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Leveraging CDM to scale-up sustainable biogas production from sisal waste

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LEVERAGING CDM TO SCALE-UP SUSTAINABLE BIOGAS PRODUCTION FROM SISAL WASTE

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ABSTRACT**:** The sisal fibre industry is a fragile one, predominant in developing countries, with Brazil, Tanzania, Kenya, Mexico and China as leading producers. Exploitation of biogas from the sisal plant (*Agave Sisalana*) could generate large sustainable development benefits, given that less than 10% of the biomass is typically extracted as fibre, and the waste products are often disposed of in an environmentally unfriendly manner. Employing an appropriate anaerobic digestion (AD) technology, sisal biogas projects may also earn carbon credits from a variety of sources: avoiding CH_4 emission from traditional waste disposal practices, reducing CO_2 emissions from offsetting fossil fuel-based electricity or reducing the use of diesel by tractors operated by the factories, and reducing N_2O emissions by replacing the use of chemical fertilizers with organic bio-slurry bi-product generated from the biogas plants. We assess the global potential for scaling up biogas production in the sisal industry by examining the role of carbon finance and the Clean Development Mechanism (CDM) in catalyzing financing and technology transfer. By examining pilot sisal biogas CDM projects being implemented in Tanzania, the paper extracts broader lessons for the technical and financial viability of scaling up sisal biogas production. The paper shows that there is relatively large biogas potential from sisal waste and by implementing a bundle of projects as CDM activities, the financial barrier can be reduced, contributing to the revitalization of an industry with large potential global environmental and local sustainable development benefits.
Keywords: anaerobic digestion, biogas, clean development mechanism (CDM), greenhouse gases (GHG), sisal waste.

1 INTRODUCTION

1.1 Background

Originating from Central America, sisal *(Agave sisalana)* is a tropical plant species whose main value lies in its extracted fibres used in manufacturing ropes, carpets, string and other cordage. This plant is cultivated commercially in estates managed by large companies in Africa (Tanzania, Kenya, Madagascar and South Africa), Latin America (Brazil, Mexico, Haiti, Jamaica and Venezuela) and some parts of China: To enhance supply out-grower schemes are sometimes used as well.

The process of extracting fibres from the sisal leaves involves an extensive use of water and energy and is done in factories using special machine called a decorticator. The leaves are crushed and beaten by a rotating wheel set with blunt knives, so that only fibres remain. The fibre accounts for only 5% of the whole sisal leaf leaving the remaining 95% as waste, which is washed away by water into onsite disposal sites or nearby rivers [1]. In a few cases, the solid materials are separated from the waste and the remaining wastewater is collected in lagoons before being discharged into the rivers. This system is very common in several sisal factories in Tanzania and Kenya.

Since sisal cultivation does not require extensive fertilizer or water inputs, the main environmental impacts of sisal factories are related to water pollution and greenhouse gas (GHG) emissions. Both the solid waste at the disposal sites and the wastewater in the lagoons increase emissions of methane gas to the atmosphere, generated after the decay of the degradable organic carbon (DOC) in the waste.

Diversification of the sisal industry (i.e., reducing dependency on fibre income and increasing resource use of the whole sisal plant) is crucial if the industry is to remain competitive. In this context, a more sustainable approach for cleaner production and income diversification is presented by using the waste as a feedstock in producing biogas using anaerobic digestion (AD) technology. Sisal biogas can be combusted to generate energy and also help mitigate GHG emissions. Due to its richness in plant nutrients, the bio-slurry can also be used as organic fertilizer in farming fields replacing the use of chemical fertilizers like Urea which contribute to the emissions of Nitrogen dioxide (N_2O).

The technology for generating biogas from sisal waste has already been demonstrated on a pilot scale (150kW capacity) at Hale sisal factory in Tanga, Tanzania. Scaling-up biogas plants to commercial scale remains a challenge, however, due to various barriers facing biogas technology deployment in developing countries and due to the fact that the technology is still relatively untested, and thus investors are reluctant, especially when there is an unappealing return on investment.

The clean development mechanism (CDM) under the Kyoto Protocol has the potential to enhance the financial viability or bankability of sisal biogas projects by adding an additional revenue stream from the sale of carbon credits or certified emission reductions (CER). This paper assesses the global potential for sisal biogas and the role of CDM to leverage a scaling-up of production, drawing upon two CDM projects under development in Tanzania. In this framework, the paper analyses the eligibility of the projects for CDM based on UNFCCC rules and regulations.

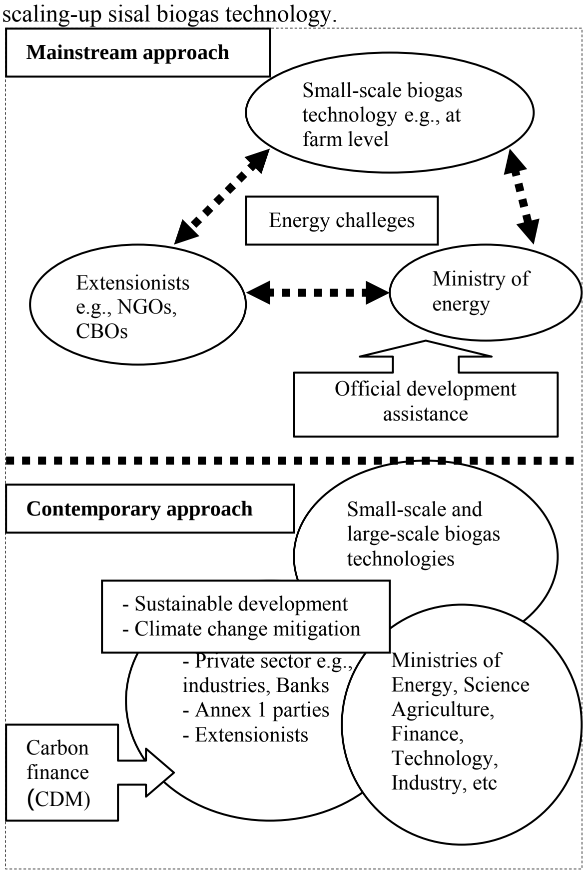
1. 2 Sisal biogas systems

Basically, a sisal biogas system (like any other biogas system) functions properly when there is a constant availability of sisal waste (feedstock) and the technology to process it. Other crucial factors are an effective institutional framework, technical knowhow and financing for the capital investment costs. In most sisal growing countries, these factors are not always well set, thus posing various barriers to scaling-up the technology (Table I). This paper assesses whether and by how much carbon financing could reduce those barriers.

Table I: Barriers to deployment of biogas/sisal biogas technology in developing countries

Barriers	Specific Challenges
Financial	- Lack of effective financial schemes for mainstreaming biogas projects. - Lack of access to affordable loans due to underfunding in agro-industrial sectors including sisal. - High upfront investment costs (i.e., plant construction costs)
Technical and technological	- Inadequate knowledge on sisal biogas technologies. - High cost of the technologies currently identified as suitable for sisal waste. - Lack of competent biogas technicians locally. - Lack of local equipment suppliers and spare parts.
Institutional and policy	- Lack of institutional support to promote biogas technology including sisal biogas. - Lack of sound fiscal policy to provide incentive to attract investment in biogas. - Unattractive feed in tariff offered by the power companies for renewable energy produced by the independent power producers (IPPs), which may affect sisal energy companies as well.
Social and entrepreneurial	- Lack of entrepreneurship business models for scaling-up sisal biogas technology. - General lack of awareness by both individuals and companies on benefits.
Operational	- Difficulties relating to diversification of operation model by sisal companies to embrace sisal biogas/energy business. - Lack of clear understanding by the sisal companies/investors of the local market potential for the produced biogas/energy.

Figure 1: Role of carbon finance through CDM in scaling-up sisal biogas technology.



Source (see reference no. 2)

1.3 The role of carbon finance and the CDM

Carbon finance is a clear potential driving factor in promoting sisal biogas production, especially in Africa, where accessibility to clean energy is still a challenge. This form of finance can significantly assist in eliminating potential barriers facing biogas projects. Potentially, CDM could also play a role in reducing dependence on official development assistance (ODA) in financing biogas projects in Africa, Carbon finance is well positioned to replace the mainstream approach of dealing with biogas challenges in developing countries (i.e., relying on government's response to the challenges through ODA) with a more integrative approach that involves a multitude of actors, both public and private (Figure 1).

Concerning sisal biogas projects, it is important to first assess their eligibility for CDM by looking at the methodological aspects of calculating the GHG emission reductions, the additionality of the projects, and the sustainable development contributions for the approval of projects by host countries.

1.4 Approach

This paper assesses the global potential for biogas from sisal waste and the role of CDM in scaling- up the technology by examining the global potential for sisal waste, technology availability and the suitability of the sisal biogas project to CDM project activities. The paper draws on the experience from the pilot sisal biogas CDM projects being implemented in Tanzania that receive technical and financial assistance from the UNEP Risoe Centre (URC), particularly those owned by KATANI Plantation Ltd and SAGERA Estates Ltd. These projects intend to produce biogas from large amount of sisal waste currently dumped into unmanaged dumping sites, and burn the biogas to generate power for onsite consumption and grid export. Being implemented as CDM projects, the projects will gain revenues from the avoided GHG emissions.

1.5 Objectives and Significance

The key objective of this paper is to assess the potential for biogas production and energy generation from sisal waste globally by analysing the role of carbon finance through CDM in scaling-up sisal biogas technology by eliminating potential barriers. The paper provides an overview of global potential for biogas and energy from sisal waste and how much revenue could be generated from sisal biogas projects toward the technological transfer and leapfrogging demonstrated in the Tanzanian case. The paper also share good practice lessons for replication of this promising bio-energy technology with widespread relevance for developing countries.

2 OVERVIEW OF SISAL INDUSTRY

2.1 Global sisal production

Over the previous two decades, the sisal industry has gone through a familiar pattern afflicting many agricultural and agro-industrial products. The industry has faced a decline in production of about 38% and its international trade shrank by about 52% [1]. Producing countries have gone through different levels of transformation, but in general production and sales declined considerably.

Currently, sisal occupies 6th place among fibre plants, representing about 2% of the world's production of plant fibres (collectively, plant fibres provide about 65% of the world's fibres) [3]. According to data from Food and Agricultural Organization (FAO) until 2007 Brazil was the largest producer of sisal accounting for about half of global sisal production [4]. Other countries with significant contributions are Mexico, Tanzania, China, Kenya, Venezuela and Madagascar. The remaining production comes from El Salvador, Haiti, South Africa, Ethiopia, Angola and Jamaica, each contributing less than 5% of the total production (Table II). Data for the year 2008 are not yet released by FAO, thus the 2007 data are employed throughout the rest of this paper (with the exception of the data employed in analysing the case studies in Tanzania).

Table II: Global sisal fibre production (2001 – 2007)

	2001	2002	2003	2004	2005	2006	2007
	kilo-tons						
Africa	**64**	**59**	**60**	**68**	**68**	**71**	**78**
Tanzania	24	24	24	27	28	31	37
Kenya	23	22	25	27	26	26	28
Madagascar	12	8.4	6.4	10	10	10	10
South Africa	2	2	2	2	2	2	2
Mozambique	1	1	1	1	1	1	1
Angola	1	1	1	1	1	1	1
Ethiopia	1	1	1	1	1	1	1
L. America	**141**	**151**	**155**	**153**	**133**	**139**	**127**
Brazil	127	138	142	140	119	126	113
Mexico	35	35	35	35	27	27	27
Venezuela	11	11	11	11	11	11	11
El Salvador	7	7	7	7	7	7	7
Haiti	2	2	2	2	2	2	2
Jamaica	0.3	0.3	0.3	0.3	0.3	0.3	0.3
China	**37**	**38**	**35**	**35**	**35**	**35**	**35**
Total	**241**	**248**	**250**	**255**	**236**	**246**	**241**

Source (see reference no. 4)

2.2 Non-utilisation of the whole sisal leaf

Global demand of sisal fibre and its end products is the basis of the industry and what determines its existence. Yet barely 5% of the sisal plant is commercially extracted as fibre while the rest is dumped as waste. Sisal waste may affect people living around the factories in many ways, especially when waste is unsustainably handled, including possible pollution of groundwater or surface water. The photos below show waste generation from the decorticator and their disposal into the disposal site/lagoons in one sisal factory in Tanzania.

Photo 1: Sisal waste generation

Due to low usage of the whole sisal plant and other challenges (like market competition from synthetic fibres), the return from the sisal industry has been relatively low. A number of studies have been carried out to diversify the industry including possibilities for commercial utilization of the waste. Apart from using waste to produce biogas, other options include using it for animal feed, organic soil improvement, in pharmaceuticals, and as raw material for bags, roofing tiles and padding [1]. However, the use of waste as feedstock in biogas production is seen as more sustainable option since a huge amount of waste can be consumed in this way compared to other options. Further, biogas could be combusted and thus ensure accessibility to renewable energy by the community and the sisal factories. This could eventually help enhance people's livelihoods.

Taking an estimate of 5% fibre in sisal leaf, global sisal waste generation in year 2001 – 2007 would be 4,573,000tons (Table III).

Table III: Estimated global sisal waste generation (2001 – 2007)

	2001	2002	2003	2004	2005	2006	2007
	kilo-tons						
Africa	**1210**	**1121**	**1142**	**1286**	**1288**	**3308**	**1490**
Tanzania	447	448	454	509	528	587	701
Kenya	209	420	475	505	486	502	524
Madagascar	228	160	122	181	181	175	173
South Africa	32	30	30	30	30	30	30
Mozambique	19	19	19	19	19	19	19
Ethiopia	13	13	13	13	13	13	13
Angola	10	10	10	10	10	10	10
L. America	**2673**	**2871**	**2945**	**2901**	**2529**	**2643**	**2419**
Brazil	2419	2624	2698	2654	2263	2385	2153
Mexico	665	665	665	665	494	494	494
Venezuela	209	200	200	200	200	200	200
El Salvador	124	124	124	124	124	124	124
Haiti	40	40	40	40	40	40	40
Jamaica	6	6	6	6	6	6	6
China	**703**	**722**	**665**	**665**	**665**	**665**	**665**
Total	**4587**	**4714**	**4752**	**4853**	**4482**	**6616**	**4573**

3 BIOGAS PRODUCTIONS AND ENERGY GENERATION FROM SISAL WASTE

3.1 Sisal waste characteristics

Sisal waste consist of considerable amounts of non-degradable compounds (i.e., lignocelluloses) compared to many other types of feedstock materials [5]. Such types of waste can be termed as moderately degrading waste as it takes a few more days and a few more months to degrade when exposed to an anaerobic conditions in a bio-digester or at a disposal site respectively [6].

When a decorticator machine is used to extract the fibres, the wastewater normally contains bundles of small fibres called flume tows. If these are not filtered out before entering into the digester, then they will delay the degradation process. In some instances, a sophisticated machine called a Hammer mill is used in fibre extraction. Though rarely used in sisal factories due to their cost, using the Hammer mill can also guarantee a better quality waste for the purpose of biogas production.

Photo 2: Sisal waste types

3.2 Technology options

Various types of AD technologies are in use today, the design for which is determined largely by the feedstock digested. Basically, in AD rectors, the immobilisation of microbial biomass takes advantage of the natural tendency of waste to form dense granules, which settle in the digester as in the Up-flow Anaerobic Sludge Blanket (UASB) reactors or involves the use of an inert medium to which the microbial organisms attach as in the Expanded Granular Sludge Bed (EGSB) reactors [7]. These high rate AD reactors have been demonstrated to allow for a continuously high and sustainable organic load rate, a short hydraulic retention time (RT) and high methane production from semi solid agro-industrial waste including sisal waste [7]. However, the commercial deployment of these types of reactors in sisal biogas production is constrained only in laboratory research as the technologies are relatively expensive compared to other technologies such as a Continuous Steered Tank Reactor (CSTR), which has also been demonstrated to be appropriate for sisal waste. The CSTR technology has been demonstrated already at a pilot sisal biogas plant at Hale Sisal Estate in Tanzania.

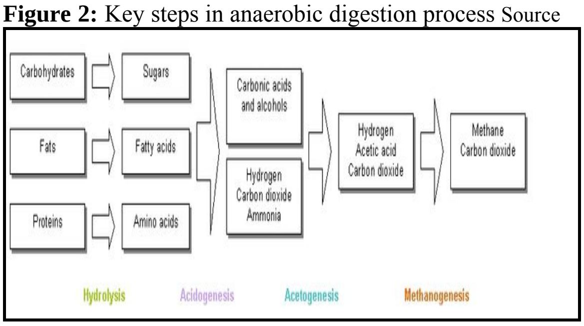
Digestibility of sisal waste can be enhanced by employing various techniques, for example by applying a batch wise (i.e., the intermittent addition of substrate into the digester) co-digestion of the waste with other biodegradable material such as fish pulp. This approach can considerably enhance feedstock degradability and thus increase biogas production to 59% - 94% when different mixing ratios are applied [8]. Co-digestive material supplies the missing nutrients to the system and thus reduces the impact of inhibitory elements present in the waste [9].

Further, biogas production and methanization from sisal waste can be enhanced by about 26% when the waste is pre-treated prior to AD processes. This can be done by using an activated sludge mixed culture under aerobic conditions in batch bioreactors at mesophilic temperature [10]. The essence of this approach is that the solubilisation of sisal waste increases when it is first treated aerobically with an activated sludge mixed culture under controlled conditions [10].

3.2.1 Key steps in biogas production

Biogas is produced as a result of anaerobic decomposition of DOC found in the organic waste. The process takes place in the digester and involves two types of bacteria known as acidogenic (acid-forming) and methanogenic (methane forming).

Figure 2: Key steps in anaerobic digestion process Source



(see reference no. 11)

Summary of the process

1. Hydrolysis – this step involves the liquefaction of the DOC in the feedstock to produce soluble degradable sugars, amino acids, and long chain fatty acids,
2. Acidogenesis – this step involves the formation of hydrogen, short chain volatile fatty acids, and alcohol from the soluble compounds produced in step 1,
3. Acetogenesis – here acetic acids and hydrogen are formed from the fatty acids and alcohols, and
4. Methanogenesis – in this final step methane and carbon dioxide are formed from the acetic acids, hydrogen, and alcohols.

The residue left from the biodegradation process is called bio-slurry, which is estimated to contain over 50% of the nutrients of the original waste and that could be used as a bio-fertilizer [9].

Table IV: Nutrients composition of sisal waste vs. bio-slurry

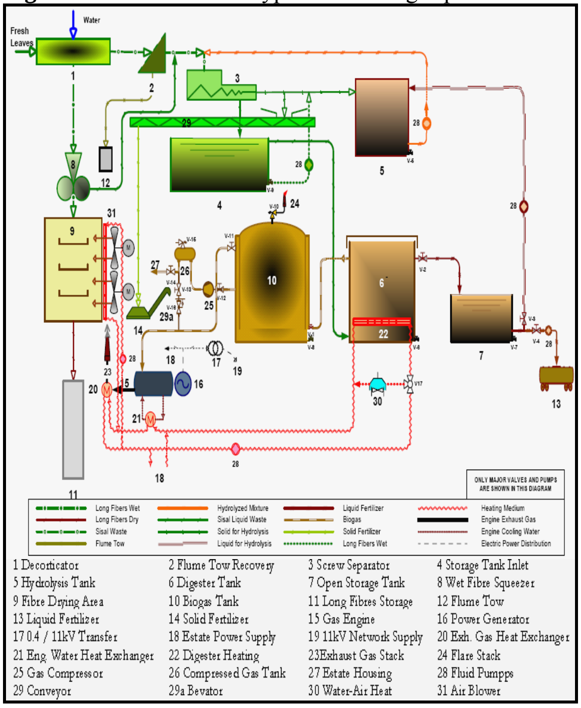
Nutrient	Composition in waste (kg/t)	Composition in bio-slurry
Nitrogen (N)	6.0	4.0
Phosphorus (P)	1.0	0.7
Potassium (K)	0.8	0.6
Magnesium (Mg)	1.6	1.1
Calcium (Ca)	25.0	17.5
Suphur (S)	2.5	1.75

Source (see reference no. 12)

3.2.2 Key features of sisal biogas plant

The technical design of a sisal biogas plant will depend mainly on the intended use or customer of the biogas. Biogas can be combusted for onsite power use or exported to consumers. It can be supplied through pipes directly to local households or compressed, bottled and sold to local communities. The biogas can also be flared in conformance to local environmental regulation, especially when there is more gas than can be used in the energy recovery system. The following illustration (Figure 3) shows a typical biogas plant comprising of key equipments including the decorticator machine, hydrolysis tank, digester, gas tank, power generator, etc. It also shows the various use options for the generated power.

Figure 3: Flow chart of a typical sisal biogas plant



Source (see reference no. 13)

3.3 Global biogas and power potentials from sisal waste

As shown in Table III, global generation of sisal waste in 2007 was about 4,573,000 tons. The below parameters are employed in estimating the global potential for biogas and power from sisal waste in 2007 (see results in Table V).

a) Mean biogas yield per tonne of sisal waste - 54 m^3
b) CHP generator efficiency - 30%
c) Methane heating value - 36 MJ/m^3
d) Methane content in biogas - 62%
e) 1 kWh is equal to 3.6 MJ
f) Operating time of biogas system - 8760 hrs

Table V: Estimated global biogas and power potential from sisal waste (2007)

	Biogas (m^3)	**Power (kWh)**	**Capacity (MW)**
Africa	**80,438,400**	**91,431,648**	**10.4**
Tanzania	37,859,400	43,033,518	4.9
Kenya	26,220,000	29,803,400	3.4
Madagascar	9,336,600	10,612,602	1.2
South Africa	1,641,600	1,865,952	0.2
Mozambique	1,026,000	1,166,220	0.1
Angola	718,200	816,354	0.1
Ethiopia	513,000	583,110	0.1
L. America	**130,609,800**	**148,459,806**	**17.0**
Brazil	116,245,800	132,132,726	15.1
Mexico	26,676,000	30,321,720	3.5
Venezuela	10,773,000	12,245,310	1.4
El Salvador	6,669,000	7,580,430	0.9
Haiti	2,154,600	2,449,062	0.3
Jamaica	307,800	349,866	0.1
China	**35,910,000**	**40,817,700**	**4.7**
Total	**246,958,200**	**280,709,154**	**32.1**

4 LEVERAGING CDM IN SISAL INDUSTRY

4.1 Overview of CDM

The Clean Development Mechanism (CDM) is one of the three flexible mechanisms of the Kyoto Protocol. CDM allows developed countries to finance emission reduction projects in developing countries that generate tradable carbon credits, which can be used by developed country entities to offset their own GHG emission reduction commitments and targets [14]. Typically, a CDM project activity will sequestrate or reduce GHG emissions above a business as usual level. A CDM project must result in real, measurable and verifiable climate change benefits. These benefits must be additional to any that would occur in its absence (additionality concept). To establish additionality, project benefits must be compared to those of reasonable reference cases known as the baseline scenario. The baseline is established on a project-specific basis using approved baseline and monitoring methodologies. For small-scale CDM projects, simplified baseline and monitoring methodologies can be used.

4.2 Eligibility of sisal biogas projects for CDM project activity

4.2.1 Baseline for sisal CDM projects

The AD of sisal waste in digesters and subsequent consumption of biogas and bio-slurry contribute to the mitigation of GHG emissions. As such sisal biogas project may qualify for CDM. Emissions can be lessened in three main ways:

- Modification of traditional waste management practices
- Replacement of fossil fuel-based energy sources
- Replacement of chemical fertilizer with bio-slurry

A. Modification of traditional sisal waste management practices

The traditional methods of dumping sisal waste into disposal sites can contribute substantially to the emission of GHGs. This happens when waste at the disposal site decays anaerobically to generate methane, which is freely emitted to the atmosphere.

The baseline should thus include the methane emissions from the sisal waste disposal sites, considering that the project activity would avoid the generation and emissions of methane gas from the disposal site. Waste management in the baseline scenario is the continuation of current practice without treating the waste to avoid their impacts on the environment. Where the wastewater in the lagoons is to be treated, then the baseline scenario is the continuation of current practice of storing the wastewater in the water lagoon despite treating it to avoid its impacts on the environment. In both cases, the baseline GHG emissions can be calculated using appropriate baseline and monitoring methodologies taking into account the actual size of the project. Several UNFCCC approved methodologies are available for these purposes.

Large-scale sisal biogas CDM project

1. Approved baseline and monitoring methodology AM0025 “Avoided emissions from organic waste through alternative waste treatment processes”

2. Approved baseline and monitoring methodology AM0039: “Methane emissions reduction from organic wastewater and bioorganic solid waste using co-composting”

Small-scale sisal biogas CDM project
1. Approved baseline and monitoring small scale CDM methodology III.F: “Avoidance of methane emissions through controlled biological treatment of biomass”
2. Approved baseline and monitoring small scale CDM methodology III.H: “Methane Recovery in Wastewater Treatment”

In the case of avoiding emissions of methane from the disposal sites, all methodologies require application of a first order decay (FOD) model in calculating the baseline methane reductions [15]. The following equation summarizes the model processes.

$$BE_{CH4,y} = \varphi \bullet (1-f_y) \bullet GWP_{CH4} \bullet (1-OX_y) \bullet \frac{16}{12} \bullet F \bullet DOC_f \bullet MCF \bullet W \bullet DOC_w \bullet e^{-kw(y-x)} \bullet (1-e^{-kw})$$

Where:

$BE_{CH4,\ y}$ - baseline emissions of methane from sisal waste in year y (tCO_2e)
φ - correction factor to account for model uncertainties
f_y - fraction of methane recovered at disposal site
GWP_{CH4} - global warming potential of methane,
OX - oxidation factor
F - fraction of methane in the emitted gas,
DOC_f– decomposable degradable organic carbon (fraction)
MCF - methane correction factor
W_y - amount of waste avoided from being dumped in the disposal site in year y (tons)
DOC_w - weight of decomposable degradable organic carbon in the waste (fraction)
kw - decay rate for sisal waste
y - year for which CH_4 emission is calculated, and
e - exponential constant (2.718).

B. Replacement of fossil fuel-based energy sources

Biogas can be combusted in a CHP system to generate power that can be consumed onsite for captive uses or exported to the main grid or off-grid to enhance accessibility to energy by communities. In countries where the grid energy mix is dominated by fossil fuel based sources, the exported power could help further mitigate CO_2 emissions by replacing power generated by dirtier sources. Where biogas or power is supplied locally, the emissions from the use of firewood, charcoal, diesel or kerosene can also be reduced.

The emission reductions for CDM projects can be established by comparing the baseline emissions against those resulting from the use of the biogas and power. Where power is exported to the grid, the baseline scenario is a continuous tendency of dependency on fossil fuel based grid sources in generating power. Where power is supplied locally to meet local energy needs for a non-electrified community, the baseline scenario is power generated and supplied locally from fossil fuel based sources. The baseline is the continuous use of fossil fuel-based sources or installation of fossil fuel energy sources to generate power to meet the energy needs for local community. Depending on the size of the project, several UNFCCC approved baseline methodologies can be employed; however, based on the case studies in this paper one can assume that most projects would be able to benefit from the simpler small-scale methodology

Large-scale sisal biogas CDM project
Approved Consolidated Methodology ACM0002 “Consolidated methodology for grid-connected electricity generation from renewable sources”

Small-scale sisal biogas CDM project
Approved small scale CDM baseline and monitoring methodology AMS I.D “Grid connected renewable energy electricity”

C. Replacement of chemical fertilizer with bio-slurry

Bio-slurry is rich in nutrients and can replace chemical fertilizers in farming fields (Table VI). Sisal biogas CDM projects can thus also potentially make a contribution to the reduction of emissions of Nitrogen dioxide (N_2O) from Urea. For projects that replace chemical fertilizer with bio-slurry produced as a bi-product of the AD process, the baseline could include emissions of N_2O from farming fields with the application of Urea.

Table VI: Plant nutrients value of bio-slurry vs. chemical fertilizers

Nutrient in 1000 kg bio-slurry	Equivalent to chemical fertilizer
17 kg N	37 kg Urea
15 kg P	94 kg Superphosphate
10 kg K	17 kg Potash

Source (see reference no. 11)

Currently, there is not yet an approved CDM methodology for this, hence it is impossible to calculate the baseline N_2O emissions or claim CERs for this component of the emission reduction mix. This would likely become material as or when the methodologies for offset projects become more sophisticated.

4.2.2 Additionality of sisal biogas CDM project activity

The additionality of any CDM activity is project-specific, and largely determined by the baseline scenario, financial circumstances of the project, and barriers to project implementation. The UNFCCC methodological “Tool for the demonstration and assessment of additionality” can be employed to justify the additionality of sisal biogas CDM projects.

Once established that the GHG emissions in the baseline situation are higher than those after the project is implemented, then it can be concluded that the project is additional in environmental terms. Any sisal biogas CDM project can be considered additional in terms of GHG reductions, especially when CH_4 emissions from the disposal sites and CO_2 emission from fossil fuel-based grid sources are taken into account in the calculations of baseline emissions.

The financial additionality of the project can be justified by conducting an investment analysis using established financial indicators such as the internal rate of return (IRR), net present value (NPV), and payback period. Financial factors to be taken into account include:

- Upfront project development and transaction costs (i.e., PDD preparation, project approval, validation, registration)

- Biogas plant installation costs (i.e., equipments, engineering, labour)
- Maintenance and operation costs (i.e., salaries, taxes, repair)
- Project revenues (i.e., CER sale, power export, bio-slurry sales, power import avoidance savings)
- Loan payments

A project's additionality can be also justified using a formal "barrier analysis" as identified and described in the CDM project design document (PDD). Sisal biogas projects are likely to face barriers as outlined above that would prevent their realization without access to carbon finance. These include technological, financial, institutional, policy, and social barriers generic to biogas projects, but also evidenced from the demonstration and pilot sisal biogas pilot projects in Tanzania.

4.2.3 Global potential for CER from sisal waste

Using the FOD model to calculate CH_4 emissions from sisal waste disposal sites and using UNFCCC approved methodology I.D for calculating grid CO_2 emission, the global CER potential from sisal waste biogas in 2007 would be 491,448tCO_2-equivalent (excluding any credit from N_2O emission avoidance by chemical fertilizer displacement) (Table VII). Since the grid emission factor for every sisal growing country is not easily established, a conservative average estimate of 0.5tCO_2/MWh is used for all countries in calculating the CERs from replacing fossil fuel-based grid sources.

Table VII: Global CER potential from sisal waste biogas in 2007

	Sisal waste disposal site BE (tCO_2-eq)	Grid electricity replacement BE (tCO_2-eq)	Total BE (tCO_2-eq)
Africa	**100,175**	**45,716**	145,891
Tanzania	47,771	21,517	69,288
Kenya	35,709	14,902	50,611
Madagascar	11,789	5306	17,095
South Africa	2044	933	2977
Mozambique	1295	583	1878
Ethiopia	886	408	1294
Angola	681	29	710
L. America	**205,600**	**74,230**	**279,830**
Brazil	146,721	66,066	212,787
Mexico	33,665	15,161	48,826
Venezuela	13,629	6123	19,752
El Salvador	8450	3790	12,240
Haiti	2726	1225	3951
Jamaica	409	175	584
China	**45,318**	**20,409**	**65,727**
Total	**351,093**	**140,355**	**491,448**

4.2.4 Sustainable development impacts

One of the purposes of CDM is to contribute to the sustainable development of the host country, and, indeed, justification of this is one of the key criteria for the approval of any CDM projects by host country authorities. Sisal biogas projects can have many positive impacts on the sustainable development of local economies and communities. These include reduction of groundwater or surface water pollution caused by current waste disposal practices and enhancement of the life standard of rural communities largely dependent on the sisal industry. Sisal biogas CDM projects may contribute to the growth or very survival of the industry itself, thus guaranteeing its benefits to local communities. Social groups most impacted by these projects include sisal harvesters, out-growers, factory workers, and riparian communities. Other potential benefits, which are significant but are dependent on the actual design of the project and the end-use consumption of the biogas, include increased accessibility to energy by local communities and enhanced local food production due to the availability of bio-slurry.

4.3 Sisal biogas CDM project planning

Planning for the implementation and operation of the project will involve carrying out feasibility studies to assess various aspects, mainly economic, technical, managerial, environmental and social. It may also involve identification of the key barriers to the project and strategizing measures to eliminate them. Project developers should differentiate between CDM specific barriers and non-CDM specific barriers. CDM specific barriers are those that relate to CDM project implementation include *inter alia*;

- CDM upfront transaction costs
- Low CER volume
- Risk of rejection of the project
- Non-delivery of CER
- Fall in price of CER

Non-CDM barriers were already mentioned in Table I in Section 1. These sorts of barriers are potential to any conventional biogas projects (i.e., non-CDM projects). Through project barrier analysis the project developers can subsequently decide whether to continue with the project or not especially when it is found that potential barriers cannot be eliminated and that the project cannot be viable. A number of are worthy to assess when planning any sisal biogas CDM project (Table VIII).

Table VIII: Parameters to assess when planning a sisal biogas CDM project

Parameters	Questions to focus
1: Economic	
Sisal biogas production potential	- Is there enough sisal waste? - Is the waste constantly available year round? - Is there appropriate technology for sisal biogas production? - Is the technology locally available? - Is the technology affordable? - Can the technology be maintained locally?
Energy generation potential from sisal biogas	- Is there technology to recover energy from sisal biogas? - Is this technology locally available? - How much energy can be generated? - How can this energy be used? - How can it be distributed/supplied
Bio-slurry production potential	- What is the volume of bio-slurry to be produced? - How can it be stored - How can it be distributed?
Market potential	- Is there demand for energy? - Is there demand for biogas? - Is there demand for bio-slurry? - What is the feed-in-tariff for exported power? - What will be the price for biogas? - What will be the price for bio-slurry?

	- What are the rules for power export to the grid/off-grid?
2: Environment	
Greenhouse gas reduction potential	- Is there potential for GHG emission reduction? - What types of GHG?
Environment management system	- Can the project improve waste management practices? - Can the project worsen waste management practices?
3: Social	- Is the project socially acceptable by the communities? - What are the impacts of the project locally? - What are the impacts of the project nationally?
4: CDM project implementation	
CDM related requirement for the country	- Is there a DNA office in the host country? - Are there clear SD criteria in the host country? - Is there clear legal framework on CER ownership? - Is there clear fiscal policy on taxation/bankability of CER? - Is there reliable accessibility to the key information?
CDM project implementation	- Is there enough capacity to prepare the PDD? - What is the approval process for the country? - What are the requirements for project validation? - What are the requirements for project registration? - How will the CER be transacted?

4.4 Financial aspects for sisal biogas CDM projects

4.4.1 Revenue streams for sisal biogas CDM projects

Sisal biogas CDM projects can generate revenues through a number of means, including the following, of which the first three are further described in this paper.

- Sale of power to the grid
- Sale of CER to potential buyers
- Avoided expenditure (fuel savings) on imported power from the electricity grid
- Sale of biogas to local community
- Sale of fertilizer

The next section gives some theoretical estimates for the global annual value of these benefit streams if all sisal waste were to be valorised to produce biogas.

A. Sale of power to the grid

The feed-in-tariffs (FiT) set by regional/national power utilities for power generated by renewable sources, such as sisal biogas, differ widely between countries and are determined by many technical and policy factors. These include energy and climate policies, the type and additional cost of the renewable technology, and the benefits to the grid of decentralized power production in a particular jurisdiction. Assuming a FiT of USD 0.10 per kWh for the potential power that could be generated by sisal biogas plants worldwide, and assuming that 50% of the generated power would be sold to the grid, then the global monetary value of power from sisal waste in 2007 would be USD 14,035,458 (Table IX). For a typical sisal biogas project, revenues from this component of the project are the most material, accounting for roughly 40 – 50% of the total project income (depending on the FiT).

Table IX: Estimate of annual global income from sisal biogas power exports to the grid (2007 data)

Country	Power (kWh)	Income (USD)
Africa	**45,715,824**	**4,571,582**
Tanzania	21,516,759	2,151,676
Kenya	14,901,700	1,490,170
Madagascar	5,306,301	530,630
South Africa	932,976	93,298
Mozambique	583,110	58,311
Angola	408,177	40,818
Ethiopia	291,555	29,156
Latin America	**74,229,903**	**7,422,990**
Brazil	66,066,363	6,606,636
Mexico	15,160,860	1,516,086
Venezuela	6,122,655	612,266
El Salvador	3,790,215	379,022
Haiti	1,224,531	122,453
Jamaica	174,933	17,493
China	**20,408,850**	**2,040,885**
Total	**140,354,577**	**14,035,458**

B. Sale of CERs

Carbon finance for a typical sisal biogas project may account for as much as 20–25% of total project revenue; the relative share is largely dependent on the contracted price for CERs, which is, among other factors, determined by risks facing the project, such as host country approval, validation, registration, liability of underperformance, and credit vintage (i.e., pre/post-2012). Other factors are project creditworthiness, project viability and local sustainanability benefits. Each CDM project may trade its CER at different prices based on these factors, but we assume a CER price of USD 15. We thus estimate that the global annual value of CERs from sisal biogas CDM projects if implemented in 2007 would be USD 7,371,714 (Table X).

Table X: Estimate of annual monetary value of CERs generated from sisal biogas projects (2007 data)

Country	CER (tCO_2-eq)	Value (USD)
Africa	**145,891**	**2,188,362**
Tanzania	69,288	1,039,316
Kenya	50,611	759,161
Madagascar	17,095	256,430
South Africa	2977	44,655
Mozambique	1878	28,172
Ethiopia	1294	19,413
Angola	710	10,652
L. America	**279,830**	**4,197,449**
Brazil	212,787	3,191,810
Mexico	48,826	732,388
Venezuela	19,752	296,275
El Salvador	12,240	183,603
Haiti	3951	59,258
Jamaica	584	8759
China	**65,727**	**985,903**
Total	**491,448**	**7,371,714**

C. Avoided expenditure (fuel savings) on imported power from the electricity grid

As in the case of FiT, the tariff for power purchased from the grid differs between countries mainly due to factors such as costs of generating and distributing the power, type of fuel used (whether renewable or fossil), whether the power is generated and distributed by the IPPs or public utilities, weather patterns, etc. Assuming a common power tariff of USD 0.11 per kWh of imported power from the grid, and 50% power consumption avoidance by sisal factories, about USD 15,439,003 would have been saved by consuming sisal biogas power (Table XI). For a typical sisal biogas CDM project, the revenue accrued from avoiding power import from the grid may be in the range of 40% of the total project income depending on grid power tariff.

Table XI: Amount of money that could be saved by consuming sisal biogas power in 2007

Country	Power (kWh)	Income (USD)
Africa	**45,715,824**	**5,028,741**
Tanzania	21,516,759	2,366,843
Kenya	14,901,700	1,639,187
Madagascar	5,306,301	583,693
South Africa	932,976	102,627
Mozambique	583,110	64,142
Angola	408,177	44,899
Ethiopia	291,555	32,071
Latin America		
Brazil	**6,606,6363**	**7267,300**
Mexico	15,160,860	1,667,695
Venezuela	6,122,655	673,492
El Salvador	3,790,215	416,924
Haiti	1,224,531	134,698
Jamaica	174,933	19,243
China	**20,408,850**	**2,244,974**
Total	**140,354,577**	**15,439,003**

4.4.2 Incremental costs of sisal biogas CDM projects

Financing sisal biogas CDM projects must cover three main activities: project planning, plant construction and project operation. In these activities two types of costs can be differentiated: CDM-specific and non-CDM specific costs. The former category of costs relate to project development and approvals, and are incurred mainly prior to project operation (with the exception of CER verification and a portion of monitoring costs) while the latter category would relate mainly to biogas plant construction, permits/licences acquisitions, and ongoing operation and maintenance of the plant. These costs would be much greater. Table XII summarizes the "incremental" costs for implementing a biogas project as a CDM activity.

Different sisal biogas CDM projects may have different financial needs depending on the specific design of the project and the ability of the project owners to raise their own capital. Projects that generate and supply energy on/off-grid will be costlier than those that simply flare the biogas. Availability of sisal waste may also determine the project costs, especially when the waste is transported from other sisal factories to the biogas plant at another sisal factory. Further, the costs for a sisal biogas CDM project can vary depending on the type of technology employed, the number of feasibility studies to be carried out, country's regulations on investment and the extent of EIA process.

Table XII: CDM project transaction costs

Activity	Small Scale	Large Scale	Cost type
CDM feasibility	2,000-8,000	5,000-30,000	Consultancy
PDD	10,000-25,000	15,000-30,000	Consultancy
Verification	5,000-25,000	5,000-10,000	Auditor fee
Project validation	7,500- 10,000	8,000-30,000	Auditor fee
Project registration/ ongoing share of proceeds*	0-25,000	10,500-350,000	UN fee (admin.)
Adaptation fund fee *	2% of CERs	2% of CERs	UN fee

*Note: Least developed countries such as Tanzania and Madagascar are exempt from the 2% adaptation fund fee and upfront registration fees; projects in other locations with average emission reductions of 15ktCO_2/year furthermore do not pay registration fees.

Source (see reference 16)

The following general conclusion can be made (while acknowledging the fact that the specific design of the project remains the key determining factor) concerning the incremental costs of any sisal biogas CDM projects:

- CDM-specific costs are small compared to non-CDM specific costs,
- The largest project cost is incurred during the construction of the biogas plant and installation of the monitoring equipment, and
- Annual operational and CDM running costs are low compared to construction costs, although they may exceed those costs over the project lifetime.

4.4.3 Types of finance for sisal waste CDM project

Sisal factories themselves through their subsidiary companies established to administer biogas/energy issues would be expected to finance a large share of planning activities as it is in most cases difficult to source external funding for these upfront costs which are at risk. Equity or grants are appropriate at this stage as these do not have to be repaid even if the projects fail.

Table XIII: Financing the planning activities for sisal biogas CDM projects

Source	Mode of financing
Government tenders and carbon funds	Partly cover the costs in return for a contract to purchase some/all of the CER
Private sector CDM project developers	Partly cover the costs in return for a contract to purchase some/all of the resulting CER.
Project owners	Sisal companies using internal funds to develop the projects.
International/Local organizations	Partly cover the costs with no intention of purchasing/owning the CER.

Finance to cover the construction activities for the sisal biogas plants can be secured from a number of sources, and can be in the form of debt, equity, credits, or a combination of these (Table XIV). Revenues from the project can be used to cover the project operation costs.

Table XIV: Financing the construction activities for sisal biogas CDM projects

Source	Mode of financing
Creditors	Debt to be repaid at an agreed interest rate and time.
Private sector CDM project developers	Own equity to finance the projects but with share from the profit.
Project owners	Own finance by sisal companies, likely for small scale sisal biogas CDM projects.
Equipment distributors	Provision of assets on lease or credit
CER buyers	Payment on delivery or for a portion of advance CERs prior to project start

The following general summary can be drawn regarding financing the construction and operation activities of any sisal biogas CDM project.

- Costs to cover planning activities can be financed by equity and grants,
- Costs for construction of the biogas plants can be covered by equity, debts and credits
- Project operation costs can be covered by the project revenues.

4.4.4 Institutional arrangement for sisal biogas CDM projects

Sisal companies are neither accustomed to energy nor CDM business activities. Therefore, new institutions or subsidiaries may need to be established by these companies to administer such activities, depending on the ultimate aim and the design of the projects. An energy company can be established as a subsidiary entity, which can also include a CER generation business or a new subsidiary company can be formed for this purpose.

The formation of national associations may further be desirable to represent various sisal companies that own or operate biogas plants. These may have a role of representing the needs of the industry with respect to determining or renegotiating FiT, CER ownership and taxation treatment, etc.

5 CASE STUDIES

Two sisal biogas projects under development in Tanzania are analysed to evaluate the potential role of CDM in scaling-up the technology. The proposed projects are designed to establish the technological and economic viability of the production of biogas, power and bio-slurry from sisal waste. They are the first projects using sisal waste as feedstock in biogas production seeking CDM approval. The baselines for both projects are the avoidance of CH_4 emissions from sisal waste disposal sites and the reduction of CO_2 emissions from the fossil fuel-based grid sources.

The projects are expected to contribute to the improvement of the competitiveness of the sisal industry by creating alternative sources of revenue and thus reducing dependency on fibre's income. These two projects have been receiving technical support from the UNEP Risoe Center (URC), especially in developing PINs and PDDs under a CDM capacity building project being implemented in the country. Note that the financial analysis and investment costs are indicative and stylized for research purposes.

A: KATANI sisal biogas CDM project

This bundled CDM project is being implemented in Tanga region, Tanzania involving five sisal estates/factrories: Hale, Magunga, Magoma, Mwelya and Ngombezi. Since the first sisal biogas plant in the world is located at Hale Sisal Estate, the aim is to scale-up this pilot plant to the other sisal estates all owned by KATANI Plantation Limited, and at the Hale site itself. A subsidiary company called Mkonge Energy System Co. Ltd was established in 2008 to administer both the proposed biogas plants and the CDM project. Several developers have shown interest in investing in the project.

Photo 3: Hale Sisal Biogas Plant

Table XV: Description of key parameters for KATANI sisal biogas CDM project

Parameter	Value
Waste production	341,640tons/yr
Biogas production	18,448,560cum/yr
Power generation	34,314,322kWh/yr
CHP installed capacity	4MW
Project emission	0tCO_2-equiv/yr
Average CER	40,439tCO_2-equiv/yr
CDM status	PDD development
Crediting period	10 years (2010-2020)
Grid emission factor	0.5tCO_2/MWh

Table XVI: Financial analysis for KATANI sisal biogas CDM project

Parameter	Value
Investment cost	12,000,000USD
Revenue from CER	606,585USD/yr
Revenue from power export	1,715,716USD/yr
Revenue from power import avoidance	1,887,288USD/yr
Total revenue	4,209,589USD/yr
NPV/IRR without CER income	306,046USD/9%
NPV/IRR with CER income	2,647,064USD/16%
Payback (Without CER/With CER)	5.0 years/4.0 years

Assumptions: Interest rate-10%; Project finance-Equity by project owner; Investment costs-Based on costs for the Hale Sisal Biogas Project (i.e., plant and machinery, personnel, grid connection, buildings, O & M costs = 3000,000 USD/MW); CDM-related costs-UNFCCC; Corporate tax-30%; CER price 15USD/tCO_2-equiv; FiT 0.10USD/kWh; Power tariff 0.11USD/kWh

B: SAGERA sisal biogas CDM project

This bundled CDM project is being implemented at Kwaraguru, Kwamdulu and Lugongo Sisal Estates all located in Tanga region, Tanzania. The project is owned by SAGERA Estates Limited. No financier has shown interest in investing in this project to date.

Photo 4: Sisal waste disposal at SAGERA Sisal Estate

Table XVII: Description of key parameters for SAGERA sisal biogas CDM project

Parameter	Value
Waste production	131,482tons/yr
Biogas production	7,100,043cum/yr
Power generation	13,206,081kWh/yr
CHP installed capacity	1.5MW
Project emission	131tCO_2-equiv/yr
Average CER	31,329tCO-equiv/yr
CDM status	PDD development
Crediting period	7-year (2010-2016)
Grid emission factor	0.5tCO_2/MWh

Table XVIII: Financial analysis for SAGERA sisal biogas CDM project

Parameter	Value
Total investment cost	4,500,000USD
Revenue from CER	469,935USD/yr
Revenue from power export	660,304USD/yr
Revenue from power import avoidance	726,335USD/yr
Total revenue	1,856,574USD/yr
NPV/IRR without CER income	1,180,197USD/16%
NPV/IRR with CER income	4,067,744USD/28%
Payback (Without CER/With CER)	4.9 years/3.2 years

Assumptions: Interest rate-10%; Project finance-Equity by project owner; Investment costs-Based on costs for the Hale Sisal Biogas Project (i.e., plant and machinery, personnel, grid connection, buildings, O & M costs = 3000,000 USD/MW); CDM-related costs-UNFCCC; Corporate tax-30%; CER price 15USD/tCO_2-equiv; FiT 0.10USD/kWh; Power tariff 0.11USD/kWh

Case studies summary

- Projects are more attractive financially when implemented as CDM as indicated by the financial analyses. As CDM enhances the project's financial viability, so too can it also potentially reduce technological barriers; more capital can be spent on identifying cost-effective options and CDM can help attract a unique set of project partners to reduce risks.
- Investment costs increase with capacity of the biogas plant and CHP system. The larger the size of the biogas plant, the greater the potential for CDM, as more CERs can be generated for a relatively constant level of transaction cost, and more power can be sold to the grid, thus enhancing the bankability of the project. Conversely, the relative impact of carbon finance on overall project economics is inversely related to the size of the project.
- The contribution of the carbon credits will also depend highly on the type of contract entered into with the buyer. In the event of advance payments or transaction costs sharing on the part of the carbon buyer, the relative increase in profitability with CDM will also increase.
- Both projects have sustainable development impacts on local community such as eliminating groundwater/surface water pollution, increasing access to power, job creation in constructing and managing the biogas plants/CDM projects, increase in agricultural yield due to the use of bio-slurry and reduce expenditure on power import by the sisal companies therefore saving money that could be used to improve employees' salaries and other amenities.

6 CONCLUSION AND RECOMMENDATIONS

There is relatively large potential for biogas production from the sisal waste worldwide using AD technology. Leading sisal producers like Brazil, China, Tanzania, Kenya and Mexico have more potential than smaller producers like Venezuela, South Africa, El Salvador, Ethiopia, Angola, Madagascar, Mozambique, Haiti and Jamaica. However, due to various barriers facing biogas technology in developing countries (i.e., technological, financial, social, institutional and operational barriers), this potential can hardly be tapped. To date there is only one sisal biogas plant worldwide, being implemented as a demonstration plant at Hale Sisal Estate in Tanga, Tanzania. Results from the case studies in Tanzania show that there is a promising future for sisal biogas technology, especially if sisal production is increased to guarantee adequate availability of waste. For both KATANI and SAGERA sisal biogas projects, the financial analyses show that the viability of the projects can be significantly enhanced when carbon revenue is added. Using data from 2007, we estimate that the global annual potential for GHG mitigation from sisal biogas is 491,448tCO_2-equivalent. If all of these emission reductions were realized through a CDM approach, the approximate annual value of the CERs generated would be 7,371,714USD. This incremental value would of course be additional to annual revenues from power export to the grid and savings linked to power import avoidance, which are estimated at USD 14,035,458 and USD 15,439,003 respectively.

The following recommendations can be considered in promoting sisal biogas technology through CDM project activities:

- *Sectoral approach*: Small scale sisal biogas CDM projects offer an exciting opportunity to demonstrate the role of sectoral approaches in financing GHG reduction projects. Sisal biogas CDM projects could be developed using a sectoral approach in order to overcome the financing, technological and other barriers faced by CDM projects implemented on an ad-hoc, project-by-project basis. A sectoral policy based approach is a government-driven mechanism that allows developing countries to set policy and programs that lower GHG emissions in a specific sector. The carbon savings will be compensated directly to the host government by an investor. The government may then pass on these benefits to the relevant sectors affected by the measures in the form of tax incentives, subsidies, concessional finance, etc. These approaches provide an innovative tool for government to finance climate friendly policy measures.
- *Debt measures to finance capital costs*: Access to concessionary debt finance (i.e. loans at interest lower than market interest or with longer debt terms or grace periods) that aligns with the technical lifetime of projects is crucial. The government may implement policies and investment incentives that address the lending assessment concerns of local banks. This can significantly reduce project costs and implementation risks, by creating market conditions and designing support schemes that result in debt terms that closely match technical realities.
- *Feed-in tariff (FiT):* the most important element of FiT scheme is that it fully removes the market risks of a project during a fixed period of time. The longer this period of guaranteed prices, the lower the cost of capital. For a typical sisal biogas CDM project a timeframe of 10 to 20 years is preferred.
- *Gaining experience from pilot sisal biogas plant*: Project developers and investors may take advantage of the pilot sisal biogas plant implemented in Tanzania in gaining experience to implement the technology in other

areas. The pilot plant can serve as training centre for demonstrating the benefits of sisal biogas technology.

- *Increased efforts to promote CDM investments*: CDM project design and approval processes are complex; therefore improving the capacity of local industry in identifying and developing the best project sites within the sector is necessary.

Further Work

- *Research on sisal biogas technology*: Due to the fact that sisal biogas technology is new, more efforts must be placed on research and development on it, special focus should be placed on improving the better use of waste by speeding up its digestibility process to reduce digester retention time and thus increasing biogas production, reducing sizes of digesters and other tanks for space and costs saving purposes and on increasing use of local materials in constructing the biogas plants to reduce capital costs. It is also important to ensure that technicians and managers are available locally.
- *Agriculture strategies to promote sisal production*: For effective application of biogas technology, sisal waste must be available adequately and reliably. This can be fulfilled by increasing sisal plantation by, for example, reviving old sisal farms and promoting the involvement of out-growers.
- *Alternative uses of the produced biogas and energy*: There is a need to diversify the uses of the produced biogas/energy to widen up the market margin for sisal biogas projects and thus attract investors. Several options can be considered in this respect such as use of biogas as fuel in vehicles and tractors, compressing biogas for domestic uses, piping the biogas for domestic and industrial uses, increase the use of the recovered heat and enhancing local grid power supply.

REFERENCES

[1] S. Shamte, Overview of the Sisal and Henequen Industry, A producers' Perspective In: Common Fund for Commodities, Alternative Application for Sisal and Henequen - Technical paper No. 14, (2001).

[2] J.H.H. Yapp and A. Rijk, CDM Potential for the Commercialization of Integrated Biogas System In: 'Proceedings of the International Biogas Technology for Poverty Reduction and Sustainable Development' 18 to 20 October 2005, Beijing, Sponsored by UN-Asia Pacific Centre for Agricultural Engineering and Machinery and Centre for Environmental Engineering and Protection, China.

[3] National Non-Food Crops Centre, Sisal, (2009), http://www.nnfcc.co.uk/metadot/index.pl?id=2434;isa=DBRow;op=show;dbview_id=2329 (accessed 25 May 2009).

[4] FAO, Statistical Bulletin Jute, Kenaf, Sisal, Abaca, Coir and Allied, (2008), Fibres.http://www.nnfcc.co.uk/metadot/index.pl?id=2434;isa=DBRow;op=show;dbview_id=2329, (accesses 26 May 2008).

[5] P. McDonald, N. Henderson and S. Heron, The Biochemistry of Silage (2nd ed), (1991), pag 26.

[6] UNFCCC, 2006, Methodological tool "Tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site", (tool can be accessed at: http://cdm.unfccc.int/methodologies/PAmethodologies/approved.html

[7] A. Mshandete and W. Parawira, Biogas, Technology research in selected sub-Saharan African countries, A review, African Journal of Biotechnology Vol. 8 (2) (2009), pag 54-66.

[8] A. Mshandete, A. Kivaisi, M. Rubindamagusi and B. Matthiasson, Anaerobic Batch Co-digestion of Sisal Waste Pulp and Fish Waste, (2008), pag 6.

[9] Nijaguna, B.T, Biogas Technology, (2002), pag 20-49

[10] A. Mshandete, L. Björnsson, A.K. Kivaisi, S. T Rubindamayugi and B. Mattiasson, (2005), Enhancement of anaerobic batch digestion of sisal pulp waste by mesophilic aerobic pre-treatment, pag 6.

[11] R. Sleat and R. Mah, Hydrolytic Bacteria In: Anaerobic digestion of biomass, (2006), pag 16.

[12] E. Malavolta, *Agave sisalana*, Nutrients Composition and Fertilizer Values, Universidade de Sao Paulo, Piracicaba, Brazil, (2007).

[13] UNIDO and Common Fund for Commodities (2004), Product and market development of sisal and henequen, Project Completion Report, Addendum B.3, Bio-energy from Sisal Waste, 1997 - 2004

[14] UNFCCC, About CDM, (2009), http://cdm.unfccc.int/about/index.html (accessed 31 May 2009)

[15] IPCC, (2006), National Guideline for National Greenhouse Gas Inventories: Volume 5, Waste, pag 66.

[16] UNEP and ECOSECURITIES, Guidebook to Financing CDM Projects, UNEP Project CD4CDM, (2007), pag 52.