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China-Ghana South-South Cooperation on Renewable Energy Technology Transfer (RETT)

SERIES

BASELINE STUDY

OF RENEWABLE ENERGY TECHNOLOGIES IN GHANA

Vol. 1

APRIL, 2018

UNDP

Present in over 170 nations and territories, the United Nations Development Programme (UNDP) helps countries to develop policies, leadership skills, partnering abilities, institutional capabilities and build resilience in order to sustain development results. In Ghana, the UNDP supports efforts and capacity building for sustainable human development related to democratic governance, inclusive growth and sustainable development in line with national programmes such as the Ghana Shared Growth Development Agenda.

ENERGY COMMISSION

The Energy Commission is the statutory body mandated to prepare, review and update indicative national plans to ensure that all reasonable demands for energy are met in a sustainable manner.

The Commission is responsible for regulating, managing, developing and utilising of energy resources in Ghana.

The Danish Government, as part of its focus on South-South Cooperation, to enable coherent cooperation between China and countries in Africa, in particular around the promotion of the UN's Sustainable Energy for All (SE4ALL) initiative, has provided funds for the implementation of the China-Ghana South-South Cooperation on Renewable Energy Technology Transfer. The project commissioned this report to broaden understanding of the renewable energy projects in Ghana.

AUTHOR

This report has been prepared by the Project Management Unit of the China-Ghana South-South Cooperation on Renewable Energy Technology Transfer Project.

ACKNOWLEDGEMENTS

The authors are grateful to the Office of the Renewable Energy Promotion of the Energy Commission, the Office of the SE4All National Secretariat of the Energy Commission, the Energy Centre and the Agriculture Engineering Services Department of the Ministry of Food and Agriculture for providing contact persons at project sites. Finally, the contributions of all persons consulted during the field trips are greatly appreciated.

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

A Baseline Study of *Renewable Energy Technologies* in Ghana

Draft Volume 1
April, 2018

Accra, Ghana, 2018

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Introduction

Part of Denmark's focus on South-South Cooperation is to enable coherent cooperation between China and countries in Africa. As part of this process, UNDP China has been funded by Denmark to develop a project titled 'China-Ghana South-South Cooperation on Renewable Energy Technology Transfer'. The project is a collaboration between the Energy Commission in Ghana and the Ministry of Science and Technology in China, together with the UNDP Country Offices in Accra and Beijing. The project will facilitate the exchange of expertise and technology between China and Ghana, thereby building on China's unique development experience.

The project aims to effect off-grid community-based electrification, increase the share of renewable energy and promote the productive uses of energy. The project also seeks to support broader socio-economic and environmental objectives, most notably poverty reduction through employment generation as well as action on climate change mitigation. The project expects to create an enabling environment in Ghana for absorbing new technology and in China for providing it appropriately. The project will also promote the production of renewable energy technologies in Ghana with a strong focus on private sector development and inclusion.

As part of activities for the first year of project implementation, the project conducted a review of renewable energy technologies under some projects in Ghana to appreciate the progress being made in the field. This involved a desk study and field inspection of renewable energy facilities nationwide. Specifically, the goals of the assignment were to:

1. Obtain relevant information on established renewable energy projects. The information obtained is to serve as a good basis to estimate the state of development of the renewable energy sector during the initial phase of project implementation and serve as a useful baseline for the project.

2. Provide a good opportunity for the Project Management Unit to interact with project implementers to understand some of the issues underlined in developing and operating their projects. As the project intends to implement and support a number of demonstration projects, the results of the exercise would feed into the initiative in order to prevent duplication of efforts and also help identify potential areas of collaboration in existing projects.

"A Baseline Study of Renewable Energy Technologies in Ghana" presents the findings of the assignment conducted. It gives a brief overview of each project visited, indicating the purpose and the agencies involved in its implementation, as well as key findings and observations made on inspection of the project. It also addresses the challenges end-users and project implementers face with the daily operation and management of the facility.

The report groups the projects under the various technologies in biogas, biomass, solar and wind. It also looks at the progress educational institutions are making in the research and development of RE technologies.

Methodology

This assignment started with the identification and extraction of Renewable Energy projects through a desk study and research. About 198 renewable energy facilities were identified with the help of data and insights obtained from the renewable energy directorate of the Energy Commission, the Sustainable Energy For All Secretariat, the Office of the Global Alliance for Clean Cookstoves and online portals. The desk study was focused on identifying the technology, capacity, description, location, sponsor, implementing agency and the cost of each project. However, not all of these parameters were openly available.

Therefore, it became needful to conduct field visits to selected project facilities, to inspect these sites and administer interviews to project implementers. The objective was to verify the information obtained through deskstudy and ascertain the status of the initiative.

Over 50 projects were visited and they comprised of mini-grids, biogas plants, solar dryers, gasifier plants, wind pumps for irrigation, solar irrigation systems, grid connected solar systems and cogeneration plants. A summary of the findings of the projects visited is shown in Appendix A.

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 perhaps because they are a cheaper alternative to promoting efficient fuel use and thereby reduce deforestation arising from cooking fuel demand. The improved cookstoves industry in Ghana has experienced a meteoric rise in development as majority of the stoves are fabricated and manufactured locally.

The Ghanaian cookstove market is well developed with strong players across all sectors. However, large segments of about 80%[1] of households using biomass as their primary fuel, especially in the north, do not have access to clean fuels. As most improved cookstoves are small, portable, charcoal stoves (catering to the popular peri-urban/urban preferred fuel in the south), the 80.2%[2] of the rural population using wood fuel have limited improved cookstoves options. However, cookstove manufacturers in Ghana have now introduced stoves that use a variety of fuels (charcoal, pellets, bio-fuels, firewood, etc.) into the market to meet the needs of all consumers. Some mainstream cookstove technologies in Ghana include Gyapa stove, Cookmate coal pot, Toyola cookstove, Chrisaac stove, Morrison Energy Stove, etc.

[1] WHO Global Health Observatory Data Repository, data from 2004; Ghana Statistical Service (2008)
[2] Ghana Living Standards Survey 5

Toyola Cookstoves

Toyola Energy Ltd is a Ghanaian company that manufactures and distributes improved charcoal cookstoves (Improved Kenyan Jiko-type) using locally available materials which the directors of the company give credit to. Enterprise Works trained the directors of the company, Mr Suraj Ologburo and Mr Enerst Kwasi Kyei, under a USAID-sponsored project (Ghana Household Energy Programme) the skills acquired for manufacturing stoves enabled them to start the production. The duo, however, modified their material selection and production and distribution processes, making the Toyola Cookstove the most purchased cookstove on the market. They are, however, still interested in improving production levels to 100 per day/artisan. In this regard, the number of components needed to assemble the stoves have been reduced, thereby reducing the unit manufacturing time.

Key findings and observations

- Toyola Cooktstoves are manufactured using locally available materials (scrap metal and fired clay liners).
- A visit to their production facility at Sapeiman in Accra revealed that simple tools are used for the manufacturing of the stoves.
- It was realised that the introduction of specialisation and division of labour have significantly improved the productivity per person from 5 to 30 per day/artisan.
- Toyola Energy Ltd is yearning towards improving production levels to 100 per day/artisan. In this regard, the number of components needed to assemble the stoves have been reduced, thereby reducing the unit manufacturing time.
- Toyola's initial success in sales was a result of the thorough market study done by the Ghana Household Energy programme (GHEP) and their clever business models.
- Toyola uses a mobile stove delivery model that brings the product to the doorstep of consumers, with a convenient payment scheme.
- Averagely, Toyola sells 50 stoves daily and manufactures 400 to 500 stoves daily.
- Toyola's stoves are sold across Ghana, Togo, Nigeria and Burkina Faso, with five production centres in Ghana and one in Togo. Averagely 80% to 90% of Toyola stoves are exported.

Figure 1: Toyola Cookstoves

(Top: Perforated ceramic lining for heat retention and aeration Bottom: Samples of completed Toyola Stoves)

- The cookstoves save about 40-50% fuel compared to the traditional stoves.

Challenges

- Scarcity of scrap metal for the production of stoves.
- Importation of expensive sheet metal for stove production.
- Demand far exceeds rate of production.

Lessons learnt and recommendations

- There is a high demand and market for improved cookstoves in Ghana and West Africa at large.
- Toyola cookstoves can further be engineered to make them more efficient in order to address increasing climate concerns.
- Re-engineering of the stoves should maintain the unique design which customers relate to in order to keep sales up.

Institutional Rocket Cookstoves

The Technology Consultancy Centre (TCC) with support from the Netherlands Development Organization (SNV), is developing new technologies for up-scaling improved institutional cookstoves. As part of this initiative, two institutional rocket cookstoves have been built at the Rural Energy and Enterprise Development Unit of TCC.

Key findings and observations

- The rocket stoves are constructed mainly from bricks and it takes five days to construct them.
- These stoves have been replicated for a number second cycle intuitions including Kumasi Senior High Technical School, Yaa Asantewaa Girls' Senior High School, Kumasi Secondary Technical School and St Augustine's College.

Figure 2: Institutional rocket cookstove built at TCC

Lessons Learnt

- The stoves are cleaner compared to the traditional tripod stoves as it is equipped with a chimney to channel smoke away from the user.
- The stoves also have a higher performance and efficiency compared to the traditional tripod stoves as it heats up faster and also reduces fuel cost by 80%.

Morrison Cookstoves for Pito Brewing

The Netherland Development Organisation (SNV) and the Kumasi Institute of Tropical Agriculture (KITA) in their quest to promote the use of more efficient cookstoves have constructed the Morrison cookstove for brewing pito at Ejisu in the Ashanti Region. The Morrison cookstoves have also been constructed in some communities such as Ayigya and Asafo.

Key findings and observations

- Morrisons cookstoves are made of clay
- These cookstoves are stationary and are positioned in line with airflow and the size of the land available.
- A chimney is designed to direct smoke away from the user.
- The cost of construction - GHS200 per unit.
- The model adapted for payment by KITA is to make an initial half payment and then pay the other half in installments over a period of time.

Challenges

- Morrison cookstoves are prone to erosion when exposed to the rain.
- They are also prone to cracks and require regular maintenance.

Figure 3: Morrison cookstove for pito brewing

Cookstoves for Thermal Processing of Gari – EnDeV Ghana

Despite Ghana's high electrification rate, connection rates are significantly lower in peri-urban and rural areas where many micro, small and medium-sized enterprises (MSMEs), as well as farming and agro-processing activities are concentrated and where productive uses of electricity lags behind household electrification. Against this backdrop, the EnDeV Ghana intervention was designed to increase access for MSMEs to productive uses of energy.

In line with Ghana's SE*for*ALL Country Action Plan, EnDeV supported the introduction of improved institutional cookstove for (ICS) the thermal processing of gari (dried and ground cassava). This was done through live demonstrations, capacity building for stove manufacturers, and support to ICS dissemination through sales-based grants. This component was implemented by SNV Ghana on behalf of EnDeV to support small-scale gari processors.

Case Studies

Crisaach cookstovess – Adidome/Mafi Kumasi

- Crisaach stoves with kalwool interior lining installed for gari producers in the Volta Region
- Two types of stove installed depending on the size of the roasting plate – maxi (cost of GH¢ 1,350) and mini (GH¢ 850) stoves.
- Beneficiaries under EnDeV paid 50% and 20% of the cost, respectively, in the first and second tranches of the project implementation.
- The improved stoves can be used to produce 150 kg of gari in a day as compared to the conventional stoves which can yield the same amount in three days

Crisaach stoves for gari processing

Conventional gari processing stove

The business model used by the gari processing groups is to give a cup of gari (worth GH¢ 5.00) for every 150 kg gari processed to the group leader to be sold to generate income for maintenance.

Morrison cookstoves – Sekaf Ghana Ltd.

Sekaf Ghana Limited, located in Tamale, is a beneficiary under the EnDeV project where a number of improved cookstoves were installed for them to process shea based bath and beauty products. The company produces about 400 metric tonnes of shea butter from about 1200 metric tonnes of shea nuts bought per year.
The cookstoves are designed to reduce the interface of shea butter with smoke and ash in the shea butter processing, with firewood as the main fuel for roasting and boiling shea nuts. Chimneys direct smoke into the atmosphere, thereby improving the health condition of over 60 women at the processing centre.

"*The company has recorded significant amount of saving in fuel by using the improved Morrison stoves for shea butter processing*" – Mr Henry Gaffrey, Manager

Morrison cookstoves for parboiling shea nut

Lawrence cookstoves – Switch Africa Green Project Adaklu

The Switch Africa Green project was designed and implemented to achieve sustainable development by engaging in transition towards an inclusive green economy, based on sustainable consumption and production patterns, while generating growth, creating decent jobs and reducing poverty.

The project designed and built improved coosktoves (Lawrence stove and traditional improved three-stone stove) with a unique installation technology through the use of kalwool in the fuel combustion in pilot areas of Adaklu, Nandom and Ekumfi Narkwa.

Additional stoves requested by micro, small and medium scale enterprises (MSMEs) use the 75:25 payment scheme (project takes 75% and the MSME beneficiary takes 25% of the cost of construction of the cookstoves).
In comparison with the traditional stoves, the project's improved biomass cookstoves (used by gari processors) improve energy efficiency by 36.5% and make savings on cooking time on 41%. They also increase production by about 42%.

Lawrence stove installed at Adaklu in the Volta Region for gari processing

Three Lawrence Cookstoves built with burnt bricks

Biogas

The fixed-dome and the floating-drum are two main digesters widely promoted by biogascompanies in Ghana. Advanced plants such as Upflow Anaerobic Sludge Blanket (UASB) and the Continuous Stirred Tank Reactor (CSTR), which are ideal for treatment of industrial and municipal wastewater, have also been explored by some few companies in Ghana. Several biogas service providers have been in the forefront of biogas plant development and dissemination across the country, the mainstream biogas service providers include Biogas Technologies West Africa, Beta Construction Engineers Limited, Biosanitation Company Limited, Institute of Industrial Research, Abu Biogas Construction Limited and Biogas Engineering Limited.[4] The Biogas Association is an association of biogas companies, researchers and other interest groups that have been established to promote the interest of biogas. There is a high biogas potential, especially within the food processing sector but this potential is currently not realised.[5] However, anaerobic treatment could prove to be a solution for the treatment of Ghana's organic waste and sewerage.

[3] 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

[4] Bensah, E. C., Mensah, M. and Antwi, E. (2011). Status and prospects for household biogas plants in Ghana – lessons, barriers, potential and way forward. IJEE 1(2): 887-898

[5] Ulrike D., Karl-Heinz P. and Nayina G. S. (2014). Sub sector analysis of potential and framework – Biogas in Ghana

HPW Fresh and Dry Ltd Biogas Plant

HPW is one of the largest factories for dried fruits in West Africa. The factory is situated at Adeiso, in the Eastern Region and utilises multiple sources of power generation systems for its operations. These includes energy from biogas, solar thermal plants, diesel generators, as well as power from the national grid.

The biogas plant was built to provide for 1/3 of the energy needed to run the factory. HPW processes mango, pineapple, coconut and banana, mainly for export. The factory produces about 250 Mt dried fruits per year.

Key Findings and observations

- The biogas facility and the solar thermal plant were constructed in 2011 when the factory was built.
- The biogas facility includes two 450m^3 concrete biogas digesters and 3 x 100 m^3 gas holding balloons.
- The feedstock to the biogas digesters are made up of shredded fruit processing waste mixed with sliced substandard fruits.
- Production capacity of fresh cut fruits is about 30 tonnes daily of which 30% is fed into the digesters as waste.
- Averagely, about 500 m^3 of gas is produced daily from the plant.
- The bio-slurry from the digester is extracted daily and used as fertiliser for pineapple plantations.
- The biogas is used to fuel a 200 kW$_{heat}$ boiler providing heat for drying the finished product. The boiler is also heated by the solar thermal plant made up of 200 collectors, and can reach a temperature of about 80°C.
- HPW uses a biomass-fired boiler with palm kernel shell as feed to generate heat for operations.
- Three diesel generators (500, 600 and 50 kVA) have also been installed to provide power for running the factory.
- Residue heat from the radiator of the 500 kVA generator is tapped through a heat exchanger for heating purposes in the processing plant.
- The company was planning on expanding their biogas facility with a third digester.

Figure 4: Concrete Digester at HPW Fresh and Dry
(Left: Two 450m^3 concrete biogas digesters. Right: Three holding balloons for the storage of the gas)

Challenges

- As the holding balloons are not protected from the weather, they are frequently punctured. This causes leakage of the biogas to the atmosphere.
- The methane content of the gas produced is about 49%, which is relatively low as a result of the high acidic content of the substrate.
- The ratio of the factories dependency on renewable energy to the national grid is about 80% to 20%.
- The concrete biogas digester is gradually wearing and weakening due to the high acidic nature of the effluent.
- The use of the digestion residues as a fertiliser is yet to be accepted by most farmers around the area.
- The company's 150 kVA biogas generator is broken down without spares for repairs.

Lesson learnt and recommendations

- Regular feeding as well as regular measurements and control of gas parameters, pH and alkalinity has resulted in a stable biological process that allows stable biogas generation.
- The company is planning on building a temporal storage facility to pre-treat the substrate before channelling it into the digester to reduce the high acidic level of the effluent.

Koforidua Regional Hospital Biogas Plant

Koforidua Regional Hospital, located at Koforidua Central Business District in the Eastern Region, houses a biogas facility which was constructed by a local company.

Key observations and findings

- The facility was intended to generate biogas for cooking from the hospital's waste.
- It is, however, non-operational and was never used due to the pungent smell of the gas produced.
- The biogas and sledge digesters are in good shape. However, the gas holder was found punctured and deflated.
- The GPS coordinates - N 6°5'55.8276", W 0°15'26.7732" and N 6°5'51.414", W 0°15'29.3616".

Challenges

- There is no documentation on the biogas plant.
- The kitchen staff and management of the hospital have lost trust in the biogas technology as it never served the purpose it was intended for.

Lessons learnt and recommendations

- Thorough feasibility study should be conducted to verify the viability of the feedstock to produce enough biogas for such projects.
- The facility could be revived and a good business model adopted in running the plant in order to provide funds for maintenance.

Figure 5: Abandoned Biogas Plant at Koforidua Hospital

Kumasi Institute of Tropical Agriculture's (KITA) Biogas Plant

KITA is a non-governmental institution that provides vocational technical training and consultancy in general tropical agriculture to practising and prospective farmers. On the school's premises is a biogas facility which happens to be the first plant under the Institutional Biogas Project sponsored by SNV and implemented by the Centre for Energy, Environment and Sustainable Development (CEESD). The project was geared towards developing local capacity to properly design, construct and maintain biogas plants.

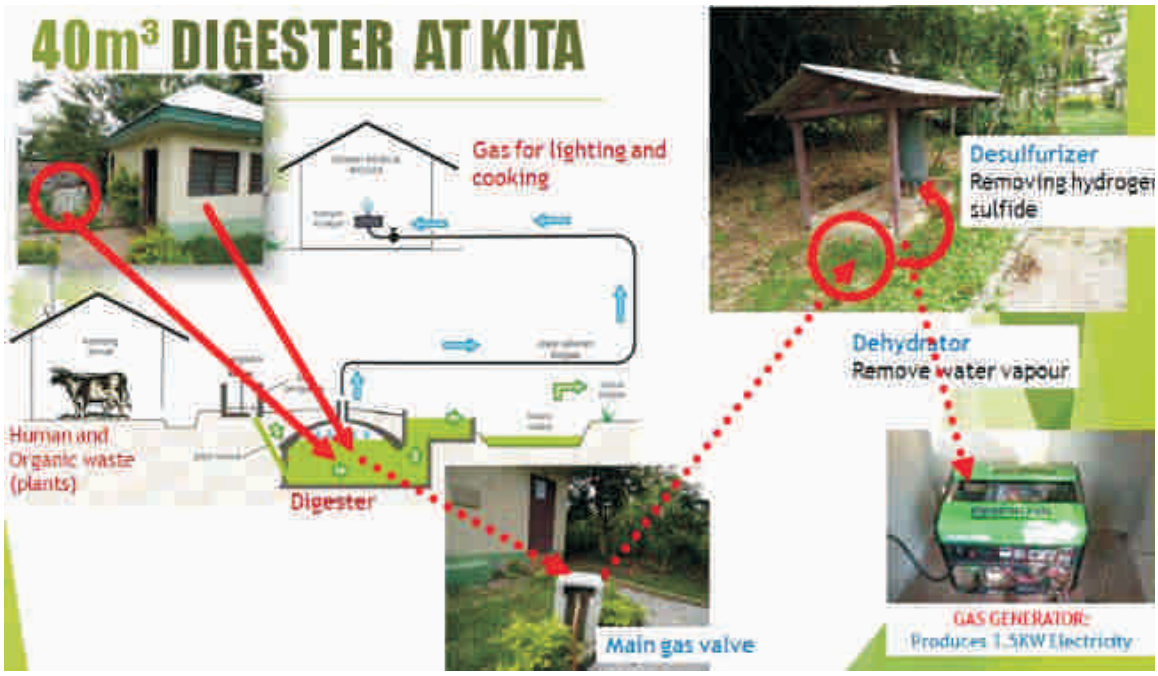
Key findings and observations

- The biogas facility has a 40m^3 fixed dome digester with a gas holder and effluent storage.
- The biogas is used to power a 15 kVA generator to generate power for lighting on campus.
- The biogas has also displaced the use of firewood as fuel for cooking in the kitchen.
- Feacal matter from a 9-seater toilet facility is connected to the digester as feedstock. Pig dung is occasionally used for inoculation.
- Cost of facility - GH¢ 70, 000.
- Date of construction – May 2015.
- The GPS coordinates - N6°40'34.0824", W1°30'9.198"

Challenge

- The major challenge is the low pressure of the biogas FROM THE SYSTEM (the pressure dropped when the attendants fed the digester with fruit waste from the system without slicing them).

Left: Gas holder. Middle top: 15 kVA biogas generator. Middle bottom: Spent sludge holder. Right: Underground digester head.



Layout of the Biogas Plant at KITA

Figure 6: Biogas Plant at the Kumasi Institute of Tropical Agriculture

Kumasi Abattoir Biogas facility

The Kumasi Abattoir is set to host a pilot biogas plant as part of a nationwide project by the United Nations Industrial Development Organisation (UNIDO) to produce energy from bio waste. The biogas plant would be the first in the UNIDO Biogas Project, a 1.28-million-Euro project, to boost renewable energy in Ghana. The construction of the raw material tank, the digester and the machine room was under way by the time the team visited the site at Kaase in Kumasi in 216.

Key findings and observations

- The project is being implemented by The Energy Centre (TEC).
- The 200m^3 biogas facility is estimated to produce 150m^3 of gas per day.
- Bio waste from the abattoir will be used as feedstock for the digester.
- The biogas produced will be used for singeing cattle.
- Plans have been made to acquire a gas holder and a 30 kVA biogas generator for power generation.
- The spent sludge will be used to produce compost and liquid fertiliser for a fish pond on site.
- The initial design of the facility does not include a compensation tank for the spent sludge.
- The GPS coordinates - N6°39'37.0692", W1°36'13.6548"

Figure 7: Civil works for a biogas facility under way at the Kumasi Abattoir

Ntiamoah Hotel Biogas Facility

Ntiamoah Hotel is located at Agona-Swedru in the Central Region of Ghana. The hotel has a biogas facility constructed by Beta Construction Engineers Limited to provide gas for the kitchen. It is one of the few biogas systems that were in operation during the visit by the team.

Key findings and observations

- The hotel has a 10m³ biogas facility with effluent storage.
- The facility was constructed in 2007 by Beta Construction Engineers Limited.
- Mowed grass, urine and faecal matter from the hotel is used as feedstock for the digester.
- Cow dung is occasionally used to inoculate the digester when gas production level drops.
- There is no gas holder for storage of biogas.
- The spent sludge is pumped from the effluent storage for watering the hotel garden.

Challenges

- Spoilt flow meter and broken down effluent storage pump.
- Excess gas is released into the atmosphere as there is no gas holder for storage.

- *Lessons learnt and recommendations*

- The hotel no longer uses their septic tanks as the hotel sewerage is treated in the digester.

Figure 8: Biogas Plant used to supplement LPG in cooking at Ntiamoah Hotel

(Left: Biogas digester with inlet and outlet chambers. Top right: Effluent storage chamber. Bottom right: Fire ignited from biogas on special biogas stove)

Ejura Slaughterhouse Biogas Plant

A biogas plant was built to treat the slaughter waste and to produce biogas for singeing cattle in the year 2000 as part of a project funded by GIZ and implemented by TEC for the Ejura District Assembly. The facility was a boon to the slaughterhouse because of the savings in firewood which was hitherto used for singeing cattle. This project fell into disrepair in 2005 and has not been rehabilitated since.

Key findings and observations

- The facility is a 50m³ twin bio-digester.
- The biogas facility has been inoperative since 2005.
- The butchers lamented that even with the minimal charges for the killing of cattle and sheep (GH¢2 for cattle and GH¢1 for sheep), people still kill these animals in their homes for commercial purposes even though it is against the District Assembly bye-laws.

Figure 9: Initial state of the Biogas Plant at Ejura

- They also reported that people prefer skinning over singeing cattle.
- The excess gas was stored in a gas holder as it was not being used for singeing cattle. However, due to the unregulated gas pressure, the gas holder exploded.
- It was realised that the digesters were filled with sand as the place gets flooded anytime it rains.

Figure 10
: Ejura Slaughterhouse Biogas Plant choked with sand and rubbish

- GPS coordinates: N7°22'42.5892", W1°20'59.9208".

Lessons learnt and recommendations

- The lack of a clearly defined ownership structure contributed to the failure of the project. No one takes responsibility for the maintenance of the facility due to the absence of a proper business model for running the facility.

Biogas Digester for Energy Generation from Shea Waste

A biogas plant has been constructed at the Cocoa Research Institute of Ghana's Substation at Bole in the Northern Region, through a collaboration between Biogas Engineering Limited and the Cocoa Research Institute of Ghana. The project started operating in 2011. The goal was to demonstrate the feasibility of generating methane gas from processed waste of shea butter to replace firewood in traditional shea butter processing.

Figure 11: Biogas digester with shea waste as effluent

Figure 12: Fire on biogas stove for parboiling sheanut

Key findings and observations

- The 50m³ biogas plant generates 12m³ of biogas daily for running a dual-fuel shea milling machine.
- Roasting the shea kernels using biogas as fuel reduces the dependency on firewood.
- Supplementing diesel with biogas for running the mill has cut-down expenditure on fuel.
- Four attendants run the facility.
- Initially, a gallon of diesel could last for almost six months when supplemented with biogas, now the same quantity of gallon lasts for less than four months at the same level of production.
- The GPS coordinates: N 9°1'27.1992", W 2°30'29.0124".

Challenges

- The processing facility reeks of hydrogen sulphide (H2S) as the H2S scrubber is multifactional .
- Cracks in the digester also causes leakage of gas.
- Difficulty in finding replacement for damaged flow meter.

Lessons learnt and recommendations

- This technology proves to be an economic way of treating shea butter waste and also taking away the drudgery in shea butter processing

Tamale SOS Village Biogas Plant

Tamale SOS Village is an orphanage located in the Northern Regional Capital City. It serves as a home and school for children who have lost parental care or at risk of losing it. The village is managed by the Department of Social Welfare in Ghana. Installed on its premises is a 70m^3 biogas plant with effluent filtration system constructed by Beta Construction Engineers Limited.

Key Findings and Observations

- The biogas facility was constructed in 2009, with the purpose of providing gas for cooking.
- Funding came from a German Organisation.
- The feedstock for the digester was mainly faecal matter and left over foods.
- The plant broke down in 2012. This was due to water entering the pump and blockages of the channels.
- The GPS coordinate is N 9°21'49.09", N

Tamale SOS biogas plant

Challenges

- The site of the installation often gets flooded resulting in water entering the pump.

Recommendations

- The surface pump should be replaced with a submersible pump as that can withstand the inflow of water.
- Savings in LPG made from using the biogas facility should be used to maintain the system.

Effluent filtration system for SOS biogas plant

Mfantsipim Senior High School's Biogas Plant

Mfantsipim Senior High School located in Cape Coast has a 200m^3 biogas facility with effluent filtration system which is fed by a 16-seater toilet facility. This facility was constructed in 2011 by Beta Construction Engineers Limited with funding from the Mfantsipim Old Boys Association. There are two units of the facility. However, one is not operational due to an accident that caused a crack in one of the digesters.

Key findings and observations

- The biogas facility is of the fixed dome type.
- Filtered effluent is pumped to an overhead tank for flushing toilets on campus.
- The spent sludge is channeled to the gardens as fertiliser.
- Gas lamps in the toilet facility is powered with biogas.
- Gasholder was punctured and deflated at the time of visit.
- The school has a 350kVA biogas generator which is not being used.

Challenges

- Difficulty in washing the effluent filtration system.
- No flow meter is installed to quantify gas production which will help troubleshoot gas leakages.
- Clogging of pipes.
- Lack of maintenance of the facility.

Lessons learnt and recommendations

- Gas can be channeled to the kitchen to offset the use of LPG for cooking.
- A model could be adopted where the savings in LPG is used for maintenance

16-seater biogas toilet facility

Biogas digesters with effluent storage and pump

Biogas Plant at Mfantsipim School

Safi Sana Ghana Limited

Safi Sana Ghana Ltd has embarked on a biogas project at Adjei Kojo in Ashaiman to generate biogas for electricity generation to the grid. The facility generates gas that is used to run a generator supplying electricity to the grid. The installed capacity is 0.1MW

Key findings and observations

- The project was funded by a 2.5 million Euro grant.
- The biogas plant has a capacity of 2500 m^3 and generates 1000 m^3 of gas daily
- Faecal matter, slaughter waste and organic waste from the market are sourced to feed the biogas digester.
- The treated effluent is used as bio fertiliser for growing seedlings which is later sold as additional revenue stream.
- Safi Sana sells electric power generated to the grid

Challenges

- Difficulty in getting a PPA for replicating the project in other regions
- Poor quality of waste – waste segregation not practised in the country
- Difficulty in acquiring land for similar projects

Recommendation

- Legislate and create incentives for separation of waste for energy purposes to reduced the high cost of sorting

Figure 137: Waste-to-Energy Plant at Safi Sana Ghana Limited

Ghana Oil Palm Development Company (GOPDC)

GOPDC is located at Kwahu in the Eastern Region of Ghana. The company is now wholly-owned by Societe d'Investissement pour l'Agriculture Tropicale of Belgium but was formerly owned by Ghana. It has about 22,500 hectares of oil palm plantations at its Kwae and Okumaning estates in the Eastern Region, which spread over a radius of about 23km.

The processing plant produces 210,000 tonnes of oil per year. Presently, GOPDC operates the largest biogas facility in the country.

Key findings and observations

- GOPDC supplies the Kwae community with power generated from a biomass-fired cogeneration plant.
- Biomass solid waste (palm fruit fibre and kernel shell) from the processing plant is fired to run a steam turbine generator.
- GOPDC has the potential to generate 4MW but currently generates 2.5MW. It also has a spare 1.5 MW turbine generator.
- The company also has a 2 x 10,000 m^3 biogas plant which produces biogas for the boilers in the refinery plant with 1 x 12,000m^3 biogas storage
- The plant has a treatment installed capacity of 160,000m^3/POME/year with a Potential biogas production of 4,000,000 NM^3/biogas/year
- The installation of the biogas plant was completed in September 2014, by contractors from South America and funded by GOPDC.
- The cost of the biogas plants 4.5 million euros and that of biomass plant is 3.5 million euros.
- The biogas plant produces 18,000 m^3/day for the plant. This has displaced the 615,000 litres of diesel that was previously consumed by the plant per year.

Challenge

- The facility has the capacity to generate 4MW worth of electric power. However, full scale generation is limited by the production of palm.

1000m^3 biogas reactor.

Figure 16:
Biomass Cogeneration and Biogas Plant at GOPDC

Lessons learnt and recommendations

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

Biomass Cogeneration

Biomass fuels are typically used most efficiently and beneficially when generating both power and heat through a Combined Heat and Power (CHP or Cogeneration) system.[6] A typical CHP system provides distributed generation of electrical and /or mechanical power, waste-heat recovery for heating, cooling or process applications. The oil palm companies in Ghana have been in the vanguard of this technology as it proves to be an economic way of utilising processing waste to generate energy.

[6] http://www.bioenergyconsult.com/tag/what-is-biomass-cogeneration/

Benso Oil Palm Plantation (BOPP)

Benso Oil Palm Plantation Ltd is a Ghana-based company engaged in the processing of palm fruits to produce palm oil and palm kernel oil. It is a subsidiary of Wilmar Africa Limited. The company is based at the Adum Banso Estate in Takoradi with a nucleus planted area of about 6799 ha.

Key findings and observations

- BOPP operates a biomass-fired cogeneration plant.
- Palm kernel shell and fruit fibre are fired in a 13.6 tonne/hr boiler to generate steam.
- Steam generated runs a 500kW turbine to generate power for the plant.
- Averagely, BOPP produces 18,000 tonnes from 85,000 tonnes of raw materials per annum.
- The mill is self-sufficient in fuel and power (95% plant efficiency).
- Treatment of liquid waste is yet to be explored. The liquid waste is applied on the plantation as fertiliser.

Figure 14: Biomass Cogeneration Plant at Benso Oil Palm Plantation

(Left: biomass boiler. Top right: 500kW m turbine generator. Bottom right: back-up diesel generator)

Twifo Oil Palm Plantation (TOPP)

Twifo Oil Palm Plantations Limited is located at Twifo Ntafrewaso near Twifo Praso, in the Central Region of Ghana. The company has a Nucleus planted area of 4234 ha. The Government of Ghana has about 80% shares in the company. TOPP produces crude palm oil and palm kernel. While all the produced palm oil is absorbed by Unilever Ghana, they sell off the palm kernel to Benso Oil Palm Plantation because of the unavailability of the kernel oil processing facility.

Key findings and observations

- TOPP operates a biomass-fired cogeneration plant.
- Palm kernel shell and fruit fibre are burnt in a 15 tonnes/hr boiler to generate steam.
- Steam generated runs a 1500kVA/1200kW turbine to generate power for the plant.
- The turbine utilises just about 50% of the generator capacity (currently generates 610kW).
- The construction of a new boiler (25 tonnes/hr) sized to match the turbine was underway at the time of visit.
- Averagely, TOPP produces 14,000-16,000tonnes of oil from 75,000-90,000tonnes of raw materials per annum.
- The mill is self-sufficient in fuel and power (90-97% of energy from the CHP).
- Treatment of liquid waste is yet to be explored. The liquid waste is applied on palm plantation as fertiliser.

Figure 15: Biomass Cogeneration Plant at Twifo Oil Palm Plantation

(*Left: biomass boiler. Middle top: 1500kVA steam turbine generator. Middle bottom: back-up diesel generator. Right: civil works for new boiler under way)*

Juaben Oil Mills

Juaben Oil Mills is a privately wholly-owned Ghanaian company established in 1981 and currently operates a 15 tonne/hour palm oil mill, 125 tonne/day palm kernel oil mill, 50 tonne/day palm oil refinery and fractionation plant and a nucleus of 425 hectares and 1000 hectare outgrower plantation.

Key findings

- Waste products of palm fibre/shells and spent bunches are used to run a 10 tonne/hr boiler and 475 kVA turbine
- The company supplies power to the Juaben community water pumping station to pump water to the community. The company, however, sometimes have to knock off power from sections of the plant for this.
- Juaben Oil Mill is self-sufficient in power and fuel.
- A diesel genset is used to start-up the plant before changing over to run on power from the cogeneration plant.
- The company is exploring the option of developing biogas technology to treat liquid effluent from the plant.
- Management in the past consulted the Ministry of Energy for support in establishing a biogas system. However, the plans for the project halted along the line. Thus, the management of the company are seeking for support in developing the biogas plant.

Project team with a representative from the research unit and the technical director of Juaben Oil Mill Ltd at the refinery plant

Challenges

- High cost of operating diesel genset.
- Inadequate funds for the construction of the designed biogas plant for the treatment of the POME

Key findings from Obooma Farm Products Ltd.

Obooma Farm Products Limited (OFPL) is a privately owned Ghanaian company that specialises in the cultivation of oil palm and the extraction of crude palm oil and palm kernel. Below are key findings from the company:

- Obooma Farm was incorporated in 1972 and started production of palm oil as a micro-mill in 1973.
- The company operates a 15mt/hr fresh fruit bunch palm oil mill and 3mt/day palm kernel oil mill.
- A 6t/hr boiler is used for generating steam for processing of the palm fruit. The company has, however, began civil works for the installation of a new boiler with the capacity of 10t/hr.

Left: 6t/hr boiler Middle: Civil works for boiler expansion, Right: Preparing palm fruits for processing

- Unlike other medium-large scale palm oil processing companies, Obooma Farm is not self-sufficient in power and energy as the company does not have a turbine for generating electricity. The company relies solely on the national grid for electricity.
- Management has a plan of acquiring a turbine for electricity generation in the near future.
- While solid waste (palm fruit bunches, kernel shell and chaff) from the processing are used to fuel the biomass boiler, handling and treatment of the POME poses a big challenge to the company, especially in the peak season when the plant operates at optimum capacity.
- In the quest of managing the POME, the company has dug two huge ponds with the depth of 25m and areas of 30625m^2 and 39375m^2 to contain the effluent. However, the powerful stench from the ponds create nuisance, especially in the raining season when ponds overflow to the surrounding lands.
- The company is seeking a solution to the POME handling challenges and shows interest in biogas technologies that can treat their waste and generate energy from the POME for the processing of palm oil and kernel oil.

POME ponds and palm oil recovery pond

Biomass Combustion

Woodfuels, consisting of firewood and charcoal, constitute the most important energy forms in Ghana. It contributes about 60%[7] of total energy consumption in the country. It is used mainly for cooking and the demand is twice as large as the other energy sources, including LPG and electricity.

Various methods have been used in wood carbonisation (commonly referred as charcoal burning) , Some of these methods are crude with low yield and very limited control of the quality of the charcoal produced while others are highly automated (e.g. retorts). Higher charcoal conversion efficiency and quality can be achieved through proper control of the carbonisation process. The most common methods of charcoal production today are earth kilns, masonry and metal kilns.[8]

While some improved charcoal production technologies have been tested and demonstrated in pilot projects across the country, the use of these technologies are limited owing to the high initial capital cost. However, the raw materials and expertise for manufacturing are available locally with organisations such as Gratis Foundation (which has the capacity to produced) charcoal kilns. The energy commission maintains a list of all licensed charcoal producers.

[7] Bioenergy Policy for Ghana, Energy Commission, August 2010.

[8] Oduoe, N., Githiomi, J. & Chikamai, B. (2006) , Charcoal production using improved earth, portable metal, drum and casamance kilns ISBN 9966-776-06-0

Best Carbon Ghana Limited

Best Carbon Ghana Limited is a manufacturer of carbonised, clean and smokeless wood charcoal for export and it is located at Ewiadaso near Daboase in the Western Region.

Key findings and observations

- Offcuts used for the production of charcoal for export are supplied by SOCFINAF to Agyeben & Associates Limited who in turn produce the charcoal specifically for Best Carbon Ghana Limited.
- The facility uses 11 locally manufactured kilns for carbonisation.
- Each kiln can produces 30 bags of charcoal per production cycle
- Best Carbon plans to export all charcoal produced to Germany.
- Charcoal dust is disposed off after carbonisation.

Challenges

- The main challenge faced by Best Carbon is the poor road access to plantation for feedstock.

Lessons learnt and recommendations

- Charcoal dust can be processed into briquettes, which is of a higher market value.
- Encourage timber concessionaires to utilise forest and sawmill off-cuts for woodfuel production.
- Collaborate with Forestry Services Davison to enforce regulations on the control of fringe communities in the harvesting and sale of the woodfuel in the forest reserve.
- Strengthen through technical assistance existing institutions for testing and certification of improved production and end use technologies for woodfuel.

Figure 17: Best Carbon's charcoal production facility at Daboase

(Top left: Charcoal dust residue at the base of a kiln. Top right: carbonised charcoal stored under a shed. Bottom left: Kilns for carbonisation. Bottom right: offcuts from timber and sawmill contractors)

Oskan Industries Ltd

Oskan Industries Ltd is a producer of high quality carbonised and semi-carbonised clean and smokeless wood charcoal for the local market and export. The company operates as a subsidiary of Energy Pool Limited. The charcoal production facility is located at Gomoa Onyadze-Ostew.

Key findings and observations

- Oskan Industries Ltd's charcoal production site is located at Winneba.
- The company operates with 10 kilns (including one exported from Poland)
- The kilns were manufactured by the Gratis Foundation in Accra.
- Each kiln can produce about 50-60 bags of charcoal per production cycle (about 1.925 tonnes).
- The estimated cost of a standard sized kiln is about GH¢ 7,000.
- An average of 50 tonnes of charcoal is exported per month and 350 bags are sold to the local market per week.
- Charcoal is exported mostly to Middle Eastern countries such as Oman, Bahrain, Kuwait, Turkey, etc.
- Oskan engages the Forest Research Institute/KNUST to test the carbon content of the charcoal produced.

Challenges

- The main challenge faced by Oskan industries is the high initial cost of the charcoal kiln.

Lessons learnt and recommendations

- Establish standards and operational procedures for woodfuel operators; (non-compliance to these would attract the necessary sanctions).

Figure 18: Oskan Industries charcoal production facility at Gomoa Onyadze.

(From left: Exported kiln from Poland, locally manufactured kiln, offcuts)

Solar Dryers

Solar dryers are used for preserving agricultural produce. They were invented several decades ago and have been disseminated and used in Ghana and other countries for many years. Over the last few years, applied research and development have been ongoing in Ghana. Small-scale experimental units have been built in the country's universities and research institutions. Large scale units have been piloted for close to a decade now, but this has failed to move into wider dissemination.

The Agricultural Engineering Services Directorate (AESD) of the Ministry of Food and Agriculture (MoFA) has led efforts towards the development of solar dryers in Ghana. These dryers are largely manufactured from local materials and built in mostly farming communities in Ghana.

Ejura solar-biomass hybrid dryer

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

Key findings and observations

- The solar biomass hybrid dryer was built by Pens Food Bank, in collaboration with the Agricultural Engineering Department of KNUST, in July 2015.
- The total cost of the facility is USD 18,000. The project was funded by Pens Food Bank Ent. (20%) and a UK-based organisation (80%).
- The project was implemented by The Energy Centre (KNUST).
- The dryer can be used for drying 5mt of produce per batch (2 batches/day) for 8 hours.
- The biomass furnace uses 30 kilos of corn husk for drying harvests per batch during the major season.
- The biomass furnace pump and the air circulation fans in the dryer are powered by solar PVs.
- The drying tariff of the solar biomass dryer is GH¢4. This is way cheaper than the GH¢20 that was initially charged for drying with the mechanical dryer.
- Pens Food Bank plans on expanding the facility in order to increase their drying capacity.

Figure 19: Solar-biomass hybrid dryer at the Ejura market

Challenges

- The solar panels for the air circulation fans are very expensive.
- A 4X12ft Perspex glass cost about GH¢300-500. This makes the construction of a dryer with a larger capacity an expensive venture.

Lesson learnt and recommendation

- More farmers patronise the facility because it is cheap and provides premium grains which gives them better prices.

Ejura-Sekyedumase solar dryer

The Ejura-Sekyedumase solar dryer project was funded by GIZ and built in the Sekyedumase market in the Ashanti Region in 2004. Farmers in the Sekyedumase District use the facility to dry farm produce such as pepper, maize, cassava chips, etc.

Key findings and observations

- The facility is managed and operated by the Nyame ne Boafo Farmers and Buyers Association in the Sekyedumase District.
- The dryer has the capacity to dry 135kg of harvest per batch. Depending on the moisture content, it takes about 3-4 days for complete drying of produce.
- The drying tariff is GH¢2 for the association members and GH¢4 for non-members.
- As at the time of the visit in 2016, the solar dryer had been inoperative since 2014.
- According to the association, the perspex glass were shuttered after a heavy rainfall in 2014 rendering the facility inoperable.
- The solar dryer design is such that there is only one vent at the base. The lighter hot air is, therefore, trapped at the apex of the dryer. There is therefore poor air circulation and temperature regulation which leads to the cracking of the perspex glass.

Challenges

- Even though the facility was inoperable at the time of visit, the Nyame ne Boafo Farmers and Buyers Association were making efforts to revive the project through a cost sharing mechanism between the association and the project sponsor, GIZ.

Dilapidated state of the dryer after windstorm

Lesson learnt and recommendation

- It was realised that the association carried out maintenance on the facility not long before the failure of the infrastructure. This might have been done with little technical knowledge hence, the failure. Technical training is, therefore, recommended for beneficiaries of such projects.

Sekyedumase solar dryer showing shuttered glass

Bonsu Solar Dryer

The Bonsu Solar Dryer project was funded by GIZ and built in Bonsu, a small town in the Brong-Ahafo Region of Ghana in 2012. The facility is used to dry maize, cassava chips, pepper and the like. This facility has saved Bonsu farmers from the drudgery of the open air drying and improved the quality of dry grains produced

Key findings and observations

- The dryer is managed and operated by the Nkoranza Maize Farmers and Buyers Association.
- The facility was built by the Agricultural Engineering Services Directorate of the Ministry of Food and Agriculture
- The dryer has the capacity to dry 145kg of harvest per batch. Depending on the moisture content, it takes about 3-4 days for complete drying of produce.
- The drying tariff is GH¢2 for the association members and GH¢4 for non-members.
- A carpenter delegated by the association is trained to maintain the dryer. This accounts for why the facility is still operational at the time of visit.

Figure 20: Bonsu solar dryer

Solar Irrigation Systems

Irrigation plays an important role in providing increased yield and year - round supply. The Ghana Irrigation Development Authority (GIDA) and the Irrigation Company of Upper Region (ICOUR) have supported development of several communities over the years. Solar irrigation systems are, however, yet to enjoy such a wide dissemination. Recently, UNDP launched a programme which saw the installation of solar-powered irrigation pumps in some communities in northern Ghana. GIZ and SNV have also supported the development of small-scale solar irrigation systems, which provide some cost saving under the ENDEV project.

With Ghana being one of the first countries to embark on the Sustainable Energy for All (SE4ALL) initiative, it is expected that solar-powered irrigation pumps will be sustained, replicated and scaled up to provide more self-employment opportunities for the youth in farming and help make Ghana the bread basket of Africa.

Solar Powered Irrigation Schemes – NewEnergy.

NewEnergy, a local-based NGO, with support from the Energy Commission and UNDP Ghana under the auspices of the SE4ALL initiative, has implemented four Solar Powered Irrigation Systems in Northern Ghana. The irrigations systems took three months to construct and was completed in December 2014 at a cost of USD 200,000. The goal of the project is to make sustainable energy for irrigation easily accessible and affordable to smallholder farmers. These systems are located in Datoyili, Fooshegu, Nankpanduri and Tamalugu.

Solar Irrigation System at Datoyili

Key findings and observations

- The irrigation system is equipped with a 2.3kW solar PV array and Lorentz DC pump together with accessories.
- Water is sourced from a nearby dam that is able to withstand the dry season.
- Furrow and drip irrigation techniques are used.
- About 12 farmers forming a cooperative are benefiting from the installed solar irrigation system. These farmers take shifts in watering their farms and payment is done only on days they use the system.
- Farmers pay GH¢5 daily to use the system per acre of land. Those with smaller farms are, however, grouped together to use the system on specific days at a different rate.
- The system is cheaper than operating a diesel powered pump for irrigation.
- There is ready access to the system for irrigation. Farmers can also use the system on credit.
- Payments from utilisation goes to New Energy which is responsible for the maintenance of the system.
- The solar powered pump could do up to 30 acres of drip irrigation.

Challenge

- Owners of neighbouring farms, especially the women, have expressed interest in using the facility, however, due to the limited capacity of the pump this has not been made possible.

Figure 21: Datoyoli solar irrigation set up

Lessons learnt and recommendations

- In replicating such installations, a submersible pump should be employed as the area is known to flood during the rainy season.
- The capacity of the pump and the panels should be increased in similar projects to make room for expansion.
- Farmers should be trained on simple maintenance practices.

Solar Irrigation System at Fooshegu

Key findings and observations

- The irrigation system was equipped with a 1.5kW solar PV array and DC pump.
- Water for irrigation was sourced from a nearby lake, which usually dries up during the dry season.
- At the time of the visit, the DC pump for irrigation had been removed and the pipes were lying idly on the ground. The solar PV array was, however, present on site.
- It is difficult getting farmers to form co-operatives to operate and manage the facility. In view of this, New Energy has made plans of relocating the facility to another community.

Challenge

- Due to decreasing water levels during the dry season the pump is not operated since the likelihood of drawing mud is high which could damage the system.

Lessons Learnt and Recommendations

- Farmers should be educated on how to put schemes in place that will enable them to pay for the use of the system and further take ownership.
- The use of underground water should be explored to address the situation when surface water dries out during the harmattan season.

Figure 22: Fooshegu solar irrigation system set up with dismantled pump

Solar Irrigation System at Tamalugu

Key Findings and Observations

- The irrigation system at Tamalugu is equipped with a 15kW DC pump with advanced communication and monitoring capabilities which enables the user to monitor and control the operation of the pump remotely via the internet.
- The DC pump is capable of delivering 166,000 litres of water per hour with maximum torque.
- Irrigation technique is furrow. This is not very efficient, therefore, the farmers are being encouraged to purchase drip irrigations kits.
- The system is capable of doing twenty eight (2-8)acres of furrow irrigation and about three (3) acres of drip irrigation
- Water for irrigation is from a tributary of the White Volta, whose level reduces during the dry season.
- Among the maintenance practices are plumbing works and periodic cleaning of the panels.
- The farmers have formed a co-operative made up of 17 men and 20 women.
- Each farmer pays GHS100 per acre for the whole season.
- Prior to the installation farmers invested most of their earnings on purchasing diesel for their pumps.

- *"Iddrisu Abubakari could produce five (5) bags of onions from five (5) acres of land in the wet season, but with the solar irrigation system he is able to produce more than five (5) bags of onions from a quarter acre of land in the dry season".*

Challenges

- The pumping pressure is low, therefore, the irrigation system is capable of doing only 1 hectare of drip irrigation.
- Owners of neighbouring farms had expressed interest in connecting to the system but they had been denied due to the limited capacity of the pump.

15kw solar PV at Tamalugu

30kw pump for irrigation

Lessons Learnt and Recommendations

- For sites that are prone to flooding a submersible DC pump should be used.
- In replicating such solar powered irrigation systems, the capacity of the pump could be increased to make room for expansion.

Aveyime Irrigation Scheme

The Aveyime Irrigation Scheme was started in 1962 at Aveyime, a village in the North Tongu District of the Volta Region of Ghana. The construction was done by Nippon Koei of Japan. It has a gross area of 760 hectares and a net irrigable area of 54 hectares. It is a project along the Volta River. Through a pumping system, water is lifted through a canal system to the paddy field. The main crop is rice and some okro.

Key findings and observations

- The project uses a combination of pumps and gravity flow system for water distribution from the Volta River. Three 38 kW asynchronous motors are used for water pumping to field.
- Before 2015, the pumping station relied solely on the grid for power for lifting water to the paddy field. A solar system has since been installed to power the pumps during the day by a Chinese company.
- The capacity of the solar system is 50 KW (200 solar modules with unit 250 W rating) without battery storage.
- The pumping station is managed and operated by GIDA. The Chinese company installed the solar system as part of their research into the viability of solar irrigation for the various irrigation schemes in Ghana.

Recommendations

- This solar system proves to be very viable for such irrigation schemes as water is mostly lifted for irrigation during the day, particularly in the dry season when the sun energy is abundant.
- A net metering scheme could be used to offset power consumed from the grid in order to cut out the idle time of the solar system.

Challenge

- A key challenge is developing a good business model to recoup investments.

Central Gonja Community Water Pumping

Two solar water pumping system were installed in December 2016 at Buipe to provide water for the Central Gonja District Assembly. The systems were installed by Pumptech Company Ltd. near the Buipe police station.

Key findings

- 3 kW PV (250W X 12) powering PS 2 – 1800W Lorentz pumps installed.
- Borehole as water source.
- 2,690 m^3 of water pumped at the time of visit.
- The facility is managed by a pump attendant with overarching supervision from Pumptech.
- System requires little maintenance.
- Reservoir available to store water during rainy season.
- Existence of a grid electricity water pumping station to complement solar pumping station.

Central Gonja solar community water pump station

Challenges

- Low water level in borehole during the dry season

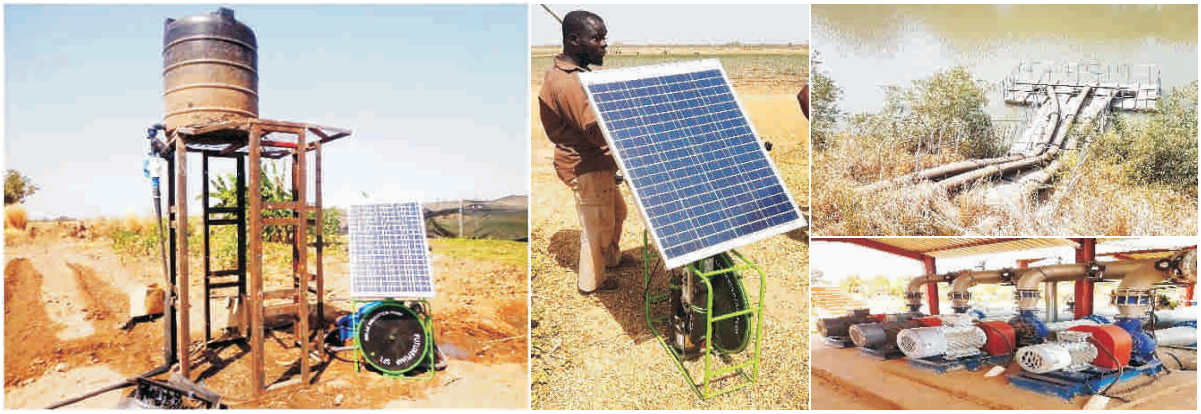
Integrated Water Management and Agricultural Development – Centre Pivot Irrigation

The Integrated Water Management and Agricultural Development (IWAD) Ghana limited was created in 2011 as a department under Wienco Ghana Ltd to lead the implementation of the Sisili-Kulpawn Irrigation project at Yagaba in the Upper East Region of the country. The core mission of this project is to expand the commercial viable irrigation practices in the Sisili-Kulpawn basin through the delivery of high quality irrigation support, new technology development, knowledge transfer, promotion of water use efficiency, sustainability and secure farmer revenues for both small holder and nucleus estates.

Centre pivot irrigation – turning parched lands into viable lands for agriculture at Yagaba

Key findings

- IWAD has acquired 800 hectares of land (leased for over 50 years) for the project
- The Sisili-Kulpawn irrigation project was started in 2014
- There are four centre pivot irrigation systems installed, each covering an area of 65 hectares
- 3 X 75 kW pumps is used to lift water from the Sisili-Kulpawn river to an 18000 m^3 reservoir from whence a similar pump house is set to pump water to the centre pivots. A 300 kVA genset is used to power the systems because of the high cost of running on grid power
- There are also five sprinkler irrigation systems developed over an area of 90 hectares
- The crops cultivated on the farms include onion, sugar cane, pepper and tomatoes.
- An 80 W solar future pump has been acquired by the project manager for demonstration purposes. This pump is portable and can operate on small holder farms. It has the capacity to lift water from a borehole into an overhead tank for drip irrigation at the nursery. The company however seeks a similar but more efficient technology as it proves to be very economical for small scale irrigation
- A four-acre land has been allotted for the installation of solar PV to connect to the grid possibly through a net metering scheme to reduce the running cost of the irrigations



Future pump for drip irrigation and intake and pump house for the centre pump system pump house

Solar Water Purification and Community Project

Solar water distillation is an inexpensive low-tech technology that is used to provide alternative for pure drinking water. With the sun's energy, this simple technology can produce gallons of purified water for domestic use. This will replace any energy of the like that is used for purification. Solar water stills can also be used to provide hot water, which would replace the burning of fossil fuel or wood for boiling water.

This cheap but efficient technology could be used to purify water out of streams and rivers to provide water for remote communities without potable water for domestic use in developing countries.

Solar-Powered Water Purification and Irrigation Facility

NewEnergy has implemented a Solar-Powered Water Purification and Irrigation Facility at Nabogu in the Northern Region of Ghana. The facility was constructed with funding from the United States African Development Foundation (USADF), under the Power Africa Off-Grid Energy Programme. The facility is intended to provide clean water for 1000 inhabitants who rely on a tributary of the White Volta for their water needs. A very efficient purification technology called Advanced Multi-Stage Filtration and Reverse Osmosis is employed for water purification.

Key findings and observations

- The facility runs on a 5kW roof mounted solar panel powering 2 DC pumps and equipment for purification.
- 3kW is used to power a pump that supplies 120,000 litres of water daily and 2kW to power the water filtration system.
- The water drawn is stored in a tank for irrigating 3.5 acres of farm land and for filtration.
- The irrigation component is owned and managed by four farmers.
- Purified water has been tested to be free of bacteria and has a higher shelf life.
- Purified water is sold at 10 pesewas per 25 litres.
- The facility has been running since August 2015.
- The project was sponsored by USADF at a cost of USD 125,000, with USD 25,000 going into the irrigation component and the remaining for the water purification system.
- The installation of the facility also came with a significant training component where the attendants were trained on the maintenance of the system.

Challenge

- Maintenance cost of the purification system is high due to the periodic replacement of the reverse osmosis

(From top: Solar PV for powering filtration system, Reverse osmosis equipment for water purification, UV and filtering apparatus)

Figure 23: Solar water purifi cation at Bongo

Lessons learnt and recommendations

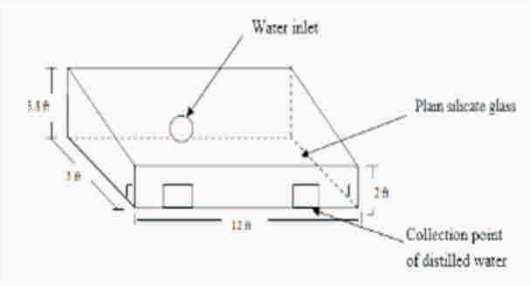
- Replicating this system would be very beneficial in rural communities in Ghana where access to clean water at an affordable cost is a huge problem.
- It is relatively easier to develop a scheme or business model that would cater for the maintenance of the system.

Bongo Solar Water Still

CEESD, with support from the Vodafone Ghana Foundation through its World of Difference programme, installed and inaugurated in two models of solar water stills at the Anafo Biisi Primary School in the Bongo District in the Upper East Region. The project was to solve the case of dental fluorosis. Dental fluorosis is discolourisation of the tooth enamel caused by injection of excessive fluoride during enamel formation endemic in the district by purifying the fluoride-contaminated underground water. The solar water still is a technology that makes use of the sun's radiation for evaporation of impure water and subsequently condenses the vapour into pure, distilled water. The solar water still purifies water by separating water from all contaminants including fluorides, salts, heavy metals, bacteria, arsenic and nitrates in the impure water.

Key findings and observation

- The facility was inaugurated in December 2006.
- Two solar water stills were constructed at a cost of GH¢ 380 to provide over 25 litres of water daily for 120 pupils in the Anafo Biisi Primary School.
- A borehole was sunk about 200m from the facility to provide water for the process.
- The project operated for a year and was successful in its purpose; however, it was not properly maintained and the system collapsed.
- It was observed during the visit that the glass covering the concrete water collection trough had been shattered.
- The GPS coordinates: N 10°49'9.6708", W 0°55'6.7692".



Schematic diagram of the solar water still at Anafo Biisi.

Initial State of the Solar water

Challenges

- During the period of use, the water was not sufficient to serve the increasing population of pupils at the Anafo Biisi Primary School.
- The facility was not well protected and was close to children play ground. The pupils played around the facility – throwing stones and destroying the glass.

Lessons learnt and recommendations

- The stills were constructed with readily available materials at Bongo with the exception of the glazing which consisted of plain silicate glass.
- The facility is cost effective and could easily be replicated to solve the pandemic at Bongo.

Pieces of the shattered glass found on the ground

- The facility should have been fenced to ward off little children.
- The problem of dental fluorosis is still prevalent in the district so the facility should be revived and the capacity increased to meet the needs of the increasing population.

The deplorable state of the water stills

Distrubuted Solar / Solar Battery Charging

Asekye Solar Charging Centre

Asekye is a small town near Dromakese in the Nkoranza South District in the Brong-Ahafo Region in Ghana. The town has a solar charging centre. The batteries charged are solely for home lighting, TV, cassette playing and radio operation. Another service provided with the solar power is the solar powered pump serving the community.

Key findings and observations

- The 300Wp PV and 850Wp inverter sized solar charging centre was built and completed on the 25th of October, 1998 by Deng.
- The project was funded by the Australian High Commission.
- Three additional chargers were later sponsored by DANIDA.
- The total cost of the charging centre was GHC 6,000. A charging fee of GH¢ 2 is paid to fully charge a battery.
- The 400Wp panel powering a DC water pump was also installed by DENG on the 28th of February, 2013.
- About 450 litres of water is pumped daily.
- The total outlay for the solar water pumping system was USD 20,000. A fee of five pesewas is charged for a fully filled 34 litre bucket.
- Construction of a solar water still with hot water storage was well under way at the time of visit. According to Mr Manu, the manager, the purpose of the solar still is to provide hot water for people in the community. This will replace the burning of firewood for hot water, especially in the evening.
- The entire residence of Mr. Atta Manu was powered with solar energy, with back-up batteries. Solar power was used for his home lighting, DC TV set, cassette and radio player, television decoder, DC refrigerator fans and even his wall clock. The solar water pump also provides his home with potable water. It was also observed that all the lamps used in the charging centre and his residence are energy efficient LED lamps.

Figure 24: Equipment at the Solar Charging Centre

Figure 25: Solar water pump and solar water still installed adjacent the centre

Figure 26: A solar freezer for commercial purposes.

Challenges

- Asekye was connected to the national grid in 2000. This access to power from the grid has reduced the patronage of the charging centre. However, some drivers still patronise the facility to charge batteries of their vehicles.

Wechiau Solar Battery Charging Centre

Under the off-grid electrification programme, the then Ministry of Mines and Energy established a 2.1kW solar battery charging centre at Wechiau in the Upper West Region. The battery charging centre comprised of 10 battery charging lines. As part of the project, 41 households were provided with 12V, 100Ah deep cycle lead acid batteries along with other PV solar home systems (PV/SHS) on a credit basis. Operators of the battery charging centre were tasked with charging batteries commercially and undertaking basic servicing of the installed PV/SHS. Monthly tariffs collected were deposited in a bank for the maintenance of the facility. Two indigenous groups were trained to operate and manage the facility.

Key findings and observation

- With the extension of the grid to Wechiau, the solar battery charging centre became redundant as the community abandoned their PV/SHS for relatively cheaper grid electricity continuous power supply.
- The centre has been turned into a community library.
- The whereabouts of the panels and other components of the centre were unknown. It was speculated that they had all been stolen.

Lessons learnt and recommendation

- There should also be a clear decommissioning plan for similar projects, especially in off-grid areas where there is close proximity to the grid in order to prevent theft of such equipment after grid extension.

Figure 27 : The Solar Battery Char ging Centre which is now the Wechiau Community Library

Figure 28: Initial state of the solar battery charging centre at Wechiau showing batteries being charged.

Source: Renewable Energy Policy Framework for Climate Change Mitigation in Ghana, REEP, July 2009

Utility Scale / Grid Connected Photovoltaic Plant

Volta River Authority's Grid-connected Solar Power Plant

The Volta River Authority (VRA), as part of its policy to establish a mixed renewable portfolio constructed a 2.5MW Solar PV Plant at Navrongo in the Upper East Region of Ghana. The plant works by converting the sun's radiation into direct current (DC) by the use of photovoltaic cells, offering a viable alternative to fossil fuels and natural gas due to its cleanliness. The DC power is subsequently converted to Alternating Current (AC) by a set of five inverters with an output voltage of 415V. This voltage is stepped up to 34.5kV and evacuated to the Navrongo substation for distribution by the Northern Electricity Distribution Company (NEDCO).

Key findings and observations

- Navrongo is located in the Kassena-Nankana District in the Upper East Region.
- The GPS coordinates: N 11°03'26.91", W 0°14'00.27".
- The plant was commissioned on 9th of May, 2013.
- Construction was done by China Wind Power at a cost of USD 8,082,025.
- The project was solely financed by VRA.
- 3,622 polycrystalline PV modules have been mounted, covering an area of 11.79 acres.
- Each panel has a rated power of 295W and rated current of 8.75A.
- Components of the solar plant also include 32 combiner boxes, five three-phase inverters, metering devices, anti-islanding devices, etc.
- The plant is designed to work autonomously. Generation shuts down automatically at night and in instances where plant output does not meet the minimum to feed into the grid.
- During the day the plant runs on power from its generation, however at night the plants relies on the grid to power relays and other protective devices.
- The plant also has a battery bank composed of 59 deep cycle batteries to provide power to relays and metering devices in the substation during total blackouts.
- Generation varies daily depending on weather conditions. The annual average peak generation is 10,000 kWh/day and peak generation occurs between 9 a.m and 2 p.m.
- The average solar radiation at Navrongo is 6.5 kWh/day.
- The plant was designed to have an overall efficiency of 80%. However, it currently operates at 70% efficiency.
- Maintenance practices include washing the panels twice a year and monitoring fuses in the combiner boxes.
- The plant has six workers who were trained by the developers of the plant to manage and operate the facility.

Solar panel array at the plant

The Plants substation

Weather station to explore the potential of CSP in the region

Officials of plant with the team

A personnel at the plant taking the team through the plant operations

The plant's control room where generation parameters and incidences are monitored remotely

Figure 29: VRA's 2.5MW Solar Plant at Navrongo

Challenges

- Speedy Replacement of equipment during emergencies is a challenge since most of them have to be imported.

Lessons learnt and recommendations

- VRA can acquire the additional acres of land behind the solar farm to expand the capacity of the plant.
- VRA is exploring the technical feasibility of deploying a Concentrated Solar Power (CSP) plant at Bongo. In view of this, the plant is also measuring and collating data on weather patterns daily.

BXC SOLAR PROJECT 20MW SOLAR PROJECT

BXC Ghana Limited is a subsidiary of Beijing Xiao-Cheng Electronic Technology Stock Company Ltd. BXC has established the largest utility scale solar project in Ghana. The installed capacity is 20MW and it has been feeding power to the grid since 2015. The project BXC is located at Gomoa Onyadze on a 150 acre land. The facility has installed 40,480pieces of PVs.

Solar PV Manufacturing

The renewable energy sector in Ghana, particularly the solar energy industry, has been primed with the establishment of a fewf solar PV manufacturing production lines in the country. This step of development is due to the enabling environment created by the government with incentives to attract private investment for the growth of the sector.

The established solar PV manufacturing companies, namely HALO Energy Industry Ltd and Strategic Power Solutions (SPS) Ltd are of the capacities of 5 MWp/year and 30 MWp/year respectively. Atlas Business Energy Systems (ABES) Ltd is another solar PV manufacturing company with a capacity below 1 MWp/year. Tradeworks Company Ltd is in the process of building a 10 MWp/year PV manufacturing plant in Accra but is yet to be commissioned for production. These companies essentially import the PV cells and other raw materials from the other countries and fabricate the panels in the country.

HALO Energy Industry Limited

HALO (Hold All Life Opportunities) Energy Industry Limited is located at the free zones enclave at Tema. The company was set up to boost the development of the RE sector in Ghana through the production of solar PV panels for the niche market in Ghana and other African countries such as Nigeria, Togo and Cote d'Ivoire. The company started operation in July 2016 with the financial support from its parent company, the HALO group in China.

Key findings

- The production line has a capacity of 5MWp per year. The cumulative capacity with the mother company in China is 30 MWp per year.
- Finance from the Halo Group in China – 25 million dollar project
- Halo Energy is located within the free zones enclave but not under the free zone policy and thus does not benefit from the incentives under the policy.
- The company supplies PV modules for government projects. Majority of the panels are however supplied to the private market in Ghana, Nigeria and other countries.
- Solar cells and materials for production are sourced from China and Europe. Equipment for the production process are also from the parent company in China.
- Power for the facility is supplied by Enclave Power Company. The company also uses a standby generator to support the production process.
- The company also designs solar systems for households and industries with an installation and maintenance licence from the Energy Commission.
- Halo Energy manages a showroom at Spintex in Accra to showcase their products.
- The company employs over 37 workers in Ghana. Supervision from Chinese experts is utilised during operations.
- The company plans to set up a similar facility in Kenya and other African countries

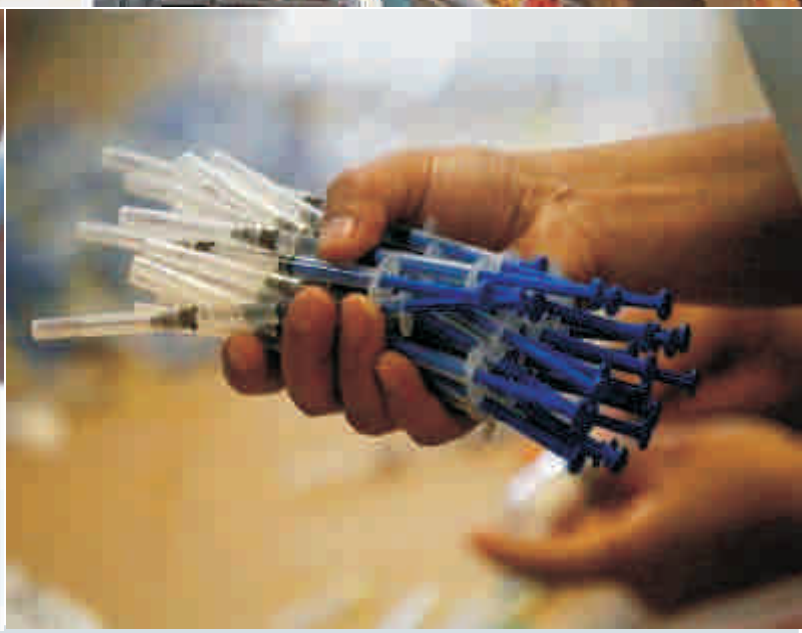
Challenges

- Cumbersome process in applying for tax exemptions on importation of materials and equipment for production
- The high cost of energy in the country makes it uneconomical to run high power equipment on the national grid
- The high cost of operation and production makes products uncompetitive with imported cheaper panels

Materials and equipment at HALO Energy PV production line facility

Recommendations

- The facility could be used to support the Ghana Standards Authority (GSA) for testing solar modules
- The company should consider registering under the free zones act to benefit from the extensive incentives under the policy



Solar Vaccine Refrigeration

Keeping heat-sensitive vaccines at the right temperature is crucial, yet often difficult in areas with limited or no electrical power or frequent long-duration power outage that makes the use of grid-powered cooling impractical for vaccine storage. About 80 solar refrigerators were installed in Ghana in the late 1980s, but they experienced a high failure rate (about 50%) soon after installation.

Several of the problems could be traced back to inadequate installation quality, fire-damaged components (possibly not using high-quality components rated to the expected electric loads), deteriorated solar-support structures, faulty wiring, heat-damaged solar panels (due to poor positioning of panels on roof) and shaded solar panels.[9] Considering the fact that there are still some remote areas in Ghana with no access to the grid, solar vaccine refrigerators could provide some health relief for inhabitants of such areas.

[9] Essandoh-Yeddu J., Performance study of solar photovoltaic refrigerator systems in Ghana, Ministry of Energy and Mines, Accra, Ghana (1994)

Solar Vaccine Fridges

Community-based health centres across the country have been equipped with solar vaccine fridges through the Community-Based Health Planning and Service (CHPS) initiative. The initiative was implemented by the Government of Ghana and supported by the European Union Micro-projects programme and the District Assembly.

It is in line with government's efforts to increase access to health care, particularly in underserved areas where patients have to travel long distances to the nearest health facility. Most of these communities do not have access to grid electricity, so they rely on solar fridges to preserve vaccines for the immunisation of babies and infants. The team visited two communities, namely Ga and Ducie, where these fridges were being used at their health centres.

Key findings and observations at Ducie CHPS

- Ducie is a small off-grid community in the Upper West Region of Ghana.
- A 12V/50W Waeco solar vaccine fridge was provided to store vaccines for immunisation.
- The vaccine fridge is powered by a 100W inverter.
- The presence of the vaccine fridge has made it convenient for the health centre to immunise infants against killer diseases.
- Without this facility mothers would have to commute a long distance to access such services from the closest health centre.
- The GPS coordinates: N 9°47'51.1116", W 2°29'31.7076"

Key findings and observations at Ga

- Ga is located in the Upper East Region of Ghana.
- A 12V/50W Waeco solar vaccine fridge was provided to store vaccines for immunisation of babies.
- The GPS coordinates: N 9°45'16.6", W 2°29'37.7".

Challenges

- For both health facilities the batteries of the solar vaccine fridges were reported to be very weak. It took a longer time to fully charge but discharges in a shorter time.

Lessons learnt and recommendation

- Providing solar vaccine fridges for off-grid communities is a laudable initiative as it does not only provide immense health benefits but also save mothers the time and cost of travelling long distances to access such services.

The solar vaccine Fridge being used at Ga

A 100W solar system provided to power a health center

Wind

Ghana has not had much success with large-scale wind energy project. The country could not boast of any commercial wind power project as of 2016. 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 (EC) with support from foreign countries. In addition, there have been several wind energy projects developed by several research institutions across the country.

However, these projects ultimately end up as prototypes for demonstration. From the year 2004, a few Poldaw wind pumps were piloted for water pumping by the Agricultural Engineering Services Department but were discontinued. However, with the available wind energy resource and proper mapping, wind power can be harnessed for energy generation.

Poldaw Wind-pump Technology

MOFA, through the Village Infrastructure Project (VIP) sponsored by the World Bank, acquired a franchise from NEALE Consulting Engineers to produce Poldaw wind pumps in Ghana. Local engineers and artisans from MOFA were trained and supervised to produce components for installation prior to the expiration of the franchise.

The manufacturing of these pumps took place at the Agriculture Engineering Services Directorates (AESD) Adaptive Trial Station (ATS) situated at Somanya in the Yilo Krobo municipality. At the end of the training period, about 20 Poldaw wind-pumps were fabricated and piloted. Some beneficiary communities include Gwollu, Tampezua, Kweiman, Mikleb Farms-Loye, Dawhenya and Akraman.

Poldaw wind-pump at Gwollu

Key findings and observations

- Gwollu is the capital of the Sissala West District in the Upper West Region.
- The wind-pump was designed to pump water from a borehole into a nearby concrete water reservoir to provide water for dry season irrigation.
- The Poldaw wind-pump has a turbine diameter of 3.5m and can pump a rated maximum of 21,000 litres of water daily.
- Underground pipes connect the reservoir to nearby farms to provide water for irrigation.
- The Poldaw wind-pump was installed in 2004 by AESD of MOFA.
- As part of its deployment, a member of the community was trained in the operation of the system and to handle simple maintenance issues.
- The pump was non-operational at the time of visit. "*According to Mr Branah Gbanah, an elder of the community, the wind-pump operated for about a period of six months, following its installation. During this period, it proved to be very useful and provide all the water requirement of the community*

Figure 30: Broken-down Poldaw windpump at Gwollu

- The GPS Coordinates: N 10°58'25.446", W 2°13'9.1848".

Challenges

- Water for irrigation is scarce during the dry season so farmers are not able to get the maximum output from their plantations. The population of the Gwollu community is increasing; therefore, it has become necessary to seek additional sources of water for farming and domestic purposes.

Lessons learnt and recommendations

- The community is ready to pay for the revival of the Poldaw wind-pump at a moderate cost. Money collected could be used for the maintenance of the facility.
- It would be relatively cost effective to renovate the system as most of the components are still in good shape.

The storage tank provided for the pumped water

Poldaw Wind-pump at Tampezua

Key observations and findings

- Tampezua is located in the Bawku East District in the Upper East Region.
- The Poldaw wind-pump was constructed with two concrete reservoirs to store and provide water for irrigation and domestic use.
- The turbine has a diameter of 3.5m and can pump a rate maximum of 21,000 litres of water daily.
- Underground pipes are connected reservoirs to nearby farms.
- The facility was operational only for a year following its installation in 2004 by AESD of MOFA.
- The GPS coordinates: N °3'30.645", W 0°15'28.9548".
- The non-operational state was attributed to the broken pumping rod.

Figure 31: Poldaw wind-pump at Tampezua

- No member of the community was trained to maintain the facility.
- The facility has been well kept with the hope of it being revived.

Challenges

- According to the Bawku District Director of MOFA, the efficiency of the wind-pump was very low as it failed to provide sufficient water for dry season irrigation.
- The lack of skill for operation and maintenance contributed to its failure.

Lessons learnt and recommendations

- The community has very low wind speeds. This could have been the factor for its low output during the period of use.
- The radiation intensity in the region is very high; therefore, the option of solar water pumps could be explored to work alongside the Poldaw wind-pump.

Concrete storage tanks at Tampezua for the pumped water

B-Bovid Farms

B-Bovid farms is an agribusiness that promotes a model of socially inclusive commercial farming that combine innovative agricultural practices with ecological farming. It is located in Prestia in the Western Region of Ghana. A Poldaw wind-pump is installed on site for pumping water for irrigation and also to cater for livestock.

Key findings and observations

- The windpump was installed in 2011 through the VIP.
- The company has a palm oil mill, palm kernel oil mill and an organic fertiliser processing factory. However, the company is yet to explore energy generation from POME and organic waste.
- The farm GPS coordinates: N 4°56'24.0684", W 1°51'34.3404".

Challenges

- The main challenge with the wind-pump is the noise produced when the turbine is running. This is because of the faulty bearing.

Lessons learnt

- The Poldaw wind-pump is the only one operational. This can be attributed to the high sense of responsibility shown by the sole proprietor

Microgrids

Improving access to modern energy services in rural areas in developing countries is a major development priority. As part of the strategies to pursue ambitious and often challenging grid connection programmes, there is increasing interest in decentralised generation and distribution through mini-grids. The MoP under GEDAP is developing microgrid power plants for remote off-grid communities. This would provide affordable, reliable and sustainable electricity for about half a million Ghanaians living in island communities and along the Volta Lake.

Pediatorkope Microgrid Plant

The Southeastern island of Pediatorkope is located in the Dangme East District of Ghana. The community has a population of about 1,500 who live on farming mussels on the Volta River. A solar/wind hybrid power plant has been installed to provide power for the communities on the island as part of the outputs of the Ghana Energy Access and Development Project (GEDAP). This USD 800,000 project was commenced four years ago and constructed by the Spanish company, TTA, with a five-year warranty agreement.

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

Figure 32: Pediatorkope Microgrid

Key findings and observations

- The facility is an AC micro-grid.
- The plant is a hybrid system of 39 kW solar, 11 kW wind with a 30 kVA diesel back-up generator.
- The prepaid meters have a load limiting functionality which limit loads according to the following categories; 0.5 kW, 1 kW and 1.5 kW.
- The micro-grid powers LED street lights are mounted throughout the community
- The 3-ph and 1-ph distribution network, as well as the network for the street lights are all carried on the same service poles.
- PV modules are mounted on high metallic structures to prevent them from being stolen and also to provide shade to the control room.
- The GPS coordinates: N 5°49'2.4384", E 0°37'40.2744".

Lesson learnt and recommendation

- An industry could be set up to benefit from the excess power generated by the plant and to provide additional funds to sustain the project

Busunu Mini-Grid

Energiebau, a German solar power company, initiated the first decentralised mini-grid in Ghana at Busunu in the Northern Region. The power system uses a 5kW solar PV array in conjunction with a 60kVA biomass electric generator powered by oil from Jatropha nuts. The mini-grid was designed to supply 36 households with electricity while creating a market for Jatropha seeds.

Key findings and observations

- The project was initiated when the community was off-grid; however, the community has now been connected to the grid.
- The systems that were installed were still in place, but the inverter of the 5kW system had broken down.
- PlanET Biogas, with the help of the state of North Rhine-Westphalia, FH Gelsenkirchen and the City Selm in Germany, is making plans to renovate the mini-grid.

Lessons learnt

- The initiative—donor supported and community managed--was not financially viable. The tariffs were too low to cover operation and maintenance cost, and the level of service was too limited in comparison to the national grid.

Top: Jathropha generator, Bottom: Solar PV array

State of Busunu's Minigrid

Black Star Energy – Solar Microgrids

Black Star Energy is a commercial company that operates solar powered minigrid systems for rural communities. The company has contracted with communities with over 2000 inhabitants in the Ashanti Region of Ghana to provide electrical power and continues to grow its services according to demand.

It deploys, owns and operates micro grids with battery storage powered by solar to provide electricity for communities and commercial businesses that need affordable, scalable power.

Key findings

- The company operates solar PV mini grids in 7 off-grid communities, namely Affulkrom, Amankyia, Anyatenten/Odumasi, Daban1/2, Beposo, Kofihuikrom and Adoowa. Black Star also operates solar charging centres in some of the communities.
- The systems are installed on leased lands mostly at the centre of the communities and as such the whole community is involved in preventing theft.
- Power generated is distributed through a single-phase distribution system through communities. The company provides smart energy meters for measuring energy consumed for billing customers. They also subsidise the cost of wiring (of about GH¢ 250) households (single room with two lighting points and sockets) of customers and amortise the cost over a period for payment.
- Customers are encouraged to use energy efficient lamps and appliances to manage their consumption
- The company supplies 24/7 constant power to households. The system capacity is increased as and when the energy demand increases
- A fixed amount of 27 Gp is charged for up to 150 Wh consumed daily. An additional 10 Gp is paid for every 100 Wh consumed daily after the first 150 Wh. Customers supported in wiring their houses also pay 50 Gp daily till they fully pay for the subsidy
- Customers buy scratch cards which they load on their mobile phones for the payment of their electricity bills

Case Study – Daaban minigrid – Black Star

A 9.9 kW solar PV minigrid is installed at Daaban in the Amansie West District in the Ashanti Region.The facility provides electricity for about 120 households with about 69 subscribed customers, most of whom are predominantly into farming and small-scale mining.

Some high-energy consumers use appliances such as refrigerators, television sets and radio systems.

Challenge

- The weak unstable mobile network in most off-grid communities creates difficulties for customers in loading energy recharge cards.

UNIVERSITY OF ENERGY AND NATURAL RESOURCES

The Energy Center KNUST

DSTC

Centre For Energy, Environment And Sustainable Development

CREK

KOFORIDUA POLYTECHNIC (Technology for Development)

KITE ...Innovating clean energy solutions...

RE Training and research / Educational Institutions

A few renewable energy courses are offered in a number of training centres in the country. The Kwame Nkrumah University of Science and Technology (KNUST), through The Energy Centre, offers annual short courses in stand-alone solar PV systems, biogas technology and wind energy. KNUST, as well as other prominent state academic institutions including the University of Energy and Natural Resources (UENR), Kumasi Technical University and Koforidua Technical University run degree and HND programmes in renewable energy technologies or allied disciplines. The University of Mines and Technology, Tarkwa, has also started an undergraduate programme in Renewable Energy Engineering and offers short courses in renewable energy technologies. These institutions provide knowledge and awareness of renewable energy sources and technologies, which is essential for the development RE in Ghana.

Koforidua Technical University

Koforidua Technical University (KTU) has been an active player in terms of research in renewable energy. The school started a BTech programme in Renewable Energy Systems Engineering in 2003 to provide training in RE production and utilisation. It has also embarked on a lot of renewable energy project such as the installation of solar charging systems in some communities in the Eastern Region, with the underwriting from JICA (Japan International Cooperation Agency). The school operates a 10 m^3 biogas plant which supplies biogas to the school kitchen for cooking and also serves as a demonstration facility for training.

Key findings and observations

- KTU conducts studies into and builds prototypes of solar water heaters, box and parabolic solar cookers and mixed-mode solar dryers.
- A project has been conducted using corn cobs to produce briquette with a crude carbonisation technology.
- The Department of Renewable Energy System Engineering, in collaboration with ECREEE, is undertaking awareness creation, capacity building and database development for solar thermal systems in Ghana.
- The 10m^3 biogas plant is operational as a result of constant monitoring and maintenance by the RE department

Challenges

- Difficulty in finding a replacement for the spoilt flow meter for the biogas plant
- Lack of funds to support RE student projects.

From left: Solar water heater, parabolic solar cooker, briquetting machine, biogas digester.

Figure 33: RE Projects implemented by Koforidua Polytechnic

Lessons learnt and recommendations

- The biogas plant is operational as a result of the monitoring and maintenance by the RE department.
- A good business model should be adopted in running the plant in order to provide funds for maintenance.

The Energy Centre (TEC), KNUST

The Energy Centre(TEC) of the Kwame Nkrumah University of Science and Technology (KNUST), Ghana, is hosted by the College of Engineering and promotes energy research, development, and demonstration activities in the university. The Centre, instituted in 2009, has been engaged in a number of RET projects including a Solar PV Testing Laboratory, a Smart Energy Management System for Research, a Solar Water Pump and Solar Thermal Centre for Demonstration and a Biogas Testing Facility.

Solar PV Testing Laboratory

A state- of- the art solar testing facility was under construction at time of the visit at the laboratory block of the College of Engineering. The purpose of the facility is to test the performance of solar PV modules against the manufacturer's specifications. The properties to be tested for include the voltage and current characteristics of PV modules as well as their lifespan. The laboratory is being put together by The Energy Centre in collaboration with the Arizona State University. The Solar PV Testing Laboratory was expected to be completed by March 2016.

Key findings and observations

- The wiring of the facility has been done but the equipment for testing is yet to be installed.
- The total cost in setting up the facility is about $120,000.

Challenges

- Plans to secure laboratory accreditation has been stalled due to the high cost involved.
- The cumbersome procurement process has delayed the installation of test equipment.

Lesson learnt and recommendation

- Instead of placing solar PV modules under intermittent sunlight to monitor the Current-Voltage Properties, employing a sun simulator will provide stable irradiation for accurate test results.

Smart Energy Management System

A smart energy management system consisting of a 44kWp Solar PV System and biodiesel generator has been installed on the premises of the College of Engineering by Energiebau Sunergy Ghana Limited. The project was managed by GIZ, with financial support from Federal Government of North Rhine Westphalia (NRW). The goal of the project is to provide uninterrupted power supply for offices and lecture halls and to facilitate students' research in solar PV.

Key findings and observations

- The solar PV system is grid-connected via a solar net meter.
- Panels installed are composed of different PV technologies (monocrystalline silicon, polycrystalline silicon and amorphous silicon) to collect data and facilitate research on the most efficient technology.
- The system is designed with battery storage with capacity of 54kWh, which is enough to last for 12 hours.
- The biodiesel generator has a capacity of 17kVA and runs on oil from Jatropha seeds
- The College has a four - acre field where it cultivates Jatropha to power the generator.
- The smart energy management system switches between the grid, the solar system and the biodiesel generator to ensure uninterrupted power supply. This is done automatically or by using a software.
- Students are not taking advantage of the facility to conduct research and publish papers on the technologies available.

Figure 34: Part of the 44kW solar PV installed at KNUST

Figure 35: Smart energy management system at KNUST

Lesson learnt and recommendation

- Courses on renewable energy should be introduced into the curricula as a basis for specialisation.

Solar Water Pump and Solar Thermal System – Photovoltaic Training Centre

At the College of Engineering, KNUST, is a solar thermal system and water pump installed by The Energy Centre as a demonstration facility to create awareness of the benefit of renewable energy. The facility was completed in May 2015 with financial support from Federal Government of North Rhine Westphalia (NRW) and managed by GIZ

Key findings and observations

- The solar water pumping system is made up of a submersible DC pump and a 750W panel.
- The water is pumped at a rate of 90 litres per minute and is supplied to the Petroleum Engineering Block.
- The collectors of the solar water thermal system are capable of heating water to a temperature of about 100°C.
- The solar thermal system is also equipped with a 300-litre tank for the storage of hot water.
- The cost in putting up the centre is about €24,000.

Challenge

- The solar thermal system is not well positioned to optimise its performance as surrounding buildings might shade the panels for most part of the day.

Lesson learnt and recommendation

- The technology is robust and, therefore, requires very little maintenance.

Figure 37: Flat plate solar thermal set up, TEC-KNUST

Figure 36: Solar PV for DC water pump, TEC-KNUST

Biogas Testing Laboratory

The laboratory is located at the College of Health Sciences at KNUST and is run and maintained by the Energy Centre and the Chemical Engineering Department. The laboratory was funded by the Federal Government of North Rhine Westphalia (NRW) with financial support from GIZ.

Key findings and observations

- The construction of the laboratory was completed in 2014.
- The laboratory allows master's and doctoral students to bring in samples for testing. At the moment it is patronised by private organisations.
- The facility is used to test the methane potential of different feedstock, the biodegradable content of feedstock and the amount of methane in the gas produced from a digester.
- The laboratory attendant obtains feedstock for the experiments from the university's livestock farm.
- GPS coordinates: 6°40'26.85"N 1°34'4.46"W.

Challenge

- The accuracy of test results is sometimes hampered by erratic power supply.

Lessons learnt and recommendations

- Awareness should be created of the existence of the laboratory and its use should be encouraged, especially by owners of biogas facilities.
- A laboratory of such nature should be provided with a dedicated backup power supply to curtail inaccuracies in test results arising from power outages.

Testing equipment at the Biogas Lab

Wind Tunnel at the Aerospace Lab

The College of Engineering is equipped with an Aerospace Laboratory intended for teaching and conducting experiments on wind dynamics and for testing prototypes. Among the equipment available is a 20hp wind tunnel, a tool that is employed in the design of turbine blades by simulating the effect of wind moving across blades.

Key finding

- The wind tunnel is not in use as the sensors and metering devices are faulty.

Challenge

- The cost of running the wind tunnel is high as it draws a lot of power.

Lessons learnt and recommendations

- The lab could be upgraded as a centre for testing locally fabricated wind turbine blades.
- Equipment such as the wind tunnel could be retrofitted to get them working at their optimum performance.

Wind Turbine Prototype

Efforts have been made by students of the College of Engineering in designing and building a wind turbine using reinforced bamboo for the turbine blades and other materials obtained locally.

Key findings and observations

- The blades of the wind turbine were constructed using bamboo and reinforced with a cardboard.
- The blades were constructed with a length of about one meter using the same principle as aircraft wings.
- The wind turbine was mounted on a building at the College of Engineering for testing but the blades began to bend as they were not able to withstand pressure from the wind.
- The completion of a 100W wind turbine generator has also been stalled due to the unavailability and high cost of materials.

Figure 38: Wind tunnel at the KNUST lab

Figure 39: 100kW wind turbine Prototype

The Technology Consultancy Centre (TCC), KNUST

The Technology Consultancy Centre of the Kwame Nkrumah University of Science and Technology (KNUST) has instituted several projects as part of its mission to provide the needed facilities for carrying out adaptive research and development. Among these projects are the Cookstove Testing and Expertise Lab (C-lab), Ferro Cement Charcoal Gasifier for demonstration and Institutional Rocket Cookstoves.

The Cookstove Testing and Expertise Lab (C - lab)

The Cookstove Testing and Expertise Laboratory was built from a partnership involving UNDP Ghana, the United States Agency for International Development (USAID), the Energy Commission and the Technology Consultancy Centre (TCC) as the host of the facility. The lab was commissioned on 31st March, 2015 and is aimed at carrying out efficiency, performance, emissions levels and heat content tests on locally produced and imported cookstoves.

Figure 40: Some equipment installed at the C-lab, TCC-KNUST

Key findings and observations

- The project cost US$150,000.
- UNDP Ghana office provided US$100,000 and TCC provided the rest through internally generated funds.
- The lab is purely commercial and revenue raised is used to run it.
- The lab also designs and prototypes cookstoves and transfers the knowledge acquired to the industry.
- The lab is partitioned into a training section, a section for prototyping of stoves and another section for testing cookstoves.
-

Challenges

- Patronage of the laboratory for testing of stoves is low because those in the cookstove industry are not aware of its existence.
- The cost involved in sending their samples for testing is relatively high.
- Erratic power supply poses a great challenge to the running of the facility.

Lessons Learnt and Recommendations

- The lab should also serve as a training facility to provide entrepreneurial and technical training for students who hope to enter the cookstove industry.
- A curriculum should be developed for training in cookstove manufacturing.
- In order to enhance laboratory activities and improve standards, the lab should be equipped with key devices such as a gas fired kiln, a pelleting machine, a humidifier and sensors for outdoor measurement.

120 kW Gasifier plant installed in Ghana - the biggest gasifier plant installed in Africa

Gasifier Plants

Gasifier plants provide an alternative to traditional combustion plants, as it is possible to generate more efficient electricity in small plants with little fuel requirement. Gasification is a clean technology that can turn biomass or any material containing carbon into synthetic gas. The gas can then be used in a gas engine for the production of electricity and heat. Even though the gasification technology is quite mature and reliable, it is new in Ghana, with a few installations across the country. Notable among the installations are the 10 kW gasifier at KNUST, the 20 kW gasifiers at Papasi and Modern Star School and the biggest gasifier plant in Africa (with the capacity of 120 kW) located at Asueyi.

Ferro Cement Charcoal Gasifier

The Ferro Cement Charcoal Gasifier was constructed by The Netherlands Development Organization (SNV) in partnership with Technology Consultancy Centre (TCC) of Kwame Nkrumah University of Science and Technology. The electricity generating capacity of the gasifier is 10kW and is fueled by synthetic natural gas (syngas) obtained through charcoal carbonisation. The gasifier is operated and maintained by the Rural Energy and Enterprise Development Unit under TCC and serves as a demonstration facility for students.

Key findings

- The gasifier is built from materials readily available locally such as cement, sand, iron rods and chicken wires.
- The gasifier uses a modified Mercedes engine built with a 10kW alternator to produce electricity.
- The engine is powered by syngas which is generated by burning wood or plastics.
- It is estimated that one bag of charcoal weighing about 30-40kg can operate the gasifier for 10 hours.
- The temperature of the gasifier can reach a maximum of 160°C.
- It cost GH₵40,000 to construct the Ferro Cement Charcoal Gasifier.

Figure 41: 10kW gasifier plant at TCC

Lessons learnt and recommendations

- The potential of the technology in providing electricity for rural areas and for productive uses such as the drying of cocoa beans should be explored.
- To sustain the operation of the gasifier, it is important that the charcoal is obtained from a sustainable source or alternatives such as forestry residues and briquettes from sawdust or faecal sludge.
- The Ferro Cement Charcoal Gasifier engine can be configured into a combined heat and power in order to maximise the efficiency of the system.

Papasi Gasifier Plant

In the quest to provide electricity to off-grid communities, the Kumasi Institute of Tropical Agriculture (KITA) has installed a gasifier plant for electricity generation at Papasi, a small town located in the Offinso North District in the Ashanti Region. The community hosts a large local palm oil and palm kernel oil industry and generates large amounts of waste from the oil processing. The facility utilises the palm kernel shells for the generation of electricity for productive uses and community lighting.

Key findings

- The project was funded by the United State Africa Development Foundation (USADF) with a total cost of USD 100,000 under the Power Africa Project.
- The project was implemented by KITA with technical support from the Centre for Energy, Environment and Sustainable Development (CEESD).
- The 20 kW gasifier plant was installed in 2016 by All Power Labs (suppliers of the gasification system) to generate electricity for community lighting and power for a palm oil processing centre in the community. A CEESD project assistant was trained during the installation to operate and carry out basic maintenance of the system.
- The facility provides power to 15 street lights and two households in the community. An inverter and battery system is used to store energy for lighting the street lights at night when the gasifier is not being used. The gasifier also powers a nut cracker, palm oil and palm nut expeller, all installed under the project.
- Palm kernel shell and chaff from the processing waste is used as feedstock for the plant. Half-filled hopper with the kernel shells can generate electricity for about four hours.
- The facility was not operational at the time of visit.

Left: 20 kW gasifier. Right: Palm oil processing centre with nut cracker and palm oil expeller

Modern Star School Gasifier Plant

Modern Star School Complex is a private school located at Adubiyilli in Tamale in the Northern Region of Ghana. The school was set up in 2015 (with about 16 teachers) and has a student population of about 100 students enrolled in technical programmes such as electrical/electronics and fashion design. The school installed a gasifier plant in February 2017 as a back-up plant for electricity generation for the school. Another key reason for the installation of the plant was to reduce the school's high electricity bills.

Key findings

- The 20 kW gasifier plant was installed by All Power Labs from the United States. The headmaster and an officer from CEESD were trained for the operation and maintenance of the facility. The installation process was also used as a training session for the technical students.
- The plant was fully funded by Radclyffe School and Damian, the school's partners in the UK.
- Wood off cuts from the timber market in Tamale is processed into wood chips with a machine and used as feedstock for the gasifier. The school management, however, plans on woodlot cultivation to provide fuel for the gasifier in the near future.
- The gasifier can power the entire school for about eight hours. when fully loaded with water. The facility is run as and when there is adequate feedstock basically to reduce the school's electricity bill.
- The school also utilises a solar PV system to power lights and fans in its administration block.

Left: 20 kW gasifier. Right: Wood off-cuts from the timber market cut into chips with a chipping machine

Challenges

Acquiring adequate amounts of wood chips for continuously running the gasifier is a key challenge as the school seeks to reduce its grid electricity consumption by running the plant.

Asueyi Gari Processing Gasifier Plant

The gasification plant is installed at Asueyi, a community within the Techiman municipality in the Brong Ahafo Region of Ghana. This community is one of the major cassava producing areas in the country. The gasifier system, composed of a down draft gasifier, gas engine, back-up generator, air generator along with a gas cleaning and cooling system, is for producing ultra clean gas for electricity and heat generation from the cassava processing waste. This project happens to be the biggest gasifier plant in Africa with the capacity of 120 kWe and comes with an automated gari roasting system for gari making.

Key findings

- The project was funded by the International Fund for Agricultural Development (IFAD).
- The gasifier plant was installed in June 2016 by Ankur Scientific Energy Technologies Pvt Ltd. (system manufacturer)
- The Asueyi Gari Processing Cooperative which comprises five processing groups is the main beneficiary of the project. The group processes gari for both the local and export market.
- Five electrical roasters equipped with rotating paddles, pan, fireplace and chimney are installed to test the technology and show new practices for producing gari. The group produces an average of about six tonnes of gari per day with their conventional processing stoves; however, an estimated amount of 30 tonnes of gari can be processed with the automated roasters per day. A warehouse has been built to store the gari produced from the

Left: Roasting centre. Right: Warehouse for storing gari

- The producer gas generated from the gasifier is for electricity and heat generation for drying/pre-heating target feedstock biomasses.
- Cassava waste in the form of peels and bark together with pieces of firewood and charcoal, is used as feedstock for the gasifier.
- The project is supported by about 60 farmers for feedstock (cassava) from a 50-acre land. The cooperative, however, plans to secure about 100 acres of land for cassava plantation for the sustainability of the project.
- The group plans to sell electricity generated from the plant to the utility off-taker in the region (NEDCo.) at an agreed price and charge members for the use of the facility to process gari to generate revenue for the maintenance of the facility.

- The group plans to explore energy generation from the cassava processing waste water as it has high biogas generation potential.
- The group has hired an administrator to manage the facility and seeks research support from interested institutions to help manage the facility.

Gasifier with its appurtenance installed in the gasifier house

Challenge

- A major challenge has been the acquisition of land for the cultivation of cassava for processing and also as feedstock for sustainability.

Conclusion

A significant number of renewable energy projects in the country are executed on a pilot basis for demonstration purposes. Sadly, most of these projects do not live long enough to scale up because of poor maintenance, lack of a clearly defined trajectory for scale-up, lack of a profitable business model and the diversion of focus on the part of project sponsors. New projects need to learn from earlier project implementers to reduce the possibility of project failure as most projects in the country seem to be executed in insolation under pilot programmes. It is important to note that many ingredients are necessary for the successful implementation of renewable energy projects.

A lot of projects are implemented with little or no education on the benefit of the project to beneficiaries. There were instances where the beneficiaries were oblivious of the existence of such renewable energy facilities on their premises. Typical case studies are the biogas plants at the Takoradi Cocoa Board Warehouse and the Koforidua Regional Hospital. This lack of awareness somewhat accounts for the low patronage of the renewable energy technologies in the country at large. The active sharing of knowledge and information on developments in renewable energy is crucial to the success of renewable energy diffusion throughout the country.

Beyond education, it is necessary to also consider the behaviour and the abilities of the prospective beneficiaries. Beneficiaries must be sensitised to the expected performance of the systems and all their roles in operating and maintaining the system. Systems should be simple and require minimal roles for the beneficiaries to operate. Preferably, systems must be designed to prevent the possibility of tampering by beneficiaries. Typical case studies are solar water stills at Anafobisi where pupils cracked the glass covering the water still and the KITA biogas plant where an attendant fed the digester with unsliced oranges, which dwindled the digester output. In cases where a system is to be operated by beneficiaries, selected operators should be adequately trained to do so.

Moreover, it was observed that no hazard signs have been mounted to ensure safety at most RE facilities visited. It is reported that inhaling high concentrations of H_2S gas released from faulty biogas plants can lead to blood poisoning or even respiratory arrest, in addition to the fact that methane, the major output of the biogas digesters is highly flammable. In spite of this, most of the biogas facilities visited had no hazard signs to warn users of the imminent dangers. Typical case studies include the biogas plant at Ejura Slaughter House, which reeked of H_2S gas.

It was also discovered that most of the failed projects were managed by the community or groups of people within the community. The major reasons for the failure include poor maintenance due to the lack of the technical skill-set for maintenance and partly due to the lack of a sense responsibility towards the facility, lack of a clearly defined ownership structure and viable business model to generate funds for maintenance. A good case study is the biogas plant at Ejura slaughter house, sponsored by GIZ and managed by the Ejura-Sekyedumase District Assembly. It was, however, realised that most projects under the management of private entities were found operational. A major reason for their success is their ability to commercialise the project to provide funds for maintenance. Case studies include the solar irrigation systems sponsored by UNDP and being implemented by NewEnergy in Tamale and the solar hybrid biomass dryer managed by Pens Food Bank Ent. at Ejura.

The study finally reveals a high potential for the replication and scale up of a number of renewable energy projects and the models being used. These projects include the Ejura Solar-Biomass Dryer, Solar Irrigation System at Tamalugu, the Solar Water Pump at Nabogu and Solar Still at Asekye. The sense of ownership and maintenance culture of the oil mills is also worth adapting to ensure the sustainability of projects.

APPENDIX A

Summary of Findings of Projects Visited

#	STATUS	DESCRIPTION	SPONSOR	IMPLEMENTING AGENCY
Solar PV Testing Laboratory, KNUST	Ongoing	The purpose of the facility is to test the performance of solar PV modules against manufacturers the specifications.	Federal Government of North Rhine Westphalia (NRW).	The Energy Centre (TEC), Arizona State University
Smart Energy Management System, KNUST	Operational	44kWp Solar PV System and biodiesel generator.	NRW	TEC
Solar Water Pump and Solar Thermal System, TEC-KNUST	Operational	750Wp solar water pump and solar thermal system.	NRW	TEC
Biogas Testing Laboratory (College of Health Sciences, KNUST)	Operational	For testing the percentage of the biodegradable content and methane production capacity in feedstock.	NRW	TEC, Chemical Engineering Department
Wind Tunnel (Aerospace Lab, KNUST)	Defunct	For testing and conducting experiments on wind dynamics	KNUST	Department of Mechanical and Aerospace Engineering KNUST
The Cookstove Testing and Expertise Lab (C-lab)-KNUST	Operational	For testing the efficiency, performance, emissions levels and heat content tests on locally-produced and imported cookstoves.	UNDP Ghana TCC (KNUST)	TCC (KNUST)
Ferro Cement Charcoal Gasifier, TCC-KNUST	Operational	The electricity generating capacity of the gasifier is 10kW and is fueled by synthetic natural gas (syngas) obtained by carbonising charcoal.	SNV	Rural Energy and Enterprise Development Unit under TCC
Institutional Rocket Cookstoves-TCC-KNUST	Operational	Rocket stoves are constructed mainly from bricks with a chimney to direct smoke from the user	SNV	Rural Energy and Enterprise Development Unit under TCC
Solar Irrigation System at Datoyili	Operational	2.3kW solar PV array and DC pump for furrow and drip irrigation	UNDP Ghana	NewEnergy
Solar Irrigation System, Fooshegu	Defunct	1.5kW solar PV array and DC pump.	UNDP Ghana	NewEnergy
Central Gonja Solar Community Water Pumping	Operational	2 x 3 kW solar PV and PS 1800 Lorentz DC pump	Central Gonja, GIZ-ENDEV	PumpTech/ Central Gonja Community
Solar Irrigation System, Tamalugu	Operational	15kW DC pump with advanced communication and monitoring capabilities via the internet.	UNDP Ghana	NewEnergy

Solar-Powered Water Purification and Irrigation Facility, Nabogu	Operational	5kW roof mounted solar panel powering two DC pumps and equipment for purification.	United States African Development Foundation (USADF)	NewEnergy
Centre Pivot Irrigation – IWAD, Yagaba	Operational	Four centre pivot irrigation systems each covering 65 hectares / four acres of land reserved for solar PV installation to offset grid energy used for irrigation	IWAD with support from USAID	IWAD
Biogas Plant, Tamale SOS Village, Tamale	Defunct	A 70m^3 digester with effluent filtration system.		
Mini-Grid, Busunu	Defunct	5kW solar PV array in conjunction with a 60kVA biomass electric generator powered with Jatropha oil.	Energiebau Germany	Energiebau Germany
Biogas Digester for Energy Generation from Shea Waste, Bole	Operational	50m^3 biogas digester capable of generating 12m^3 of biogas daily.	World Bank	Biogas Engineering Limited (BEL), Cocoa Research Institute of Ghana (CRIG).
Koforidua Polytechnic Biogas Plant, Koforidua	Operational	10 m^3 biogas plant		Department of Renewable Energy System Engineering, Koforidua Polytechnic
Biomass-Fired Cogeneration Plant, Ghana Oil Palm Development Company (GOPDC), Kwae	Operational	Biomass fired coogeneration plant with a 1.5MW and 2.5MW steam turbine generator	GOPDC	GOPDC
Biogas Plant, Ghana Oil Palm Development Company (GOPDC), Kwae	Operational	2 x 1000 m^3 biogas plant producing 18000 m^3 of biogas per day	GOPDC	GOPDC
Koforidua Regional Hospital-Biogas Plant	Defunct			
Pediatorkope Microgrid Plant, Pediatorkope	Ongoing	Hybrid system of 39 kW solar, 11 kW wind with a 30 kVA diesel back-up generator.	World Bank under GEDAP	MoP
HPW Fresh and Dry Ltd's Biogas and Solar Thermal Plant, Adeiso	Operational	Two 450m^3 concrete biogas digesters and 3 x 100 m^3 gas holding balloons.	HPW Fresh and Dry Ltd	HPW Fresh and Dry Ltd
		200 solar thermal collectors used in conjuction with a biogas plant to heat a 200 kW heat boiler.	HPW Fresh and Dry Ltd	HPW Fresh and Dry Ltd
Ntiamoah Hotel Biogas Facility, Agona-Swedru	Operational	10m^3 biogas facility with effluent storage.	Ntiamoah Hotel	Ntiamoah Hotel
Oskan Industries Ltd, Gomoa Onyadze-Ostew	Operational	Charcoal production facilty equipped with six metallic kilns.	Oskan Industries Ltd	Oskan Industries Ltd

Mfantsipim Senior High School Biogas Plant, Cape Coast	Operational	16-seater 200m^3 biogas toilet facility with effluent filtration system.	Mfantsipim Old Boys Association	Mfantsipim Senior High School
Twifo Oil Palm Plantation (TOPP), Twifo Ntafrewaso	Operational	Biomass fired cogeneration plant with a 15 tonnes/hr steam boiler and a 1500kVA/1200kW turbine for power generation.	TOPP	TOPP
Benso Oil Palm Plantation (BOPP), Adum Banso	Operational	Biomass fired cogeneration plant with a 13.6 tonnes/hr steam boiler and a 500kW turbine for power generation	BOPP	BOPP
Best Carbon Ghana Limited, Ewiadaso	Operational	Charcoal production facilty equipped with 11 locally fabricated metallic kilns.	Best Carbon Ghana Limited	Best Carbon Ghana Limited
Takoradi Cocoa Board Warehouse's Biogas Plant, Kadjebril	Defunct	200m^3 fixed dome biogas plant.	Cocoa Board Takoradi	Cocoa Board Takoradi
Poldaw Windpump, B-Bovid Farms, Prestia	Operational	Poldaw windpump	MOFA and World Bank under VIP	MOFA
Hemang Hydro Power Potential Site, Hemang	Ongoing	90MW hydro power potential site along the Pra River in Hemang	GoG	GoG
KITA Biogas plant	Operational	9-seater toilet 40m^3 biogas plant with a gas holder, effluent storage and a 15 kVA biogas generator.	SNV	CEESD
Morrison Cookstoves for Pito brewing, Ejisu	Operational	Efficient stoves built from clay and outlined with cement.	SNV	SNV, KITA
Biogas Plant, Kumasi Abattoir, Kumasi	Ongoing	200m^3 biogas facility estimated to produce 150m^3 of gas per day.	UNIDO	The Energy Centre (TEC).
Dompoase landfill site, Dompoase	Ongoing	100-acre landfill site for exploring the potential of tapping landfill gas for power generation.	World Bank	Kumasi Metropolitan Assembly (KMA)
Hybrid Solar-Biomass Dryer, Ejura	Operational	Solar biomass hybrid dryer	Pens Food Bank Ent., UK- based organisation.	The Energy Centre (TEC)
Biogas Plant, Ejura Slaughterhouse	Defunct	50m^3 twin bio -digester biogas plant	GIZ	The Energy Centre (TEC)
Solar Dryer, Ejura-Sekyedumase	Defunct	2 tonnes solar dryer	GIZ	MOFA
Solar Dryer, Bonsu	Operational	2 tonnes solar dryer	GIZ	MOFA

Solar Charging Centre, Asekye	Operational	300Wp solar PV with 850Wp inverter solar charging centre with a 400Wp solar PV powering a DC water pump.	Australian High Commission	Renewable Energy Service Centre
Wechiau Solar Battery Charging Project, Wechiau, Upper West	Defunct	2.1kW solar battery charging center	Ministry of Mines and Energy	Ministry of Mines and Energy
Poldaw Windpump, Gwollu, Upper West	Defunct	Poldaw windpump - 3.5m diameter, 21,000 litres of water daily	World Bank- Village Infrastructure Project	AESD
Poldaw Windpump, Tampezua, Upper East	Defunct	Poldaw windpump - 3.5m diameter, 21,000 litres of water daily	World Bank- Village Infrastructure Project	AESD
VRA's Grid-connected Solar Power Plant, Navrongo, Upper East	Operational	2.5MW Grid connected Solar PV Plant	VRA	China Wind Power/VRA
Solar Water Still, Bongo	Defuct	25litre concrete solar water still	Vodafone Foundation	CEESD
Solar Vaccine Fridge, Ga, Upper East	Operational	50W solar vaccine fridge and LED lights on a 100W solar system	European Union	GoG- District Assembly
Solar Vaccine Fridge, Ducie, Upper West	Operational	50W solar vaccine fridge and LED lights on a 100W solar system	European Union	GoG- District Assembly

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