China-Ghana South-South Cooperation on Renewable Energy Technology Transfer

Identification of barriers to renewable energy technology transfer to Ghana

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AUTHORS

This report has been prepared by:

- **Ing. Edem C. Bensah (lead author),** Centre for Renewable Energy and Energy Efficiency, CREK, Kumasi Polytechnic, Ghana
- **Dr. Francis Kemausuor,** The Energy Centre, College of Engineering, KNUST, Ghana
- **Ing. Edward Antwi,** CREK, Kumasi Polytechnic, Ghana
- **Julius Ahiekpor,** CREK, Kumasi Polytechnic, Ghana

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EXECUTIVE SUMMARY

Background

The lack of knowledge and technical skills, low quality training, ineffective regulations and lack of financing have been identified among key barriers to the dissemination and usage of renewable energy technologies (RETs) in Ghana. Consequently, UNDP and Energy Commission are implementing a four-year project dubbed 'China-Ghana South-South Cooperation on Renewable Energy Technology Transfer (RETT)' to expedite the transfer and diffusion of RET from China to Ghana. The project is funded by the Danish Government in support of coherent cooperation between China and countries in Africa within the framework of the UN's Sustainable Energy for All (SE4ALL) initiative.

The project supports broader national socio-economic and environmental objectives, most notably poverty reduction through employment generation and supporting action on climate change mitigation. The project will do so by creating an enabling environment for technology transfer and promote the production of RETs in Ghana with a strong focus on private sector development and inclusion. In the first year of implementation (2015), the project is focusing on establishing an enabling environment for the transfer, production and regulation of the use of RETs in Ghana.

As one of the outputs of the project, this report identifies and examines the barriers to RETT to Ghana and proposes concrete mitigation actions for the removal of key barriers in a roadmap, drawing from lessons from Ghana's history in RETT as well as lessons from other developing countries. It provides information on the stage of technology transfer of prioritised RETs and proposes timelines for the achievement of full technology know-how. The assignment has been carried out via in-depth desk review studies, surveys, and interviews with stakeholders in Ghana and experts in China. The proposed roadmap is expected to form the foundation for the development of a RE Masterplan for Ghana. Some of the key points of the assignment are summarised below.

Constitutes and elements of RETT

Technology transfer (TT) is generally defined as the movement of information form one point to another. Technology transfer can be vertical or horizontal. Vertical transfer refers to transfer of technology from basic research to applied research, development, and production. On the other hand, horizontal (international) technology transfer involves the movement of technology used in one place, organisation, or context to another place, organisation, or context. Consequently, RETT refers to the movement of mature (advanced and appropriate) renewable energy technologies from one country to another, usually from an industrialized to a developing country.

This enables the receiving country to acquire, adapt, deploy and diffuse renewable energy technologies from overseas and further innovate as a result of the capabilities acquired through the technology transfer process. The movement may involve equipment, skill and know-how, values and capital occurring at various stages.

Three stages of technology transfer are identified: the first stage involves the movement of equipment and capital goods; the second stage includes skills and know-how for operating and maintaining equipment; and the third stage involves the transfer of knowledge and expertise for generating and managing technological change. At this stage new technological capacity is created through technology transfer and active independent learning, creation and innovation of the recipient. Technology transfer process is successful when the recipient is able to acquire, use, replicate and possible resell the technology.

Review of Ghana's technology transfer regulations, 1992 (LI 1547)

Ghana's technology transfer regulation (LI 1547) was enacted in 1992 as a legislative instrument enforceable by the Ghana Investment Centre, now the Ghana Investment Promotion Centre (GIPC), established by an Act of parliament in 2013 (Act 865). GIPC is the government agency responsible for encouragement and promotion of investments in Ghana through the creation of an attractive incentive framework and enabling environment for investments. The technology transfer regulations (LI 1547) require that all technologies transferred to Ghana for the purposes of doing business must be entered into an agreement between the transferor and local partner and duly registered with GIPC.

Cross-border technology transfer agreements have become an important element of the overall business strategy of any firm that seeks to expand its operations globally. These agreements provide the framework under which an owner (transferor) of a technology (specialized knowledge or expertise) can transfer certain legal rights to a partner (transferee) in foreign country while retaining title and control of such technology. The LI 1547 does not place any restrictions on the use of local components, raw materials or labour. However, it encourages innovation by allowing for transferred technology to be modified, adapted or improved by recipient with or without the consent of the owner of the technology. It is recommended that the LI be amended to address contemporary issues in technology transfer. These include specifying how Intellectual Property Rights (IPRs) are shared, enforcing research and development, and specifying sanctions for breach of contract.

History, current and future trends of RETT to Ghana

Ghana has had experience with RE development and technology transfer (TT) since the first hydropower plant was constructed in Ghana more than 50 years ago. Since that first plant was handed over to Ghanaian management, two other hydropower plants have been constructed and are fully managed by Ghanaians. A lot has happened in the area of RE development and TT since then. Interestingly, many of the RE projects implemented in Ghana were not meant as pure TT projects, however, by their nature, they were TT related. With time, Ghanaians have learnt to accept, embrace and adapt to these technologies. Some of the technologies went through vertical technology transfer while others took the horizontal transfer route.

Solar PV systems, first introduced to Ghana for lighting, have been adapted and now provide power for other uses as well. Many of the projects that were implemented have specific TT components such as training of technicians, development of manuals, and preparatory processes leading to local manufacturing. Solar dryer experiments have been conducted for close to two decades but commercial scale projects have been lacking due to high cost of acrylic glazing materials. Close to four decades of biogas development in Ghana has not led to a scale-up of the technology due to challenges such as poor level of construction; lack of skilled attendants; and poor maintenance, and weak government support.

Of the other bioenergy types, only pellets had made in-road into large scale manufacturing, but by a single company even though support frameworks for such investments are not encouraging. Improved cookstoves have enjoyed several TT related activities and there is a lot of local manufacturing capacity for especially household stoves. A number of institutions in the country conduct training in RE technologies, leading to the award of all levels of academic certificates, from basic participation certificates, through bachelor degrees to PhD.

It should be noted that many Ghanaian RE projects often miss ‘further innovation’ eventually as projects fail to proceed to local manufacture, notwithstanding the numerous capacity building activities. The projects succeed in adapting, deploying and diffusing RE into the country but falls short of innovating. Ghana’s target of about 5000 MW of installed electricity generation capacity by 2020 means that about 500 MW (or 10%) target for RE electricity by 2020 could bring TT to the limelight. Ghana must cease this opportunity, under the China-Ghana South-South project, to develop local capacity in the design, manufacture, installation, operation and maintenance of RE systems in the country. Doing this would likely lead to cost reduction and opportunities for local manufacture that can have several positive impacts. In this vein, China’s ‘superpower’ status in RE infrastructure could benefit Ghana immensely under the current project.

Success stories of RETT globally

There are several RETT success stories in developing countries across the globe with China epitomizing a country with an all-round success. Other developing countries, including some in Africa, have implemented successful projects that serve as lessons for Ghana. Some of the countries reviewed in this document include South Africa, Zimbabwe and Tunisia (for solar water heating); Kenya (for solar lighting and institutional cookstoves); Algeria (for Integrated Solar Combined-Cycle); Rwanda (for micro-gasification pellet stove programme), Nepal (for domestic biogas); and multi-country initiatives such as the African Biogas Partnership Programme (ABPP) implemented in Burkina Faso, Rwanda, Kenya, Ethiopia and others. Morocco is a shining example, with the upcoming commissioning of what is being described as 'the largest solar plant in the world.'

Some of the key success factors in the countries reviewed include: development of local manufacturing capacity; 'hardline' policies: e.g. strict building efficiency codes and banning of conventional systems; building on niches within the specific countries; taking advantage of opportunities and massive awareness campaigns. For technology transfer to be successful, it must be accepted that some things are (sometimes) achieved the 'hard way,' and with commitment and dedication. Zimbabwe's plan to ban imported water heaters (after completion of its local capacity development in solar water heaters manufacturing) is a lesson that could truly drive innovation, and worth considering in Ghana.

Barriers to RETT to Ghana

In spite of the high RE resource base, penetration of modern RE in Ghana's final energy mix has been very marginal. This is due to a number of barriers that are militating against RETT to Ghana. A total of 48 barriers were identified in the desktop study. The identified barriers were grouped under 8 themes reflecting their main area of impact as follows:

1. **Financial and economic barriers** – High upfront costs; high interest rate; limited access to capital; lack of consumer financing options; unstable currency; subsidies on conventional systems; and high operations and maintenance cost;
2. **Market barriers** – Underdeveloped supply chain; small market size; unstable market situation; failed past experience; and lack of successful reference projects;
3. **Policy and regulatory barriers** – Insufficient legal and regulatory framework; lack of enforcement of codes and standards; unfavourable policies; corruption; intellectual property rights; low level of political will; inadequate re codes and standards; and problems in land acquisition;
4. **Technical barriers** – Difficulty in obtaining equipment and spare parts; immature technology; poor operations and maintenance of facilities; new technology too complicated; and lack of infrastructure;

5. **Human skills barriers** – Lack of skilled personnel for manufacturing and installation; lack of personnel for preparing project; lack of service and maintenance specialists; and inadequate training facilities;
6. **Socio-cultural barriers** – Lack of interest in shifting from conventional energy to RE; consumer preference and social biases; lack of confidence in new technology; dispersed/widely distributed settlement; lack of understanding of local needs; and fear of failure;
7. **Information and awareness barriers** – Poor or lack of information about cost and benefits of RETs; and media not interested in RET promotion;
8. **Network barriers** – Weak connections between stakeholders promoting the new technology; strong network of conventional technologies favoured by legislation; difficult access to external manufacturers/institutions; lack of involvement of stakeholders in decision making; and weak network between foreign institutions and local ones.

A total of 71 stakeholders were initially identified as playing important roles or involved to some extent in RETT. The list comprises stakeholders from academic and research institutions, manufacturers/producers and service providers, international NGOs and developmental partners, policy and regulatory bodies, and financial institutions. The stakeholders were made to review the identified barriers by ranking them in terms of their importance using an ordinal scale. A total of 51 stakeholders were reached for their views on the identified barriers.

Screening and establishment of key barriers to RETT

The initial ranking of barriers based on the least score per the assessment by the stakeholders produced 20 important barriers. The 20 barriers were further reduced to nine key barriers by considering barriers that were scored more than 50% by the respondents. The nine key barriers were regrouped using the PESTEL analysis as follow:

Category	Key barriers
Political	Lack of enforcement and political will
Economic	High Initial Cost High Interest rate Unstable currency Limited access to capital
Technical	Inadequate training facilities Lack of skilled personnel for manufacturing
Socio-cultural	Poor or lack of information about cost and benefits of RETs

Mitigation actions for removing key barriers to RETT

Mitigation measures to reduce the effect or completely eliminate the nine key barriers were proposed, as follows:

Barriers	Mitigation actions
Political	a. Expedite the development of RE master plan b. Operationalize the RE fund under RE law c. Develop national programmes on prioritised RETs d. Develop/adopt standards, codes and labels for biogas plants, SWH, solar dryers, wind mills and other RETs.
Economic	a. Develop and implement tax incentives on prioritised RETS b. Provide financial support for RET investment in prioritised sectors
Technical	a. Strengthen existing training facilities b. Build capacity of researchers and trainers in RETs c. Build capacity of researchers and trainers in RETs d. Conduct capacity building programmes for entrepreneurs and local enterprises e. Arrange networks and partnerships for local enterprises with counterparts in other countries
Socio-cultural	a. Run cost benefit campaign on the use of RE products b. Include RETs in technology catalogue

SWOT analyses have been conducted for all proposed mitigation measures.

Identification and prioritisation of RETs for TT to Ghana

RE technologies for off-grid applications were identified as having potential for technology transfer and evaluated:

- Biomass and bioenergy (biogas, ethanol, biodiesel, bio-oil and syn-gas, solid fuels and improved cookstoves, and improved charcoal kiln);
- Solar thermal technologies (water still, water heater, dryer);
- Solar PV technology;
- Solar lantern;
- Mini- and micro-hydro; and
- Standalone wind turbine.

Other technologies were screened out based on the following reasons:

- Landfill gas - Process of harnessing landfill gas complicated; lack of well-engineered landfill sites; economics unfavourable;

- Solar ovens/cookers - Not too successful in Ghana; appear not to fit into traditional cooking;
- Concentrated solar power/heating - Low direct normal radiation (DNI) in Ghana; and
- Solar fuel - Immature technology; under development.

The selected RETs were evaluated and ranked using the multi-criteria and multi-perspective decision tool, Analytical Hierarchy Process (AHP), by 33 experts and stakeholders in a consultative workshop organised by UNDP and Energy Commission on 24-25 November 2015. The goal for evaluating and prioritizing RETs as agreed by participants was 'prioritization of RETs to identify high impact technologies for national support.' The RETs were evaluated based on a set of criteria and sub-criteria in relation to the goal. The ranking of criteria, sub-criteria and RETs and based on collective agreement by stakeholders is shown below:

Item	Details	Rank
Criteria	Economic	1
	Technical	2
	Environmental	3
	Socio-cultural and political	4
Sub-criteria	Investment (upfront cost)	1
	Economic viability	2
	Market potential (scalability and replicability)	3
	Resource availability	4
	Ease of local manufacture, repair and component supply	5
	Jobs creation	6
	Proven technology (technical maturity)	7
	Emission reduction	8
	Land requirement	9
	Adverse impact of RET on environment	10
	Macro-economic benefits	11
	Social acceptability	12

Item	Details	Rank
RETs	Solar lantern	1
	Solar dryers	2
	Solar PV	3
	Solar water heaters	4
	Solid fuels	5
	Biogas	6
	Solar water stills	7
	Efficient charcoal kilns	8
	Standalone wind turbines	9
	Mini- and micro-hydro	10
	Ethanol	11
	Biodiesel	12
	Bio-oil and synthetic-gas	13

Experts ranked the economic criterion as the most important in achieving the goal, followed by technical, environmental and socio-cultural and political. From the ranking of sub-criteria, stakeholders agree RETs that are prioritized for national support must have favourable indicators as far as the economic sub-criteria are concerned. Finally, stakeholders ranked solar lanterns as the alternative with the highest impact in relation to the goal. Solar lanterns have already received considerable national interest and large programmes such as GEDAP have prioritised solar lanterns for dissemination especially in areas remote from grid power.

Roadmap for RETT to Ghana

A roadmap with concrete actions and timelines has been proposed for the removal of key barriers to RETT and diffusion in Ghana. The roadmap takes into consideration the current stage of TT with respect to prioritised RETs and provides timelines for the achievement of full manufacturing capabilities of the technologies. Specific areas to focus whenever appropriate are highlighted. The policy timeline is focused on what government can do to accelerate RETT to Ghana in order to meet the national RE targets. This is essential in cases where proposed actions relate to legislation or use of government funds. However, in many other cases, there are opportunities for other stakeholders such as development partners, research and tertiary institutions, enterprises and NGOs to facilitate these activities, with or without government support. These stakeholders need to play different but complementary roles in policy development and implementation from the national to the local level. Key aspects of the roadmap pertains to the capitalisation and operationalisation of the RE Fund and the development of the RE master plan, which will serve as a catalyst to support RETT and diffusion, as well as growth of private companies in the sector.

Wind pump for irrigation in Ghana
Photo: AESD-MOFA

INTRODUCTION

1.1 Background

This report is the main deliverable of the assignment "Identification of Barriers to Renewable Energy Technology Transfer to Ghana" which has been undertaken for the United Nations Development Programme (UNDP) and Energy Commission. It is part of a larger initiative dubbed China-Ghana Renewable Energy Technology (RET) Transfer Cooperation, financed by the Danish Government and implemented by UNDP. The project will lead to the establishment of a South-South Cooperation (SSC) Centre in China to promote Renewable Energy Technology Transfer (RETT) from China to Ghana through various packets of training and capacity building.

It is accepted that RE can play a crucial role in enhancing electricity access especially in rural and isolated communities if its development receives the necessary support from all stakeholders. Though access to electricity in Ghana (73%) is high in relation to the sub-Saharan African average (24%)[1], there are still many rural communities that live under extreme socio-economic challenges due to factors that include lack of access to grid electricity. Further, most of these communities may be rural, isolated or scattered where the national grid is unlikely to reach them anytime soon[2]. In addition, Ghana has frequently faced difficulties in generating sufficient electricity to meet the energy requirements needed for growth and economic development. This has resulted in frequent power outages and planned power rationing across the country in recent years, leading to reduced workforce productivity, high cost of doing business, and lack of power for essential activities in the home.

RETT would have several advantages for Ghana in aspects such as strengthening human resource in research and development, cost reduction of RE products, increased local manufacture and income as well as employment generation. However, the potential benefits of RETs could elude Ghana if the key barriers to effective RETT are not identified and assessed, so as to implement effective strategies and action plans for removing the barriers.

1.2 Objectives and scope

This assignment is focused on developing a roadmap detailing actions, measures and strategies for the removal of all forms of barriers to effective RETT in Ghana, with emphasis on cooperation between China and Ghana.

The underlying final report aims at:

1. Describing RETT and its components and forms;
2. Reviewing Ghana's Technology Transfer Regulations, 1992 (LI 1547) and assessing its appropriateness to addressing trends in RETT;
3. Studying past and current RETT programmes in Ghana, emphasizing studies from China and developing countries;
4. Studying successful case studies of RETT at the global level, analysing factors that contributed to the success as well as lessons from such programmes;
5. Prioritizing relevant RETs based on their potential for technology transfer in Ghana, with emphasis on China and other developing countries;
6. Examining barriers to RETT, highlighting any Chinese experience whenever possible;
7. Examining and screening all barriers, identifying key ones and proposing concrete measures to tackle the barriers; and
8. Proposing a detailed roadmap for RETT in Ghana.

[1] UNEP Finance Initiative. Financing Renewable Energy in Developing Countries: Drivers and barriers for private finance in sub-Saharan Africa, February 2012.

[2] Ahiekpor, J.C. Overview of Solar Projects in Ghana. A Study conducted for SNV-Ghana, 2013.

1.3 Approach and strategy

The assignment has been carried out through desk-based research, using data and insights obtained from published materials, as well as field trips involving semi-structured interviews with key actors and stakeholders in Ghana (Figure 1). In total, forty-eight experts and stakeholders in Ghana were interviewed, comprising private companies and enterprises, technology suppliers, service providers, academic experts and researchers, developmental partners, non-governmental organisations (NGOs), community-based organisations (CBOs) and gender-based organisations, and government advisors and policy makers, across all sectors of RE. A summary of the profile of actors consulted is shown in Annex A. Experts from China were also interviewed via Skype and email exchanges.

1.4 Report structure

This rest of the report is structured as follows:

- Section 2 provides a description of RETT and its components and forms;
- Section 3 reviews Ghana's Technology Transfer Regulations, 1992 (LI 1547) with the view of assessing its appropriateness to trends in RETT;
- Section 4 provides information on the history of RETT in Ghana and highlights lessons learnt. It further outlines current RETT activities in Ghana and highlights future trends in RETT in view of the country's strategic position as a business hub in the sub-region;
- In Section 5, successful case studies of RETT in other developing countries are discussed, focussing on how barriers to RETT were removed;
- In Section 6, barriers affecting RETT globally are critically analysed with specific references to Ghana;
- Section 7 screens all barriers identified, establishing key ones and proposes mitigation actions for removing them;
- Section 8 identifies and evaluates RETs with high potential for transfer to Ghana from China and other countries;
- Finally, Section 9 details a roadmap proposed for RETT from China and other countries to Ghana.

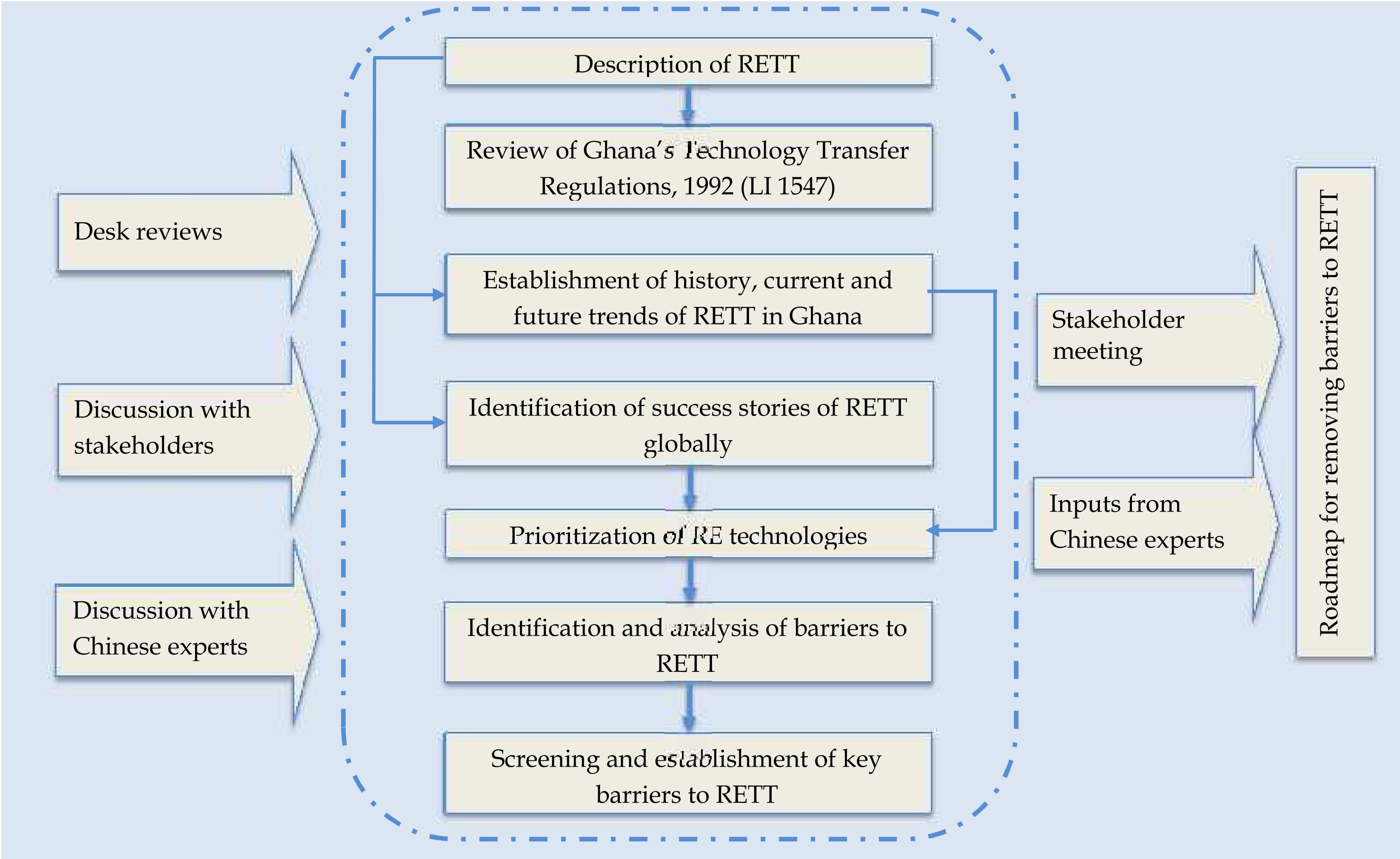

Figure 1 **Approach used to undertake the assignment**

Solar water heater assembled by DENG
Photo: Edem Bensah

2. CONSTITUENTS AND ELEMENTS OF RENEWABLE ENERGY TECHNOLOGY TRANSFER

2.1 Introduction to technology transfer

Technology transfer (TT) has been defined and measured in many different ways and by a wide range of disciplines[3]. It has been defined as the process of movement of technology from one entity to another. The transfer may be said to be successful if the recipient, can effectively utilise the technology transferred and eventually assimilate it[4].

[3] Pueyo A and Linares P (2012). RETT to developing countries: One size does not fit all. IDS Working Paper. 2012 (412).

[4] Ramanathan, K (2014). An overview of Technology Transfer and Technology Transfer Models.

The movement may involve physical assets, know-how, and technical knowledge[5]. TT has also been defined as the movement of knowledge, skill, organisation, values and capital from the point of generation to the point of adaptation and application.

Inspite of the seemingly complexity in the definition of TT, the end result for the recipient must be the ability to use, replicate, improve and, possibly, re-sell the technology[6]. TT must avoid creating and maintaining dependency on the supplier to ensure sustained and equitable development. Therefore, transfer of technology is more than just the moving of high-tech equipment from the developed to the developing world, or within the developing world. It involves far more than equipment and other so-called "hard" technologies, for it also includes total systems and their component parts, including know-how, goods and services, equipment, and organizational and managerial procedures across and within countries, stakeholder organizations and institutions.

Cohen (2004)[7] distinguished between technology trade and real technology transfer, as technology trade is merely the import of equipment or the execution of projects on a turnkey basis, while technology transfer involves mastering the imported know-how of core technologies and the development and generation of technologies utilising scientific and technological capacities. There exist three different flows of transferred technological content:[8]

- The first flow involves import of capital goods and equipment - increases the production capacity of the recipient but on its own does not enable the recipient to use the imported facilities efficiently or to generate technological change;
- The second flow includes skills and know-how for operating and maintaining equipment. It places the human resources of the importer at the technological level required to operate the imported technology efficiently, but without indigenous efforts beyond learning how to use the technology it would not enable technological change;
- The third flow encompasses knowledge and expertise for generating and managing technological change. It creates new technological capacity through technology transfer and active independent learning, creation and innovation of the recipient.

According to Ramanathan (2014), the mode of TT can be classified as vertical (internal) or horizontal (external). Vertical transfer refers to technology being transferred from research to development to production. Thus it follows the progressive stages of invention, innovation and development, with the technology becoming more commercialised as it proceeds through each stage. Vertical transfer can be within one organisation or a transaction between, say, a research institute and a manufacturing company.

Horizontal transfer refers to a matured technology being transferred from one operational environment to another.

[5] Bozeman, B. (2000). Technology transfer and public policy. A review of research and Theory. Research Policy.

[6] UNEP-IETC (2003). Technology transfer: The seven Cs for the successful transfer and uptake of environmentally sound technologies. Osaka, Japan.

[7] Cohen, W. M., Goto A., Nagata A., Nelson R. R., and Walsh J. (2002). R&D Spillovers, Patents and the Incentives to Innovate in Japan and the United States'. Research Policy 31(8–9): 1349–67.

[8] See Pueyo and Linares, 2012

The technology is already commercialised and the purpose is to disseminate the technology and extend its application into other contexts. This type of transfer is used by companies wishing to maximise the return from their technology, but being unable to do this by direct selling of end products in a market. Horizontal transfer is more common when technology is being transferred from industrialised to developing countries. There is usually no further improvement or change to the technology unless it needs to be modified to suit local circumstances or environmental regulation, in which case when it is adapted and/or refined.[9]

2.2 Renewable energy technology transfer (RETT)

In the context of renewable energy technologies, technology transfer may refer to the diffusion of mature (advanced and appropriate) renewable energy technologies from one country to another. This enables the receiving country to acquire, adapt, deploy and diffuse renewable energy technologies from overseas and further innovate as a result of the capabilities acquired through the technology transfer process (Figure 2).

The process starts with the identification of a need. The needs are the driving forces for technology uptake. To avoid the transfer of inadequate, unsustainable, or unsafe technologies, technology recipients should be able to identify and select technologies that are appropriate to their actual needs, circumstances and capacities[10]. For instance in the case of renewable energy technologies, lack of access to modern energy services and environmental pollution and the apparent lack of technologies to meet these needs are driving forces for technology uptake. Even though the need is apparent, it does not necessarily lead to technological and knowledge transfer.

In Ghana the RE Law (Act 832) defines renewable energy as energy obtained from non-depleting sources including: wind; solar; hydro; biomass; bio-fuel; landfill gas; sewerage gas; geothermal energy; and ocean energy. The Law seeks to provide an enabling environment and framework for the development and utilization of these RE sources for the production of heat and power in an efficient and environmentally sustainable manner. To benefit sustainably in any RETT process to Ghana, RETs that are appropriate to the country's immediate needs, circumstances and with potential capacities must be selected.

Currently, RETs such as solar energy in its various forms (photovoltaic, heating and thermal or concentrated), wind power technologies and several modern forms of biomass conversion technologies (particularly biogas digesters), are registering the fastest deployment growth rates in both developed and developing countries, and their upfront costs are declining fast. These technologies can be applied in a broad range of development contexts and, in particular, demonstrate significant potential for application in rural as well as urban areas in developing countries through small-grid and non-grid systems.[11]

[9] UNIDO (2002). Innovative technology transfer framework linked to trade for UNIDO Action.
[10] See UNEP-IETC (2003).
[11] UNCTAD, 2011. Powering development with RETs.

It is worthy of note that only a limited number of developing countries are making their mark as developers of RETs. The experiences of China, India and other emerging economies show that public support, political will and concerted policy coordination are key to promoting technological capabilities over time. Greater support for education (especially at the tertiary level) and for the development of small and medium-sized enterprises, as well as financial support for larger firms and public science are important. Some studies have also noted that expertise in these countries initially concentrated to a large extent on less technology-intensive RETs such as biofuels, solar thermal and geothermal. Many of these countries either have existing expertise, or stand good chances of developing such expertise.

RETT could take several forms depending on the level of capabilities of the recipient. However, as pointed out earlier, it should not be limited to only the transfer of hi-tech equipment but should include skills and capacity development, organizational and managerial procedures for technological change as well as supportive regulatory framework to acquire, use and adopt the technology.

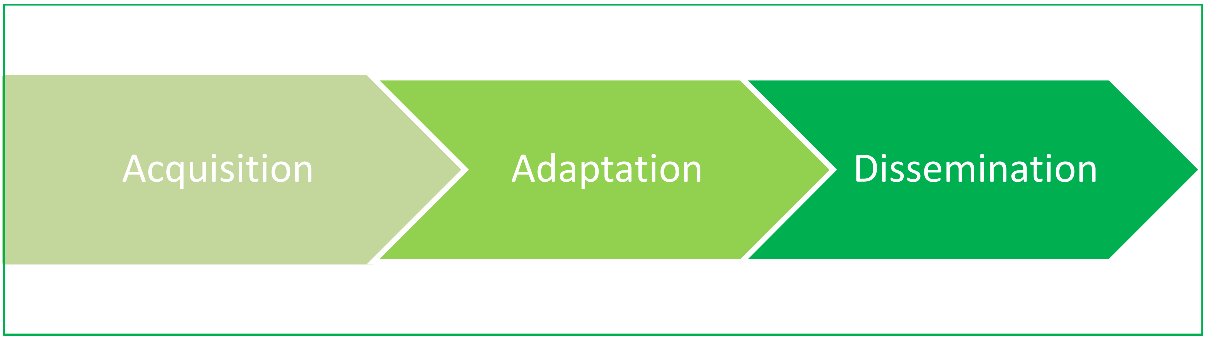

Figure 2 **Main process for technology transfer**

2.3 Conclusion

Based on the above discussion, the following conclusions may be drawn:

- Commercial technology transfer may be defined as a mutually agreed upon, intentional, and proactive process by which technology flows from an entity that owns the technology (the transferor) to an entity seeking the technology (the transferee). The transfer involves cost and expenditure that is negotiated and agreed upon by the transferee and transferor. The transfer may be said to be successful if the transferee can successfully utilise the technology for business gains and eventually assimilate it;
- Technology transfer can be vertical or horizontal technology transfer. Vertical transfer refers to transfer of technology from basic research to applied research, development, and production while horizontal technology transfer involves the movement of technology used in one place, organisation, or context to another place, organisation, or context; and

- In today's globalised and liberalised business setting, many technology transfer modes could be deployed depending on how the technology development aims of the transferor and transferee are linked. Technology transfer can commence from a simple level to a much more comprehensive one with time. The mode chosen would depend on the corporate strategies of the transferor and transferee and the technological capability of the transferee.

Puxin biogas digesters at Hebron Prayer Camp, near Nsawam
Photo: Edem Bensah

3. GHANA'S TECHNOLOGY TRANSFER REGULATIONS

3.1 Background

Cross-border technology transfer agreements have become an important element of the overall business strategy of any firm that seeks to expand its operations globally. These agreements provide the framework under which an owner (transferor) of a technology (specialized knowledge or expertise) can transfer certain legal rights to a partner (transferee) in a foreign country while retaining title and control of such technology[12].

TT agreements can offer a number of potential business advantages to the transferor when the transferor wishes to rely on local partners in a recipient country as opposed to setting up operations on its own to conduct activities for which the technology is being transferred.

[12] Gutterman, A. (2009). Regulations of Technology Transfer Arrangements.

Some of the benefits include low cost of market access and manufacturing, cheap labour, available raw materials, and loyalties. For example, if the transferor is interested in manufacturing and distributing its products in a foreign country it may efficiently do so by licensing the relevant technology to a local manufacturer (transferee) that can use the available labour and raw materials and tap into its existing distribution channels in the market.

Developed nations tend to place restrictions on transfers (exports) that involve certain sensitive form of technology to other countries. For example, the United States has a comprehensive set of regulations, statutes and executive orders with respect to export controls, all of which are intended to curb worldwide proliferation of weapons of mass destruction and prevent certain countries from obtaining technologies that may contribute to their military potentials.

The recipient countries also benefit from TT regulations. According to Gutterman (2009), many countries in the developing world enacted TT regulations in the early 1990s due to the potential advantages to them of inbound technology transfers from industrialized countries. The advantages include introduction of the latest technologies into the domestic market, development of local capacities, increased level of employment, and foreign direct investment. Due to this potential benefits, governments in recipient countries are often tempted to relax the terms that could be included in the technology transfer regulations in order to attract investors. Some of these waivers include conditions that manufacturing activities involved could only be carried out using local components and labour and reducing the amount to be paid in taxes and loyalties.

Consequently, technology transfer regulations can take a variety of different forms as each country will have its own specific concerns based on domestic, economics and political conditions at the time the law is enacted. These regulations can be reviewed from time to time to meet modern international and national requirements and their potential effect on the development of the national economy.

Among the most common areas of concern in recent years are royalty rates, the scope and content of control that the transferor seeks to impose on the transferee, the nature of implied representations, warranties regarding quality and performance, governing laws, terms of agreement and dispute resolution procedures.

For instance, technology transfer regulations in India have undergone transformations. For many years India took a very restrictive and protectionist approach to technology transfers between transferors and local transferees. The terms of technology licensing agreements were subject to the following conditions and restrictions:

1. Royalty percentages could not normally exceed 5% and the term of agreement could not exceed 10 years;
2. No minimum guaranteed royalty was allowed;
3. Exports of the licensed product could not be restricted by the transferor, except to jurisdictions where it had existing license agreements;

4. Clauses that bound the Indian party with respect to the procurement of capital goods, components, or raw materials had to be avoided;
5. Indian transferee had to be allowed to freely sublicense the technical know-how to another Indian part if it became necessary;
6. Provision for interest on delayed payments were not allowed;
7. Foreign brand names were not allowed for use on products for internal sales; and
8. Agreements have to be subject to Indian laws.

Recently, however, Indian technology transfer regulations have been liberalized in order to promote technology capacity and competiveness of industry in India and the government now claims that acquisition of foreign technology is encouraged through foreign technology collaboration agreements. The terms of payment under such agreements include technical know-how fees, payment for design and drawings, payment for engineering services and royalties.

3.2 Review of technology transfer regulation (LI 1547)

Ghana's technology transfer regulation (LI 1547) was approved in 1992 as a legislative instrument enforceable by the Ghana Investment Centre, now the Ghana Investment Promotion Centre (GIPC), established by an Act of parliament in 2013 (Act 865). GIPC is the government agency responsible for encouragement and promotion of investments in Ghana, to provide for the creation of an attractive incentive framework and enabling environment for investments in Ghana. The functions of GIPC include *inter alia*:

- Formulate investment promotion policies and plans, promotional incentives and marketing strategies to attract foreign and local investments in advanced technology industries and skill-intensive services which enjoy good export market prospects;
- Initiate and support measures that will enhance the investment climate in Ghana for both Ghanaian and non-Ghanaian enterprises; and
- Register and keep records of all technology transfer agreements.

The technology transfer regulations (LI 1547) require that all technologies transferred to Ghana for the purposes of doing business must be entered into an agreement between the transferor and local partner and duly registered with GIPC. It has provisions to protect both the transferor and transferee in the implementation of such agreements.

In the early 1990's, governments in developed countries including Ghana saw technology transfer laws as a tool to foster development of local technical capabilities and increase local employment. This often resulted in comprehensive restrictions on the terms that could be included in a licensed agreement. Though these restrictions may be good, industries in Ghana may relax/compromise the terms of these agreements which may not necessarily lead to a comprehensive transfer of technology.

The following sections attempts to review provisions in LI 1547 to ascertain if they are still relevant for the promotion of particular, RETT to Ghana.

3.2.1 Restrictions on agreements

Apart from the provisions of the regulations, no other restrictions are imposed on the registration of a technology transfer agreement in Ghana. Unlike other jurisdictions where the use of local components, raw materials and labour are part of the agreements, Ghana has more liberal regulations. The transferor and transferee can decide and agree on their source of labour and raw materials, provided it is not an imposition from the transferor. However, the regulations require the transferor to provide requisite training for the transferee and its personnel for the effective utilisation of the technology. Moreover, agreements which contain the following clauses are inapplicable and unenforceable under the regulations:

- Transfer of technologies that are freely and easily available in Ghana;
- Restriction on the volume of production or the sale of transferee's products in Ghana;
- Prohibition of exportation of products to specific geographical areas other than areas the transferor has previously granted exclusive rights to third parties;
- Clauses that bound the Ghanaian party with respect to the procurement of capital goods, components, or raw materials;
- Obligatory transfer of improvements or innovations introduced or developed by the transferee to transferor;
- Payment for patents and intellectual property rights after their expiration;
- Clauses which prohibit the use of licensed technical know-how acquired from the technology transferred after expiry of the agreement.

It is worthy of note that, the government of Ghana is developing a local content law which may seek to place restrictions on the use of labour and local materials when passed. Some sectors such as the upstream oil and gas industry already has a local content policy.

3.2.2 Improvement and adaptation of licensed technology

LI 1547 encourages research and development activities of the recipient (Transferee) to **improve**, **modify** and **adapt** licensed technology as stated in section 4 clauses (k) and (m) which are part of the inapplicable and unenforceable clauses (Box 1). The terms of the technology transfer agreements can neither restrict research and development activities of the transferee to improve and adapt the licensed technology nor require the transferee to seek the consent of the transferor before any modification can be made to licensed technology.

Even though this may be regarded as weak protection of intellectual property right (IPR), the provisions made by LI1547 are necessary for sustainable RETT in a small developing country like Ghana. According to Srinivas (2009)[13], experience of developing countries in Asia shows weak IP protection helped in building up local capacities even if the countries were at low levels of development.

[13] Srinivas, K.R (2009). Climate change, Technology Transfer and Intellectual Property Rights. RIS-DP 153.

For example, it has been pointed out by Kim (2003)[14] that in the initial stages of industrial development, Korea acquired and assimilated mature technologies and undertook reverse engineering and duplicative imitation. At those stages strong IP protection would hinder rather than enable technology transfer or development of indigenous capacity to learn by doing.

In Ghana's Patent Law (Law 305A), however, any invention as a result of improvement, modification or adoption of licence technology does not exclusively belong to the transferee but shared equally as stipulated in section 10 of the law (Box 2).

The Patent Law provides protection and ownership of original inventions and intellectual property. There are other laws in Ghana that strongly protect intellectual property including the Industrial Design Act, and Trademarks Act.

Also, TT regulation enjoins the transferee to keep the licensed technology confidential and use it only for its own purposes during and after expiration of the agreement. The transferee cannot, except with the consent of the transferor, sub-license the know-how or technology.

Box 1 **Section 4 of Technology Transfer Regulations, LI 1547**

Where a technology transfer agreement contains any of the clauses specified in this paragraph or contains a clause the effect of which is the same as or similar to any of the said clauses, that clause shall be inapplicable and unenforceable:

(g) clauses which provide for obligatory transfer by the transferee of improvements or innovations introduced or developed or patents acquired by the transferee in respect of the licensed technology to the transferor, except that such clause, excluding patents acquired by transferee, may be permissible where they are mutual or reciprocal; or
(k) clause which restrict R&D activities of the transferee to improve and adapt the licenced technology or restrict the transferee access to continue improvements in techniques and processes related to the licensed technology; or
(m) clauses which require the consent of the transferor before any modifications to products, processes or plants can be effected by transferee or which impose on the transferee obligations to introduce unnecessary designs; except where the licensed technology is used to manufacture specific products under a license or trademark.

[14] Kim, L. (2003). Technology transfer and intellectual property rights: the Korean experience. Geneva: ICTSD.

Box 2 **Section 10 of Patent Law of Ghana, Law 305A**

(1) Notwithstanding the provisions of section 8 and in the absence of contractual provisions to the contrary, the right to a patent for an invention made in execution of a commission or an employment contract the express object of which is research or the exercise of inventive activity by the employee shall belong to the person who commissioned the work or to the employer as the case may be; except that where the invention is of very exceptional importance the inventor shall be entitled to reasonable remuneration.

(2) Subject to subsection (1) of this section, and in the absence of an order of the Patents Tribunal established under section 70 of this Law varying the proportions, the right to a patent for an invention made by an employee as a result of the use of the resources, data, means, materials, installations or equipment of the employer shall, subject to the provisions of subsections (3) to (8) of this section, belong jointly and in equal shares to the employee and employer.

3.3 Gaps identified and recommendations

Ghana's TT regulation provides the necessary guidelines to attract investment and transfer of technologies to Ghana. It addresses most issues of unfair business practices. However, the following short-comings were identified and must be resolved to better promote TT and its development especially in the area of RE:

1. **Breach of agreement**
   The regulations do not address the consequences of the various breaches of the terms in the agreement including the failure of the transferor to transfer the licensed technology, use of the technology beyond the scope of the transferee, failure of transferee to remit royalties and failure of transferee or transferor to maintain confidentiality;

2. **Research and development**
   The regulation does allow for transferee to modify or adapt licensed technology, however, it does not make provision for including research and development as part of the activities of the agreement. This is necessary to encourage the parties to commit resources to research and development of their operations locally. In China for instance, it is a requirement for the transferor to permit the transferee to exploit even patents and must make available all technological materials relevant to the exploitation of the patent.

3. **Sharing of IPRs**
   Parties must be allowed to decide on how technological achievements obtained from any improvements or adaptation of the licensed technology should be shared. Though the patent law makes provision for ownership and sharing of IPRs the procedure to acquire patent can be cumbersome and often discourages applicants. If a sharing regime is allowed to be included in the TT agreements, it could enhance the sharing of information, easy learning and use of licensed technology.

4. **Ownership of technology**
   The current regulations do not require the transferor to prove ownership of the technology.

The transferor must guarantee that it is the lawful owner of the licensed technology. This ensures that the transferor will be liable, absent an agreement to the contrary by the parties, if the use of technology by the transferee in accordance with the terms of the agreement infringes on the legitimate right and interests of others.

5. **Technical services and consulting**

   The regulations do not include guidelines for contracts relating to technical services and consulting. Technical consulting contracts include contracts under feasibility studies, technological forecast, technical investigations, and analytical evaluation reports provided for specific projects. Technical services include contracts in which one party undertakes to solve specific technical problems by using its technical expertise for the other party.

6. **Duration of agreement**

   For agreements that involve the exploitation of patents, the duration of such an agreement must not exceed the duration of the validity of the patent. Royalties must stop when the patent becomes invalid.

3.3 Conclusion

Ghana has a TT regulation that protects both the transferor and transferee in the implementation of such agreements. However, it is weak in ensuring acquisition of knowledge and expertise needed for creating technological change for the transferred technology, usually leaving the country at the stage of importation of equipment, repairs, sales and marketing of finished products without the ability to innovate and create.

Construction of fixed-dome biogas plant
Photo: Wisdom Ahiataku-Togobo, MoP

4. HISTORY, CURRENT AND FUTURE TRENDS OF RETT IN GHANA

4.1 Background

The threat of energy security and global warming continue to spur interest in renewable energy (RE) deployment around the world. Many developing countries, such as Ghana, have had to rely on imported technology, even as they seek to build their own capacity in renewable energy technology development. A number of RE related projects have been implemented in Ghana spanning over 30 years. Many of these projects have served as learning curves, through which the industry has learnt to adapt and evolve. In principle, Ghana has been the home of RE development from the very beginning of electricity technology development.

The very first electricity generation plant built in Ghana was a hydro power project (in Akosombo) that has been managed by Ghanaian engineers for more than half a century. Interestingly, the second power plant built in the country is also a hydro power plant (built in Kpong). Thermal power plants took over much later and more or less became the centre of attention until the Bui hydro power plant was commissioned in 2013. It is worth mentioning that under Ghana's Renewable Energy Act, only hydro power plants of capacity 100 MW or below are considered renewable and qualifies for RE feed-in-tariffs.

Beyond the hydro power plants, a lot has happened in the RE sector in Ghana to date. A careful appraisal of many of these RE projects in Ghana indicate that the lot may not have been intended as pure technology transfer projects, but by their nature, were technology transfer related. Even though several of the projects were meant as developmental projects, often to bridge the gap between rural and urban lighting and fuel provision, Ghanaians have learnt to accept these technologies, embrace them, and adapt to them as the years have gone by.

After several decades though, the diffusion of many of these RE technologies has still been through imports from source countries, rather than manufactured locally. That trend may yet change as interesting developments take place, with the recent news that two solar PV assembly plants have been commissioned in Ghana.

Under the current China UNDP – Ghana UNPE Technology Transfer project, a lot of interesting developments may yet happen. This part of the report would discuss the history and current trends of RETTs in Ghana under the various technologies: thus solar, biogas, wind, small-hydro and improved cookstoves. Thereafter, a likely future trend, based on the outlook, would be provided, using the trend from the past and ongoing projects. Annex B shows a summary of projects with some renewable energy technology transfer components.

4.2 Solar PV (stand-alone and grid-connected) and solar Lanterns

According to Ahiekpor[15], several solar energy projects have been initiated in Ghana since 1989. In the beginning, solar energy provision was meant for basic lighting in rural communities, under various government projects, some of which were funded by bilateral and multilateral agencies. The systems for basic lighting served as a learning curve to a certain degree, and as Ghanaians became innovative with solar systems, but also through observation of innovation elsewhere, other uses of solar energy were introduced.

The new applications include: radio and TV operation in addition to basic lighting, vaccine refrigeration, classroom lighting and television for distance education, street lighting, solar water pumping for irrigation, solar battery charging, solar water heating, communication, and recently centralized grid-connected plants.

[15] See Ahiekpor, J. C. (2013)

In a way, use of these technologies have intensified as global prices of solar systems have dipped with time. Solar energy deployment in Ghana first started under government projects that were supported by external donors with the view to providing rural lighting solutions. In many of these projects, government has worked directly with local system suppliers, which has tended to build further capacity of these local companies, who have also learnt to innovate with time.

One of the early projects with technology transfer components is *Lighting Africa*, a joint World Bank-IFC program launched in September 2007. The project ran from September 2009 to June 2012 and was meant to 'create an enabling environment for the introduction of innovative new off-grid lighting solutions and the phase out of traditional lighting sources'[16]. It also served as a market entry mechanism by providing market intelligence, lowering policy and regulatory barriers, and providing business development support.

There were some notable technology transfer successes in this project which included:

- Provision of advisory services to government, *manufacturers* and *suppliers*;
- *Training* selected *manufacturers* and *distributors* on funding opportunities, distribution models and business management; and
- *Training technicians* to provide after sales services and maintenance.

Under a Dutch government led solar project in 2007 dubbed *Affordable Lighting for All*, a number of technology/knowledge transfer activities were undertaken. The supply chain linked Philips Lighting (a foreign manufacturer), with Deng Limited (a local distributor), as well as other local distributors and retailers for the sale and distribution of solar lighting systems. The local distributors were expected to have technical knowledge or engage technicians to provide better technical services. *Training activities* were carried out for the local actors and a *training manual* was developed in this regard.

In a more recent project, the government has begun distributing solar lanterns to rural off-grid communities to replace kerosene lanterns. The programme is aimed at providing 200,000 solar lanterns in off-grid rural homes over a period of five years. This programme had further innovation in the solar lantern design as mobile phone charging units were included. Local distributors: Wilkins Engineering and Mono Eco-Green Energy, are supplying the systems, further deepening the technology transfer process. The second phase of the project, which is expected to span two years (2014 – 2016), would support the establishment of *local assembly of solar lanterns,* a direct technology transfer activity. Other projects have been promoted by GEDAP (Box 3).

Somehow, consciously and intuitively, these projects have had technology transfer imbedded in them, driving innovation and local capacity in the assembly of components, with the ultimate aim of local manufacture.

[16] Ahiekpor, J. C. (2013). Solar Lantern Projects in Ghana: An Overview. Final Draft Report prepared for the Netherlands Development Organisation (SNV)

The solar lanterns and solar home systems are supplied by local companies with a view to driving local participation and innovation, to reach a point where the local industries could be in a position to locally manufacture these lanterns, a situation that may happen sooner than later.

Box 3 **GEDAP solar project**

Background

This project is part of component four of the Electricity Access and Renewable Energy (EARE) component of the GEDAP project. The objective is to increase electricity access via solar photovoltaic systems to poor rural households in remote regions of Ghana where solar PV systems in communities where grid service will not arrive for the next ten years or more. The increased access to electricity will improve the quality of life, enhance educational services, and provide income-generating opportunities. EARE seeks to assist the GOG to establish an enabling environment and facilitate market development to attract private investments in large-scale commercialization of renewable energy and energy efficiency improvement.

It has four components:

1. Renewable energy policy framework and renewable energy/energy efficiency (RE/EE) capacity building;
2. Large scale grid-connected renewable energy;
3. Mini-grid renewable energy and Energy Service Companies (ESCOs); and
4. Stand-alone renewable energy systems.

The project aimed to install 15,000 solar lanterns and small home systems (SHSs), benefiting about 90,000 people between 2009 and 2012. The project used the dealer credit sale model in which accredited dealers compete in an open market to sell and install the solar systems, and customers finance the purchase of solar systems through consumer credit provided by rural banks.

Project benefits

- About 16,500 systems comprising 8000 solar lanterns and 8500 solar home systems have been installed.
- Several technicians have been trained to install and maintain the systems.
- Several small spin-off businesses have resulted from the project.

Challenges

The project took off slowly at the initial implementations stages as a result of the following challenges:

- Lack of adequate well trained solar installers to cater for the increased installation rates of the participating companies
- Failure of earlier installed systems and projects

- Lack of full time staff with knowledge on solar products at the financial institutions
- Solar companies' delays in responding to system faults and supply requests
- Perceived inferiority of solar systems compared to the grid due to usage limitations

Conclusion

The project was successful as it exceeded its target. About 16500 solar systems were disseminated. This was made possible by project features to address key barriers facing the dissemination of Solar PV systems in Ghana. These features include:

- Well established selection criteria for participating communities;
- Consumer credit of up to three years through local rural banks to address the affordability barrier;
- Service contracts that bundle supply, installation, maintenance, and battery replacement services to ensure project sustainability and loan repayment; and
- GEF-funded technical assistance to dealers for developing the market and setting up presence in deep rural areas.

Technology transfer fact sheet			
Form/type of TT	Specific TT components	Outputs/outcomes	Stage of TT
- Technical know-how and practical training	- Import of equipment and accessories - Training of artisans on installation and maintenance of systems	- Over 7500 solar lanterns installed - Over 8000 Solar home systems installed - Provided lighting needs for over 90,000 people	Stage 2

Alongside promoting off-grid systems, a number of grid-connected systems have also been developed, some of which were a result of direct technology transfer initiatives, especially those associated with universities and research centres. The 44 kW systems at KNUST is the foremost project in this regard (Box 2). Table 1 provides a summary of the higher capacity grid-connected systems in the country. Box 4 shows part of the 44 kW_p installation at KNUST.

Other projects that were implemented by KNUST outside of campus were principally meant as technology transfer initiatives. One of such is the African Union funded *Potential of distributed grid-connected solar Photovoltaic (PV) systems in rural electrification in Africa* which is supported by Africa Union with close to a million Euros. The project seeks to demonstrate the potential of distributed grid-connected solar PV systems in rural electrification for improved affordability and sustainable energy access. One of the early achievements of this project is the installation of an Automatic Weather Station in Walewale (Northern Region) for monitoring solar radiation and other parameters as well as preparations for the installation of 30 kWp grid-connected systems in the same area.[17]

Under another African Union funded project, KNUST is partnering with institutions from France and Burkina Faso to assess potential sites and rank them for the development of Concentrated Solar Power (CSP) in West Africa. One of the highlights of the project is the design and optimization of a turbine for a waterless CSP, a technology transfer component in which the West African institutions would benefit directly from their French counterpart. The African Union is providing about 0.8 million Euro for the project which focuses principally on technology development[18]. It is said that market drives innovation. The growth in Ghana's solar energy market is leading to the assembly of solar panels in Ghana, a situation that could potentially lead to a manufacture of the solar cells themselves, an area that could be the next centre of attraction for China and Ghana with regards to RETT.

Table 1 **Main solar grid-connected systems in Ghana**[19]

Institution Name	Locality	Region	Installed Capacity (kW)
BXC Company Ghana Ltd.	Gomoa Onyadze	Central Region	20,000.00
Volta River Authority (VRA)	Navrongo	Upper East	2,500.00
Noguchi Mem. Institute, Uni. Of Ghana	Legon, Accra	Greater Accra	315.00
Ministry of Energy	Accra	Greater Accra	50.00
KNUST	Kumasi	Ashanti	44.00
Wienco Gh Ltd	Atempoku	Eastern	42.77
Trade Works Company Ltd (Office)	South Dome	Greater Accra	10.58
Valley View University	Oyibi	Greater Accra	8.36
R. Tuffour - Residence	Sakumono	Greater Accra	7.60
Residence installed by TW	West Legon	Greater Accra	5.17
Energy Commission	Accra	Greater Accra	4.25

Box 4 **Solar grid-connected system at KNUST**

Background

The College of Engineering at Kwame Nkrumah University of Science and Technology is one of the pioneering solar energy capacity building places in the country. For many years, solar resource data has been collected at the college's solar laboratory.

[17] TEC-KNUST. http://energycentre. knust. edu. gh/projects/on-going-projects/au-grid-solar-project

[18] TEC-KNUST. http://energycentre.knust.edu. gh/projects/on-going-projects/csp4africa-project

[19] http://ghea.energycom.gov.gh/database/index.php#

Project details

The college has installed a 44 kW solar grid-connected system on some of the roofs of its lecture theatres and office blocks; and has monitoring equipment that takes readings at hourly intervals. The grid-connected system was carried out in three phases: a first phase of 4kW, a second phase of 20kW, and a third phase of 20kW.

The 24kW total installed in the first two phases were donated by the German state of North Rhine Westphalia to aid in research into grid-connected solar PV systems. The last 20kW system was donated by the World Bank. Different PV technologies were used so that their performance could be assessed.

The technologies used in the 24kW system are as follows: Amorphous Silicon (6kW); Polycrystalline Silicon (6kW); Monocrystalline Silicon (4kW); Sanyo Hybrid Heterojunction with Intrinsic Thin layer (4kW); CIS Thin Film (4kW). Details of some of the systems are shown in the table below.

Part of the 44 kW KNUST grid connected solar PV
Photo: TEC, KNUST

Impact

Since its installation, the college has used the system to train participants of their annual short course programme on solar grid-connected systems. Over 50 participants have so far been trained in solar PV grid-connected systems.

	Poly	Mono	CIS	Amorphous	Hybrid
Nominal power, kW	4.05	3.99	4.05	4	4
Modules total number	18	21	81	40	16
Total surface area, m^2	30.6	28.1	68.6	58.9	22.6
Max DC power, kW	4.04	4.04	4.04	4.04	4.04
Max AC-active power, kW	3.80	3.80	3.80	3.80	3.80

Performance ratio approx. (%)	79	81	81	79	87
Min PV temp, ^{0}C	-10	-10	-10	-10	-10
Design temperature, ^{0}C	50	50	50	50	50
Max PV temp, ^{0}C	70	70	70	70	70

Technology transfer fact sheet			
Form/type of TT	Specific TT components	Outputs/outcomes	Stage of TT
- Investment - Knowledge sharing - Technical know-how and practical training	- Design of solar PV systems - Equipment and accessories - Training on installation and maintenance - Research on performance	- Training of over 20 research assistants and short course participants	Stage 2

4.3 Solar thermal systems

Solar thermal systems refer to solar water heating systems and solar dryers. Solar water heaters could be a great source of demand side management tool in especially hotels and guest houses, considering the amount of energy that must go into water heating. A number of companies already retail and install solar water heaters in the country, even though it is yet to gain wider popularity. Few hotels, including Anita Hotel in Kumasi as well as Oak Plaza and African Reagent Hotels in Accra, have installed solar water heaters. Apart from the hotels, some residential facilities have also installed solar water systems but the total installed countrywide is unknown. Among the prominent installations is the site of the Bui Power Authority, where fifty 150-litre evacuated tube water heaters are installed for use at their residential facilities on site.

Solar dryers have also not seen wider commercial application in Ghana. A number of experimental systems have been designed on the various tertiary education and research facilities across the country. Commercial scale versions of solar dryers have been piloted by the Agricultural Engineering Services Directorate (AESD) of the Ministry of Food and Agriculture (Box 5).

Box 5 ***Piloting solar dryers for drying of agricultural produce***[20]

Background

Drying of maize by small scale farmers in Ghana is mostly done by spreading the grains on shoulders of roads, bare floor on compounds, used sewed fertilizer bags, polyethylene sheets and tarpaulins among others. These methods of drying lead to contamination by sand, domestic animal droppings and urine and other foreign matter.

Project details

To address the challenge of drying crops, the Ministry of Agriculture sourced and introduced solar dryers in some farming communities in 2012. The programme, which was implemented by the Ministry's Engineering Directorate in 2012 in collaboration with GIZ/MOAP, installed and promoted the use of solar dryers in two communities in the Brong Ahafo and one in Ashanti regions for first stage drying of maize. Parameters measured were temperature and humidity in the drying chamber as well as moisture content of the maize. The analysis of the measured data was to inform necessary modification on the solar dryer to increase its efficiency for pre-drying of maize in humid areas and hopefully lead to increased production. A 2-tonne three tier drying tray solar dryer was installed at the Sekyedumase market for both traders and farmers. This served as a demonstration activity in the community, as beneficiaries were encouraged to acquire their own. Farmers and traders were trained on the use and maintenance of the dryer. In all, about 25 solar dryers were installed nationwide by the Ministry of Agriculture during the active phase of the project.

Challenges

However, acrylic materials used for constructing the dryers are imported and expensive, stalling the solar dryer programme. To sustain such a project and reduce costs, acrylic materials meant for solar dryers may have to be imported duty-free or efforts made to manufacture the material locally, especially because the market potential is huge in the country.

Technology transfer fact sheet			
Form/type of TT	Specific TT components	Outputs/outcomes	Stage of TT
- Technical know how	- Design, construction and maintenance of system - Awareness creation on importance of solar dryers - Training of potential end users on maintenance of system	- Two, community based demonstration facilities installed at Sekyedumase and Bonsu - 25 solar dryers installed - 5 carpenters trained on construction and maintenance of solar dryers	Stage 3

[20] Information culled from personal conversation with Mr. Johnson Panni (Agricultural Engineering Services Directorate of the Ministry of Food and Agriculture) as well as project reports provided by him.

Photo: AESD

4.4 Biogas

According to Bensah and Brew-Hammond[21], biogas technology began receiving attention from the government of Ghana in the 1980s. Prior to that, most plants that were constructed collapsed due to immature technology. A collaboration was therefore sought with China, in what would become the resurgence of biogas technology dissemination in Ghana. This began the genesis of biogas technology transfer from China to Ghana. Years later, the Chinese fixed dome biogas plant would become the foremost biogas technology promoted in Ghana.

The preparation for construction of a number of Chinese fixed dome plants at Appolonia was supposed to be the beginning of a vigorous campaign to promote biogas technology in Ghana, with the project commissioned in 1992. The Appolonia biogas plants were constructed by experts from the Energy Ministry and the Institute of Industrial Research (IIR) of the CSIR, with support from

[21] Bensah, E. C. and Brew-Hammond, A. (2010). Biogas technology dissemination in Ghana: history, current status, future prospects, and policy significance. IJEE 1(2): 277-294

China. Around that time, a staff of KNUST had also been trained in Germany on the construction and operation of biogas plants, and had started promoting the technology. Thereafter, the Catholic Secretariat and GTZ also became involved in the dissemination of biogas technology in Ghana. The Appolonia project faced a number of challenges, which slowed down government interest in biogas technology. These challenges were related to sustainable feedstock supply for digesters owing to drudgery involved in collecting dung from kraals that were about half to three-quarters of a mile from the plant, maintenance, and uncooperative attitude of some of the inhabitants (Bensah and Brew-Hammond, 2010). After a while, the slurry were also being left unused due to transport challenges and drudgery involved. In addition, there were socio-cultural challenges with the collection and use of digested faecal material from the plant for agricultural activities. Maintenance worsened as many households failed to pay monthly fees for caretakers of the community plant. The plant was completely abandoned when grid electricity was extended to Appolonia under the rural electrification programme in the late 2000s. The project is discussed in detail in Annex C.

From the year 2000 onwards, biogas technology dissemination became market driven, with the springing up of a number of private companies who had received training in Germany and elsewhere. Two technology types have dominated the biogas industry in Ghana: the Indian floating-drum and the Chinese fixed-dome digesters, with the later becoming predominant due to ease of maintenance (refer to Box 6 for the recent construction at the Kumasi Institute of Tropical Agriculture).

Generally, biogas technology dissemination has faced a number of challenges, many of which may have discouraged the widespread dissemination of the technology. Some of the major challenges, which should be addressed by the present technology transfer initiative, include:

- Poor level of construction;
- Lack of skilled attendants; and
- Poor maintenance

Recent activities have sought to introduce technologies directly constructed by foreign companies or with a lot of foreign assistance. Examples include the concrete plant at Adeiso, owned by the fruit processing company *HPW Fresh and Dry* (Annex D) for the production of biogas for electricity generation. The plant was built by a foreign company but is wholly operated by local workers and maintained by Ghanaian biogas experts.

The Ghana Oil Palm Development Corporation (GOPDC) also commissioned a biogas plant on 19 September 2014 at their mill for extraction of methane from palm oil mill effluent (POME). The system was built to increase renewable energy utilization through the capture and combustion of methane and to avoid the discharge of effluents that do not meet environmental standards into water courses. The 2000 m^3 plant has an electricity generation capacity of 4 MW.

Another plant constructed by foreign companies is the Upflow Anaerobic Sludge Blanket plant at Guinness Ghana Ltd. in

Kumasi, a plant that is intended for managing process waste.

There is also an ongoing project being implemented by UNIDO in coordination with the Ministry of Trade and Industry (MoTI) of Ghana and The Energy Centre, Kwame Nkrumah University of Science and Technology (KNUST), and supported by the Ministry of Trade, Industry and Energy (MOTIE) of Korea[22]. The project is promoting industrial-scale biogas technologies for electricity and thermal applications, and aim to, in the process, build capacity of companies for optimal exploitation of biogas opportunities. The technology transfer components of the project are to:

- Demonstrate technical feasibility and commercial viability of industrial-scale biogas technology, and support its market-based replication; and
- Promote research on appropriate biogas technologies and resource potential at a national level

The construction of the plant, which is currently ongoing, is a direct technology transfer activity. The plant design and drawings were provided by Korean engineers and the construction is being undertaken by Ghanaian engineers. In the installation phase, a Korean engineer is expected in the country to assist the Ghanaian engineers to install electrical systems and other important components. Beyond the construction, the next phase of the project would involve training for future beneficiaries of biogas systems, in the management and maintenance of biogas systems, another technology/knowledge transfer benefit expected from the project. With the assistance of GIZ, KNUST is establishing a state of the art biogas laboratory on campus for research and training.

Box 6 **Case study of 3.5 kW biogas plant at Kumasi Institute of Tropical Agriculture (KITA)**

Background

Biogas technology has had a checkered history in Ghana with a lot of failed projects that serve as major disincentives to end users. The main reference point for an electric power generating biogas plant has been the Appolonia biogas plant which failed due to a myriad of problems key among them is lack of maintenance due to lack of ownership by the people and the lack of feedstock to feed the plant.

Factsheet	
Size of digester	40 m^3
Type of digester	Fixed dome
Daily gas production	10 - 12 m^3
Power generation	3.5 kW for 4 hours per day
Other uses of the gas	Cooking
Feedstock composition	Fecal matter, pig dung, kitchen waste

SNV-Ghana keen on reviving the biogas sector without repeating the same mistake that militated against the Appolonia biogas plant rather chose the path of Technology Transfer by:

[22] TEC-KNUST. http://energycentre.knust.edu.gh/ projects/on-going-projects/unido-biogas-project

1. developing local capacity to properly design, construct and maintain biogas plants through mentorship from an experienced biogas expert with over 30 years' experience in Nepal, Burkina Faso and India;
2. providing a much better reference point for further studies and data collection leading to informed decision on mass dissemination strategies; and
3. A realistic cost benefit analysis on the entire value chain based on the operation of an existing plant.

The choice of KITA as a beneficiary institution was based on four main factors:

1. Need for both electric power and cooking energy – The erratic power supply in the country at the time of construction meant that students could not learn during nights of power outage. Downtime for administrative staff increased with each day of power outage. Also, the primary source of fuel for students was wood fuel, a major contributor to poor health and deforestation.
2. Resource availability – The availability of resource in terms of feedstock to feed the plant on a continuous basis was very important. KITA as an Agricultural Institute was managing a sizable piggery which could yield considerable amount of dung daily. Also, the student population of 250 had the potential of providing substantial amount of fecal matter. In addition, food waste from the kitchen and soft organic matter from the school farms were all adjudged to be quite significant and possible feed material for the digester.
3. Availability of space and water – availability of space was also a determining factor since the construction of the digester and its ancillaries as well as the toilet facility required space. Also, water availability was essential for the smooth operation of the digester.
4. Potential of using effluent for agricultural purposes – since the project was looking at closing the carbon cycle, the potential to use the effluent for agricultural purposes was a very important determinant. KITA has a number of school farms operated and managed by students as part of their training.

A local consulting body, Centre for Energy, Environment and Sustainable Development was recruited to work with an international SNV senior biogas expert in the person of Jan Lam. After a thorough resource assessment, a 40 m^3 digester connected to a 10 seat toilet facility with an inlet for animal and kitchen waste was designed and constructed.

Feed composition

KITA has a student population of about 250. This in addition to a pig population of 120, makes available a lot of fermentable biomass in the form of human faeces and pig dung. In addition, food waste from student hostels was factored into the resource base. The designers also considered the availability of soft organic matter in the form of cabbage leaves and carrot leaves which were cultivated as part of student projects all year round.

Feedstock composition and potential gas yield

Feedstock	Estimated quantities (kg)	Potential gas production m^3/day)
Faecal matter	56	0.034
Kitchen/food waste	40	4.8
Piggery waste	70	3.85
Farm waste (grass)	10	2.98
Total	176	11.664

Type of plant

A fixed dome digester was selected primarily due to the relative ease of maintenance as compared to the floating drum. Also the construction process was expected to lead to knowledge and skills transfer in dome construction and brick laying. Construction began in December 2013 and completed in January 2014.

Gas utilization

The digester produces about 10 - 12 m^3 of biogas daily. The gas line is fitted with a dehydrator for moisture removal and a hydrogen sulphide (H_2S) scrubber. The gas is piped to the kitchen where students use it as their main source of cooking fuel replacing wood fuel and charcoal. Part of the gas is piped to a biogas generator for the generation of 3.5 kW power for 4 hours per day. This has contributed significantly to reducing power consumption from the grid and the downtimes for administrative staff during power outages.

Innovations in the design

The toilet bowls are placed on slabs sitting right on top of a channel that leads straight into the digester. The use of a channel to evacuate the toilet rather than pipes is a positive deviation from most digesters built in Ghana. Choking and cracking of pipes are some of the main problems leading to the breakdown of the biogas digesters. Also, the digester was optimized to retain more of the solid matter and less of water as opposed to conventional systems that retain more of water and less of organic matter.

Plant layout of biogas plant at KITA

Use of the effluent

To ensure that the effluent generated is devoid of any pathogenic activity, a composting facility was designed and built as part of the plant. The composting facility aerobically treats the effluent by co-composting the liquid effluent from the digester and solid organic matter from the school farms and gardens. The mature compost is used directly on the school farm as a soil conditioner to boost productivity.

WASH component

The facility has a strong sanitation component which ensures that students have a more hygienic place to defecate. Also, wash basins fitted with running water have been provided to enable users of the toilet facilities wash their hands with soap and water.

End users perspective

According to the management of KITA, the biogas facility has been very beneficial to them. Students no longer use charcoal and firewood to prepare food. Energy bills have been reduced by about 10-15%. The compost enables students to practice organic farming and permaculture as well as carry out comparative test on the yield of food crops on soils conditioned with organic fertilizer and inorganic fertilizer.

Challenges

The main challenge has been feeding the digester during the times students are on vacation. Management of KITA has been able to find a way around it with their innovative student's vacation programme. The programme ensures that a handful of students stay on campus and work on the schools farms and piggery. These students are tasked to feed the digester with pig dung on a daily basis to ensure that microbial activity is not depleted.

Perspective of local consulting body (CEESD)

According to the Executive Director of CEESD, until the inception of the programme, CEESD experience of constructing biogas digesters was limited to only floating drum. Thus, the entire programme of transferring technology was very useful. Through the programme, staff of CEESD acquired important skills such as:

1. Correct brick layering;
2. Curing of bricks after layering;
3. Constructing, closing and ceiling the dome to become airtight; and
4. Construction of biogas stoves.

Technology transfer fact sheet			
Form/type of TT	Specific TT components	Outputs/outcomes	Stage of TT
- Knowledge sharing - Technical know-how and practical training in fixed dome digester - Organizational/ best practices	- Design and sizing of digester and gasholder - Proper construction and brick laying techniques - Gas piping and instrumentation - Technical know-how on system configuration for power generation - Operation and maintenance	- Three engineers trained on design and construction of fixed dome digesters - Five artisans trained on brick layering	Stage 3

4.5 Other bioenergy types

Apart from biogas, other bioenergy types have also been promoted or attempted in Ghana. These include modern solid biofuels: pellets and briquette, liquid biofuels: biodiesel and bioethanol, and waste-to-electricity technologies: combustion, gasification and pyrolysis. Many of these technologies have not moved into commercialization. Of the solid biofuels, pellets have had the most impact, using technology developed in India. Abellon CleanEnergy Ghana Ltd, a subsidiary of Abellon CleanEnergy, has built a pellet production mill in Ghana with a production capacity of 250 tonnes of pellets per day using sawdust from the Sokoban Wood Village in Kumasi. With the exception of the top management, the majority of workers at the plant are Ghanaians, who have been trained to operate the facility (Box 7). The other modern solid biofuel, briquette, has not enjoyed the same success. Attempts were made to produce briquettes in Kumasi but the business went bankrupt and folded up, due to a poor business model.

With regards to liquid biofuels, efforts were made but the industry never really took off, suffering from a lack of political will on the part of government. Whereas developers made attempts to move beyond feedstock development into the production of liquid biofuels, there has been very little commitment from government, leading to a lack of infrastructural development and a subsequent collapse of several of the projects that were initiated. Apart from the introduction of a few agricultural machines for feedstock cultivation, not much has been achieved by way of technology transfer in the liquid biofuels industry. A biodiesel processing factory under construction by Kimminic Ghana Ltd. in the Yeji area stalled due to financial constraints. Before its collapse, the principal processing equipment had been imported from China but never completed installation (Figure 3).

Figure 3 **Kimminic's 'uncompleted' biodiesel factory in the Yeji area**

An ethanol production project started by Caltech Ventures in the Volta Region in 2007 failed to flourish due to a lack of investment.

In 2014, Kasapreko Company Limited (KCL), a Ghanaian beverage producer, entered into a partnership deal with Caltech Ventures to produce ethanol from cassava for local use and promote technology transfer in other areas as well.[23] Under the deal, Kasapreko Company Limited (KCL) is investing US$7.5 million in the cassava plantation, aimed at increasing cassava yields for the production of ethanol in the country. Ethanol production is expected to finally commence in 2015 with an initial three million litres of ethanol a year, to supplement KCL's imports which are in excess of 25 million litres annually. The project would also provide sufficient cassava flour to produce starch adhesive to feed a corrugated carton plant that Kasapreko is currently putting up in Accra. Ultimately, the project is also aimed at generating about 600 megawatts of power from cassava waste using a gasification technology.

Of the waste-to-electricity plants, combustion plants using steam turbines to generate electricity are a popular concept in the oil palm milling industry in Ghana, notwithstanding the fact that only a fraction of the potential has been explored. Combustion plants have been operating in Ghana for a number of years now and are wholly operated by Ghanaian engineers. But after many years of operating the technology, very little attempt has been made to manufacture the components locally, defeating the technology transfer process. More sophisticated technologies of the second generation, such as gasifiers and pyrolyzers are not commercialized yet but have been experimented in academic and research institutions.

Utilising lignocellulosic materials to produce energy has not also been commercially implemented yet but there has been a lot of

[23] http://graphic.com.gh/news/general-news/23232-company-secures-deal-to-produce-ethanol.html

foreign support into training activities, especially on KNUST campus (Box 8).

Box 7 **Technology transfer in pellet production**

Background

Abellon CleanEnergy is an Indian-based company that produces biomass pellets and pellet stoves for households and institutions. The company focusses on using biomass residues such as sawdust to produce carbon-neutral pellets. The company operates in India, Canada and Italy and has pellets produced from several biomass residues depending on area of location. Abellon established its first plant in Africa at the Sokoban wood village in Kumasi in 2011. The 250 tonne/day plant however began operation in 2014. It employs about 50 locals in addition to over 100 casual workers. The company exports most of its products to Europe and USA, has made strides in introducing pellets and pellets stoves to the industrial and commercial sectors in Ghana for powering of boilers as well as in stoves for cooking and heating purposes.

Project benefits

The plant produces pellets from sawdust and wood waste generated from saw mills and other wood-based activities at the Sokoban wood village in Kumasi. This has contributed to reduced pollution and contributed to environmental sustainability since over 100 tonnes of saw dust is generated by the wood village daily with no sustainable option of using the waste[24].

Challenges

The major challenge has been the under-developed pellet market in Ghana and Africa. The company does not enjoy any tax incentive and there appears to be no coordinated national programme to support the sector. The company has also not yet received Intellectual Protection of its products after three years of applying to the national body.

(a) Pelletising plant at Abellon
Photo: Abellon CleanEnergy

(b) Packaged pellets
Photo: Edem Bensah

[24] Millennium Cities Initiative, 2013. Sokoban Wood Village Project in Kumasi, Ghana. MCI working paper series on investment in the millennium cities, MCI Working Papers Series, No. 23.

Technology transfer fact sheet			
Form/type of TT	Specific TT components	Outputs/outcomes	Stage of TT
- Investment - Knowledge transfer	- Equipment and accessories - Local production of biomass - Use of pellet stoves in institutions and industries	- Employment of 50 locals in plant operation and maintenance - Importation and sale of industrial pellet stoves	Stage 1

Box 8 **Research into second generation biofuels**

Background

The Danish Technical University (DTU) has partnered KNUST and other institutions in Ghana on developmental research projects in the area of second generation (2G) biofuels, with funding from DANIDA. Three different projects under a total funding of USD 4 million are under implementation, namely:

- Biofuels production from lignocellulosic materials (2gbionrg);
- Bioelectricity generation using microbial fuel cell (MFC) technology; and
- Seaweed biorefinery in Ghana (SeaBioGha).

2gbionrg (2011-2017) focuses on investigation and development of technologies for producing bioethanol and biogas from organic waste residues. It will lead to the establishment of a modern biofuel lab at KNUST as well as a pilot plant for ethanol production from residues such as maize stalks, rice husk, sawdust, as well as biomass such as elephant grass. Under SeaBiogha (2015-2019), seaweed species suitable for polysaccharides (e.g. carrageenan, alginate and fucoidan) and biofuels production will be identified and cultivated using locally constructed digesters. A pilot biorefinery will be built for scale-up research in seaweed conversion to biofuels. So far, only few African countries (e.g Tanzania and South Africa) have engaged in seaweed production and are now benefiting from this industry. Ghana has high potential for seaweed production because of its large natural seaweed resources (200 species) and a long shoreline which is suitable for seaweed cultivation. Opportunities exist for seaweed production and processing in Ghana.

Project benefits

All three projects have components involving collective research and knowledge sharing, training of PhD and MSc students in Denmark and Ghana. So far, six PhD and nine MSc students are funded under the programme. The projects support national programmes aimed at encouraging green growth through renewable energy development, waste reduction and recovery.

Sea weeds at Old Ningo and Prampram
Photo: SeaBioGha, KNUST

Technology transfer fact sheet			
Form/type of TT	Specific TT components	Outputs/outcomes	Stage of TT
- Organizational practices - Knowledge sharing - Technical know-how and practical training in biofuels from agricultural residues and sea weed; and Microbial Fuel Cell (MFC)	- Training in biomass characterization, pretreatment technologies, hydrolysis and fermentation - Training in MFC system design and fabrication - Establishment of biofuel laboratory at KNUST - Demonstration plants expected to be established	- Six PhD students - Ten MSc students - Biofuels laboratory	Stage 2

4.6 Wind

Ghana has not had success with wind energy development and the country cannot boast of any commercial wind power project as at 2015. Activities in the wind energy sector have so far been limited to resource assessment, where several studies have taken place, led by the Energy Commission with support from foreign countries. There have also been activities that were solely private-sector led. In 2003, a joint venture between NEK Umweltechnik AG of Switzerland and Atlantic International Holding Company Ltd measured wind speeds at Prampram with the intention to install a 50 MW plant but implementation is yet to take place.[25] A few Poldaw wind pumps were piloted for water pumping by the AESD but these were discontinued. Even though the AESD has a facility at Somanya that has capacity to produce the Poldaw wind pumps,

[25] Wuddah-Martey, M. (2009). Utilization of Wind Energy Resources in Ghana. A presentation to The Energy Centre, KNUST.

it appears there has been little motivation to continue with production.

Some international wind energy companies have set up businesses in Ghana to harness the wind energy potential in the country. These include Ghana Wind Power Ltd (GhaWiPo) a developer[26], and NEK (Ghana)[27] who also provide services for other players in the industry. The presence of these global players should serve as a technology transfer source for the many Ghanaian individuals and organizations that engage with them.

The Volta River Authority (VRA) has also commenced activities with support from foreign wind energy companies to assess sites for wind power development.

This again has the tendency to transfer technology from the foreign partners to the local electricity generation company. With the VRA's vast expertise in hydro, thermal and to some extent solar power generation, further expertise in wind energy could boost the company's quest to strengthen capacity in the power generation business.

Fabrication of Poldaw wind pumps in Ghana
Photo: AESD-MOFA

4.7 Mini-hydro

Through the several years of operating the Akosombo and Kpong hydropower plants and currently the Bui plant, Ghana has developed a lot of expertise in the hydropower industry. This remains, however, at the operation and maintenance stages only. The recent construction of the Bui hydropower dam had a lot of input from Ghanaian engineers, with technology imported from China.

Like wind, not much has been done in the area of mini-hydro technology transfer. Here again, a lot of local efforts has gone into assessment of resource potential with some international support but no project implementation yet.

[26] www.ghanawindpower.com/htdocs/main.php

[27] http://www.nek-ghana.com/

4.8 Improved cookstoves

Traditional, inefficient wood-based cookstoves have been used extensively in Africa for cooking and heating purposes in homes, institutions and businesses. Improved cookstoves are being introduced to increase thermal efficiency and reduce smoke emissions, among other objectives. Since their introduction, improved cookstoves have enjoyed a lot of technology transfer initiatives in Ghana (Box 9), perhaps because unlike biogas, improved cookstoves are a cheaper alternative to promoting efficient fuel use and thereby reduce deforestation arising from cooking fuel demand.

The very first improved cookstove documented in Ghana is the Ahibenso Improved Charcoal stove, which was introduced on the market in 1989. Initially, the stove was an all-metal type and hence became hot and easily worn out in a short period of use. The Technology Consultancy Centre of KNUST under the financial support of UNDP/GEF Small Grants Programme, developed an improved Ahibenso cookstove, which had the inside layer insulated with refractory linings[28]. This was the first in a series of innovations that have taken place in the promotion of improved cooskstoves in Ghana.

A lot of other technology transfer related activities have since taken place. In promoting the wider use of Ahibenso stove, the Ministry of Energy concentrated on providing the necessary framework for the uptake of the technology[29]. This involved the training of local artisans and manufacturers who were encouraged to produce the stoves. In the early days, a total of 40 artisans within Ashanti and the coastal regions were trained. The promotion of the Ahibenso stove lost steam when the Ministry's funding ended. Artisans who were trained in the manufacture of the improved stoves could not sustain their production because it required much time and material to fabricate a unit of Ahibenso compared to that required for the fabrication of one traditional coalpot, thereby making the improved version more expensive.

Much later on, the Gyapa stove was introduced in 2002 by Enterprise works.[30] The Toyola improved charcoal stove, a similar design to the Gyapa stove, was also introduced in 2006, as detailed in Box 9. Apart from household size stoves, efforts have also been made to promote improved institutional cookstoves for schools and other institutions. Many of the institutional stoves have been built using local expertise, with the Technology Transfer Centre of KNUST playing a major role in this regard. A programme supported by the UNDP and the Ministry of Energy has trained some women in the use of local materials to construct improved cookstoves.

[28] TCC (2008). The New Insulated Ahibenso Charcoal Stove. An Energy Saving Charcoal Stove for the Household. Technology Consultancy Centre (TCC), KNUST, Kumasi.

[29] Energy Commission, 2006. Strategic National Energy Plan: Annex I of IV – Energy Demand Sectors of the Economy

[30] Enterprise Works/Vita, 2009. Clean Energy for Household Cooking in Ghana.

Box 9 **Technology transfer in improved cookstoves**

Background

The dominance of woodfuel as the main source of cooking fuel in Ghana has come at a great cost to the environment. Ghana has lost more than 7 million hectares of forest (about the size of the Northern Region) in the last decade to felling of wood for timber and domestic fuel. The dominance of woodfuel was not so much of a problem as compared to the nature of stoves in use. Until the early 1990s when the Government of Ghana introduced the improved cookstoves programme, all the stoves in use were very inefficient to say the least. The introduction of the more efficient Ahibenso cookstove in 1992 saw the rapid penetration of the stoves in the market in the first year. Close to 12,000 stoves were sold in the first year of introduction. In spite of the initial success, the stove programme failed due to:

1. High initial cost of the stoves
2. unavailability of the stoves on the market
3. the complex design of the stoves which was quite different from conventional coal pot design
4. poor quality of the stoves produced by trained artisans which failed to match aesthetically the ones shown on television[31]

Aside these, the programme had a very strong government backing with government financing the entire programme – production, distribution and dissemination. The withdrawal of government financing support brought the entire programme to a halt[32]. While Ghana was struggling to find a solution to the inefficient stoves on the market, Kenya had made great strides with the design, fabrication and dissemination of an improved charcoal cookstove called 'Jiko' stove with the support of EnterpriseWorks/Vita[33]. The stove has the shape of an hour glass with a ceramic liner to retain heat and a metal cladding. In 2002 EnterpriseWorks/Vita a division of Relief International riding on the success of the Kenyan improved coosktoves programme saw the need to transfer the technology to Ghana by equipping artisans with the skill to locally fabricate the stove.

Approach

Under their Clean Energy for Household Cooking Programme, two training sessions were held for 78 artisans and technologist in Accra and Kumasi on the design and fabrication of the improved coosktoves.[34] The initial goal was to reduce indoor air-pollution in 40,000 urban homes and 5,000 rural homes in Ghana[35]. The training also touched on the how to fabricate the clay liners which is the main distinguishing feature of the improved cookstoves.

[31] Energica (2009), Prefeasibility Study for an improved cook stoves project in Northern Ghana.
[32] Global Alliance for Clean Cookstoves (2012). Ghana Market Assessment – Sector Mapping.
[33] http://www.enterpriseworks.org/display. cfm?id=3&sub=15&cont=7
[34] http://www.growinginclusivemarkets.org/ media/cases/Ghana_Toyola_2010.pdf
[35] http://www.enterpriseworks.org/pubs/ May%2007%20Gyapa%20Summary.pdf

Results

Until 2007, EnterpriseWorks/Vita was the only producer of the Gyapa cookstoves until two of the members broke away to form Toyola Company Limited and Man and Man Company Limited. The two companies produced and marketed Toyola Stoves and Man and Man Stoves respectively[36]. All three brands of stoves are similar in design with similar performance characteristics which mimics the Jiko stoves. The production processes are also similar. All three companies have a large network of artisans who support them with the fabrication of the liners and stove casing separately and the assembling of the stoves. This model ensured division of labour leading to the optimization of the production process. The individual capacities of the three companies to produce stoves have grown tremendously from a few stoves per week to thousands of stoves per week in response to growing demand for the stoves locally and in the sub-region. Gyapa Stoves for instance has a network of about 450 stove manufactures and over 500 retailers of the stoves across the country[37].

A – Gyapa Cookstove

B- The new Man and Man cookstove

C - Toyola Cookstove

Dissemination models

The path to growth has been fuelled primarily by a strong demand for the stoves because of its fuel saving property and funding from carbon finance which have been used to expand production and to increase market access. Since 2007 about 700,000[38] stoves have been produced and disseminated between these EnterpriseWorks/Vita and Toyola companies. Toyola Company sells their stoves with a money box which end users use to keep savings from charcoal consumption. This has proved to be very effective as end users tangibly see the benefit of using the stoves.

[36] See Global Alliance for Clean Cookstoves (2012)

[37] http://www.gyapa.com/gyapa-fuel-efficient-cookstove.html, Assessed on 28/10/2015

[38] Authors own estimation based on the reported number of stoves disseminated by the two companies and using their individual production capacities.

Challenges – downside

Notwithstanding the successes chalked in terms of the transfer of skills, adaptation of the technology and the dissemination of the stoves, the programme had at least one major flaw which was the non-involvement of research and academic institutions. Leaving out academic and research institutions has led them to largely play passive roles leading to the following:

1. Aside the initial design that the artisans and technologist were introduced to, they have struggled to come out with innovative designs different from the Jiko model. Apart from the stove designs, incorporation of new other locally available insulation materials has been very limited;
2. The success of the programme has left in its wake a deficit of ideas on the production of firewood cooktstoves. There is still no locally designed firewood cookstoves commercially available on the market. The involvement of research and academic institutions would have led to the development of at least an improved firewood stoves model that is affordable and acceptable to end users.

Consistency of product quality has been another key challenge confronting the cookstoves sectors. The involvement of many artisans in the production chain raises a number of quality concerns especially when the production process has not been standardized. This coupled with the absence of a testing facility and standards as reference points have exacerbated the challenge. This is however about to change with the commissioning of two testing facilities at Technology Consultancy Centre in KNUST, Kumasi and Institute of Industrial Research of the Council for Scientific and Industrial Research, Accra.

Fact sheet		
Stove Brand	Gyapa	Toyola
Capacity per month	11,000	30,000
Total stove distributed/sold	487,434	207,000
Potential CO_2 offset	A total of 696,215 VERs as at 2013, 1,077,601 tCO_2 as at 2015	390,000 tCO_2

Technology transfer fact sheet			
Form/type of TT	Specific TT components	Outputs/outcomes	Stage of TT
- Knowledge sharing - Technical know-how and practical training in JIKO type improved cookstoves	- design and fabrication - Marking and cutting of patterns on metal sheets - Assembling of metal sheets - Inserting of ceramic liners into metal case - Spraying of the stove	- 78 technologists, artisans and college graduates	Stage 3

4.9 Renewable energy training activities

A few renewable energy courses are offered at a number of training centres in the country. Wilkins Engineering, one of the pioneering solar systems retailers in the country, offers training in solar PV installation to the public. The Kwame Nkrumah University of Science and Technology (KNUST), first through the Mechanical Engineering Department, and later through The Energy Centre, offers annual short courses in stand-alone solar PV systems installation, solar grid-connected systems, biogas technology and wind energy. KNUST also runs a graduate programme leading to the award of a Master's Degree in Renewable Energy Technology. A collaboration between The Energy Centre and a university in Norway has won close to one million dollars grant from the Norwegian government to strengthen and expand the Renewable Energy Technology master's programme at KNUST, with teaching and practical support from professors at the Norwegian University. Under the expansion, PhD scholarships are being made available for solar and bioenergy research.

Other prominent state academic institutions, including University of Energy and Natural Resources (UENR), Kumasi Polytechnic and Koforidua Polytechnic, run degree and HND programmes in renewable energy technologies or allied disciplines. The Department of Energy Systems Engineering at Koforidua Polytechnic runs an HND and BTech in Renewable Energy Systems Engineering aimed at Competency-Based training approach to prepare engineers to design and implement energy systems for innovative applications. Koforidua Polytechnic is currently collaborating with ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE) to create awareness, build capacity, and develop a database for solar thermal systems in Ghana (see Box 10). The Department of Energy and Environmental Engineering at UENR runs an undergraduate programme in Renewable Energy Engineering.

The Centre for Renewable Energy and Energy efficiency at Kumasi Polytechnic (CREK) undertakes applied research in areas of renewable energy and energy efficiency. The Centre is establishing four laboratories representing each of the focus areas – solar, bioenergy, wind, and energy efficiency. The Centre will also be equipped with a workshop for developing and fabricating applications.

Construction of Centre for RE & EE, Kumasi Polytechnic, December 2015
Photo: Edem Bensah

Box 10 **Technology transfer in solar thermal technology**

Under the auspices of the ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE), the Department of Renewable Energy System Engineering of Koforidua Polytechnic, together with four other academic and research institutions in Nigeria, Burkina Faso, Senegal and Cape Verde are implementing a solar thermal systems project, SOLTRAIN West Africa.

The project is aimed at conducting market surveys, undertaking awareness creation, capacity building and database development for solar water heating and solar dryers in the five countries. The Koforidua Polytechnic is responsible for the Ghana part of the project. Under the market survey module which has already been completed, the project surveyed solar thermal installations in the country, assessed capacity of professionals and technicians in the industry, surveyed importers and collected data on origin of solar thermal installations in the country.

The next phase of the project is a training module that would seek to train stakeholders in the industry, policy makers and technicians on several aspects of solar thermal systems in order to increase their capacity to deal with solar thermal systems. The third phase would comprise demonstration exercises where systems would be installed and piloted in selected government institutions. Monitoring systems are to be installed to monitor the performance of installed systems. It is expected that beneficiaries would pay only 20% of the total installation costs whereas the project pays the remaining 80%. This module is expected to showcase the technology to a wider number of stakeholders. Technologies to be piloted would be imported from a foreign country but a decision has not been taken as to which country that would be.

The last phase of the project is an awareness creation programme that would employ among other things the use of mobile vans to create awareness among the general public. The knowledge transfer component of the project has already begun, with the training of four lecturers from the Koforidua Polytechnic in Cape Verde (ECREEE) on solar thermal technologies. The training was conducted by the Institute for Sustainable Technologies, based in Austria.

Technology transfer fact sheet			
Form/type of TT	Specific TT components	Outputs/outcomes	Stage of TT
- Knowledge sharing - Technical capacity building - Pilot and demonstration systems (yet to be undertaken) - Installations and end-user training (yet to be undertaken)	- Market survey - Capacity building on SWH and dryer design and engineering - Construction of 25 demonstration facilities - Setting up of a solar thermal testing facility in one of the participating countries - Training stakeholders on solar thermal devices	- Training of four researchers at Koforidua Polytechnic in Cape Verde - Needs and capacity assessment study in Ghana	Stage 1

4.10 Future of RETT in Ghana

In the future, Ghana is seeking to become self-sufficient in energy supply and would want to do this using the plethora of resources/ technologies at her disposal, including renewable energy. Ghana is hoping to generate more than 5000 MW of power by 2020 and become a major power exporter in the Sub-Region. Renewable energy has a role to play in this regard, as also corroborated by the RE Act and the National Energy Policy.

Technology transfer has a lot to play in how Ghana's energy future shifts towards renewables. It has been argued that RE alternatives are credible option which could address the shortfall in energy delivery and access to vulnerable communities by supplementing meaningfully other energy generation sources in the country namely hydro and thermal power generation sources. Until date, very little has been achieved in RE penetration in the Ghana energy mix. Notwithstanding efforts to promote these technologies, they have not seen much commercial success. At best, some of the efforts at disseminating off-grid RETs have been ad-hoc and some of these may have occurred in recent times because of the power crisis that the country is currently facing.

With regards to technology development itself, the achievements in cookstove development is laudable. Ghanaian technicians and trainees have almost mastered the craft of designing and fabricating improved cookstoves. The same cannot be said of the other technologies though. The recent commissioning of a solar PV panel assembly plant in the country is a step in the right direction. Beyond assembling of panels, however, a lot remains to be done. Ghana should be moving beyond just assembling solar panels into manufacturing them, as well as manufacturing balance of system components. A huge market remains to be tapped in the sub-region for solar systems technology due to the favourable climate situation. In the area of biogas technology, there is the need for the development of modern skill sets that would enhance the capacity of local companies to better understand and build more robust biogas plants, to boost user confidence in the technology.

RETT would have several advantages for Ghana. To the ordinary Ghanaian consumer, cost reduction may be one of the most anticipated benefits of RETT. But beyond cost reduction, the opportunities for local manufacture can have several positive impacts. According to Tse[39], solar electric systems offer better opportunities for savings through local manufacture, mainly because the processes for many balance of system components can be easily adapted to other, non-solar uses. Such a plant could flexibly manufacture components for other uses when demand for solar PV is low. For example, an electrical fabrication plant for manufacturing controllers and inverters can also be used to produce voltage stabilizers and battery chargers for automobiles.

Experts in biogas plant construction could channel their knowledge in underground systems to promote and market modern rainwater harvesting systems if the market for biogas systems fail at some point. Other advantages, such as employment generation, calls for special attention to RETT.

The current China-Ghana South-South Cooperation on Renewable Energy Technology Transfer could not have come at a better time in Ghana's development, a time when a lot is happening in the energy sector. There is perhaps no better developing country with technology transfer experience than China. China belongs to the group of economies that are expanding the most and, more interestingly, it is also a destination for research and development (R&D) related investments by foreign companies and countries. This has brought a lot of highly sophisticated technology to China, making it one of the largest economies in the world today, and a technology powerhouse. Within just a few years, China has moved from importing technology, to locally manufacturing and exporting similar technology.

China has achieved this feat not only at the lower level of technology, but at the higher levels as well. It has been reported, for example, that between 2008 and 2012, China switched from being an importer of high-speed trains to the world's largest manufacturer, largely attributed to the transfer of foreign technology to Chinese state-owned enterprises.

China has also achieved a lot in renewable energy. According to the 2015 edition of the Renewables Global Status Report, China made the highest investment or net capacity addition into hydropower, solar PV, wind power and solar water heating in 2013. It is now the country with the highest total capacity in renewable energy, with or without hydropower. In 2013, China invested more in RE than did all of Europe combined, and it invested more in renewable power capacity than in fossil fuels.

[39] Tse, M., 2000. Commercialization of Renewable Energy Technologies in Ghana: Barriers and Opportunities. Paper presented at the Expert/Stakeholder Workshop on Renewable Energy in Ghana, 15-17 August.

All these achievements place China on a good pedestal, with regards to technology transfer. The fact that China is itself on the ascendancy due to the benefits it has derived from technology transfer, rightly positions them be able to assist other developing countries and lead them towards achieving similar feat. Ghana could learn and benefit a lot from a technology transfer partnership with China. Already, China has assisted Ghana in the construction and operation of the Bui hydropower dam.

4.11 Conclusion

In many Ghanaian RE projects, the 'further innovation' is often missing at the end as projects fail to proceed to local manufacture, notwithstanding the numerous capacity building activities. The projects succeed in adapting, deploying and diffusing RE into the country but falls short of innovating. Ghana's target of about 5000 MW of installed electricity generation capacity by 2020 means that about 500 MW (or 10%) target for RE electricity by 2020 could bring TT to the limelight. Ghana must cease this opportunity to develop local capacity in the design, manufacture, installation, operation and maintenance of RE systems in the country. Doing this would likely lead to cost reduction and opportunities for local manufacture that can have several positive impacts. In this vein, China's 'superpower' status in RE infrastructure could benefit Ghana immensely under the current project.

Improved institutional stoves at Alliance High School, Kenya.
Photo: UNDP-Kenya

5. SUCCESS STORIES OF RETT GLOBALLY

5.1 Introduction

This section identifies some successful RETT programmes in other developing countries which could provide valuable ideas for RETT from China and other countries to Ghana. The barriers encountered, strategies and measures employed to deal with barriers, and lessons learnt for each case study are highlighted. The case studies cover the areas of solar thermal, solar PV and bioenergy.

5.2 Solar thermal: case study of solar water heater (SWH) TT programmes

SWH is the largest contributor to solar energy utilization among solar technologies. Globally, the installed operating capacity was estimated at 172 GW as at 2009.[40] The major SWH markets are in Europe (especially Austria, Germany, and Greece), Israel and China while installations are rapidly increasing in emerging economies such as India, Brazil and Turkey. Developing countries that have concrete SWH targets include China, India, Morocco, Uganda, and Mozambique. Tunisia (Annex E) and South Africa (Box 11) have the highest penetration of SWH in Africa owing to the introduction of favourable policies and regulatory frameworks that have supported the sector over the years. Uganda and Mozambique are among the countries with concrete target on SWH. Zimbabwe also has a history of technology transfer and development in SWH (Box 12).

Box 11 **South Africa: National SWH programme – Eskom rebate scheme**

Background

SWH programmes were small and uncoordinated in the years before 2005. Targets were not realised due to the absence of a policy framework. Between 2005 and 2008, rampant power cuts caused increased in SWH acquisition. However, local capacity to meet demand was only a third. Initiatives were taken by Cape Town to support SWH which helped to trigger a national programme. Policy interventions in SWH began in 2008, paving the way for steady growth of the sector. The key drivers for policy initiatives were high energy consumption from use of electric water heaters, possibility to reduce peak power demands, energy poverty and carbon footprint, and opportunities for job creation.

Key interventions

A national SWH programme was introduced in 2008 under a rebate scheme implemented by Eskom, the main utility company, with a target of 5 million SWH by 2020 as well as local manufacturing capacity of about 200,000 per annum in 2014. Local manufactures and installers received training. The financial support features of the programme include rebate scheme (subsidy on capital cost) for consumers and compulsory replacement of electric heaters, resulting in increased penetration among all segments of the population.

Outcome

From 2008-2012, over 220,000 and 57,000 low and high-pressure systems, respectively, were installed under Eskom rebate scheme. The figures were however below targets due to several barriers encountered.

[40] UNEP-RISOE Centre, 2011. Diffusion of RETs: case studies of enabling frameworks in developing countries. UNEP technology transfer perspective series.

Barriers

The major obstacles faced included delays in testing SWH equipment for approval (under Eskom programme), lack of public trust on hardware including some from China, and faulty installations. South Africa also faced bottlenecks as a result of the lack of an entity to manage the SWH programmes. Moreover, high upfront cost, high financing cost due to high interest rates, low tariffs and low cost of electric heaters, lack of awareness on long term benefits, lack of quality control and standards, low R&D, low economies of scale, lack of expertise in installation and maintenance, and competition from cheap imports were additional challenges.

Lessons

The high interest rates to local suppliers was a major challenge and the involvement of the financial sector was found to be a key factor in ensuring success. While energy efficiency building code was introduced to create market for SWH, it was realised that most local companies produced few components, mostly tanks, and import the rest or import all components which are cheaper. Thus localisation programmes have aimed to incentivise local producers to increase local content of their products from about 20 to 80%, after realising that past roll-out programmes have favoured foreign imports[41].

Though South Africa has a well thought through policy, the impacts of its SWH programmes are lower (compared to Tunisia) and market growth has been low, leading to non-achievement of policy targets[42]. One important lesson of the rollout SHW programme in SA points to the delay in including domestic content (protectionist) requirements which resulted in domination of imports and destruction of the competiveness of locally manufactured products.

Technology transfer fact sheet			
Form/type of TT	Specific TT components	Outputs/outcomes	Stage of TT
- Knowledge sharing - Technical training and know-how acquisition	- Design and manufacture of several SWH models - Assembly of components and maintenance of systems - SWH testing centres	- Capacity building of several local manufacturers and installers - Over 220,000 low pressure and 57,000 pressure heaters installed in four years	Stage 3

[41] Boyed A, Rennkamp B. Technological capability and transfer for achieving South Africa's development goals. Climate Policy, DOI: 10.1080/14693062.2013.831299

[42] See UNEP-RISOE, 2011.

Box 12 Zimbabwe – Building SWH for local conditions

Technical cooperation with Austria

The Austrian government, through the Austrian Development Cooperation (ADC), has financed several TT programmes in SHW in Southern Africa for over a decade, with technical training delivered by Austrian institutions such as Institute for Sustainable Technologies (AEE-INTEC). AEE-INTEC worked with Zimbabwean organisations to develop SWH models suitable to local conditions, with adequate provision made for training of local enterprises and the supply of tools and hardware to selected trainees/companies[43]. Local enterprises subsequently constructed and marketed several systems for both household and institutional use. In order to provide continuous technical support, the university of Zimbabwe has been undertaking R&D in addition to running technical courses to support innovations in the industry. Other SWH TT programmes such as Soltrain (Box 13) have also boosted the technical competence of many manufacturers and installers.

In a move to create market for the sector, Zimbabwe is making plans to introduce regulations banning the importation and use of electric water heaters, while mandating all new structures to incorporate SWH. This initiative if implemented is expected to save between 300-400 MW, freeing power for industry and other productive activities. The roadmap designed for the realisation of this ambitious policy direction involves the building of capacity of local companies in the manufacture of SWH and geysers.

Technology transfer fact sheet			
Form/type of TT	Specific TT components	Outputs/outcomes	Stage of TT
- Knowledge sharing - Technical training and know-how - Supply of tools and hardware	- Design and manufacture of several SWH models - Assembly of components and maintenance of systems	- Capacity of several local enterprises build - Running of courses by colleges	Stage 3

Box 13 Southern African Solar Thermal Training and Demonstration Initiative (Soltrain)

Southern African institutions have benefited from a TT programme in SWH called Soltrain. Soltrain was aimed at supporting target countries (Lesotho, Mozambique, Namibia, South

[43] Hove T, Mubvakure B, Schwarzlmueller A. (2007). Conservation of the business capacity for solar water heater manufacturing and installation in Zimbabwe: Final report on the survey on demand of solar water heaters in the institutional sector.

Africa and Zimbabwe) to switch from the use of electric heaters to SHW by providing technical training to institutions and enterprises. The programme also provided support in formulation of favourable policies and effective administration with the help of experts from Institute for Sustainable Technologies (AEE-INTEC) in Austria.

Some outcomes from the first phase of the project (2009-2012) include technical capacity building of 400 trainers, training of 600 people in dissemination courses, organisation of policy related workshops for 200 actors, and installation of solar demonstration systems in 60 non-profit organisations resulting in energy output of 711 645 kWh per annum. The second phase spanned the period 2012-2015 and the major achievements of the project are shown in the fact sheet below. The demonstration plants enabled the application of knowledge acquired in the training programmes to actual installation, operation and maintenance of various SWH models and system sizes.

Technology transfer fact sheet			
Form/type of TT	Specific TT components	Outputs/outcomes[44]	Stage of TT
- Knowledge sharing - Technical training - Acquisition of know-how - Pilot and demonstration systems	- Design and fabrication of solar water heaters - Policy formulation - Effective administration	- 1,600 people trained in courses - 100 demonstration facilities installed - Awareness creation on benefit of SWH	Stage 3

5.3 Solar lighting: China-Kenya solid state solar TT centre

China and Kenya have deepened their technology transfer cooperation in solar energy through the establishment of a modern facility for technology development, transfer and training, as well as information sharing, focusing on the assembly of solar lighting applications to serve the Kenyan and East African Region[45]. The solid state lighting technology centre is expected to lay the platform for a local assembly plant for solar applications. The collaboration involves a Kenyan company, Sunyale Africa that supplies solar lighting products to homes and institutions, and a company from Beijing. The facility will be used to train technicians on the latest technologies in the industry. It is observed that favourable policy and regulatory frameworks in Kenyan have been the catalyst for such collaboration.

5.4 Concentrated solar power in India

Background

Solar concentrators uses mirrors and lenses to channel solar radiation onto a target receiver, raising the temperature of the target. Small scale concentrated solar power (CSP), classified within 0.1-2 MW, are suitable for

[44] AEE INTECH (2015). Soltrain: Applications, facts, cost, solar yields, environmental effects.
[45] http://www.pv-magazine.com/news/details/beitrag/china--kenya-establish-solar-technology-transfer-centre_100019259/#axzz3mvr0Jp77

meeting low to medium temperature process heat as well as in institutions such as hotels and hospitals for heating water or cooking. According to Carbon Trust[46], the dissemination of small scale CSP technologies in industrial heating as well as in rural (off-grid) applications, face barriers such as the lack of proven or optimised technology, lack of awareness, lack of confidence in the suitability of the technology in rural areas and high investment costs. However, incorporating CSP in off-grid situations provides benefits owing to the ability to store heat efficiently compared to solar PV. Heat stored could be used for cooking and heating water in the evening.

India case study

India has installed over 70 small scale CSPs (SCSPs) for industrial applications, representing the largest programme in the world. India's Solar Mission recognises SCSPs as having the potential to support both micro- and macroeconomic benefits such as increased energy access to rural folks and energy security, reduced land degradation and job creation, and thus has clear support framework in place for SCSPs for both on- and off-grid situations.

The country has also benefited from many international support in its SCSP programmes, from UNDP, UNEP, GIZ and UNIDO. Further, India's ministry of New and Renewable Energy supports SCSP technology development and provides subsidies to end-users. Most systems in India are installed for institutional cooking while a few applications are in food processing, dairy sector and metal treatment. In 2012, UNDP partnered with India's Ministry of New and Renewable Energy (MNRE) and GEF to introduce a major programme in CSH known as Market Development and Promotion of Solar Concentrator based Process Heat Applications, with financial support from GEF.

The programme was aimed at the removal of barriers to commercial dissemination of small-scale CSP in the industrial sector. The project included the building of 30 demo plants and 60 replication plants, introduction of two technologies, standard testing of CSH, and activities for removing financial barriers, among others[47]. Out of a total budget of about 24 million USD, the GEF contributed 4.4 million USD and the Indian government supported with 6 million USD while the rest is borne by industry and financial sector.

Arun dish at Akshardham temple, Delhi
Source: MNRE, UNDP, India[48]

In a typical project, solar dishes (16m^2 ×10) were installed for hot water generation for a

[46] Carbon Trust, 2013. Small-scale Concentrated Solar Power A review of current activity and potential to accelerate deployment.

[47] UNDP. Market development and promotion of solar concentrator based process heat applications in India.

[48] http://sblf.sustainabilityoutlook.in/file_space/SBLF%20Summit%20Presentations%202013/UNDP_GEF.pdf

paper mill at Ludhiana in India in 2011. The company initially used wood for boiling water for its operations but the new solar concentrator technology (used from 9 a.m – 5 p.m) is integrated with the existing biomass system.
The investment was about USD 45,000, with a grant of about 30% of cost provided by MNRE. The solar system is able to generate steam at 10 kg/cm^2 at a temperature of 90-98 ^{0}C. The mill is making savings from wood to the tune of 70 kg/h, with an IRR and payback of about 24% and 3 y for the situation with subsidy. Initial challenge encountered pertained to broken mirrors which were later replaced.[49]

Ten 16 m^2 Scheffler dishes at B.S. Paper Mill, Ludhiana, India. Source: MNRE, India

5.5 Integrated solar combined-cycle (ISCC) in Algeria

When RET such as solar PV is integrated into an existing or planned thermal plant (gas-fired, oil-fired or coal-fired power plants), it is termed hybridization of the thermal plant. In Africa, successful case studies are in Algeria and Egypt where concentrated solar power (CSP) is hydridized with gas-fired power plants.

In Algeria, an Integrated Solar Combined-Cycle (ISCC) technology, which combines solar energy with the combined cycle, was successfully established in 2011. The project was established under a Public Private Agreement (PPA) with a favourable tariff period of 25 years. The plant was developed and operated by Abener ensuring that Sonatrach, the owners, receive know-how in its operation over the years.

The Hassi R'mel plant consists of a 150 MWe hybrid power plant composed of a combined cycle and a 20 MWe solar thermal plant. The technology incorporate parabolic troughs with solar field aperture area of about 180,000 m^2. The project cost was approximately 315 million Euros. It is located directly on the gas field, allowing ready access to gas, power grid, as well as high direct normal irradiation. Even though feed-in-tariffs for purely solar power projects are not encouraging under present systems in Algeria, highly hydribized solar based plants (≥ 25% solar) receive significant financial incentives that have made such projects economical.[50]

5.6 Improved cookstoves technology transfer programmes

Traditional, inefficient wood-based cookstoves have been used extensively in Africa for cooking and heating purposes in homes,

[49] MNRE. Concentrated solar heat. Ministry of New and Renewable Energy, India.
[50] Gertig C, Alcobert A.D., Lopez C.H., Lopez RR. Algeria: a case study of solarized gas turbine systems. http://www.gl-garradhassan.com/assets/downloads/Algeria_-_A_Case_Study_for_Solarised_Gas_Turbine_Systems.pdf

institutions and businesses. The use of inefficient wood-based cookstoves is known to present several developmental challenges in the form of high wood consumption per used energy released, large emissions of smoke which cause indoor pollution, drudgery involved in fuel collection and use, and increased stress on forest cover, among others.

In Africa, the development and promotion of improved or clean woodfuel cookstoves have lagged behind charcoal stoves. While many countries are yet to introduce concrete programmes aimed at whipping up all-round interest in clean firewood stoves, other countries have made considerable efforts in developing technical capability, encouraging knowledge and technology transfer as well as improving marketing and distribution, financing arrangements, and policy and regulatory environment. This section takes a look at some initiatives across the continent that have technology transfer components, highlighting barriers encountered and lessons that have led to the success of such programmes.

A case study of institutional cookstove programmes with TT components in Kenya is discussed in Box 14. In addition, a Southern African based cookstove TT programme is shown in Box 15.

Box 14 **Kenya: a success story of TT in institutional cookstoves**

The dissemination of the Kenya Ceramic Jiko stove is among the most successful improved cookstove programmes in Africa as over 1.5 million units have been sold. Similarly, Kenya has achieved some level of success in developing and marketing locally produced wood-based stoves for the domestic and industrial use. The potential for distribution of efficient stoves to institutions in Kenya is high as the country has over 95% of its institutions depending on woodfuel for cooking and heating water, thus creating pressure on vegetation. In an attempt to promote institutional wood stoves, several technical training programmes have been initiated by international organisations such as Bellerive Foundation, Global Village Energy Partnership and GIZ to build the capacity of local companies and artisans. Kenya also is home to one of the biggest donor-supported programmes in cookstoves – Market transformation for efficient biomass stoves for institutions and small and medium-scale enterprises which is discussed below in addition to other TT programmes.

Market transformation for efficient biomass stoves for institutions and small and medium-scale enterprises

Background

Kenya's Ministry of Energy (MoE) has supported specific programmes to promote institutional stoves in conjunction with UNDP and other stakeholders. One of such initiatives was a four year programme, Market Transformation for Efficient Biomass Stoves for Institutions and Small and Medium-Scale Enterprises (MTES), under the Global Environment Facility (GEF) that targeted cookstove dissemination in institutions and small businesses from 2007-2010. The main aim of the programme was to remove market barriers to the adoption of modern biomass energy practices and clean cookstoves by institutions and small businesses. The MTES was developed to build on earlier institutional stove programmes funded by the GEF Small Grants Programme (SGP) under a revolving credit fund scheme that grew to USD 200,000 in 2007 and USD 750,000 in 2010 (Matiru and Schaffler, 2011). GEF contributed USD 1 million while UNDP, MoE, and other bodies provided additional support (cash/kind).

Implementation: activities and strategies

The MTES was coordinated by UNDP and executed by the MoE through the NGO, Renewable Energy Technology Assistance Programme (RETAP). A project management unit was established under RETAP for daily coordination of activities while a steering committee, co-chaired by UNDP and the Ministry, provided leadership and direction. Further UNDP provided logistical support in addition to monitoring projects operations and outputs against set targets while the MoE performed key roles in advancing the development of favourable policy with the involvement of key government ministries and sectors including finance, environment, forestry, health education, industry and agriculture[51].

Improved institutional wood stoves were fabricated and supplied mainly by a leading company, Rural Technology Enterprises (RTE) that has supported cookstove initiatives since 1984. The programme also had components related to the cultivation of fast-growing energy crops such as some varieties of eucalyptus in woodlots to specifically provide wood for institutional kitchens[52]. Private entrepreneurs and companies were responsible for growing, nurturing and supply of eucalyptus seedlings to schools, with the latter supported to have woodlots grown to serve as wood supply for improved institutional cookstoves.

Outputs and outcomes

According to UNDP-Kenya, over 2000 well-engineered and locally manufactured stoves were distributed to schools, restaurants, hotels and households, yielding over 12,000 tonnes of CO_2 emission reduction. As at 2008, about 10-15% of educational institutions were using improved institutional cookstoves in Kenya. Moreover, the project led to the cultivation of over 600 thousand trees on about 34 hectares of plantations, sequestering over 10,000 tonnes of CO_2.

Barriers and lessons

The weakest link was the lack of follow-up and monitoring on the establishment of the woodlots which appeared to be the least successful. Another challenge encountered include irregular supply of materials such as stainless steel for stove fabrication, high cost of stoves,

[51] Matiru V., Schaffler. 2011. Market transformation for highly efficient biomass stoves for institutions and medium-scale enterprises in Kenya: terminal evaluation, UNDP.

[52] UNDP, Mid-term evaluation report on the market transformation for highly efficient biomass stoves for institutions and medium-scale enterprises in Kenya, 2008

sustaining funding for the programme and data collection. The programme's overall success was attributed to among others: interest due to positive impacts on end-users, involvement of several governmental departments with clear-cut functions, support from the financial sector, judicious use of consultants to work on specific tasks, info dissemination and networking, and formation of associations among informal players. Further it was observed that the operations of stove manufacturers needed to be brought into the formal sector. It was realized that more schools could patronize the improved stoves if a loan guarantee scheme is formalized under the Ministry of Education to take care of upfront costs. The development and implementation of appropriate strategies and policies needed support of all sector departments in order to sustainably grow the industry. Moreover, there was the need to decentralize activities with time including nursing of seedlings. Increased awareness of end users critical to the success of the programme.

The MoE is collaborating with the Educational Ministry to mandate schools to use only improved cookstoves while standards for improved stoves are being developed in collaboration with many partners including GIZ through the Energising Development programme[53].

Technology transfer fact sheet			
Form/type of TT	Specific TT components	Outputs/outcomes	Stage of TT
- Knowledge sharing - Skills-based training - Acquisition of know-how	- Fabrication of cookstoves - Training in cultivation and nurturing of woodlots	- Over 2000 stoves distributed to institutions and households - Cultivation of over 600,000 trees on 34 hectares of land	Stage 3

Bellerive Foundation – TT in institutional cookstoves

The Bellerive Foundation in partnership with UNDP and GIZ has supported the development of technical capacity and know-how in institutional cookstove in Kenya since 1983. Designs by the Foundation have gone through many modifications over the years in consideration of availability of raw materials, local manufacture capacities, consumer preference and thermal efficiency. Consequently, well-engineered designs have been developed, manufactured by local enterprises and sold in institutions.

Challenges encountered by the Foundation included poor operational and managerial practices by consumers and ineffective dissemination system centred in the capital; however, follow-up services involving two visits to end users led to considerable improvement in stove

[53] GIZ. Energizing Development Kenya Country Programme. https://www.giz.de/en/worldwide/21975.html

management and longevity (Davey). According to a recent report by Global Alliance for Clean Cookstoves (GACC), the main barrier has been the unavailability of flexible financing systems to cover for the high upfront costs. Moreover, the quality of stoves has deteriorated in some cases as producers attempt to produce stoves at lower costs with the hope of meeting the financial capabilities of end users.

Capacity building by GVEP in institutional cookstoves

Under the GACC and with a USD 43,000 funding support from the US charity Adventure Project, the Global Village Energy Partnership (GVEP) has trained about 150 cookstove manufacturers in Kenya in the design and manufacturing practices of a new improved stove called Jiko Smart for both charcoal and firewood, in addition to market promotion drives and programmes. The efficiency of the stove has been established based on tests conducted at various centres including University of Nairobi, Makerere University and the Kenya Industrial Research and Development Institute (KIRDI). According to GVEP, over 2000 models were sold from July 2014 to May 2015 owing to its high energy efficiency, improved safety and durability relative to local ones. GVEP is focussing on supporting manufacturers to obtain credit in order to expand their operations.

Box 15 Programme for Basic Energy and Conservation (ProBEC)

Introduction

Southern African countries (Lesotho, Malawi, Mozambique, Namibia, South Africa, Tanzania, Zambia and Zimbabwe) have benefited from technology transfer in improved cookstove design, fabrication and installation under a project dubbed Programme for Basic Energy and Conservation (ProBEC). ProBEC was initiated by Southern Africa Development Cooperation (SADC) and implemented by GIZ with funding from the German Government. The programme was developed to support the cookstove sector in SADC member countries whose programmes have suffered from challenges such as lack of awareness and sustainable financing for stoves, low-level of awareness, inadequate training for end-users and lack of policy support[54]

Activities and strategies

Under ProBEC, the Aprovecho Research Centre worked with entrepreneurs and local actors in the target countries to develop institutional cookstoves for each country, targeting clients such as schools, prisons and tea-estate kitchens etc.[55]. Aprovecho further provided research support as well as project monitoring and evaluation. Participating countries were supported to develop biomass energy strategies and operational plans for effective dissemination.

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[54]Global Alliance for Clean Cookstoves, Tanzania market study, 2012.
http://cleancookstoves.org/resources_files/tanzania-market-assessment-mapping.pdf
[55] https://www.ashden.org/files/Aprovecho2006.pdf

Outputs and lessons

From 2004-2006, over 700 institutional (50-300 litre pots) stoves were constructed locally and sold to institutions in Malawi. Ken Steel Manufacturing, one of Malawian enterprises that benefited from the transfer of technology and know-how in 2004, was able to manufacture and sell over 1500 stoves from 2004-2007.[56],[57] In Tanzania, many trained artisans of institutional stoves under ProBEC stopped operation after the end of the programme in 2010 due to lack of entrepreneurial zeal and sustainable financing.

Woodbased institutional stove manufacturing in Malawi. Source: http://www.hedon.info/docs/cec/Probec_institutional_stoves.pdf

Institutional stove used in Tanzania (credit: Christa Roth). Source: http://www.hedon.info/docs/BP53-Roth-11.pdf

Technology transfer fact sheet			
Form/type of TT	Specific TT components	Outputs/outcomes	Stage of TT
- Knowledge sharing - Skill-based training - Acquisition of know-how	- Design and development of stoves appropriate to local conditions in participating countries - Technical research support - Project monitoring and evaluation - Training of private enterprises and artisans	- Private enterprises established - Over 700 stoves disseminated in Malawi in three years	Stage 3

5.7 Pelletisation

[56] Hedon. http://www.hedon.info/docs/cec/Probec_institutional_stoves.pdf
[57] Roth C, Michel A, Messinger C, Getting Technologies to the market – the case of the Rocket Stove in Malawi, 2007, http://www.hedon.info/docs/BP53-Roth-11.pdf

Pelletisation is the process of drying and pressing biomass materials under high pressure to produce cylindrical pieces of compressed and extruded material known as pellets. Pellets have a smaller volume and a higher volumetric energy density and are more efficient to store, transport and convert into energy. Pellets can be used for central heating, small-scale electricity generation and for household cooking. The demand for pellets is increasing at about 25-30% per year (Kusumaningrum and Munawar, 2014), creating a strong market opportunity globally.

The process of biomass pelletisation is highly developed and the equipment for pelletisation are widely available from vendors. Operation of pellet plants are simple.

Pellet stoves are available for household cooking, steam generation in homes and industries and space heating. They generate less smoke and have high combustion efficiencies. An interesting household –based programme on the use of pellet stoves and pellet fuel is the case of Inyenyeri in Rwanda (Box 16).

Box 16 **Rwanda: Inyenyeri micro-gasification pellet stove programme**

Inyenyeri is a biomass energy company that provides pellets to households in Rwanda for heating and cooking purposes. The company produces fuel pellets made of twigs and non-wood biomass such as elephant grass, banana leaves and coffee bean husks. The company's business operations are interspersed with training and job creation activities such as supporting entrepreneurs to supply stoves.

The stoves are leased to customers at a nominal cost of USD 7/year and customers have the option of paying for stoves by supplying biomass for pellet production, allowing even poor households to own the stoves. Moreover, the company exchanges pellets, which are less costly than charcoal, with biomass supplied by individuals. Households or individuals also have the option of supplying the company with the biochar left in the stove after combustion; this becomes one means for verifying the use of the stove, enabling it to receive carbon revenues. This business and market model have enabled the company to market a relatively expensive stove without subsidies or microcredit scheme. Pellets are sold to urban customers for revenue generation to the company.

Technology transfer fact sheet			
Form/type of TT	Specific TT components	Outputs/outcomes	Stage of TT
- Investment - Training and know-how	- Pellet production - Use of pellet stoves	Not available	Stage 2

5.8 Biogas technology

Many developing countries have had experiences with domestic biogas initiatives and successful countries such as China, Nepal and India have implemented varied strategies and policy regimes, usually targeting specific groups or sectors. Biogas programmes in Africa have lagged behind their Asian counterparts (see Annex F) even though the level of success varies considerably on the continent, with countries such as Kenya and Tanzania making considerable strides in the sector.

Some success stories of biogas programmes having TT components are discussed under the African biogas partnership programme (Box 17).

Lessons: biogas case studies

Lessons from successful countries such as Nepal and China point to the fact that biogas programmes cannot be let alone to the private sector and as such the involvement of other stakeholders – government, financial sector, developmental partners and NGOs – are crucial to largescale dissemination. The direct involvement of parastatal organizations and relevant regulatory bodies are prerequisite to success. Moreover, successful countries have dedicated offices for biogas dissemination at both national and grassroots levels. For example, Kenya has Kenya Domestic Biogas Programme (KENDRIP) with full technical and administrative personnel that coordinates biogas programmes at the household level.

Many successful countries have had to introduce some level of financial incentives (interest-free loans, direct subsidies, etc.) to end-users. It is important to note that biogas programmes need to be adapted to the specific environment of the country. Thus, in Nepal, private companies are the main drivers of biogas technology while in Vietnam, the provinces are the main focal points[58].

Factors that have also influenced successes elsewhere are outlined below:

- Favourable policies and legal regimes that particularly emphasize biogas technology. For example, in Nepal, the Biogas Sector Partnership (BSP-Nepal) works under the local authorities and backed by the Social Organization Act. Further, a biogas coordinating committee under the Alternative Energy Promotion Centre (AEPC) of Ministry of Science and Technology is responsible for coordinating all stakeholders in the biogas sector;
- The development of comprehensive programme with clear cut actions, measures and interventions for the achievement of targets as pertains under the ABPP (Box 17) and the biogas programme of Nepal (Annex F). In most cases, such programmes rest on market assessment of the industry, development of standardized digester models, institutional set-up, and implementation modalities all involving open and participatory approach of all stakeholders;

[58] SNV, Building viable domestic biogas programmes: success factors in sector development, 2009.

- Comprehensive and large scale programmes require effective institutional coordination, with separate functions in areas such as marketing, promotion, financing, construction, follow-up services, training and extension services, research and development, operations and maintenance, quality control, and management. Development of strategies that recognize the contribution of various stakeholders including grassroots organisations are key to successful biogas programmes;
- Supply-side competition favours the end-user as such monopolies should be avoided in any well-thought through programme;
- The role of government or national entities ideally should be focused on facilitating various aspects in relation to promotion, regulation, monitoring and arranging for funding from donors.
- The development of standardized plants, standards for construction of plants and quality control systems are very important. A regulatory system that sanctions companies that deliver poor services and awards those that performs creditably will improve the image of the technology.

Box 17 **African biogas partnership programme (ABPP)**

Background

ABPP is a Regional biogas programme that has been running since 2009. The programme is funded by the Dutch government, governments of target countries (Tanzania, Kenya, Ethiopia, Uganda and Burkina Faso), and beneficiary households, among others. The programme is aimed at creating a commercial biogas sector at the domestic level in the target countries. Under ABPP, SNV provides technical and advisory services with inputs from experience in Asian programmes while HIVOS provides programme management. Each country has developed its unique programme taking into consideration local conditions and inputs from stakeholders.

Activities

Extensive training activities were planned into the programme with the aim of building capacity of local companies and artisans in design, development, construction, and operation of biogas digesters. In addition, the private sector received entrepreneurial capacity building. There was also emphasis on appliance development and bioslurry utilisation.

In Burkina Faso, about 4,000 masons were trained and 5,500 digesters were installed by end of 2014. The number of installations was even higher in Ethiopia as nearly 10,000 plants were constructed by end of 2014. A major success of the Ethiopian programme has been the use of the digested slurry – in raw or composted form in agricultural work, enabling some farmers to sell slurry/compost to local farmers.

In Kenya, over 82 registered companies, 240 registered sole proprietors and two associations were created under the programme. A major success of the Kenyan programme was the establishment of credit partnerships with financial institutions, resulting in the financing of installations at low interest rates, with flexible payment arrangements. In addition, more women benefited from credit and training and capacity building.[59]

In Uganda, the programme led to the dissemination of about 5,000 plants from 2009-2013. Research efforts led to the development of a low cost stove for biogas leading to overall cost reduction. The Ugandan programme specifically had an expert recruited to advise programme managers on gender issues. This resulted in the training of the highest percentage of female masons/technicians in the ABPP programme.

In Tanzania, a modified CAMARTEC digester was adopted for dissemination and about 2500 digesters for mainly rural cattle households were installed by 2011.[60] The success of the programme was partly as a result of targeting rural cattle farmers who were able to make full use of both slurry and gas.

Challenges

The high cost of biogas installations has been a major challenge in all the target countries, reducing penetration of systems among rural households. Other challenges include inadequate credit facilities and weak private sector development especially in Ethiopia. Lack of after sales services, low-grade appliances and poor workmanship were difficulties encountered in Tanzania. However, this challenge has been well dealt with in Uganda where a centralised centre for client services was established to ensure standards and accountability to the client by biogas construction enterprises.

In Burkina Faso, the government provides a subsidy of 30% of the cost of installations. In Uganda, the number of installations dropped significantly when subsidies were removed, though sales bounced back following intensive capacity building by biogas service providers. In order to reduce installation cost, the programme is supported by extensive research aimed at reducing digester cost through the development of new models.[61]

Outcome

The first phase of the programme (2009-2013) culminated in the construction of over 34,000 plants out of a target of 70,000. A major success of the programme was its gender sensitive interventions: for example women constituted 54% and 57% of users trained in plant operation/maintenance and bioslury use, respectively. The achievements of the programme have caused partners to extend it to 2017. Under Phase II, DGIS is supporting the programme

[59] ABPP. Kenya. http://africabiogas.org/kenya/
[60] See Kileo and Akyoo (2015)
[61] ABPP. Burkina Fasso. http://africabiogas.org/burkina-faso/

with 20 m Euros out of the total budget of 87.9 m Euros for 100,000 plants, with significant contributions coming from beneficiary households, host governments, and other donors. The programme is expected to explore new areas with diversification in terms of strategies for particular regions and population segments such as women. The programme is expected to include countries with commitment to biogas technology including Cameroun, Rwanda, Zimbabwe, Zambia and Benin.

Technology transfer fact sheet			
Form/type of TT	Specific TT components	Outputs/outcomes	Stage of TT
- Knowledge sharing - Technical know-how and practical training - Organizational /best practices	- Design and sizing of digester and gasholder - Design and construction of bio-latrines - Operation and maintenance - Biogas appliance design and fabrication - Bio-slurry composting and utilization - Capacity building in entrepreneurship - Gender mainstreaming – training of women in plant operation and maintenance, as well as bio-slurry application in agriculture	- Overall – more than 34,000 biogas units installations in four years *Burkina Faso* - 400 masons trained - Over 5,500 digesters installed *Ethiopia* - About 10,000 digesters installed *Kenya* - Over 550 masons trained *Uganda* - Over 5000 digesters installed - One expert on gender issues employed - High number of female masons trained	Stage 3

5.9 Conclusion

Ghana must accept that some things are achieved the ‘hard way’ as other countries have done. Zimbabwe’s plan to ban imported water heaters (after completion of its local capacity development in solar water heaters manufacturing) is a lesson that would truly drive innovation. Like ‘operation feed yourself’, it is time to take a stand if Ghana is to succeed in boosting RE technology transfer.

Solar water still at Bongo
Photo: CEESD

6. BARRIERS TO RENEWABLE ENERGY TECHNOLOGY TRANSFER TO GHANA

6.1 Background

Developing countries face a daunting task of bridging the energy poverty gap as access to clean and modern energy services continue to elude majority of the citizens. Unlike developed countries, where issues regarding the climate effects of fossil fuels appears to be the main driver for promoting RETs, the driving force for the adoption of RETs in developing countries is access to modern energy services. In Ghana for instance, in spite of the relative high access to electricity (76%) there are still a large number of off-grid communities. Also, dependency on woodfuels in the form of charcoal and firewood is still high (42%) in the final energy demand as shown in Figure 4[62]. The remaining 58% is taken up by oil and natural gas (50%) and hydro (8%).

[62] Energy Commission (2014). National Energy Statistics 2000 – 2013, Accra.

This is an indication that modern fuel sources and clean renewable energy options currently play a minimal role in the energy mix of the country.

Global indications of the health effect of some household fuels have also given impetus to the adoption of RETs. More than 16,600 mortalities as a result of the use of dirty fuels and poor fuel combustion technologies are recorded in Ghana annually[63]. Currently, the contribution of modern renewable energy to the generation mix of the country is about 0.3%[64] (i.e. not counting woodfuel).

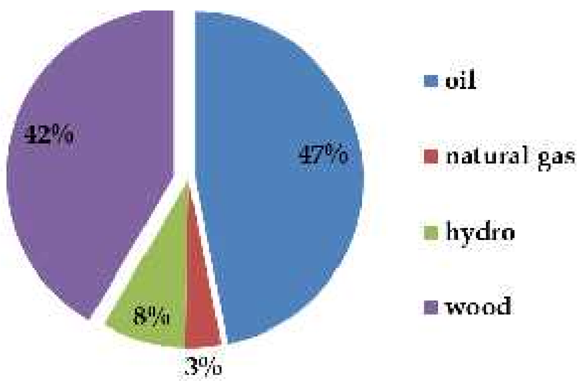

Figure 4 Final energy demand in 2013 (Source: EC, 2014)

The situation with transportation fuels is much worse; Ghana is solely dependent on fossil derived fuels to meet all her transportation needs. The contribution of gaseous fuels such as biogas to the energy mix is negligible, given the number of biogas installations in the country and the high default rate of the existing installations[65]. The exploitation of solar energy for purposes of drying is in the very least carried out in its crudest form – open air drying, thus difficult to quantify and properly integrate into the energy mix of the country.

As has already been defined, transfer of technology could be technical, where machinery, tools and equipment are involved and non-technical, which involves knowledge and skills acquisition. Successful transfer of technology thus involves the adoption, adaptation and dissemination of the technology. The inability of Ghana to successfully adopt, adapt and disseminate RETs may be due to a number of barriers. Many of these barriers have been discussed in separate reports and meeting transcripts. The following section discusses specific barriers to the various RETs.

6.2 Specific barriers

The barriers affecting RETTs have been put into eight main groups – Economic and Financial, Market, Technical, Network, Legal and Regulatory Framework, Information and Awareness, Socio-cultural and Human Skills barriers. Under each category, specific barriers have been identified and discussed below.

6.2.1 Market barriers

The following are sub barriers under market barriers:

- *Market size*

The size of the market for a particular renewable energy technology is usually a

[63] GoG (2012). Sustainable Energy for All Action Plan. Accra: Government of Ghana.

[64] GoG (2014). Scaling up RE - Scoping Mission. Accra: Government of Ghana.

[65] See Bensah and (2010).

driving force for the transfer of technology and hence could also become a barrier. The larger the market size, the more willing entrepreneurs are to exploit the possibility of acquiring the technology, adapting and disseminating it. Likewise, the smaller the market size, the less likelihood that entrepreneurs will invest in technology transfer. In the case of Ghana, it is difficult to classify size of the market as a potential barrier for some RETs. Some RETs with larger market size have not seen massive deployment as is the case in other places.

Domestic biogas for instance has a market potential of about 278,000 units for dung fed systems[66], however, less than 200[67] units have been constructed nationwide so far. Again, the market for charcoal is quite high; however, technology transfer in terms of more efficient and environmentally friendly kilns to produce the charcoal has been clearly missing in spite of the growing demand for the product. Other RETs like solar PVs and cookstoves need larger market to increase volumes and reduce cost.

- *Failed past experience*

Generally RETs are perceived to be unreliable by end users even though that may not be the case. Failed demonstration projects re-enforces the perception of an immature technology that cannot be relied upon[68]. This is evident in a number of RET solutions piloted in the past. Again, the biogas technology and some solar lanterns come up readily as an example.

- *Controlled market in favour of conventional systems*

Until recently (2015), the Government of Ghana was heavily subsidizing transportation fuel on the market completely leaving out market forces to determine the true price of the commodity even when the price of crude oil increased on the international market. Meanwhile no subsidies have ever been announced for bioenergy products.

Producers of liquid biofuels do not even have any means of selling their products to potential users since there are no dispensing mechanisms for fuel derived from RE sources. Also, even though standards for biofuels have been developed and adopted, testing and certification procedures are still under development.

- *Lack of successful reference projects*

Successful reference projects serve to boost confidence in the technology leading to acceptability of the technology among end users. It also serves as a very powerful marketing tool for sceptics. The absence of successful reference projects reinforces the perception of either an immature technology or a failed technology. Further, project financiers may consider RETs too risky for the lack of visible projects.

[66] Heegde, T. F., Sonder, K. (2007). Domestic biogas in Africa; a first assesment of the potential and need. NV.
[67] Authors own assessment based on the reported 100 known biogas units in Ghana as of 2009 by Bensah and Brew-Hammond, 2010.
[68] Mulinda, C., Hu, Q., Pan, K. (2013). Dissemination and problems of African biogas technology. Energy and Power Engineering, 506-512.

- *Supply chain*

An effective supply chain is important especially during scaling up or mass dissemination of RETs. The lack of high quality planting seeds and unavailability of feedstock for the production of bioenergy have been identified as some of the main barriers to mass production of bioenergy. Similarly, raw materials in the form of semi-finished products like vacuum tubes for the manufacturing of solar water heaters are not readily available on the market.

6.2.2 Economic and financial barriers

The following are specific economic and financial sub barriers that affect RETT:

- *Access to finance and long term capital*

The cost of acquiring technology globally is usually high because of patent rights. This is the case with some RETs like solar PV, wind and small hydro turbines but not so much for some biogas technologies such as fixed dome and floating drum biogas digesters and some improved cookstove models like the Jiko type. Even though financial mechanisms such as equity finance, venture capital fund, debt financing and crowd financing among others are available to entrepreneurs, some of them are not fully developed in Ghana.

For instance, crowd financing is not fully developed in Ghana and hence inaccessible to entrepreneurs. Equity finance is also not very popular in Ghana thus the only financial mechanism available to Ghanaian entrepreneurs is perhaps debt finance.

Ghana's financial market is crowded with a lot of commercial banks and other financial institutions, which play a critical role in the transfer of technology by making available funds and letters of credit to investors and local entrepreneurs to finance project activities. Due to lack of staff with knowledge in RETs, these institutions are unable to appraise project proposals, resulting in little support to RE projects.

Also, uncertainty surrounding pricing of RETs elevates the risk factor which make banks shy away from financing RE projects. Access to long term financing has been identified as one of the major barriers to the successful implementation of Biogas and Landfill gas.[69]
It is worth noting that Fidelity Bank has established an RE desk[70] to support RE project development in Ghana.

- *Cost of finance-high interest rate*

Since most entrepreneurs prefer debt financing to other forms of financing, cost of finance plays a very important role in decision making regarding whether to access support from banks or otherwise. Currently, the base rates of most banks are above 30% making cost of borrowing very expensive in Ghana.

[69] Daniel, U., Pasch , K.-H., Nayina, G. S. (2014). Biogas in Ghana, Sub-sector analysis of potential and framework conditions, GIZ.

[70] See Daniel *et al.* (2014).

- *Lack of consumer financing options*

The size of the market alone cannot be used to determine the penetration rates of a particular RET. The ability of the market to afford the RETT is an equally important barrier. Base of the pyramid end-users of solar PV systems need financial incentives to enable them purchase solar PV systems because of the high costs. Also, the interest rates charged on financing schemes are usually high and thus prohibitive to end users[71]. Similarly, it has been reported that farmers are unable to afford solar dryers because of the apparent high initial cost of the product.

GEDAP solar PV and lantern project, implemented by ARP Apex Bank, was highly successful because of flexible financing scheme available to middle level income groups to access various products (Box 3).

- *Business climate (currency fluctuations)*

A number of factors goes into the determination of business climate, however, currency fluctuations has been selected due to its distinctive role in Ghana's economy. A continuously weak currency increases the cost of imports.

The local currency, Ghana Cedi, has depreciated more than 500% to major trading currencies like the Dollar in the last ten years. This is in sharp contrast to the relatively stable US dollar and the Chinese Yuan which have depreciated marginally within the same period. The first quarter business barometer of the Ghana Association of Industries (comprising all micro, small, medium, large and giant scale industries) identified a fluctuating currency as the second most important factor militating against them in Ghana.[72]

- *Guaranteed price for energy services (feed-in tariffs)*

Hitherto, unavailability of feed-in-tariffs for electricity generation from RE sources were identified as one of the main barriers to the adoption of RETs in Ghana. The Public Utility Regulatory Commission (PURC) has been able to set the feed-in-tariffs for Ghana since 2013.

Table 2 FIT in Ghana

Technology	FIT, GHp/ kWh
Solar	40.21
Wind	31.1085
Small Hydro ≤ 10 MW	26.5574
Medium Hydro > 10 MW, ≤ 100 MW	22.7436
Landfill and sewage gas	31.4696

Source: PURC, 2013

Since the publication of the FIT, the local currency has depreciated by about 14.5 % to the dollar in 2014 and by the end of the first quarter of 2015, the cedi had depreciated by about 12.01 % already. Although the year has not ended, projections are not good. Since the FIT rates were published in Ghana Cedis, cumulatively it would have lost about 25% of its value already. Local and international investors extensively use the FITs rates to evaluate their projects and once the rates have

[71] See Ahiekpor (2013).

[72] AGI. (2015). The AGI business barometer, Association of Ghana Industries, Accra.

lost value in recent times an upward review may be necessary, otherwise the participation of entrepreneurs leading to technology transfer may be very limited in the coming years.

Discussions with the Energy Commission and the Renewable Energy Directorate of the Ministry of Power however indicate that the dollar rate at the time of the approval of FIT is applicable. This means that the FIT could be higher than the nominal figures published by the PURC. In that case, depreciation of the cedi does not have a negative effect on the FIT.

Meanwhile, the Guarantee period of the Power Purchase Agreement (PPA) has also been a subject of concern for most project developers. Ghana's FIT guarantee period of 10 years is seen as a disincentive for project developers. The reason is the high risk of uncertainty after the 10 year period. Other countries using the FIT to drive the market have a guarantee period of 15 – 20 years. A shorter guarantee period scares banks away because of the high risk of uncertainty beyond the 10 year guarantee period.

- *Insufficient incentives*

Inadequate tax rebates and incentive packages have been flagged as one of the barriers to RETs penetration in the sub region. Tax rebates and incentives are necessary because of the high cost of RETs and some of the market barriers outlined above. In response to the need for tax rebate and incentives, the Government of Ghana has put in place complete import duty and value added tax exemption for solar PV and wind energy generation systems[73]. It is instructive to say however that, other RETs do not enjoy similar tax exemptions. For instance some components of biogas systems such as de-sulphurizers, biogas storage balloons, pipes and valves are not exempted from import duties even though most of them are imported.

Similarly, components of solar water heaters, small hydro plants, and large biogas systems do not enjoy tax exemptions and rebate. Taxes and incentives are used extensively by central governments including the government of the People's Republic of China to prop-up nascent companies to gain market access or competitive advantage in a very stiff or highly controlled market and in some cases reach scalability. Thus, the extensive review of all taxes and incentives on offer for the implementation of RETs to also include other technologies will greatly enhance interest in RETs which will lead to successful RETTS.

- *Operations and maintenance cost*

Operation and maintenance (O&M) cost of RETs could be one of the major barriers to its mass dissemination and successful adoption. Low maintenance cost will drive the market in a positive direction however high O&M cost will most likely kill the market.

[73] IEA. (2012, July 16). polices and implementation. Retrieved September 27, 2015, from IEA/IRENA Joint Policies and Measures Table.

6.2.3 Human skills

The following are sub barriers related to human skills:

- *Technical skills to operate and maintain RET*

Technical skills form a key component of RETT worldwide. Many RET projects have failed because of the lack of technical skills to operate and maintain the systems. DENG engineering and The Energy Centre have in the past years been involved in training of experts in solar PV, solar pump and recently grid connected solar PV system design, installation and maintenance.

The barrier nonetheless exists for other RETS. In the area of solar energy development and utilization for instance, lack of skilled manpower to design and install solar PV systems is still a major technical barrier[74]. The inability of technicians and engineers in Ghana to design heavy duty solar dryers was identified as one of the barriers in the promotion of solar water heater technology[75].

Similarly, the lack of skilled personnel in correctly designing, fabricating and maintaining biogas plants were identified as the main reasons for the mass failure of biogas plants in Ghana. In the case of solid biomass for instance, the lack of knowledge in planting and harvesting of trees was identified as one of the major barriers to the proper exploitation of biomass resources in Ghana.

- *Project development skills*

Project management skills are often low especially at the local level and this was reported as one of the key challenges affecting the mass dissemination of bioenergy products.

- *Inadequate training centres*

Currently there are few training centres in the country mainly located in Accra and Kumasi. The attention of all the training centres is mainly focused on solar PV systems design, installation and maintenance. There are currently no training centres dedicated to training in wind energy, solar drying and solar water heating technologies, mini and small hydro technologies, etc. The Energy Centre of KNUST is the only training centre offering training on biogas technology and bio fuel production in the country.

- *Research and Development*

The ability to adapt technology to suit a particular climate and conditions depends on a very strong research and development capacity. Research on RETs in Ghana is scattered in several academic departments of the various universities and research organizations in the country. The research carried out is at best uncoordinated and in some cases fundamental in nature rather than applied.

[74] Quansah, D. A., & Ramde, E. (undated). Potentials, Opportunities and Barriers for the Deployment and Usage of Solar Energy Technologies and Services in West Africa. Praia: ECREEE.

[75] UNFCCC. (2003). Ghana's Climate Change Technology Needs Assessment Report.

Applied research usually has the highest potential of market uptake as opposed to fundamental research in developing countries. A strong R&D capacity led Tanzania to develop a home grown version of biogas digesters called CAMARTEC, an improvement on the earlier fixed dome digesters disseminated in Tanzania which was prone to gas leakages. Unfortunately, even though Ghana has made strides in the adoption of clean cookstoves, we are yet to innovate and come out with different models of cookstoves aside the Jiko model that was adopted from Kenya.

6.2.4 Technical barrier

- *Poor operations and maintenance facilities*

After sales servicing plays a very important role in any successful dissemination programme. The unavailability of well-trained maintenance and servicing facilities in the country capable of supporting end users with after sales and servicing is a major disincentive for end users. For instance the maintenance of solar dryers, biogas plants, wind mills and solar water heaters by experienced hands often leads to the frequent breakdown of the plant and subsequently lends credence to the assertions that the RET may not be good.

- *Lack of infrastructure facilities*

Location of production facilities depends to a large extent on the availability of infrastructure like roads and electricity. Manufactures of cookstoves, solar dryers, solar water heaters and industrial biogas systems depend on power. Other technologies like domestic biogas plants may not require the availability of power but rather good roads to convey materials to site. The unavailability of the infrastructure facilities thus have a negative effect on the manufacturing and dissemination of RETs

- *Difficulty in getting spare parts and equipment*

The unavailability of spare parts like vacuum tubes and appropriate glazing materials on the market for RETs like solar water heaters and solar dryers respectively are a barrier to mass production. Also, the inability of suppliers to readily replace defunct parts of RETs significantly affects the confidence end users have in the system.

6.2.5 Information and awareness

Each country is unique in the way it responds to technological change. Ghana is no exception. The process of dissemination relies heavily on the availability of information to end users to make informed choices. Information on cost of acquisition, the benefits to be derived from using the technology and operations and maintenance should be readily available to end users (Painuly, 2001).

Gboney (2009), identified lack of awareness on RETs as a major barrier to its dissemination. Similarly, the lack of information on the benefit of solar water heaters has been identified as one of the major barriers to its dissemination (UNFCCC, 2003).

6.2.6 Legal and regulatory barriers

- *Inadequate standard and codes*

The lack of technical codes for the manufacturing, installation and maintenance of RETs was identified as one of the key barriers affecting the technology transfer for solar water heater in the Technology Needs assessment carried out in 2003. The absence of technical standards leads to possibility of consumers being ripped off as a result of product failure. Gboney (2009) also identified the absence of technical standards as a major barrier in his report on international support to promote technology transfer for renewable energy in Ghana. Since then the Energy Commission has published a number of codes and standards for Utility scale RE systems:

a. Renewable energy sub-code for transmission and distribution system;
b. Renewable energy sub-code for distribution system; and
c. Net metering sub-code for connecting renewable energy generating system to the distribution system.

These regulations addresses key concerns of utility scale RETs in the area of equal access to distribution and transmission lines but of little significance to small scale RETs

Aside these, the Energy Commission in conjunction with the Ghana Standards Authority (GSA) and supported by UNDP is developing a Ghanaian Standard for clean cooking stoves. Also, GSA, has developed standards and a testing centre for solar panels. There are presently no standards for solar dryers, solar water heaters, wind mills, small and mini hydro plants and biofuels such as biogas and biodiesel systems. This obviously reiterates the fact that, this barrier has not been removed and continues to affect RETT adversely.

- *Lack of enforcement*

By law, the Energy Commission (EC) is tasked with the responsibility of enforcing codes and standards in the renewable energy arena. The absence of codes and standards makes it difficult for the commission to enforce any law. The absence of enforcement leads to a high default rate. This inadvertently kills confidence in RETs. The enforcement body is also expected to regulate companies and service providers in the sector to ensure product and service quality. Already, a mechanism has been put in place by EC to enforce regulations on production and transportation of charcoal for export and this should be extended to importers of RE systems.

Even though companies involved in importation and installation of RET systems are required to obtain licence from the EC, a cursory observation of the registry of licenced companies shows that almost all of them are solar PV related. Even though the requirement for licences hold for all RETs, none of the major biogas, improved cookstoves manufacturers or importers, or wind service providers was cited in the registry.[76]

[76] http://www.energycom.gov.gh/index.php/register-of-licenses

http://www.energycom.gov.gh/index.php/register-of-licenses

This means companies involved in these RETs are operating without any form of regulation and enforcement by the EC and are thus at liberty to import or install RET systems of any quality.

- *Unfavourable policies*

The push for the adoption of RETs can be driven fast with the adoption of the right policies and enabling framework. The absence of the right policies or unfavourable policies can either slow down the rapid adoption of the RET or completely kill the market. The EC has developed a number of policy documents including:

a. Renewable Energy Act (Act 832);
b. Bioenergy policy document to spur the development of biofuels in Ghana;
c. Strategic National Energy Plan (SNEP) which captures policies and strategies for the inclusion of renewable energy technologies in the national energy mix; and
d. Sustainable Energy for All Action Plan.

Further, the Environmental Protection Agency is developing a green economy policy document that seeks to direct Ghana's developmental growth on a green and sustainable path.

There are still some outstanding issues such as:

a. The preparation of a Renewable Energy Master Plan;
b. The setting up of a renewable energy authority;
c. Operationalization of the renewable energy fund.

The production of biodiesel from energy crops for instance has stalled completely because of the absence of an enabling environment. Additional policies might be needed to give the market the necessary spark. Similarly, biogas, solar water heaters, solar dryers, landfill gas and small and mini hydro may need some final details ironed out to spur interest in those sectors.

- *Political will*

Several policies have been spelt out by successive governments all with the aim of promoting RETs. For the policies and action plans to translate into tangible projects a strong political will to engineer and drive the process is required. The extent to which the government is ready to push RETs penetration remains to be seen.

- *Political interference*

Political interference in RETs projects is one of the key barriers to RETs penetration. Instead of allowing technocrats to lead RETs project, some politicians with no or very little experience sometimes interfere unnecessarily with projects for political expediency. The result is either the project fails woefully to achieve its goals or ends as soon as the political dispensation of the politician is over.

- *Land acquisition*

Ghana's complex land tenure system makes acquisition of land very cumbersome and also quite expensive for project developers of solar PV farms, wind farms and bioenergy crops cultivation that require large tracks of land.

- *Challenges with license acquisition*

Interestingly, the Energy Commission has received over 300 applications for license from RE companies to generate power. However, the Regulator is cautious to grant license due to the financial state of the off-taker – Electricity Company of Ghana (ECG). The financial health of ECG has often been called into question a number of times. The utility provider is debt ridden. Thus, its ability to pay the RE companies is very much in doubt. Other service providers are also unable to find financial closure for their projects because of reluctance of government to provide guarantees in the event of ECG defaulting in payment, contributing to inability of some companies to meet the requirement for licence acquisition. Also, the net effect of the contribution of RETs into the pricing of electricity is also a major source of worry to the regulator. Small scale RET service providers may not require license from EC, however, the process leading to the acquisition of business registration certificate, license to operate from District and Municipal Assemblies and in some cases environmental permit from the Environmental Protection Agency (EPA) may be cumbersome.

In addition, challenges in acquisition of IPRs could also affect the successful transfer of Technology.

- *Administration hurdles in developing contracts*

There are quite a number of administrative documentation required to start an RET project. The administrative processes are often too cumbersome and sits with several ministries with different mandate, making it frustrating to get to develop a project. A solar farm projects for instance will require an EIA from the EPA, a permit from EC, a power purchase agreement from PURC and ECG, a District or Municipal Assembly permit, Tax certificate among others. These agencies are under four different ministries: Ministry of Power, Ministry of Environment, Science, Technology and Innovation, Ministry of Local Government, and Ministry of Finance.

- *Intellectual Property (IP) rights protection*

One key law that enhances Technology transfer is the protecting of property rights. Even though Ghana does not have an explicit IPR law, components of IPR are captured in separate laws. IPR laws operational in Ghana are the Patent Act, 2003 (Act 657), the Copyright Act, 2005 (Act 690), Industrial Design Act, 2003 (Act 660) and the Layout Designs of integrated Circuit Act, 2004 (Act 667). Apart from the Copyright Regulation Law 2010, (LI 1962), Legislative Instruments on the other laws have either not been developed or passed into law yet.

The ability of the law to protect foreign parties interested in TT is very crucial to spur interest. This is usually coupled to a strong legal system that guarantees the right of individuals and corporate bodies. The absence of a strong intellectual property rights protection law captured in the regulation mechanisms leaves room for potential foreign entities/partners to rate high the risk of losing their property rights and their inability to use the local legal system to retrieve what is rightfully theirs. Arbitration in general is costly, however when the local laws are inefficient to deal with the situation, resorting to international arbitration escalates the cost entirely and that scares would-be investors away. Potential TT interest from China will be looking critically at the IP protection laws and regulations in the Country. Like a two edged sword it has both advantages and disadvantages for Chinese interest, as shown in Box 18.

Box 18 **Merits and demerits of weak IP lays**

Advantage of weak IP laws in Ghana to foreign companies

Ghana has been at the receiving end of cheap and inferior products from China and other countries at least in the area of textiles, smart phones, medicine and some solar products due to weak standards and enforcement. This has resulted in reduced competitiveness of some local companies and have caused others to close down. In addition, Ghana's porous borders makes it particularly vulnerable to importation of infringed goods, which has been estimated to cost the country about $200 million annually in revenue.[77]

Disadvantage of weak IP laws in Ghana

The obvious disadvantage of a weak regulation of IP rights in Ghana to Chinese interest will be high risk factor of losing their IP rights or frustrations in fighting IP rights in courts. Looking at China's economic muscle as the second largest economy in the world and a leading exporter of technology, engaging in technology trade will become more attractive than TT especially when the risk of losing IP rights is rated high.

[77] Ghana News Agency, (2014), Counterfeiting and piracy, a drain on Ghanaian Industries.

6.2.7 Socio-cultural barriers

Lack of interest in shifting from conventional energy to RE may be due to lack of incentives to encourage the shift especially when the conventional energy is more reliable and cheaper. A couple of barriers that are socio-cultural in nature are presented below.

- *Lack of understanding of local needs*

Understanding of local needs is important at the project design stage for RETs dissemination. Often perceived local needs are not the real needs and this leads to total rejection of the RET intervention. Several RETs have failed to attain the desired impact because of the mismatch between the perceived needs of the potential beneficiaries and the proposed solution. This is particularly evident in donor funded projects where interventions are designed for the people without the active participation of the potential beneficiaries. The effect of the abandonment or the failure of a project has catastrophic effect on mass dissemination as people will be making references to the failed project.

Other sub barriers include:

a. Consumer preferences and social biases - consumers seeing RETs as temporal solutions and hence preferring conventional systems to RETs;

b. Lack of confidence in new technology – consumers have little or no confidence in RETs due to failed past experience, knowledge of failed projects or lack of access to information about RETs to inform decision making; and
c. Dispersed/widely distributed settlement – The inability of service providers to reach end users easily as a result of widely dispersed settlement leading to additional costs.

- *Fear of failure*

The fear of failure of projects is mostly associated with RETs with high default rate such as biogas and to some extent solar lanterns. End users are often sceptical because of knowledge or experience of failed projects in the past.

6.2.8 Network barriers

- *Lack of involvement of stakeholders in decision making*

RETTs involves the active participation of various players. The involvement of all stakeholders in decision making ensures project ownership and wins the support of everyone involved. When a section of the stakeholders feel left out, they are likely to reject the RET intervention which will stall any possibility of technology transfer.

- *Strong network among conventional technology developers and favoured by legislation*

Utility companies often form a network to protect their interest. Even though in Ghana there is no such association, the Volta River Authority (VRA), Electricity Company of Ghana (ECG) and Ghana Grid Company Limited (GridCo) are in some way connected through working partnership and the fact that they fall under the same ministry. ECG may continue to be the sole distributor of the power in the southern part of the country for a long time. The same goes for GridCo which is the sole evacuator/transmitter of power. Utility scale RETs will have to deal with these companies at all cost in one way or the other.

- *Weak network between foreign institutions and local ones*

For technology transfer to be effective, foreign and local institutions must be connected. The weaker the network between foreign and local institutions the more unlikely technology transfer will take place. The network must not be limited only to manufacturing institutions but also research and development institutions and training institutions to support the industry with technical skills and innovations.

Table 3 shows a summary of the main barriers identified for specific RETs.

Table 3 **Barriers to RETT in specific sectors**

Main barriers	Sub-barriers
Solar PV applications	
Financial	• High currency depreciation • Absence of taxes and rebates on individual components of solar PV systems because of multiple use of components • Lack of consumer financing options for solar PV products • Short guaranteed period for FIT • High initial capital cost for standalone home systems
Technical	• Lack of technical skills to design grid connected systems • Lack of maintenance facilities in rural areas • Lack of training facilities across the country
Economic (market)	• Small market size for solar water pumps, solar PV for vaccine refrigeration and solar irrigation • Limited understanding of issues of integrating renewables into the grid within utility companies
Socio-cultural	• Lack of interest in shifting from conventional energy to solar PV
Legal and regulatory framework	• Land acquisition for utility scale solar PVs • Inadequate codes and standards
Information and awareness	• Inadequate information about cost and benefits of solar PV systems
Network Barriers	• Strong network among conventional technology developers and favoured by legislation
Solar thermal systems	
Financial	• Unstable currency • High capital cost compared with conventional technologies like immersion heaters (for water heaters) and open air drying (for dryers)
Technical	• Low technical skills to design, fabricate and maintain solar thermal devices like solar water heaters and dryers • Low political will • Lack of standardization of designs • Absence of codes and standards for design and installation of systems
Economic (Market)	• Small market size due to high access to electricity from the grid for solar water heaters
Socio-Cultural	• Fear of failure due to failed past experience
Legal and regulatory framework	• Absence of regulations • Lack of enforcement of standards due to their absence • Absence of a renewable energy pricing framework
Awareness and Information	• Low awareness/knowledge about benefits of using solar dryers and solar water heaters

Main barriers	Sub-barriers
Wind energy systems	
Financial	• Short guaranteed period for FIT • Unstable currency • High initial capital cost
Technical	• Inadequate nationwide wind speed data • High end technology • Lack of expertise in design, installation and maintenance of wind power systems
Economic (market)	• Lack of successful reference projects in Ghana
Legal and regulatory framework	• Absence of regulations, codes and standards • Problems in land acquisition for large scale wind farms
Small- and mini-hydro systems	
Financial	• Access to finance for projects in general is low • High capital cost but long payback period • High currency depreciation • Low guaranteed price for energy services • Absence of taxes rebates for system components
Technical	• Low technical knowledge about availability of resource • Inadequate technical expertise to design, construct and maintain systems
Economic (market)	• Lack of reference projects • Lack of access to long term finance • Highly controlled market for conventional systems • Lack of financial resources by end users to pay for RET products • Supply chain channel for raw materials and product distribution
Socio-Cultural	• Low awareness/knowledge about RETs
Legal and regulatory framework	• Absence of standards and codes • Lack of enforcement of standards due to their absence • Absence of a renewable energy pricing framework • Lack of political will to develop identified and appraised projects • Ineffective policy coordination among government actors
Improved cookstoves	
Financial	• Low access to long terms financial instruments • High capital cost and lack of consumer financing options • High currency depreciation • Absence of subsidies on improved cookstoves
Technical	• Low research and development activity in the area • Low technical expertise to improve on existing designs and models • Lack of training centres for artisans involved in the manufacturing process
Economic (market)	• Weak supply chain channel for raw materials and product distribution
Socio-Cultural	• Low awareness/knowledge about the benefit of clean cookstoves

Main barriers	Sub-barriers
Legal and regulatory framework	• Absence of standards and codes • Lack of enforcement of standards due to their absence • Absence of wood fuel conservation policy to guide the exploitation of forest resources for domestic fuel
Liquid biofuels	
Financial	• Access to finance for projects in general is low • High capital cost • Lack of access to long term finance • Lack of consumer financing options
Technical	• Low technical skills to efficiently produce biofuels • Low research and development activities • Lack of expertise to purify and blend biodiesel with fossil fuel • Lack of capacity to adopt engines to run on vegetable oils
Economic (market)	• Weak supply channel for product distribution • Lack of planting materials • Unavailability of abundant feedstock for the production of the fuel
Socio-cultural	• Multiple use of potential feedstock such as sugarcane • Use of food crops unsustainable
Legal and regulatory framework	• Absence of standards and codes • Lack of enforcement of standards due to their absence • Absence of dedicated testing centres for liquid biofuels • Land acquisition • Potential conflict with food crops for land
Gaseous biofuels – biogas and landfill gas	
Financial	• High initial cost • Limited financing mechanism for potential end users • Absence of tax rebates on imported components of biogas technologies like storage tanks, H_2S scrubber, generator, etc.
Technical	• Lack of support for research and development into designs, the use of local materials, new feedstock, digestion efficiency, etc.
Economic (Market)	• Weak supply channel for raw materials • Failed past experience
Awareness and Information	• Low awareness/knowledge about biogas and landfill gas
Socio-cultural	• Unwillingness to move away from construction of septic tanks to biogas plants • Lack of successful reference projects • Fear of failure due to past experience • Inadequate involvement of community members in decision making • Cultural inertia in accepting biogas as cooking fuel
Legal and regulatory framework	• Absence of biogas technology in the building codes of Ghana • Institutional arrangement and jurisdictional complexities in ownership of waste at the District and Municipal level

Main barriers	Sub-barriers
	• Land acquisition problems in large scale project or community based systems • Difficulties in siting engineered landfills

6.3 Conclusion

Technology Transfer to Ghana in renewable energy technologies have been relatively slow even though the apparent driving force of energy access and environmental concerns are evident. This is mainly due to number of barriers affecting the successful transfer of technology to the country. A total of 48 barriers were identified through the desk study and grouped into eight major categories comprising:

- Economic and financial barriers;
- Market barriers;
- Human skills barriers;
- Technical barriers;
- Information and awareness creation barriers;
- Legal and regulatory barriers;
- Socio-cultural barriers; and
- Network barriers.

In all, seven economic and financial barriers, five market barriers, ten legal and regulatory barriers and two information and awareness creation barriers were identified and studied. The rest include five technical barriers, four human skills barriers, five network barriers and ten socio-cultural barriers. Barriers affecting technology transfer pertaining to specific RETs such as solar PV systems, solar thermal applications, wind energy systems and liquid and gaseous biofuels were also identified and discussed.

A failed biotoilet project at Gambaga
Picture: Edem Bensah

7. SCREENING AND ESTABLISHMENT OF KEY BARRIERS TO RENEWABLE ENERGY TECHNOLOGY TRANSFER

7.1 Methodology

This activity involved the identification of a comprehensive list of barriers to RETT through desk study, and the application of PEST analysis to consider the Political, Legal, Economic, Social and Technological issues confronting RETT. In all 48 different barriers to RETT were identified as shown in Table 4. These barriers were evaluated and ranked by stakeholders[78] to identify the most important barriers that need to be removed in the short to medium term to enhance RETT to Ghana.

[78] A list of stakeholders consulted is provided in Appendix A.

The stakeholders with expertise, experience and involved in different aspects of RE in Ghana ranked the barriers as either very important, important, or not important using a semi-structured questionnaire (Annex G).

7.2 Analysis and results

The responses from 50 stakeholders were analysed using SPSS version 20. Dimension reduction methodology was adopted to reduce the number of indicators to the critical number that offered reasonable explanations to the underlying factors that affected barriers to technology adoption. Specifically, Categorical Principal Component Analysis (CATPCA) was used because of the categorical nature of the variables that defined the indicators.

From the analysis, 20 out of the 48 barriers were identified by the stakeholders as important barriers based on a total score between 49 and 98. Table 5 shows the important barriers to RETT to Ghana. However, since the objective is to identify the most important barriers to RETT and develop actionable and attainable roadmap for removing these barriers, the factors in Table 2 are further screened to identify the most critical barriers. This is achieved on the basis that at least half (50%) of the respondents. considered such barrier as very important as coded in the questionnaire.

In all nine barriers are identified as critical to RETT to Ghana with economic issues being the major issue as shown in Table 6.

7.3 Conclusion

In this section, stakeholders in the renewable energy sector in Ghana were identified and interviewed, with the aim of identifying the key barriers to RETT. A semi-structured questionnaire was prepared and used for the ranking of barriers identified through desk studies. After engaging with 51 stakeholders comprising experts in research and development institutions, international and non-governmental organizations, policy and regulatory bodies, developmental partners and companies involved in RET trade, installation and maintenance across the nation, the initial list of 48 barriers were ranked and screened down to nine key barriers. The key barriers identified in order of importance are:

i. High initial cost of RET;
ii. High interest rate;
iii. High currency fluctuations;
iv. Limited access to capital;
v. Lack of enforcement;
vi. Political will;
vii. Inadequate training facilities;
viii. Lack of skilled personnel for manufacturing and maintenance; and
ix. Inadequate information on cost and benefits of RETs.

The key barriers are discussed and regrouped under 4 main themes – political, economic, and socio-cultural and Technical barriers using PESTEL analysis.

Table 4 **Perceived barriers to RETT**

Category	Barrier
Economic	High initial cost
	Insufficient incentives
	Subsidies on conventional technologies
	Low feed-in-tariff/electricity tariff
	High interest rates
	Lack of consumer financing options
	Operation/maintenance costs
	Limited access to capital
	Unstable currency
	Under-developed supply channels
	Small market size
	Unstable market situation
Political, legal, and regulatory	Insufficient legal and regulatory framework
	Lack of enforcement
	Unfavourable policies
	Political will
	Political interference
	Problems in land acquisition
	Challenges with license acquisition
	Administrative hurdles (in developing contracts, etc.)
	Corruption
	Intellectual property rights
	Inadequate RE codes and standards
Technological	Difficulty in getting equipment and spare parts
	Immature technology
	Poor operation and maintenance facilities
	New technology is too complicated
	Lack of infrastructure facilities ()
	Weak connections between stakeholders promoting the new technology
	Strong networks of conventional technologies favoured by legislation
	Difficult access to external manufacturers/institutions
	Lack of skilled personnel for manufacturing and installation
	Lack of skilled personnel for preparing projects
	Lack of service and maintenance specialists
	Failed past experience/project/technology
	Lack of successful reference projects in the country
	Inadequate training facilities

Socio-cultural	Lack of interest in shifting from conventional energy to RE (sticking to the status-quo)
	Consumer preferences and social biases
	Lack of confidence in new technologies
	Dispersed/widely distributed settlements
	Lack of understanding of local needs
	Fear of failure
	Poor or lack of information about costs and benefits RETs
	Media not interested in RET promotion
	Weak network between foreign institutions and local ones
	Lack of involvement of stakeholders in decision-making
	The RET is not important for our needs

Table 5 **Important barriers after screening of stakeholders responses**

Category	Barrier	Significance
Economic	High initial cost	56
	High interest rates	70
	Unstable currency	73
	Limited access to capital	75
	Insufficient incentives	82
	Lack of consumer financing options	82
	Under-developed supply channels	86
	Subsidies on conventional technologies	97
Political, legal, and regulatory	Lack of enforcement	80
	Political will	80
	Administrative hurdles (in developing contracts, etc.)	89
	Political interference	93
Technological	Inadequate training facilities	78
	Lack of skilled personnel for manufacturing and installation	80
	Weak connections between stakeholders promoting the new technology	86
	Lack of skilled personnel for preparing projects	91
	Lack of service and maintenance specialists	97
Socio-cultural	Poor or lack of information about costs and benefits RETs	78
	Lack of interest in shifting from conventional energy to RE	89
	Consumer preferences and social biases	92

Table 6 **Key barriers to RETT to Ghana.**

Category	Barrier	% of very important response
Economic	High initial cost	90%
	High interest rates	69%
	Unstable currency	63%
	Limited access to capital	63%
Political and legal	Lack of enforcement	51%
	Political will	59%
Technical	Inadequate training facilities	53%
	Lack of skilled personnel for manufacturing and installation	51%
Social-cultural	Poor or lack of information about costs and benefits RETs	51%

Institutional cookstoves at Yaa Asantewaa Girls SHS
Photo: Edem Bensah

8. REMOVAL OF BARRIERS TO RENEWABLE ENERGY TECHNOLOGY TRANSFER TO GHANA

8.1 Introduction

This section discusses mitigation actions and specific steps proposed for the removal of the nine key barriers to RETT in relation to the following order: political and legal, economic, technical and socio-cultural factors. The section also discusses previous and on-going efforts and interventions by various stakeholders aimed at addressing the barriers. The strengths, weaknesses, opportunities and threats (SWOT) for implementing proposed actions are also highlighted.

8.2 Political barriers

8.2.1 Previous and current interventions

- *Institutional structures*

The Government of Ghana has shown a great deal of commitment in terms of putting in place the necessary institutional framework for the RE sector. A directorate for Renewable and Alternative Energy has been established under the Ministry of Power to initiate, harmonize and coordinate all RE policies. The Energy Commission which has the core mandate to advise the government on Energy has an established and well-resourced RE unit.

- *Policies and laws*

The passage and enactment of the RE law which serves as the main guiding document for the development of RE resources in the country is a major step towards the promotion of RE in the country. Other RE policy frameworks include:

i. The National Energy Policy. This is the main policy document guiding the energy sector;
ii. The Draft Bioenergy Policy. Though still in draft form yet to be finalized, the document spells out target and strategies for achieving bioenergy inclusion in the energy mix of Ghana; and
iii. National Environment Policy. This is the main guiding policy document on the environment. It spells out national targets and strategies to achieve the targets.

Progress has also been made with the development of programmes and action plans such as:

i. Strategic National Energy Plan (SNEP);
ii. Sustainable Energy for All (SE4All) Action Plan for Ghana;
iii. Feed-in Tariffs set-up by the Public Utilities Regulatory Commission (PURC) for RETs up to 200 kW in 2013. Since then there has been updates to reflect current economic trends;
iv. NAMAs[79] on Solar PV based lanterns for lighting, PV based power plant for electricity, improved cookstoves (ICS) and LPG cooking solution, under the auspices of the Ministry of Environment Science, Technology and Innovation (MESTI) with support from UNDP;
v. Standardized baselines on charcoal production under the aegis of MESTI with support from UNFCCC;
vi. Investment plan for scaling-up RE programme in Ghana (SREP) under the auspices of Ministry of Power; and
vii. Energy for Poverty Reduction Action Plan (EPRAP).

- *Codes and standards on RETs*

Codes and standards already developed are related to:

i. Solar PV and batteries. Ghana Standards Authority (GSA) has developed standards for the testing of solar PV panels and batteries;

[79] Nationally Appropriate Mitigation Actions

ii. Cookstoves. Standards for improved cookstoves are currently under development under the auspices of GSA with funding from UNDP and Energy Commission. A mirror committee which was setup to prepare the standards is working in tandem with ISO Technical Committee TC 185 to draw up appropriate standards for the Ghanaian market. A draft standard has been circulated to solicit comments from stakeholders.

- *Testing Centres*

The government with the support of developmental partners has setup and commissioned two improved cookstoves testing centres in Ghana. The testing centre at Institute of Industrial Research (IIR) of the CSIR[80] was funded by Global Alliance for Clean Cookstoves while EC secured funding from UNDP for the one at Technology Consultancy Centre (TCC), KNUST.

GSA with the support of Government and UNDP has commissioned a state of the art of solar PV and batteries testing centre. The centre has been in operation since 2014 albeit with some challenges.

In spite of these measures, stakeholders identified lack of political will as a key barrier to RETT. The following are proposed mitigation actions and specific steps to remove this barrier.

8.2.2 Mitigation actions and measures

1. *Expedite development of RE master plan (REMP)*

The absence of REMP is seen as a major policy defect in the development of RETs and subsequently TT. The various policy documents discussed above apart from setting targets and proposing strategies to achieve the set target fails to provide concrete plans for achieving the targets. The REMP is expected to encapsulate all the various policy goals and strategies into a concrete plan with timelines for its implementation and will thus serve as the main guiding document for the development, deployment and integration of RETs into the energy mix. The development of a REMP has been on the table for some time now. South Africa and Nigeria are some of the countries in Sub Sahara Africa with a REMP. Under SREP, government is seeking funds from developmental partners to develop the plan.

Given that, this is a very important activity government has an obligation to expedite the development of the REMP by:

i. Securing funds from any source possible including government revenue sources and or donor/multilateral support funds committed for the development of the REMP;
ii. Once the funds are secured, a consultant must be engaged with specific terms of reference to develop the plan;

[80] Council for Scientific and Industrial Research

iii. The development of the REMP must be stakeholder driven and owned. All stakeholders in the RE sector must be involved in at least the validation of the REMP. This will ensure total cooperation during its implementation

A major problem with previous plans is the fact that they are often not been aligned to the national development agenda. Previous and current governments usually draw up their own development agenda to guide the allocation of resources. For instance from 2001 – 2008 Ghana Poverty Reduction Strategy (GPRS) I and II were the main policy guiding document for the government. Similarly the Ghana Shared Growth Development Agenda (GSDA) I and II have been the main policy guiding document for the present government since 2009. Government's allocation of resources revolves around these policy documents hence the need to integrate the master plan into the development of these policy documents to ensure that funds are allocated for its implementation.

2. *Capitalise and operationalise RE Fund*

The setting up an RE fund has been given legal backing under the RE law (ACT 832). Subsequently Government has opened an account for the fund but with no seed money The RE fund among other things as spelt out in the RE law is supposed to support RE development, training and R&D.

Since there are no funds in the RE account, it is deemed that the fund has not been operationalized. The following steps are being proposed to ensure the operationalisation of the RE fund:

i. The absence of clear guidelines for the utilization of the fund may lead to the mistrust about the usage of the fund among stakeholders. Therefore the Energy Commission which is the main custodian of the RE fund must develop and publish the guidelines for the utilization of the RE fund;
ii. The RE law spells out a number of possible sources of funding for the fund for possible exploitation by government. However, the absence of a seed money in the account does not project the nation as being serious with the development of its RE sector. Government should as a matter of urgency dedicate an appreciable amount of money to the RE fund;
iii. Once government shows commitment by providing seed money, development partners will most likely be comfortable in contributing to the fund. Government can therefore begin high level engagement with donors to support and sustain the fund.
iv. Alternative funding sources as spelt out in under section 5 of the RE law should be exploited by the EC to ensure that the fund is sustained.

3. *Develop national programmes on prioritised RETs*

One of the key policy gaps in the RE sector is the absence of national programmes on specific RETs. As has been cited in earlier section of this report, South Africa, Uganda, Ethiopia, Tanzania, Burkina Faso, among others had or in some cases continues to have national programmes for the deployment of specific RETs.

Apart from the 200 institutional biogas plants under the SE4All action plan, Ghana does not have any national programme on any of the RETs. A recently announced solar roof top programme has not yet seen the light of day. The following steps are proposed:

i. A consultant must be engaged to develop a guiding document for such national programmes. The document will serve as the blue print for the implementation of the programme:
ii. Stakeholders must be engaged to validate the developed blue print
iii. To ensure that the programme is well financed, part of the RE fund must be dedicated for the programme
iv. National coordinating office must be setup to coordinate the smooth implementation of the programme.

The coordinating office must not be within the frontline governmental agencies like the EC or Ministry of Power rather parastatal institutions like Universities, Polytechnics and other research institutions or Non-governmental Organizations could also be possible host as pertains in other countries. This will ensure that such programmees are not given political colours during its implementation. It will also ensure continuity of the programme beyond the life of a particular government.

4. *Develop/adopt standards, codes and labels for other RETs*

Another key barrier that was identified by stakeholders is the development and enforcement of standards and codes. Presently there are no codes and standards for a lot of the RETs to guide its exploitation. Because there are no codes and standards, regulation becomes a major problem. The proposed mitigation measure is to develop/adopt standards and codes for the following RETs:

- Biogas;
- Solar water heater;
- Solar dryers;
- Wind mills; and
- Small and mini-hydro, among others

GSA is the sole body mandated by law for the development or adoption of standards of almost all products produced or imported into the country. They also have the sole mandate to test the products even though third parties can be engaged to also carry out the test.

The following are specific steps are proposed:

i. Build capacity of staff and equip the Ghana Standards Authority (GSA)
ii. Engage with organisations with experience in other countries
iii. Obtain funding from RE fund and from donor agencies
iv. Develop and pass LI on standards, codes and labels for RETs
v. Build capacity of staff and equip the EC for effective monitoring and enforcement

The summary of mitigation actions and specific steps for addressing the political-related barriers to RETT is outlined in Table 7. The SWOT analysis of proposed mitigation measures is shown in Table 8.

Table 7 **Mitigation measures to address political barriers**

Key barrier	Previous and current interventions	Mitigation actions	Steps	Responsible bodies
Lack of political will	1. National Energy Policy 2. RE Law 2011 (Act 832) 3. Bioenergy policy (draft) 4. SNEP 5. EPRAP 6. Feed-in Tariffs (FITs) for RE 7. Import duty exemption on solar PV and wind turbines 8. SE4All Action Plan 9. National Climate Change Policy (NCCP) 10. NAMAs[81] on cookstoves, solar lanterns, etc. 11. Standardised Baselines (SBs) on charcoal 12. Ghana's INDC[82]	1. Expedite development of RE master plan	a. Secure funding for RE masterplan b. Engage consultants to develop RE masterplan c. Engage stakeholders d. Align and integrate masterplan into GSGDA	• Ministry of Power (MoP) • Energy Commission (EC) • National Development Planning Commission (NDPC)
		2. Capitalise and operationalise RE fund under RE law	a. Develop guidelines for utilisation of RE fund b. Government should dedicate seed money to the RE fund c. Engage with bilateral and multilateral donor agencies for additional funding d. Identify alternative funding mechanisms	• MoP • EC • Ministry of Finance
		3. Develop national programmes on prioritised RETs	a. Engage consultants to develop national programmes on prioritised RETs b. Engage stakeholders c. Dedicate financial resources under RE fund for prioritised RETs d. Set up coordination offices to coordinate programmes	• MoP • EC

[81] Nationally Appropriate Mitigation Actions
[82] Intended Nationally Determined Contribution

Key barrier	Previous and current interventions	Mitigation actions	Steps	Responsible bodies
Inadequate standards and codes	1. Standards exist for solar PV module and batteries, as well as wind energy systems 2. Standards on cookstoves are under development	Develop/adopt standards, codes and labels for biogas plants, SWH, solar dryers, wind mills and other RETs.	a. Build capacity of staff and equip the Ghana Standards Authority (GSA) b. Engage with organisations with experience in other countries c. Obtain funding from RE fund and from donor agencies d. Develop and pass LI on standards, codes and labels for RETs e. Build capacity of staff and equip the EC for effective monitoring and enforcement	• GSA • EC • Parliament

Table 8 **SWOT analysis of mitigation measures under political barriers**

Strengths	Weaknesses	Opportunities	Threats
Expedite development of RE master plan			
a. Commitment of Ministry of Power, Energy Commission and other local stakeholders b. Support of developmental partners notably UNDP, GIZ, DANIDA, World Bank, etc. c. Availability of RE law d. Availability of national policy documents – National Energy Policy, SNEP, Bioenergy Policy (draft), etc. e. Availability of FITs for RE sector	a. RE Authority not established b. Draft Bioenergy Policy not yet approved	a. High potential of RE resources in Ghana b. RE resources well-known and well-mapped	a. Lack of funds for development and implementation b. Delays in review and approval of masterplan c. Interest in integrating masterplan into national developmental plan (GSDGA[83])

[83] Ghana Shared Growth and Development Agenda (GSGDA) II, 2014-2017

Strengths	Weaknesses	Opportunities	Threats
f. Availability of local capacity			
Operationalise RE fund under RE law			
a. RE fund regularised under RE law b. RE fund account established	a. Absence of clear-cut institutional framework for operationalising the fund b. Inability of government to commit funds	a. Efforts to achieving national RE targets b. Support from bilateral and multilateral donor agencies (World Bank, DANIDA, GIZ, JICA, DGIS, European Commission, Chinese Government, GEF, etc.)	a. Government commitment to allocate funds for RE Fund b. Lack of dedicated funds c. Inadequate support of external donors
Develop national programmes on prioritised RETs			
a. RE Law supports funding of RETs b. Availability of local expertise c. Experience in previous national programmes such as GEDAP, SHEP, etc. d. Strong institutional framework and networking g. Availability of national policy documents – National Energy Policy, SNEP, Bioenergy Policy (draft), etc.	a. RE Authority not yet established b. RE Fund not yet operationalised c. Poor record in pursuing RE targets	a. Support from bilateral and multilateral donor agencies (World Bank, DANIDA, GIZ, JICA, DGIS, European Commission, Chinese Government, GEF, etc.) b. Experience and lessons from other countries in the South on similar programmes	a. Government commitment to develop specific programmes on prioritised RETs b. Government commitment to allocate funds for prioritised programmes c. Possibility of not receiving external support

8.3 Economic barriers

8.3.1 Previous and current interventions

Four economic factors were identified by stakeholders as key barriers to RETT. High initial cost, unstable currency, limited access to capital and high interest rate. A number of interventions have been piloted in the past some of which were very successful in addressing the barriers to some extent. The GEDAP project for instance sought to address access to finance and high initial cost of the RETs to consumers. The high success chalked by GEDAP can be attributed to two key interventions of reducing the price of the RETs and making consumer financing options readily available to consumers.

On the side of government, import duty tax exemptions on complete solar energy systems comprising panels, inverters, batteries and charge controllers and wind energy products have been helpful in addressing high cost of solar PV systems and wind energy systems. Some entrepreneurs on the other hand have benefited from concessionary loan schemes by funding bodies like the Acumen fund and the erstwhile E+Co fund. The refrigerator rebate scheme has been largely successful even though it was not specifically directed at RETs.

These interventions even though have been helpful in the past have failed to completely remove the barriers hence the need to propose additional measures. The following are proposed mitigation measures to remove the key barriers.

8.3.2 Mitigation actions and measures

1. *Develop and implement tax incentives on prioritised RETS*

Tax incentives could take the form of tax holidays for RE companies for a number of years, import duty expanded to cover other RETs or semi-finished products needed for the manufacturing of RETs, tax rebate systems for RE companies, waiver on Value Added Tax for locally produced RETs, among others. This will reduce the initial cost of setting up business on the side of the entrepreneur which will result in reduced price of the commodity for the consumer. The following are specific steps:

i. Implement import tax incentives for raw materials and intermediate products for local fabrication of prioritised RETs;
ii. Initiate tax holidays and incentives for investment on prioritised RET.

2. *Provide financial support for RET investment in prioritised sectors*

Financial support for RE firms can take the form of grants for indigenous start-up companies, demonstration and pilot plants or buy down the cost of new technology. Financial support scheme could also be used to mitigate the financing and technology risk to make it more comfortable for banks to support:

i. provide soft loans supporting RET investment;
ii. Provide direct financing to RET entrepreneurs;

iii. Seek grants from bilateral and multilateral donors to set up incentives and soft loan schemes; and
iv. Use part of the RE fund to support consumer financing and RET investment.

3. Provide government guarantee for loans

The summary of mitigation actions and specific steps for addressing the economic-related barriers to RETT is outlined in Table 9. The SWOT analysis of proposed mitigation measures is shown in Table 10.

Table 9 **Mitigation measures to address economic barriers**

Key barrier	Previous and current interventions	Mitigation actions	Steps	Responsible bodies
High initial cost	1. Consumer financing schemes (eg. GEDAP) 2. Supplier side (import duty exemptions on solar systems and wind mills) 3. Refrigerator rebate scheme	1. Develop and implement tax incentives on prioritised RETS	a. Implement import tax incentives for raw materials and intermediate products for local fabrication of prioritised RETs b. Initiate tax holidays and incentives for investment on prioritised RET	• MoP • Ministry of Finance • Ghana Investment Promotion Council (GIPC) • Ghana Revenue Authority (GRA)
		2. Provide financial support for RET investment in prioritised sectors	a. Provide soft loans supporting RET investment b. Provide direct financing to RET entrepreneurs c. Seek grants from bilateral and multilateral donors to set up incentives and soft loan schemes d. Use part of the RE fund to support consumer financing and RET investment	• MoP • Ministry of Finance • EC • Financial Institutions
High interest rate	E&CO and Acumen Fund supported projects	3. Provide financial support for RET investment in prioritised sectors	a. Provide soft loans supporting RET investment b. Provide direct financing to RET entrepreneurs c. Seek grants from bilateral and multilateral donors to set up incentives and soft loan schemes	• MoP • EC • Ministry of Finance

Key barrier	Previous and current interventions	Mitigation actions	Steps	Responsible bodies
			d. Use part of the RE fund to support consumer financing and RET investment	
Limited access to capital		4. Provide financial support for RET investment in prioritised sectors	a. Provide soft loans supporting RET investment b. Provide direct financing to RET entrepreneurs c. Seek grants from bilateral and multilateral donors to set up incentives and soft loan schemes d. Use part of the RE fund to support consumer financing and RET investment	• MoP • EC • Ministry of Finance

Table 10 **SWOT analysis of mitigation measures under economic barriers**

Strength	Weaknesses	Opportunities	Threats
Develop and implement tax incentives on prioritized RETs			
a. Import duty waiver on solar and wind power systems already exist b. GIPC Act c. Local experience in developing tax incentive schemes	a. Ambiguous tax incentives subject to the interpretation of the tax officer b. Weak institutional network	a. National targets on RE b. Experience and lessons from other countries in the South on similar programmes c. Support from bilateral and multilateral donor agencies (World Bank, DANIDA, GIZ, JICA, DGIS, European Commission, Chinese Government, GEF, etc.)	a. Loss of government revenue b. Abuse of the incentive schemes
Provide financial support for RET investment in prioritised sectors			
a. Ghana Infrastructure Fund b. Local experience in setting-up similar funds (e.g. GEDAP)	a. RE Fund not yet operationalised	a. Start-up companies in RETs may be beneficiaries b. Support from bilateral and multilateral donor agencies (World Bank, DANIDA, GIZ, JICA, DGIS, European Commission, Chinese Government, GEF, etc.)	a. Ability to pay back loan b. Misapplication of fund

8.4 Technical barriers

8.4.1 Previous and current interventions

Until recently, DENG engineering used to be the only institution offering training on solar PV and solar pump installation. Currently a number of institutions including TEC and TCC all of KNUST, the Energy Systems Department of Koforidua Polytechnic, the University of Energy and Natural Resources at Sunyani and the Ghana Technology University College run training programmes on some RETs. In addition to the training programmes, KNUST presently offers master's degree and PhD programmes in RETs.

The government through the Skills Development Fund (SDF) under the Council for Technical and Vocational Education and Training (COTVET) is also supporting the establishment of a Centre for Renewable Energy and Energy Efficiency (CREK) at Kumasi Polytechnic purposely to offer skills based training in RETs to Small and Medium Scale Enterprises (SMEs) and graduates of technical and vocational schools and colleges. The identification of inadequate training facilities means there are significant gaps that need to be filled.

Apart from TEC-KNUST that offers training a wide spectrum of training in RETs, the others are limited to stand alone solar PVs, grid connected solar PV and solar water pumps neglecting the other RETs. To address this gap, the following mitigation measures are proposed.

8.4.2 Mitigation actions and measures

1. *Strengthen existing training facilities*

Instead of setting up new centres the aforementioned centres and training institutions should be strengthened to be able to deliver training on all aspects of RETs. To be able to achieve this the following steps are proposed:

i. Support existing institutions to expand programmes to cover priority RETs;
ii. Harmonize and standardize training materials. All training manuals should be harmonized and standardized to guarantee quality. Already, EC with the support of GIZ is seeking to harmonize the solar energy training manuals. Similar activities should be embarked on in biogas, wind mills, SWH and solar dryers and other RETs;
iii. Build capacity of key RE research and training institutions in prioritised RETs;
iv. Enhance and encourage coordination between institutions. Training institutions should be collaborating on common themes. Unhealthy competition might lead to the stifling of ideas and can slow down progress in RETT. A platform must be created by the EC to foster cooperation among the institutions;
v. Allocate portion of RE Fund to expand training and research facilities; and
vi. Set-up dedicated funds for RETs deployment and demonstration.

2. *Build capacity of researchers and trainers in RETs*

There is already existing capacities in the training institutions on some RETs like solar PV systems, biogas, biofuels and solar dryers. In areas such as wind mills design and construction and small- and mini-hydro systems, there is limited expertise. The capacity of trainers must be built to international standards by carrying out the following actions.

i. Promote networking with external centres of excellence. Existing training centres and institutions should be linked to international partners in China and other countries where they could go for refresher training programmes; and
ii. Dedicate part of RE fund for capacity development. The RE law is explicit on the utilization of the fund and it makes room for capacity development. In this regard, part of the fund should be set aside to support capacity building.

3. *Setup dedicated centres of excellence in the prioritized RETs*

Dedicated centres of excellence in particular RETs can play important roles in TT. Through research and development, they are able to adapt technologies to suit environmental and socio-cultural conditions and in some cases replace components with local materials. Dedicated centres will also conduct continuous research with the view of improving the transferred technology. The actions below should be carried out:

i. Develop modalities for establishing centres in existing institutions; and
ii. Allocate funds for the establishment of the centres

4. *Conduct capacity building programmes for entrepreneurs and local enterprises*

Entrepreneurs and local enterprises need regular refresher training programmes to update their knowledge in RETs as well as changing trends in industry. The following are specific steps proposed:

i. Undertake capacity needs assessment of local enterprises;
ii. Develop skills oriented programmes and training manuals in prioritised RETs for industrial players;
iii. Conduct regular technical training for local enterprises in prioritised RETs; and
iv. Build collaborative linkages between local enterprises and their counterparts in China and other developing countries advanced in RETs.

5. *Arrange networks and partnerships for local enterprises*

Local enterprises can leverage on the skills and advanced knowledge of foreign partners to expand their activities. This can be done by:

i. Exploring possibilities for networking with foreign companies in China and other advanced developing countries;
ii. Linking local enterprises to counterparts in China and other developing countries;
iii. Funding trips and visits of local firms to foreign exhibitions and trade shows on prioritised RETs; and

iv. Identifying and funding training programmes in Ghana with experts from China and other developing countries.

Tables 11 and 12 shows mitigation measures and SWOT analysis for the technical barriers, respectively.

Table 11 **Mitigation measures to address technical barriers**

Key barrier	Previous and current interventions	Mitigation actions	Steps	Responsible bodies
Inadequate training facilities	Established training facilities including: • UENR • TEC-KNUST • CREK-K'POLY, • Energy Systems Dept. – Kedua Polytechnic • GTUC • DENG	1. Strengthen existing training facilities	a. Support existing institutions to expand programmes to cover priority RETs b. Harmonize and standardize training materials c. Build capacity of key RE research/training institutions in prioritised RETs d. Enhance and encourage coordination between institutions e. Allocation portion of RE Fund to expand training and research facilities f. Set-up dedicated funds for RETs deployment and demonstration	• MoP • EC • Ministry of Education • COTVET
		2. Build capacity of researchers and trainers in RETs	a. Promote networking with external centres of excellence b. Dedicate part of RE fund for capacity development	• MoP • EC • Ministry of Education • COTVET
		3. Set-up dedicated centres of excellence in the prioritised areas	c. Develop modalities for established centres in existing institutions d. Allocate funds for the establishment of the centres	• MoP • EC • Ministry of Education • COTVET

Key barrier	Previous and current interventions	Mitigation actions	Steps	Responsible bodies
Lack of skilled personnel for manufacturing and maintenance	• Solar PV module assembly plants • Pellets manufacturing plant • Cookstoves manufacturers • Biogas service companies	1. Conduct capacity building programmes for entrepreneurs and local enterprises	a. Undertake capacity needs assessment of local enterprises b. Develop training skills oriented programmes/manuals in prioritised RETs c. Conduct regular technical training for local enterprises in prioritised RETs d. Build collaborative linkages between local enterprises and their counterparts in China or other developing countries advanced in RETs	• MoP • EC • Ministry of Education
		2. Arrange networks and partnerships for local enterprises with counterparts in other countries	a. Explore possibilities for networking b. Link local enterprises to counterparts in China and other developing countries c. Fund trips and visits of local firms to foreign exhibitions and trade shows on prioritised RETs d. Identify and fund training programmes in Ghana with experts from China and other developing countries	• MoP • EC

Table 12 **SWOT analysis of mitigation measures under technical barriers**

Strength	Weaknesses	Opportunities	Threats
Strengthen existing training facilities			
a. Some training facilities already exist b. Availability of local expertise c. Supported by National Energy Policy d. Emphasized by Renewable Energy Act under Section 32(3)	a. High cost of certain equipment b. Existing training facilities spread across the southern parts of the country c. Poor maintenance culture d. Weak collaboration among existing training centres	a. Universities/polytechnics/research institutions spread across country and could serve as starting point b. Support from external training and technology centres	a. Lack of funds accessibility b. Misuse of facilities c. Budget cuts may peg this lower on government's developmental agenda d. Training centres deviating from their mandate
Build capacity of researchers and trainers in RETs			
a. Availability of some research and training expertise b. Some training facilities already exist c. Supported by National Energy Policy d. Emphasized by Renewable Energy Act under Section 32(3) e. RE training programmes exist among some institutions (e.g. TEC-KNUST)	a. Weak collaboration with external expertise b. High cost of external training	a. Lower training costs using local expertise b. Existing bilateral agreements between Ghana and other countries c. Universities/polytechnics/research institutions spread across country and could serve as starting point d. Support from external training and technology centres	a. Lack of funding (nationally) for technological advancement b. Budget cuts may peg this lower on government's developmental agenda

Strength	Weaknesses	Opportunities	Threats
Set-up dedicated centre of excellence in the prioritized RETs			
a. Climate Innovation Centre established by World Bank b. Centre for RE and EE established at Kumasi Polytechnic c. Established technology transfer centres by MESTI (e.g. CRTDI of Kumasi Polytechnic) d. Availability of local expertise	a. High cost of certain equipment b. Existing training facilities spread across the southern parts of the country c. Poor maintenance culture d. Weak collaboration among existing training centres	a. Universities/polytechnics/research institutions spread across country and could serve as starting point b. Support from external training and technology centres	a. Lack of funds accessibility b. Misuse of facilities c. Budget cuts may peg this lower on government's developmental agenda

8.5 Socio-cultural barriers

8.5.1 Previous and current interventions

The Ministry of Power has implemented several awareness campaign on RETs under programmes such as GEDPA and JICA standalone solar projects among others. Others such as the Lighting Africa Project had an awareness creation component infused into the programme. Currently, the Ghana Alliance for Clean Cookstoves (GhACOO) in partnership with the Global Alliance for Clean Coostove are embarking on a major awareness creation campaign on the benefits of using an improved cookstoves.

Nonetheless, stakeholders identified poor or lack of information about cost and benefit of using RETs as a major barrier to TT. The mitigation actions proposed are outlined below.

8.5.2 Mitigation actions and measures

1. *Run sustained cost and benefit campaign on the use of RE products*

All the previous campaigns were tied to specific project promoting specific interventions so once the programme comes to an end, the campaign seizes. This mitigation action should be run independent of programmes or project and should only seize or come to an end when the objective of informing the citizenry about the cost and benefit of using RETs is achieved.

2. *Include RETs in the technology catalogue*

The Energy Commission has published a Technology catalogue which captures some technologies for harnessing energy. The present catalogue though under revision does not include all RETs. The absence of RETs in the Technology catalogue is a huge knowledge gap that needs to be filled. In addition to adding the RETs, basic information on cost and benefits of using the technologies should be included to serve as a guide to users and to some extent even project developers. The catalogue must be frequently updated to reflect current trends and information about the Technologies.

Table 13 summarises proposed mitigation actions for addressing the socio-cultural barriers and Table 14 shows the SWO analysis of the measures.

Table 13 **Mitigation measures to address socio-cultural barriers**

Key barrier	Previous and current interventions	Mitigation actions	Steps	Responsible bodies
Lack of information about cost and benefits of RETs	Awareness creation on: • improved cookstoves (e.g. Ghana Alliance on Clean Cookstoves and Global Alliance on Clean Cookstoves) • solar PV systems (e.g. Lighting Africa and GEDAP)	1. Run cost benefit campaign on the use of RE products	a. Increase awareness by involving all stakeholders b. Promote pilot and demonstration projects c. Promote awareness targeting consumers/end-users in mass media	• MoP • MESTI • EC • NGOs, CSOs[84], CBOs[85] and Women Groups
		2. Include RETs in technology catalogue	a. Include RETs in the next update of the catalogue b. Frequently update catalogue with new info on RETs c. Make technology update available on EC website	• EC

Table 14 **SWOT analysis of mitigation measures under socio-cultural barriers**

Strength	Weaknesses	Opportunities	Threats
Run cost-benefit awareness campaign			
a. Existing media platforms and networks b. Similar ongoing campaigns (cookstoves, etc.)	a. Lack of dedicated funds b. Lack of successful demonstration projects	a. National policy to increase RE penetration in generation mix b. National climate change mitigation targets	a. Illiteracy rate b. Subsidies for conventional energy sources
Include RETs in technology catalogue			
a. Existing technology catalogue	a. Lack of dedicated funds	a. Readily available global information on RETs	a. Inclusion of erroneous information

[84] Civil Society Organisations
[85] Community-based Organisations

8.6 Conclusion

It has been demonstrated in Ghana and other developing countries through previous projects that the transfer of RE technology is practically achievable if barriers to specific technologies are identified and addressed. Domestic biogas digesters and clean cookstoves are well-known success stories of technology transfer in Ghana. Although they have been several interventions in the past to facilitate the transfer of RE technologies to Ghana, there are still major barriers that hamper successful diffusion of RETs in the country.

In this section, the key barriers to RETT identified in section 7 are further elaborated and concrete mitigation actions for removing key barriers are proposed as follows:

- Technical barriers
  - Strengthen existing training facilities;
  - Build capacity of researchers and trainers in RETs;
  - Set-up dedicated centres of excellence in the prioritised areas;
  - Conduct capacity building programmes for entrepreneurs and local enterprises; and
  - Arrange networks and partnerships for local enterprises with counterparts in other countries.
- Political barriers
  - Develop national programmes on prioritised RETs;
  - Capitalise and operationalise RE fund under RE law;
  - Expedite development of RE master plan; and
  - Develop/adopt standards, codes and labels for biogas plants, SWH, solar dryers, wind mills and other RETs.
- Economic barriers
  - Develop and implement tax incentives on prioritised RETS; and
  - Provide financial support for RET investment in prioritised sectors.
- Socio-cultural
  - Run cost benefit campaign on the use of RE products; and
  - Include RETs in technology catalogue.

A SWOT analysis is performed to identify the Strengths, Weaknesses, Opportunities and Threats of the proposed mitigation actions.

Flat plate solar water heaters at Oak Plaza Hotel, Accra
Photo: Edem Bensah

9. IDENTIFICATION AND PRIORITIZATION OF RENEWABLE ENERGY TECHNOLOGIES FOR TRANSFER TO GHANA

9.1 Background

Renewable Energy (RE) generally refers to energy sources that can be regenerated within a human lifetime, namely direct solar radiation or sunlight; biomass including wood-fuels and plant materials, animal and human waste; wind; geothermal; and hydro. On the other hand, Energy Efficiency (EE) describes technologies, applications, actions, measures, and policies that improve energy usage and reduce wastage.

Technologies such as clean and efficient biomass cookstoves, RE-based heat pumps and solar PV offer savings in fuel in addition to increased share of RE, indicating overlaps between RE and EE technologies.[86] This section identifies RETs suitable for mainly off-grid applications. The technologies are first screened to remove those that are unsuitable in the Ghanaian context or have technical barriers that are yet to be overcome at the global level.

[86] IRENA (2015). Synergies between RE and EE. Working paper based on REMAP 2030.

The selected list is then ranked using the multi criteria decision tool – Analytical Hierarchy Process (AHP) using the set of criteria and sub-criteria, highlighting RETs with high potential for TT to Ghana from China and other countries. The list of technologies identified for ranking under AHP is given in Table 15 and those screened out and thus not included in ranking is shown in Table 16.

Table 15 **List of RETs for evaluation**

Area	Initial list of RETs
Biomass and bioenergy	Biogas
	Ethanol
	Biodiesel
	Bio-oil (from pyrolyzers) and syn-gas (gasifiers)
	Solid fuels and clean cookstoves
	Clean charcoal kiln
Solar thermal	Solar water still
	Solar water heater
	Solar dryer
Solar photovoltaic	Solar PV
Solar lighting	Solar lantern
Hydropower	Mini- and micro-hydro
Wind energy	Standalone wind turbine

Table 16 **RETs screened out**

Area	RETs screened out	Reason for screening out technology
Biomass and bioenergy	Landfill gas	Process of harnessing landfill gas complicated; lack of well-engineered landfill sites; economics unfavourable.
Solar energy	Solar ovens/cookers	Not too successful in Ghana; appear not to fit into traditional cooking
	Concentrated solar power/heating	Low direct normal radiation (DNI) in Ghana.
	Solar fuel	Immature technology; under development

9.2 Evaluation and ranking of RETs

In this section the Analytical Hierarchy Process (AHP) (Saaty, 1980)[87] is used to evaluate and screen appropriate RETs (Table 15). The AHP model (Figure 5) has four levels consisting of the goal, criteria, sub-criteria and RETs. The selection of criteria and sub-criteria is based on desk studies in the previous sections, similar activities undertaken in other countries (Amer and Daim, 2011[88]; Li-bo and Tao, 2014[89]), barriers to RETT shown in Table 16, and stakeholders' views from a consultation meeting that was held on 24-25th November, 2015 at Koforidua in the Eastern Region. The goal for evaluating and prioritizing RETs as agreed by participants is 'prioritization of RETs to identify high impact technologies for national support.' The list of criteria and sub-criteria with respect to the goal and based on collective agreement by stakeholders is shown in the AHP model (Figure 5).

The description and indicators for each sub-criterion are given in Table 17. A questionnaire developed for the assessment of the technologies under the AHP is shown in Annex G, based on the allocation of 100 points among criteria in relation to the goal, and sub-criteria with respect to each criterion. The selected RETs are also evaluated via pairwise comparison under each of the sub-criteria.

[87] Saaty T. L. (1980). The Analytic Hierarchy Process, McGraw Hill International.
[88] Amer M., Daim T. U. (2011). Selection of renewable energy technologies for a developing county: A case of Pakistan. Energy for Sustainable Development 15 (2011) 420–435
[89] Li-bo Z., Tao Y. (2014). The evaluation and selection of renewable energy technologies in China Energy, The 6th International Conference on Applied Energy – ICAE2014, Procedia 61 (2014) 2554 – 2557

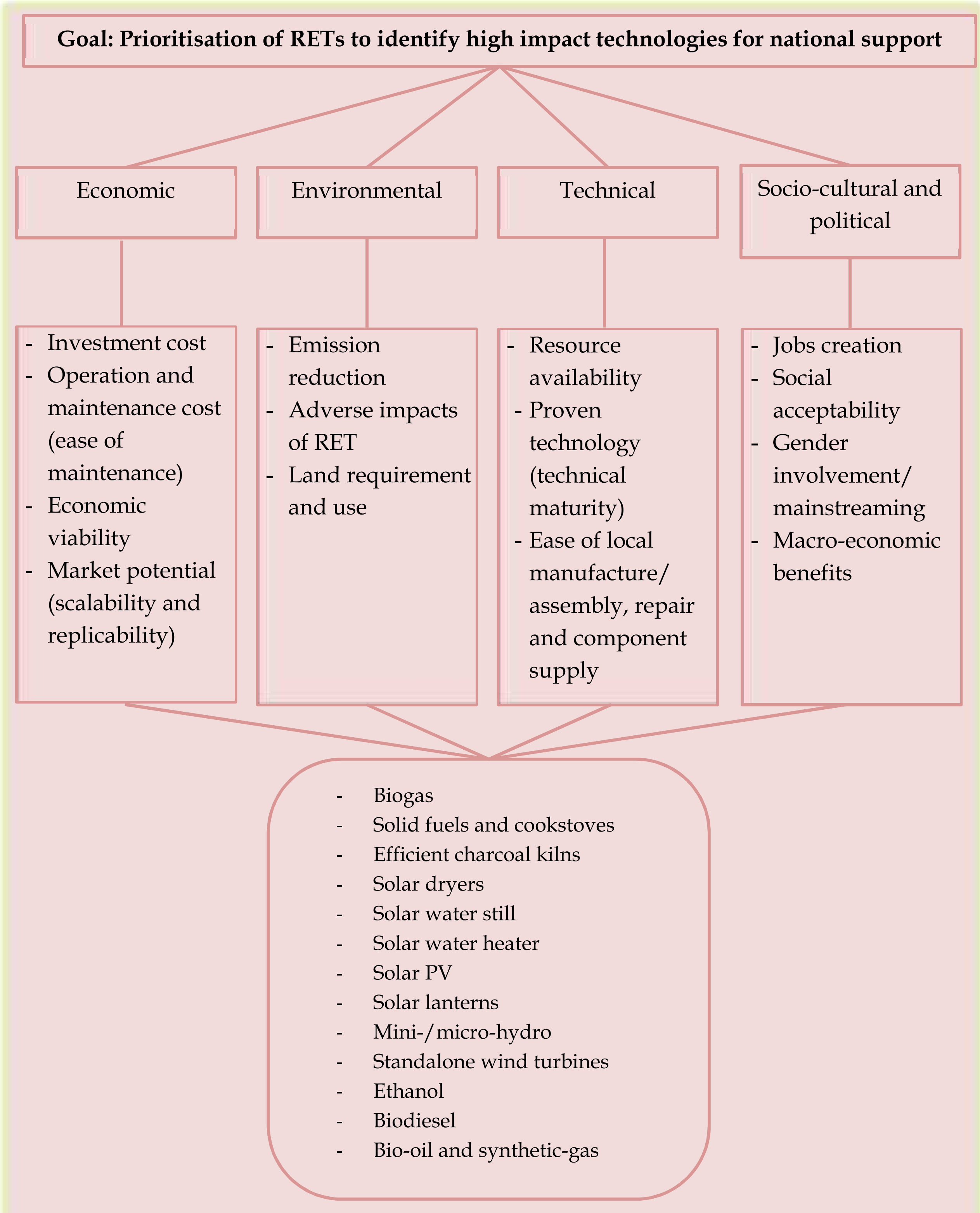

Figure 5 **AHP model for the evaluation and ranking of decentralized RETs in Ghana**

Table 17 **List of sub-criteria for prioritizing RETs**

Criteria	Sub-Criteria	Description	Key Point
Economic	Investment (upfront cost)	Total upfront cost of having a RET for a household or institution.	The lower the investment cost to consumers/users, the more favourable the RET
	Operation and maintenance cost (ease of maintenance)	The cost of operating or maintaining RET by a user (household/institution). Include cost of spare parts, cost of paying experts to do maintenance, and frequency of maintenance.	The lower the cost operation and maintenance the better
	Economic viability	Economic/financial benefits derived by users for paying for the RET. Include income savings from reduce expenses as a result of the RET.	The higher the financial (economic) benefits, the better.
	Market potential (scalability and replicability)	Possibility of building business on RET at existing economic conditions. Also includes Ghana's competitive advantage in the RET and market potential in the Sub-Region.	The higher the market potential of the RET, the better.
Environmental	Emission reduction	Potential to contribute to greenhouse gas emissions reduction based on the conventional fuel displaced or improvement in fuel/energy efficiency as a result of the RET.	The higher the emissions reduction potential, the more favourable the RET
	Adverse impacts of RET on environment	Waste generated through the process of manufacture, use and decommissioning of RET after life span.	The RET that results in lower waste generation (from manufacturing to end-use) is better
	Land requirement and use	Requirement for land for manufacture, installation or use of the RET. Every RET requires land (or space) and may affect the landscape	The RET that requires less land area per unit energy output is better

Criteria	Sub-Criteria	Description	Key Point
Technical	Resource availability	Availability of renewable resource for the generation of energy. E.g. solar irradiation, wind speed, biomass, hydro-sources, etc.	The higher the resource availability for the RET, the better.
	Technology maturity	How well is the technology developed and successfully disseminated in Ghana and other developing countries	The RET with higher technology maturity is more desirable
	Ease of local manufacture/assembly, repair and component supply	The potential to set-up local manufacture/assembly plants of the RET. Potential for higher local content in manufacturing, fabrication, installation and repair.	The RET with higher possibility of local content in fabrication, installation and supply is considered better.
Socio-cultural and political	Jobs creation	Employment opportunities from design, development, fabrication/manufacture, supply of components, distribution, installation and repair.	The RET with higher job creation potential is preferable.
	Social acceptability	The adaptability of RET to local use. Acceptable of technology by households and institutions. Positivity of public opinion.	Higher social acceptability is better.
	Gender involvement/mainstreaming	Possibility of women involvement in all aspects of the RET	The RET that allows higher women involvement is better.
	Macro-economic benefits	Benefits through the use of local resources. Contribution to national energy security; contribution to attainment of national developmental goals such as GSGDA[90].	The RET that produces more macro-economic benefits is deemed better.

[90] Ghana Shared Growth Developmental Agenda

9.3 Results of the AHP model

The AHP questionnaire was completed by 33 respondents. The consistency ratio (0.10) was determined for each respondent for the criteria (1), sub-criteria (4) and the RETs under each sub-criteria (14), totalling 19 outputs. In few cases, the consistency ratio was relaxed when a maximum of five out of a total of 19 fall above 0.1 but below 0.2. The data from ten respondents were rejected as one or more of the CR exceeded 0.2. The relative weights of the criteria (Table 18) and sub-criteria (Table 19) with respect to the goal were built through pairwise comparisons by stakeholders. Experts ranked the economic criterion as the most important in achieving the goal, followed by technical, environmental and socio-cultural and political.

Among the economic criteria, the investment (upfront) cost of the RET is ranked as the most important. As a developing country with limited financial resources, the ability to pay for the upfront cost is critical to large scale dissemination. The economic viability, which ranks second, is seen as critical since any large scale RET programme is likely to receive high patronage if the economic returns derived by users are significantly measureable.

Under the environmental criterion, the emission reduction potential was found to be the most important parameter. This is against the backdrop that Ghana is fully considering moving along the path of low-carbon development. Resource availability and ease of local development of the technology are ranked as the two most important sub-criteria in the technology criterion, indicating the positive opinion by stakeholders to RETs that can be produced locally and disseminated at a larger scale. Job creation is ranked highest followed by macro-economic benefits under the socio-cultural and political criterion. Thus, stakeholders believe RET dissemination should also lead to employment opportunities for the large numbers of unemployed youth, contributing to the achievement of national developmental targets. In addition, the RET should be locally owned and produced from local resources, enabling the achievement of energy security while reducing dependence on foreign energy resources.

The relative weights of sub-criteria in relation to the goal have been determined by allowing each criterion to have three sub-criteria. Thus, operation and maintenance cost as well as gender mainstreaming, which are the lowest ranked under the economic and socio-cultural & political sub-criteria respectively, were ignored. The ranking of the relative importance of the sub-criteria is given in Table 20. Not surprisingly, stakeholders agree RETs that are prioritized for national support must have favourable indicators as far as the economic sub-criteria are concerned.

Table 18 **Relative weights of the criteria in relation to the goal**

Criteria	Relative weight	Rank
Economic	0.28	1
Technical	0.26	2
Environmental	0.24	3
Socio-cultural and political	0.22	4

Table 19 **Relative weights of the sub-criteria in relation to the respective criterion**

Criteria	Sub-criteria	Relative weight with respect to each criterion
Economic	Investment (upfront cost)	0.270
	Operation and maintenance cost	0.214
	Economic viability	0.261
	Market potential	0.255
Environmental	Emission reduction	0.344
	Adverse impact of RET on environment	0.319
	Land requirement	0.337
Technical	Resource availability	0.348
	Proven technology (technical maturity)	0.323
	Ease of local manufacture, repair and component supply	0.329
Socio-cultural and political	Jobs creation	0.293
	Social acceptability	0.235
	Gender involvement/mainstreaming	0.220
	Macro-economic benefits	0.253

Table 20 **Relative weights of the sub-criteria in relation to the goal**

Sub-criteria	Relative weight with respect to the goal	Rank
Investment (upfront cost)	0.09729	1
Economic viability	0.09405	2
Market potential (scalability and replicability)	0.09174	3
Resource availability	0.08966	4
Ease of local manufacture, repair and component supply	0.08475	5
Jobs creation	0.08320	6
Proven technology (technical maturity)	0.08318	7
Emission reduction	0.08185	8
Land requirement	0.08017	9
Adverse impact of RET on environment	0.07597	10
Macro-economic benefits	0.07163	11
Social acceptability	0.06651	12

Finally, based on pairwise judgements between alternate RETs with respect to the sub-criteria, the results of the evaluation of the RETs are given in Table 21. Stakeholders ranked solar lanterns as the alternative with the highest impact in relation to the goal. Solar lanterns have already received considerable national interest and large programmes such as GEDAP have prioritised solar lanterns for dissemination especially in areas remote from grid power. Solar dryers received favourable judgements by respondents owing to their high possibility of local deployment at relatively low costs to end-users. Moreover, the potential contribution of solar dryers to agricultural output at the national level as well as high market potential and the possibility of job creation are attributes that ensured the high ranking.

Solar PV and solar water heater are ranked fourth and fifth respectively, and both technologies can be produced locally, creating jobs for the youth, and improving energy security (macro-economic benefits). Moreover, the market potential of both are considerable though unlike solar PV, SWHs are less supported at the national level. The market for SWHs however is booming due to recent power crises and the hospitality sector is responsible for the increased demand, with all systems imported mainly from China and Europe.

The last three ranked RETs – ethanol, biodiesel and bio-oil and synthetic-gas – have several limitations that make their contribution to the goal low. There is a lack of successful biodiesel production projects from *Jatropha* or other crops and the economics of biodiesel are unfavourable. The use of edible oils for biodiesel is seen by many as unsustainable; moreover, there is lack of infrastructure for biodiesel dispensing stations. Ethanol (1st generation) requires the use of food materials while cellulosic ethanol (2nd generation) production is complicated especially for small scale applications; moreover, technologies are still at research/pilot stages. In addition, ethanol is expensive when used as cooking fuel and there is a lack of infrastructure when used as fuel in petrol engines.

Bio-oil, synthetic-gas and derivative fuels from pyrolysers and gasifiers require complex technologies and are unfit at current conditions in Ghana.

Table 21 **Relative weights of the RETs in relation to the goal**

RET	Relative weight	Rank
Solar lantern	0.0862	1
Solar dryer	0.0822	2
Solar PV	0.0821	3
Solar water heater	0.0818	4
Solid fuels	0.0805	5
Biogas	0.0792	6
Solar water still	0.0788	7
Efficient charcoal kilns	0.0765	8
Standalone wind turbine	0.0731	9
Mini- and micro-hydro	0.0719	10
Ethanol	0.0707	11
Biodiesel	0.0695	12
Bio-oil and synthetic-gas	0.0674	13

9.4 Conclusion

In this section, RETs that have high potential for technology transfer and diffusion from China and other countries to Ghana have been identified and assessed. The technologies selected and evaluated include solar PV, solar thermal technologies (water heaters, water distillers, and dryers), solar lanterns, mini- and micro-hydro, wind turbines and biomass conversion technologies (biogas, ethanol, biodiesel, bio-oil and syn-gas, solid fuels and improved charcoal kiln). Other technologies were screened out based on the following reasons:

- Landfill gas - Process of harnessing landfill gas complicated; lack of well-engineered landfill sites; economics unfavourable.
- Solar ovens/cookers - Not too successful in Ghana; appear not to fit into traditional cooking;
- Concentrated solar power/heating - Low direct normal radiation (DNI) in Ghana.
- Solar fuel - Immature technology; under development

The selected RETs were evaluated and ranked by stakeholders in the energy sector using the multi-criteria and multi-perspective decision tool, Analytical Hierarchy Process (AHP). The assessment was based on the potential of a technology to attainment of the developmental goals of country. Solar lantern was ranked as the alternative RET with the highest impact, followed by the following in a descending order: solar dryer, solar PV, solar water heater, solid fuels, biogas, solar water still, efficient charcoal kilns, standalone wind turbine, mini- and micro-hydro, ethanol, biodiesel, bio-oil and synthetic-gas. Thus, comprehensive national programmes in RE should focus more on those that are viewed by stakeholders to have high impact on national development.

Ekem cookstove liner factory, Winneba
Photo: Edem Bensah

10. ROADMAP FOR RENEWABLE ENERGY TECHNOLOGY TRANSFER TO GHANA

10.1 Roadmap for removing barriers to RETT

Section 8 outlines policy tools required as potential measures to address the identified barriers to RETT and dissemination to Ghana. Specific activities needed for effective and efficient implementation of the policy actions are also proposed. However, to transform these actions into specific viable reforms require significant policy development, including consideration of timing and budget allocation, consultation and balancing of stakeholder interests, distributional impact of costs and benefits, and legal and legislative issues.

It is beyond the scope of this work to address all of these issues, particularly for such a wide range of policy options. However in order to provide a more concrete outline of the policy options and how they might be coordinated, taking into account stakeholder responsibilities, they have been presented here in the form of a proposed policy timeline from 2016 to 2025.

The policy timeline is focused on what government can do to accelerate RETT to Ghana in order to meet the national RE targets by 2025. This is essential in cases where proposed actions relate to legislation or use of government funds. However, in many other cases, there are opportunities for other stakeholders such as development partners, research and tertiary institutions, enterprises and NGOs to facilitate these activities, with or without government support. These stakeholders need to play different but complementary roles in policy development and implementation from the national to the local level.

The roadmap for the proposed actions is shown in Table 22. Targets for prioritised RETs, taken as the eighth highest ranked technologies (Table 21), with respect to attainment of the third stage of technology transfer where full manufacturing capabilities are mastered, are provided in Section 10.2

Table 22 **Roadmap for removal of barriers to RETT to Ghana**

Mitigation Actions	Specific activities	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	Responsible body
Work Package 1 – Increase Government Commitment/ Political Will												
I. Expedite development of RE master plan	Secure funding for RE master plan											EC, MoP, UNDP
	Engage consultants to develop RE master plan											EC, UNDP
	Engage stakeholders											EC, UNDP
	Align and integrate master plan into national development plan (e.g. GSGDA II)											MoP, MoF, NDPC
II. Operationalise RE fund under RE law	Develop guidelines for utilisation of RE fund											EC, MoP
	Government should dedicate seed money to the RE fund											MoP, MoF
	Engage with bilateral and multilateral donor agencies for additional funding											MoF, MoP
	Identify alternative funding mechanism											EC, MoP
III. Develop national programmes on prioritised RETs	Engage consultants											EC, UNDP
	Engage stakeholders											EC, UNDP
	Dedicate financial resources under RE fund for prioritised RETs											MoF
	Set up coordination offices to coordinate programmes											MoP

Mitigation Actions	Specific activities	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	Responsible body
Work Package 1 – Increase Government Commitment/ Political Will												
IV. Develop/ adopt standards, codes and labels for biogas plants, SWH, solar dryers, wind mills and other RETs.	Build capacity of staff of the Ghana Standards Authority (GSA) and EC											GSA, EC, UNDP
	Engage with organisations with experience in other countries											GSA, EC
	Obtain funding from RE fund and from donor agencies											EC, MoP, UNDP
	Equip the Ghana Standards Authority (GSA)											EC, MoP, GSA
	Develop and pass LI on standards, codes and labels for RETs											GSA, EC, Parliament
Work Package 2 – Reduce investment cost												
I. Develop and implement tax incentives on prioritised RETS	Implement import tax incentives for raw materials and intermediate products for local manufacturing of prioritised RETs[91]											MoP, EC, MoF, GIPC, GRA
	Initiate tax holidays and incentives for investment on prioritised RET											
II. Provide financial support for RET investment in prioritised sectors	Provide soft loans supporting RET investment											MoP, EC, MoF, Financial institutions
	Provide direct financing to RET entrepreneurs											
	Seek grants from bilateral and multilateral donors to set up incentives and soft loan schemes											EC, MoP, UNDP
	Use part of the RE fund to support consumer financing and RET investment											EC, MoP

[91] The tax incentive policy should be reviewed after the first five years of implementation by Government to measure its effectiveness.

Mitigation Actions	Specific activities	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	Responsible body
Work Package 3 – Enhance technical capacity												
I. Strengthen existing training facilities	Support existing institutions to expand programmes to cover prioritised RETs											EC, MoP
	Harmonize and standardize training materials											EC, MoE, COTVET
	Build capacity of key RE research/training institutions in prioritised RETs											EC, MoP, UNDP, PMU in China
	Enhance and encourage coordination between institutions											EC, MoP
	Allocate portion of RE Fund to expand training and research facilities											EC, MoP
	Set-up dedicated funds for RETs deployment and demonstration											EC, MoP
II. Build capacity of researchers and trainers in RETs	Promote networking with external centres of excellence											EC, MoP, UNDP, PMU in China[92]
	Dedicate part of RE fund for capacity development											EC, MoP
III. Set-up dedicated centres of excellence in the prioritised areas	Develop modalities for established centres in existing institutions											EC, MoP, Ministry of Education (MoE)
	Allocate funds for the establishment of the centres											EC, MoP, MoE

[92] Programme management unit in China under the China-Ghana SSC project

Mitigation Actions	Specific activities	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	Responsible body
Work Package 3 – Enhance technical capacity												
IV. Conduct capacity building programmes for entrepreneurs and local enterprises	Undertake capacity needs assessment of local enterprises											EC, MoP, NBSSI
	Develop training skills oriented programmes/manuals in prioritised RETs											EC, MoP
	Conduct regular technical training for local enterprises in prioritised RETs											EC, MoP
	Build collaborative linkages between local enterprises and their counterparts in China or other developing countries advanced in RETs											EC, UNDP, PMU in China
V. Arrange networks and partnerships for local enterprises with counterparts in other countries	Explore possibilities for networking											MoP, EC
	Link local enterprises to counterparts in China and other developing countries											EC, UNDP, PMU in China
	Fund trips and visits of local firms to foreign exhibitions and trade shows on prioritised RETs											EC
	Identify and fund training programmes in Ghana with experts from China and other developing countries											EC, PMU in China
Work package 4 – Address information Gap												
Run cost benefit campaign on the use of RE products	Run cost benefit campaign on the use of RE products											EC, MoP, CSOs, NGOs, CBOs, Women Groups
Include RETs in technology catalogue	Include RETs in technology catalogue											EC

10.2 Targets for prioritised RETs

The current stages of TT for prioritised RETs are shown in Table 23. The various stages of individual RETs with respect to TT in Ghana are discussed below.

Table 23 **Stages of TT for prioritised RETs in Ghana**

Technology	Stage		
	1	2	3
Solar lantern	✓	✓	
Solar dryers	✓	✓	✓
Solar PV	✓	✓	
Solar water heaters	✓	✓	
Solid fuels and cookstoves	✓	✓	✓
Biogas	✓	✓	✓
Solar water stills	✓		
Efficient charcoal kilns	✓	✓	✓
Standalone wind turbines	✓	✓	
Mini- and micro-hydro (using general experience in hydro)	✓	✓	

10.2.1 Solar lanterns

Solar lanterns are lanterns that are powered by solar PV panels and batteries. Once charged using the solar PV panel, solar lanterns provide bright lights that can be used for lighting at night. Modern day solar lanterns have mobile phone battery charging units that allow the charging of mobile phones. Over the last ten (10) years or so, Ghana has been actively promoting the importation of solar lanterns for distribution and sale to, especially, rural and remote communities.

Recap: Types and stages of TT

Recall that there are two types of TT: vertical and horizontal.

Vertical TT occurs when information is transmitted from basic research to applied research, from applied research to development, and from development to production. Vertical transfer follows the progressive stages of invention (basic research), innovation (applied research), development and commercialisation.

Horizontal TT occurs when a matured technology is moved from one operational environment to another. It is more common when technology is transferred from industrialised to developing countries. There are three stages in horizontal TT:

I. Stage I involves import of capital goods and equipment. This increases the production capacity of the recipient but on its own does not enable the recipient to use the imported facilities efficiently or to generate technological change in country;

II. Stage II includes skills and know-how for operating and maintaining equipment. It places the human resources of the recipient at the technological level required to operate the imported technology efficiently;

III. Stage III encompasses knowledge and expertise for generating and managing technological change. It creates new technological capacity through TT and active independent learning, creation and innovation of the recipient.

Table 24 **Targets for each RET**

Technology	2016	2018	2020	2022	2024	2026	2028	2030
Solar lantern								
Solar dryers								
Solar PV								
Solar water heaters								
Solid fuels and cookstoves								
Biogas								
Solar water stills								
Efficient charcoal kilns								

Colour Key

Stage 1	Stage 2	Stage 3

Other programmes have also been promoted by NGOs as well as bilateral and multilateral agencies. This process adequately covers stage 1 of the TT process. Efforts towards stage 2 have begun, with recent programmes aiming to include components of adequate repair skills, including the development of training manuals. Going forward, these efforts would have to be intensified in order for stage 2 of the TT process to be reached fully.

With regards to stage 3, the recent GoG programme that is aimed at distributing 2 million solar lanterns plans to add local manufacturing capacity building to the project. Government is hoping to secure funding from the Climate Investment Fund to implement this project under the Scaling-up Renewable Energy Programme in Ghana Project. This is expected to begin in 2016. In addition, under the "a million lives project", a solar lantern assembly plant is expected to be established soon. With solar lanterns not being so complex, we expect local component manufacture to begin first by 2018, paving the way for intensification. More than half of the components should be manufactured in Ghana by 2020, with designs perfected by about 2025.

10.2.2 Solar dryers

Solar dryers are not a complicated technology for local manufacture. They have been disseminated in Ghana using the vertical transfer process. They were invented several decades ago and have been used in other countries for so many years. Over the last few years, applied research and development has been ongoing in Ghana. Small-scale experimental units have been built in the country's universities and research institutions for about two decades. Large scale units have been piloted for close to a decade now, but this has failed to move into wider dissemination. Efforts towards piloting larger scale community based systems have been led by the Agricultural Engineering Services Directorate (AESD) of the Ministry of Food and Agriculture (MOFA). Recently, The Energy Center of KNUST has also begun piloting these systems in maize growing communities. Systems have been designed and fully built in Ghana, using largely local materials for the structure. The main challenge has been the high cost of the acrylic glazing material, which is still imported.

Following the RET prioritisation process, experts regard solar dryers as a priority technology. As a matter of fact, solar dryers are already a priority RET under Ghana's SE4ALL Action Plan. About a 1,000 unites were expected to established in all ten regions by 2014 but this failed to materialise.

This should be revisited in the RE Masterplan and barriers hindering the non-implementation addressed. For this reason, government through the appropriate agencies must pay special attention to issues surrounding solar dryers. In the short term, joint programmes with the private sector to import acrylic glazing material for solar dryers would have to be considered. Depending on other expected end-uses of the acrylic glazing materials, import duty reduction should be considered for those destined for the solar dryer industry. In the medium to long term, and depending on the scale intended for solar dryer dissemination, manufacturing of acrylic glazing materials would have to be considered. We expect manufacturing to begin by 2020 and for economy of scale to be fully realised by 2025.

10.2.3 Solar PV

Solar PV stand-alone systems have been promoted in Ghana on a larger scale and would perhaps had performed better were it not for the high initial cost, especially for rural communities. The promotion of solar PV has gone through different phases of development with the active participation of a number of NGOs, backed by research support from academic & research institutions, as well as other associations, such as AGSI. Its uptake has been encouraging, leading to the set-up of a number of retailing and installation units, which are mainly concentrated in the capital city, but also in Kumasi and a few other cities in the country.

Stages 1 and 2 of the horizontal TT process have been realised. Stage 3 has just begun, with the commencing of the assembly of solar PV panels in the country. This would have to be intensified, to move towards local manufacture of the cells. But beyond the cells, other components should also be studied for local manufacture. These include batteries, inverters, and other balance of systems. While we do not expect manufacture of 100% of the components to be realised soon, we must draw programmes to target specific components that can also benefit other areas. Local manufacture of batteries for instance, would be more useful because batteries would also be needed for solar lanterns.

10.2.4 Solid fuels and cookstoves

This is an area where capacity building efforts have intensified over the past few years with a number of vibrant local manufacturers of cookstoves. The Ghana Alliance for Clean Cookstoves (GHACCO) has played a major role in cookstove dissemination with awareness creation campaigns that target end-users.

With regards to the TT process, Ghana is already in stage 3 of the process with local manufacturing of the Gyapa stove and its variants. Going forward, we need to develop capacity to come up with improved designs beyond the Gyapa, most especially stoves that can burn pellets and other fuel woods. At some point, government should consider banning the importation of cookstoves to enable the local private sector fully drive the process. An outright ban should be in place by 2020, four years from now.

Manufacturing of pellets have begun in Ghana, however, the entire components for the installation of the plant were imported. Because of the scattered resource base, it is important to develop capacity in the manufacture of smaller units that can be used in areas where feedstock sources are low. In doing this, government could set a minimum capacity level for foreign investors in pellet manufacturing, so that small-scale systems would be left solely to Ghanaian entrepreneurs. This could be addressed by existing regulations at the GIPC that are meant to protect local interest in small-scale businesses.

While small-scale (often household units) for briquette production have been tried, large scale manufacture has still eluded us. Capacity building in the manufacture of briquette equipment components should be combined with capacity building for the design and manufacturing of pelletising equipment. Some of the ITTCs such as those established within Suame Magazine and allied facilities should be transformed into Centres of Excellence, for the design and manufacture of these components, with support from the technical academic and research institutions. Others centres could also be set up in locations where feedstock availability could promote local business.

10.2.5 Biogas

Like clean cookstoves, biogas technology can be said to have already reached stage 3 in the design, construction and maintenance of household and institutional systems, although modern designs are still led by foreign contractors. It appears that institutions that have installed large-scale biogas plants in the past have had little confidence in Ghanaian entrepreneurs to install these systems and have gone in for foreign designs and expertise. In some of these installations, the fact that those recipient institutions are foreign owned may have informed the choice of foreign expertise for the installations.

Typical examples are the large scale plants at HPW Fresh and Dry (Adeiso) and Guinness Ghana Limited (Kumasi). A plant that is currently under construction at the Kumasi Abattoir (with facilitation from The Energy Center at KNUST) is being supervised by Ghanaian engineers, even though the designs were brought from Korea, and Korean engineers are expected to supervise the installation of electrical systems.

Capacity building efforts are needed to upgrade Ghanaian engineers and entrepreneurs so that they are able to design and construct large-scale modern plants.

10.2.6 Solar water stills

Even though small-scale solar water stills are not a complicated technology, it has failed to make in-roads into the Ghanaian market. In the past, it was not considered a priority technology. However, experts are of the view that this should be given priority consideration, given its socio-economic importance to especially rural communities where access to clean water is a huge challenge. A lot more studies should go into the implementation of solar water stills, given the low solar radiation levels in Ghana.

10.2.7 Efficient charcoal kilns

Charcoal kilns in Ghana are reported to have efficiencies of about 15% on weight basis, which implies that only 15% of the wood raw material end up as charcoal. This is unsustainable, and is a potential source of deforestation, given the high contribution of charcoal to Ghana's energy mix.

Efficient charcoal kilns have been experimented over the past couple of decades, with efforts led by the CSIR-IIR, in a more horizontal TT process. Again this is not a complicated technology and stage 3 of the vertical TT process may have been reached. Its dissemination has, however, been poor. Local manufacturing capacity building shouldn't take much technological effort, rather a well implemented programme targeted at the right audience, which should be in locations where charcoal is produced on large scale.

Admittedly, it is challenging for many local charcoal producers to adopt 'constructed' improved kilns. This is due to the nature of the business, requiring that carbonisation is done close to the location of the raw material. Even on the same plot of land, it is often difficult moving logs from one end of the field to the other and may necessitate moving the kiln. But even if it were easy to manage movement within the same plot, when the kiln would have to be transported over hundreds of metres, it may pose a huge challenge to producers.

A more vigorous campaign should be targeted at those businesses who produce charcoal for exports. A key policy in this regard could be that by 2020, all charcoal exported from Ghana should be produced from improved kilns of a certain minimum efficiency, using a principle similar to the woodlot system for sourcing the raw material.

10.3 Institutional support from China and other countries

There are many institutions in China and other developing countries as well as industrialised nations that are better placed to provide technical and other support to Ghana and thus help promote RETT to Ghana. A list of potential bodies is shown in Table 25 for various RETs.

Table 25 **Institutions capable of supporting RETT to Ghana**

RET	Research institute	Country
Solar PV and lighting	• International Solar Energy Centre for Technology Promotion and Transfer (ISEC) of UNIDO • Beijing Solar Energy Research Institute (BSERI)	China
	• JRC Institute for Energy and Transport (JRC-IET)	Italy
	• Centre for Renewable Energy Systems Technology (CREST) Loughborough University	UK
	• Fraunhofer Institute for Solar Energy Systems	Germany
Solar water heater	• ISEC - UNIDO • BSERI • Gansu Natural Energy Research Institute (GNERI)	China
	• Solar Energy Research Institute (SERI) of University of Malaysia	Malaysia
	• Institute for Sustainable Technologies (AEE INTEC)	Austria
	• University of Zimbabwe	Zimbabwe
Solar water still	• ISEC – UNIDO	China
	• Florida Solar Energy Centre of the University of Central Florida	USA
	Fraunhofer Institute for Solar Energy Systems	Germany
Solar dryer	• ISEC – UNIDO	China
	• Solar Energy Research Institute (SERI) of University of Malaysia	Malaysia
	• Australian Centre for International Agricultural Research (ACIAR)	Australia

RET	Research institute	Country
Simple biogas digesters (fixed-dome, floating-drum, etc.)	• Biogas Research and Training Centre (BRTC)	China
	• Centre for Agricultural Mechanization and Rural Technology (CAMARTEC)	Tanzania
Industrial biogas digesters	• BRTC	China
	• Biogas Institute of the Ministry of Agriculture (BIOMA)	
Solid fuels (pellets and briquettes)	• The Energy and Resources Institute (TERI)	India
	• Qingdao Institute of Bioenergy and Bioprocess Technology (QIBEBT) of the Chines Academy of Sciences (CAS) • Guangzhou Institute of Energy Conversion of the Chines Academy of Sciences (CAS)	China
Cookstoves	• Instove • Aprovecho Research Centre	USA
Improved charcoal kilns	• The Energy and Resources Institute (TERI)	India
Biofuels (Cellulosic ethanol, microbial fuel cell,)	• QIBEBT of the Chines Academy of Sciences • Guangzhou Institute of Energy Conversion of the Chines Academy of Sciences (CAS)	China
	• Technical University of Denmark (DTU Chemical Engineering)	Denmark
	• National Renewable Energy Laboratory (NREL)	USA
	• The Energy and Resources Institute (TERI)	India
	• German Biomass Research Center (DBFZ)	Germany
Wind energy	• China Electrical Power Research Institute (CEPRI)	China
	• Technical University of Denmark (DTU)	Denmark
	• NREL	USA
	• Renewable Energy National Centre (CENER)	Spain
	• Energy Research Center	The Netherlands
	• Institut für Solare Energieversorgung (ISET) of Germany	Germany
	• University of Tokyo	Japan
Small/mini-hydro	• International Centre for Small Hydro • Hangzhou Regional Center for Small Hydro Power (HRC) • China Institute of Water Resources and Hydropower Research	China
Standalone wind turbines	• ISEC - UNIDO	China
	• National Institute of Wind Energy	India
	• NREL	USA

10.4 Conclusion

For the prioritised RETs, it came to light that Ghana has reached at least stage 2 of the horizontal technology transfer process, i.e. Ghanaians have the know-how to operate and maintain these technologies fairly, judging from recent activities. Three of the technologies: biogas, improved cookstoves and solar dryers have reached stage 3 of the technology transfer process. For these three, there is expertise in Ghana for the design, construction, operation and maintenance. To remove barriers hindering the technology transfer process, policy actions have been proposed, and a roadmap developed for the implementation of these actions.

The roadmap proposes specific activities needed for effective and efficient implementation of the policy actions needed to remove barriers to RETT. The timeline for the roadmap is from 2016 to 2025 and is focussed on what government and other stakeholders could do to accelerate RETT to Ghana in order to meet the national RE targets by 2020 and beyond.

The following are some deadlines proposed for some key mitigation actions:

- Development of RE master plan – 2017;
- Finalising national programme for prioritised RETs – 2018;
- Setting up dedicated centres of excellence for the prioritised RETs – 2019;
- Strengthening existing training facilities – 2020;
- Implementing tax incentives on prioritised RETs – 2021; and
- Developing and passing LI on standard and codes for RETs – 2021.

The main agencies responsible for undertaking these actions include the Ministry of Power, Energy Commission and Ghana Standards Authority, with support from the UNDP and NGOs.

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LIST OF ABBREVIATIONS

ABPP	African biogas partnership programme
ADC	Austrian Development Cooperation
AEE-INTEC	Institute for Sustainable Technologies
AEPC	Alternative Energy Promotion Centre
AESD	Agricultural Engineering Services Directorate
ALFA	Affordable Lighting for All
ANME	National Agency for Energy Conservation
BSU	Biogas Solutions Uganda Ltd
BTECH	Bachelor of Technology
CAMARTEC	Centre for Agricultural Mechanization and Rural Technology
CBO	Community Based Organisation
CEESD	Centre for Energy, Environment and Sustainable Development
CSIR	Centre for Scientific and Industrial Research
CSP	Concentrated Solar Power
DANIDA	Danish International Development Agency
DGIS	Netherlands Directorate-General for International Cooperation
DTU	Danish Technical University
EARE	Electricity Access and Renewable Energy
EC	Energy Commission
ECG	Electricity Company of Ghana
ECOWAS	Economic Community of West African States
ECREEE	ECOWAS Centre for Renewable Energy and Energy Efficiency
EE	Energy Efficiency
EIA	Environmental Impact Assessment

EPA	Environmental Protection Agency
ESCOs	Energy Service Companies
EWV	Enterprise Works/ VITA
FAO	Food and Agricultural Organisation
FIT	Feed-in-Tariff
GACC	Global Alliance for Clean Cookstoves
GEDAP	Ghana Energy Development and Access Project
GEF	Global Environment Facility
GhaWiPo	Ghana Wind Power Ltd
GIPC	Ghana Investment Promotion Centre
GoG	Government of Ghana
GTZ/GIZ	Deutsche Gesellschaft für Internationale
GVEP	Global Village Energy Partnership
H_2S	Hydrogen Sulfide
HIVOS	Humanistisch Instituut voor Ontwikkelingssamenwerking
HND	Higher National Diploma
IIR	Institute of Industrial Research
IP	Intellectual Property
ISCC	Integrated Solar Combined-Cycle
ISSB	Interlocking Stabilized Soil Blocks
KIRDI	Kenya Industrial Research and Development Institute
KITA	Kumasi Institute of Tropical Agriculture
Kedua Poly	Koforidua Polytechnic
KNUST	Kwame Nkrumah University of Science and Technology
K'POLY	Kumasi Polytechnic
LI	Legislative Instrument
MFIs	Micro-Finance Institutions

MNRE	India's Ministry of New and Renewable Energy
MOAP	Market Oriented Agriculture Programme
MoTI	Ministry of Trade and Industry
MOTIE	Ministry of Trade, Industry and Energy
MTES	Institutions and Small and Medium-Scale Enterprises
NGO	Non-Governmental Organisation
RET	Renewable Energy Technology
RETT	Renewable Energy Technology Transfer
RTE	Rural Technology Enterprises
SADC	Southern Africa Development Cooperation
SESA	Sustainable Energy Solutions for Africa
SGP	GEF Small Grants Programme
SHS	Small Home Systems
SNV	Netherlands Development Organisation
SSC	South-South Cooperation
SSD	Solid State Digester
SWH	Solar Water Heater
TCC	Technology Consultancy Centre
TDBP	Tanzania Domestic Biogas Programme
TEL	Toyola Energy Limited
TT	Technology Transfer
UENR	University of Energy and Natural Resources
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNICEF	United Nations Children's Fund
UNIDO	United Nations Industrial Development Organisation
VRA	Volta River Authority

PNB-BF	National Programme of Biodigesters of Burkina Faso
PPA	Public Private Agreement
PPP	Public Private Partnership
ProBEC	Programme for Basic Energy and Conservation
PROSOL	Programme Solaire
PURC	Public Utility Regulatory Commission
PV	Photovoltaic
RE	Renewable Energy

ANNEX A-I List of experts interviewed during field trips

S/N	Date	Expert	Organisation	Comment/specific barrier mentioned/issue raised
				Academic and research institutions
1	10/10/15	Dr. Nana Sarfo Agyemang Derkyi	Univ of Energy and Natural Resources (UENR)	Regulatory RE frameworks exists but enforcement is lacking. Solar PV has great potential for TT to Ghana.
2	13/10/15	Isaac Yankey	Koforidua Polytechnic, Energy Systems Dept.	Additional barriers to RETT include poor data, gender imbalance in the sector and inadequate financial instruments for supporting growth in the sector. Many gaps in current policies on RE, focussing mainly on import duties.
3	13/10/15	Faustina A. Boakye	GeoFaus Consult and Energy	Awareness creation about RET products and services is poor. Gender mainstreaming into RETT must be prioritised. Inclusion of women and girls in training programmes. Women entrepreneurship in RET should be encouraged. Raw materials and products manufactured in Ghana are taxed but finished products imported enjoy tax incentives. Land disputes affect large RE projects development.
4	15/10/15	Joseph Akowuah	KNUST	No comment
5	15/10/15	Prof. Ahmad Addo	The Energy Centre, KNUST	No comment
6	16/10/15	Ebenezer Nyarko Kumi	UENR	No comment
7	16/10/15	Eric Essandoh	UENR	The project would likely unearth a lot of critical issues that are hindering the transfer of renewable energy technologies
8	18/10/15	Dr Lena Dzifa Mensah	The Energy Centre, KNUST	Asked if project would lead to an outcome that would be implemented.
9	19/10/15	Divine Atsu	Koforidua Polytechnic	Policies should make it mandatory for hotels to install and produce hot water using solar thermal systems
10	19/10/15	Emmanuel Okoh Agyemang	Koforidua Polytechnic	If barriers are surmounted, we can deploy RE technologies in their numbers in Ghana. It is about time Ghana developed these technologies to push forward our development agenda and develop

S/N	Date	Expert	Organisation	Comment/specific barrier mentioned/issue raised
				the energy sector. Exercise is very useful to assess where we stand and the way forward.
11	19/10/15	Frimpong Baa-Poku	Koforidua Polytechnic	No comment
12	19/10/15	Ampaw Nyarko	Koforidua Polytechnic	With the right technologies, we will be able to harness efficient energy from our RE resources
13	21/10/15	David Ato Quansah	The Energy Centre, KNUST	No comment
14	22/10/15	Ishmael Edjekumhene	KITE	Existing laws and regulations are adequate. LI 1547 addresses contemporary issues in TT and is adequate.
15	22/10/15	Lawrence Amaning	Best Performance Eng. and Energy Solutions	Awareness creation on RETs is very low. Regular stakeholder meetings for discussions on war forward important. Policy enforcement critical. EPA should play key roles on RETT promotion.
16	02/11/15	Addo	Kumasi Polytechnic	No comment
17	02/11/15	Araba	Kumasi Polytechnic	No comment
18	19/10/15	Richard Bayitse	CSIR-IIR	Biogas for electricity generation is not viable in Ghana presently due to lack of infrastructure
19	20/10/15	Cidonne Akusika Klutse	KITE	No comment
			Companies and enterprises	
20	10/10/15	Prof. Fred Akuffo	Aeko Solar Ltd.	There is credit available in the banks but the high interest rate is the key barrier. There should be promotion of market growth and focus on technical capacity development as well as development of high quality RETs that are globally competitive.
21	14/10/15	Dr. George Nana Akwasi Rockson	Zoomlion Ghana Ltd.	Developmental partners and international organisations should channel more support in RET to private sector relative to Government institutions. Government organisations are increasing get directly involved in projects execution instead of giving the opportunities to the private sector.

S/N	Date	Expert	Organisation	Comment/specific barrier mentioned/issue raised
22	15/10/15	Christopher Schandorf	SV Tech Ghana	Tax exemptions for imported solar water heaters (SWH) needed to reduce upfront costs. Support in promotion of solar water heaters needed to encourage schools, hospitals, etc. to use them. Media involvement in promotion critical but currently absent. Nonetheless, the recent power crisis has led to a boost in the sector in addition to increased electricity tariffs.
23	15/10/15	Raymond Ategbi Okrofu	Safi Sana	Biogas technology has added advantages in waste management, job creation and health related benefits so should be promoted
24	17/10/15	Pragnesh Mishra	Abellon Clean Energy	Investors should be protected with effective Intellectual Protection Rights. The patent act is strictly not followed and there are undue delays on patent requests by the national body. Government should support the growth of RETT and development in Ghana through incentives such as tax exemptions. There are not support systems for such technology development and growth in Ghana though conventional fuels/technologies receive tax incentives.
25	19/10/15	Mark Kofi Koblah	Fortes Ghana	No comment
26	19/10/15	Nana Asante Frimpong	Solar 4 Ghana Co. Ltd. (Wonoo Ent. Ltd)	Poor consumer protection. Poor identification of households affect ability of RE businesses to implement credit schemes. High interest rate is a major barrier. Clear-cut policies in the form of regulations absent. Difficult in doing business outside Accra. Government Ministries must not get involved in business.
27	20/10/15	Kwasi Twum and James Awuku Kpodo	Apana Solution	All state institutions/public places should install biogas facilities and this should be made a firm policy that runs through EPA, EC, MESTI, Ministry of Power, Ministry of Housing There is a complete lack of policy coordination among various government agencies Government should take active role in the sensitization of the public about biogas
28	20/10/15	Ing. Bukari Danladi	VRA/NEDCo	Accelerating the pace of technology transfer will enhance RE deployment in Ghana

S/N	Date	Expert	Organisation	Comment/specific barrier mentioned/issue raised
29	20/10/15	Kofi Frimpong	Wilkins Engineering	Lack of stable grid impedes the development of grid-connected solar
30	22/10/15	Erasmus Osei-Essah	Cookclean	No comment
31	22/10/15	Victor	Tradeworks	No comment
32	22/10/15	Desmond	Tradeworks	No comment
33	22/10/15	John A. Idan	Biogas technology Africa limited (BTAL)	Biogas has great potential in Ghana. All challenges in RETs are opportunities.
34	22/10/15	Kenneth Cornelius and Jens Schmidt	DENG limited	High cost of assembling/manufacturing RET products in Ghana. Cheaper to import from China and other countries. Standards should be enforced to ensure level playing field for all actors in the RE sector as current conditions favour cheap and inferior products. There are low volumes to create manufacturing plants in solar technologies as existing regulations do not force developers to go green as exist in other countries. There should be fund dedicated to support the sector with manageable interest rates.
35	23/10/15	Charles Annan	Koajay	No comment
36	30/10/15	Yaw Agyei	Man and Man Ent	No comment
		International organisation and developmental partners		
37	14/10/15	George Ortsin	UNDP GEF-SGP	Current policies need revision by making it cheaper for RETT and RET acquisition and growth. Prioritized RET sectors should include biogas and biodiesel. Outcome of this study should be made available to all.
38	15/10/15	Lovans Owusu-Takyi and Ian Robinson	SNV, Ghana	Funding mechanism for RETs should be explored vigorously for both consumers and project implementers High import duty on cookstoves are killing the market especially for foreign brands of clean cookstoves
39	20/10/15	Emmanuel Kodwo Sackey	Danish Embassy (support to private sector dev)	Laws and policies are available but there is ambiguity and a lack of clarity on incentives for RETs. Solar PV and off-grid wind power have high potential in Ghana. Objectives of LI 1547 should be revised to reflect changing trends.

S/N	Date	Expert	Organisation	Comment/specific barrier mentioned/issue raised
40	20/10/15	Seena Kitami	Embassy of Japan	Ghana should balance its energy supply and so far RE does not seem to be playing a major role
41	23/10/15	Joshua Biliwi Mabe	JICA	There is a disconnect between policy direction and what is actually happening on the ground at the policy level Not much effort has been put into technology transfer at the policy level
			Policy and regulatory bodies	
42	16/10/15	George Brantuo, Catherine Amegashie and Johnson Panni	Agric Engineering Services Directorate – MOFA	Adherence to good and standard agricultural practices will ensure the adoption of RETs in the production and processing of agricultural produce in Ghana
43	16/10/15	Ing. Wiliam Nimako	GSA	Ghana should adopt the Chinese experience in TT – promote vigorously and later regulate Sustainability should be looked critically and must be incorporated in the building codes of the country so as to punish defaulters
44	22/10/15	Julius Nkansah-Nyarko	Energy Commission	No comment
45	22/10/15	Ebenezer Ashie	Energy Commission	No comment
46	23/10/15	Kwabena Out-Danquah	Energy Commission	Initial costs are very critical. Policies are adequate for now but EC continues to develop more
47	23/10/15	Dr Joseph Essandoh-Yeddu	Energy Commission	Barriers differ for different technologies and are sometimes dependent on business models
48	23/10/15	Richard Adjei	GIPC	No comment
49	23/10/15	Bridget Osei	GIPC	No comment
50	28/10/15	Daniel Tutu Benefor and Joy Hesse Ankomah	EPA	Inter-ministerial ownership of RE framework and TT are disjointed between ministries Develop market, work on access to capital, proper regulation and installation and maintenance regulations

S/N	*Date*	*Expert*	*Organisation*	*Comment/specific barrier mentioned/issue raised*
				Different Governmental agencies carrying out separate activities in the same RE sector – e.g. MESTI 200 institutional biogas completely divulged from SE4All biogas programme

ANNEX A-II List of participants during stakeholder consultation

SN	Name	Designation	Organisation	Email	Teleph
1	Stephen Kanor-Kudaya	RE Advisor	GIZ	stkanor@yahoo.com	024257
2	Ekow Appiah Kwofie	Planning Engineer	ECG	eappkwofi@gmail.com	055421
3	Dr. M. H. Duku	Bioenergy Expert	PSD	mosesduku@yahoo.com	024444
4	Kofi Ampomah-Benefo	Research Scientist	CSIR-IIR	kabenefo@gmail.com	024448
5	Isaac K. Yankey	Lecturer	K'dua Poly	ikyankey@gmail.com	020600
6	Felix Addo-Yobo	Dep. Director	NDPC	felix.addoyobo@ndpc.gov.g h	050509
7	Essel Ben Hagan	Consultant	UNDP/AIT	ebenhagan@gmail.com	024360
8	Bernard Modey	Director Systems Operations	GRIDCO	bernard.modey@gridcog h.com	024432
9	Abubakar S. Salifu	PRO	BXC	abusafrica@gmail.com	024383
10	Francis Kemausuor	Lecturer/Fellow	TEC	kemausuor@gmail.com	020745
11	Ing. Seth Mahu	Dep. Director	MOP	smagbeve@yahoo.com	024420
12	Albert K. Sunnu	Snr. Lecturer	KNUST	albertsunnu@yahoo.com	020815
13	Eric Osei Essandoh	Asst. Lecturer	UENR	ericodnew@yahoo.com	020884
14	Hanania Djibom	Relationship Manager	FAB	hdjibom@firstatlanticba nk.com.gh	024214
15	Kojo Biney	Exec. Committee Member	GREDA	kojo@smartinvestors.co.u k	024278
16	Albert Boateng	Reg. Coordinator	CTI PFAN	albert.boateng@pplint.com	020899
17	Edem C. Bensah	Reseracher	K. Poly	edem.bensah@gmail.com	024645
18	Julius Ahiekpor	Snr. Lecturer	K. Poly	juliusahiekpor@yahoo.co. uk	024452
19	Elkem Doh	Project Engineer	Wilkins	elikemabrahamdoh@gmai l.com	054011
20	Frederick Ken. Appiah	PPO, Renewables	EC	fred.ken.appiah@gmail.co m	020832
21	Kwame B. Fredua	PO	EPA	kwame.fredua@epa.gov.g h	020731
22	Charles Kofi Owusu	Project Officer	KITE	ckowusu@kiteonline.net	024323
23	Raymond Okrofu	Country Manager	Safi Sana	raymond.okrofu@safisana .org	024485
24	Johnson Panni	Dep. Director	MOFA	jypanni@yahoo.co.uk	020817
25	Ethel Linda Mensah	EIC Manager	EC	lindaethel19@gmail.com	020882
26	Edward Kofi Ahiabor	MD	TTF	ekahiabor@gmail.com	024320
27	Dr. Nana S. A. Derkyi	Head of Dept. Energy EN. Eng	UENR	nana.derkyi@uenr.edu.gh	024016
28	Prosper A. Amuquandoh	Inspector	EC	ugprosper@yahoo.com	020859
29	Okine Yamoah	Area Engineer	NEDCO	jyamoah@ymail,com	020646

SN	Name	Designation	Organisation	Email	Telephone #
30	Lovans Owusu-Takyi	Advisor, RE & Tech Transfer F	SNV/ISEES	livanstakyi@gmail.com/lowusu-takyi@outlook.com	0204208268
31	Dr. Eric Ofori Antwi	Lecturer	UENR	ericofosuantwi@gmail.com	0208812106
32	Dr. Kofi Barimah	Research Director	GTUC	kbarimah@gtuc.edu.gh	0208132190
33	Abrokwa Kofi Michael	Asst. Program Officer	Energy Commission	abrokwakofibklyn@outlook.com	0264783342
34	Papa Yaw Owusu Obeng	Technical Officer	UNDP/EC	pypapus@gmail.com	0279383224
35	Kwabena Agyei Danso	Technical Officer	UNDP/EC	k.danso@outlook.com	0206805115
36	Oforiwa Asare	Project Asst.	UNDP/EC	afidede83@gmail.com	0202292691
37	Eric Antwi - Agyei	Project Coordinator	UNDP/EC	eantwiagyei@yahoo.com	0244566371
38	Ebenezer Ashie	Project Advisor	SE4ALL/EC	ebenashie@gmail.com	0233886165
39	Seth Adjei-Boye	Infrastructure Specialist	Swiss Embassy	seth.adjeiboye@eda.admin.ch	0302225008
40	Erasmus Osei-Essah	General Manager	Cookclean Gh. Ltd	erasmus@cookclean.net	0244267978
41	Shirley Enguah	Carbon Officer	Cookclean Gh. Ltd	shirley@cookclean.net	0206903449

ANNEX B Summary of projects with RETT components

RE Type	Description of programme /project	Source country	Impact	Reason for failure or success	Cost	Source
Solar PV	UNDP / GEF renewable Energy Project		Provided 2000 homes with solar systems	Customer tariff was too low to recover operation and maintenance cost		World Bank (2008)[93]
Solar PV	Spanish project	Spain	Supplied 10 communities with solar home system	Customer tariff was too low to recover operation and maintenance cost		World Bank (2008)
Solar battery Charging stations	DANIDA Project		Supplied 14 solar battery charging stations	High interest loans served as a disincentive to consumers; for customers who managed to eventually secure the loans, repayment rate was very low		World Bank (2008)
Improved cookstoves (Ahibenso stove)	Ministry of Mines & Energy	Ghana	Provided about 30,000 pieces of improved stoves to residents of Accra and the other regional capitals	Programme stalled once government support ended. Also, artisan version of the stove did not live up to the industrialized version promoted, and was not adopted by the potential consumer.		
Off- grid PV Rural Electrification Project	Ministry of Energy; Isofoton SA of Spain; Wilkins Engineering (local Partner)	Spain	1,923 solar home systems (SHS) installed; 14 hospitals equipped with vaccine refrigerators and solar lighting; 200 solar street lights; 48 schools and community centres	Provided unserved communities with access to modern electric energy services.	US$ 5 million 50% concessionary loan and 50% official export credit	

[93] Avato, P. and Coony, J. (2008). Accelerating Clean Energy Technology Research, Development, and Deployment. World Bank Working Paper No. 138, Washington D.C., USA

RE Type	Description of programme /project	Source country	Impact	Reason for failure or success	Cost	Source
			electrified with solar PV; etc. Total installed capacity of 261,600 kWp		from Spanish Government	
Gyapa cooking stove	Enterprise Works/ VITA (EWV)	Kenya	The manufacturing and commercialization of consumer – oriented designed stoves that reduce Indoor Air Pollution, use less fuel, last longer and are safer than traditional stoves	EWV trained local markets workers to manufacture the Gyapa stoves and then linked them with local retail outlets; Local ceramists were also trained to produce the stove's ceramic liner; Over 300 jobs already created under the Gyapa stove project		Enterprise Works/Vita (2009)[94]
Toyola Stove	Toyola Energy Limited (TEL)	Ghana	Stove projected to reduce charcoal use, save strees and cut CO_2 emissions by 150,000 tonnes	Has provided about 200 jobs to people; Reduced deforestation and forest degradation		Edjekumhene and Cobson-cobbold (2011) [95]
Solar Lantern and Solar Home Systems	GEDAP Solar Project	Ghana	To install 7500 solar lanterns and 7500 small home systems	Lack of well-trained installers to cater for the increased installation rates of the participating companies; Political interference; Lack of full time staff with knowledge on solar products at the financial institutions; Customers tampering with systems;	Total cost of project is $ 4.75 million	Edjekumhene and Cobson-cobbold (2011)

[94] Enterprise Works/Vita, 2009. Clean Energy for Household Cooking in Ghana. Available from http://www.enterpriseworks.org/display.cfm?id=3&sub=15&cont=7
[95] Edjekumhene, I. and Cobson-cobbold, J. C. (2011). Low-Carbon Africa: Ghana. Available from christianaid.org.uk/low-carbon-africa

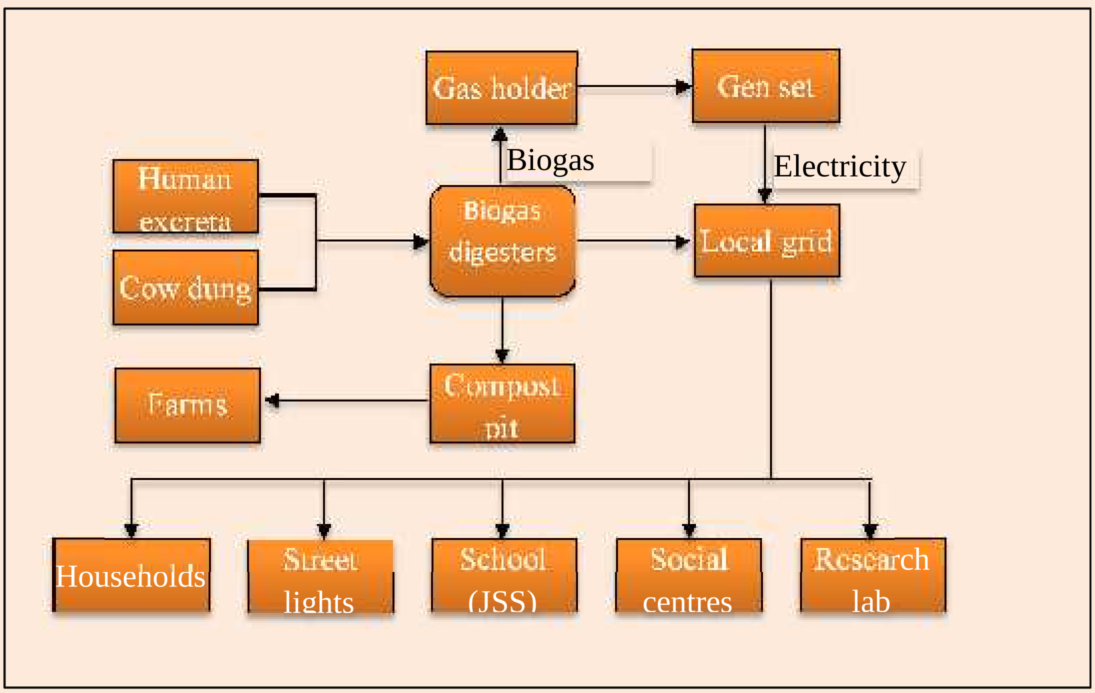
RE Type	Description of programme /project	Source country	Impact	Reason for failure or success	Cost	Source
				Companies delay in responding to system faults and requests		
Solar lantern	Affordable Lighting for All (ALFA), the first pilot under the Sustainable Energy Solutions for Africa (SESA)	Dutch	To develop and test commercially sustainable (non-exclusive) distribution and marketing chains for electric lighting products and services in off- areas.	Training activities were carried out for the selected local distributors, retailers, sales agents (connectors) and credit officers of some selected micro-finance institutions		Edjekumhene and Cobson-cobbold (2011)
Biogas	UNIDO BIOGAS PROJECT	Korea	Supporting green industrial development in Ghana: Biogas technology and business for sustainable growth	On - going	€ 1,280,000	The Energy Centre, KNUST
Biogas	Appolonia Household Biogas Programme	UNDP, China	A total of 19 fixed-dome digesters, including six 15m³ and two 30 m³ Deenbandhu digesters, and eight 10 m³ and three 15 m³ Chinese-dome models were disseminated	Absence of maintenance services; Lack of operational knowledge		
Bioenergy	Brong Ahafo and Northern Regions	Japan	40 MFPs installed in Northern and Brong Ahafo Regions, 12 individual and 11 group entrepreneurs trained, 15 artisans trained and 8 tooled, 3 CBOs trained to support further deployment of MFPs, etc.	Challenges with continuous supply of fuel		KITE Project Catalogue

ANNEX C Appolonia biogas programmes

Background

Appolonia[96], a cattle-rearing rural community in the eastern plains of Accra, was chosen for pilot and demonstration programmes in the early years of biogas development in Ghana. Two projects were piloted by the Ministry of Energy (MoE)[97]:

- construction of nineteen fixed-dome digesters for cooking by selected households in 1986, and
- construction of ten 50 m^3 digester system for electricity generation for 15 streetlights and small load appliances for 21 households, five social/community centres and a school in 1992. The cost of investment was USD 2,700 and the annual maintenance cost was about USD 2,300[98].



[96] Appolonia is currently engulfed by real estate development owing to expansion of housing infrastructure from Accra.
[97] Bensah, E. C. and A. Brew-Hammond, 2012, "Technical Evaluation and Standardization of Biogas Plants in Ghana," Lambert Academic Publishing, ISBN 978-3-8484-0102-4.
[98] Boakye F.A 2008. Sustainability of alternative energy resources for Ghanaian women: a case study of the Appolonia biogas project. Master of Professional Studies in International Development, Faculty of the Graduate School of Cornell University.

The design and engineering of the digesters were performed by experts from the MoE, CSIR-IIR and other organizations who had benefited from training programmes at the BRTC in Chingdu, under a cooperation agreement between Ghana and China. Technicians/caretakers were trained to manage the facility, with beneficiary households expected to contribute monthly fees to support the Ministry in paying for operational and maintenance costs. For the biogas systems, beneficiary households provided huts for the stoves and other accessories.

Project benefits

The construction of the system was supported by community members who provided unskilled labour in the form of supply of water for women and excavation and other construction activities by the men. The project functioned satisfactorily and delivered energy to the rural folks in the first four years as gas generated from domestic plants was used for cooking food, reducing the work involved in firewood gathering while improving their health through reduction in in-door pollution. Power from the community plant provided street lighting and lighting in the homes and the school while solar PV system integrated into the project provided power to the plant during the day. The bioslurry was applied to the farms of some farmers and hygiene improved due to the use of well-engineered latrines for efficient collection of human waste in the digesters for biogas generation.

Challenges

Many challenges arose with both systems which eventually led to their collapse. The electrification project experienced several setbacks related to feedstock for digesters owing to drudgery involved in collecting dung from kraals that were about half to three-quarters of a mile from the plant, maintenance, and uncooperative attitude of some of the inhabitants[99]. Fulani herdsmen prevent women from collecting dung due to the belief that the presence of menstruating women affected milk production by the cows. After a while, the slurry were also being left unused due to transport challenges and drudgery involved. In addition, there were socio-cultural challenges with the collection and use of digested faecal material from the plant for agricultural activities.

The project faced ownership problems as all costs were borne by government or donors. Occasionally, dung was purchased or obtained by the Ministry from Fulani herdsmen for the digesters (Boakye, 2008). Maintenance worsened as many households failed to pay monthly fees for caretakers of the community plant. The feeding challenges necessitated women to get involved in dung collection and feeding of the plant, a task that was the responsibility of men/caretakers. In some cases, diesel was purchased and used to feed the generators for power at high costs to government. The plant was completely abandoned when grid

[99] Bensah E. C., Brew-Hammond A. (2010). Biogas technology dissemination in Ghana: history, current status, future prospects, and policy implications. International Journal on Energy and Environment, Volume 1, Issue 2; pp. 277 – 294.

electricity was extended to Appolonia under the rural electrification programme in the late 2000.

Conclusion

Though, the project developers ensured effective dialogue with community members and inputs from the people were considered in the project framework, the ownership issue was not properly addressed. Moreover, the district assembly and community were not adequately involved in the implementation. Difficulties in project operation created low morale and lack of enthusiasm and commitment among the members. No communal spirit needed for general maintenance was present. Women were also not involved adequately in decision making.

(a) (b)

(a) Remains of a 10 m3 fixed dome plant at Appolonia; (b) Remains of a 15 m3 fixed dome plant at Appolonia; Source: Edem Bensah

ANNEX D Anaerobic waste treatment plant at HPW Fresh & Dry Ltd: building know-how the hard way

Background

HPW Fresh & Dry Ltd. is a company located at Adeiso (Eastern Region) that produces fruit juice from mainly mangoes and pineapples. About 20-25 tonnes/day of fruits are processed, generating about 10 ton/day of mango peels and pits as well as pineapple peels, cores and crowns. In 2011, the company presided over the construction of two anaerobic digestion plants with total capacity of a 900 m^3 to treat its waste, with technical support from a Swiss technician and Biogas Engineering Ltd. in Ghana. The digesters are two stirred tank digesters of 450 m^3 each, heated with waste heat from the process plant and maintained at 38 ^{0}C. The gas generated, having a 52-53% methane content, falls between 800-1000 m^3 per day, is stored in four balloon gasholders, which are connected to a 150 kVA generator. Occasionally, poultry manure is added to improve the digestion process and methane fraction in the gas.

Project benefits

The gas is able to generate about 50 kW of power or used in process steam generation which reduces the company's operational costs. The plant has improved hygienic conditions at the plant and the slurry from the digesters is applied on the company's farms.

Challenges

Inadequate gas volumes, low methane content as well as other factors have led to efficiencies in power generation and the company is planning to use the gas only for process steam generation. The company has struggled to find use for large volumes of digested slurry generated daily from the digesters. The introduction of the liquid fertilizer to local farmers did not yield much interest and the company resorted to using it on their own farms.

Conclusion

The company has gained considerable knowledge, skills and know-how by initiating and supervising the design and construction of its own digesters, as well as operation and maintenance. This is a success story of industrial anaerobic digestion in Ghana where the commitment and perseverance led to acquisition of know-how in digester installation and operation, resulting in considerable reduction in investment cost.

ANNEX E Tunisia: SWH programme – Programme Solaire (PROSOL)

Background

In Tunisia, policies on solar water heater were introduced as far back as the 80s. However, most programmes introduced failed due to quality issues, lack of incentives, poor maintenance and follow-up services. In 1996, the GEF funded a successful SWH project that helped create an enabling environment for growth in the sector. The project led to an increase in SWH penetration through awareness creation, capacity building, and introduction of incentives. However, challenges were still encountered in technology reliability, financing challenges, and the high investment cost.

To consolidate on the achievement of the GEF-funded project, Programme Solaire (PROSOL) was introduced in 2005 by the Ministry of Industry, Energy and Small and Middle Size Enterprises, the National Agency for Energy Conservation (ANME), and UNEP, with additional support from the Italian government. International support was mainly used at the initial stages to build capacity of stakeholders along the value chain – manufactures and suppliers, financial institutions, consumers, etc.

Key interventions

PROSOL introduced several interventions to tackle the barriers encountered as follows:

- Leadership, coordination and management by ANME;
- Technical training for installers and suppliers as well as quality control involving certification of products as well as follow-up services and maintenance
- Provision of 20% subsidy to offset part of the initial cost of installation and interest rate subsidy for consumers with credit payment spread in five years (2005-2006);
- Direct lending to end-users with loan guaranteed by the utility company (2007-2012);
- Targeted and continuous awareness programme for consumers (households), financial sector, and regulatory/governmental bodies; in the case of banks, concessionary loans were offered making the technology affordable by reducing upfront costs.

End-users are able to have installations through a credit scheme from the Tunisian electricity firm, freeing them from the high upfront cost and allowing them to repay through monthly bills.

Output

By the end of 2010, PROSOL resulted in an increase in the capacity of installations from about 7,000 to over 80,000 m^2; moreover, the total collector surface area had increased by over 400%, resulting in a market for seven manufacturers, over 40 suppliers, and over 400 active installers[100]. New jobs created were estimated at about 3000 and the net financial gain was found to be far higher than the investment from government and other partners into the programme[101].

Lessons

The major drivers for SWH interventions include energy security, reduced demand on grid electricity and job creation. Incentives were included to create interest in SWH technologies until commercial viability are achieved. Favourable factors about PROSOL included the availability of 20% subsidy on cost of SWH installations, flexible loans available to residential customers and simple administrative procedures. Financing mechanisms for SWH focused on credit-based market as opposed to cash-based one for consumers without capital to pay for the upfront cost. The financial arrangement allows the payment of several thousands of loans in a more reliable and efficient manner.

Another important factor for the success of the Tunisian programme involved the participation of developmental partners such as UNEP, which provided advisory support – financial, logistical, managerial, and monitoring and evaluation. Further, manufacturers and installers are well trained and certified which ensure delivery of standard services. This programme success has caused the government to extend it to the end of 2016.

[100] IRENA (2015), Africa 2030: Roadmap for a Renewable Energy Future. IRENA, Abu Dhabi
[101]Climate Policy Initiative (2012). San Giorgio Group Case Study: Prosol Tunisia. http://climatepolicyinitiative.org/wp-content/uploads/2012/08/Prosol-Tunisia-SGG-Case-Study.pdf

ANNEX F Biogas support programme of Nepal

Background

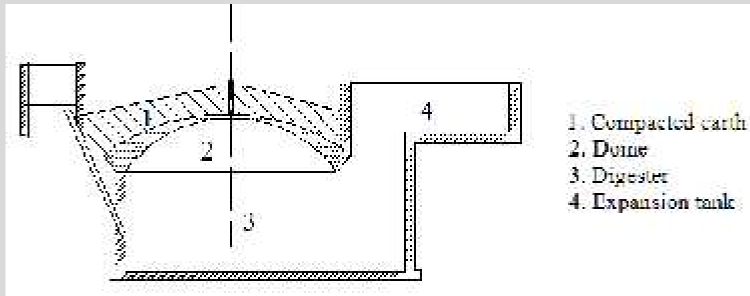
In Nepal, interest in biogas programmes began around 1975 as a result of direct involvement of the government through the provision of interest free loans to end users (Sigwal, 1999). Further support was obtained from Nepal's Agricultural Development Bank (ADB) which financed training and sensitisation initiatives and supported the establishment of Gobar Gas Company (GGC) in 1977 to spearhead technology development and awareness creation (GTZ, 1999a).

Biogas programmes however received its greatest boost when Nepal was selected by the Netherlands Development Organisation (SNV) as one of SNV's focal countries in 1988, and as a result received technical, training and other support. Several biogas models were tested in the early days of Nepal's programme including Chines fixed dome and floating drum digesters. However, the standardized, concrete-based fixed dome (GGC 2047) has been the main type of digester promoted over the years, coming in volumes ranging from 4 to 50 m^3 (GGC/BSP, 1994).

In addition, organisations such as FAO, UNICEF supported the biogas industry in training, skills development, information sharing and awareness creation (CES/IOE, 2000). FAO supported the development of a manual on biogas technology using experts from Nepal, China and other countries. It further trained stakeholders from sectors such as forestry, agriculture, soil conservation, wildlife and banks, as a means to creating awareness and providing background information for the promotion and facilitation of biogas extension activities at the district level.

Activities and strategies

In 2002, the Biogas Support Programme (BSP), a comprehensive and ambitious biogas dissemination project that helped transform the industry was initiated with financial support from Netherlands Directorate-General for International Cooperation (DGIS). Before the BSP, GGC was the only entity providing services in the industry while the ADB was the only institution supporting biogas farmers with loans. The BSP introduced flexible financial arrangements including subsidy schemes to ensure rural folks are able to afford the cost of installations, leading to the installation of about 25,000 digesters yearly (GTZ, 1999A). Quality control measures were also introduced. The focus of biogas programmes has been on small digesters for rural cattle farmers. By 2004, over 140,000 plants have been installed involving over 11,000 workforce (Bajgain and Shakya, 2005). The involvement of SNV was gradually reduced to advisory services and the BSP was transformed into an independent institute called Biogas Sector Partnership – Nepal (BSP-N).



Outputs

By 2008, over 60 biogas construction companies, about 15 qualified local appliance manufacturing workshops, and over 120 Micro-Finance Institutions (MFIs) supported biogas farmers with loans, and about 30 local and international NGOs provided various services in the biogas sector (SNV, 2009).

Annex G Questionnaire for data collection on barriers to RETT (for private companies)[102]

Identification of Barriers to Renewable Energy Technology Transfer to Ghana

Questionnaire	**For**	Companies/enterprises
	Date	

Contact information

Name of company		
Location of company		
Name of respondent		
Position/office		
Phone number		Email:

Renewable Energy Technology Transfer (RETT)

Note: RETT comprises the following: exchange of proprietary knowledge, know-how, organizational practices, technical artefacts, tools, machinery and components in any aspect of renewable energy (solar, wind, bioenergy, small-hydro, etc.)

1. Has your institution/unit been involved in any RETT or RE dissemination, in-country or cross-country?

   ☐ Yes ☐ No

   If No, please do not continue. Thank you very much for your time!

2. In which RE areas has your company received technology transfer support? Also provide the source of the RETT in the Table below.

RE technology	Type of RETT	Year acquired	Country of origin	Outcome/remarks
E.g. (solar water heater)	*Fabrication*	*2012*	*China*	*Successful*

[102] Note: Similar questionnaire were also prepared for other groups – Academic and research organisations, policy and regulatory bodies, developmental partners, and financial institutions.

Note: Examples of renewable energy (RE) applications/technologies are listed below:

- **Solar energy**: solar photovoltaic, solar dryer, solar water heater, solar water pumping, etc.
- **Bioenergy**: biogas, biodiesel, bioethanol, briquette, biomass pellets, etc.
- **Wind energy**: wind turbine, etc.
- **Energy efficiency**: biomass cookstoves, charcoal kilns, etc.
- **Small/mini-hydro**: turbines, etc.

3. What are the major challenges/problems your company/enterprise is facing?

B. Partnerships with external institutions

Does your company have any collaboration with any RE-based organisation in/outside Ghana

☐ Yes ☐ No

If yes, kindly complete the table below

Name of organisation	Location	Specific areas of partnership

Barriers to Technology transfer

4. Rank the barriers to RETT in Ghana based on their level of importance:

1 – very important, 2 – important, 3 – not important

(Please leave blank if you have no idea of a particular barrier)

	Barriers	Rank
	Economic and financial barriers	
i.	High initial cost	
ii.	Insufficient incentives	
iii.	Subsidies on conventional technologies (e.g. subsidy on grid electricity)	
iv.	Low feed-in-tariff/electricity tariff	
v.	High interest rates	
vi.	Lack of consumer financing options	
vii.	Operation/maintenance costs	
viii.	Limited access to capital	
ix.	Unstable currency	
	Market barriers	
x.	Under-developed supply channels	
xi.	Small market size	
xii.	Unstable market situation	

xiii.	Failed past experience/project/technology	
xiv.	Lack of successful reference projects in the country	
xv.	The RET is not important for our needs	
	Policy, legal and regulatory barriers	
xvi.	Insufficient legal and regulatory framework	
xvii.	Lack of enforcement	
xviii.	Unfavourable policies	
xix.	Political will	
xx.	Political interference	
xxi.	Problems in land acquisition	
xxii.	Challenges with license acquisition	
xxiii.	Administrative hurdles (in developing RETT contracts, clearances, licensing, etc.)	
xxiv.	Corruption	
xxv.	Intellectual property rights	
xxvi.	Inadequate RE codes and standards	
	Technical barriers	
xxvii.	Difficulty in getting equipment and spare parts	
xxviii.	Immature technology	
xxix.	Poor operation and maintenance facilities	
xxx.	Inadequate standards, codes and certification	
xxxi.	New technology is too complicated	
xxxii.	Lack of infrastructure facilities (please specify)	
	Network barrier	
xxxiii.	Weak connections between stakeholders promoting the new technology	
xxxiv.	Strong networks of conventional technologies favoured by legislation	
xxxv.	Difficult access to external manufacturers/institutions	
xxxvi.	Lack of involvement of stakeholders in decision-making	
xxvii.	Weak network between foreign institutions and local ones	
	Human skills barrier	
xxxviii.	Lack of skilled personnel for manufacturing and installation	
xxxix.	Lack of skilled personnel for preparing projects	
xl.	Lack of service and maintenance specialists	
xli.	Inadequate training facilities	
	Socio-cultural barriers	
xlii.	Lack of interest in shifting from conventional energy to RE (sticking to the status-quo)	
xliii.	Consumer preferences and social biases	
xliv.	Lack of confidence in new technologies	
xlv.	Dispersed/widely distributed settlements	

xlvi.	Lack of understanding of local needs	
xlvii.	Fear of failure	
	Information and awareness	
xlviii.	Poor or lack of information about costs and benefits RETs	
xlix.	Media not interested in RET promotion	
	Other barriers (please specify)	
l.		
li.		
lii.		

D. Overall ranking of barriers to RETT

5. Please rank the barriers as grouped in the table below based on their importance:

1 – very important, 2 – important – not important

Barrier	**Rank**
Economic and financial barriers	
Market barriers	
Policy, legal and regulatory barriers	
Technical barriers	
Network barriers	
Human skills barriers	
Socio-cultural barriers	
Information and awareness	

E. Ghana's Technology Transfer Regulations, 1992 (LI 1547)

6. Are existing regulation and laws adequate to promoting RETT in Ghana?

☐ Yes ☐ No

7. If No, can you give reasons?

8. Are you aware of Ghana's Technology Transfer Regulations, 1992 (LI 1547)?

☐ Yes ☐ No

9. Does the current policy in technology transfer need revision?

☐ Yes ☐ No

10. If yes can you specify which areas need revision?

11. What should be incorporated for it to address contemporary issues on technology transfer in Ghana?

F. Please give your final comments, remarks and observations