption, business and finance models. Capabilities also exist in important off-grid and mini-grid technologies relevant to Ghana such as solar, wind and biomass as well on productive end-use technologies.

Areas of technology development and risk management need to be developed and existing strengths on business and finance models augmented and consolidated to ensure that Ghanaian institutions can contribute significantly to the country's SE4ALL objectives and plans. The Technical Assistance Programme has been developed for seeking funding from Ghana's development partners for SE4ALL. Financing and implementation of this technical assistance programme for Sustainable Energy would be an important element to ensure that the SE4ALL efforts are nationally sustainable in the long term.

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9 ANNEX A: LIST OF INSTITUTIONS SURVEYED

No.	Institution	Contact Person	Focus Area	Response
	Government			
1.	CSIR-IIR	Dr. Gabriel Nii Laryea	RE for productive uses, biogas technology	
2.	Ministry of Food and Agriculture, Agriculture Engineering Services Directorate (AESD)	Mr. Gamel Ahmed	RE for productive uses (wind pump for irrigation, solar dryers)	Yes
3.	GRATIS Foundation	Mr. Raymond Owusu	Custom RE for productive uses(Wind rope pump)	
4.	Savannah Accelerated Development Authority	Mr. Yakubu	RE for productive uses (solar for irrigation	
5.	Wienco/ IWAD GH	Mr Busia Dawuni	RE for productive uses (solar for irrigation)	Yes
6.	Energy Foundation	Mr. Stephen Duodu	RE for productive uses (e.g. wind pump for irrigation, etc.)	Yes
7.	DENG/ Deng Solar Training Center	Mr. Kenneth Cornelius	Consultancy of RE products installations, importation and capacity building in RE(solar)	Yes
8.	Wilkins Engineering	Mr. Kofi Omane Frimpong	RE for lighting and appliances (solar)	Yes
9.	Ghana Irrigation Development Authority	Mr Prosper Glitse	Irrigation	Yes
	Academia			
10.	Ghana Technology University College	Dr. Francis Agyenim Boateng	Capacity building in RE(Mainly solar home systems)	
11.	Technology Consultancy Centre - KNUST	Mr. Michael Kommey	Cookstove sector gasifier, RE for productive uses (Solar thermal and wind irrigation	Yes
	NGOs/CSOs			
12.	New Energy	Mr. Mahama Amadu	RE technologies and applications (e.g. Solar PV for irrigation, SHS)	Yes
13.	Agricultural and Rural Development Association	Mr. Kingsley Nii Addy	RE for productive uses and lighting (e.g. solar for irrigation)	

No.	Institution	Contact Person	Focus Area	Response
	Others			
14.	Ashesi University, Climate Innovation Centre	Mr. Michael Kwatia	Focus areas are yet to be defined. CIC at the formative stage	Yes
15.	Business model issue			
16.	KITE	Mr. Ishmael Edjekumhene	Energy enterprise development services, policy advocacy, capacity building	Yes
	Risk management			
17.	University of Ghana - Institute of Statistical, Social and Economic Research			
18.	PwC	Venan Sondo		Yes

10 ANNEX B: QUESTIONNAIRE USED FOR INSTITUTIONAL SURVEY

African Development Bank-Energy Commission - Ghana SE4ALL - Technology Transfer - Questionnaire

1. When was your organisation established? What is your latest annual financial turnover?

2. List specific areas[37] of technical capabilities within renewable energy, energy access, energy efficiency and productive use of energy?

3. List capabilities of the organisation in business models and risk assessments for energy access and clean energy?

4. List the number of patents as well as peer-reviewed journal publications by the institute and its researchers? List also the international collaborations the organisation has had in clean energy and energy access.

5. Please provide any other relevant information about your plans, annual reports, publications etc. available in electronic form or make specific recommendations and suggestions.

[37] Select from clean cooking, SHS and mini-grid for energy access, irrigation and food processing for productive use, solar, biomass, wind and mini-hydro for renewable energy and industry or energy management for energy efficiency.

11 ANNEX C: TECHNICAL ASSISTANCE LOGICAL FRAMEWORK

INTENDED OUTPUTS	OUTPUT TARGETS	INDICATIVE ACTIVITIES	EXECUTION AND BENEFICIARIES	BUDGET
Output 1: Development of technology development capability Baseline: • Limited publications, patents on sustainable energy from Ghanaian institutions • Limited number of researchers engaged in sustainable energy research	• 25 research grants awarded (5 years); • At least 25 publications and/or patent applications (5 years); • 30 exchange/residency visits between Ghanaian research institutes and international research institutes (5 years).	1 Establish and operate the sustainable energy research grants programme 2 Identification of partner research institutions and establish bilateral agreement framework 3 Establish and operate the research collaboration facility	Execution: EC in coordination with MoP, MESTI, CSIR. Beneficiaries: All Ghanaian research institutions - private, public and NGOs.	• 25 research grants US$ 50,000 each; • Yearly management of research grants programme - US$ 50,000/year; • Establishment of the research collaboration programme - US$ 100,000; • 30 exchange residency valued at US$ 10,000 each; • Yearly management of research grants programme - US$ 20,000/year. **Total Budget US$ 2,000,000**
Output 2 : Development of risk identification and management capabilities Baseline: • Limited application of risk identification and management in sustainable energy projects and	• Risk assessment and management framework developed (year 1); • Risk management course developed and implemented (year 2)	1 Development of the Ghana SE4ALL Risk management framework; 2 Development of a 3/5 day course curriculum. Implementing on-line course and classroom	Execution: EC and selected education and training partner; Beneficiaries: - private, public, research and NGO	• Risk management framework development and implementation - US$ 50,000; • Development and implementation of on-line and classroom courses -

INTENDED OUTPUTS	OUTPUT TARGETS	INDICATIVE ACTIVITIES	EXECUTION AND BENEFICIARIES	BUDGET
programmes; • Limited capability among institutions surveyed	• 100 people trained and certified (5 years).	based courses; 3 Implementation of classroom based training programmes.	project managers of sustainable energy project, teaching faculty management institutes.	US$ 100,000; • Sponsorships and scholarships of training programmes - US$ 150,000. **Total Budget: US$ 300,000**
Output 3: Developing priority technology capabilities Baseline: • Ghanaian institutions surveyed have limited hydro-power development capabilities • Electrical pump sets do not have energy efficiency standards and labelling	• Energy efficiency labelling programme in place (Year 3); • High level of awareness on efficient pump set labels (Year 5); • 3 south-south exchange and study tours on hydro and biomass power (2) and efficient pump labelling (1).	1 Development of electric pump standards and labelling framework; 2 Multi-media awareness campaign on energy efficiency labels for pump sets; 3 Organising 2 south-south exchange and study tours on hydro and bio-energy and 1 study tour on pump set labels.	Execution: EC Beneficiaries: - decision makers, private, public, research and NGO institutions.	• Development of the standards and labelling framework - US$ 300,000; • National multimedia promotional campaign of the energy efficient pump set labels – US$ 100,000; • 3 study tours on priority technologies of hydro and biomass power and efficient pump sets US$ 100,000 - each. **Total Budget: US$ 700,000**
Output 4: Augmenting business and financial model capabilities Baseline: • Considerable business and financial model understanding and capabilities with surveyed institutions • Limited opportunities for transfer of best business	• South-south exchange and study tours on business and financial models for rural electrification organized (5 years); • Two visits by rural electrification business and financial model and finance experts to	1 Organising 3 south-south exchange and study tours on rural electrification business and financial models for Ghanaian stakeholders 2 Organising 2 visits and lecture series by international experts on business and financial models for rural	Execution: EC Beneficiaries: - decision makers, private, public, research, banking & finance and NGO institutions.	• 3 study tours on rural electrification business and finance models - US$ 100,000 each; • 2 visits and lecture series by international experts - US$ 25,000 each. **Total Budget: US$ 350,000**

INTENDED OUTPUTS	OUTPUT TARGETS	INDICATIVE ACTIVITIES	EXECUTION AND BENEFICIARIES	BUDGET
practices and financial models from other developing countries	Ghana (5 years).	electrification		
Output 5: Augmenting technology absorption capabilities Baseline: • High levels of collaboration between Ghanaian and international organisations in the sustainable energy issues • Evidence of application of such technology know-how in projects being implemented in Ghana in sustainable energy	• 20 small grants made to Ghanaian researchers on collaborative research plans with host institutions for research collaboration and for presentation of papers in reputed international sustainable energy academic and research conferences	1 Process for evaluation and selection of grant applications and administration of the grants and outputs; 2 20 small grants for Ghanaian researchers for research collaboration and participation in international conferences on sustainable energy.	Execution: EC in coordination with MoP, MESTI, CSIR. Beneficiaries: All Ghanaian research institutions - public, academic and NGOs.	• 20 small grants in the range of US$ 3000 to US$ 5000 for Ghanaian researchers for research collaborations and conference participation - US$ 3-5000/each • Yearly management of the selection and grant-making process - US$ 10,000/year **Total Budget: US$ 150,000**
Total Budget for Technical Assistance on Sustainable Energy Technology Capacity Building				**US$ 3,600,0000**