Bioenergy for Sustainable Local Energy Services and Energy Access in Africa

SUMMARY REPORT

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Aston University BIRMINGHAM UK
AIGUASOL
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About the BSEAA2 Programme

NIRAS-LTS partnered with Aston University, E4tech and AIGUASOL to implement a two-year project entitled 'Bioenergy for Sustainable Local Energy Services and Energy Access in Africa - Phase 2' (BSEAA2). BSEAA2 was part of the Transforming Energy Access (TEA) programme, which is funded with UK aid from the UK government. TEA is a research and innovation platform supporting the technologies, business models and skills needed to enable an inclusive clean energy transition. TEA works via partnerships to support emerging clean energy generation technologies, productive appliances, smart networks, energy storage and more. It increases access to clean, modern energy services for people and enterprises in sub-Saharan Africa (SSA) and South Asia, improving their lives, creating jobs and boosting green economic opportunities. The objective of BSEAA2 was to identify and support the development of innovative opportunities to accelerate the adoption of commercial-scale bioenergy technology in SSA.

The research had a practical focus; it was designed to lead to the development of resources and tools to assist industry and investors to assess the feasibility, use and applications of bioenergy technologies.

Acknowledgements

This research would not have been possible without the kind assistance of numerous people in the project's target countries, to whom the whole team is grateful.

A full list of designations and organisations are mentioned in the accompanying demand sector reports. Special thanks also to the team's national consultants, Bernard Osawa, Darius Boshoff, Emmanuel Michael Biririza, Francis Kemausuor, Hannes Muntingh and Linus Orakwe. They played a vital role in the project, during the challenging period of COVID-19, undertaking in-country research and field visits on behalf of the team ensuring the pace and quality of research remained unaffected.

PHOTO	CREDIT
Alternative fuel conveyor system, Lafarge Africa Ewekoro Cement Plant, Ogun State, Nigeria	**Linus Orakwe** Study consultant
Biomass boiler at Makomboki Tea Factory, Murang'a County, Kenya	**Simon Thuo** Study consultant
Combined heat and power plant at Tanganyika Wattle Company, Njombe, Tanzania	**Emmanuel Michael Biririza** Study consultant
Biogas plant at Ghana Oil Palm Development Company, Kwae	**Alex Bulnes** Siat Group
Biogas plant at Olivado (EPZ) Ltd, Murang'a County, Kenya	**Hannes Muntingh** Study consultant
Biogas CHP plant at Uilenkraal dairy farm, Darling, South Africa	**Darius Boshoff** Study consultant
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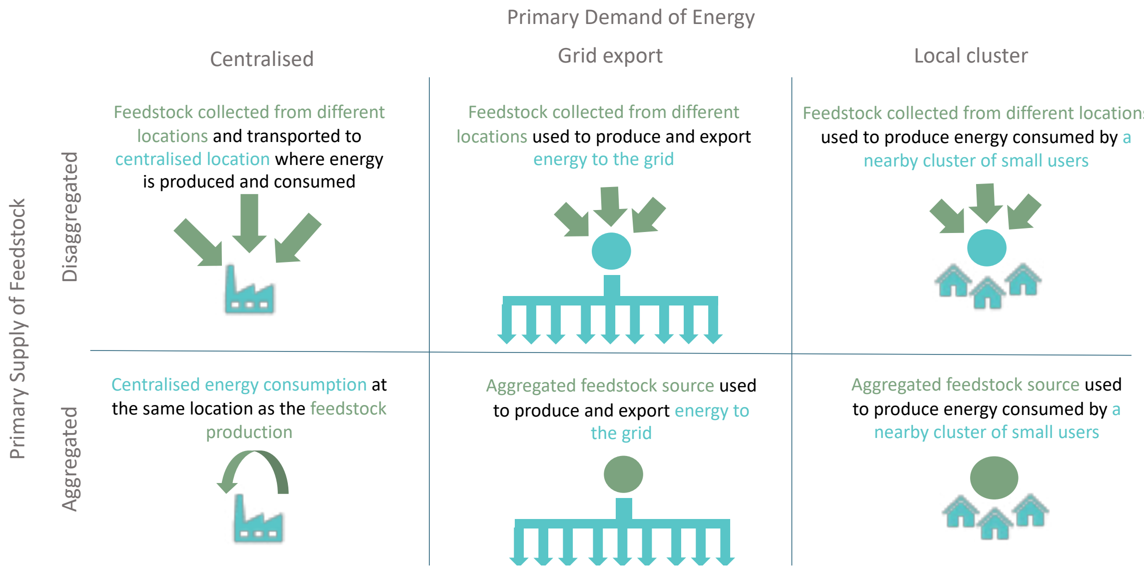
1. Research Objectives and Approach

Building upon BSEAA Phase 1 (2016/17), BSEAA Phase 2 focused on opportunities for anaerobic digestion (AD) and combustion for electricity and/or heat generation in the range 10 kW to 5 MW, with a Technology Readiness Level of 5+. That is, technologies successfully piloted in a representative commercial setting in SSA.

Challenges and opportunities for commercial deployment of these technologies were investigated in ten countries in SSA (Ethiopia, Ghana, Kenya, Mozambique, Nigeria, Rwanda, South Africa, Tanzania, Uganda and Zambia), through six inter-linked themes of biomass resources, technology, economic competitiveness, commercial viability, institutional, market and regulatory frameworks, and gender and inclusion (G&I).

The project began with the identification, analysis and screening of a range of bio energy 'pathways' comprising a specific biomass feedstock, feedstock category, conversion technology (AD or combustion), end use and demand sector, to identify the most promising opportunities for further investigation. A framework was also created for characterising these pathways, to identify the most successful archetypes[1] with proven potential for growth (Figure 1.1)

Figure 1. 1. Framework for bioenergy supply chain archetypes'



An overwhelming majority of the operational AD and combustion-based bioenergy projects in the target countries were found to fit into the archetype of aggregated feedstock supply and centralised energy demand (bottom-left in the framework), most of them in the agro-processing and livestock sectors. A small but growing number of enterprises were also found using disaggregated feedstock to meet centralised demand for energy (heat-only), particularly in the cement and tea sectors. Very few operational examples were found of combustion or AD-based projects selling heat or electricity to local clusters or to national grids, with marginal to no commercial success.

[1] A 'supply chain archetype', for the purposes of BSEAA2, is a specific combination of feedstock source and primary energy demand, which together define how feedstock is obtained and how energy is produced, distributed and consumed.

This analysis of commercial experiences led to the prioritisation of those pathways focused on meeting centralised, energy demand amongst existing enterprises, within promising demand sectors with proven potential for growth and expansion. Seven priority demand sectors in five countries, were shortlisted (as summarised in Table 1.1).

A report documenting this systematic process of identifying, analysing and screening potential bioenergy pathways based on an assessment of the landscape for bioenergy development against the study's five research themes is separately available.

Table 1 1. Shortlisted demand sectors for BSEAA2 research

No.	Demand sector	Biomass resource	Technology	Country
1	Cement manufacturing	Biomass residues, part-replacing fossil fuel	Combustion for heat	Nigeria
2	Tea processing	Biomass briquettes, part-replacing fuelwood		Kenya
3	Wood processing	Wood processing residues	Combustion for CHP*	Tanzania
4	Palm oil processing	Palm oil mill effluent	AD for CHP	Ghana
5	Horticulture	Fruit & vegetable processing residues		Kenya
6	Dairy	Cattle manure		South Africa
7	Sisal processing	Sisal processing residues	AD for electricity	Kenya

* combined heat and power

These seven demand sectors were then investigated in more detail to explore the experiences of both adopters and non-adopters of bioenergy technologies. Information was gathered from site visits, published literature and from stakeholders active in bioenergy in each country, and with partners of the TEA programme.

For each Demand Sector, a 'Base Case' and a 'Bioenergy Case' were identified:

- The **Base Case** refers to the industry standard for energy use in the given demand sector in the target country; that is, the default heat, power or CHP solution used by most similar businesses.
- The **Bioenergy Case** refers to a specific enterprise (or 'flagship project') that has transitioned to the use of bioenergy for heat and/or electricity generation in the target demand sector, using either combustion or AD.

While the in-depth research for each demand sector was focused on one promising target SSA country, where the existence of at least one operational venture could be verified, the prospects for replication in other relevant target countries was also assessed qualitatively, based on the commercial landscape for that demand sector.

Seven demand sector reports analysed the Bioenergy Case across the six study themes, as described in Table 1 2.

Table 1.2. Research approach by theme'

Theme	Demand sector
Biomass resources	Country-level resource assessments determined availability, properties, bioenergy potential and supply chain considerations for the most promising feedstocks in each demand sector. A mass-energy balance (MEB) model allowed the theoretical replication potential to be estimated, based on the assessment of the biomass resource.
Technology	The technological implications of bioenergy for heat and/or power production in each demand sector were determined, based on experiences at the Bioenergy Case flagship projects. From this, opportunities and requirements for wider adoption linked to technology and technology supply chains were assessed.
Economic competitiveness	A Life-Cycle Cost (LCC) modelling toolkit was used to compare energy costs under the Base Case and the Bioenergy Case for each demand sector, to determine the Levelised Cost of Energy (LCOE) for electricity and/or heat, based on the key operating parameters of the Bioenergy Case and the economic parameters (for e.g. discount rate, general growth rate, currency exchange rate) of the focus country for that demand sector. In the case of electricity-based applications, this analysis was based on the price of electricity that would otherwise be incurred in that context. Sensitivity analyses determined the impact on LCOE of changes in relevant input parameters. Given these estimates are based on the relevant economic parameters of the focus country, the relative attractiveness of the Bioenergy Case can be different in other target countries and as such would need to be assessed on a case by case basis.
Commercial viability	The commercial viability of the chosen bioenergy solution in each demand sector was investigated, based on the factors affecting successful adoption in the Bioenergy Case flagship projects. The potential for wider uptake in the same sector was also determined, based on barriers, enablers, market size and finance.
Institutional, market and regulatory framework	Institutional, market and regulatory frameworks were investigated for each demand sector and country, to identify factors enabling or inhibiting the adoption of bioenergy. From this, the key changes needed to enhance prospects for scale-up and replication were identified. The same demand sector was also assessed in other target countries, to determine the prospects for replication, based on the commercial environment in each of those countries, where applicable though not to quantify either total energy demand in the sector, or the scale of the replication opportunity.
Gender and inclusion	Relevant G&I issues were investigated in each demand sector, and potential areas for improved awareness, inclusion and participation of women were identified. The focus was mainly on the production and supply of feedstocks under smallholder or corporate control, as relevant, and, where applicable, the bioenergy conversion process.

The thematic analyses for the Bioenergy Case were compared with Base Case examples in each demand sector, to identify the opportunities and constraints for other enterprises in the same sector to adopt similar solutions. Detailed reports for each demand sector have been developed under this project. This report summarises the key findings and recommendations to guide investors, project developers and policy makers regarding the constraints and opportunities for bioenergy development within these sectors.

2. Overview of the Demand Sectors

Cement Manufacturing in Nigeria

Nigeria is Africa's largest cement producer, with a production capacity of nearly 50 million tonnes in 2018. Its cement industry has traditionally used natural gas, petroleum products and coal to supply heat for processing limestone into clinker, the main ingredient of cement. While fossil fuels are plentiful in Nigeria, there has been interest in the cement industry in exploring 'co-processing' with alternative fuels (AF). This drive has been led by Lafarge Africa and its AF subsidiary, Geocycle,[2] which now co-processes fossil fuels with biomass at four of its five plants. The BSEAA2 research explored the commercial prospects for part-replacement of fossil fuels with biomass to provide heat in Nigeria's cement industry (as the Bioenergy Case), based on the operational experiences of Lafarge's Ewekoro plant in Ogun State.

Tea Processing in Kenya

Kenya is the world's largest exporter of black tea. Production is dominated by smallholders through 70 factories owned by over 650,000 growers, through 54 farmer-owned companies. These companies are, in turn, shareholders in Kenya Tea Development Agency (KTDA) Holdings Ltd. They produce over 60% of Kenya's exported tea and are the main focus of this research. Tea processing requires significant quantities of thermal energy, accounting for 90% of a typical factory's energy needs and up to 30% of costs. Heat is produced at all KTDA factories using fuel wood. With this energy source becoming more difficult and expensive to obtain in some areas, some have explored alternative biomass fuels such as briquettes and agriprocessing residues. The research explored the prospects for part-replacement of fuelwood with non-wood biomass to provide heat for tea processing, drawing on the experiences of Makomboki tea factory in Murang'a County, the Bioenergy Case for this demand sector.

Wood Processing in Tanzania

Tanzania has East Africa's most extensive forest resources and some of the region's largest plantation management and wood processing industries, which generate significant quantities of residues from the production of sawn timber, poles and tannin. Only two of these companies use those residues for CHP to meet their internal electricity and heat demands and sell excess electricity to the grid. Others use their residues only to generate heat for wood drying. Given the availability of suitable feed stock and the environmental benefits of reduced greenhouse gas emissions and more environment-friendly handling of wastes that adoption of bioenergy could offer, the landscape for residue-based CHP use in Tanzania's wood processing industry was explored, based on the experiences of the Tanganyika Wattle Company (TANWAT) in Njombe, to identify the opportunities and barriers for wider adoption.

Palm Oil Processing in Ghana

Oil palm is an important commercial crop in Ghana and the processing of palm oil provides a significant source of rural income and employment. Large-scale processors, who account for 40% of oil output, have sufficient throughput, financial capacity, energy demand and human resources to support investments in modern bioenergy technology. The six largest processors have installed combustion-based CHP plants that use solid oil palm residues to supply their own electricity and process heat. Only one company (GOPDC) also uses palm oil mill effluent (POME), an acidic processing by product, as feed stock for an AD system to generate biogas, which supplies heat to its oil refining operation at Kwae in Eastern Region. AD also reduces the environmental risks of improper POME disposal and produces digestate with nutritional benefits for soils. The research explored the commercial opportunity for POME based AD in Ghana's palm oil industry, based on GOPDC's experiences.

Horticulture in Kenya

Kenya has a large and diverse horticulture industry, including an important export sector and rapidly growing domestic demand, which supports significant employment and value addition for hundreds of thousands of farmers. Large quantities of residues are generated during grading, cleaning and processing fruits and vegetables. While solid residues are generally composted or fed to livestock, liquid residues can create disposal problems. This presents an excellent opportunity for AD as a waste management and energy supply solution. But despite the potential for using horticulture residues for bioenergy for CHP at commercial scale, and a strong regulatory framework for small-scale electricity generation, only a handful of horticulture companies have installed AD systems based on these feed stocks. The research analysed the commercial opportunities for wider adoption of AD in Kenya's horticulture sector, based on experiences at Olivado EPZ, an avocado oil processor in Murang'a County.

Dairy in South Africa

South Africa has the largest commercial dairy industry in SSA. The sector is undergoing consolidation, with the number of commercial dairy farms decreasing from 50,000 in 2000 to less than 1,200 today, while average herd size has increased from 170 to 1,000. This consolidation presents an opportunity for producing energy from cattle manure in farms where large herds are stalled indoors. However, despite South Africa being a leader in the biogas industry in SSA, there has been limited adoption of AD within the dairy sector. The research explored the landscape for AD in South Africa's dairy industry and the potential for further adoption, based on experiences at the Uilenkraal dairy farm in Western Cape Province, as the Bioenergy Case.

Sisal Processing in Kenya

Kenya is the world's third largest sisal producer, producing about 25,000 t of sisal fibre per year, of which 95% comes from ten large estates. AD based on sisal processing wastes can be used to generate electricity and ensure safe waste management, with the potential for at least 20 MWe of AD-based generating capacity. However, only one estate, Kilifi Plantations Ltd. (KPL), has invested in AD for biogas based electricity generation. The experiences of KPL and other estates were investigated to establish the constraints and opportunities for AD in Kenya's sisal industry.

[2] Geocycle is a special purpose vehicle set up to provide waste management services to Holcim's own cement operations and to other public and private entities globally.

3. Potential for Bioenergy Development in Demand Sectors

Cement Manufacturing in Nigeria

BIOMASS RESOURCE

An assessment of biomass resources indicates that there is sufficient feedstock availability within existing supply chains in Nigeria to satisfy demand for coprocessing in the cement manufacturing sector. Palm oil residues could meet just below 50% of the demand (assuming a 35% biomass substitution rate), with sufficient availability of other biomass such as wood processing residues, groundnut shells and rice husks to provide the balance - although context-specific barriers to access and collection may exist. While there are some seasonality and aggregation considerations, with proper planning and sufficient diversification, the availability of biomass resources for co-processing with fossil fuels is not a bottleneck to wider adoption within the industry.

TECHNOLOGY

Based on Lafarge Africa's experience with biomass coprocessing at its Ewekoro plant, technology selection, sourcing and operation is also not a constraint to the wider adoption of bioenergy in cement manufacturing. Biomass feedstocks present few technical challenges as they are largely free of harmful chemicals and can be cleaned, dried and resized, as necessary, using standard equipment that is readily available domestically and internationally. Modalities for biomass storage, handling and feeding are well understood within the industry, and the necessary modifications to precalciners and kilns for supplementary biomass feeding can be achieved using cement companies' own in-house engineering capacity. This applies even to relatively small cement plants, as the principles are transferable. Scaling up the use of bioenergy in the cement industry is not, therefore, constrained by technical or technological limitations.

ECONOMIC VIABILITY

The economic analysis indicates a slightly more favourable economic case for the use of bioenergy than fossil fuels (natural gas) in cement manufacturing in Nigeria, based on operating parameters at Ewekoro. Sensitivity analysis reveals that the economic case strengthens as the bioenergy substitution rate increases, if biomass can be procured for less than USD 65/t. Biomass coprocessing also reduces exposure to fossil fuel price fluctuations and supply interruptions, which are common in Nigeria and other SSA countries.

COMMERCIAL PROSPECTS FOR REPLICATION

The commercial case for the partial substitution of natural gas with biomass for cement manufacturing by LafargeAfrica was driven by unreliable gas supplies, the competitive cost of biomass and a commitment to reducing GHG emissions. A critical enabling factor has been the presence of a specialised AF resource handling company (Geocycle) and experienced fuel aggregation companies, which have together been responsible for the development of biomass supply chains for Lafarge Africa. This model has been extremely successful in achieving commercial viability and contributing to corporate climate change and sustainability targets. In addition, it supports sustainable agricultural processing and contributes to rural development through waste recovery, job creation and increased incomes to farmers and rural enterprises.

INSTITUTIONAL, MARKET AND REGULATORY FRAMEWORK

The institutional, market and regulatory framework in Nigeria was not a driver for Lafarge Africa's decision to pursue a shift to bioenergy. While policy or regulation could support wider adoption of their approach, particularly if used to de-risk the development of biomass supply chains, this has so far been neither a barrier nor an enabler for investment in bioenergy for cement manufacturing in Nigeria.

REPLICATION POTENTIAL IN OTHER TARGET SSA COUNTRIES

There is a significant potential for wider adoption of bioenergy in the cement sector in Nigeria and in the other BSEAA2 target countries in SSA, where co-processing with biomass fuels is already practised to some extent. Geocycle is already working successfully supplying local bioenergy to Holcim's cement plants in Kenya (wood residues, rice husks, etc.), Uganda (coffee residues) and Tanzania (wood residues, coffee residues, etc.), and some plants in Ethiopia use small quantities of biomass (including coffee husks and wood residues).

CONCLUSION

The decision by individual cement companies to adopt bioenergy will depend upon the cost of developing reliable, cost-effective and sufficient fuel supplies, relative to current fossil fuel solutions, and the cost of adapting or installing equipment to handle bioenergy. The need to set up supply chains with new, unfamiliar partners capable of delivering sufficient feedstocks at prices competitive with fossil fuels, and to undertake suitable technological modifications to incorporate biomass co-processing in cement manufacturing, are key factors for other producers looking to adopt this model. The environmental drive to 'green' cement by using renewable energy has been an important driver for Holcim to set up Geocyle as a special purpose vehicle for finding economically sound AF substitutes for fossil fuels, especially bioenergy in Africa. However, this is not necessarily a key motivating factor and is highly dependent upon cement companies' specific sustainability and social responsibility commitments.

Given the good business case for bioenergy adoption in this sector, sharing lessons from the experiences of companies such as Lafarge Africa can help boost confidence amongst other players regarding the commercial and environmental benefits of such a transition. As more cement manufacturers adopt bioenergy, collective expertise will grow and this approach to heat production for cement manufacturing will become normalised and will make further replication easier in future.

Tea Processing in Kenya

BIOMASS RESOURCE

The biomass resource assessments indicate that availability and access to suitable feedstock is not a bottleneck to wider adoption of non-fuelwood biomass fuels for tea processing in Kenya. The three residues used for bulk briquette production, namely sugar bagasse, sawdust and pineapple leaves, are available in sufficient quantities to comfortably meet KTDA's goal of achieving 20% non-fuelwood bioenergy substitution at its 70 factories. Bagasse briquettes alone could supply energy for over half of Kenya's annual tea production of about 439 kt. There is also substantial additional feedstock potential from other sources such as coffee husks, maize stalks and cobs, wood processing residues and nut shells, which could be blended with the three current feedstocks, though adoption potential is likely to be lower due to cost, quality, seasonality and aggregation constraints. The assessment indicates that there is also sufficient production capacity from KTDA's current pre-qualified briquette suppliers, as well as several additional suppliers, to meet KTDA's potential requirement for alternative fuels. There are therefore no significant supply-side barriers to increased briquette production.

TECHNOLOGY

Based on the experiences of KTDA, Makomboki and briquette suppliers, technology acquisition, operation and maintenance is not a constraint to the wider adoption of non-wood biomass fuels in this sector. Suitable boilers and ancillary equipment for withering troughs and tea dryers are available from reputable local and international suppliers, and there is a sufficiently large customer base within Kenya to ensure access to spares, replacements and manufacturer support. KTDA factories have many years' experience operating this robust equipment and there is well-developed operating expertise among factory staff and regional engineering support teams. KTDA Holdings subsidiary company, TEMEC, can repair, maintain and even produce key technical equipment and spares for KTDA's factories. With training of factory personnel and machinery upgrades (such as movable grates to address clinkering and ash removal, and automatic briquette feeders), tea factories could achieve briquette feeding ratios greater than the 20% blending level targeted by KTDA. There are also dedicated boilers on the market that can operate with 100% briquettes, pellets or loose biomass residues. But for economic reasons discussed below, KTDA factories have not considered investing in equipment replacements of this nature.

ECONOMIC VIABILITY

Economic analysis shows an unfavourable result for the partial substitution of fuelwood with briquettes, which results in a significantly higher cost of thermal energy. Increasing the substitution rate only increases the cost differential. Sensitivity analysis based on operating parameters of Makomboki Tea Factory shows that the tipping point of viability is achieved at a delivered briquette cost of around USD75/t, which is substantially lower than the current cost of around USD168/t. While there may be boiler performance improvements attributable to the use of drier and more standardised briquettes, this cost differential has meant that no more than three KTDA factories have so far bought briquettes from the three suppliers pre-qualified under the latest procurement round.

COMMERCIAL PROSPECTS FOR REPLICATION

Although energy from briquettes is around twice as expensive as fuelwood, at the point of delivery, there are a number of commercial benefits that might motivate tea factories to consider using briquettes to supplement fuelwood. Such motivating factors may include market expectations, the need to ensure that fuel supply is diverse, secure, stable and sustainable, and to build functional relationships with supportive development partners. However, these benefits are currently insufficient to overcome the cost barrier. Despite the presence of ample feedstock and sufficient production capacity amongst pre-qualified briquette suppliers, there has been only limited uptake of briquettes by KTDA factories network. Unless there is a significant change in relative fuel costs, this suggests very limited replication potential within KTDA factories, who can access sustainably produced fuelwood from local farmers (often their own shareholders), KTDA plantations and other suppliers, at lower cost.

INSTITUTIONAL, MARKET AND REGULATORY FRAMEWORK

The institutional, market and regulatory assessment indicates that KTDA operates in a highly structured, bottom-up framework, in which decisions on investment, management, operations and fuel acquisition start at a factory level. Alternative energy initiatives may be promoted by KTDA Management Services, but it is the decision of individual factories, and ultimately their farmer members, to decide which fuels and technologies they adopt, based on their own situations, preferences and financial positions. Fuelwood grown on small private farms is currently the cheapest option, as it is not subject to regulation and costs incurred by plantation-grown wood and biomass briquettes, such as taxes, movement permits and county cess payments. To reduce the cost differential between fuelwood and briquettes, and to open fairer competition, A VAT exemption was awarded to briquettes in July 2021. Exemptions from the other permits and fees would improve the prospects for commercial forestry concerns and briquette manufacturers to compete with informal wood producers.

REPLICATION POTENTIAL IN OTHER TARGET SSA COUNTRIES

Kenya's promotion of smallholder tea production, ownership and management has good potential for replication in other tea-producing countries in SSA. Several international organisations (such as Gatsby and The Wood Foundation) are already supporting this approach elsewhere in East Africa. However, the Kenya experience suggests there may be limited potential for alternative bioenergy for tea processing in other BSEAA2 target countries. As in Kenya, fuelwood is the key fuel in almost all tea factories in SSA, whether large tea estates or smallholder cooperatives. There is no evidence of commercial motivation for purchasing alternative fuels, beyond the opportunistic use of locally available biomass residues.

CONCLUSION

In sum, KTDA's experience of exploring alternative fuel options for its factories has been valuable as part of a wider rationalisation of energy consumption within the smallholder tea sector. This has revealed the scope for numerous improvements in the way fuel is handled, prepared and fed, and the ways in which boilers and related machinery are operated, managed and maintained. So while an envisaged switch away from fuelwood to alternative forms of bioenergy is assessed to be more expensive in the tea sector and currently suggests limited replication potential, a potential does exist for strengthening the business case for such enterprises through more equitable regulatory and fiscal treatment of biomass briquettes and sustainably grown fuelwood. This will ultimately also support the diversification and strengthening of bioenergy supply chains on which tea factories depend, even when retaining a fuelwood-dominated supply system.

Wood Processing in Tanzania

BIOMASS RESOURCE

The biomass resource assessment shows that availability and access to suitable biomass is not a bottleneck to wider adoption of CHP in Tanzania's wood processing industry. There is significant underutilised biomass potential from wood processing residues and supply is expected to increase as the industry continues to grow. That growth could provide a valuable bioenergy resource for heat and power generation to meet Tanzania's growing electricity demand, in line with the country's focus on expanding rural access to electricity, strengthening the national grid and reducing GHG emissions in the electricity sector.

TECHNOLOGY

Based on experiences from TANWAT, technology selection, sourcing and operation are not constraints to the wider adoption of bioenergy in this sector. Biomass boilers and steam turbines are a proven combination at 1-5 MW scale, with several (mainly Asian) suppliers providing equipment of quality and cost that now out-compete European and North American manufacturers. While there is some scope for process enhancements and the use of more modern CHP systems, the key barriers to wider adoption are not technical or operational.

ECONOMIC VIABILITY

The economic analysis indicates a significant cost-saving for heat from a residue-based CHP system, compared with a stand-alone low-pressure boiler, and a modest saving for electricity compared with reliance on the grid and stand-by generators. That saving is much improved if revenue from sales of surplus electricity to the grid is factored in. The positive economic case arises due to TANWAT's uniquely diverse production lines for timber, poles and tannin that result in high demand for process heat, which underpins the economic case for combustion-based bioenergy. Even with a significant need for electricity, a minimum capacity factor of 79% is required to achieve a cost reduction in electricity, indicating that combustion-based CHP is not necessarily economically attractive if electricity demand is the primary requirement of the enterprise.

COMMERCIAL PROSPECTS FOR REPLICATION

While there is some scope for process enhancements and the use of more modern CHP systems, the opportunity for bioenergy-based CHP production in Tanzania's wood processing sector is highly constrained, with no new wood processing CHP project commissioned in the past five years. Only one other wood processing company (Mufindi Paper Mills) uses bioenergy-based CHP production, and together with TANWAT also sells power to the grid through a legacy power purchase agreement (PPA) with the state-owned utility, TANESCO. Other wood processors in Tanzania have insufficient internal requirements for heat and power to justify a CHP investment. Several have considered investing, with an eye on exporting surplus electricity to the grid, but have refrained from doing so as their internal heat and power demands are insufficient, new PPAs for sale of surplus electricity to TANESCO are not available, and they would only be eligible for commercially unviable feed-in tariffs.

INSTITUTIONAL, MARKET AND REGULATORY FRAMEWORK

Beyond practical constraints for self-use, the other key barrier restricting wider adoption of CHP in the wood processing industry is policy-related. Aggressive grid development and major investment in natural gas, hydropower, solar PV and wind generation have led to significant grid extension and stabilisation over the last 10 years. While Tanzania's current policy and regulatory framework is, on paper, more supportive of bioenergy electricity development in the BSEAA2 scale range (10 kWe to 5 MWe) than all the target SSA countries except South Africa, the utility is not incentivised to procure electricity from small independent power producers. A lack of practical government support for bioenergy, particularly from more attractive feed-in tariffs and long-term PPAs, has thus significantly reduced the incentives for generating and selling electricity from wood processing residues and other biomass. Given Tanzania's large territory, dispersed rural population and significant distances to transmit electricity to relatively few major load centres, a strong case should exist for baseload embedded power generation - such as from small-to-medium-sized wood industry CHP to strengthen the grid in remote areas. Unfortunately, this case has not been successfully made.

REPLICATION POTENTIAL IN OTHER TARGET SSA COUNTRIES

Of the other BSEAA2 target countries in SSA, only South Africa uses wood residues for CHP, in both its large pulp and paper sector and its commercial timber sector. The policy and commercial enabling environments in the other eight target countries do not favour investment in wood residue-based bioenergy, beyond the production of heat for processing timber or other wood products, despite the potential benefits of generating useful energy from wastes, supporting inward commercial investment in the forestry sector, generating sustainable rural development impacts and contributing to grid stability and climate change mitigation and adaptation objectives.

CONCLUSION

In sum, while the wood processing industry in Tanzania generates considerable (and growing) quantities of residues, a combination of low internal heat and power demand at processing enterprises, relatively cheap and relatively reliable grid power, low FiTs and a government focus on large-scale hydropower, discourage new investments in bioenergy technology. Thus, while the TANWAT model has the potential to develop strong rural embedded generation, support local sustainable development objectives and reduce demand for fossil fuels for electricity generation to meet Tanzania's climate change targets, replication in today's political and economic circumstances is unlikely.

To promote the more widespread use of wood residues for bioenergy in Tanzania's wood processing sector:

- EWURA, the energy regulator, should increase its FiTs for wood residue bioenergy CHP generation to ~US¢20 per kWh, to reflect actual commercial costs;
- TANESCO should commit to PPAs that guarantee the purchase of electricity from new, or expanded, wood residue energy CHP projects;
- The Rural Energy Agency and its development partners should support the development of wood residue CHP projects; and
- PPAs commissioned by TANESCO should be of sufficient duration to enable capital costs to be recovered and a commercial profit to be realised.

Palm Oil Processing in Ghana

BIOMASS RESOURCE

Biomass resource assessments indicate that there is sufficient POME available at Ghana's six largest palm oil processors to meet the potential heat demand if they wished to refine all their crude palm oil, which is not currently the case at four of these six large oil palm processors. Feedstock supply is therefore not a barrier to wider replication of GOPDC's AD investment for heat production, although seasonality of POME supply may be a constraint to 100% year-round adoption of POME-based AD.

TECHNOLOGY

Based on the experiences of GOPDC and specialist developers of AD solutions for the palm oil industry, such as Biotec International, technology selection, sourcing and operation is not a constraint to the wider adoption of AD in this sector. Suitable technology for POME-based AD has been fine-tuned across Latin America and SE Asia over the past 30+ years. The leading technology providers offer integrated partnerships, custom-built designs and extended on-site training, which is vital to engender customer confidence in immature markets such as West Africa.

ECONOMIC VIABILITY

The economic viability assessment indicates cost savings by replacing diesel with biogas to generate heat for oil refining. The need for supplementary process heat was probably the main driver for GOPDC's investment in AD. In contrast with AD investments in other industries and in other countries, demand for electricity was not a motivating factor, given sufficient availability of power from the company's existing combustion-based CHP plant and the national grid.

COMMERCIAL PROSPECTS FOR REPLICATION

From a commercial perspective, wider adoption of AD in Ghana's palm oil industry is hampered by the fact that all the large processors have combustion-based CHP plants that already meet their requirements for process heat and contribute to their power needs, with the balance of electricity purchased cheaply from the grid. Only one (Juaben Oil Mills), in addition to GOPDC, has a refinery with an additional demand for heat. However, Juaben Oil Mill's owners have decided to expand their combustion-based CHP capacity to meet this demand, rather than set up an AD plant. Other potential motivations for adopting AD, such as more rigorous enforcement of POME treatment and disposal regulations, are unlikely to make the commercial case stronger, given that there are less costly alternatives for effective POME management. While the efficacy of AD digestate as a fertiliser for oil palm plantations is not yet fully determined, this may improve the business case for AD in the future.

INSTITUTIONAL, MARKET AND REGULATORY FRAMEWORK

The policy, regulatory and market context for electricity in Ghana is another key barrier to wider adoption of AD by palm oil processors. Significant investments were made in fossil fuel generating capacity to meet major electricity shortfalls during the 2000s, to the extent that Ghana now has an

oversupply of electricity on the grid primarily from fossil-fuel electricity generation.
This has led to virtually no new renewable electricity capacity on the grid being licensed by Ghana's Energy Commission (the regulator) since 2018.
This has stifled investment in grid-based renewable electricity, a situation that will last for several years.
It effectively prevents bioenergy development for electricity generation, except for self-consumption, and significantly constrains investment in power generation from oil palm processing residues by Ghana's six large palm oil producers. It is hoped that the new National Energy Plan, currently under legislative review, will break this bottleneck to encourage biomass-based electricity generation into the grid in the near future, particularly in areas with weak electricity infrastructure.

REPLICATION POTENTIAL IN OTHER TARGET SSA COUNTRIES

Most of the other BSEAA2 target SSA countries have either only recently introduced oil palm or have been pursuing its development at very small-scale, using mostly artisanal techniques, resulting in a nascent or non-existent AD opportunity.
Only in Nigeria, the world's fifth largest palm oil producer, where there are significant shortages of electricity and a poor national power infrastructure, do significant opportunities exist for licensing renewable electricity IPPs, with relatively high USD-tied FiTs for biomass-based renewable electricity derived from palm oil residues. This may offer potential for further development of POME-based AD in West Africa, similar to that already developed by Presco in Nigeria (as sister company to GOPDC in Ghana), which is generating electricity for own use and export to the grid from POME-based AD.

CONCLUSION

In sum, although POME is a plentiful resource in Ghana's industrial palm oil industry, the potential for wider deployment of AD is limited, given that all the large processors already have combustion-based CHP systems for meeting their on-site energy demands fuelled with solid oil palm residues, access to cheap and abundant grid electricity and an inability to export surplus power to the grid, at least for the time being. While there may be other commercial drivers for the adoption of AD, such as stronger environmental enforcement and digestate valorisation, replication potential is likely to be limited to those mills with an additional demand for process heat (e.g. from a refinery), which a CHP system alone cannot satisfy.

Horticulture in Kenya

BIOMASS RESOURCE

Resource assessment indicates that availability and access to suitable horticultural residues is generally not a bottleneck to the adoption of AD in fruit and vegetable processing enterprises in Kenya that generate liquid effluents and moisture-rich residue streams. The potential is highest in centralised facilities in rural areas that require both a cost-effective waste management system and an energy supply option, where they are dependent upon relatively unreliable and expensive grid electricity. While there is theoretical potential for using wastes from local fruit and vegetable markets for AD, unclear ownership and lack of aggregation hampers the opportunity for conversion to bioenergy. While the Kenyan horticultural sector has been slow to adopt AD, the assessment indicates potential to expand capacity from processing residues, particularly within the pineapple, mango and avocado (oil) sub-sectors. Existing uses for residues need careful consideration, so as not to negatively impact the return of nutrients and organic matter to fields, irrigation or livestock.

TECHNOLOGY

An assessment of technology supply chains, on the other hand, indicates that technology selection, sourcing and operation are constraints to wider adoption of AD in Kenya's horticulture sector. Where there is a requirement for generating electricity on site, solar power is seen as a cheaper and more reliable substitute for diesel generators, to complement grid electricity. But for certain types of processing that need a reliable supply of heat, AD may offer a solution. Technological barriers to wider adoption include the high cost and operational sophistication of biogas technology. Olivado's experience indicates that these challenges can be overcome through adaptation and localisation of technology to reduce costs, and on-the-job training of staff to build competency for installing and operating such technologies. This may be a daunting challenge for potential adopters and speaks to a need for experienced technology developers to offer an outsourced package of customised technology and a management team to operate and maintain the facility on behalf of the investors or owners.

ECONOMIC VIABILITY

The economic assessment demonstrates the high economic viability of investing in a plant with similar processing and waste management requirements to Olivado. The key factors contributing to its economic success are the significant onsite demand for heat and power, and the company's success in building an AD system cheaply (compared with turnkey European AD systems of similar size and performance), avoided liquid waste disposal costs and the ability to valorise multiple outputs (e.g. from the potential sale of digestate as a fertiliser and the bottling of biogas as vehicle fuel). Sensitivity assessments indicate that the Bioenergy Case would be viable for any CAPEX below USD 5,110 per kW of installed capacity (compared with around USD 3,300/kW for the Olivado facility).

COMMERCIAL PROSPECTS FOR REPLICATION

A commercial case can be made for wider adoption of AD, based on the experiences of Olivado, with certain enabling factors such as high on-site energy requirements, high waste treatment or disposal costs or high expenditure on diesel (owing to weak or unreliable grid power). However, a number of barriers are holding back deployment in the Kenyan horticulture industry. Few processors have large onsite energy demands. Where these demands do exist, solar PV is likely to represent a cheaper 'turnkey' option than AD. Many fruit and vegetable processors are also located close to urban centres, where reliable grid electricity is accessible. While waste disposal can be a challenge and hence an opportunity for AD - it is often not seen as a critical cost factor. The standard industry solutions are to compost solid wastes and to treat liquid wastes before safe discharge. Securing finance is another bottleneck to replication, owing to the low or non-existent familiarity of local banks with commercial-scale AD projects. To build confidence in the market, some form of external validation, cost-sharing or guarantee scheme is likely to be required, if AD projects are to obtain financing from local financial institutions.

INSTITUTIONAL, MARKET AND REGULATORY FRAMEWORK

A key barrier to wider adoption of AD within the horticulture industry in Kenya is the unattractive policy and regulatory framework for electricity generation and supply, with a FiT of USD 0.10/kWh for biogas projects with a generating capacity of 200 kW to 10 MW. This FiT has failed to stimulate significant investment from horticultural producers. Moreover, Kenya Power, the national utility, lacks the incentives to invest in upgrading its distribution infrastructure to handle new electricity generated from rural generators to feed into the grid, further disincentivising investment in AD-based power generation. While the recent exemption of biogas and pre-fabricated biogas digesters from VAT is a step in the right direction, high import duties on AD equipment (such as engines, pumps, valves, gas membranes and monitoring systems) are further impediment to such investments. Simply put, Kenya's electricity policy, regulatory, tax and institutional environment provides essentially very poor incentive to invest in horticulture-based AD.

REPLICATION POTENTIAL IN OTHER TARGET SSA COUNTRIES

The potential for horticultural residue-based AD in other target countries exists, but is currently untapped. This is because many of the limiting factors identified in Kenya, such as low electricity FiTs, poor electricity infrastructure in rural areas, high duties on imported bioenergy equipment and a lack of tax or VAT relief, also exist in many of the other target countries with significant horticulture sectors, including Uganda, Tanzania and South Africa.

CONCLUSION

In sum, there is a largely untapped opportunity for AD-based bioenergy generation in the horticulture sector in Kenya, and the flagship project at Olivado demonstrates potential for improving the commercial case in other sub-sectors. Local technology developers should be supported to continue developing cost-competitive alternatives to imported AD technology and the Government of Kenya should double its FiT for biogas-derived electricity, with the energy regulator (the EPRA) making this a priority. Furthermore, the Ministry of Energy and the EPRA should require Kenya Power to

- Prioritise developing biogas electricity PPAs;
- Put in place the mechanisms for doing so; and
- Strengthen the grid to improve the reliability of supply and grid export. Stricter enforcement of waste treatment and disposal regulations by the National Environment Management Authority (NEMA), together with minimization or removal of duties on import of biogas equipment, could further help boost the attractiveness of AD in Kenya's horticulture sector

Dairy in South Africa

BIOMASS RESOURCE

The biomass resource assessment indicates that the opportunity for wider adoption of AD in the South African dairy sector exists mainly on large commercial dairy farms with herds of at least 400 stalled lactating cows (800 in total, given that only 50% of cows are usually lactating). According to the biomass resource assessment, about 240 dairy herds in SA, with a total of at least 180,000 lactating dairy cows, meet this requirement. Availability and access to suitable biomass within large scale dairy farms in South Africa is therefore not a bottleneck to wider adoption. The power generation potential from manure-based AD and the electricity demand from the dairy sector are both highest in the Western Cape, Eastern Cape, KwaZulu-Natal and Free State Provinces, where milk production is concentrated, making these the most promising regions for further biogas-based electricity production.

TECHNOLOGY

While access to suitable AD technology is not a barrier to adoption within the dairy industry, much of that technology was developed in subsidised European environments and replication in SSA is hampered by high cost and impact on payback time. This realisation is driving a small number of specialist South African companies to develop locally-manufactured versions of European technology. They are adopting proven technical principles from international suppliers and combining these with selective importation of competitively-sourced components, local manufacture of equipment and cost-cutting design modifications. This blended approach cuts costs and can stimulate wider adoption. They are also offering outsourced installation and management services that permit the investor to focus on their core commercial business (i.e. milk production), while leaving the technically complex aspects of managing digester performance and the CHP plant to the technology provider, who sells power back to the project owner.

ECONOMIC VIABILITY

The economic analysis reveals a favourable reduction in the net cost of electricity after installing a 400 kW biogas-powered CHP plant at the Uilenkraal dairy, with an estimated reduction in LCOE for electricity of 23% over a 10-year modelling period. Sensitivity analysis reveals that the AD plant can provide cheaper power than full grid reliance down to a total power demand that is about one third of the current demand, and down to a bioenergy fraction (the percentage of power derived from the AD plant) of about 20% (compared with 72% at present). For plants of a similar size, an average grid power cost above USD 77/MWh favours such an investment, significantly lower than the farm owners' current grid power cost of around USD 126/MWh. The investment is, therefore, economically competitive, not only under current parameters, but also at significantly lower power output levels, and with significantly cheaper grid power.

COMMERCIAL PROSPECTS FOR REPLICATION

From a commercial perspective, further adoption of AD in South Africa's dairy sector is likely to be limited to those few large farms that have significant on-site power demands, either for their own milk processing plants or an ancillary enterprise such as a feed mill. But the number of combined producer/processors has been falling, with milk production being predominantly rural and most dairy processors located in large towns and cities, so the opportunity is limited. Potential adopters also need access to finance, for which the separation of the AD operation from the farm's core business helps de-risk the investment by the farm owner.

INSTITUTIONAL, MARKET AND REGULATORY FRAMEWORK

Beyond practical constraints for self-use, the other key barrier restricting wider adoption of AD by dairy farms in South Africa relates to electricity policy. For most potential adopters, commercial viability relies on the ability to sell surplus power at an attractive tariff and with minimal bureaucracy, which is currently a constraining factor. South Africa's progressive policies to support renewable energy development, including its very successful Renewable Energy Independent Power Producer Procurement Programme (REIPPPP), have provided a strong impetus for renewable electricity growth over the past decade. There have also been encouraging recent amendments to the electricity regulations, given the increasing unreliability of the national grid. These changes mandate Eskom, the state-owned national utility, to work with municipalities and large industries to procure electricity directly from small-scale producers capable of supply upward of 100kW of renewable electricity. While this opens interesting new opportunities for such small-scale power producers, uptake has been limited owing to the high costs and administrative requirements for 'wheeling' electricity using Eskom's grid, especially for rural generators such as dairy farms. For more dairy farms to become interested in generating power from AD and selling that power, Eskom will need to significantly reduce its wheeling charges and administrative requirements (reporting and onerous application procedures, etc.) and improve its rural network infrastructure (e.g. by upgrading grid connections) to accommodate smaller scale embedded generators.

REPLICATION POTENTIAL IN OTHER TARGET SSA COUNTRIES

None of the other SSA BSEAA2 target countries has a dairy sector as large and modern as South Africa's, but several (including Kenya, Uganda, Tanzania and Zambia) are growing and becoming more formalised, under the framework of cooperatives and large commercial dairies. Pilots to set up AD-based milk chillers that enable small dairy farmers using small (e.g., 20 litre milk storage capacity) AD units to chill their milk are being implemented in these four countries. While commercial viability is yet to be demonstrated, this innovation has the potential to increase the supply of milk from currently remote locations to larger processors and markets.

CONCLUSION

In sum, there is a strong underlying technical potential for bioenergy use in large commercial dairy farms in South Africa, and more widely in SSA. Wider uptake will largely depend on innovation in localisation and cost reduction of AD technologies, sufficiency of internal demand for heat and /or power at milk production sites, and a conducive policy framework for small-scale power producers to sell surplus electricity to the grid or to wheel power to willing off-takers

Sisal Processing In Kenya

BIOMASS RESOURCE

The resource estimates for sisal in Kenya indicate that the current quantities of sisal processing wastes (in the form of pulp and wastewater) are more than sufficient to meet the electricity requirements of the sisal industry. Sisal residues are centrally-located at processing plants and well-suited to biogas production. Given the lack of competing uses for these residues, which need to be safely treated and disposed of, their use as feedstock for AD also offers a waste management solution. In addition, there are opportunities to valorise the digestate from AD-based electricity production as a source of fertiliser for the estates and nearby farmers. Therefore, the availability of sufficient feedstock is not seen as a barrier to wider replication of AD based on sisal residues, and should in fact be a motivating factor for its adoption.

TECHNOLOGY

Technology selection, sourcing and operation is considered a constraint to the wider adoption of AD in the sisal sector. Most providers of commercial-scale AD systems in SSA are based in Europe. KPL's AD investment was largely funded with German development funds, while a similar plant at Hale Sisal Estate near Tanga in Tanzania was largely funded by UNIDO, both using German technology. These technology providers have typically supplied only one AD system, indicating a small and immature market for this technology. The German technology partners in the KPL biogas project have become discouraged by the challenging commercial environment, following an optimistic start in the late 2000s, and are not thought to have been involved in any other AD installations in Africa. This lack of diverse, Africa-focused commercial experience, and the absence of supply chains in SSA for equipment, servicing or spares, means that other potential project developers lack confidence in the reliability and performance of sisal-based AD technology. High CAPEX is a further important deterrent to investment.

ECONOMIC VIABILITY

Based on the current operating parameters of the flagship project at KPL, the economic assessment indicates a higher cost of electricity from the AD plant grid electricity. Technical challenges linked to a power factor penalty by Kenya Power, and an unattractive FiT (USD0.10 per kWh for biogas-based generation from 200 kW to 10 MW capacity) deters the project owners from utilising all the available waste to maximise electricity production.

A sensitivity analysis demonstrates, however, that such an AD investment could be economically viable if the AD plant capital costs were reduced by 68% (to approximately USD138,000) or if the FiT was increased to USD0.18/kWh.

COMMERCIAL PROSPECTS FOR REPLICATION

A commercial case can be made for replication of the Kilifi AD venture based on avoided costs of sisal waste disposal, the opportunity to meet the significant onsite electricity requirements linked to sisal processing and the potential to feed surplus power into the grid. Experiences from the project indicate, however, that this commercial case is currently weak, primarily due to the lack of interest in electricity procurement from sisal-based bioenergy on the part of Kenya Power, and the lack of necessary support from the EPRA for commercially-viable FiTs that would make investment in bio-electricity from sisal (and other biomass) financially viable. Furthermore, waste disposal is not seen as a key driver, with many sisal estates deploying cheaper forms of waste treatment such as aerobic ponds or enzyme treatment. Securing finance for such AD projects is not a major barrier, and the large sisal estates could potentially finance such projects themselves, if the business case was convincing.

INSTITUTIONAL, MARKET AND REGULATORY FRAMEWORK

It is an important finding of the study that the key barrier to wider adoption of AD within the sisal industry in Kenya is the unattractive policy and regulatory framework for electricity generation and supply. Interest in sisal AD-derived electricity generation has waned significantly over the past decade, primarily due to a very low FiT for biogas-derived electricity. Moreover, Kenya Power lacks the incentives to invest in upgrading its distribution infrastructure to handle new electricity generated from small rural generators[3] to feed into the grid, further discouraging investment into AD-based power generation.

REPLICATION POTENTIAL IN OTHER TARGET SSA COUNTRIES

Of the other four BSEAA2 target SSA countries that produce sisal (Tanzania, Mozambique, Ethiopia and South Africa), Tanzania presents the single largest opportunity for replicating the AD experiences of KPL in Kenya. However, Hale Estate suffers from a number of the same issues as KPL in Kenya, with inadequate policy and regulatory support, particularly for more attractive FiTs and long-term PPAs for sisal AD-generated electricity, similarly deterring interest and investment in this sector.

CONCLUSION

In sum, the opportunity for AD-based bioenergy generation in Kenya's sisal sector is currently discouraging, owing to various, technological, economic, and policy and regulatory barriers, although there is a potential for improving its commercial case. The key recommendation is for the Government of Kenya to increase its FiT for biogas-derived electricity to USD 0.18/kWh, with the EPRA making this a priority. The Ministry of Energy and the EPRA should require Kenya Power to

- Prioritise developing biogas electricity PPAs;
- Put in place the mechanisms for doing so; and
- Strengthen the grid (particularly medium voltage lines in key sisal producing areas in Eastern Kenya), to improve the reliability of supply. NEMA's enforcement of waste treatment and disposal regulations, coupled with lower equipment costs and locally adapted technology, could further help boost the prospects for adoption of AD in the sisal industry

[3] Kenya Power, like TANESCO (Tanzania), Eskom (South Africa) and many other monopoly utilities, does not like to connect small-scale embedded generation (SSEGs) because it is impossible to control their despatch of electricity, and Kenya Power wants to be able to control how much electricity is put onto the grid at any time.

4. Conclusions and Way Forward

Extensive research into energy use in the seven prioritised demand sectors in SSA indicates that there is considerable potential for the adoption of bioenergy to substitute for other energy sources, especially from fossil fuels. While the BSEAA2 project has located and studied innovative, commercially successful and technically sound enterprises using bioenergy in five of the ten target SSA countries, there are similar opportunities in the same demand sectors in all these countries, and others, under the right conditions. But it has been shown that the successful adoption of bioenergy, whether for thermal applications, electricity supply or for combined heat and power, depends upon a complex combination of both supply side and demand side considerations.

In the case of purely thermal applications, the use of biomass fuels to generate industrial heat is generally straightforward, given that there is no relevant ministry, regulatory authority or heat use specification. Technical considerations are also straightforward, with robust technology supply chains and significant local expertise available for operation and maintenance.

Where the feedstock is not produced on-site, such as in the cement manufacturing and tea processing sectors, the barriers to adopting bioenergy to substitute for fossil fuels arise primarily from the cost and logistics of identifying, sourcing, procuring, aggregating, transporting and supplying the relevant biomass fuels to the plant location. Seasonality considerations of locally available feedstock are also important in matching supply with demand and ensuring stable and secure supply of fuel source. Dedicated resources, specialist skills and investment in sourcing and aggregation are required to set up durable and commercially viable supply chains for such biofuels. From a supply side perspective, this is the most difficult component of a bioenergy project. Most enterprises that seek to switch from one fuel source to another, particularly from fossil fuels to biomass, fail because they do not get the supply side right. This challenge is substantially reduced when the biomass resource is self-generated by the project owners and available at the processing location, as with POME at palm oil mills, dairy cattle manure in dairy farms and wood residues at wood processing plants, among others.

The demand sectors that involve the production of electricity and possibly heat (wood processing, dairy, horticulture and sisal) face different barriers from pure thermal applications. In these sectors, feedstock availability and access is not a constraint, given that the biomass resource is generated on site, is often plentiful and is under ownership of the entity producing and using the bioenergy.

Technology is not a limiting factor in the case of combustion-based CHP. Biomass boilers and steam turbines are a proven combination at 1-5 MW scale, with several (mainly Asian) suppliers offering high quality, competitively priced technology with reliable after-sales support.

In contrast, there are still technological barriers to the wider adoption of AD, owing to high cost and operational sophistication. The cost challenge can be partly overcome through adaptation and localisation by adopting proven technical principles from international suppliers and combining this with selective import of competitively sourced components, local manufacture of equipment and cost-cutting design modifications. Challenges related to accessing to technical skills and expertise are a further deterrent to potential adopters. But experience from the researched demand sectors indicates that there are a small number of Africa-based technology developers with the requisite skills and ability to offer an outsourced package of custom-built technology and management services to operate and maintain facilities on behalf of investors or owners. Such an approach permits the investor to focus on their core commercial business, while the technology provider handles the technically complex aspects of managing digester performance and the CHP plant, and sells electricity (and potentially heat) back to the project owner. Further technology development would benefit from finance for a project preparation facility to support experienced technology providers to roll out additional systems, for awareness raising amongst potential adopters and for supporting market research on optimal valorisation of all outputs.

Securing investment finance is another bottleneck to replication, owing to the low or non-existent familiarity of local banks and other financiers with commercial-scale AD projects. This has an effect on the potential interest rates that such enterprises can access impacting the overall attractiveness of a project. To build confidence in the market, some form of external validation, cost-sharing, risk mitigation or guarantee scheme is likely to be required, if AD projects are to obtain financing from local financial institutions instead of continuing to rely primarily on international development finance institutions.

Overall, the commercial case for bioenergy was found to be strongest where sufficient internal (on-site) demand exists for both the heat and electricity produced. Internal demand for heat is especially important for improving the economic case, as this resource is otherwise wasted and unvalued. In instances of variable demand, combining bioenergy with other technologies such as solar can support more favourable supply and demand matching. However this requires careful planning and consideration as no commercially successful cases of such hybrid systems have yet been identified in SSA to date.

Additional economic benefits from valorisation of digestate or avoided costs of waste disposal can also have a non-trivial impact on the commercial viability of a bioenergy-based venture. However, the scale of this impact will depend on current waste management regulations and laws, and waste disposal practices followed by such businesses.

If there is insufficient internal demand for the bioenergy outputs, then an enterprise must enter the market for selling some of the electricity it generates. This exposes project developers to a variety of institutional, policy and regulatory barriers, as selling electricity involves entities such as ministries of energy, energy regulators and energy supply companies, and requires adherence to various laws on licensing, standards, pricing, tariffs and equipment specifications, among others.

Electricity is highly regulated in all ten of the SSA target countries by state-owned or public companies that operate as monopolies or quasi-monopolies.[4] Selling into markets controlled by such dominant entities is extremely difficult, compounded by agencies that regulate the electricity prices technical specifications, and markets access. Electricity sale prices (most often feed-in-tariffs) are far too low in all the BSEAA2 target countries (except South Africa) to make a bioenergy project viable, if it expects to sell all or most of its electricity into the grid. Access to the grid poses particular problems for small-scale independent power producers (particularly under 1 MWe), for whom the rules tend to be most onerous. Obstacles include special metering specifications and costs, licensing and inspection stipulations, unattractive wheeling arrangements and power factor surcharges.

Put simply, when electricity enters the equation, bioenergy development in SSA is highly constrained by unsupportive or poorly-enforced policies in all the target countries, whether it be Ghana, where the regulator has stopped licensing all renewable electricity suppliers because of oversupply of fossil fuel-generated electricity, or Tanzania, where the policy framework for small-scale bioenergy electricity is good on paper, but neither the regulator nor the national utility has any interest in dealing with bioenergy electricity suppliers in the BSEAA2 range, i.e. 10 kWe to 5 MWe.

Bioenergy for thermal applications (e.g. cement manufacturing and tea processing), offers the most growth potential within the sectors and countries studied, with supportive or unobtrusive regulatory environments. When it comes to electricity, investment will be limited to enterprises with significant internal requirements and it currently makes little sense to invest in a bioenergy project that depends on external electricity sales to be profitable. To catalyse investment and further adoption of bioenergy in Africa for electricity or CHP-based applications, a more transparent and supportive enabling environment is required for the sale of electricity from small-scale producers via attractive FiTs, wheeling and other forms of electricity sales, such as dispatchable generation via the grid.

[4] South Africa differs because electrification evolved, as it did in Europe, from cities/municipalities and large factories/mines developing their own generation and grids. 40% of the distribution network in South Africa is owned and operated by municipalities, but they own less than 5% of generation capacity. The Copperbelt in Zambia still has its own electricity system, generation, transmission and distribution which is not under the national monopoly ZESCO, but these are legacy situations.

Bioenergy for Sustainable Local Energy Services and Energy Access in Africa

SUMMARY REPORT

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