CLEANER INTEGRAL UTILIZATION OF SISAL WASTE FOR BIOGAS AND BIOFERTILIZERS

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PROJECT COMPLETION REPORT

October 2011

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ACKNOWLEDGEMENTS

I prepared this document from several sources. One source was Mr. Francis Nkuba, the Project National Coordinator who gave me this assignment in the first place and provided me with information from his personal experience with the project as well as his views for future development. Mr. Nkuba was so kind as to provide me with transport and actually drive me to the project site at Hale when I needed to make a site visit on 27th September 2011.

Mr. Hamisi Mapinda, the Director General of Tanzania Sisal Board, was kind enough to provide me with additional documentation on the project. He also availed to me his personal ideas on the implementation of the project. His ideas have been instrumental in helping me to form an educated opinion on the project, some of which I have expressed in my recommendations.

Another important source of information was Mr. Gilead Kissaka, the Project Technical Officer, based at the project site at Hale. Mr. Kissaka's wealth of the technical information pertaining to the project was more than useful for preparation of this document.

In the process of preparing this document, it was inevitable to consult documents prepared by the project officers. I have made profuse use of technical project reports, progress reports and similar write-ups written by these gentlemen in the process of reporting on the project. They were kind enough to provide some of them to me in soft copy. In some cases I have used the text from these documents almost verbatim. In particular all quantitative information presented in this document is quoted directly from these sources. Even though I have not acknowledged this within my text I would like to take this opportunity to put this on record.

At the end of this document I have listed some of the documents I consulted during this study. That is not the complete list of the documents I studied, nor is it a listing of all the websites I visited during preparation of this document. I have omitted others not because they were not helpful, but for purposes of keeping the document manageable.

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LIST OF ABBREVIATIONS

BOD	Biological Oxygen Demand
CDM	Clean Development Mechanism
CFC	Common Fund for Commodities
CH_4	Methane
CO_2	Carbon dioxide
CSTR	Continuously Stirred Tank Reactor
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EWURA	Energy and Water Utilities Regulatory Authority
FAO	The Food and Agriculture Organization of the United Nations
FIGHF	FAO Intergovernmental Group on Hard Fibres
H_2s	Hydrogen sulphide
kW	Kilowatt
kWe	Kilowatt electrical
MW	Megawatt
NCPC	National Cleaner Production Centre
REA	Rural Energy Agency
SAT	Sisal Association of Tanzania
SIDO	The Tanzania Small Industries Development Organisation
TANESCO	Tanzania Electric Supply Company
TATC	Tanzania Automotive Technology Centre
TSB	Tanzania Sisal Board
Tsh	Tanzania Shilling[1]
UASBR	Upflow Anaerobic Sludge Blanket Reactor
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention for Climate Change
UNIDO	United Nations Industrial development Organisation
US$	United States Dollar

[1] At the time of preparing this report US$ 1 was equivalent to about Tshs 1,662

ABSTRACT

Decomposition of sisal biomass (under anaerobic conditions) releases methane and carbon dioxide into the atmosphere. A little over half of this biogas is methane, about a quarter is, carbon dioxide, the rest is oxygen and small quantities of hydrogen sulphide. After the Rio Summit of 1992, UNIDO and UNEP launched pilot projects in resource-efficient and cleaner production to demonstrate preventive environmental strategies.

The wet sisal leaf decortication process, in which about 97 percent is “waste” biomass, is recognised to be an environmental hazard. Studies in Tanzania have shown that this biomass is over twenty times as polluting as average domestic waste.

In 2000 the sisal industry in Tanzania developed a proposal for a project to establish a pilot plant to demonstrate the feasibility of producing biogas and electricity from sisal leaf waste, and explore utilization of the liquid and solid biogas by-products as fertilizers.

The project was initially to be implemented at Kwaraguru Estate of Amboni Limited. It turned out that Amboni Limited was unable to host the project and it was relocated to Katani Limited. It was originally intended to end in May 2007 but due to this implementation was delayed

A pilot plant was set up at Hale Estate owned by Katani Limited in Tanga, Tanzania. The project was co-financed by CFC, UNIDO, Tanzania Government and Katani Limited at a budget cost of US$ 1,503,312

In the search for an efficient fibre extraction technique to produce the best by-product for biogas production, the roller crusher, hammer mill and conventional decorticator were evaluated for this project. The roller crusher was discarded as impractical. Modifications were made on the stationary decorticator by installing a system of conveyors to transport the biomass from the decorticator to a flume tow (short fibre) recovery plant instead of propelling this waste by water.

In the design of the biogas plant, the primary determinant factor was the leaf potential at the estate. With this primary consideration the plant was designed for producing 300 kW (electrical). For practical considerations, a digester of the continuously stirred tank reactor type (CSTR) was selected. Construction of the biogas plant was completed in May 2007. The plant consists of five tanks: a collection tank, one hydrolysis tank, a digester tank, a biogas storage tank and an after-storage tank.

Initially one combined heat and power plant with the capacity to generate 150 kW electricity was installed. It soon became clear that the biogas plant was producing more gas than one CHP could utilize. A second CHP of same capacity was purchased.

At present the estate has a shortage of feedstock. Therefore the decorticator and hammer mill do not produce enough biomass to generate the quantity of biogas capable of running the two CHP units. The electricity generated is not enough to run the decorticator, 2 hammer mills, brushing machines, press, pumps and for domestic uses all together. It is used to run either the hammer mill alone or the decorticator, brushing machine and baling press.

The data shows that in the biogas from sisal at Hale, methane is just over half of the total gas produced.

The project has demonstrated satisfactorily that a normal-size estate can produce enough biogas of sufficient quality to be used for domestic purposes such as cooking and heating and for running a CHP for generation of electricity.

The power installation at Hale is currently not producing enough electricity to run the estate, because the estate simply does not have a sufficiently large planted area to produce the quantities of feedstock and the processing facility needs to covert to dry decortication to increase the total solid content in the feedstock so that more gas is produced. In 2011 Hale Estate had less than 500 hectares under mature sisal. Katani Limited has sourced funds for accelerated planting of sisal at Hale Estate. It plans to plant 600 hectares in 2012 and the same in 2013 and thereafter 240 hectares each year. When the new planting matures Hale Estate will have a potential to produce 2 MW of electricity from the biogas plant. Thus the biogas plant will be expanded to 500 kWe in 2012 and 1 MWe in 2015 and finally to 2MWe in 2017.

The project has demonstrated satisfactorily that a normal-size estate can produce enough biogas of sufficient quality to be used for running a gas-engine powered generator. Also it has shown that an installation comparable to the one at Hale can produce all the power needed to run an estate and have a small surplus for sale.

The total expenditure in the Hale pilot plant up to end of 2010 was US$ 1,974,479, including personnel expenses, technical assistance, training, dissemination and operational expenses. Information provided by experts in the project at Hale is that when fully operational, most estates have a leaf potential sufficient for a 500 kW installation. A feasibility study on the Hale pilot plant has estimated that the installed capacity of the plant could be raised to 500 kW by an additional investment of US$ 287,791.

The pilot plant has successfully demonstrated that the polluting effect of the sisal industry to the environment can be eliminated through the economic use of one hundred percent of the sisal leaf as compared to the present 4 percent. Production of biogas from the dry decortication at the Corona will reduce the amount of water used in the fibre production process and reduce the amount of waste dumped in water ways.

A draft document of the national strategy for utilization of sisal waste for energy and fertilizer production was submitted to the Project Coordinating Committee meeting in 22nd October 2007. This was linked to the industry vision for 2025 which projects to generate up to 500 MW of electricity from sisal waste.

Some indicative studies have been carried out on the value of sisal effluent as a fertilizer. However, the project has not been able to provide sufficient quantitative data based on scientific investigation to make recommendations on the value of the biogas waste as a fertilizer. A proposal for a scientific field fertilizer trial by JPFirst Limited of Tanga at a cost estimate of US$ 3,470 was not implemented for lack of funds.

The project has been publicised using several methods: three dissemination workshops were held, the pilot biogas plant was inaugurated by the President of the United Republic of Tanzania on 16th July 2008. UNIDO in Tanzania has produced a number of newsletters and posters. Both the Tanzania Sisal Board and Katani Limited have set up websites at www.tsbtz.org and www.katanitz.com respectively. On 6th April 2011 a sisal stakeholders meeting was held in Tanga.

A number of sisal companies have drawn up plans to build biogas plants on their respective estates. Mohamed Enterprises Limited is one of these. Tanzania Sisal Board constructed one small plant at Manala Village in Magu District, Mwanza Region on the shores of Lake Victoria. Oxfam GB in collaboration with Katani Limited has introduced sisal growing to 16,500 farmers in 300 villages in

Kishapu District of Shinyanga Region including setting up processing facilities where community biogas plants can be built. More than 50 community biogas plants are planned for Kishapu District in Shinyanga Region. Kilifi Plantations Limited in Kenya has already built a 300 kW sisal biogas plant. Migotiyo Plantations Limited (formerly known as Alphega) is also considering building one.

The project encountered several challenges during implementation:

- removal of fibre from the decortication residues
- conversion from wet to dry decortication
- the market for short fibres
- the rusting of the steel tanks
- the economics of connecting to the national electricity grid
- insufficient leaf potential on the farm to utilise the installed capacity of the biogas plant

Several conclusions can be drawn from the experience at the pilot plant at Hale Estate:

- sisal has the potential for becoming an energy crop without introducing undue competition with food crops for land
- in producing energy from sisal, the pollution problem of sisal fibre production can be solved
- a new opportunity for supplying clean, renewable power to rural communities, which will improve the health standard of communities will stimulate the growth of rural industries.
- with some purification to remove carbon dioxide, oxygen and other minor impurities, biogas produced from the plant at Hale can be suitable for use as a fuel in internal combustion engines

Even though the pilot plant at Hale Estate has shown a lot of opportunities, it should be replicated with care. A few recommendations for the Hale installation and any new project can be made:

- an expert study proposes a two-stage biogas plant, wherein hydrolysis and acidification take place in two hydrolysis tanks at a low pH, instead of the one-stage system such as the one at the Hale pilot plant.
- the steel tanks at Hale should have had enamel coating to resist the acidic sisal material.
- concrete tanks are more sturdy than steel ones, but their adoption should take into account the fact that airtight concrete structures are difficult to achieve
- the biogas production infrastructure will depend on the leaf processed per day at each Estate .

BACKGROUND TO THE PROJECT

It is estimated that the total area in Tanzania designated for cultivation sisal is about 185,000 hectares. At the recommended planting density of between 4,000 and 6,600 plants per hectare, the production potential from this land may reach a quarter of a million tons of fibre per year. Indeed, in 1964 a total of 234,000 tons of sisal fibre were exported from 487,000 hectares in Tanzania. Of course production has since plummeted. The lowest production reported was in 2000 when only 20,489 tons of fibre were produced. In 2010 some 24,676 tons of fibre were realised.

Studies have shown that one ton of dry fibre produced in the processing of sisal leaves produces about 24 tons of sisal residues as biomass, which is usually diluted with water to about 50 tons. Using this ratio of fibre to biomass waste, the 24,676 tons of fibre produced in 2010, for example, would have generated over half a million tons biomass as waste.

The sisal residue material is usually left to decompose on nearby land and the waste water within it flows to nearby ways untreated. This brings about a drop in the pH of nearby river water while at the same time causing the biological oxygen demand (BOD) to rise far above acceptable levels. Biological oxygen demand is the amount of dissolved oxygen needed by aerobic biological organisms in a body of water to break down organic material present in a given water sample at certain temperature over a specific time period.

Decomposition of sisal biomass (under anaerobic conditions) releases methane and carbon dioxide into the atmosphere.

After the Rio Summit of 1992, UNIDO and the United Nations Environment Programme (UNEP) launched pilot projects in resource-efficient and cleaner production practices to demonstrate preventive environmental strategies. Upon their successful completion, both partners agreed to sustain such production by establishing national capacities, known as the National Cleaner Production Centres (NCPCs), in developing countries and economies in transition. They focus on reducing the use of energy, water and other natural resources while also reducing the generation of waste and emissions, especially from small and medium-sized enterprises (UNIDO at http://www.unido.org/index.php?id=1001545)

The traditional sisal industry is faced with a number of issues on the economic, social and environmental fronts.

Despite of their ecological advantages, sisal and henequen have continually faced stiff competition from synthetic material in the harvest and baler twine market. Even in applications like cordage, sacks, bags and mats, sisal has been facing competition from synthetics. The development of harvesting techniques that utilise less or no twine have added to these issues to force a decline in the sisal market.


The sisal plant

Production and exports of sisal are steadily declining and are expected to continue on the downward trend for some time.

Sisal is a robust plant that will grow well in a wide range of climatic and soil conditions. Thus it has the potential for income security for the population in areas where it is grown. The decline in consumption of sisal products has been accompanied by a significant increase in unemployment. Figures provided by the Tanzania Sisal Board reveal that during the 1960's the sisal industry was employing over half a million workers. This number has dropped to almost 100,000, inclusive of seasonal workers.

In Tanzania the major sources of energy are biomass, which constitutes 90 percent, oil and natural gas (7.5 percent), electricity (1.5 percent), coal, solar and wind (1 percent combined). The installed capacity of electricity at present is 1,051 MW, of which 561 MW comes from hydropower and 490 MW from thermal sources. The negligible amount of electricity produced from biomass is mainly from sugarcane bagasse cogeneration of 35.8 MW. Due to the heavy dependence on biomass energy mainly fuel wood and charcoal over 90,000 hectares of forests are being lost every year resulting in deforestation and decrease in water availability in many rivers which subsequently reduces even the little electricity produced from hydropower. In addition to this only 2 percent of the rural households are connected to electricity and 30 percent in urban areas or an average of only 14 percent connected country wide.

Sisal farming is one of the more organised farming systems in Tanzania. The crop is cultivated on extensive and contiguous tracts of land with considerable mechanization, especially during the farm opening phases. For this reason sisal farming is accompanied by considerable depletion of the natural vegetation, resulting, among other things, in difficulties by the population in obtaining fuel wood for cooking.

A sisal field in Korogwe District, Tanzania. Notice the near depletion of natural vegetation. It is common practice to plant annual crops between rows when the sisal is still young (not in this photograph)

The wet sisal leaf decortication process, which has been in use in the industry for the last 100 years, is recognised to be an environmental hazard. Fibre constitutes only about 4 percent of the leaf; the remaining 96 percent is biomass. Studies in Tanzania have shown that the biomass from this process is 20 to 30 times as polluting as average domestic waste.

Considering that fibre, which is the traditionally desired product from sisal, is only about 4 percent of the sisal plant, environmental pollution from sisal processing is considerable. Because of this, the sisal industry has been directed to address its pollution problem or face closure.

These issues are not limited to the Tanzanian situation; they are global.

Attempts to address the polluting effect of sisal waste have been made by researching into possible applications of what are traditionally waste products from the processing of sisal. Treating the sisal leaf waste has been demonstrated to yield products that are environmentally friendly and have an economic value. Such products include biogas, manure, animal feed, alcohol, citric acid, hecogenin, simple sugars, pulp and paper. Of these products, biogas has received most attention at production level in Tanzania.

The Tanzania Small Scale Development Organization (SIDO) initiated biogas technology as early as 1975. In the early 1980s the Biogas Extension Service adopted technology from India, China and Germany to establish biogas plants in the coffee and banana growing areas around Arusha. It is reported that by 1992 there were over 600 biogas plants in Tanzania, thanks to the Biogas Extension Service later put under CAMARTEC.

Biogas production takes care of the pollution problem caused by processing of the sisal leaf for fibre. It in addition produces a slurry by-product, which when properly disposed of can be turned to beneficial use. For example, the processed effluent from biogas digesters has been demonstrated to be a more effective fertilizer at improving soil structure than chemical fertilizers.

Efforts to improve productivity and utilisation of sisal waste could contribute positively towards the issues facing the sisal industry. Utilisation of the sisal waste to make products of economic value will improve the economics of the industry and contribute towards solving the environmental issues associated with sisal decortications for fibre.

In 2000 the sisal industry in Tanzania developed a proposal for a project to establish a pilot plant that would demonstrate the importance of large-scale treatment of sisal leaf-waste to produce biologically inactive materials that are harmless to the environment. The proposal on *cleaner integral utilization of sisal waste for biogas and bio-fertilizers* envisaged that the success of the pilot plant would lead to treatment of all leaf waste produced on all sisal plantations in Tanzania. This would make the sisal fibre production process more environmentally friendly.

In the proposal, it was envisioned to treat the leaf waste to introduce additional activities at the Hale Estate factory:

- Removing the short fibres from the decortication effluent and delivering the leaf juice to bio-digesters for decomposition. This process would produce biogas with a high methane content
- The biogas would be utilized as fuel for generating electricity
- The slurry left behind would be applied to the fields using liquid fertilizer spraying equipment

PROJECT AIMS AND OBJECTIVES

The main objective of the project on cleaner integral utilization of sisal waste for biogas and bio-fertilizers was to establish a pilot biogas demonstration plant, providing technical, economic and financial data to prove the feasibility of biogas production and electricity generation from sisal waste. The project thus aimed at reducing environmental pollution and degradation, and improving soil fertility by using the biogas process by-products as bio fertilizers.

The project goal was to improve the economic viability of the sisal industry by providing cheaper energy from the sisal waste produced by the fibre production process and improve its competitive-ness in local and international markets.

Stated Project Objectives

The project had five main objectives:

(a) Design, build and operate a pilot demonstration facility to produce biogas from sisal leaf waste
(b) Design, build and operate a pilot system for generation of electricity from the produced biogas, with an operational distribution system
(c) Proposal for a national strategy for sound and environmentally friendly utilization of sisal waste for energy production
(d) Carry out a study on utilization of the liquid and solid biogas by-products as fertilizers/composite, with recommendations for commercial application
(e) Project dissemination and project management.

Stated Project Output Expectations

The project was expected to produce the following outputs:

(a) Detailed designs and drawings for a pilot plant
(b) Operational pilot demonstration facility
(c) Trained personnel
(d) Data and reports on biogas production
(e) Feasibility study
(f) National strategy for biogas and energy production from sisal waste
(g) Study on utilization of biogas by-products as fertilizer
(h) Dissemination of project results worldwide.

STUDY APPROACH

This report has been prepared by studying publications from and related to the project. Informal and formal unstructured interviews were held with the project national coordinator, the project technical officer and the Director General of the Tanzania Sisal Board. A field trip was undertaken on 27th September 2011 to Tanzania to get a first-hand practical impression of the situation prevailing at the project site. During this field trip the design of the sisal biomass production process and alternatives were examined. An assessment of the shortfalls, achievements and challenges in project implementation was made.

PROJECT DESIGN AND IMPLEMENTATION

Project Inception

The project was a brainchild of the Tanzanian sisal industry. The original project only planned to develop an alternative design that would incorporate pulp and paper operations requiring steam for heating and generating electricity. The idea of establishing a pulp mill, however, was later abandoned and in its place emerged the idea of a pilot biogas plant that was originally envisaged to be co-financed by several donors.

Financing for the biogas project proved difficult due to lack of a pilot biogas plant from which the feasibility of the technology could be demonstrated. The Common Fund for Commodities (CFC) was asked and agreed to finance the development of the pilot plant.

The following organisations were key players in the project:

- the United Nations Industrial Development Organisation (UNIDO) as Project Executing Agency and co-financier
- Tanzania Sisal Board (TSB) as counterpart to UNIDO on behalf of the Government of the United Republic of Tanzania were one of the financiers
- Common Fund for Commodities (CFC) as the main financier
- the FAO Intergovernmental Group on Hard Fibres (FIGHF) as the Commodity Body
- Hale sisal estate as the project location
- the Sisal Association of Tanzania (SAT) representing sisal growers and marketers
- Katani Limited as the local implementing agency

A project agreement was signed between CFC, FIGHF and UNIDO and a memorandum of understanding between UNIDO (as project executing agency), Katani Limited and the Tanzania Sisal Board.

A participatory approach was used to identify where to locate the plant. Initially it was earmarked to be implemented at Amboni Limited's Kwaraguru Estate, some 20 km from where it is today. The company found itself in financial problems that made it impossible for the estate to host the project and it had to be moved to a new site.

Expressions of interest were invited from all players in the Tanzania sisal industry and four companies submitted their expressions of interest in the project. These were:

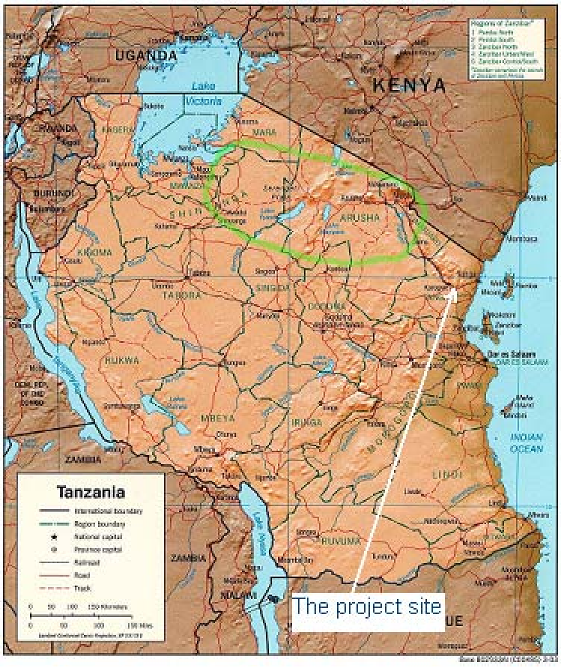
- Amboni Plantations Ltd
- Mohamed Enterprises Ltd
- Amboni Properties Ltd
- Katani Limited

All companies that bid for the project were visited by officials from the National Implementing Agency, the Collaborating institution, from UNIDO as the Project Implementing Agency, from FAO as the Commodity Body and from CFC as the financier.

The expressions of interest were evaluated by UNIDO and representatives of the Tanzanian Collaborating Institution. Katani Limited was appointed to implement the project at the company's Hale Estate.

Profile of the Project Site

Hale Estate is about 70 km from Tanga City, located adjacent to the Tanga – Arusha tarmac road, some four kilometres from the junction to Dar es Salaam, Morogoro and Dodoma. The railway line connecting Tanga to Dar es Salaam passes nearby.



The estate has a total land area of 4,280 hectares. It is administered under two divisions, each with an office, water and facilities for decortication, brushing and baling.

At the time of preparing the proposal in 2,000 the estate had 830 ha of mature sisal, with a potential sisal leaf production of 1,000 tons per year. The estate's leaf waste production projections for the year 2000 were around 54 tons per day, an amount exceeding the proposed bio-digester requirements of about 36 tons of waste per day.

Project Landmarks

A ***preliminary environmental impact assessment*** was commissioned by UNIDO to ascertain the possible negative or positive effects of the project. Apparently, the results of this study were for the internal use of UNIDO.

A ***Project Tender Committee*** was established in 2006 to guide the project on procurement of service and equipment in compliance with Tanzanian procurement procedures. The committee was chaired by the Tanzania Sisal Board and convened its meetings on demand.

In 2006 the ***terms of reference*** for the construction work of the power generation facility were drawn up. The size of the proposed power generation facility was to be between 140 and 150 kW, produced through a biogas-powered internal combustion spark-ignition engine.

The contract for a ***soil investigation*** was awarded by Katani Limited to Megatech Construction Company, who produced their report in February 2006. The conclusion of the study was that the bearing capacity of the soil on the proposed plant site could confidently be adopted for the design of the foundation with a width of 1.5 meters and a depth of 2 meters.

UNIDO awarded the contract for the ***construction work*** to BEB BioEnergy Berlin GmbH, with Sichuan Guojiao Energy and Environmental Protection Engineering Co. Ltd. as sub-contractors, in early 2006. BEB submitted its technical and commercial proposals in April 2006. Construction started in January 2007 and was completed in May 2007. The contractors (BEB) were asked to stay on for a further period of one year to monitor the plant and provide training to personnel.

Immediately after start of the construction work, an ***environmental impact assessment*** study was commissioned by Tanzania Sisal Board to City Engineering Company Ltd. The report, submitted to the National Environment Management Council (NEMC) in February 2007, held the conclusion that the project idea was received favourably by the population and that the project did not pose adverse threats to the environment.

Installation of the first Combined Heat and Power (CHP) unit started in May 2007. The plant started generating power on 13th July 2007 and was run for 97 days in 2007. During this period a total of 51,129 kWh of electricity was generated and used internally and at the estate production units. The power generated was not sufficient to run both the decorticator and the two hammer mills, so these were operated one at a time.

In December 2007 the ***generator broke down***. Repairs to the old generator were attempted but it did not work reliably so a replacement was shipped from China. The installation of the new generator was completed on 19th February 2008 and electricity production commenced.

The plant was ***handed over*** in September 2008

The amount of biogas produced was more than could be used by one generator (CHP unit), so a case was argued for a second generator. ***Installation of the 2nd CHP*** was completed in March 2009.

Training was done for both operator-level and management-level personnel for staff of various estates in the sisal industry. Most of the training was on-site, on the job; some staff were sent abroad for further training. In 2006 for example 18 officers from the industry were trained on biogas in China.

In October 2007 BEB published its ***final report*** on installation and commissioning of the sisal biogas plant at Hale Estate.

The proposal for ***national strategy for sound and environmentally friendly utilization of sisal waste for energy production*** was submitted at the dissemination workshop held on 22nd October 2007. This proposal was integrated into the industry vision for 2025 in which production of sisal fibre in Tanzania was targeted to increase to one million tons by expanding sisal planting into other regions of Tanzania and using the sisal waste to produce up to 500 MW of electricity.

In the course of the project life 4 ***project coordinating committee meetings*** were held. The last one was held at Katani Limited on 20th April 2011.

The project planning followed the logical framework approach in which the project objectives, activities, outputs to be achieved and costs involved were stated. The project had two components from which the outputs would be pilot demonstration facilities for the production of biogas and electricity respectively.

Design Considerations

Component 1: Pilot Demonstration Facility to Produce Biogas from Sisal

In order to produce biogas, modifications, additions or introduction of new technology was necessary in the fibre production process at Hale. The conventional fibre production process uses the wet decortications method. The biomass by-product from wet decortication is not suitable for feeding into biogas production tanks. In the search for a fibre extraction technique that would efficiently produce the best by-product for biogas production, three methods were evaluated:

- The conventional decorticator
- The roller crasher
- The hammer mill

The Stationary Decorticator

The conventional decorticator (also known as the corona) is a technology for producing long fibre. Prior to the idea of this project, almost all sisal estates in Tanzania used only this method for fibre production.

The basic defibering units in a decorticator are two drums 100 and 150 cm diameter with blunt beater blades attached to them. Jets of water are directed into the fibre as it passes through each drum to wash the fibre and carry away the waste.

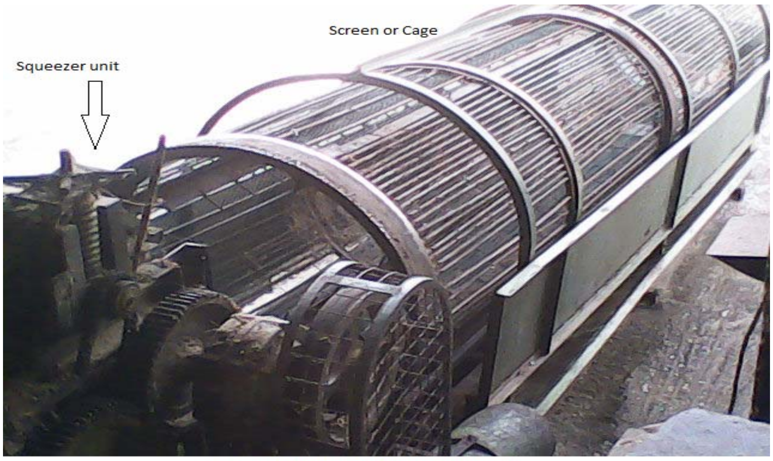
The waste from this process contains more anything between 94 and 97 percent of the materials in the green leaf as well as the water introduced in the drums. It also contains a considerable amount short fibre known as *flume tow*. In the normal long fibre extraction process, the flume tow is not efficiently recovered, as demand for this kind of fibre is not particularly high in the cordage and other industries. Most of it is dumped on the land or water ways together with the other components of the decorticator waste.

The stationary decorticator

Decortication produces clean long fibre, which has an established market for agricultural uses such as baling and twine. The process involves the use of great amounts of water. At Hale Estate, it is estimated that when the mill is operating at full capacity, it uses approximately 45 cubic meters of water per day. The bulk of this water is for propelling the leaf waste away from the factory. This process produces clean long fibre but has big losses because it includes large quantities of short fibres in the waste.

The waste produced from the decorticator cannot be fed directly into the biogas production system because it could choke the system due to the high fibre content. To solve this problem, a system of conveyors was added at the end of the decorticator to transport the leaf waste to a flume tow recovery unit.

The flume tow recovery unit essentially consists of a squeezer and a rotary screen shaker. This is a revolving cylindrical cage that separates leaf tissue and short fibre. The tissues drop out to be fed into the biogas production system and the fibre is collected at the output end of the flume tow recovery unit.



The flume tow recovery unit at Hale Estate

Katani Limited made this new system of handling the sisal waste from the stationary decorticator by installing a squeezer and carding machine from materials available on its estates. These machines have been coupled to the flume tow recovery unit. The company also installed a system of conveyors from the stationary decorticator to the flume tow recovery plant.

This system of conveyors by-passes the water propulsion system and reduces the water consumption of the mill from the 45 cubic meters to approximately 4.5 cubic meters per day when the plant is operating at full capacity. This enables sisal waste from the stationary decorticator to be used in the biogas plant after short fibres are removed at the flume tow recovery unit. Before installation of this system the large quantities of water required for propelling the leaf waste diluted the substrate to levels where the optimal total solid content of 6 percent was impossible to achieve.

To complete this conversion from wet to dry decortications, a system for washing the fibre after it exits the decorticator needs to be installed. Then the water input into the decortications drums can be shut off to produce the undiluted leaf residue.

The Roller Crasher

A prototype of a roller crasher was developed for producing pulpable fibre, also referred to as short fibre. The short fibre is useful in composite, cement manufacturing and plastics used in the manufacture of vehicle parts. At Hale the material has been successfully used in the making of paper, roofing tiles and tea bags. It is said that the paper produced from sisal pulp is highly suitable for making currency notes due to its high folding resistance.


Prototype of the roller crasher

The roller crasher consists of a pair of spiked drums rotating at differential speeds for crushing the chipped leaf, a collector and a fibre washer. It is necessary to chop the leaves in order to protect the system from choking. The technology proved to be inefficient as it required first chopping up the sisal leaves to 8-cm pieces and running multiple feeds into the roller assembly before clean fibre could be produced. In the process, it damaged the fibre.

The Hammer Mill

This machine also produces pulpable fibre. The leaf is first chipped into approximately 8-cm pieces by a chipper unit. The leaves must first be chipped into short pieces for the same reason as in the case of the roller crasher: to avoid choking of the mill. The prototype for the chipper was developed by the Tanzania Automotive Technology Centre (TATC) at Kibaha near Dar es Salaam.

The chipped leaves are conveyed into the mill chamber along a semi-cylindrical trough, propelled in its dry state by a rotating corkscrew. Apart from transporting the chipped leaves to the mill, this rotor cork-screw also helps to homogenise the material before it enters the mill.


Cork screw rotor

At Hale Estate two hammer mills are serially connected: the first hammer mill feeds its fibre into the second one for further and final washing. This system uses only a minimum amount of water and produces clean fibre with near-perfect fibre extraction. Because of its fibre extraction efficiency it produces clean sludge for direct feeding into the collection tank to begin the biogas production process.


The layout of the hammer mill at Hale Estate

The Biogas Plant

The biogas production system at Hale is fed by the decorticator – or, more specifically, the flume tow recovery plant – and the hammer mill. The idea of the roller crasher was discarded due to its relatively poor practicability.

The biogas production installation at Hale is a system of four tanks: a collection tank from which material is pumped into a hydrolysis tank. After a few days, the biomass is fed into the digester tank from where the biogas produced is conveyed to a gas storage tank.

In the construction system at Hale, most of the biogas is collected from the digester tank. The project had fifteen design options for construction of the digester tank:

(a) Complete Mix (Continuously Stirred Tank Reactor) – fully homogeneous contents

(b) Upflow Anaerobic Sludge Blanket Reactor (UASB)
(c) Batch- fed reactor, such as the anaerobic sequential batch reactor (ASBR)
(d) Lagoon – energy recovery from treatment oriented design
(e) Temperature-phased anaerobic digester (TPAD)
(f) Suspended particle reactor
(g) Anaerobic filter reactor
(h) Upflow solids reactor
(i) Continuously stirred tank reactor with solids recycle
(j) Anaerobic pump digester
(k) Fluidized- and expanded- bed reactors
(l) Fixed film anaerobic digester
(m) Plug Flow – mimics a series of laterally mixed units

Only two of these options were evaluated: one of these is what is referred to as the Upflow Anaerobic Sludge Blanket Reactor (UASB); the other is known as the Continuously Stirred Tank Reactor (CSTR).

In a CSTR, the tank reactor is equipped with an impeller. The biomass is introduced into the tank, the impeller stirs the sludge to ensure proper mixing, while the reactor effluent is removed.

The UASB reactor consists of a circular tank in which the waste flows upward through an anaerobic sludge blanket which comprises about half the volume of the reactor. The reactor consists of a digester compartment containing the sludge bed, a gas-solids separator in the upper part of the reactor, and an internal settler for sludge retention at the top of the reactor vessel.

The initial plan was to use the Upflow Anaerobic Sludge Blanket Reactor (UASBR) but due to the complexity of the technology it was decided to use the Continuously Stirred Tank Reactor (CSTR) technology. Also the CSTR technology was said to be more economical.

In May 2006 Bio-Energy Berlin GmbH (BEB) from Germany was awarded the contract to design, construct and commission a pilot biogas plant of 150 kWe. Designs and drawings were completed in June 2006. The size of the various tanks was calculated on the basis of available feedstock potential at the estate, which is two trailer-loads per day.

The biogas production plant at Hale Estate with the four tanks
the hydrolysis tank (A) the digester; (B)
the gas storage tank (C) the after-storage tank (D)

The biogas production infrastructure consists of a 50 m³ collection tank which was constructed underground and covered with a steel top. The four above ground tanks comprise

- a 300 m³ hydrolysis steel tank
- a 1,700 m³ mesophillic digester tank
- a 500 m³ tank filled with water on which a 350 m³ gas tank on steel rails floats. This pair of tanks stores biogas at near atmospheric pressure, and
- a 500 m³ after storage slurry tank
- a 12 m³ H_2S removal tank and 6-metre high steel gas flare.

The after-storage tank was constructed as a secondary digester to continue producing gas from the substrate.

The sisal biomass has an initial low bacteria content; not enough to cause fermentation at an acceptable rate. To speed up the process the CSTR system was primed with cow dung to inoculate bacteria for anaerobic digestion. The cow dung was collected from Buhuri Livestock Training Institute near Tanga. Charging with cow dung starter material was continued for three and a half months. Feeding into the collection tank and hydrolysis tank started on 17th April 2007 to July 2007. Digester feeding started on 3rd June 2007. A total of 143.55 cubic metres of cow dung was used as starter material.

During operation sisal residues with total solid content of around 12 to 15 percent from the hammer mills and stationary decorticator are diluted to 6 percent in the collection tank and then pumped to the hydrolysis tank where they stay for five days. They are thereafter pumped to the CSTR digester for further fermentation to produce biogas. The biogas, containing methane and carbon dioxide, is passed through the H_2S tank for removal of hydrogen sulphide. It is thereafter stored in a 350 m^3 gas tank from where it is delivered to the CHP units as fuel.

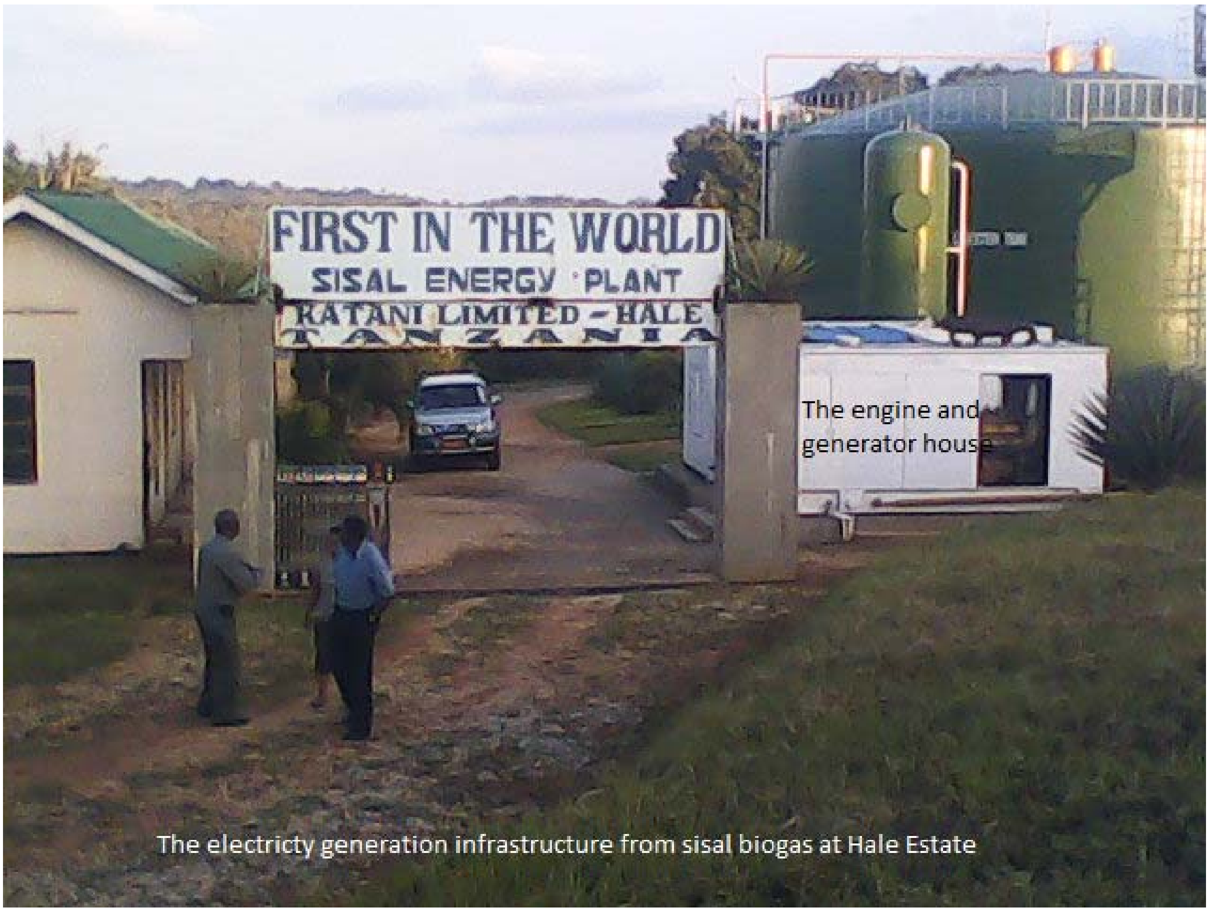
The designed feeding capacity was 65 tons of sisal residues of 6 percent total solids content per day. This level in bulk terms was achieved from 2008 to 2010 but the total solid content declined from 4.5 to about 1 percent in 2011.

Component 2: Pilot System for Generating Electricity Using Biogas from Sisal

The power requirements at Hale Sisal Estate are rated at 250 kW. This is on the basis of the fact that the estate is fed through a 250 kW transformer. In practice the estate power needs are under 200 kW.

Installation of the first power production unit was completed on 13th June 2007. These power generation units are known in the project as CHP units, an abbreviation for Combined Heat and Power generation units. One expert from Jinan assisted by one BEB Engineer, Katani Engineer, TATC Engineer, four technicians and 14 helpers were involved in completing the installation of the engine and generator sent from Jinan Diesel Company Limited.

The generators installed are 150kW capacity, powered by V-12 spark ignition engines. The electricity generated is directed to a power distribution board. The heated engine coolant is circulated through the biogas production tanks to warm up the sludge; the heat generated from the engine exhaust is not harnessed.



The electricty generation infrastructure from sisal biogas at Hale Estate

Component 3: Proposal for a National Strategy for Sound and Environmentally Friendly Utilization of Sisal Waste for Energy Production

Preliminary estimates of energy demand for sisal production based on the industry vision of a million tons by 2025 is set at 500 million kWH per year, equivalent to an installed capacity of 48.61 MWe. The potential biogas production from the sisal waste is estimated at 500 MWe. These are very favourable statistics in terms of the development potential of the industry.

A draft national strategy for utilization of sisal waste for energy and fertilizer production was submitted to the Project Coordinating Committee meeting in August 2007. This was incorporated into the industry vision for 2025 in which production of sisal fibre in Tanzania is targeted to increase to one million tons by expanding sisal planting to 12 regions in Tanzania. Non-governmental organizations and the Government of the United Republic of Tanzania have been sensitized to support this initiative.

Component 4: Study on Utilization of the Liquid and Solid Biogas By-Products as Fertilizer

Overflow from the after storage tank of the biogas plant is mainly in liquid form. This material has a total solid content less than 1 percent. The liquid is expected to be of nutritional value to plants.

Investigations on the effectiveness of this material as a fertilizer were initiated in 2007 with trials using waste from a small biogas plant. These trials have only served to provide information on how to design and implement the fertilizer field trials. Scientific field trials are yet to be carried out.

Component 5: Project Management and Project Dissemination

Although the project proposal was prepared by Katani Limited, the biogas plant was initially earmarked to be installed on Kwaraguru Estate of Amboni Limited. There may have been technical as well as social considerations for this setup.

Project management was provided by UNIDO as the Project Executing Agency. Within Tanzania the Tanzania Sisal Board (TSB) was the counterpart organisation, acting on behalf of the government of the United Republic of Tanzania. The day-to-day management of the project was done through the National Project Coordinator and a Project Technical officer.

There was established a Project Coordinating Committee to chart the way forward. A Project Implementation Committee was formed, responsible for reviewing developments. The project Coordinating Committee was chaired by the TSB Director General. Other members of the committee were representatives from CFC, FAO, UNIDO, TSB, Katani Limited and the Sisal Association of Tanzania (SAT), representing sisal growers, processors and marketing agencies.

A Project Tender Committee was formed in 2006, chaired by the Tanzania Sisal Board, to guide the project on procurement of service and equipment in compliance with Tanzanian procurement procedures. The committee convened its meetings on demand.

The strategy for disseminating the results of the project included construction of websites for the Tanzania Sisal Board and Katani Limited. Other initiatives involved the holding of dissemination workshops and sisal stakeholder meetings. UNIDO in Tanzania produced a number of newsletters and posters on the pilot biogas plant. Attempts to make a project presence on The Internet through the Commonwealth website were made but there was no unanimous agreement on the benfits of such a presence.

Modifications to the Project Implementation

Component 1: Pilot Demonstration Facility to Produce Biogas from Sisal

Initially the project envisaged setting up a 150 kW biogas plant. Shortly after the start of implementation it was realized that the biogas plant was producing more gas than one generator could handle. Also it became apparent that this was risky because if the one generator failed, as occurred in 2008, the plant stopped. A proposal was therefore submitted to CFC to increase capacity by adding on a second generator. CFC approved using the remaining project funds to procure a second power generator.

The project was to end in May 2007 but implementation was delayed after the project had to be moved from the originally intended implementing institution at Kwaraguru Estate to Hale Estate and when the request for a second generator was made. These changes were approved by the Project Coordinating Committee and subsequently submitted to CFC through UNIDO.

Component 2: Pilot System for Generating Electricity Using Biogas from Sisal

The biogas is used to run a 150 kW generator and supply electricity within the plant and the estate factory. It soon became clear that more biogas was being produced in the digester than could be utilised by the one CHP. A second CHP was therefore procured.

At present the estate has a shortage of feedstock. Therefore the decorticator and hammer mill do not produce enough biomass to generate the quantity of biogas capable of running the two CHP units.

It is reported by the estate's management that the power output from the two CHPs combined exceeds the power requirements of the estate. It was found necessary to explore possibilities of selling power to the national electricity supply company.

The electricity generated is not enough to run the decorticator, 2 hammer mills, brushing machines, press, pumps and for domestic uses all together. It is used to run either the hammer mill alone or the decorticator, brushing machine and baling press.

PROJECT ACHIEVEMENTS

Component 1: Pilot Demonstration Facility to Produce Biogas from Sisal

Production of biogas is proportional to the amount of biomass fed to the plant. This means that the production of biogas is directly related to the fibre production process.

According to project documents consulted, the highest gas production achieved was 947 cubic meters per day at 2.6 percent total solids. When the plant is fed regularly, this gas production is equivalent to 2,185 cubic meters per day at 6 percent total solids, which is well above the 1,800 cubic meters per day envisaged at the project's inception.

Biogas production data for the Hale pilot plant from 2007 to 2011 is kept in a spreadsheet. The data includes analysis of the biogas produced in terms of the component gases. The spreadsheet contains daily records of biogas production and its gaseous composition. However, the data on gaseous composition is available only for 2007 and 2008, and then not for each production day. The available data on the biogas produced from the plant shows the following gaseous composition of the sisal biogas:

Table 1: Composition of Biogas From the Hale Pilot Plant

		2007	2008	average
Methane	(%)	59	50	55
Carbon Dioxide	(%)	25	30	27
Oxygen	(%)	16	20	18
Hydrogen Sulphide	(%)	trace	trace	trace
Total	**(%)**	**100**	**100**	**100**

Methane (CH_4) is the desired component of the biogas for cooking or burning in the CHP units. The other components are impurities. The data shows that in the biogas from sisal at Hale, methane is just over half of the total gas produced.

The current situation at Hale is that there is not enough feedstock to run both the decorticator and the hammer mill on the regular work shifts. The reason for this is that Katani Limited is behind in its replanting programme and therefore has a low leaf potential.

Most estates in Tanzania are of sizes comparable to Hale. The project has demonstrated satisfactorily that a normal-size estate can produce enough biogas of sufficient quality to be used for domestic purposes such as cooking and heating and for running a CHP for generation of electricity. During the site visit, a gas stove running on the biogas from the plant was observed. The CHP was not running at the time but it was started up and used to run the decorticator as part of data capturing for preparation of this document.

The quantity of carbon dioxide, oxygen and other impurities is too high for direct use in the automotive industry. A purification plant is necessary if the biogas is to be used in automobiles. It is estimated that such purification upgrade the biogas to about 97 percent methane. Likewise, these impurities must be removed in order to successfully compress the biogas to liquid state for bottling.

The biogas production statistics from the beginning of the project to the end of 2010 are presented in Table 2.

Component 2: Pilot System for Generating Electricity Using Biogas from Sisal

The power plant at Hale Estate comprises two 150 kW CHPs. The highest power generation was achieved in 2008 when the plant was operated for 154 days, generating 73,094 kWh of electricity. Operation of the generator improved from an average of 3.9 hours per day year round in 2007 to 5.9 hours per day in 2008. The electricity generated was sufficient and was used to run the biogas plant and the estate operations. This has reduced use of main power supply from the national electricity grid.

At present, the CHP unit is operated only when the decorticator or the hammer mill is to be operated. Mainly this is because there is not enough biomass to production biogas in sufficient quantity to run the generator full time. It is reported that one CHP at Hale consumes about 80 cubic meters of biogas per hour of operation.

Even though the biogas and power installation at Hale is currently not producing enough electricity to run the estate, the reason for this is at farm agronomic management level. The estate simply does not have a sufficiently large planted area to produce the quantities of feedstock required to meet the biogas installed capacity.

The project has demonstrated satisfactorily that a normal-size estate can produce enough biogas of sufficient quality to be used for running a gas-engine powered generator. Also it has shown that an installation comparable to the one at Hale can produce all the power needed to run an estate and have a small surplus for sale. Using power generated from the by-products of fibre production may cut the operational costs of an estate considerably by cutting the cost of electricity, which is estimated to be between 20 and 40 percent of operational costs in most estates.

Table 2 summarises the production figures for biogas and electricity for the period 2007 to 2010

Table 2: Biogas and electricity production statistics (2007 - 2010)

Parameters	Unit	2007	2008	2009	2010
Gas Produced	m^3	53,121	84,027	67,332	52,791
CHP Operating Time	hrs	377	812	1041	966
Gas at Digester total solids	m^3	18.08	11.1	4.7	3.1
Gas at 6 percent total solids	m^3	38.57	39.2	25.6	19.7
Gas at 12.5 percent total solids	m^3	80.35	81.7	53.4	41.1
Electricity Produced	kWh	51,129	73,094	79,337	63,597

The total project funding was USD 1,503,312. This amount includes the cost of research, training and operational expenses of the project. To assess the achievement of this objective it is important to separate those costs that will not be incurred in replicating this installation in another estate and then make an assessment of whether the project can be financially attractive.

The investment cost of the pilot plant installation at Hale is said to be as follows:

Table 3: Estimated Investment Costs (in US$) at Hale Pilot Plant

Vehicles, machinery and equipment	543,597
Civil works	166,647
Materials and supplies	57,909
Total investment costs	**768,153**

These figures are indicative. In fact the total expenditure in the Hale pilot plant up to end 2010 was US$ 1,974,479, but this includes personnel expenses, technical assistance, training, dissemination and operational expenses. All the same they provide a basis for individual companies to develop financial ideas for replanting and processing of sisal waste for electricity generation.

In a feasibility study on the Hale pilot plant, Walter and Katharina Danner have estimated that the installed capacity of the plant could be raised to 500 kW by an additional investment of US$ 287,791. This would bring the total cost to a little under US$ 2,290,000.

In the same feasibility report, the investment cost for a new 500 kW biogas plant processing sisal waste from a stationary decorticator milling 90 metres of sisal leaves per day is estimated at USD 2,225,281.

Component 3: Proposal for a National Strategy for Sound and Environmentally Friendly Utilization of Sisal Waste for Energy Production

This component of the project was implemented by Katani Limited and Tanzania Sisal Board. A sisal development vision and strategy was discussed by sisal stakeholders at a workshop held on 27th April 2007 and had unanimous support from all who attended. The Government continuously provided support to the project financially. During the period 2006 to 2010 the Government disbursed Tshs 841,280,550 (equivalent to approximately US$ 584,223 at the exchange rate prevalent by December 2010) to the Project.

A draft document of the national strategy for utilization of sisal waste for energy and fertilizer production was submitted to the Project Coordinating Committee meeting in 22nd October 2007. This was linked to the industry vision for 2025 in which production of sisal fibre in Tanzania is targeted to increase to one million tons by expanding sisal planting to 12 regions of Tanzania. Non Governmental organizations and the Government of the United Republic of Tanzania have been sensitized to support this initiative. Oxfam has already started work in Kishapu District of Shinyanga Region with plans to expand to other regions of Tanzania.

The production level aimed at by the industry vision of 2025 is likely to produce enough sisal waste to generate up to 500 MW of electricity.

This project objective has helped shape the vision not only of the sisal industry but the energy sector as well by extension.

Component 4: Study on Utilization of the Liquid and Solid Biogas By-Products as Fertilizer

The overflow from the after storage tank of the biogas plant is almost 99 percent liquid. The liquid is expected to be a useful organic fertilizer that is completely degraded as volatile solids have been removed during biogas formation. The project modified two water bowsers and fitted one to a lorry to apply the liquid fertilizer in the sisal fields.

Preliminary trials on vegetables have shown good results in using sisal bio-fertilizer.

A one hectare plot planted with simsim and another trial with water melon were set up in October 2008 but both trials failed due to attack by diseases.

Field inspection during preparation of this document of individual crops and parts on Hale Estate itself where this material has been applied shows visually good response to crop performance.

Apart from the failed attempts just described, there have been tentative recommendations based on laboratory analysis by the Agricultural Research Institute at Mlingano in Tanga and the University of Dar es Salaam Department of Molecular Biology and Biotechnology.

A proposal for a scientific field fertilizer trial by JPFirst Limited of Tanga at a cost estimate of US$ 3,470 was not implemented for lack of funds.

The project has not been able to provide sufficient quantitative data based on scientific investigation to make recommendations on the value of the biogas waste as a fertilizer. More work is necessary to reach this objective. This component of the project is necessary in order to demonstrate that fibre and biogas production can be turned into a pollution-free industry.

Component 5: Project Management and Dissemination

Project Management

Project management was provided by a National Project Coordinator in the person of Mr. Francis Nkuba. He was assisted by a Project Technical Officer, Mr. Gilead Kissaka. There was also a Development Manager provided by Katani Limited (Mr. Juma S. Shamte), an officer from the Tanzania Sisal Board and an accountant from the Board, one secretary and a driver.

Staff at the project site included a secretary, 6 security guards, 3 operators, four technicians and two auxiliary personnel.

Three committees were set up: the Project Implementation Committee to monitor the project, a Project Tender Committee to ensure adherence to approved procurement procedures, and the Project Coordinating Committee whose task was to provide direction.

Dissemination of Results

The activities undertaken within the context of the project to disseminate the results of the pilot biogas and electricity plants at Hale Estate are documented in project reports prepared by Francis Nkuba, the Project National Coordinator.

Three dissemination workshops, including two international workshops, were held where the project results were presented. Stakeholders were encouraged to visit the plant. Many people have since visited the plant. This has resulted in increased interest to develop similar projects in other estates, and household and community biogas plants in other sisal growing areas.

The President of the United Republic of Tanzania His Excellency Jakaya Mrisho Kikwete inaugurated the pilot biogas plant at Hale Estate on 16th July 2008. The occasion was well attended and received wide coverage in the media thus contributing to dissemination of project results.

UNIDO in Tanzania has produced a number of newsletters and posters on the pilot biogas plant at Hale Estate. Katani Limited has created a website at www.katanitz.com with a page on sisal energy on which this project is highlighted. The Tanzania Sisal Board has also created a website at www.tsbtz.org. Both organizations produce posters and a newsletter on sisal where news on biogas development prominently features.

On 6th April 2011 a sisal stakeholders meeting was held in Tanga where the developments in the biogas technology were presented. The results of the feasibility study on biogas and electricity production from sisal waste were also discussed. The stakeholders noted the developments and endorsed the feasibility study.

Some reservations were expressed by the stakeholders concerning the amount of investment required, the difficulties of adapting the technology to conventional decorticators, and the price of electricity. To address these issues there have been recommendations to use lobe pumps and shredders to solve the problem of adapting the technology to conventional decorticators. The stakeholders have submitted a well-argued recommendation to the Government to approve a preferential feed-in tariff into the national electricity grid of Tshs 250 per kWh of electricity.

Efforts to sensitive stakeholders, non-governmental organizations (NGOs) and the Government of the United Republic of Tanzania have yielded some results.

Katani Limited is operating a biogas plant in one estate of Hale. A number of sisal companies have drawn up plans to build biogas plants on their respective estates. Mohamed Enterprises is one of these.

Tanzania Sisal Board constructed one small plant at Manala Village in Magu District, Mwanza Region on the shores of Lake Victoria.

Oxfam plans to introduce sisal growing to 16,500 farmers in 300 villages with processing facilities where community biogas plants can be built. More than 50 community biogas plants are planned for Kishapu District in Shinyanga Region by Oxfam.

Interest has also spread to Kenya where Kilifi Plantations Limited has already built a 300 kW sisal biogas plant. Migotiyo Plantations Limited is also considering building one.

Substantial information on the biogas project has already been posted onto the worldwide web by a number of organisations, chief among them being UNIDO and FAO.

Training

Eighteen Officers from Katani Limited and Tanzania Sisal Board were trained on biogas in Chengdu China in 2006. Two officers and two technicians were given further training on the CHP unit in Jinan China during the biogas training in 2006 before the CHP unit was shipped. Subsequent to this, 18 workers who participated in the construction work received on-the-job training during the start up period on the CHP unit.

A total of 14 participants from the sisal industry received biogas training during hand over in September 2009 and were trained in CHP maintenance and operation. Since then three new technicians have been recruited at the plant and trained in the operation and maintenance of the two CHP units and the biogas production operations.

Table 4 summarises the achievements of the project in terms of the eight outputs that were expected from the project by matching of the final results against planned outputs.

Table 4: Summary of Project Achievements

PLANNED OUTPUT	ACTUAL OUTPUT	REMARKS
Detailed designs and drawings for a pilot plant.	Designs and drawings were completed in June 2006	Objective achieved
Operational pilot demonstration facility.	• Erection and welding of the steel tanks was completed in May 2007. • Installation of the first Combined Heat and Power (CHP) unit was completed on 13th June 2007 • The plant started generating power on 13th July 2007 and generated a total of 51,129 kWh of electricity in 2007	Objective achieved
Trained personnel	• In 2006 a total of 18 people were trained in China on biogas • Between January and May 2007, 18 workers received on-the-job training on operating the biogas plant • In September 2008, 14 participants from the sisal industry were trained in biogas production, maintenance and management	Objective achieved
Data and reports on biogas production	Project documents were produced regularly during the life of the project: progress reports, review reports, minutes of PCC meetings, consultant reports, contractors' reports	Objective achieved
Feasibility study	A feasibility study was undertaken in May 2010	Objective achieved
National strategy for biogas and energy production from sisal waste	The proposal for national strategy for sound and environmentally friendly utilization of sisal waste for energy production was completed in 2007 and linked to the industry growth vision	Objective achieved
Study on utilization of biogas by-products as fertilizer	Indicative studies have been done, mainly laboratory analysis. No conclusive field trials have been done	Objective not fully achieved
Dissemination of project results worldwide.	• Three dissemination workshops including two international workshops • The President of the United Republic of Tanzania inaugurated the pilot biogas plant • UNIDO in Tanzania has produced a number of newsletters and posters • Katani Limited has created a website www.katanitz.com and Tanzania Sisal Board has also created a website www.tsbtz.org • A number of institutions have participated in the project • Several documents pertaining to the project are available on the Internet	Objective achieved but tangible results of dis-semination activities require perseverance

Economics of Operating a Biogas Plant

According to industry experts, an estate processing 100 tons per month has the potential for a 500 kW biogas installation. Information provided by the Tanzania Sisal Board from 28 sisal companies shows that of the 53 estates, 14 already have a leaf potential of over 100 tons per month.

The total costs of the project will include the cost of equipment for connection to the national grid, and the cost of a tanker lorry and a fertilizer sprayer. This means that the total investment for biogas production, electricity generation and fertilization can be safely estimated at US$ 2,700,000. The economic life of a biogas plant is estimated at 20 years. Therefore the investment cost can be amortized at about US$ 11,200 per month

The biogas installation will increase operational costs in terms of 2 technicians and 3 operators. Two additional drivers will be needed for transporting the fertilizer material. The total additional personnel cost is estimated at US$ 1,212 per month.

Operational costs of the equipment include maintenance and repair, oils and lubricants, fuel, insurance and licensing for the lorry. The total machine operational cost is estimated at US$ 11,000 per month.

The current feed-in tariff to TANESCO is Tshs 121.13 per kWh. It is expected that before long this will be increased to Tshs 133 per kWH. It is estimated that the power requirements of a normal-sized estate is below 200 kW. An estate producing 500 kW would have about 300 kW for sale to TANESCO. That means an estate will be able to sell 216,000 kWh per month to TANESCO at Tshs 133, grossing the equivalent of US$ 17,411.

The current purchase price of power from TANESCO is Tshs 157 per kWH plus an energy charge of Tshs 129 per kWh – a total of Tshs 286. The own consumption of kW 200 means a total of 144,000 kWh per month. This means that this would save the estate the equivalent of US$ 24,960 per month

The fertilizer equivalent of the biogas by-product from the biogas plant at Hale has been calculated to about US$ 10,000 per month. The economics of a biogas plant for producing electricity from sisal biomass is summarised in Table 5.

Table 5: The Economics of Running a Biogas Plant

Investment Costs	2,700,000		
Monthly Amortization		11,250	
Monthly Operational Costs			
Technicians, Operators, & Drivers		1,212	
Oils and lubricants		1,000	
Transportation of fertilizer		7,000	
Maintenance of equipment		3,000	
Monthly Revenue			
Sale of electricity to TANESCO			17,441
Savings on the electricity bill			24,960
Fertilizer equivalent			10,800
		23,462	**53,171**
Gross monthly surplus			**29,709**

These calculations show that operating a biogas plant will bring in an extra net income of approximately US$ 29,709 per month. If the proposed feed-in tariff into TANESCO of Tsh 250 is accepted by EWURA, other factors being equal, this amount would increase to about US$ 45,000 per month.

An estate working a six-day week of one shift of 130 meters of sisal leaf per day will produce about 1,500 tons of line fibre per year. At current prices this is equivalent to about US$ 1,575,000 gross annual income. It is estimated that the production costs amount to about 80 percent of sales. This means that the gross surplus from fibre production would be about US$ 26,250 per month.

By these calculations, the production of electricity from a sisal biogas plant will at least as profitable as the sale of fibre. This in effect means that sisal growing will be at least twice as profitable as it is when only fibre is produced.

Secondary Achievements

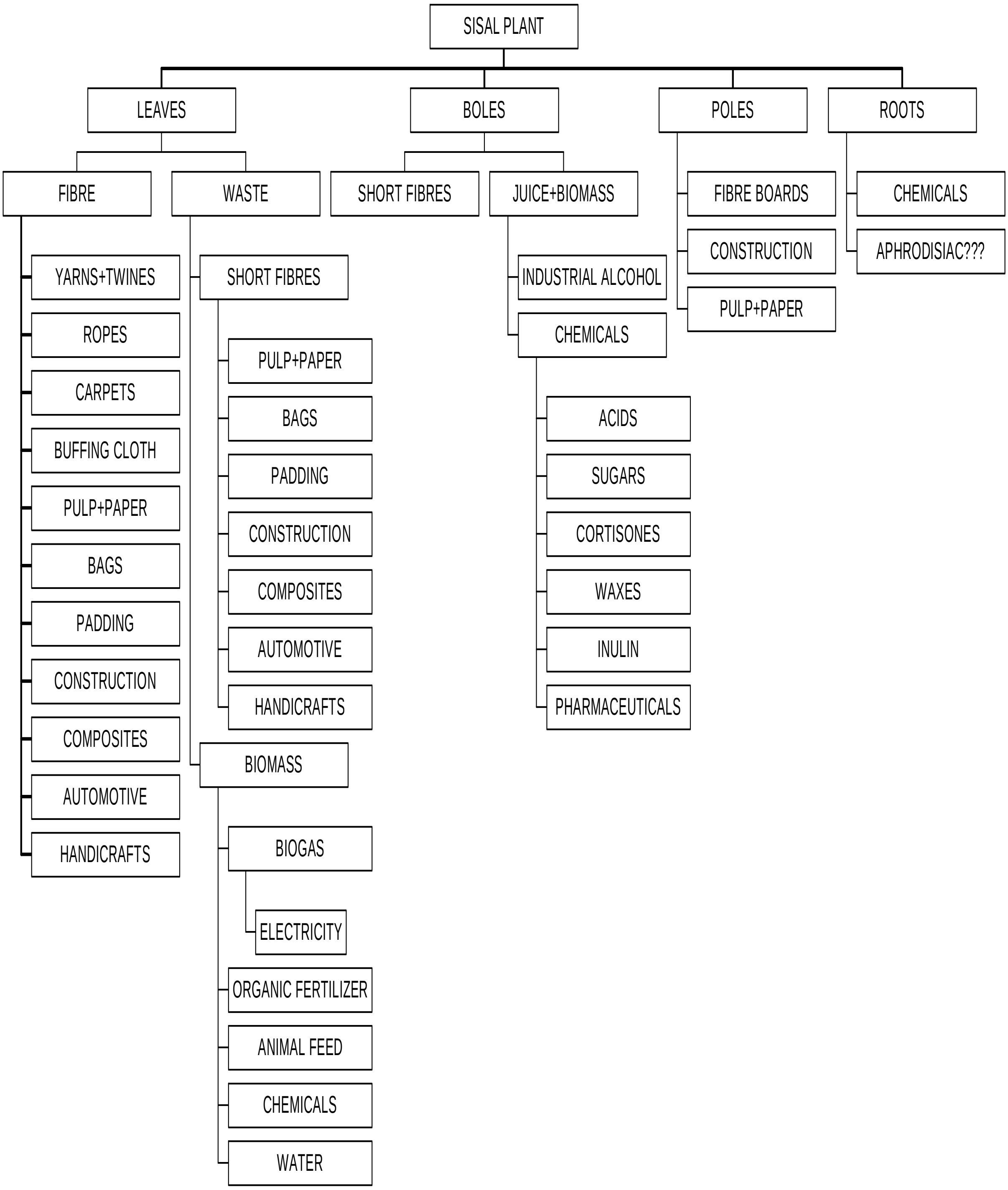
Cleaner Environment

The project has demonstrated that by utilising the biomass residues from the fibre production process for biogas reduces the amount of toxic material dumped into the soil and water. The conventional decortication method includes substantial amount of soil residue as short fibre (flume tow). At the pilot plant, this is processed to reduce the soil content in the final decortication residue. The pH of the fresh residue from the decorticator and hammer mills as measured in the collection tank is around 5 with a total solid content between 1 and 2 percent. By the time it exits from the after-storage tank, the pH of the liquid effluent is consistently neutral at pH 7. This effluent has a total solid content of less than half a percent, the rest is liquid. Even with the present knowledge on its value as a fertilizer, this liquid disposed of in an environment-friendly way by spraying it into the sisal fields.

The pilot plant has successfully demonstrated that the polluting effect of the sisal industry to the environment can be eliminated through the economic use of one hundred percent of the sisal leaf as compared to the conventional 4 percent.

There is majority consensus in the sisal industry that sisal is poised to become an energy crop. Putting this thinking into practice will naturally eliminate all waste on the sisal plant. This vision is displayed on a board at the Hale Estate decortication plant as seen on the photograph below.

UTILISATION OF THE SISAL PLANT.



The project opens the way to reversing the declining trend of the commodity by developing new products that increase utilization of the crop. It is now common knowledge in the sisal industry that all parts of the sisal plant can be of commercial value.

Improvement in Rural Standard of Life

The fact that sisal is grown in rural areas far from urban centres, the benefits from biogas are a new opportunity for modernising and improving the livelihood of rural populations:

- The electricity produced from the estates could reasonably be distributed to surrounding villages
- Biogas could be sold in pressurised containers to rural (and urban) populations. The use of (bio)gas for cooking in the rural areas will go some way to improve the health of rural people in view of the cleaner burning afforded by gas compared to wood, charcoal or kerosene

As has been stated, the wet decortication method uses a lot of water. Production of biogas from these decorticators will reduce the amount of water used in the fibre production process and reduce the amount of waste dumped in water ways, also making this resource available for other uses. It will also reduce, or eliminate completely, the pollution of water sources.

Adoption of the Project Results

Most of the local sisal companies have expressed interest in investing in sisal biogas plants. In fact, Kilifi Plantations in Kenya has already built one 300 kW biogas plant. Katani Ltd, Segera Estates Ltd, Mohammed Enterprises Tanzania Ltd and Amboni Plantations Ltd are said to be developing business plans for investment in biogas plants. Katani Limited plans to build biogas plants on its 5 sisal estates. Migotiyo Estate in Kenya (formerly Alphega) also plans to build a biogas plant. Katani Ltd and Oxfam are working together to develop a sisal smallholder scheme and build community biogas plants in 300 villages in Shinyanga Region for 16,500 farmers. The National Ranching Company has expressed interest to use the technology at two abattoirs in Dodoma and Ruvu.

The slow progress in taking up the technology is due to the high investment costs and the low tariffs offered by EWURA at the moment. TANESCO has requested for an increase of 155% in tariffs from the Energy and Water Utilities Regulatory Authority (EWURA) and under present power shortages an increase in power tariffs is unavoidable.

UNEP Risoe and the Swedish Energy Agency have provided capacity building support to the project to enable it be registered as a Clean Development Mechanism (CDM) project. This support in capacity building of local experts will give them the skills to prepare project idea notes and project design documents for the Clean Development Mechanism under the United Nations Framework Convention for Climate Change (UNFCCC).

A number of companies and financial institutions have shown interest in financing replication projects. For example, Katani Limited has signed joint venture agreements with a number of firms.

CHALLENGES ENCOUNTERED

Modifications to the Existing Decorticator

The major problem in the biogas plant is removal of fibre from the decortication residues. The flume tow plant was originally not designed for biogas feedstock production but for flume tow production. With modifications of the cage, the flume tow plant was operated with low biomass discharge due to small screen size used (8 mm) to minimize inclusion of fibres in biomass. When a bigger screen of 12 mm was used more fibre passed through and produced more output, but it chocked the stirrer and pump in the collection tank. It was found that the flume tow plant should have double the length (12 meters) to be able to operate satisfactorily for the biogas plant.

Conversion from wet to dry decortication as has been described on page 9 has not been completed at Hale Estate due to lack of funds.

The hammer mill was operated only with one or two trailer loads per day depending on the orders for short fibre, hence little biomass was produced. The market for short fibres is yet to stabilize. This is a major bottleneck to the biogas plant operation.

Design Shortcomings

Table 2 on page 17, shows that biogas production at the pilot plant increased from 53,121 cubic metres in 2007 to an all-time high of 84,027 cubic metres in 2008. Thereafter it started to decline. By 2010 gas production had dropped to 52,791 cubic metres. Part of the cause of this decline was that gas was escaping into the atmosphere. This was evidenced by bubbling, which had been noticed at the digester pipe that goes to the after-storage tank as well as at the return pipe on top of the digester. Because the hydrolysis tank is open at the top, some gas is lost into the atmosphere. This design also poses a rust problem. Indeed the hydrolysis tank was more affected by rust than the others.

Experts brought in to look at the problem suggested to use a two stage heated hydrolysis system as a solution to reduce biogas losses. The experts opined that 70 percent of the biogas is produced at hydrolysis and only 30 percent in the digester. The hydrolysis tank at Hale is open and not heated.

The Financial implications of Connecting to the National Power Grid

The combined electricity generation capacity of the two CHP units at Hale exceeds the estate's power requirements. So, in order to run both the two generators installed at Hale Estate fully the plant needs to be connected to the national grid. The connection cost quoted by TANESCO was Euro 45,111.35, to cover the transformer, circuit breaker and synchronization gear. This is a one-time investment cost. This funding is lacking at the moment.

EWURA has offered a feed-in tariff from biogas electricity of Tshs 121.13 (about 7.3 US Dollar cents) per kWh. At a sisal stakeholders meeting on 6th April 2011 the sisal industry stakeholders, basing on the feasibility study by Walter and Katharina Danner, proposed to EWURA a preferential feed-in tariff of Tshs 250 (15 US Dollar cents) per kWh to give incentive to prospective investors in biogas plants. This matter has not been resolved yet.

The pilot plant at Hale Estate has not attempted connecting to the national electricity grid. There are several reasons for this, even before the cost-benefit ratios implied in the investment and operating costs on one hand and the revenue expected from the feed-in tariff offered by EWURA. If both generators at Hale were running full time, the plant would be producing 300 kW, which is more than the estate can consume. Without feeding the excess into the national grid, this would be a waste. However, in order to produce enough biogas to run both generators full time both the hammer mill and the decorticator have to work at their full capacities. This is not possible because the leaf potential on the farm is not sufficient. To reach the required leaf potential, Katani Limited needs to embark on a replanting programme, but since replanting has not started, there is a waiting period of about three years before the first harvest from any new planting.

Cost of Adaptation of the Technology

Although the project has been received positively at all levels and several players in the sisal industry have shown interest, replication of the technology still faces a number of challenges. These include:

- cost of the technology
- optimization of biogas production
- modification of stationary decorticators
- commercialization of the fertilizer use
- scrubbing of the biogas to enable it to be used as fuel in vehicles

The Undeveloped Market Potential for Short Fibres

The hammer mill technology has all the technical advantages over the decorticator method. It is more efficient, produces clean fibre and clean biomass for biogas, and uses less water, It, however, produces the short (pulping) fibre, whose market is less developed.

If the factory were operating at its full capacity of 10.5 tonnes per hour continuously, it would produce enough biogas to run the two CHP units for power production.

Conversion of the sisal plant from a primarily fibre crop to a mainly energy crop requires some pioneering efforts. It requires the concerted efforts of many players to demonstrate whether it is more profitable to produce short fibre, biogas and electricity from sisal than it is to produce long fibre. There are favourable hypotheses among experts in the project but the project at its pilot plant at Hale has fallen short of demonstrating this in practical terms. The available experience does not provide concrete data to show the minimum commercially viable installation (including the choice between or combination of corona and hammer mills) for a standard-size estate in Tanzania.

Rusting of the Steel Tanks and Other Deficiencies in the Pilot Plant

Over the years that the plant has been installed the steel biogas tanks have heavily rusted. Two drums of rust terminator paint were received from the contractor (BEB BioEnergy Berlin) in 2009. The paint proved capable of arresting rust on the outside but was ineffective on the inner rusting. Tanzania Pipeline and Tanks Inspectors, a local company, offered cathodic protection services for the facility at Hale for US Dollars 35,000 in 2009. The request for funding this activity together with ultrasonic inspection of the vessels to determine the extent of rusting was submitted to UNIDO. In 2010, UNIDO allocated approximately USD 50,000 for ultrasonic inspection to determine the extent of rusting, sandblasting and painting and procurement of 1,141 litres of paint. The ultrasonic inspection was carried out by TEMDO of Arusha, Tanzania, following a competitive tender procedure.

Subsequent literature review revealed that cathodic protection could affect the microbes essential for the production of biogas. Therefore, coupled with the tight budget provided by UNIDO, this idea was discarded without experimenting. In future, experiments will have to be undertaken as the cost of sandblasting and painting every two years could be a heavy cost during operations.

Use of Biogas as Fuel in Vehicles

Biogas upgrading has been studied at length. This involves removing carbon dioxide ($C0_2$) and hydrogen sulphide (H_2S) from the biogas which contains 50 to 60 percent methane. To be able to use the sisal biogas as transportation fuel it is necessary to remove carbon dioxide, oxygen, hydrogen sulphide and other impurities, thereby increasing the methane content to between 97 and 99 percent. This can then be compressed to liquid form and used in gas engine vehicles to replace fossil fuel. Biogas used for transportation has higher value than biogas used for electricity generation.

Quotations from China and Sweden were received in 2008 and forwarded to UNIDO. In February 2009 a grant application was made for Euro 900,000 from NUTEK Demo Environment in Sweden to finance a pilot biogas scrubbing facility to produce 82 litres diesel-equivalent per hour. NUTEK was to cover half of the equipment cost and 80 percent of the services cost (i.e. training, shipment, technical expertise, clearing, project management, administration, installation and commissioning costs including trial runs). The application was not approved in 2009 but another application was submitted in 2010. It is still pending.

Operational Problems

The following problems have affected operation of the project at one time or another:

- The gas meter at the H_2S tank has broken down
- The control computer broke down in 2009 and has not been repaired or replaced
- The first CHP broke down in 2008 and was replaced with a new one
- The hydrolysis tank flow meter has broken down and has not been repaired or replaced
- The gas analyzer was taken to UK for service in 2009 and upon re-importation the Tanzania Revenue Authority demanded import duty of TShs 3 million (approximately US$ 2,000 at the time). Eventually Katani Limited paid about one third of this amount following negotiations with the tax authority
- The second CHP operated for a while and developed starting problems
- Stirrer No.1 (15 kW) in the digester tank has broken down
- Fencing and honging of tanks has not been implemented for lack of funds.

MAIN CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Economic Viability

Experts say that a sisal estate with a total area of 1,200 hectares under sisal and running one decorticator in one shift of 130 metres per day and has a capacity to produce a minimum of 500 kW. Almost all estates in Tanzania have a land area bigger than 1,200 ha. Calculations in this report have shown that the own consumption and sale of the extra electricity produced from the biogas adds 70 to 100 percent of the net revenues realised from the sale of sisal fibre. This significantly improves the profitability of the sisal estates and the competitiveness of sisal fibre in the market.

Food Security

The project has demonstrated that sisal has the potential for becoming an energy crop. Traditionally sisal growing areas in Tanzania do not come into competition with food crops for land. Even the planned expansion is not likely to result into serious competition with food crops for land. Parallel biofuel crops such as jatropha (*Jatropha curcas* L) have a high risk of competing with food crops for land, thereby leading to reduced food security. This would be in contradiction with national and global food security goals. The successful utilisation of sisal as an energy crop would help arrest this threat.

In actual fact the project will contribute significantly to food crop production by providing as a by-product a fertilizer that many can afford. Research results on solid fertilizer use have shown yields can be increased by up to 40 percent per hectare on the present yields.

Improves Resource Utilisation and Environmental Benefits

The conventional decortication process at Hale Estate uses a lot of water per day. The bulk of the water is needed for propelling the leaf waste away from the corona. This waste water is dumped back into valleys at Hale Estate or, in some estates, into rivers. At present the estates pay only for the water rights to utilise this water but there is talk of imposing a capacity levy on these companies. It has been found that tapping the leaf waste for biogas production reduces the water requirements to only ten percent of this amount. This in turn reduces the problem of water pollution significantly, increasing compliance with environmental statutory requirements.

Potential for Raising the Standard Rural Populations

The main source of power generation in Tanzania is from river flow. In the last few years the country has been experiencing increasingly erratic power supply due to inadequate river discharges. Even so, the electricity supplied by TANESCO is used mainly in urban centres and reaches less than 20 percent of the entire population.

The project provides a new opportunity for producing clean, renewable power to rural communities from the normal rural activity: farming. It is foreseeable that availability of affordable electricity in rural areas might stimulate the growth of small-scale industries.

The use of biogas to replace wood, charcoal and kerosene for cooking will have a positive impact of the health of the rural population.

Sisal Biogas as Fuel in Vehicles

The biogas produced from the plant at Hale has been demonstrated to be suitable for use as a fuel in internal combustion engines. The electricity generators at the estate are run on this gas. The main production issue that remains to be solved in order to commercialise is to do with removal of unwanted gases (mainly CO_2 and O_2), which means a biogas upgrading facility.

Financing of activities to enable commercialisation of sisal biogas in transportation has proved difficult. This is due to the absence of demonstrable viability of such a project. A pilot biogas upgrading plant would enable financiers to appreciate the potential for sisal biogas as a fuel in vehicles.

Recommendations

In May 2010 UNIDO commissioned Rottaler Modell to prepare a feasibility study for generation of biogas and electricity from sisal waste. Walter and Katharina Danner from Rottaler Modell met sisal stakeholders in Tanga and Dar es Salaam.

In the report, Walter and Katharina Danner propose a two-stage biogas plant instead of the one-stage system such as the one at the Hale pilot plant. The two-stage system has hydrolysis and acidification taking place in two hydrolysis tanks at a low pH of down to 4.5. Acetic acid formation then follows. In the digester, methane formation operates at neutral pH of between 6.7 and 7.5. Separating hydrolysis/acidification from methane formation provides an optimal environment for the different groups of microorganisms. The two-stage system increases biogas yields by between 15 and 40 percent by degrading the cellulosic part of the material at higher temperatures and lower pH in the hydrolysis tanks through acidification. The system shortens the retention period resulting in tanks being smaller thus reducing investment costs.

A shift processing 90 metres of sisal leaves per day for 288 days would produce 0.5 MW of electricity. Such a plant in a single-stage system would require 2 tanks each 2,500 cubic metres or a total of 5,000 cubic metres. A two-stage system would require 2 hydrolysis tanks each 200 cubic metres and a digester of 1,500 cubic metres or 1,900 cubic metres of tank capacity. This means that to go to 0.5 MW at Hale requires only one additional closed hydrolysis tank of 200 cubic metre capacity plus the required generation equipment. The two-stage system gives flexibility in the feedstock and one can use more than two different feedstock materials including normal grass.

Walter and Katharina Danner have proposed heating of the hydrolysis tank which is not presently done. Temperatures of above 40^{o}C stimulate the bacterial action and reduce the retention time from 5 days to two days in the hydrolysis tank. Sisal waste contains high cellulosic and hemicellulosic components and is very fibrous. This makes it difficult to digest. Walter and Katharina Danner recommended reducing water content in sisal waste as will be achieved by changing to dry decortication and using conveyors to convey the sisal waste.

The collection tank at Hale can be eliminated as the sisal waste has very low total solids and can therefore be pumped. In a two-stage system sisal waste can be pumped directly from the channel into the hydrolysis tank using lobe pumps as they suck.

The steel tanks at Hale should have had enamel coating to resist the acidic sisal material. Though steel tanks are not as sturdy as concrete tanks, the report does not recommend concrete tanks in Tanzania as airtightness in concrete structures is difficult to achieve. Gas-tight steel tanks are of widespread use in the world and can easily be imported. The construction time is also lower.

The report has provided an economic evaluation of a 0.5 MW biogas plant using sisal waste and grass costing USD 2,225,281 with layout, plant schematics, gas and digestate piping plans and plant operation costs.

Walter Danner and Katharina Danner have evaluated the biogas project profitability at 40 percent equity and 60 percent debt with a loan interest of 15 percent at various feed-in-tariffs of Tshs 120, 150, 200, 250, 300 and 400 per kWh. The internal rates of return at those feed-in-tariffs are 2.63 percent, 5.52 percent, 10.33 percent, 15.14 percent, 19.95 percent and 29.57 percent respectively. The consultants have recommended a feed-in-tariff of Tshs 250 per kWh to make biogas projects in Tanzania viable.

On Replication of the Project

It must be accepted that the production of long fibre is still the main economic activity in the sisal industry. As long as this remains the case, production of biogas will be from the stationary decorticator. At Hale the wet decortication process was converted to dry decortication by introducing a lengthy system of conveyors to link the decorticator to the biogas production facility.

In any new installations a shredder can be installed immediately at the end of the decorticator, thereby eliminating the need for the cost and space requirements for the system of conveyors.

It is reported that ordinary grass could be added with the leaf waste in the biogas production process. The social and economic opportunities that this technology would open are substantial: not only would the farmer be able to sell the leaf, they would also weed their farms and sell the weeds for biogas production. Selling “weeds” is not entirely a novel idea; it is done for feeding zero-grazed livestock. However, the idea of a ready market for weed material could be a new incentive for keeping fields clean.

On Construction of the Biogas Plant

The pilot plant at Hale used steel in the tanks. Steel tanks are subject to rusting and have proved to have high cost of maintenance. There is a need to evaluate the cost of concrete tanks instead of steel tanks. The high investment cost especially in tanks is a barrier to sisal biogas development.

The biogas production infrastructure at Hale Estate is inefficient. It constitutes five storage tanks: the collection tank, the hydrolysis tank, the anaerobic digester, the gas storage tank and the after-storage tank. These tanks are connected in series where essentially biogas is tapped only from the anaerobic digester. It is, however, possible to increase gas productivity by converting this system to a parallel connection so that biogas is collected from all four tanks.

UNIDO has produced a consultant report on a feasibility study for the project. The findings of this study need to be followed up.

On Commercialisation of the Biofertilizer

Only limited fertilizer experimentation has been undertaken on short term crops. One of the reasons why comprehensive trials were not run is that the project requires slurry tankers and tractors to carry the liquid fertilizer to the field. The funds availed did not take this into consideration.

Before any attempts can be made to use the biofertilizer on a commercial basis it is necessary to carry out proper fertilizer trials on sisal and other smallholder annual crops.

Another aspect of the biofertilizer that needs looking into is the packaging of the material for commercialisation.

On Dissemination of Results

The Hale pilot project faces a few challenges. First there is the shortage of sisal leaf production to run both the decorticator and the hammer mill at full capacity. Then there is the difficulty of balancing between use of the highly efficient hammer mill to produce short fibre whose market is undeveloped and the dry decortications which is inefficient for biogas production but produces long fibre which has a better established market. There is also the problem of producing more biogas than can be used for generating electricity if the two mills were to operate at full capacity.

The Tanzania Sisal Board and Katani Limited both have set up web sites as part of the information dissemination effort. The Katani Limited web site has a directly accessible web page that has information on production of biogas and electricity from sisal. The TSB website, however, does not have pages dedicated to the project or direct links to such pages.

It would provide more publicity for the project achievements if both web sites had single-click links from their home pages to the project page. The TSB web site could also be constructed such that a search from the common search engines for this subject would lead directly to the project page.

The efforts that have been started by such organisations as Oxfam to introduce household and community biogas plants need to be encouraged and disseminated with the participation of effective instruments such as the media. Because of its multi-sectoral nature, the project provides opportunities for development of partnerships involving sisal smallholder and large-scale farmers, communities surrounding the estates, government institutions dealing with water, energy and environment, the general public, investors in renewable energy and financial institutions.

The Tanzania Sisal Board, which is a government body, needs to be facilitated to take up its role in putting this partnership potential into practice.

On Harnessing the CHP Heat Energy

The generator is known in the project as a combined heat and power generation unit. This implies that both the heat generated by the engine and electricity are meant to be harnessed. Actually the heat is needed for, among other things, drying the fibre. It is said that using this heat to artificially dry the fibre would produce cleaner fibre than relying on the weather.

About 70 percent of biogas used in CHP is converted into heat of which 4 to 50 percent could be recovered as useful heat for drying and heating. The temperature of the CHP exhaust gases at exit is 200 degrees Celcius. At Hale only some of the coolant heat is harnessed for warming up the tank contents.

Techniques for harnessing the heat from the CHP units for drying the short fibres to produce high quality fibre for pulp and composites need to be developed.

On the Possibility of Adding Grass into the Biogas Production Process

Addition of biomass from ordinary grass with the sisal waste has been discussed as a possibility. At present, the estates have to spend money to keep the sisal fields clean. The weeds are usually left on the ground. On the other hand, farmers do not earn any income from weeding their own maize, orange or coconut plots. Because the weeding of their own plots is not immediately rewarding, many fields are not kept as clean as they ought to be. If ordinary grass can be used in the biogas production process, this will mean that people do not have to be employed by the estates to make money from weeding the farms; they can clean the estates and their own fields and sell the grass to the biogas plants. The rural economic benefits from application of this project can be significant.

This idea has not been tested at Hale to establish its viability. Studies will need to be undertaken to determine whether it would be an added benefit to incorporate grass in a biogas production plant. Experience from Europe should be taken with care as grass there is grown in more controlled conditions than in Tanzania.

Notwithstanding the aforementioned, it must be said that there could be a negative aspect to this possibility. Taking away the weeded grass from the fields essentially means exporting nutrients. So, this will contribute to some extent to nutrient depletion on fields. Some mechanism of replenishing these nutrients must be worked out. Fortunately this is more a matter of logistics involving the use of the end by-product of biogas production – the effluent from the after-storage tank.

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RELEVANT WEB SITES VISITED

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The Katani Limited website http://www.katanitz.com

The Tanzania Sisal Board website http://www.tsbtz.org

The UNIDO website http://www.unido.org