Bioenergy for Sustainable Energy Access in Africa

PO 7420

Project Completion and Handover Report

by LTS International Limited, the University of Edinburgh and E4tech

21st September 2017

The document has been prepared, as part of a study commissioned and funded by DFID, by LTS International, E4tech and The University of Edinburgh. Any statements made represent the views of the authors and should not be construed as the opinion or position of DFID.

Executive Summary

Introduction

Between September 2016 and August 2017, a consortium of LTS International, E4tech and The University of Edinburgh implemented Phase I of the DFID-funded Bioenergy for Sustainable Energy Access in Africa (BSEAA) research assignment. This 12 month study set out to investigate the challenges and opportunities affecting the adoption and roll out of bioenergy technology across Sub-Saharan Africa (SSA).

Phase I was to define the scope of any future research in this area, through which DFID may support targeted research into the identified barriers and opportunities, and the development of innovative solutions. We also understood that DFID is intending to implement further research in this area under the larger Transforming Energy Access (TEA) Programme, which will test innovative technology applications and business models to accelerate the provision of affordable, clean energy-based services.

This report, the final output of BSEAA Phase I, summarises the various stages of the study, the reports that were produced and the implications for any future research in this area.

The five reports produced during Phase I are as follows:

1. Inception Report
2. Literature Review and Stakeholder mapping Report
3. Technology Value Chain Prioritization Report
4. Technology Country Case Study Report
5. Project Handover and Completion Report (this document)

Inception phase

During a six-week period of study design in late 2016, it was agreed that bioenergy technology would be analysed in the context of 'Technology Value Chains' that originate with biomass feedstocks that are converted to solid, liquid or gaseous biofuels, and in turn to bioenergy for heat, power, cooling or transport applications. DFID confirmed an interest in commercial bioenergy at community, institutional and industrial scales with an output range of 10 kW_e to 5 MW_e. It was also agreed to focus on technologies at Technology Readiness Level (TRL) 5 to 9.

Literature review and stakeholder mapping

Approach

A list of 27 potential bioenergy conversion technologies was reduced to 15 options for further analysis based on TRL status, operating scale, existence of functioning examples, prospects in SSA, appropriateness (in terms of technological sophistication, infrastructure requirements and social workability) and innovation potential. The shortlisted technologies were then investigated through review of academic and non-academic literature, and mapping of stakeholders in SSA's bioenergy sector, to provide evidence for narrower technology prioritisation. SSA countries were also screened to identify those with closest synergy with DFID interests, most conducive commercial environments, highest indications of bioenergy demand, greatest interest levels and optimal impact potential.

Findings

Based on the volume and nature of academic research, as well as a composite score from the non-academic literature that considered deployment level, appropriateness, replication potential, competitiveness and innovation opportunities, the following technologies were selected for more in-depth investigation:

a) Combustion-to-steam turbine
b) Gasification-to-internal combustion engine
c) Anaerobic digestion-to-internal combustion engine.

Ten countries were at the same time prioritised for BSEAA research (Ethiopia, Ghana, Kenya, Mozambique, Nigeria, Rwanda, South Africa, Tanzania, Uganda and Zambia). Stakeholder mapping during this phase also generated a network of project developers, technology providers, investors and development agencies for further information gathering.

Technology Value Chain prioritisation

Approach

Having identified ten promising countries and three technologies for more in-depth investigation, the study then set out to prioritise TVCs that combined these technologies with particular feedstocks and end uses. It was agreed that a shortlisted TVC for each technology should have been attempted in at least one verifiable example in SSA within the last decade at 10 kW to 5 MW scale. Systematic web searches and stakeholder investigation identified qualifying examples, with operational details verified through personal contact.

Findings

The research generated a database of 153 project examples in SSA using a wide variety of feedstocks, though fewer than 100 installations had been constructed and a majority were no longer believed to be functioning, especially among the gasification projects. TVCs were prioritised based on current or recent reported operation. Even those project developers and financiers specifically interested in developing bioenergy opportunities in Africa were found to have taken only a few initiatives beyond the stage of feasibility assessment.

Anaerobic digestion was deemed the most promising technology for case study research. As well as offering innovation potential in technology, feedstocks and business models, the commercial biogas sector is seeing growing investment in SSA, to which DFID could add impetus through targeted research. The technology has high adoption levels outside the continent from which to draw lessons, offers significant feedstock flexibility across multiple waste streams, represents a relatively passive mode of fuel production, offers despatchable energy and provides co-benefits from waste disposal and digestate production.

Gasification meanwhile has an inconsistent track record at small scales. State of the art systems are complex to maintain, while simpler technologies are polluting and unreliable. Failure rates in SSA are close to 100% due to problems with gas quality or lack of maintenance expertise and spare parts. Nevertheless, it was thought that further research into the small number of plants might reveal areas for potential research support.

No **steam turbine** installations were found at small scale in SSA, so no opportunity arose for case study analysis. It was agreed instead that desk research would be conducted into the technical and economic feasibility of sub-1 MW heat or power applications and potential innovation opportunities that might exist.

During the next phase, a sample of anaerobic digestion and gasification projects were to be selected as working examples of the prioritised TVCs from which to draw experiences and lessons. These would be described in Case Study Reports identifying the main barriers and opportunities for replication and innovation, giving an indication of research areas that DFID might usefully support in the future.

Country Case Study analysis

Approach

From the database of bioenergy projects in SSA, 45 examples were identified of anaerobic digestion systems linked to gas or dual-fuel engines for heat or power in the desired scale range. Output was split roughly equally between large (>1 MW_e), medium (0.1-1 MW_e) and small (<100 kW_e) installations. Just 12 were thought to be functioning and a similar number with unclear status were also potentially operational. 47 examples were meanwhile identified of gasifiers powering engines to deliver heat or power, the majority of them below 100 kW_e. Of the 13 gasifier projects that had reached implementation stage, no more than seven were believed to be operational.

18 of these biogas and gasification plants were then visited in seven SSA countries. The aim at each site was to identify barriers to replication that DFID-supported research could potentially address. Visits to biomass-based steam turbine plants were not feasible as no small-size installations could be identified. Parallel desk

research was instead carried out into sub-1 MW steam turbines to identify research and innovation opportunities.

Identified Barriers

It was found that six types of barriers are experienced by developers of **anaerobic digestion** projects:

Barrier 1: Unreliable feedstock supply

All of the successful biogas projects have sufficient feedstock on-site as a by-product of the developer's own business or an adjacent business with an equity stake. There was no successful example where the primary feedstock was being brought in from elsewhere. Novel feedstocks (e.g. lignocellulosic materials or dryland plants) may represent a breakthrough in expanding the range of feedstock options for SSA.

Barrier 2: Costly and insufficiently adapted technology

The high cost of European and North American biogas systems is a barrier to investment in SSA. Technology transferred without modification may also prove inappropriate for local operating conditions. For replication beyond well-resourced agribusinesses, cheaper designs are needed – potentially from Newly Industrialised Countries - that are adapted to the local context.

Barrier 3: Limited operator technical capacity

Insufficient operator skills have in some cases led to technical problems such as incorrect substrate temperature, pH, solids content or microbiological conditions. Systems have under-performed or broken down as a result. There is a need to elevate skill levels through training and operational exposure.

Barrier 4: Lack of viable business models

A number of factors are resulting in unviable business models. Besides insecurity of feedstock supply, they include reliance on a sole income stream, which is rarely a viable biogas strategy in SSA; and insufficient financial engagement of project owners resulting in commercially unrealistic models. Projects fully funded by donor grants have encountered viability problems. There is a need to prioritise sites that allow valorisation of multiple outputs. Given also the lack of commercial financing for biogas in SSA, donor resources need to be applied more strategically.

Barrier 5: Unfavourable policy and regulation

Most early developers of biogas projects target captive heat and power demand within agri-businesses. Replication beyond captive sites requires a supportive framework of government incentives, such as attractive feed-in tariffs and fair access to the grid.

In many SSA countries, environmental regulations are not enforced and polluters may face no penalties for waste dumping. This makes investment in biogas less economically attractive as a waste clean-up technology.

Barrier 6: Limited access to manufacturer support and spare parts

Only one European biogas technology provider has permanent representation in SSA, so plant managers must usually be self-contained with their own in-house personnel. Lack of local support and poor access to spare parts dis-incentivises further uptake of the technology.

The developers of the six **gasification** projects that were visited had meanwhile encountered more significant barriers that make replication very challenging:

Barrier 1: Feedstock quality and availability constraints

Sensitivity to feedstock specifications means that gasification is an inflexible technology, which limits the potential feedstock range and supply-side adaptability.

Barrier 2: Technology limitations

Operating parameters must adhere to precise manufacturer specifications or high outputs of char, tar and particulate matter may cause cleaning problems, result in engine failure and the generation of excessive toxic by-products. Small-scale gasification also lacks the same degree of power despatchability as other energy technologies, requiring a gas storage system or battery bank.

Barrier 3: Lack of viable business models

Anchor customers are often lacking in the profiled projects, none valorise heat or char, and all were financed to some extent with donor funds. These factors have resulted in commercially unrealistic models and have often led to over-sized systems.

Barrier 4: Limited operator technical capacity

It is challenging to secure the skills required to operate gasification systems in rural locations. There are few qualified individuals who can operate and maintain them successfully, compounding the problem of reliability and reputation.

Barrier 5: Poor access to manufacturer support and spare parts

All gasification equipment is imported to Africa and only one supplier is represented on the continent, resulting in limited access to technical support or spares. The absence of technical back-up further degrades the reputation of gasification.

Finally, the study confirmed the poor efficiency of **steam turbines** compared to alternative technologies at sub-1 MW output levels, for inherent technical reasons. There may still be opportunities to retrofit steam turbines for CHP in agri-businesses with an existing heat generation system and significant electricity demand in countries with high electricity costs (e.g. Kenya, Rwanda and Ghana).

Potential research opportunities

In defining the limits of further research support from DFID, the team proposed a focus on **anaerobic digestion**. Case Study research into the small number of functioning **gasification** plants in SSA confirmed that the barriers to replication are so significant and wide-ranging, especially in small-scale community settings, that there is no realistic opportunity for research to boost replication potential and it is not proposed that gasification-related research is supported. Desk research into the technical and economic feasibility of sub-1 MW heat or power applications from **steam turbines** reveals potential for retrofitting for CHP at plants with a functioning heat generation system and significant electricity demand. Further feasibility research on this theme is a supplementary option for future research.

Project completion and handover

Future DFID support for research is expected to respond to the identified challenges facing the deployment of bioenergy in SSA by exploring appropriate solutions. The emphasis will be on those barriers for which research can offer particular value over other types of intervention. Research that addresses technological barriers will be prioritised.

Assuming a technology focus on anaerobic digestion, examples of potentially relevant research themes to address the identified barriers are offered in section 6.2 (and in full in the Technology Country Case Study Report). An open call would elicit a wider variety of ideas that DFID can screen for relevance and impact potential. DFID may choose to focus on a sub-set of the barriers in framing its call, to maximise the impact of available resources.

The study team will ensure that the outputs of the Phase I research are handed over to the TEA Programme management. Core team members from LTS and E4tech will meet with the TEA programme Managing Agent to ensure that the richness and intent of the supporting analysis is also conveyed verbally.

Cooperation with other donor-funded programmes such as the Africa-EU Renewable Energy Cooperation Programme would be valuable to maximise effectiveness and reach.