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Assessment of Identified Agro-industries in Tanzania
Technical Report

MOHAMMED ENTERPRISES LTD.

15.02.2016

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1 Waste-to-Energy potential

In the course of the local assessment five sites of four companies in Tanzania Mohammed Enterprise Ltd. were analysed. The main type of waste, Sisal processing waste, was identified and its potential to generate energy (*Waste-to-Energy*) was determined.

The assessment of the biogas potential was done based on the available substrate qualities and quantities. A summary of the assessment results of Mohammed Enterprise Ltd. regarding potential electricity capacity based at 7,000 operating hours per year are given in Table 1: Waste-to-Energy potential of Mohammed Enterprise Ltd.

Table 1: Waste-to-Energy potential of Mohammed Enterprise Ltd.

Company	**Substrate Source**	**No. of plants**	**Total capacity [kW]**	**Biogas uage**
Mohammed Enterprise Ltd. (MeTL)	Sisal processing waste	5	2,210-2,510	Own Usage Feed-in of Excess

All five assessed Sisal processing sites have a comparable size. The processing of the plants works similar on each site. The main difference is the capacity and operating time of the decortication machines which separate the fibres from the pulp. The *homogeneous characteristics* of the Sisal fibre production process are advantageous A summary of the information determined in the course of the local assessment for each individual site is shown in Table 2.

Table 2: Summary Mohammed Enterprise Ltd. (MeTL)

		Mazinde				
		Mazinde	**Maboga**	**Mjesani**	**Hassani**	**Hussani**
Planted Sisal Area	[ha]	2,910	1,940	1,235	2,170	2,100
Processed Sisal Leaves	[m^3/year]	36,000	24,000	28,000	30,000	44,000
Produced Dry Fibre	[t/year]	980	650	600	800	900
Installed back-up diesel GenSet	[kW]	290	450	180	180	180
Investment Costs incl. CHPP	[US$]	2,578,000-2,801,800	2,111,000-2,226,300	2,209,400-2,113,500	2,291,800-2,458,000	2,883,600-2,654,400
Running Costs incl. CHPP	[US$/year]	189,200-220,000	126,100-146,600	145,500-134,600	156,300-180,400	226,400-201,100
Potential power generation	[GWh/year]	3.6-4.2	2.4-2.8	2.6-2.8	3-3.4	3.8-4.3

Potential capacity	**[kW]**	**520-600**	**345-400**	**370-400**	**430-490**	**550-620**
CO_2 Avoidance	[Kt/year]	1.9-2.2	1.3-1.5	1.4-1.5	1.6-1.8	2-2.3
Simple ROI $_{CSTR}$	[%]	14-15	13-14	14	14-15	15
Simple Payback $_{CSTR}$	[years]	6.5-7	7-7.5	7	6.5-7	6.5

1.1 Electric Energy

The potential energy capacity on ranges between *345-620 kW* per site. Using the substrates in the most efficient way, altogether *2,215-2,510 kW* can be installed at Mohammed Enterprise Ltd. Less than *10%* of the produced electricity is needed to cover the *own-consumption*, to substitute current electricity demand, diesel demand or other energy sources such as wood. The rest of the produced electricity is fed into TANESCO national grid of Tanzania using *the Standardized Small Power Projects Tariff for Biomass power plants 200 kW – 1 MW*. The CO_2 emission reduction of each side ranges from 1,270-2,290 tons per year with a total of *8,200-9,300 tons per year*. With an assumed lifetime of 15 years of the biogas plants, the *total reduction* would add up to *123,000-139,000 tons* CO_2*.*

Using the *feed-in tariff is currently economical more feasible* than substitution of own electricity demand – with the exception of substituting diesel used in the back-up GenSets. Nevertheless own production of electricity has several additional advantages for the agro-industry operators, such as low standstill time due to black-out protection and *planning security* due to independency from market electricity prices. The change of the *feed-in tariff is a critical factor* for feasible biogas production in Tanzania.

1.2 Financial Analysis

A financial analysis was carried out based on the baseline biogas technology the "Continuous-Stirred-Tank-Reactor" (CSTR) (See Chapter 2.1.1 Biogas Technologies). *Simple Payback* for the assessed plants varies from *6.5-7.5 years*. The resulting *Return-of-Invest* is calculated with *13-15%*. To lower investment costs and thus enhance the economic feasibility of the planned biogas plants, further technologies are suggested in this report, such as usage of combinations of CHCR with UASB or the usage of Covered Lagoons. After a first analysis and discussion with biogas plant constructors it is expected that the *combination of CHCR with a low tech UASB* and the *Concrete Covered Lagoon* have a simple payback time *lower than 6 years* with a *Return-of-Invests over 20%.*

Before the installation of biogas plants it is of importance to perform a *Dynamic Amortisation (Payback)* and *Return of Investment* calculation dependent from the local used money (equity or loan), interests and inflation. Also the specific production costs per kWh_{el} should be calculated using the *Annuity method*. According to the (Worldbank, 2016), *the lending interest rate was 16.3%* with an *inflation of 4.7%* at the end of *2014* – the average lending interest rate for 2015 was not published at time of finalisation of this report. With the resulting *real interest rate of 11.7%*, economic feasibility using loans will be difficult.

Lowering the osts would help to increase the feasibility of the plants. One way would be to provide the needed process heat through more cost effective systems such as thermal solar power instead of the CHPP. The *engine without heat usag*e has considerable lower investment costs. If using a CHPP to provide process heat of the biogas plant, further options of usage such as *usage for Sisal fibre drying* should be considered.

1.3 Biogas Technology

In the current production process of Sisal fibre large amounts of water is used for the washing of the fibre. The washing water can be separated from the Sisal processing waste water for technologies such as the *CSTR with high dry matter (12% DM)*, or used together for technologies such as a *Covered Lagoon with low dry matter (6% DM)*. Both waste water streams can be separately used by combining biogas technologies such as *CSTR with UASB* reactor. It is important to *remove all fibres* before feed into the fermenter to avoid sinking and floating layers as well as problems with the pumps.

Only few experiences with the usage of waste water from Sisal production exist for all both technologies. Setting up a demonstration site to prove technical, economic and ecological advantages of the biogas technology is expected to *trigger the market and facilitate replication*. A detailed monitoring of the first biogas plants will be most important for early and fast problem identification and solution.

After biogas production the processed *digestate can be used as fertilizer* at the Sisal fields. Currently no return of nutrients to the fields is taken place. This could enhance the soil quality and lead to a higher yield.

A special case is Maboga Sisal processing which is part of the Mazinde Sisal Group of Estates from MeTL. In this process, natural *salty ground water is used for washing the fibres*. The salt water could have negative impacts on the biogas production and biogas yield, thus the washing water should be separated from the pulp before fed into the biogas plant.

1.4 Utilized Technical Equipment and Machines

Due to lack of local production the utilized *biogas technology has to be imported*. To identify the import conditions and customs will be essential to guarantee a successful project implementation. It also has to be considered that for the installation international experts are needed. The operation and maintenance of the biogas plant will assume *intense local capacity building*. For replication and scale-up a *local production* of biogas technologies or parts of the technology with local service providers will enhance the economic feasibility.

Real scale production of the biogas plant will depend from the used technology, the precision of installation and the local know-how in operating the biogas plants.

2 Biogas production and utilization

Biogas is derived in the course of the fermentation of any type of biomass, for example from biogenic waste such as manure, garbage, sewage sludge, bio-waste, food wastes and plant residues. Under anaerobic conditions i.e. the exclusion of oxygen, the microorganisms involved in the degradation process produce a gas mixture, the biogas, which contains an average of 60% methane depending on the raw materials used.

2.1 Biogas production

Figure 1: Continuous Stirred Tank Reactor (CSTR)

2.1.1 Biogas Technologies

Continuous Stirred Tank Reactor (CSTR)

The state-of-the-art Continuous Stirred Tank Reactor (CSTR) can use various input materials and is used as baseline for the calculation in this report. CSTR are especially effective for wet fermentation with a DM-content up to 15-20%.

Table 3: Investment and running costs of CSTR

Investment Costs – CSTR incl. CHPP		
150 kW	[US$/kWel]	7,000[1]
250 kW	[US$/kWel]	6,500[2]
500 kW	[US$/kWel]	5,000[3]
750 kW	[US$/kWel]	4,350[4]
1,000 kW	[US$/kWel]	3,800[5]
Running Costs – CSTR incl. CHPP	[US$/kWel]	370

[1] (KTBL, 2013)
[2] (KTBL, 2013)
[3] (KTBL, 2013)
[4] (KTBL, 2013)
[5] (KTBL, 2013)

Up Flow Anaerobic Sludge Blanket (UASB) Reactor

The UASB reactor was originally designed for waste water treatment and can be used for substrates with low DM content. The advantage of this system is the low hydraulic retention time and thus low fermenter volume.

Indicative CAPEX for 500 kW	[US$/kWel]	5,500

Covered Lagoon

The covered lagoon is a very low cost option for treatment of easy degradable substrates such as manure. It is built horizontal in the ground. For more difficult substrates a high tech covered lagoon exists on the market build out of concrete and including agitation systems.

Indicative CAPEX for low-tech (no stirring, no heating) with 500kW	[US$/kWel]	2,500
Indicative CAPES for high-tech (concrete walls, stirring and heating) with 500 kW	[US$/kWel]	3,200

Plug-flow fermenter

Plug-flow fermenters are built for higher DM content such as CSTR. It is built horizontal. Plug-Flow have the advantage that the four phases of biogas production (i.e. hydrolysis, acidogenesis, acetogenesis and methanogenesis) are strictly separated and thus a very high degree of degradation can be achieved.

Indicative CAPEX for 500 kW	[US$/kWel]	5,500

Combined Hybrid Concentrator Reactor (CHCR) together with an UASB Rector

In the CHCR solid and liquid waste streams can be treated. The pre-digested waste is pumped to a second process step, a low-tech UASB reactor for after treatment. With this combination fermenter volume and thus costs can be saved.

Indicative CAPEX for 500 kW	[US$/kWel]	3,000[6]

Due to missing local production and suppliers of biogas technology, all equipment has to be imported to Tanzania. For the installation it will be necessary to import Know-how in the form of technicians of the biogas plant suppliers for the local implementation of the biogas plant. These costs have to be added to the ones above.

[6] (KTBL, 2013)

2.1.2 Production Costs of Electric Energy

The Gesellschaft für Technische Zusammenarbeit (GTZ) carried out a study about the usage of agro-industrial wastes in Kenya. Within this study, the GTZ calculated the specific production costs of one kWh_{el} for CSTR and UASB reactor. Results of the local assessment can be compared to the figures given in Table 4.

Table 4: Specific electricity production costs from biogas in Kenya

Description	Unit	Value
CSTR Reactor – 250 kW el	[US$ ct/kWh_{el}]	7.58 – 15.24[7]
UASB Reactor – 250 kW el	[US$ ct/kWh_{el}]	7.74 – 18.90[8]

2.1.3 Feed-in Tariffs

Tanzanian government installed a standardized small power projects tariff, which is a feed-in tariff especially for small power projects in the range of 200 kW to 1 MW. There is a specific tariff for biomass projects, which is given in Table 5. In a rough comparison of electricity production costs to feed-in tariff, it can be seen that biogas production and electricity production from biogas shall be feasible under current market conditions.

Table 5: TANESCO Standardized Small Power Projects Tariff for Biomass power plants 200 kW – 1 MW

Size of the power plant	Unit	Value
200 kW	[US$ ct/kWh_{el}]	17.90
300 kW	[US$ ct/kWh_{el}]	16.90
400 kW	[US$ ct/kWh_{el}]	16.10
500 kW	[US$ ct/kWh_{el}]	15.70
750 kW	[US$ ct/kWh_{el}]	14.90
1 MW	[US$ ct/kWh_{el}]	14.70

[7] (GTZ, 2010)
[8] (GTZ, 2010)

2.2 Biogas usage

Biogas is an energy carrier which can be used to produce heat or electricity. If upgraded to biomethane, which is equally to natural gas, it can be filled in CNG cylinders and used as vehicle fuel or to substitute natural gas in any use cases.

2.2.1 Electricity conversion

Electricity production from biogas is normally performed? using a Central Heat and Power Plant (CHPP) where electricity is produced and the waste heat is used to provide heated water for example for heating the fermenter. Excess heat can be used to substitute process water or for drying of agro-industrial (by-) products. Average CHPP data for used for the calculation are given in Table 6.

Table 6: Assumptions electricity potential

Description	Unit	Value
Methane energy content	[kWh/m^3]	9.97[9]
CHPP electric efficiency	[% of input]	35[10]
CHPP heat efficiency	[% of input]	44.5[11]
Operating hours	[hours per year]	7,000[12]

2.2.2 Biogas upgrading

After upgrading of biogas to biomethane, it possesses an equal quality / chemical composition to natural gas. There are different state-of-the-art technologies for biogas upgrading such as Pressure Swing Adsorption (PSA); Pressure Water Scrubbing (PWS); Membrane, Amine, Cryogenic upgrading.

For the assessed Tanzanian agro-industries, the most important reason to install biogas plant is the independent production of electricity. Currently, black-outs happen several times every day (depending from season and location). This leads to a high demand of diesel to supply the back-up generators. The constant stop-and-go has also negative impacts on the lifetime of used machines and maintenance costs. Stand still time causes expensive overtimes of employees or lower production.

Under these circumstances, the conversion of the obtained biogas to electricity should be the preferred usage. Another option could be the upgrade of the excess biogas to natural gas and the usage as vehicle fuel for

[9] (KTBL, 2013)
[10] (KTBL, 2013)
[11] (KTBL, 2013)
[12] (KTBL, 2013)

agricultural machineries of the agro-industries or private cars of their employees. The evaluation of this option is not a part of the current study.

Table 7: Financial framework in Tanzania

Description	**Unit**	**Value**
Exchange Rate $_{TZA-US\$}$	[Relation]	2000:1
Interest Rate Tanzania $_{2014}$	[%]	16.3[13]
Inflation Tanzania $_{2014}$	[%]	4.7[14]
Tanzania CO_2 grid-emission factor	[t CO_2/kWh]	0.529[15]

[13] (Worldbank, 2016)
[14] (Worldbank, 2016)
[15] CAMCO 2014

3 Sisal processing waste potential

The Sisal sub-sector is one of the oldest agricultural industries in Tanzania. Sisal (Agave Sisalana) was introduced from Mexico and since then, the industry grew and became the most extensive commercial agriculture and primary processing industry in East and Central Africa[16].

The growth rate of Sisal differs by species, climatic conditions and cultivation. According to the Tanzania Sisal Broad and mentioned in the tables below, there are predominantly two species, Algave Sisalana and Hybrid 11648, grown in Tanzania. Sisal can be harvested annually from year three till eight or eleven. To ensure continuous yields, crop rotation systems are applied[17].

The leaves grow in circles around the bole of the plant and farmers harvest four or five circles once a year, depending on soil and climate conditions. Each circle consists of about 13 leaves. Harvests can take place throughout the year, so the farmers can supply the decorticating estates with continuous amounts of leaves[18].

3.1 Decortication process

The decortications units (or Coronas) separate the fibre from the parenchyma with beater knives. Considerable amounts of power and water is needed. The water consumption lies between 36,000-45,000 litres per hour mainly from washing the fibre to reduce the organic impurities from the fibre. Most of the decortication units are over 60 years old and inefficient in terms of power and water consumption as well as maintenance. In the next step the extracted fibres is dried in the sun for 3 to 5 days, depending to the weather conditions. After that, it is brushed, graded and pressed into bales of 250 kg. Afterwards, the fibres are used to produce twine, doormats, car mats or reinforce materials and others.[19].

Figure 2: Sisal decortication unit at Hussani

[16] (FAO, 2013)
[17] (FAO, 2013)
[18] (Franck, 2005)
[19] (FAO, 2013)

3.2 Calculation method for biogas potential

During processing the mass of the Sisal leave is separated in

- 4% wet long fibre (2% dried fibre)
- 15% wet short fibre “flunto”
- 81% waste water

The first method for calculating the biogas potential was based on the “meters” of *processed leaves*. The second method for calculating the biogas potential was based on the amount of produced *dried fibre.* The current appearance of diluted Sisal waste water is illustrated Figure 3.

Figure 3: Sisal waste water diluted

- Waste potential from *processed leaves*

After being harvested, the leaves were processed at the Sisal estates. According to the production manager, one leave has 0.3 to 0.4 kg. The leaves were collected in “bondles”, each contains 30 leaves. 110 “bondles” make one “metre”. A “metre” consists of one cubic metre of leaves (Figure 4: Harvesting Sisal leaves[20]). Due to the length of the leaves one “metre” has 1.16 ton. Thus an important production parameter is the “metres” of processed leaves per day.

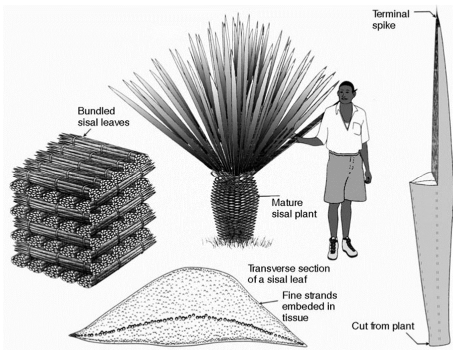

Figure 4: Harvesting Sisal leaves

- Waste potential from *dried fibre*

The product itself, the dried fibre counts only 2 percent of the whole Sisal plant. Thus many publications promote 98% waste per processed raw material for biogas production. However, immediately after the decortication process, the wet fibre makes up 4% of the whole plant. Additionally, there is still 15% short fibre left in the waste. This short rest-fibre is called “flunto” or “flume” and can hardly degrade during the biogas process without pre-treatment.

[20] (Jarman, 1998)

Figure 5: Drying of Sisal fibers at Hassani

In Table 8 the properties for waste characterisation and biogas production from Sisal are summarised. For more transparent presentation the dry matter content and the biomethane potentials were separated into two groups, "diluted" (Sisal waste with washing water) and "undiluted" (Sisal waste without washing water)".

Table 8: Characterisation of Sisal leaves and waste

Description	Unit	Value
Weight of Sisal leaves	[t/m^3]	1,155
Dry Fibre	[% of processed leaves]	2
Wet Fibre	[% of processed leaves]	4
Flunto (i.e. short fibers)	[% of processed leaves]	15
Waste for biogas production	[% of processed leaves]	81
Dry Matter - undiluted[21]	[% of waste water]	12
Washing Water for dilution	[% of waste water]	100
Dry Matter Content – diluted[22]	[% of waste water]	6
Organic Dry Matter (Volatile Solids)[23]	[% of Dry Matter]	85
Methane content in biogas	[%]	60
Biomethane Potential[24]	[m^3/t VS]	330
Security Factor	[%]	10
Biomethane potential – undiluted	**[m^3/t waste water]**	**30.3**
Biomethane potential – diluted	**[m^3/t waste water]**	**15.1**

[21] (GTZ, 2010)
[22] (GTZ, 2010)
[23] (GTZ, 2010)
[24] (GTZ, 2010)

Figure 6 shows a sample of dried wet waste. It is visible that the waste is partly consisting of Sisal pulp and Sisal small fibres which currently have no use case. . As mentioned before in this text the rest-fibre is difficult to degrade. Thus, it may (oder could) cause blockages in the biogas plant. Therefore, a separation of the fibres will be necessary before using the Sisal wet waste as feed in the biogas fermenters.

Figure 6: Sisal dried wet waste

For removing the rest-fibres (flunto), a screw squeezer with a drum was developed as illustrated in Figure 7. This machine can be installed right after the decortication unit.

4 Detailed description of Mohammed Enterprise Ltd. (MeTL)

Mohammed Enterprises Limited (MeTL) Group is leading economic force in Tanzania with major investments and successful operating companies in all key business sectors. The Group employs more than 20,000 people across the country and has diverse interests in trading, agriculture, manufacturing, energy and petroleum, financial services, mobile telephony, infrastructure and real state, transport and logistics and distribution.

MeTL is a major player in the countries commercial agricultural sector, contributing further to national development. MeTL has invested in acquiring a total of 47,000 hectares of dilapidated Sisal farms and tea estates in different regions of Tanzania and has successfully revived these farms into active, commercial agriculture centres. Essential infrastructure such as staff housing, labour camps, access roads, schooling and dispensary facilities have been established on all their farms. Other requirements such as utility vehicles and farming equipment are regularly replayed on each farm. Their agricultural development activity provides employment for more than 5,000 people during the peak season and MeTL endeavour to impart skills through own experts in the field to improve the knowledge of labour force. Currently MeTL primarily cultivates Sisal and tea as major crops.

4.1 Site 1: Mazinde

Figure 8: Mazinde Sisal Group of Estates

4.1.1 Mazinde Sisal processing

Mazinde Sisal processing is part of the Mazinde Sisal Group of Estates owned by Mohammed Enterprise Ltd. The planted Sisal area of Mazinde Estate covers 9,418 ha. This Estate includes Maboga which means that the planted Sisal were processed at both locations.

36,500 m^3 of Sisal leaves are processed every year with a total yearly production of 980 t of quality dry Sisal fibers.

Mazinde estate is connected to the main grid of TANESCO. The decortication units are mainly operated while running using TANESCO electricity. For times of black-outs, a 290 kW diesel back-up generator set is installed.

A summary of the Mazinde site description is given in Table 9.

Table 9: Mazinde site description

Description	Unit	Value
Site total area	[ha]	9,418
Site planted area	[ha]	4,855
Processed leaves	[m^3/year]	36,500
Produced dry fibre	[t/year]	980
Current electricity supply		Connected to TANESCO main grid
Installed Diesel Back-up GenSet	[kW]	290 kW

Technical Assessment

The technical assessment was done during a local audit where all the key operating figures such as processed leaves per day and produced fibre per day were evaluated. A summary of selected parameters is given in Table 10.

Table 10: Mazinde potential electric capacity

Calculation using:		processed leaves	produced dry fibre
		36,500 m^3/ year	980 t / year
Waste water for biogas production – undiluted	[t / year]	34,200	39,700
Waste water for biogas production – diluted	[t / year]	68,300	79,400
Biomethane potential	[m^3 / year]	1,034,600	1,202,900
Electric potential	[kWh/year]	3,610,200	4,197,400
Electric capacity	[kW]	520	600
CO_2 avoidance	[t CO_2 / year]	1,910	2,220

Depending on the used calculation method, Mazinde Sisal Estate has the potential for an installed capacity of 520 - 600 kW with assumed operating hours of 7,000 per year. With the produced electricity, 1,910 – 2,220 t CO_2/year can be avoided.

Based on the assessed data, the basic fermenter design for a CSTR and for a Concrete Covered Lagoon was done and summed up in Table 11.

Table 11: Mazinde fermenter design

Description	Unit	produced dry fibre
Waste water for biogas production – undiluted	[m^3/year]	39,700
Dry Matter content	[% of waste water]	12
Hydraulic Retention Time	[days]	43
Necessary Fermenter Volume	[m^3]	4.000
Loading Rate	[VS/m^3 ferm.vol. *day]	2.37
Process temperature	[temperature niveau]	mesophilic

Financial Analysis

The financial analysis was carried out based on literature data and own expertise. The amortization time was calculated using the Simple Payback Method. The Return of Invest was also calculated without considering interests and inflation. The summary of the financial analysis for a CSTR fermenter for Mazinde Sisal estate is given in Table 12.

Table 12: Mazinde financial analysis

	Calculation based on:	processed leaves	produced dry fibre
		36,500 m^3/ year	980 t / year
Investment Costs incl. CHPP	[US$]	2,578,000	2,801,800
Running Costs incl. CHPP	[US$/year]	189,200	220,000
Revenues grid-feeding	[US$/year]	483,400	569,800
Revenues own consumption			
Electricity Substitution incl. kVA charge	[US$/year]	52,100	52,100
Diesel Substitution	[US$/year]	15,100	15,100
Simple Payback incl. CHPP	[years]	7.1	6.7
ROI incl. CHPP	[%]	14	15

4.1.2 Maboga Sisal processing

Figure 9: Decorticator/Corona at Maboga in Mazinde Estate

Maboga Sisal processing is part of the Mazinde Sisal Group of Estates owned by Katani Ltd. which is owned by Mohammed Enterprise Ltd. The planted Sisal part of Mazinde Estate. 24,300 m^3 of Sisal leaves are processed every year with a total yearly production of 650 t of quality dry Sisal fibers.

Mazinde estate is connected to the main grid of TANESCO. The decortication units are mainly operated while running using TANESCO electricity. For times of black-outs, a 180 kW diesel back-up generator set was installed. A summary of the Mazinde site description is given in Table 13.

Table 13: Maboga site description

Description	**Unit**	**Value**
Site total area	[ha]	With Mazinde Estate
Site planted area	[ha]	With Mazinde Estate
Processed leaves	[m^3/year]	24,300
Produced dry fibre	[t/year]	650
Current electricity supply		Connected to TANESCO main grid
Installed Diesel Back-up GenSet	[kW]	180

Technical Assessment

The technical assessment was done during a local audit where all the key operating figures such as processed leaves per day and produced fibre per day were evaluated.

At Maboga Sisal processing salt water is used for washing the Sisal fibers. A negative impact on the biogas production is not expected but it has to be considered during plant design. A summary of selected parameters is given in Table 14.

Table 14: Maboga potential electric capacity

Calculation using:		**processed leaves**	**produced dry fibre**
		24,300 m^3/ year	650 t / year
Waste water for biogas production – undiluted	[t / year]	26,500	22,800
Waste water for biogas production – diluted	[t / year]	52,900	45,500
Biomethane potential	[m^3 / year]	801,900	689,700
Electric potential	[kWh/year]	2,798,200	2,406,800
Electric capacity	[kW]	400	345
CO_2 avoidance	[t CO_2 / year]	1,270	1,480

Depending on the used calculation method, Maboga Sisal Processing has the potential for an installed capacity of 345 – 400 kW with assumed operating hours of 7,000 per year. With the produced electricity, 1,270 – 1,480 t CO_2/year can be avoided.

Based on the assessed data, the basic fermenter design for a CSTR and for a Concrete Covered Lagoon was done and summed up in Table 15.

.

Table 15: Maboga fermenter design

Description	Unit	produced dry fibre
Waste water for biogas production – undiluted	[m^3/year]	26,500
Dry Matter content	[% of waste water]	12
Hydraulic Retention Time	[days]	43
Necessary Fermenter Volume	[m^3]	2,700
Loading Rate	[VS/m^3 ferm.vol. *day]	2.37
Process temperature	[temperature niveau]	mesophilic

Financial Analysis

The financial analysis was carried out based on literature data and own expertise. The amortisation time was calculated using the simple payback method. The Return of Invest was also calculated without considering interests and inflation. The summary of the financial analysis for a CSTR fermenter for Maboga Sisal processing is given in Table 16.

Table 16: Maboga financial analysis

	Calculation based on:	processed leaves	produced dry fibre
		24,300 m^3/ year	650 t / year
Investment Costs incl. CHPP	[US$]	2,111,000	2,226,300
Running Costs incl. CHPP	[US$/year]	126,100	146,600
Revenues grid-feeding	[US$/year]	353,000	416,000
Revenues own consumption			
Electricity Substitution incl. kVA charge	[US$/year]	34,700	34,700
Diesel Substitution	[US$/year]	10,100	10,100
Simple Payback incl. CHPP	[years]	7.8	7.1
ROI incl. CHPP	[%]	13	14

4.2 Site 2: Mjesani

Figure 10: Waste transportion at Mjesani

Mjesani Sisal Estate is owned by Mohammed Enterprise Ltd. (MeTL). The planted Sisal area of Mjesani covers 1,236 ha. 28,100 m^3 of Sisal leaves are processed every year with a total yearly production of 600 t of quality dry Sisal fibers.

Mjesani estate is connected to the main grid of TANESCO. The decortication units are mainly operated while running using TANESCO electricity. For times of black-outs, a 290 kW diesel back-up generator set was installed. A summary of the Mwelya site description is given in Table 17.

Table 17: Mjesani site description

Description	**Unit**	**Value**
Site total area	[ha]	9,000
Site planted area	[ha]	1,236
Processed leaves	[m^3/year]	28,100
Produced dry fibre	[t/year]	600
Current electricity supply		Connected to TANESCO main grid
Installed Diesel Back-up GenSet	[kW]	290

4.2.1 Technical Assessment

The technical assessment was performed during a local audit where all the key operating figures such as processed leaves per day and produced fibre per day were evaluated. A summary of selected parameters is given in Table 18.

Table 18: Mjesani potential electric capacity

	Calculation using:	**processed leaves**	**produced dry fibre**
		28,100 m^3/year	600 t/year
Waste water for biogas production – undiluted	[t / year]	26,300	24,300
Waste water for biogas production – diluted	[t / year]	52,500	48,600
Biomethane potential	[m^3 / year]	795,800	736,100
Electric potential	[kWh/year]	2,777,100	2,568,800
Electric capacity	[kW]	400	370
CO_2 avoidance	[t CO_2 / year]	1,470	1,340

Depending on the used calculation method, Mjesani Sisal Estate has the potential for an installed capacity of 370 – 400 kW with assumed operating hours of 7,000 per year. With the produced electricity, 1,340 – 1,470 t CO_2/year can be avoided.

Based on the assessed data, the basic fermenter design for a CSTR and for a Concrete Covered Lagoon was calculated and summed up in Table 19.

Table 19: Mjesani fermenter design

Description		**processed dry fibre**
Waste water for biogas production – undiluted	[m^3/year]	26,300
Dry Matter content	[% of waste water]	12%
Hydraulic Retention Time	[days]	43
Necessary Fermenter Volume	[m^3]	3,100
Loading Rate	[VS/m^3 ferm.vol. *day]	2.37
Process temperature	[temperature niveau]	mesophilic

4.2.2 Financial Analysis

The financial analysis was carried out based on literature data and own expertise. The amortisation time was calculated using the Simple Payback Method. The Return of Invest was also calculated without considering interests and inflation. The summary of the financial analysis for a CSTR fermenter for Mjesani Sisal estate is given inTable 20.

Table 20: Mjesani financial analysis

Calculation based on:		**processed leaves**	**produced dry fibre**
		28,100 m^3/ year	600 t / year
Investment Costs incl. CHPP	[US$]	2,209,400	2.113.500
Running Costs incl. CHPP	[US$/year]	145,500	134,600
Revenues grid-feeding	[US$/year]	396,000	362.400
Revenues own consumption			
Electricity Substitution incl. kVA charge	[US$/year]	46,400	46,400
Diesel Substitution	[US$/year]	17,300	17,300
Simple Payback incl. CHPP	[years]	7.0	7.3
ROI incl. CHPP	[%]	14	14

4.3 Site 3: Hassani

Figure 11: Corona at Hassani

Hassani Sisal Estate is owned by Mohammed Enterprise Ltd. (MeTL). The planted Sisal area of Hassani covers around 2,170 ha. 30,200 of m^3 Sisal leaves are processed every year with a total yearly production of 800 t of high quality dry Sisal fibers.

Hassani estate is connected to the main grid of TANESCO. The decortication units are mainly operated while running using TANESCO electricity. For times of black-outs a 180 kW diesel back-up generator set was installed. A summary of the Mwelya site description is given in Table 21.

Table 21: Hassani site description

Description	Unit	Value
Site total area	[ha]	2,408
Site planted area	[ha]	2,170
Processed leaves	[m^3/year]	30,200
Produced dry fibre	[t/year]	800
Current electricity supply		Connected to TANESCO main grid
Installed Diesel Back-up GenSet	[kW]	180

4.3.1 Technical Assessment

The technical assessment was done during a local audit where all the key operating figures such as processed leaves per day and produced fiber per day were evaluated. A summary of selected parameters is given in Table 22.

Table 22: Hassani potential electric capacity

	Calculation using:	processed leaves	produced dry fibre
		30,200 m^3/year	800 t/year
Waste water for biogas production – undiluted	[t / year]	28,200	32,600
Waste water for biogas production – diluted	[t / year]	56,400	65,100
Biomethane potential	[m^3 / year]	854,700	986,400
Electric potential	[kWh/year]	2,892,500	3,442,200
Electric capacity	[kW]	430	500
CO_2 avoidance	[t CO_2 / year]	1,580	1,820

Depending on the used calculation method, Hassani Sisal Estate has the potential for an installed capacity of 430 – 500 kW with assumed operating hours of 7,000 per year. With the produced electricity, 1,580 – 1,820 t CO_2/year can be avoided.

Based on the assessed data, the basic fermenter design for a CSTR and for a Concrete Covered Lagoon was calculated and summed up in Table 23.

Table 23: Hassani fermenter design

Description	Unit	Value
Waste water for biogas production	[m^3/year]	32,600
Dry Matter content	[% of waste water]	12%
Hydraulic Retention Time	[days]	43
Necessary Fermenter Volume	[m^3]	3,850
Loading Rate	[VS/m^3 ferm.vol. *day]	2.37
Process temperature	[temperature niveau]	mesophilic

4.3.2 Financial Analysis

The financial analysis was carried out based on literature data and own expertise. The amortisation time was calculated using the Simple Payback method. The Return of Invest was also calculated without considering interests and inflation. The summary of the financial analysis for a CSTR fermenter for Hassani Sisal estate is given in Table 24.

Table 24: Hassani financial analysis

	Calculation based on:	**processed leaves**	**produced dry fibre**
		30,200 m^3/ year	800 t / year
Investment Costs incl. CHPP	[US$]	2,291,800	2,458,000
Running Costs incl. CHPP	[US$/year]	156,300	180,400
Revenues grid-feeding	[US$/year]	432,200	504,400
Revenues own consumption			
Electricity Substitution incl. kVA charge	[US$/year]	42,700	42,700
Diesel Substitution	[US$/year]	10,400	10,400
Simple Payback incl. CHPP	[years]	7.0	6.5
ROI incl. CHPP	[%]	14	15

4.4 Site 4: Hussani

Figure 12: Separation unit from Chinese Corona at Hussani

Hussani Sisal Estate is owned by Mohammed Enterprise Ltd. (MeTL). The planted Sisal area of Hussani covers 2,098 ha. 43,500 m^3 of Sisal leaves are processed every year with a total yearly production of 900 t of high quality dry Sisal fibers.

Hussani estate is connected to the main grid of TANESCO. The decortication units are mainly operated while running using TANESCO electricity. For times of black-outs, a 180 kW diesel back-up generator set was installed. A summary of the Mwelya site description is given in Table 25.

Table 25: Hussani site description

Description	Unit	Value
Site total area	[ha]	2,175
Site planted area	[ha]	2,098
Processed leaves	[m^3/year]	43,700
Produced dry fibre	[t/year]	900
Current electricity supply		Connected to TANESCO main grid
Installed Diesel Back-up GenSet	[kW]	180

4.4.1 Technical Assessment

The technical assessment was done during a local audit where all the key operating figures such as processed leaves per day and produced fibre were evaluated. A summary of selected parameters is given in Table 26.

Table 26: Hussani potential electric capacity

	Calculation using:	**processed leaves**	**produced dry fibre**
		43,700 m^3/year	900 t/year
Waste water for biogas production – undiluted	[t / year]	40,900	36,300
Waste water for biogas production – diluted	[t / year]	81,700	72,600
Biomethane potential	[m^3 / year]	1,238,000	1,099,900
Electric potential	[kWh/year]	4,320,000	3,838,200
Electric capacity	[kW]	620	550
CO_2 avoidance	[t CO_2 / year]	2,290	2,030

Dependent from the used calculation method, Hussani Sisal Estate has the potential for an installed capacity of 550 – 620 kW with assumed operating hours of 7,000 per year. With the produced electricity, 2,030 – 2,290 t CO_2/year can be avoided.

Based on the assessed data, the basic fermenter design for a CSTR and for a Concrete Covered Lagoon was calculated and summed up in Table 27.

Table 27: Hussani fermenter design

Description	**Unit**	**produced dry fibre**
Waste water for biogas production – undiluted	[m^3/year]	36,300
Dry Matter content	[% of waste water]	12%
Hydraulic Retention Time	[days]	43
Necessary Fermenter Volume	[m^3]	4,820
Loading Rate	[VS/m^3 ferm.vol. *day]	2.37
Process temperature	[temperature niveau]	mesophilic

4.4.2 Financial Analysis

The financial analysis was carried out based on literature data and own expertise. The amortisation time was calculated using the Simple Payback Method. The Return of Invest was also calculated without considering interests and inflation. The summary of the financial analysis for a CSTR fermenter for Hussani Sisal estate is given in Table 28.

Table 28: Hussani financial analysis

	Calculation based on:	**processed leaves**	**produced dry fibre**
		43,700 m^3/ year	900 t / year
Investment Costs incl. CHPP	[US$]	2,883,600	2,651,400
Running Costs incl. CHPP	[US$/year]	226,400	201,100
Revenues grid-feeding	[US$/year]	573.700	590,000
Revenues own consumption			
Electricity Substitution incl. kVA charge	[US$/year]	68,200	68,200
Diesel Substitution	[US$/year]	16,900	16,900
Simple Payback incl. CHPP	[years]	6.7	6.9
ROI incl. CHPP	[%]	15	15

5 Literature

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