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MSc. Sustainable Energy Planning and Management

Analysis of Possibility of CDM Through Biogas Production and Electricity Generation From Sisal Waste in Tanzania

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Abstract

Currently and in recent years there has been an increasing concern on the impacts of the greenhouse gases (GHGs) on the climate change. To a larger extent, the industrialized countries are the major contributors of the GHGs into the atmosphere due to the increased industrial activities which demand an extensive use of energy, most of which produced by fossil-fuel resources such as coal, natural gas, and diesel. In general, the developing countries are less emitter but have always been the victims of the impacts of climate change, most of which are devastating such as increased droughts, floods, and sea level rise.

The clean development mechanism (CDM) is one of the mitigation tools for GHGs reduction set by the Kyoto Protocol. The CDM has two major objectives; one is to help the industrialized countries (Annex I) achieve their emission reduction targets, and two is to assist the developing countries (Non-Annex I) achieve the sustainable development (SD) through greener investments. Different types of projects can be implemented as CDM project based on the specific conditions mainly concern with the key objectives of CDM. Currently, there are 1079 registered CDM project in developing countries, many of which are located Asia and Latin America. Africa has only 25 projects, of which only one is found in Tanzania.

Despite having high potentials for CDM project activities for example in the fields of energy, agriculture, agro-industrial, transportation, industry, forestry, cogeneration, waste management, renewable energy, fuel switch, and retrofitting, yet Tanzania has not fully benefited from the CDM advantages. This Thesis is a one step further towards securing fully benefits of CDM activities in Tanzania. This Thesis looks as to how the sisal waste CDM project activities can successfully be implemented in Tanzania. Being one of the top sisal producers in the world, Tanzania produces more that 200,000 tons of sisal waste per year, which is dumped uncontrollably into the disposal sites. The waste at the disposal sites undergo decay and emit methane into the atmosphere increasing the problems of climate change. As the sisal industry in Tanzania is growing rapidly, the impact of sisal waste on the climate change through methane emission is also expected to rise.

Using various models, methodologies, and tools, this Thesis has revealed that it is possible to reduce the significant amount of GHGs emission from the sisal waste disposal site by using the sisal waste to produce biogas. Further emission reductions will be achieved by replacing the fossil fuel used to generate the grid electricity with the electricity produced using the biogas. This Thesis has demonstrated that the sisal waste CDM project will be able to meet all the criteria for CDM such as additionality and SD impact. However, the Thesis has revealed that various risks may prevent the implementation of the sisal waste CDM project. Such risks may involve the baseline/monitoring methodologies, sisal biogas technology, project financing risk, and post Kyoto risk.

Acknowledgement

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Acronyms

CDM – Clean development mechanism
CEEST – Centre for environment, energy, science, and technology
CER – Certified emission reduction
CFC - Carbon fluorocarbons
CHP – Combined heat and power
COP – Conference of Parties
CP – Crediting period
DNA - Designated national authority
DOE – Designated operational entity
EB – Executive Board
EEI – Energy efficient improvement
ER – Emission reduction
EWURA – Energy and water utilities regulatory authority
FAO – Food and agriculture organization
FOD – First order decay
GDP – Growth domestic product
GJ – Giga joule
GHG – Greenhouse gas
GWh – Gigawatt hour
IPCC – International panel for climate change
IRR – Internal rate of return
kt - kiloton
LCMR – Long cost must run
MEM – Ministry of energy and mineral
MJ – Mega joule
MW - Megawatt
NPV – Net present value
ODA – Official development assistance
PDD – Project design document
PIN – Project idea note
RT – Retention time
SD – Sustainable development
SWOT – Strengths, weaknesses, opportunities, threats
TANESCO – Tanzania electricity supply company
tCO_2 – Tons of carbon dioxide
TJ – Tera-joule
UNEP – United Nations Environmental Programme
UNFCCC – United Nations Framework for Climate Change Conventions
UNIDO – United Nations Industrial Development Organization
VPO – Vice President's Office
VS – Volatile solids
WBCSD – World business council for sustainable development

I dedicate this Thesis work to my late Grandmother, may GOD rest her soul in Heaven

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1

Introduction

This first chapter introduces the study. The chapter presents the background to the research, identifies key issues to be focused on in this research, specifies the aim and objectives of the study, and develops the research questions. Specifically, the key points to be identified by this chapter are the status of the sisal industry in Tanzania - 1.2; the potential for biogas and electricity generation from sisal waste - 1.3; the concept of climate change - 1.4; and the concept of clean development mechanism (CDM) - 1.5. Lastly, the chapter describes the structure of the present research project.

1.1 Background

Increasingly, there has been a growing concern about the impact of anthropogenic activities on the global climate. Central to this concern is the notion that production activities such as industrial processes, agricultural processes, transportation, and energy production lead to the generation of large amounts of GHGs, which are freely emitted to the atmosphere (IPCC, 2007). Based on various scientific investigations, the impacts of climate change are devastating and include a rise in the sea level, changes in weather patterns, a drop in agricultural yields, the extinction of wildlife species, and an increase in the range of disease vectors (IPCC, 2001). Thus, there has been a rising need to stabilize the concentration of GHG gases in the atmosphere by reducing their production from sources or avoiding their emission into the atmosphere.

The Kyoto Protocol, adopted in 1997, commits high polluting countries (i.e., developed countries) to implement mechanisms to reduce emissions to certain levels specified by the Kyoto Treaty (UN, 1998). Low polluting countries (i.e., least developed countries) have no legal obligations on emission reductions, but they can voluntarily help high polluters to achieve their emission targets through three mechanisms, namely, Joint Implementation, Emission Trading, and Clean Development Mechanism (CDM) (UNFCCC, 1997). Fundamentally, these mechanisms allow high polluters to achieve emission reduction targets by purchasing emissions credits through projects operating in low polluting countries (UNEP, 2005). CDM is intended for Third World countries (generally countries in Africa, Asia, and Latin America).

It is expected that through CDM activities, Third World countries could benefit by obtaining new technologies, accessing cleaner energy, conserving the environment, improving production processes, and ultimately achieving sustainable development. Despite all of these opportunities, Tanzania has yet to benefit fully from CDM advantages. Currently, out of about 945 registered CDM project activities, only one is found in Tanzania (UNFCCC, 2008). In recognizing these facts, the focus of this study is on CDM development in Tanzania. Specifically, the study evaluates the possibilities of implementing CDM activities in Tanzania based on the biogas and energy production from sisal wastes.

The processes of extracting sisal fibre produce a large amount of waste as only 4% of the sisal leaf is fibre; the rest, 96%, is considered waste. The sisal wastes have only a few uses, which have never been successfully practiced. There have been a few attempts to use waste materials as natural fertilizer, raw material for making tiles, and to use the waste materials in pharmaceutical researches (Shamte, 2001). However, large amounts of waste are still disposed of and continue to pollute the environment as there are not enough incentives to promote the above-mentioned alternative uses of waste materials. Therefore, the produced waste is continuously disposed of in the unmanaged dumpsites where they are left to decay, producing methane, which is emitted to the atmosphere. Sometimes, the waste materials are channelled into the rivers and streams, thus polluting water resources.

Essentially, it is expected that through the manipulation of sisal wastes to produce biogas, it might be possible to reduce GHG emissions by avoiding the escape of methane (CH_4) produced at the disposal sites, and by reducing emissions of carbon dioxide (CO_2) by replacing grid electricity produced from fossil fuels. However, understanding and justifying this necessitates a step-by-step evaluation of the technical, economical, environmental, and social elements of a typical CDM project. Apparently, there has never been any in-depth study conducted to evaluate such important factors. Using a specified case, the study examines the above-mentioned factors by applying specific approved United Nations Framework Convention for Climate Change (UNFCCC) methodologies and tools to execute various key calculations. In addition, this study is intended to produce key information to be used in the preparation of Project Design Documents (PDD) for the proposed small scale sisal waste CDM project to be implemented in Tanga, Tanzania. The information in this report may also be replicated in other sisal growing areas in Tanzania or other countries.

1.2 Overview of the sisal industry in Tanzania

This section gives an insight into sisal production in Tanzania. It also examines sisal waste production potential and the status of sisal waste management. The overview provided in this section will help to give an idea of the potential for biogas production and electricity generation from sisal waste in Tanzania, and also the possibility of CDM project activity.

1.2.1 Status of sisal production

Sisal *(Agave Sisalana)* originated in Central America. Sisal is a plant that yields sisal fibres, which are primarily used as raw material for the production of ropes, strings, and other cordages (Hartemink and Wrenk, 1995). Currently, sisal is grown predominantly in tropical regions of Africa (i.e., Tanzania and Kenya), Central and South America (i.e., Brazil and Mexico) and Asia (particularly in China). The sisal plant has the characteristics of enduring difficult conditions such as drought, diseases, or even bad topographic conditions (Shamte, 2001). Basically, sisal can be planted at any time of the year and be harvested all year round.

When a sisal plant matures, it produces a stalk which bears large number of plantlets called bulbils (Mlingano Sisal Research Station, 1965). These plantlets are taken from the stalk and raised in nurseries for about two years and then replanted in the field (ibid). Normally, it takes between 2-3 years before harvesting of the first leaves starts and harvesting may continue for 8 years or more before leaf production ceases (Hartemink and Wrenk, 1995). The recorded average yields of sisal leaves (t/ha) are as follows: Africa 0.7, Central America 0.5, South America 0.7, and Asia 1.1 (FAO, 2000)

Photo 1.1 Sisal plant, bulbils, and harvested leaves

Historically, sisal was introduced into Tanzania by German settlers in the 1880s when a few plants were planted in Pangani, Tanga region. The first sisal plantation was established in the same region in the 1900s (Hartemink and Wrenk, 1995). Since then, sisal has been grown extensively at estates with a huge investment in machinery for sisal processing.

The sisal industry in Tanzania has experienced rises and falls due to a number of factors. Essentially, the industry expanded as a result of the construction of railway lines passing through the major sisal producing regions in the country. This facilitated the transportation of sisal from these regions to major ports in the country. Data show that Tanzania made its first sisal export in 1898 (Hartemink and Wrenk, 1995). The export rose to 1400 tonnes in 1905, and increased to 20,000 tonnes in 1913 but halted in 1914 due to the effects of World War I (ibid). Production was revived after the war and increased to 100,000 tons in 1938, reaching its highest level in 1964 with 234,000 tons produced on 201 estates (of about 427,000 hectares) (FAO and CFC, 2001). This successful performance kept Tanzania at the top of the world's sisal fibre producing countries in the 1960s (UNIDO, 2008).

The sisal industry started to shrink in the 1970s when the production declined dramatically, reaching 32,000 tons in 1989, and 20,000 tons in 2000 (with only 52 sisal estates) (FAO and CFC, 2001) – see Figure 1.1. According to Shamte (2001), the following problems contributed to the decline:

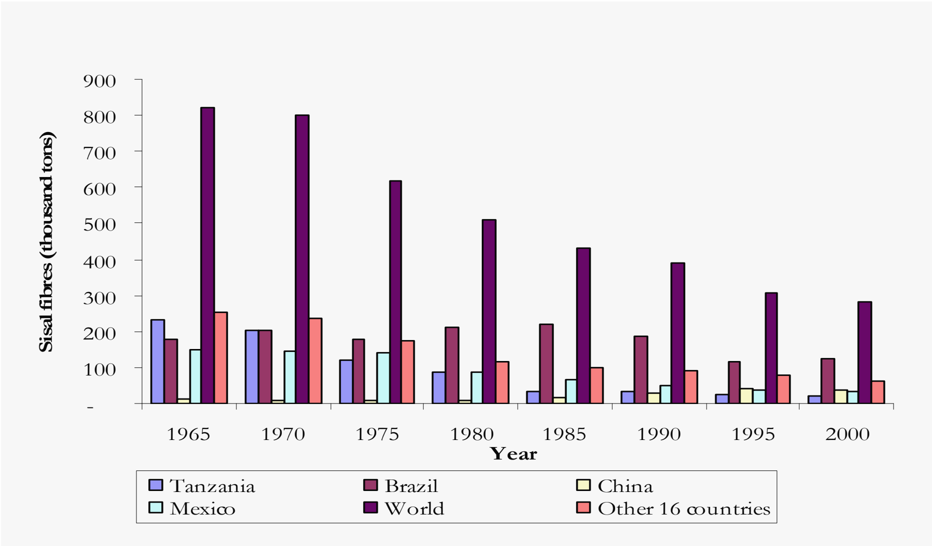
1. Demand side problems, which include unfair terms of trade, free trade barriers, and competition from synthetic fibres. These factors contributed to a dramatic fall in the price of sisal in the world market (Shamte, 2001).

2. Supply side problems, which include insufficient research and development on sisal farming and processing; poor economic and agricultural policies, and a shift in ownership status of the industry from colonialism to nationalism which proved huge difficulties due to a lack of experience by the government (Shamte, 2001).

Thus, during the late 1990s, various programmes were launched by the government to revive the industry, including privatisation of the state-owned estates, leasing plantations to local growers (i.e., out growers), and replanting abandoned fields (Shamte, 2001). Internationally, increased concern about the environmental impacts of synthetic fibres also played a role in reviving the industry in terms of a rise in the price of sisal fibre in the world market (Tanzania Sisal Board, 2008).

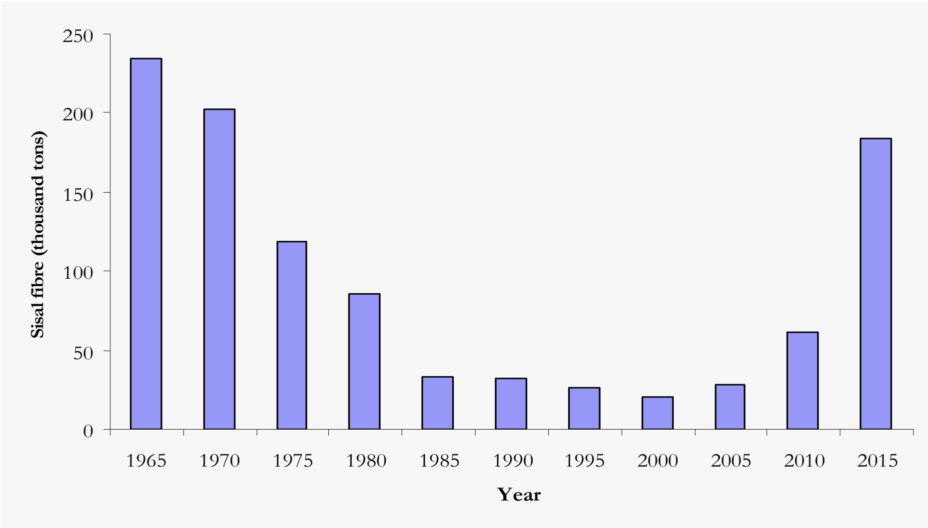
Therefore, from 2000 on, sisal production increased considerably reaching about 24,000 tons in 2001, 2002, and 2003; 25,000tons in 2004, 28,000 tons in 2005, 31,000 tons in 2006, and 33,000 tons in 2007 (Tanzania Sisal Board, 2008). Plans are underway now to establish more plantations in other areas of the country that have never grown sisal before. The trend and projected production of sisal fibre in Tanzania is as shown in Figure 1.2

Figure 1.1 Sisal productions in Tanzania compared to other countries (1965-2000)



Source: Based on data from FAO (2000)

Figure 1.2 Trend in sisal fibre production and future projection (1965-2015)

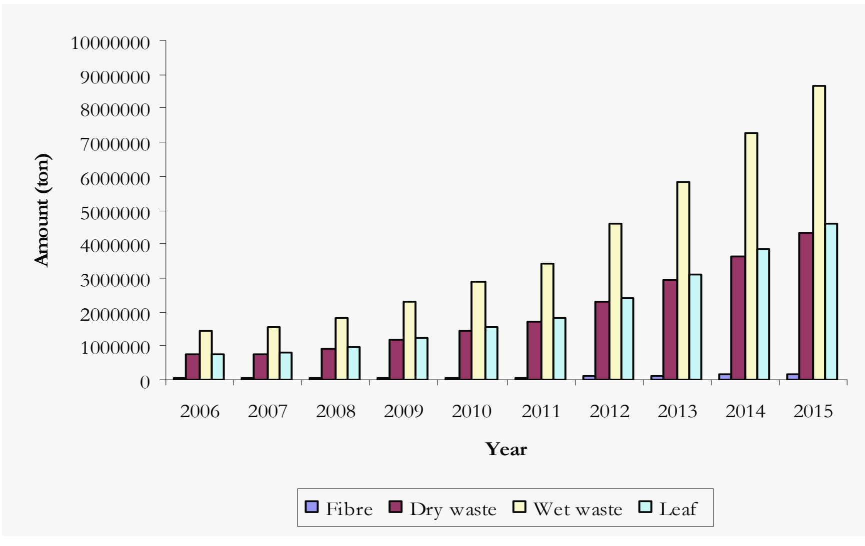


Source: Based on data from FAO (2000)

1.2.2 Potential for sisal waste production

The amount of sisal waste produced in a year can be estimated based on the amount of sisal leaves processed to produce sisal fibres, which also relies on the yearly harvest of sisal leaves and the market status of the fibres. In a conservative manner, it is estimated that for every 25 tons of fresh sisal leaves, only 2.5 tons (i.e., 10%) are fibres; the rest (i.e., 90%) is considered as waste. As the process of decortication involves the addition of water equal to the weight of leaves processed (1:1 ratio) (Katani Ltd, 2008), the average weight of waste at any particular time is twice the original weight. In other words, in a typical sisal processing unit, the weight of the dry sisal waste is half the weight of the wet waste. Based on these facts, the status and potential of sisal waste production in Tanzania is as shown in Figure 1.3 (i.e., 2006 - 2015)

Figure 1.3 Status and potential of sisal waste production in Tanzania (2001-2007)



Source: Based on data from Tanzania Sisal Board (2008)

1.2.3 Sisal waste management

As just mentioned, the sisal factories produce abundant amount of waste during sisal processing. The produced wastes are washed away from the decorticators by water to some dump sites where they accumulate or to nearby rivers and streams. This leads to problems such as bad smell caused by decay of waste in the dumps. In a few cases, waste materials may cause flooding downstream especially during heavy rains.

This poor method of waste disposal and its associated impacts makes sisal industry in Tanzania as a threat to the human health especially when the contaminated water is consumed by the communities living in the downstream. From the environmental perspectives, it is a sustainable approach for a cleaner utilization of sisal waste to avoid negative impacts associated with waste disposal (Shamte, 2001). The following photos show how waste is produced from the sisal leaves in the decorticator machine and how it is disposed into the disposal site. Specifically, photo A shows the decortication process (i.e. decortication is the process of removing fibres from the sisal leaves using the decorticator machine plus large amount of water); photo B shows the separation of sisal waste from the sisal fibre; photo C shows the streaming of waste from the decorticator to the disposal site; and photo D shows dumping of sisal waste at the disposal site or into the river and streams. In these photos, it can be realized that waste disposal is not controlled. Apparently, in almost all sisal factories in Tanzania, the waste management systems such as waste treatment or post-utilization of waste are not significantly implemented

Photo 1.2 Waste production and disposal in sisal production process

Thus, it can be concluded that the potential expansion of the sisal industry in Tanzania might lead to a significant increase in waste production and ultimately pose a large environmental problem, especially the increase in the emission of methane into the atmosphere and the pollution of water resources. It is estimated that these problems will increase further due to a lack of strictness or of any strategic long-term plans to control the disposal of waste produced from sisal factories. Among the possible control mechanisms for waste management, are the economic utilization of waste in biogas production and electricity generation, as pointed out earlier. These potential methods are described in the next section.

1.3 Biogas and electricity potentials from sisal waste in Tanzania

The potential for electricity generation from sisal waste is determined by the availability of a reliable amount of sisal waste and the technology needed to convert it. There are two possibilities for the generation of electricity from sisal waste: direct combustion of waste and conversion of waste into biogas followed by combustion using a biogas engine generator or gas turbine. This study follows the latter options since they are already practiced in a small pilot project at Hale Sisal Estate in Tanga, Tanzania. This made it slightly easier to obtain the relevant data necessary for estimating potential biogas and energy production. The following data and assumptions were used to estimate biogas and electricity production in Tanzania; the results are displayed in Figures 1.4 and 1.5 below

- Mean gas yield per ton of sisal waste (m^3) – 50 (Hale estimate)
- Biogas production efficiency by the digesters (%) – 33 (Hale estimate)
- Estimated total volatile solids (VS) in waste (%) - 9 (Mshandete et al, 2008)
- Biogas engine generator efficiency (%) – 35 (Hale estimate)
- CH_4 heating value (MJ/m^3) - 22 (Nijaguna, 2006)
- CH_4 content in biogas (%) – 60 (Hale estimate)
- 1 GWh - 3.6 GJ
- Operating hours of biogas and electricity facilities - 8760

Figure 1.4 Biogas production potential from sisal waste in Tanzania

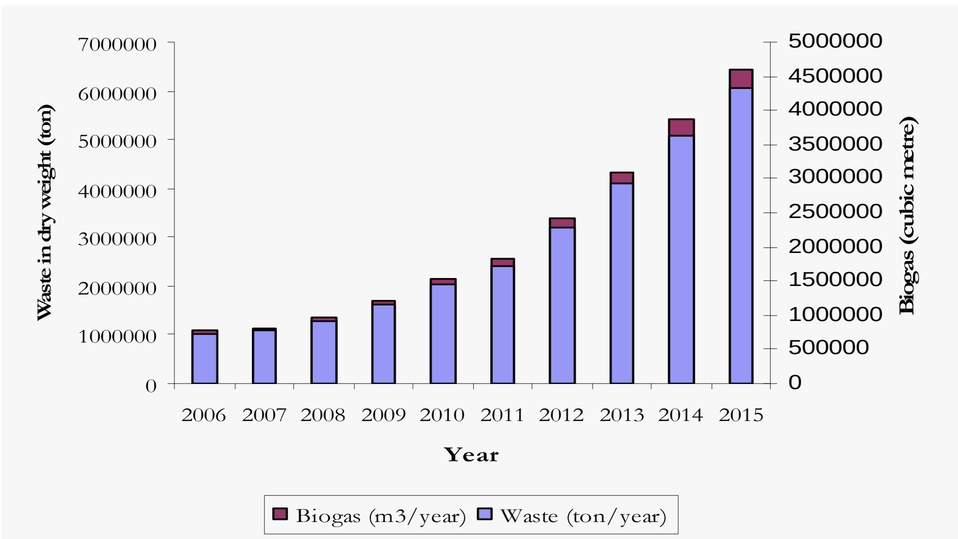
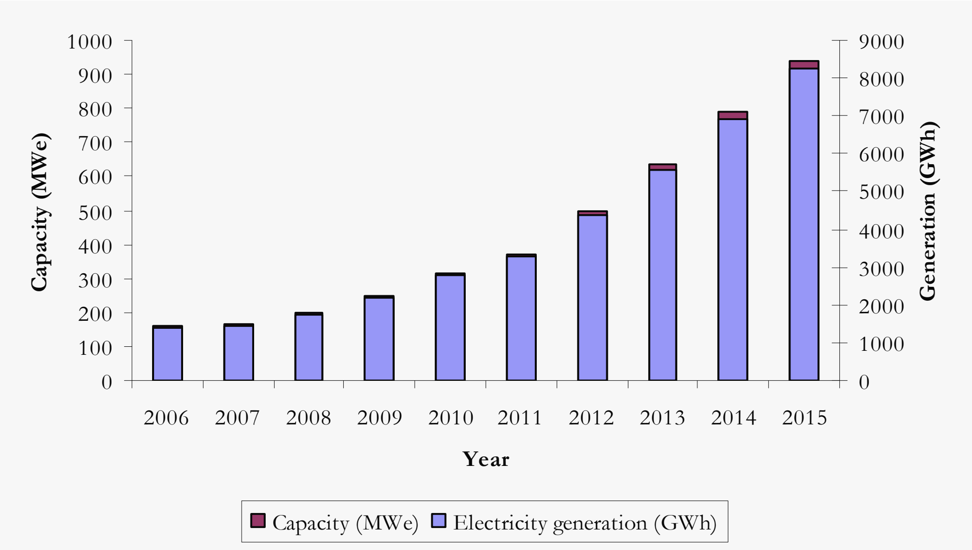


Figure 1.5 Electricity generation potential from sisal waste (2006-2015)



As it can be seen in the graph above that the potential for biogas and electricity production in Tanzania is high. The potential could be even higher if the more efficient digesters and gas engine generators could be installed. The data derived from Hale Biogas Plant are actually based on the production and capacity of the Hale Biogas Plant, which is only 150kW. In order to fully exploit the above potential, large scale biogas plants should be installed in various sisal growing regions in the country where it will be easier to get enough waste for anaerobic digestion. Apart from that, there should be mechanisms to ensure the produced biogas/electricity is economically utilized. This possibility will be analysed later in this report by being linked with the impacts of sisal waste CDM project on socio-economic development in Tanzania.

1.4 The concept of climate change

This section introduces the concept of climate change and global warming. The intention is to understand factors that accelerate climate change and global warming, and the associated impacts. In addition, this section describes the status of GHG emissions in Tanzania and the contribution of sisal waste in the emission of GHGs.

1.4.1 Climate change and GHGs

Climate change refers to a 'change in the state of the climate that can be identified (e.g., using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer' (Hegerl *et al.*, 2007). Apart from the anthropogenic activities mentioned earlier, natural processes on earth like solar radiation and volcanoes can also contribute to climate change (IPCC, 2001). Basically, the concept refers to change in the average state of the atmosphere due to high concentrations of GHGs, which contribute to a rise in the global temperature through the greenhouse effect (Miller and Edwards, 2001).

According to IPCC, 'the global average air temperature near the Earth's surface rose 0.74± 0.18 ºC during the 100 years ending in 2005 and is expected to rise further 1.1 to 6.4 ºC during the 21st century' (IPCC, 2007). The GHGs of significant importance are Carbon Dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O), Perfluorocarbons (PFCs), Hydrofluorocarbons (HFCs), and Sulphur hexafluoride (SF_6). Their sources are shown in Table 1.1.

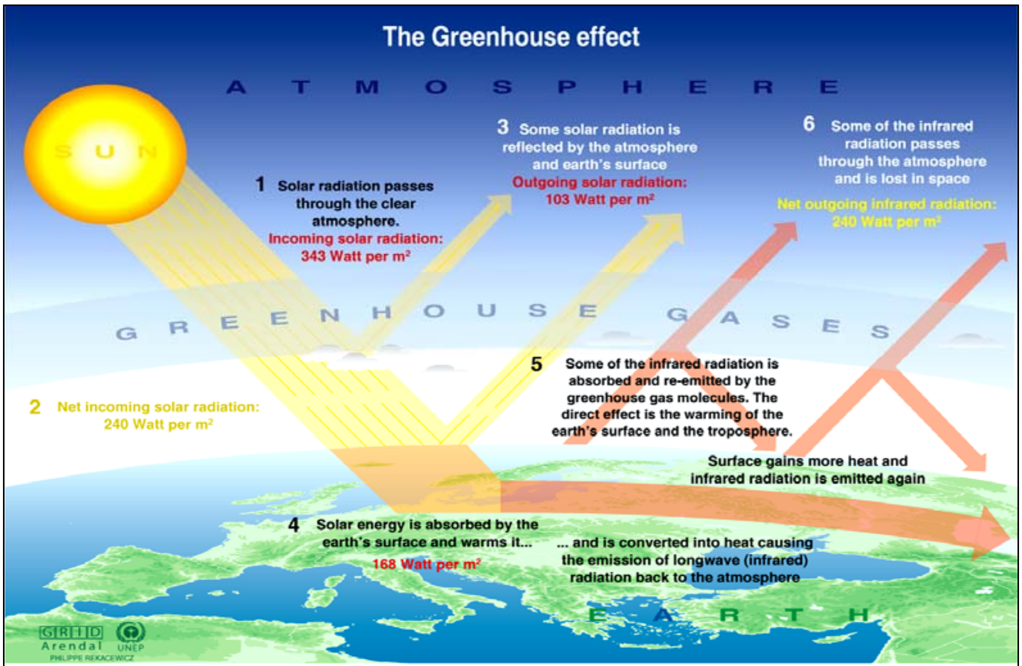
Table 1.1 Anthropogenic sources of GHGs

Gas	Source
Carbon Dioxide (CO_2)	fossil fuel combustion (e.g., energy generation from diesel, natural gas, oil, and coal) land use change (e.g., deforestation, mining, and agriculture), and industrial processes (e.g., cement production) (IPCC, 2001)
Methane (CH_4)	rice agriculture, natural wetlands, energy generation processes, landfills, ruminants, and biomass burning (IPCC, 2001)
Nitrous Oxide (N_2O)	agricultural activities (i.e. increase of N caused by application of fertilizers on the agricultural soil), industrial sources (e.g., nylon and nitric acid production), fossil fuel fired plants, vehicle emissions, and biomass burning (EPA, 2006)
Perfluorocarbons (PFCs), and Sulphur hexafluoride (SF_6), and Hydrofluorocarbons (HFCs)	aluminium and magnesium production, semi-conductors manufacturing, and production of HFC_{23} from HCFC-22 used in refrigeration, air conditions, and in production of synthetic polymers (EPA, 2006)

Figure 1.6 depicts the process of the greenhouse effect. The figure shows how solar energy is absorbed by the earth's surface, causing the earth to warm up and emit infrared radiation to the atmosphere. It is estimated that the earth absorbs about 70% of the incoming solar radiation warming the land, atmosphere and oceans; the remaining 30% is reflected (IPCC, 2001). The GHGs in the atmosphere absorb the infrared radiation emitted by the heated surface of the earth and then re-emit the radiations in all directions upward and downward to the earth (ibid). In this way, the earth's surface gains more heat and re-emits the radiations to the atmosphere (EPA, 2006).

The increase in GHG emissions caused by human activities leads to disturbances in the greenhouse mechanisms whereby more heat is trapped by the GHGs. This will result in an increase in the global warming as more heat will be re-emitted back to the earth (IPCC, 2001).

Figure 1.6 Greenhouse effect



Sources: Okanagan university college in Canada, Department of geography, University of Oxford, school of geography; United States Environmental Protection Agency (EPA), Washington; Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge university press, 1996.

Source: UNEP/GRID-Arendal (2000)

1.4.2 GHGs and climate change in Tanzania

Like many other developing countries, Tanzania makes a minimum contribution to the global GHG emissions. However, the country remains highly vulnerable to the impacts of climate change due to a lack of enough adaptability capacity. Some of the forecasted climate change impacts in Tanzania include desertification, reduced freshwater availability, coastal erosion and coral bleaching, loss of forest quality, and drop in food production (IPCC, 2001; CEEST, 1999).

According to the UNFCCC database, the GHG emissions in Tanzania in the last inventory year (1994) were as follows: CO_2 - 813,680,000 tons with land use change and forestry sector contributing 95%, the energy sector 4%, and industrial sector 1%; CH_4 - 117,728,000 tons; and N_2O - 21,392,000 tons (UNFCCC, 2008). These figures give a total per capita emission of CO_2 equivalent to less than 1 ton of CO_2, which is very small compared to the per capita emission in developed countries and other developing countries. The emission of CH_4 came from biomass combustion, livestock management, rice production, waste management, and coal mining activities. The CO_2 emission came from the burning of fossil fuel and biomass (CEEST, 1999).

It should be noted that the 1994 figures are used in this study, as there have been no other comprehensive studies done to estimate more recent GHG emissions in the Tanzania. Therefore, it is assumed that the above estimations prevail to date though there is a high possibility of their being underestimations. Various scenarios may be considered in justifying a possible increase in GHG emission in the country including an increase in the human population, expansion of the industrial sector, an increase in agricultural production, and GDP growth. All these activities could contribute significantly to the generation of dangerous gases that are emitted to the atmosphere. Furthermore, due to an increase in sisal production in the country in recent years, it is obvious that there is a significant addition of GHG emissions from the sisal waste disposal sites.

Table 1.2 Annual GHGs emissions for Tanzania in tons CO_2 equivalent

	Emissions in tons CO_2 equivalent (including LULUCF/LUCF)*	
Gas	**1990**	**Last Inventory Year (1994)**
CO_2	66,224,000	813,680,000
CH_4	48,350,000	117,728,000
N_2O	15,155,000	21,392,000
Total	**129,729,000**	**952,800,000**

*LULUCF/LUCF stands for land use and land use change and forestry/land use change and forestry
Source: Based on data from UNFCCC (2008)

1.4.3 Impacts of sisal waste on GHG emissions

As mentioned previously, sisal waste is produced from fibre extraction process in the decorticator by the addition of a large quantity of water. The impacts on the GHG emission result from the accumulation of waste at the disposal site where anaerobic decomposition occurring below the surface leads to the production of CH_4. According to IPCC, methane is a powerful greenhouse gas with 21 times more GWP than CO_2 (IPCC, 1996). Also the concentration of methane in the atmosphere has been increasing by 1% per year since the 1960s, which is double the increase of CO_2 (IPCC 2001). Therefore, avoiding or reducing CH_4 emissions to the atmosphere is a highly desirable option.

Methane emissions from sisal waste could be reduced by applying waste management practices that favour aerobic decomposition (Lehtomaki, 2006) that will lead to the production of less harmful biogenic carbon dioxide (IPCC, 2006), or capturing methane by treating sisal waste in controlled anaerobic conditions producing biogas to be used as energy source (CFC and UNIDO, 2004). These practices have been done extensively in landfills or other agro-industrial wastes such as palm oil. However, there has been no attempt made in the case of sisal waste disposal sites.

In all cases, the amount of methane emission from the disposal sites is estimated by considering several factors including the proportion of degradable organic compound in the waste, the amount of waste dumped at the disposal site, the oxidation factor, the decay rate of sisal waste, and the global warming potential of methane (IPCC, 1996). The above factors are used in Chapter five to estimate methane emission from the sisal waste disposal site in order to calculate the emission reduction (ER) as a result of utilizing sisal waste in biogas production.

1.5 Overview of clean development mechanism (CDM)

A detailed description of CDM is provided in Chapter 4 of this Thesis. This section gives an overview of the concept by describing its origin and importance and by discussing whether the project is eligible for CDM activities. In addition, the section describes the status of CDM in Tanzania and compares it with other countries eligible for CDM project activities.

1.5.1 Origin of CDM

CDM can be traced back to 1992 when the international treaty, the Framework Convention on Climate Change (UNFCCC), was adopted at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in an effort to tackle the problem of global warming (UN, 1998). The objective of UNFCCC was 'to achieve stabilization of greenhouse gas concentrations in the atmosphere at a low enough level to prevent dangerous anthropogenic interference with the climate system' (UNFCCC, 2008).

The treaty started with a "non-binding policy" requiring industrialized countries (grouped as Annex 1) voluntarily to ´´reduce their emissions to target levels below their 1990 emission levels by the year 2000´´ (UN, 1998). Should they fail to do so, the responsible countries are obliged to buy emission credits from developing countries (grouped as Non-annex 1). Since entering into force in March, 1994, the parties (i.e., members) of UNFCCC meet annually in Conferences of the Parties (COP) to assess progress in climate change mitigation (UNFCCC, 2008).

However, due to a continuous increase in GHG emissions globally, it was agreed by the parties that there was a need for binding obligations in reducing emissions. Therefore**,** the Kyoto Protocol was adopted at the COP 3 in Kyoto, Japan, on 11 December 1997 (UNFCCC, 2008). The blueprint for implementation of the protocol was adopted at COP 7 in Marrakesh in 2001. On 16 February 2005, the protocol entered into force (UNFCCC, 2008). Basically, the Protocol commits high polluters to reducing their GHG emissions below levels specified for each country in the protocol within five years (2008 - 2012), plus an emissions reduction of at least 5% below 1990 emissions (UNFCCC, 2008).

Due to clear difficulties in implementing the Treaty, the CDM was established by COP 3. As pointed out earlier, CDM allows developed countries to meet emission reduction targets by buying emission credits from renewable projects implemented in developing countries (UNEP, 2005). Paragraph 5, Article 12 of the Kyoto Protocol outlines several '*must*' criteria of CDM activities including (UNEP, 2005):

- Participation by the country governments in CDM must be voluntary.
- Participating governments must have ratified the Kyoto Treaty.
- The CDM project must produce real emission reduction by reducing the increase in/or stabilizing the amount of GHGs in the atmosphere
- Emission reduction must be physically verifiable and measurable
- CDM project must result in implementation of technologies/processes that result in a long term trend towards cutting GHGs emissions.
- The CDM project must be additional – meaning, it must reduce more emissions than those that would have occurred in its absence
- CDM project funding must not result from diversion of Official Development Assistance (ODA)

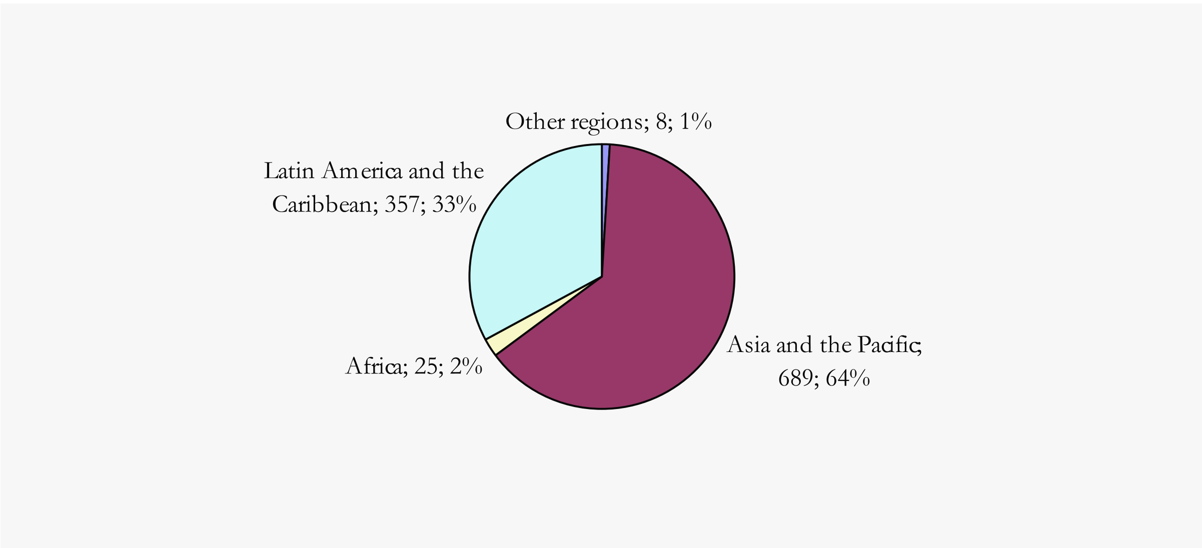
A CDM project can be either a GHG mitigation or sequestration project activity including the following (UNFCCC, 2008):

- Renewable energy technology (RET) and
- Energy efficiency improvement (EEI)
- Fuel switching
- Combined Heat and Power (CHP)
- Methane capture and destruction
- Capture and destruction of high GWP gases and Nitrous Oxide
- Emission reduction from industrial processes
- Emission reduction in transport and agricultural sectors
- Afforestation and reforestation activities
- Industrial equipment improvement using less GHG intensive technologies
- Expansion of existing plants using less GHG intensive technologies

1.5.2 CDM status and challenges in Tanzania

Tanzania ratified both UNFCCC and the Kyoto Protocol in 1996 and 2000 respectively (VPO, 2007). However, as mentioned earlier, it is still far from benefiting from CDM advantages. Figure 1.7 shows distributions of CDM by region where it can be seen that Africa constitutes only 25 (3%) of the total (1079) registered CDM projects. Of these, only one project is found in Tanzania.

Figure 1.7 Registered CDM projects by region (June, 2008)



Source: UNFCCC (2008)

The potential for CDM in Tanzania can be estimated from various sectors including energy, agriculture, agro-industrial, transportation, industry, forestry, cogeneration, waste management, renewable energy, fuel switch, and retrofitting (VPO, 2007). Successful implementation of CDM in Tanzania may stimulate new investments in various sectors, facilitate access to new technologies and access to modern energy, create new employment opportunities, and assist in poverty reduction. Presently, there are a few proposed CDM project in the country that are in different stages of development, as shown in Table 1.3

Table 1.3 Proposed CDM project activities in Tanzania

Title	Status	Type	Scale	Years	Developers/Consultants
Landfill gas recovery and electricity generation at "Mtoni Dumpsite", Dar es Salaam (Ref. 908)	Registered	Waste management	Large	10	Biotecnogas as PDD Consultants
Afforestation in grassland areas of Uchindile, Kilombero, Tanzania & Mapanda, Mufindi, Tanzania	PIN not approved; Opted voluntary market	Afforestation	large	20	Green Resources as PDD Consultants
Tanzania Planting Company (TPC) Moshi-Bagasse cogeneration	PIN submitted but not approved	Renewable energy	??	??	TPC
200MW Singida Wind Farm	PIN submitted	Renewable energy	large	??	Wind Energy Tanzania Ltd/ CAMCO International
Biogas and energy production from sisal waste	PIN stage	Renewable energy	small	??	Katani Ltd (Sisal Production Company)
Vingunguti Landfill Gas Capture and Power Project	PIN stage	Waste management	small	??	Mwanguya and Kyoto Works
Biomass Cogeneration Project, Tanga Cement (17.5 MW)	PIN stage	Renewable energy	Large scale	??	Tanga Cement Ltd
Use of Biolatrine for methane capture and destruction at 5 Prisons in Arusha, Moshi and Tanga	PIN stage	Waste management	small	??	Carmatec Ltd, Arusha
Zege 70kW Microhydro	PIN stage	Renewable energy	Small scale	??	TaTEDO
Forest Plantation in Kimange, Kwang'andu & Rupungwi in Bagamoyo	PIN stage	Afforestation	??	??	Community Development Corporation Ltd.
Fuel Switch from Diesel Gensets to Gas at Mtwara and Lindi	PIN stage	Fuel Switching	Large scale	??	Artimus Tanzania Ltd
Same and Mwanga Forest Project	??	Afforestation	??		Safari Jet Services Ltd
Tanzania Biomass Energy Efficiency Improvement	??	Biomass energy	??		TASONABI

Source: Designated National Authority, Vice President's Office (2007)

The major challenges that make Tanzania unable to utilize CDM advantages effectively are a lack of interest in CDM by key stakeholders (both private and public sectors) and a lack of the expertise necessary to initiate and implement CDM projects. Essentially, the formulation and successful implementation of a CDM project activity requires adequate understanding and knowledge of various key elements of CDM. Specifically, it requires that the project developers should have sufficient knowledge that they are able to identify appropriate project opportunities that could be eligible under CDM; execute legal and regulatory mechanisms associated with implementation of potential CDM projects; and identify and evaluate specific requirements for a CDM project, such as the evaluation of technological, economic, environmental, and social issues of a CDM project activity, as required by Kyoto Protocol.

These factors are important especially in ensuring and facilitating the approval of CDM projects by the DNA and registration of the project by the CDM Executive Board. It should be remembered here that a project that fails to meet '*a must*' criteria of a typical CDM project activity will never be a CDM project.

Importantly, a well selected project activity and a neatly prepared PDD based on the factors mentioned above will eliminate another huge challenge of CDM development in Tanzania, which is the lack of funding to support CDM projects implementation. This is based on the fact that there has been a tendency for financial institutions and potential buyers of emission credits to be reluctant to engage in CDM financing activities due to risks associated with the project benefits and long term existence (UNEP, 2007). Mainly, this has been attributed to failures of project developers to produce genuine project proposals justifying fundamental requirements of the particular CDM project activities.

1.6 Objectives and research question

Several key issues have been introduced in the previous sections of this chapter in order to define the scope of this study. From these key issues three major themes can be developed;

i. Growth potential of the sisal industry in Tanzania: this has both positive and negative effects: the positive effect is helping the country's economic growth due to an increase in fibre production, and the negative effect is its contribution to environmental pollution as a result of the uncontrolled disposal of sisal waste. The latter effect is a concern of this study. The study approaches this by focusing on the utilization of sisal waste in biogas and energy generation to reduce their impacts on the environment.

ii. Problem of GHGs and climate change - this is contributed to by an increase in the generation and emissions of GHGs into the atmosphere by various anthropogenic activities including sisal production, which happens in sisal waste disposal sites. This study aims to analyse this using the concept of CDM.

iii. CDM development in Tanzania - it was shown that only 25 of the 953 registered CDM projects are located in Africa, out of which only one is found in Tanzania. That means the country is lagging behind and is yet to exploit the benefits of CDM. The key barriers to CDM development were identified as lack of interest and expertise in CDM by key stakeholders. This leads to a lack of investment in CDM projects despite the presence of the high potential for CDM in the country. This project may contribute to the body of knowledge on CDM through analysing key issues required for a successful sisal waste CDM project in Tanzania.

Based on the above themes, this research aims to analyse the possibility of implementing successful CDM projects based on the generation of biogas and electricity from sisal waste in four sisal estates in the Tanga region, Tanzania. The research question to be followed by this study is:

Is it feasible to implement the CDM projects based on biogas production and electricity generation from sisal waste in Tanzania?

To answer the above research question and to achieve the study's aim, the following are the major objectives of the research:

i. to estimate the greenhouse gases (GHGs) emission reductions if the sisal waste is used in biogas production and electricity generation in the selected sisal factories in Tanzania.

ii. to examine the viability of implementing a sisal waste CDM project in the selected case study in by assessing key factors such as the project additionality and the sustainable development impacts of the project with the intention of developing materials relevant for preparing the PDD for the sisal waste CDM project. Together with this, the feasibility studies on economic, risk and barriers, and socio-economic impact of the CDM project will be conducted.

1.9 Research's structure

This research report consists of eight chapters including this introductory chapter, which introduces the study by identifying the key issues to be dealt with in this research. The second chapter describes the key concepts, methodologies, and tools used in executing key calculations mainly those involved with GHG emissions. It also describes the approach applied in analyzing the data and the methods used in data collection.

Having introduced the study and described the concepts and methods, Chapter Three is dedicated to the description of biogas production technologies where various technological concepts on biogas are examined. In this chapter, there is also a description of specific factors concerning sisal biogas technology.

In Chapter Four there is a detailed description of key elements of CDM. Concepts such as additionality, baseline scenario, and sustainable development impact criteria of a CDM project are described. In Chapter Five, the case study is assessed. Together with the previous chapters, this chapter adds more materials relevant for Chapter Six which offers a feasibility analysis for CDM possibility in Tanzania. Importantly, the key factors to be analysed in Chapter Six include the economic feasibility of the proposed sisal waste CDM project, barrier and risks, and the socio-economic impact of the project. After this chapter, there is a conclusion chapter where all the issues described and analysed in this report are summarized. Basically, this final chapter uses the summaries and key points from each chapter to conclude the study. Other important segments of this research report include the appendices and the references, which are provided in the final pages after the conclusion chapter.

2

Methodological Framework

This chapter describes the key methods, models, and tools applied in this study. Specifically, the chapter describes the methods used in data collection and introduces the methodologies and tools applied in executing key calculations for CDM. Basically, the CDM methodologies and tools introduced in this chapter were strategically chosen from various UNFCCC approved methodologies and tools for calculating baseline emissions for CDM project activities globally. In addition, this Chapter describes various approaches applied in analysing the data including the SWOT analysis.

2.1 Data collection methods

Two methods were used to collect data for this research: field work and a literature review. The fieldwork involved travelling to Tanzania while the literature review involved reviewing relevant books and academic materials. The data collection methods are described in detail below.

2.1.1 Fieldwork

Three major activities were conducted during the fieldwork in Tanzania including conducting interviews with key people and making observations of the situations. General and specific descriptions of the aforementioned activities are presented below.

Interviews: Interview, as a method for data collection, is suitable for collecting different types of information, both qualitative and quantitative. In doing the interviews, an interviewer can 'judge the quality of the responses of the subjects, to notice if a question has not been properly understood, and to reassure and encourage the respondent to be full in his/her answers' (Walliman, 2005). Basically, there are three major types of interview: structured, semi-structured, and open-ended/unstructured (Walliman, 2005). The interviews can be conducted either on a face-to-face basis or by telephone depending on factors such as accessibility to interviewees, budget, and how quickly the required data need to be obtained. Furthermore, the type of interview to be employed by a particular research depends largely on the type of information to be elicited.

Basically, the structured interview is applied when very precise answers are required to very precise questions, where the closed questions must be formulated (Walliman, 2005). The open-ended/unstructured interview is useful when the information sought is unpredictable (Yin, 2005). In other words, this method is advantageous when the interviewer needs more flexibility during the interview while avoiding restricting him/herself to a certain defined set of questions that could lead to a lack of adequate relevant data. The semi-structured interview lies between the two types of interviews just mentioned, whereby some specific information can be obtained based on a set of defined questions, and additional information can be gathered through open-ended questions (Yin, 2002; Walliman, 2005).

This research employed a semi-structured interview method in the data collection. This method was purposely applied to ensure that all quantitative data relevant for the study were obtained. The specific interview guidelines can be found in the appendices (see Appendix I). The qualitative data were collected without using the closed questions found in the interview guidelines; instead, the questions were posed to the respondent based on the type of information needed and the real situation on the ground. At least four interviews where conducted during the fieldwork. People interviewed in this study included biogas experts, CDM stakeholders, and sisal industry experts. Both biogas and sisal industry experts were interviewed in the Tanga region where the case study is located while the CDM stakeholders were interviewed in Dar es Salaam. Other relevant data that were not obtained in the field for various reasons were requested through e-mails and telephone conversations.

Direct observation: The direct observation method is one of the quickest and most efficient methods of gathering preliminary knowledge or assessing of the situation to be studied (Walliman, 2005). Observational evidence is useful in providing invaluable information on the topic being investigated (Yin, 2002). Observation may occur in two forms: one involves the participation of the researcher in the events and the second involves detachment from the event. Mainly, the observation method can be useful when the researcher is trying to understand the situation based on the action rather than on verbally explained knowledge or knowledge derived from the literature (Yin, 2002).

To a significant extent, this study employed the observation method, especially in the case areas. Various key issues relevant to the study were observed during the fieldwork including the pilot biogas facilities at the Hale sisal estate in Tanga, biogas production processes, sisal growing, sisal processing activities, and sisal waste management mechanisms. Through observation it was also possible to take the various photographs that have been used in several chapters of this research report.

2.1.2 Literature review

The literature (i.e., books, research report, memoranda, letters, presentations, agendas, and other documents) plays an important role in research studies (Yin, 2002). In any research, conducting a literature review helps to retrieve specific details used to corroborate the evidence and facts collected using other methods, such as interview, observation, or survey (Walliman, 2005).

In this study, much of the literature review was conducted purposely to obtain information that was not could not be obtained using interviews and observations. Specifically, the literature review was used to gather information on the concepts of CDM, climate change, CDM methodologies and tools, methane emission from sisal waste, and biogas production technologies. Some of the literature was accessed electronically through the internet search and some physically from various sources.

2.2 CDM methodologies and tools

This section presents the CDM baseline methodologies and tools applied in this study. As mentioned earlier, the methodologies and tools applied in this research project are UNFCCC approved methodologies for CDM project activities globally. The methodologies consist of a number of formulae for calculating baseline emissions, project emissions, and leakage emissions. Basically, the chosen methodologies were considered based on the two major baseline scenarios examined in this study. These scenarios are described further in Chapter Five, but they are mentioned below so as to allow the methodologies to be described later.

1. Avoidance of methane emission from the sisal waste disposal sites. In this, it is assumed that, in the absence of proposed CDM project activity, the current practice of dumping sisal waste at the disposal site would continue resulting in the generation and emission of methane into the atmosphere.

2. Reduction of CO_2 emission by avoiding/or replacing electricity production from fossil fuels in the national electricity system. In this, scenario, it is assumed that, in the absence of CDM project activity, the grid capacity would be fulfilled by the old or newly grid-connected fossil fuel sources.

Further to the above two baseline scenarios, this study analysed two other possibilities for GHG mitigations through sisal waste CDM projects: (i) reduction of N_2O emissions from agricultural fields by replacing nitrogen rich fertilizers with organic fertilizers obtained from the biogas production process and (ii) avoidance of methane emissions by flaring biogas produced from sisal waste. In dealing with these two scenarios, there is no intention to apply any approved methodology or tool to calculate the baseline emissions. Instead, these two options are dealt with only when assessing the various socio-economic benefits for the proposed sisal waste CDM project activity. This will involve various calculations to estimate the impacts of the proposed project on improving peoples' livelihood. The methodologies and tools for the chosen two baseline scenarios are described below.

2.2.1 Avoidance of methane emission from the sisal waste disposal sites

In this scenario, a UNFCCC approved methodology III D (Methane recovery from agricultural and agro-industrial activities) is applied (this methodology is found here: http://cdm.unfccc.int/methodologies/SSCmethodologies/index.html). This methodology is chosen since the proposed CDM project is an agro-industrial processing activity involving the mechanical extraction of sisal fibres from sisal leaves. Using this methodology, the emission reduction achieved by the CDM project can be estimated by subtracting the project emission and leakage emission from the baseline emission (UNFCCC, 2007).

$$ER_{y,\ estimated} = BE_y - PE_y - Leakage$$

where:

ER$_{y, estimated}$ – estimated emission reduction in year y,

BE$_y$ - baseline emission in year y, and

PE$_y$ - project emission in year y.

The BE$_y$ represents the emission of methane that would occur after the anaerobic decomposition of sisal waste at the disposal sites following a series of reactions. In its simplest form, methane production at the solid waste disposal site follows the phases shown and presented in Figure 2.1 (Bingemer and Crutzen, 1987):

1. Initial adjustment: Organic biodegradable components in the waste called degradable organic carbons (DOCs) undergo microbial decomposition in an aerobic condition (in the presence of oxygen gas) soon after they are put into the disposal site,

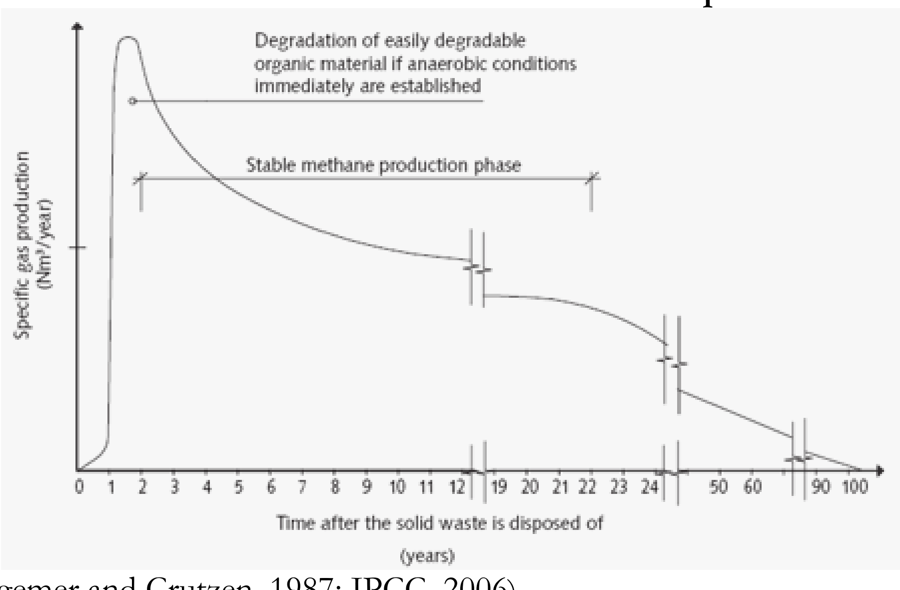
2. Transitional phase: Oxygen depletion and anaerobic digestion commence with the help of anaerobic digestion bacteria,

3. Acid phase: Hydrolysis of high mass compound takes place and its products are mostly acids,

4. Methane fermentation phase: Special type of bacteria convert the acid produced in the stage 3 into methane and CO_2, and

5. Maturation phase: Final phase where the rate of methane formation diminishes since most of the DOCs have been decomposed in the previous phases and the amount left in the disposal site is slowly degrading.

Figure 2.1 Production of methane from the solid waste disposal site



Source: (Bingemer and Crutzen, 1987; IPCC, 2006)

There are several models describing the formation and emission of methane gas from the disposal site, such as the Mass - balance model of IPCC, the First order decay (FOD) model of IPCC, the Scholl Canyon kinetic model, and so on. The FOD model and the Scholl Canyon kinetic model follow more or less a similar principle where the time factor of the degradation process is taken into account. Using the FOD model specifically, it is believed that the DOC degrades progressively during the first few years of waste in the disposal site thus increasing CH_4 generation, but as the DOC content in the waste declines, CH_4 generation is also reduced (IPCC, 2006). The FOD model is thought to produce better estimates on annual methane emissions than does the Mass – balance model (ibid).

The idea behind the Mass - balance model is that the flow rate of waste into the disposal site is equal to the outflow and that all generated CH_4 is released the same year the waste is dumped into the disposal site. Thus, the mass – balance equation does not consider the timing of the biological reactions that lead to CH_4 formation at the disposal site. If waste quantities and waste composition remain constant throughout the years, the mass-balance model would produce the correct results.

Based on the above facts, this study estimates the BE_y using the FOD. The IPCC and UNFCCC have developed a simple approach to estimate the amount of DOC in the waste, methane generation from DOC, and CH_4 emission from the disposal site using the FOD model. Importantly, a generalized method to calculate the baseline emissions is clearly presented in a UNFCCC methodological tool called 'tool to estimate methane emission from dumping of waste at the disposal sites (this too is found here: http://cdm.unfccc.int/methodologies/SSCmethodologies/index.html). The various aspects of the FOD model and its associated methods are presented below.

i. Decomposable degradable organic carbon (DDOC) in the waste

As just mentioned, the DOC is a key determinant for methane production from waste. This is represented as $DDOC_m$ in the FOD model where *m* stands for the mass of waste that can degrade under anaerobic condition into methane. Other factors influencing methane generation at the disposal site includes, the amount of waste that is disposed at the disposal site each year and the implemented methods for waste management (IPCC, 2006). The $DDOC_m$ is calculated using the following IPPC developed formula.

$$DDOC_m = W_y \cdot DOC_w \cdot DOC_f \cdot MCF$$

where:

W_y - amount of waste dumped at the disposal site in year y,
DOC_w - weight of degradable organic carbon in the waste,
DOC_f - degradable organic carbon that decomposes (fraction), and
MCF - methane correction factor (i.e., section of the waste that decomposes under aerobic conditions before the system turns anaerobic).

ii. Methane generation from decomposable degradable organic carbon ($CH_{4\ generat}$)

After calculating the amount of $DDOC_m$ in the waste material, the following step is to estimate methane generation from the $DDOC_m$ using the following formula (IPCC, 2006):

$$CH_{4\ generat,y} = DDOC_{m\ decomp,y} \bullet F \bullet 16/12$$

where:

$CH_{4\ generat,y}$ - amount of CH4 generated from $DDOC_m$
$DDOC_{m\ decomp,y}$ - $DDOC_m$ decomposed in year y
F - fraction of CH_4, by volume, in generated gas from the disposal site
16/12 - molecular weight ratio of CH_4/C

Based on the assumption that simply the presence of $DDOC_m$ in the waste predicts methane production from the waste disposal site, the $DDOC_{m\ decomp,y}$ is calculated using the following formula (IPCC, 2006).

$$DDOC_{m\ decomp,y} = DDOC_{ma,y-1} \bullet (1 - e^{-k})$$

where:

$DDOC_{ma,y-1}$ – $DDOC_m$ accumulated in the disposal site at the end of the year (y-1),
k - decay rate of waste, and
e - exponential constant.

iii Methane emission from the disposal site

Having estimated the amount of methane produced from the decomposable degradable organic carbon in the waste material, finally the amount of CH_4 emitted from the waste disposal site in a particular year is estimated by applying the following formula (IPCC, 2006):

$$CH_{4\ emissions} = (CH_{4\ generat,y} - f_y) \bullet (1-OX_y)$$

where:

$CH_{4\ emissions}$ - methane emitted in year y
$CH_{4\ generat,y}$ – amount of methane generated in the disposal site in year y
f_y - fraction of methane recovered at the disposal site and used in other ways in year y (note that this is applied only when mechanisms to recover methane from waste are installed at the disposal site, otherwise it is insignificant)

OX_y - oxidation factor in year y (this accounts for a failed methane emission by being oxidized to carbon dioxide in the top layers of the disposal site; in most cases it is insignificant)

By combining the above individual methods, a generalized method shown below is applied to calculate the baseline emission for a sisal waste CDM project in a particular year y during the project lifetime (UNFCCC, 2008).

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

Where:

$BE_{CH4,y}$ - baseline emissions of methane from sisal waste in year y (tCO2e),
φ - model correction factor to account for model uncertainties,
f_y - fraction of methane recovered at the disposal site,
GWP_{CH4} - global warming potential of methane,
OX - oxidation factor
F - volume 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),
k_w - decay rate for the sisal waste,
y - year for which CH_4 emission is calculated, and
e - exponential constant (2.718).

The project emissions in the year y (PEy) refer to the emissions that may occur when the CDM project is operational as a result of technologies/processes used by the project (UNFCCC, 2007). For the proposed sisal biogas plants, the PEy is estimated to be zero as no onsite emissions are expected within the boundary of the project. On the contrary, the leakage emissions refer to emissions that occur outside the boundary of the CDM project but are attributable to the project activities (UNFCCC, 2007). The UNFCCC estimates that the leakage emissions for small scale CDM project activities are minimal and therefore a default value of zero is used; for large scale CDM projects, the potential leakage emission must be included in the calculation of ER (UNFCCC, 2007). Leakage emissions can be caused, for example, by emissions produced by the vehicles used in transporting waste from the production site to the treatment plant. In the situation where waste is produced and consumed onsite without the need for any mechanical transportation, as in the case of sisal biogas plant, the leakage emission is zero.

Based on the above descriptions of $BE_{CH4,y}$, (PEy), and leakage, the method for estimating the emission reduction (ER) that would have occurred at the waste disposal site in the absence of CDM project activity in year y is as follows:

$$ER_{, y, estimated} = BE_{CH4, y}$$

where:

$ER_{, y, estimated}$ – estimated emission reduction in year y, and

BE_y - baseline emission in year y.

2.2.2 Reduction of carbon dioxide emission from grid sources

In this baseline scenario, an approved methodology I.D (i.e., Grid connected renewable electricity generation) is used. This methodology is applicable only to small scale CDM project activities that have the installed capacity of 15 MW or less. This criterion is fulfilled by the proposed sisal waste CDM project, which is expected to have a total installed capacity of 8 MW. In this case, the baseline emission is calculated using the following formula (UNFCCC, 2008):

$$BE_y = EG_y \bullet EF_y$$

where:

BE_y - baseline emission in year y (tCO_2/MWh),

EG_y - total electricity generated by the project in year y (MWh), and

EF_y - grid emission factor in year y (tCO_2)

Total electricity generated by the CDM project in year y (EG_y) can be calculated simply using the project specific data for that year. However, in the case of the grid emission factor, data on the national electricity system must be used. The two options detailed below can be followed to calculate the grid emission factor depending on the availability of key data. This study employs the second option due to the lack of key data for option one.

Option one: Using this option, the grid emission factor is the weighted average emission (in $kgCO_2$ e/kWh) of all existing generation units in the system (UNEP, 2005). The grid emission factor is calculated as the sum of total emissions from each unit divided by the sum of their generations in that year (UNEP, 2005). The total emission from each unit is estimated as the product of total fuel consumed by the units and carbon intensity of the fuel (ibid)

Option two: Following this option, the grid emission factor is the average of the approximate operating margin (OM) and the build margin (BM) (UNEP, 2005). These values are calculated using a UNFCCC tool called "tool to calculate the emission factor for an electricity system" which is found at this site: http://cdm.unfccc.int/methodologies/SSCmethodologies/index.html.

Using the second option, the grid emission factor can be calculated using the most recent available data before the start of the project (i.e., three years back) or data from when the project is operational. The following steps can be followed to calculate the grid emission factor.

1. Describe the electric power system.
2. Select OM method.
3. Calculate the OM emission factor.
4. Identify power plants to for BM calculation.
5. Calculate the BM emission factor.
6. Calculate the CM emissions factor/Grid emission factor.

By definition, the OM refers to a group of power plants feeding the grid whose capacity would be affected by the proposed CDM project activity (UNFCCC, 2007). The BM refers to a group of new recently built power units whose capacity would be affected by the proposed CDM project activity (ibid). The weighted average of the emission factors for both OP and BM gives a combined margin (CM) emission factor, which is the grid emission factor. The OM emission factor can be calculated using one of the following methods depending on the characteristics of the country's grid and the availability of key data (UNFCCC 2007).

i. simple OM,
ii. average OM,
iii. dispatch data analysis OM, or
iv. simple adjusted OM

Option one can be used only if low cost must run (LCMR) plants constitute less than 50% of the total grid generation based on long-term averages for hydroelectricity generation (UNFCCC, 2007). The LCMR units are ´´power plants with low marginal generation costs or power plants that are dispatched independently of the daily or seasonal load of the grid, e.g., hydro, geothermal, wind, nuclear, and solar generation ´´ (UNEP, 2005). Option two (average OM) should be used if the LCMR plants constitute more that 50% of the total grid generation (UNFCCC, 2007).

The dispatch data analysis OM emission factor is estimated based on the power plants that are actually dispatched at the margin every hour the grid electricity is displaced by the CDM project (UNFCCC, 2007). Thus, annual monitoring of hours displacement is needed to ensure proper recording. The simple adjusted OM emission factor is a variation of option one, in which the power plants' local and imports are separated in LCMR plants and other power sources (ibid).

In countries such as Tanzania where the grid data are inconsistent, it is difficult to use options three and four. Options one and two are relatively simple as alternative tracks can be followed to fit in the data available at the time of calculation. This study uses option two due to the fact that the Tanzanian grid is contributed to by more than 50% by LCMR resources (tanesco.com, 2008). Based on the available data on grid production and capacity, the following formulae are used to calculate the average OM emission factor (UNFCCC, 2007):

(a)

$$EF_{grid,OMaverage} = \frac{\sum_{i,y} EG_{m,y} \bullet EF_{EL,m,y}}{\sum EG_y}$$

(b)

$$EF_{EL,m,y} = \frac{EF_{CO2,m,i,y} \bullet 3.6}{\eta_{m,y}}$$

where:

$EF_{grid,OMaverage,y}$ - average OM emission factor in year y (tCO_2/MWh),

$EF_{EL,m,y}$ - CO_2 emission factor of power unit m in year y (tCO_2/MWh)

EG_y - net electricity delivered to the grid by all power sources in year y (MWh),

i - all fuels used in power units in the grid in year y, and

y - most recent years for which data is available.

$\eta_{m,y}$ - average net energy conversion efficiency of power unit m in year y (%)

The build margin emission factor can be estimated by including either of the following lists of power plants (UNFCCC, 2007)

i. Five recently built power plants (i.e., they should not be registered as CDM projects).
ii. Recently built power plants that comprise 20% of the total grid generation (in MWh)

The following formula is used to calculate the build margin emission factor (UNFCCC, 2007):

$$EF_{grid,BM,y} = \frac{\sum_m EG_{m,y} \bullet EF_{EL,m,y}}{\sum_m EG_{m,y}}$$

where:

$EF_{grid,BM,y}$ - build margin CO_2 emission factor in year y (tCO_2/MWh),

$EG_{m,y}$ - net quantity of electricity generated and delivered to the grid by power unit m in year y (MWh),

$EF_{EL,m,y}$ - CO_2 emission factor of power unit m in year y (tCO_2/MWh),

m - power units included in the build margin, and

y - most recent historical year for which power generation data is available.

Lastly the CM emission factor for the grid in year y is calculated using the following formula (UNFCCC, 2007):

$$\boldsymbol{EF_{grid,CM,y} = EF_{grid,OM,y} \bullet w_{OM} + EF_{grid,BM,y} \bullet w_{BM}}$$

where:

$EF_{grid,BM,y}$ - build margin CO_2 emission factor in year y (tCO_2/MWh),

$EF_{grid,OM,y}$ - operating margin CO_2 emission factor in year y (tCO_2/MWh),

w_{OM} - weighting of operating margin emissions factor (%), and

w_{BM} - weighting of build margin emissions factor (%).

2.3 Analytical approach

This study conducts feasibility analysis for possibility of CDM through sisal waste. Data and results obtained from various calculations will be analysed both quantitatively and qualitatively using various concepts relating to economics, structural, and socio-economic development. The analysis will be conducted by focusing much on answering the research question and meeting the objectives of the research. Basically, the general data relating to CDM will be analysed by being linked with the specific data obtained from the case study. The aim is to examine the applicability of the generic CDM data in the Tanzanian context through sisal waste CDM project possibility.

In addition to that, the SWOT analysis is applied to analyse the possibility of implementing the CDM project based on various results obtained from various analyses done in this study. The acronyms SWOT stands for strengths, weaknesses, opportunities, and threats. The SWOT analysis is analysis of these four parameters. SWOT analysis is an extremely useful tool for understanding and decision-making for all types of situations in projects, business and organizations (Chapman, 2008). Basically, this method is applied in business planning, strategic planning, marketing planning, and product development (ibid). For this study, which is mainly focusing on planning for implementation of sisal waste CDM project in Tanzania, SWOT analysis will help to understand that possibility.

3

Biogas Technology

This chapter describes different aspects of biogas production and consumption. First, the chapter gives a general overview of biogas technology – 3.1; then describes different types of reactor technologies applied worldwide – 3.2; and explains various ways of utilizing biogas – 3.3. Lastly, the chapter identifies and illustrates key features of a typical sisal biogas plant in Section 3.4.

3.1 Overview of biogas technology

In this section, a general overview of biogas technology is provided. Specifically, the section describes different types of feedstock and biodegradability characteristics, explains key steps of anaerobic digestion, and describes factors known to influence biogas production. Apart from giving general information, this section provides specific information for sisal waste characteristics as well.

3.1.1 Feedstock and biodegradability

Biogas technology refers to the production of biogas and organic fertilizer from organic wastes. The biogas is produced as a result of a controlled anaerobic decomposition of organic waste, while fertilizer is a by-product of the process. The produced biogas can be used as fuel to generate electricity or heat, or both in a combined heat and power (CHP) system. Electricity can be exported to the grid or consumed onsite while heat is used for the digester or district heating. The produced organic fertilizer can be utilized as manure in farms replacing chemical fertilizers, which have negative impacts on the environment. Various organic wastes can be used as feedstock in anaerobic decomposition; they can be divided into three main categories (Nijaguna, 2006):

1. Land based – includes energy crops and their wastes (e.g., maize, wheat, sugar cane, weeds, corn, palms, and so on), forest litter, agro-industrial wastes (e.g., sisal waste, oil cakes, bagasse, rice bran, tobacco, seeds, fruits, vegetable, tea, cotton dust);
2. Animal based – includes animal wastes (i.e., dung, urine, and litter), human wastes (i.e., excreta and urine), poultry litter, fishery wastes, and slaughterhouse waste; and
3. Water based material – includes marine algae, sea weeds, and water hyacinth.

Depending on the type of feedstock used in the anaerobic digestion system, various factors must be considered, especially regarding the selection and treatment of the feedstock. This is important so as to ensure the easy digestibility of the feedstock when put into the digester. The quality of the feedstock in terms of contents of degradable organic compounds largely determines the biogas production potential of the anaerobic digestion system (Nijaguna, 2006). The wastes generated from processing land-based feedstock like sisal waste normally consist of a large amount of non-degradable compounds compared to other types of waste (McDonald *et al.,* 1991). These wastes can be regarded as moderately degrading feedstock as it takes a little more days and a few more months/years to decompose when put into the digestion system or in the disposal sites respectively (UNFCCC, 2006; Nijaguna, 2006).

Normally, the major compounds contained in the feedstock are lignocelluloses (i.e., lignin, cellulose, and hemicelluloses), non-structural carbohydrates (i.e., glucose, sucrose, and fructose), proteins, and lipids (Lehtomaki, 2006). The pre-digestion treatment of certain types of feedstock can secure the digestion process since the complex compounds are broken down into smaller easily degradable elements (Lehtomaki, 2006; McDonald, *et al.*, 1991). Basically, the pre treatment increases the surface area for micro-organisms to act upon the feedstock (ibid). The pre-treatment of the feedstock may be conducted using the various techniques mentioned below (Nijaguna, 2006)

1. Biological – processes such as pre-composting and microbial delignification using various techniques such as storing bedding waste deep underground for a specific period of time. Biological pre-treatment is a highly favoured method as its relatively cheap and fast compared to others.
2. Physical – this involves processes such as crushing and chopping the feedstock materials into smaller sizes. This method is not a favoured mechanism as it is an energy intensive process and the increase in gas production is not proportional to the energy invested.
3. Chemical – this involves mechanisms such as the addition of acid/alkali into the digester to neutralize the pH. However, due to the high costs of treatment chemicals and the impacts of these chemical on the environment, this method is not widely applied either.

There is a lack of enough knowledge about the biodegradability characteristics of sisal waste as only few studies have addressed this issue (see photo of sisal waste below). The research conducted by Mshandete *et al.* (2008), showed that the digestibility of sisal waste and biogas yield can be enhanced by applying a batch wise (i.e., the intermittent addition of substrate into the digester) co-digestion of sisal waste with fish pulp. The study revealed that there is a considerable increase in sisal waste biodegradability, which could increase biogas production to 59% - 94%, when different mixing ratios are applied (Mshandete *et al*, 2008). Basically, the co-digestive materials supply the missing nutrients to the system and reduce the impact of inhibitory elements present in the substrate (Nijaguna, 2006).

In another study, also conducted by Mshandete *et al.* (2005), it was shown that biogas production and methanization can be enhanced by 26% by pre-treating sisal waste before the start of anaerobic processes using an activated sludge mixed culture under aerobic conditions in batch bioreactors at mesophilic temperature (Mshandete *et al.*, 2005). The key observation is that the solubilisation of sisal waste increases when it is first treated aerobically with an activated sludge mixed culture under controlled conditions (ibid).

Photo 3.1 fresh sisal waste from the decorticator

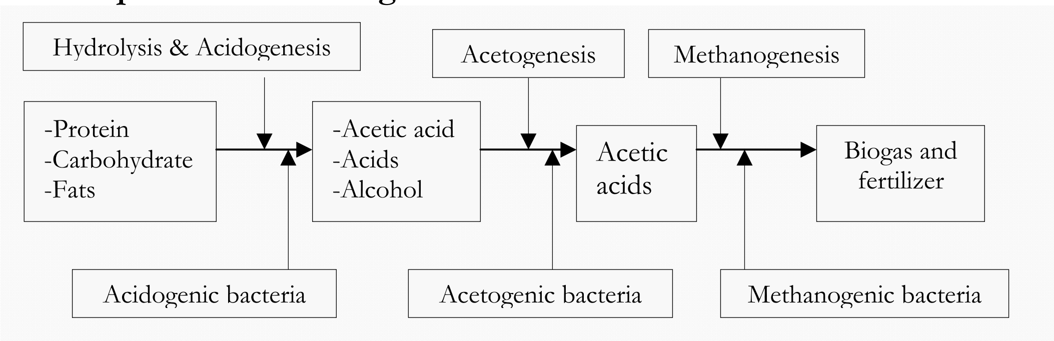
3.1.2 Process of anaerobic digestion

Principally, every anaerobic digestion system (including sisal waste digestion) involves two types of bacteria, namely, acid-forming bacteria and methane-forming bacteria (Nijaguna, 2006). A typical anaerobic digestion system follows the following steps (Thomas *et al.,* 1993; Nijaguna, 2006):

1. Hydrolysis – This is the liquefaction of the biodegradable compounds 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 the hydrolysis stage,
3. Acetogenesis – In this step, acetic/acetate acids and hydrogen are formed from the fatty acids and alcohols produced in the previous steps, and
4. Methanogenesis – In this step, methane and carbon dioxide are formed from the acetic/acetate acids, hydrogen, and alcohols formed in the last stages

Generally, steps 1, 2, and 3 are mainly acid-forming steps whereby complex compounds (i.e., protein, fat, and carbohydrates) are broken down by acid-forming bacteria (acidogenic and acetogenic bacteria) into smaller degradable molecules. The final step is a methane-forming step whereby methanogenic bacteria) convert the acids produced in steps 1, 2, and 3 into CH_4 and CO_2 (i.e., biogas) as shown in Figure 3.1.

Figure 3.1 Steps in anaerobic digestion



The residue left from the process contains at least 70% of nutrients compared to the original waste and they can thus be used as organic fertilizer (Nijaguna, 2006). The residue is often less odorous than the original waste, and thus it is easier to handle and apply it in the farming fields (FAO, 2004). The nutrients contained in the biogas residue include nitrogen, potassium, phosphorous and others required for plant growth (Mata-Alvarez *et al,,* 2000). The estimated value of biogas fertilizer compared to chemical fertilizers is shown in Table 3.1. For sisal waste, the composition of the nutrients is shown in Table 3.2 below. The nutrient composition in the sisal waste biogas residues is estimated by taking 70% of the contents in the original waste. The socio-economic impact of substituting chemical fertilizer with biogas fertilizer will be analysed later in Chapter six of this report.

Table 3.1 Value of biogas fertilizer compared to artificial fertilizers

N, P, K in 1000 kg (dry) biogas residue	Equivalent to chemical fertilizer
17 kg N	37 kg Urea
15 kg P	94 kg Superphosphate
10 kg K	17 kg Potash

Source: Nijaguna (2006)

Table 3.2 Nutrient composition of sisal waste and sisal biogas residues

Nutrient	Composition in waste (kg/ton)	Composition in residue (kg/ton)
Nitrogen (N)	6	4
Phosphorus (P)	1	0.7
Potassium (K)	0.8	0.6
Magnesium (Mg)	1.6	1.1
Calcium (Ca)	25	17.5
Sulphur (S)	2.5	1.75

(Malavolta, 2007)

The produced biogas consists of methane, carbon dioxide, hydrogen sulphide, oxygen and nitrogen. The gas has the characteristics of being clean, flammable, non-poisonous, odourless, and with a density of 1.05 - 1.2 kg/Nm^3 (Nijaguna, 2006). Table 3.3 shows an estimated gaseous composition of biogas. Basically, the higher the amount of methane and the lower the amount of carbon dioxide, the higher the calorific value of the biogas and vice versa (Mata-Alvarez *et al.,* 2000). The comparison of the calorific value of biogas compared with other fuels will be provided later in this chapter.

Table 3.3 Estimated composition of biogas

Gas component	Content in %
Methane, CH_4	50-65 (60% for sisal biogas)
Carbon dioxide, CO_2	25-50 (25-30 for sisal biogas)
Hydrogen, H_2	1.0 (same for sisal biogas)
Nitrogen, N_2	0.5 (same for sisal biogas)
Hydrogen Sulphide, H_2S	0.3 (same for sisal biogas)
Oxygen, O_2	0.1 (same for sisal biogas)

Source: (Mata-Alvarez *et al,* 2000; Katani Ltd, 2008)

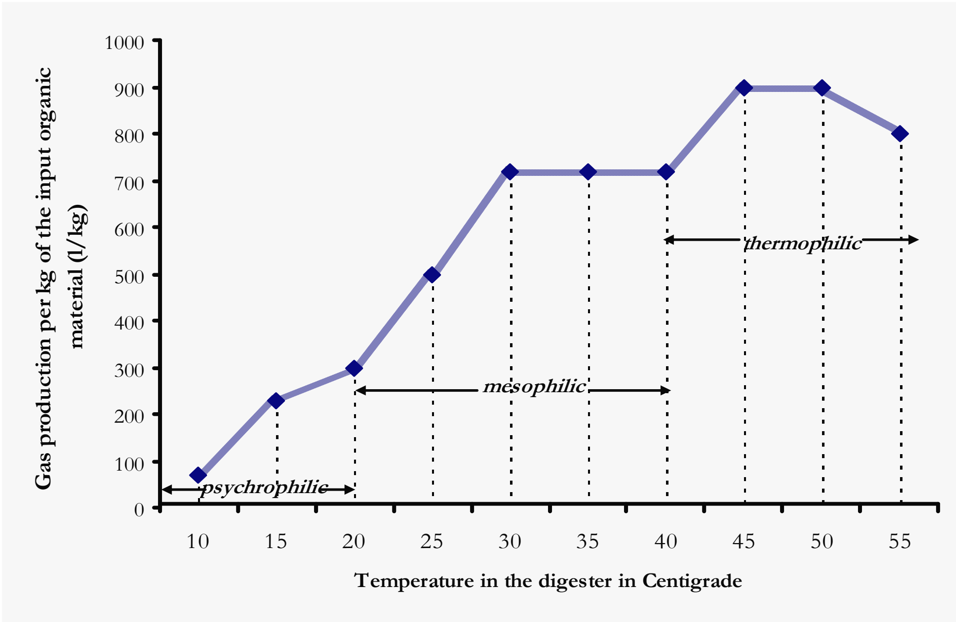
3.1.3 Determinants of biogas production

Apart from the contents of the biodegradable organic compounds in the feedstock, effectiveness in biogas production also relies on several factors including temperature, pH, retention period, water content, presence of toxic materials in the feedstock, and the C/N (Lehtomaki, 2006; Mata-Alvarez *et al.,* 2000; Thomas *et al*, 1993). These factors and their influence on biogas production are described below.

Temperature: The rate of anaerobic digestion is influenced largely by temperature changes since the digestion micro-organisms are active only in a certain range of temperature (Vesilind, 2000). The optimum temperature range helps the solubility of organic compounds and thus speeds up the digestion process. Basically, an increase in temperature leads to an increase in biogas production up to a certain level before production starts to decline (Nijaguna, 2006). Three types of temperature ranges are known in anaerobic digestion systems: psychrophilic (below 20 ºC), mesophilic (20-40 ºC), and thermophilic (40 – 65 ºC) (ibid).

The bacteria active in the mesophilic temperature range are called mesophilic bacteria while those in the thermophilic range are known as thermophilic bacteria. The mesophilic bacteria have the advantage of surviving large temperature fluctuations, and this makes the mesophilic temperature range very common in biogas plants (Vesilind, 2000). On the contrary, the thermophilic bacteria are very sensitive to temperature fluctuations and any sudden change in temperature, say of 3± ºC can stop the digestion process (ibid). At the psychrophilic temperature range, the micro-organisms are inactive and thus cannot contribute to biogas production (see Figure 3.2). In sisal waste biogas technology, both mesophillic and thermophillic temperatures can be applied, though the former has been proved to be more effective than the latter (Katani Ltd, 2008)

Figure 3.2 Influence of temperature ranges on biogas production



Source: Based on data from Nijaguna (2006)

pH: The enzymatic characteristics of micro-organisms involved in anaerobic digestion are largely influenced by pH levels, and any divergence from the optimal pH (i.e., 6.8 -7.5) leads to a drop in their functioning; this directly lowers biogas production (Vesilind, 2000). Basically, the methanogenic bacteria are more sensitive to pH than are acidogenic and acetogenic bacteria who can survive a pH as low as a 5.5 pH (Nijaguna, 2006). Mainly, the acidity is attributed by the concentration of acids produced by the degraded proteins while the alkalinity is mainly added by the produced methane (ibid). In case of high acidity or alkalinity, external neutralizers can be added to restore the pH (Thomas *et al.*, 1993; Nijaguna, 2006). The experience from Hale Biogas Plant shows that, for sisal biogas production, the pH remains more or less neutral during the whole process.

Retention time: Retention time (RT) refers to the number of days the feedstock must remain in the digester and is expressed in days (Nijaguna, 2006). The optimal RT is important to allow micro-organism to regenerate, and any inaccuracy leads to a drop in biogas production. The RT is calculated as the digester's volume divided by the volume of the feedstock added per day. The RT depends on the rate of biodegradability of the feedstock, exposure of feedstock to bacteria enzymes, temperature level, and water content (Nijaguna, 2006). Generally, if all factors remain optimal, a higher RT leads to greater gas production up to a level where production will start to decline (Vesilind, 2000).

Importantly, the RT is a crucial factor in predicting the size of the biogas facility, specifically, the size of the digester tank. Therefore, in this study, in Chapter Five, various retention times are analysed in order to estimate the size of the proposed sisal biogas plants. The estimation will be drawn from the experience from Hale sisal biogas plant (Katani Ltd, 2008).

Presence of toxic material: An excessive concentration of ammonia, cations (Na^+, K^+, and Ca^+), antibiotics, pesticides, and heavy metals like zinc, chromium, and nickel are toxic to the micro-organisms involved in the digestion process (Nijaguna, 2006). Heavy metals are present mostly in industrial waste while pesticides and antibiotics occur mostly in agricultural and animal wastes. As the production of sisal waste does not involve the addition of any kind of chemicals, the produced waste is normally chemical free. Furthermore, in most cases, sisal farming is conducted without the addition of chemical fertilizer or pesticides; this decreases the possibility of any increase in the levels of cations and heavy metals in the waste. However, in cases where chemical fertilizer and pesticides are used in sisal farming, it is important to measure their amount in the waste and also their impact on biogas production.

Water content: Micro-organisms need water in order to survive and be effective since water helps their movement and also the hydration of complex compounds to simplify digestion (Nijaguna, 2006). Basically, when the system contains too much water, the temperature drops and biogas production declines. When the water content is below the optimal level, active acids may accumulate and hamper the digestion process (ibid).

Balancing the water content in the digestion system is crucial since the water content of different types of feedstock varies. For dry feedstock, addition of too much water in the system may cause them to float on the water as most of them have low densities (Jerger and Tsao, 2000). This condition will prevent micro organisms from functioning properly and biogas production will decline. For liquid wastes such as sewage or sisal waste, the water content is already high; therefore, to balance the system, more solids must be added before the start of the digestion process (Nijaguna, 2006). Generally, for most anaerobic digestion systems, including sisal biogas system, the recommended substrate to water ratio is 1:1 and the maximum total solid content is 7 - 9% (Thomas *et al.*, 1993; Katani Ltd, 2008).

3.2 Reactor technologies for anaerobic digestion

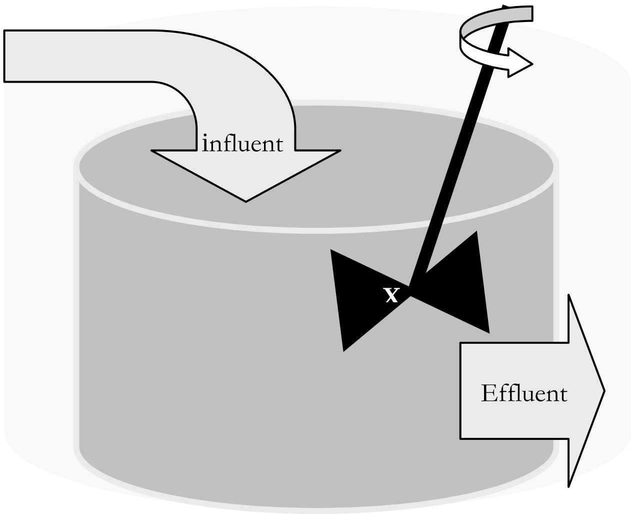
Two types of reactor systems are followed in anaerobic digestion, namely, batch process and continuous process. In a batch process, the feedstock is put into the digester at the start of the digestion process, and then the digester is closed for the whole period without more feedstock being added (Paques, 2007). In this case, the production of biogas tends to be in batches with a low production rate at the start of the process, a high rate in the middle, and a low again at the end when only a little digestible feedstock is left.

In a continuous process, the digester is continuously fed with fresh feedstock and continually emptied leading to constant biogas production (Paques, 2007). There are at least four types of continuous digester technologies applied worldwide including continuous stirred tank reactor (CSTR), up flow anaerobic sludge blanket (UASB), expanded granular sludge blanket (EGSB), and internal circulation reactor (ICR) (ibid).

Continuous stirred tank reactor (CSTR)

In the continuous stirred tank reactor (CSTR), the feedstock fed into the digester is continuously stirred using a motorized agitator (Schmidt, 1998). The essence of stirring is to ensure a proper mixing with the micro-organisms. For an effective functioning of the CSTR digester, it is important to maintain a uniform composition of feedstock in the digester throughout the digestion period. Specifically, there must be an equal flow of material in and out of the digester to avoid a digester overflow or drain (ibid).

Figure 3.3 Continuous stirred tank reactor (CSTR) system

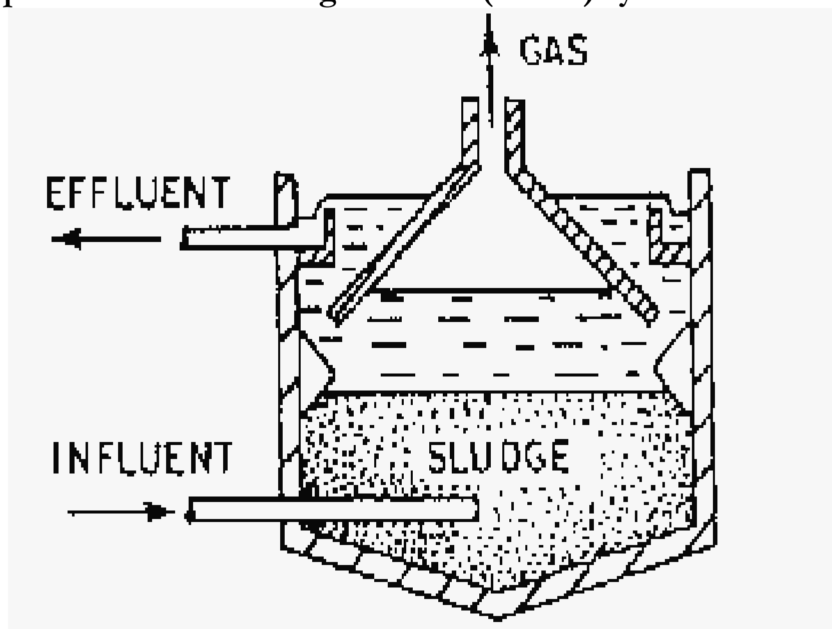


X - Motorized agitator

Up flow anaerobic sludge blanket (UASB)

The distinctive feature of a UASB reactor is the formation of a blanket of dense granular sludge, which is suspended within the digester tank (Kato. *et al.*, 1994). The blanket helps to sustain both liquid and organic materials in the digester (ibid). The feedstock is fed into the digester from below through the influent pipes. Basically, the anaerobic digestion bacteria proliferate on top of granules within several days of RT. The feedstock from below flows upward, passing through the blanket and come into contact with the micro-organisms (ibid). The upward flow plus the forces of gravity within the digester helps to suspend the granular blanket (Lettinga *et al*, 1980). Importantly, to ensure an effective functioning of the UASB, a regular monitoring of the digester is necessary in order to maintain the sludge blanket (ibid).

Figure 3.4 Up-flow anaerobic sludge blanket (UASB) system

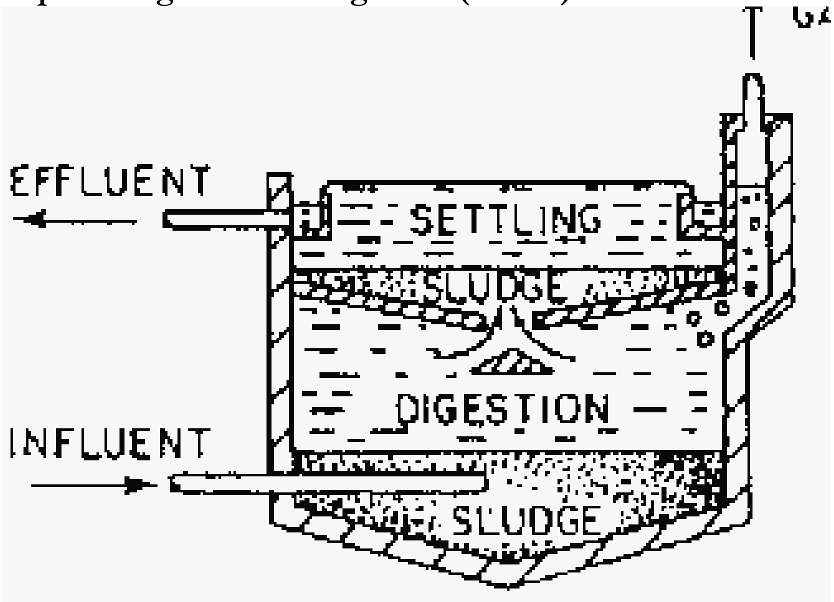


Source: FAO (2008)

Expanded granular sludge bed (EGSB)

The expanded granular sludge bed (EGSB) resembles the UASB technology described above. The basic difference between them is that in EGSB, the upward flow of materials through the granular sludge blanket in the digester is considerably faster than in UASB (Kato *et al.*, 1994). To achieve the fast flow of materials upward, the digester is built by installing tall tanks, or encompassing an effluent recycle, or both (Franklin, 2001). This design increases the expansion of the sludge blanket, improving the waste-sludge contact, facilitating the isolation of inactive particles from the sludge blanket, and finally improving biogas production (Kato. *et al.*, 1994)

Figure 3.5 Expanded granular sludge bed (EGSB)



Source: FAO (2008)

Internal Circulation Reactor (ICR)

The internal circulation reactor (ICR) follows similar principles to those used in UASB and EGSB. The distinguishing feature in this technology is the recycling of waste for further biogas production within the digester (Paques, 2007).

3.3 Utilization of biogas in energy generation

Biogas can be used as a heat source in cooking, water heating, heat pumps, or as fuel in generating electricity using gas engine generators or gas turbines. The energy content of biogas depends on the amount of CH_4 in the biogas, which is flammable. At 60% - 65% CH_4, the biogas has a calorific value of 22 - 25 MJ/m^3 (Nijaguna, 2006). As stated earlier, the net calorific value of biogas increases with the decrease in the contents of CO_2 and the increase in the contents of CH_4 (Lens and Westermann, 2005; Nijaguna, 2006). The effective heat provided by biogas is the highest per unit of most fuels including wood fuel and charcoal (Nijaguna, 2006). Also, depending on the efficiency of the thermal device, biogas competes closely with Liquefied Petroleum Gas (LPG) and kerosene (ibid). Table 3.4 compares the different calorific values of different fuels with that of biogas.

Table 3.4 Comparison of biogas and other fuels

Fuel	Unit	Calorific value (kJ)	Thermal efficiency of device (%)	Effective heat (kJ)
Biogas	m^3	22000	55	11000
Kerosene	ltr	38000	40	15000
Charcoal	kg	29000	30	9000
LPG	kg	45563	55	25000
Electricity	kWh	3600	70	2520
Wood fuel	kg	20000	12	1000

Source: Nijaguna (2006)

In a large scale utilization of biogas, especially in electricity generation, several factors are considered as worthy of note including the cleaning of biogas by removing H_2S, CO_2, and other impurities through a process called scrubbing (Lens and Westermann, 2005). According to Nijaguna, scrubbing can enhance the calorific value of biogas to about 34 – 36 MJ/m^3 (ibid). The essence of scrubbing is to avoid the corrosive effect of H_2S and CO_2 on a plant's equipments such as its gas storage tanks, as both gases can react with moisture and form various acids that readily attack and corrode metals (ibid). Various biogas scrubbing technologies exist and are shown in Table 3.5. .

Table 3.5 Biogas upgrading technologies

Process	Description
CO_2 and H_2S scrubbing	CO_2 and H_2S are adsorbed by means of washing liquid (e.g. water caustic soda solution, Sodium hydroxide, Calcium hydroxide, water, and Monoethanoamine (MEA) washing)
Adsorption	CO_2 are bound at an adsorbent over electrostatic forces, adsorbed
Membrane process, wet	CO_2 and H_2S are separated due to different permeation rates at a membrane and afterwards adsorbed by a washing liquid (MEA)
Membrane process, dry	CO_2 and H_2S are separated due to different permeation rates at a membrane
CO_2 and H_2S liquefaction	Phase separation of liquid CO_2 and H_2S and gaseous methane

Source: Lens and Westermann (2005)

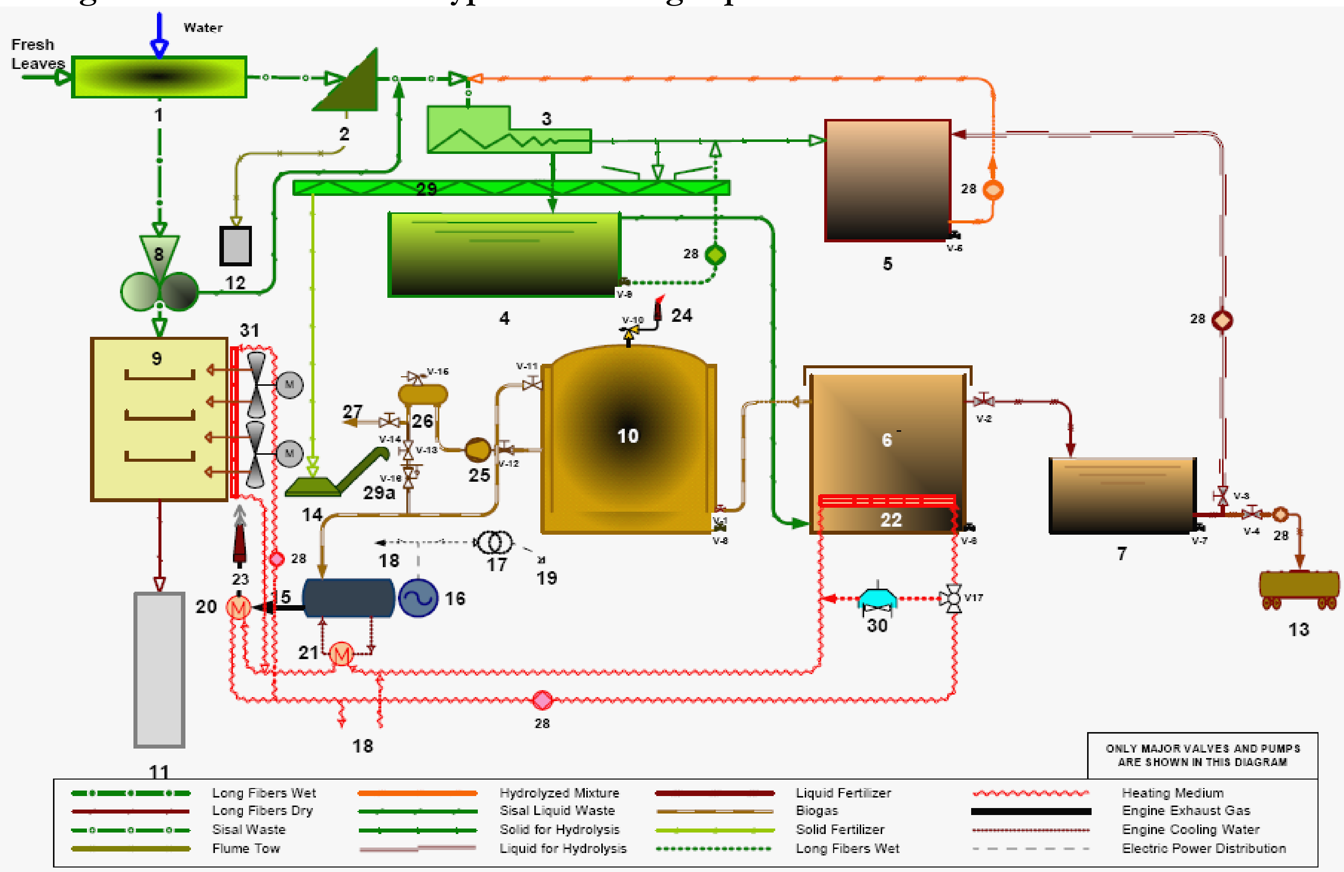
3.4 Key features for a sisal biogas plant

Basically, the key equipments for any biogas plant are similar, though some specific modifications can be introduced based on the type of feedstock to be processed and on the biogas consumption. Any biogas plant would be expected to include the following equipments (CFC and UNIDO, 2004).

- Feedstock storage tank,
- Hydrolysis tank,
- Digester tank,
- After storage tank/Fertilizer tank,
- Gas storage tank,
- Desulphurization tank,
- Flare (if there is any flaring), and
- Biogas engine generator (if biogas is used in power generation)

For a sisal biogas plant, depending on the intended use of the produced biogas (whether energy generation, or flaring, or both), various additional equipments can be installed. Figure 3.4 shows the key equipments for a typical sisal biogas plant and the multi-use options of the produced biogas. Based on the experimental work done by UNIDO, both UASB and CSTR technologies can be applied in sisal biogas production (CFC and UNIDO, 2004). These technologies can be applied at both methophilic and thermophilic temperatures; however, as stated earlier, the methophilic temperature has been found to be more appropriate than the thermophilic. The CSTR technology is currently being implemented at a pilot sisal biogas plant at Hale Sisal Estate in Tanga, Tanzania.

Figure 3.6 Flowchart for a typical sisal biogas plant



1 Decorticator	2 Flume Tow Recovery	3 Screw Separator	4 Storage Tank Inlet
5 Hydrolysis Tank	6 Digester Tank	7 Open Storage Tank	8 Wet Fibre Squeezer
9 Fibre Drying Area	10 Biogas Tank	11 Long Fibres Storage	12 Flume Tow
13 Liquid Fertilizer	14 Solid Fertilizer	15 Gas Engine	16 Power Generator
17 0.4 / 11kV Transfer	18 Estate Power Supply	19 11kV Network Supply	20 Exh. Gas Heat Exchanger
21 Eng. Water Heat Exchanger	22 Digester Heating	23Exhaust Gas Stack	24 Flare Stack
25 Gas Compressor	26 Compressed Gas Tank	27 Estate Housing	28 Fluid Pumpps
29 Conveyor	29a Bevator	30 Water-Air Heat	31 Air Blower

Source: (CFC and UNIDO, 2004)

Functions of key equipments in figure 3.4

1: *Decorticator*: A decorticator is a machine that processes sisal leaf to generate sisal fibre. The decortication process involves an addition of significant amount of waster to lessen the dry sisal leaf for fibre extraction.

2: *Flume Tow recovery*: Some produced watery waste may have large bundles of fibre in it. The flume tow recovery involves the manual reduction of these bundles. After this stage, the waste passes through a screw separator (no. 3) to step four. The flume tow is stored at the flume tow storage area (no. 12)

Photo 3.1 Decortication process and Flume Tow recovery

4: *Storage Tank Inlet*: The required amount of waste from the decorticator is channelled down to the biogas plant and stored in the collection tank. In this tank, some indigestible materials may be released as solid fertilizer (no. 14) by the conveyor (no. 29) and stored in the bevator (no. 29a)

5: *Hydrolysis tank*: Intermittently, waste is released through pipes into the hydrolysis tank from the collection tank. Here, waste is hydrated for easy break down and the pH is kept neutral for optimal functioning of the micro-organisms.

6: *Digester tank*: From the hydrolysis tank, the hydrated waste is channelled into the digester tank. The production of biogas occurs in the digester tank. Here, acidogenic, acetogenic, and methanogenic bacteria decompose the degradable organic materials in the waste to methane and carbon dioxide. The residue materials are channelled into the open storage tank. The digester is also connected to the compressor gas tank (no. 25), which is connected to the estate housing (no. 27) for biogas supply.

7: *Open storage tank*: This is the equipment where the fertilizer produced in the digester is stored, or piped outside to be collected for consumption (no. 13). Some undigested materials may, in some cases, be channelled back to the digester where re-digestion takes place.

10: *Biogas Tank*: From the digester, the produced biogas is treated to remove hydrogen sulphide and then stored in the gas storage tank. The storage tank is connected to the biogas engine (no. 15) and the power generator (no. 16), delivering biogas for energy generation. The generator is connected to the power supply system (no. 17) delivering electricity to both Estate housing (no. 18) and the grid (no. 19). The excess biogas is flared through the flare stack (no. 24) located on top of the gas storage tank and the excess gas stack (no. 23) connected to the generator.

20: *Exhaust Gas Heat Exchanger*: This step, together with step 21 is where heat produced by the biogas engine and generator is captured and transported through pipes to the digester (no. 22) to help activate the fermentation of micro-organisms. Heat transfer to the digester is facilitated by water air heat (no. 30) and fluid pumps (no. 28) connected to the digester heating pipes.

31: *Air Blower*: For optimal consumption of the energy produced from the biogas, the extra heat can be blown by air blower and used to dry wet sisal fibre (no. 8 and no. 9). The dried fibres are stored at the fibre storage area (no. 11)

Summary

This chapter has given an overview of biogas technology, both general and specific for sisal waste. Generally, it has been shown that the efficiency of the biogas plant depends on various key factors including: type of waste/feedstock and its biodegradability characteristics, temperature level in the digester, water contents, pH, retention time, presence of toxic chemicals, and type of reactor technology used. These factors collectively determine the performance of the digester and thus biogas production, and they must be given high priority.

Specifically, it was shown that, sisal waste can be effectively used in biogas production since it has all key characteristics required for anaerobic digestion. However, compared to other technologies, sisal biogas technology is completely new as it is just recently been tasted for the first time in a pilot plant in Tanzania. Though the performance of the technology seems to be more promising but for large scale commercial application of the technology more investments on researches and development are required. Having described the biogas technology, the next chapter, describes key issues on the concept of CDM.

4

Detailed Description of Key Issues of CDM

The general overview of CDM was given in the introductory chapter. This chapter provides a detailed description of key aspects of CDM project activity. Specifically, the chapter explains the complete cycle of CDM project – 4.1; baseline issues in CDM – 4.2; additionality requirement for a CDM project – 4.3; and the contribution of a CDM project to the sustainable development of the host country – 4.4; Lastly, this chapter describes various financing aspects of a CDM project – 4.5 and identifies the key documents required for a successful registration of a CDM project – 4.6.

4.1 The CDM project cycle

There are several key steps through which a potential CDM project must pass before it is able to generate the certified emission reduction (CER). By definition, CERs are carbon credits generated by a CDM project activity; they are expressed in tons of CO_2 equivalent (tCO_2 -e) (UNFCCC, 1997). The steps followed by a CDM project are extremely scrupulous and involve a variety of stakeholders including both local and international entities. These steps include feasibility assessment, design and formulation, national approval, validation, registration, verification, certification, and issuance of CER (ibid). The steps are shown in Table 4.1 and are explained after.

Table 4.1 Key steps in CDM project cycle

Time frame	Project developers	Designated National Authority (DNA)	Designated Operational Entity (DOE)	CDM Executive Body (CDM-EB)
6 - 12 months	1: project feasibility assessment			
	2: project design and formulation			
		3: national approval		
			4: validation	
1.5 months				5: registration
Crediting period			6: verification	
			7: certification	
				8: issuance of CER

Source: based on UNEP (2004) and UNEP (2007)

1: Project feasibility assessment: In this step, the project developers conduct preliminary analyses of key aspects of the project to examine its viability. This involves analyses of the economic and financial costs, such as money to be invested in the project and the anticipated profits. Other aspects assessed in this stage include the technology to be employed, the possible environmental impacts, and the socio-economic impacts of the project on local communities and national at large.

2: Project design and formulation: This step involves the identification or development of baseline and monitoring methodologies, estimations of reductions in GHG emissions, and the development of reports on environmental impacts and a statement of stakeholders' comments, and the presentation of feasibility studies obtained in the previous stage. This key information is compiled in the project design document (PDD) and submitted to the DNA and CDM-EB for approval and registration. Alternatively, the project developers may decide to present the information in the project idea note (PIN) prior to development of PDD.

The DNA is the central authority in the host country responsible for approving potential CDM projects. In Tanzania, the DNA is located at the Vice President's Office, the Division of Environment. The DNA approves the potential CDM projects in consultation with various key stakeholders including the Tanzania Investment Centre, the National Development Corporation, and the National Environment Management Council.

3: National approval: The PDD submitted to the DNA is thoroughly screened to examine the compliance of the project with key CDM criteria. The DNA considers the additionality and the sustainability aspects of the proposed CDM project. The additionality of the project is assessed based on UNFCCC criteria while sustainability is assessed based on the country's SD development criteria. Once the project is approved, the DNA issues a letter of approval confirming that the project will assist in achieving sustainable development and will reduce GHGs emissions.

4: Project validation: An approved project must be validated before it is registered as a CDM project. The designated operational entity (DOE) appointed by the project developers is responsible for validating the project. Typically, the DOE is a private company accredited by the CDM-EB, it can be a consulting firm, a law firm, or an accounting company and it must be capable of carrying out an independent and plausible assessment of GHG emissions reductions (UNEP, 2004). The DOE validate the project based on information in the PDD by examining if:

- parties involved in a CDM project have ratified the Kyoto Protocol
- additionality criterion is fulfilled (see section 4.3),
- the approved baseline/monitoring methodologies have been applied; if a new methodology is used the project developers have followed the UNFCCC modalities and procedure for developing new methodologies,
- the PDD was prepared in a transparent manner by involving local stakeholders,
- The PDD include a report of the environmental impact analysis conducted based on host country's regulations. The report must indicate possible environmental impacts and remedies.
- If the CDM project is not a part of a large scale CDM project (especially for small scale CDM project activities) (UNFCCC, 1997)

When the project is validated, the validation report is produced and forwarded to the CDM-EB for further scrutiny and registration.

5: Project registration: The CDM – EB register/reject the project by reviewing the validation reports provided by the DOE based on the guidance of the Conference of Parties (UNEP, 2004). The registration period ranges between 4-8 weeks depending on the size of the project. Once the registration is confirmed, the project developers start to seek means to finance project implementation. Once the fund is secured and the project is already operational, the project participants monitor the project performance using specified monitoring plan and methodology described in the PDD (ibid)

6: Project verification: Verification of the CDM project is done by the assigned DOE following review of the monitoring report developed by the project participants. For small scale CDM project, the same DOE contracted to validate the project can also conduct verification, for large scale projects, a different verifier should be contracted. Verification is done to determine if whether the registered CDM project has achieved the GHGs emissions as stated in the PDD. Then, the DOE produces a verification report for project certification.

7: Project certification: The project certification is also conducted by the DOE. The DOE produces a certification report which constitutes of a request to the CDM – EB for issuance of CERs equal to the amounts stated in the PDD. To ensure the transparency, the certification report must be made available by all stakeholders.

8: Issuance of CERs: This is a last step of the CDM project cycle. The decision to issue CERs is taken by the CDM – EB within 15 day from the date of receipt of the request for CERs issuance from the verifier (UNFCCC, 1997). Basically, sell of CERs is negotiated by the project owners themselves, especially regarding CERs ownership (whether an investor or developers) and appropriate trading mechanisms (whether a direct sell or through a third party). The process of CERs issuance is controlled by the CDM Registry (UNEP, 2004).

4.2 Small scale CDM project activities

The modalities and procedures for CDM projects identify various types of project which can be undertaken at small scale levels. Small scale CDM project activities are aimed at simplifying registration process and costs associated with CDM through the following:

- Use of a simplified PDD
- Application of simplified baseline and monitoring methodologies
- Possibility to bundle many small scale projects activities during planning, registration, or verification stages. The bundled projects can be presented in a single PDD to reduce cost and time for developing individual PDDs. However,

the CDM EB do not allow debundling of large scale CDM projects for the purpose of establishing small scale projects activities.
- Possibility of using the same DOE in validation and certification stages

Therefore, apart from general CDM requirements, specific criteria apply for small scale CDM project activities. Based on these criteria, the small scale CDM activities are categorized into three groups (UNEP, 2004):

- Renewable energy project activity with a maximum energy output capacity equivalent of up to 15 MW or an appropriate equivalent. The energy output capacity refers to an installed/rated capacity as indicated by the manufacturer of the machine regardless of actual load factor.
- Energy efficient improvement projects that reduce energy consumption on the supply and/or demand side by up to the equivalent of 15 GWh per year
- Other project activities that can reduce GHGs emissions up to 60 kt CO_2/year and have project emission of less than 15 kt of CO_2 - equivalent per year

Table 4.2 Categories and types of small scale CDM project activities

Project type category	Small scale project activity
I: Renewable energy projects	A. Electricity generation by the user B. Mechanical energy for the user C. Thermal energy for the user D. Renewable electricity generation for a grid
II: Energy efficiency improvement project	A. Supply side energy efficiency improvements (transmission and distribution) B. Supply side energy efficiency improvements (generation) C. Demand side energy efficiency programmes for specific technology D. Energy efficiency and fuel switching measures for industrial facilities E. Energy efficiency and fuel switching measures for buildings
III: Other project activities	A. Agriculture B. Switching fossil fuels C. Emission reductions by low-GHGs emission vehicles D. Methane recovery E. Methane avoidance

Source: UNEP, 2004

The CDM projects which involve construction of various physical infrastructures (e.g., power plant or flaring system) are highly expensive if they are taken at large scale level compared to small scale. The small scale CDM option can be an advantageous in countries like Tanzania where it is difficult to efficiently develop huge projects due to various risky related to financing, CDM registration and validation, technology, and other risks related to project performances. These risks will be analysed in Chapter six in relation to the proposed sisal waste CDM project activity. The list in the table above offers the possibility for project developers to choose types of projects which could be implemented at the lowest possible costs.

4.3 Baseline in CDM

For a project to become a CDM project, the GHGs emissions associated with the project activities must be lower than emissions in the baseline. The baseline is a comparative level of emission against which the GHGs gas emission reduction of a CDM project is measured. The scenarios that describe the emissions by sources in the absence of CDM project activity is called baseline scenario (UNFCCC, 1997). That means a concept baseline refers to the amount of GHGs emissions occurred in the baseline scenario. The modalities and procedures for CDM, in the Marrakech Accord, stipulate the guidelines which identify the key concepts for establishing the baseline for a CDM project activity as listed below (UNFCCC, 1997; UNEP, 2005):

- A baseline should be a project-specific and should be designed based on relevant national and/or sectoral policies or regulations.
- All potential GHGs listed in the Kyoto Protocol emitted within the boundary of the CDM project must be included in the baseline.
- The baseline GHGs emissions within the project boundary must be monitored by the project developers, be significant, and be reasonably attributable to the CDM project activity.
- The baseline should be defined by considering the CERs that are earned within the CDM project boundary and the leakage emissions (see chapter two for the definition of leakage)
- Transparency and conservativeness should be applied in choosing additionality and methodologies or in estimating and assuming various parameters. Transparency implies that the baseline methodology should also be replicable by the third party based completely on the data given in the methodology documentation Conservativeness means that the assumptions should be lower to avoid uncertainties and overestimations of GHGs emission reduction.
- The project participants may choose to apply an approved baseline methodologies or develop a new methodology if an appropriate approved methodology is not available.
- Two crediting period options can be selected by the project participants; a non renewable ten-year period or a seven-year period which can be renewed twice to make a total of twenty one years.

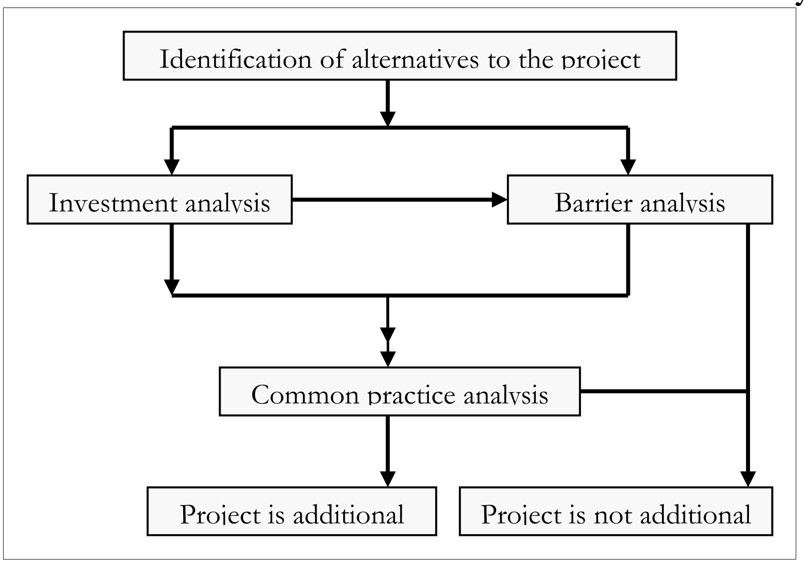
Generally, the establishment of the baseline involves the description of step to identify the baseline scenario, step to estimate the GHGs emissions, and step to justify additionality. In the Chapter two, the baseline scenarios and methodologies for this study were described. These baseline scenario and methodologies were developed based on the ideas and guidelines provided above. The chosen baseline scenarios will further be substantiated when making the analysis of the case study in Chapter five. Furthermore, this study analyses the feasible crediting periods mentioned above (a seven-year two times renewable crediting period or a ten-year non-renewable crediting period) based on the expected costs and income for the proposed sisal waste CDM project activity. The justification of additionality of the CDM project is difficult and most challenging task. The next section describes the process to follow to justify the CDM project additionality.

4.4 Additionality of a CDM project

The CDM project must be additional in terms of GHGs emission reduction and financially as well. Basically, if the project's emission is greater than the baseline emission, the project is not additional and therefore can not become a CDM project. The financing additionality is determined when the project's return with CER revenue is higher than return without CER based on the specified economic indicators such as internal rate of return or net present value (UNEP, 2005). If the project, without CER revenue has higher return than when with CER revenue, the project is considered as financially attractive, and thus not additional. Meaning that, this project can be undertaken anyway even if it is not registered as a CDM project.

The CDM – EB have developed non-mandatory tools (i.e., a tool for the demonstration and assessment of additionality and a combined tool to identify the baseline scenario and additionality) that offer essential guidelines in assessing the additionality of the CDM projects. Depending on the circumstances of the proposed CDM project activity, either of the tools mentioned above can be applied. Basically, if all potential alternative scenarios (to be explained below) to the proposed CDM project activity are available options, the latter tool is used and if at least one alternative scenario is non-available, the former tool is used. This study use some of the ideas presented in the former tool (see Figure 4.1 below) to substantiate the additionality of the proposed sisal waste CDM project activity.

Figure 4.1 Tool for the demonstration and assessment of additionality



Source: UNFCCC (2007)

Identification of alternative scenario: This step involves an identification of mostly likely alternatives scenario to the proposed CDM project (the options which could be followed if the project could not be implemented as a CDM project activity). The identified scenario should be consistent with the host country's laws and regulations of even if these laws and regulations have objectives other than GHGs emission reduction (UNFCCC, 2007). The identified credible scenarios are considered for further assessment, others are dropped. After this, the project developers may choose to follow either investment analysis or barrier analysis or both. This study considers both options.

Investment analysis: In this step the proposed CDM project activity is analysed to determine whether it is financially attractive than the identified alternative scenarios, without incomes from CERs (UNEP, 2004). If it is concluded that the proposed CDM project is a least financial attractive than at least one alternative, then it is considered for further assessment, or else, the project is not additional, and barrier analysis may be undertaken.

Barrier analysis: Barrier analysis is done to examine barriers and risks that can potentially prevent implementation of the proposed CDM project and that do not prevent implementation of at least one of the alternative scenarios. The following parameters can be used to make barrier analysis including (UNFCCC, 2007):

- Investment – mainly concerned with investment risky of the project relating to situation in the country where the project is to be implemented,
- Technological – for example lack of skilled manpower to implement the technology, lack of technological infrastructure, and risk on technological failure,
- Barriers due to prevailing practice – the project developer can demonstrate that the proposed CDM project activity is the first of its kind, and
- Other barriers associated with the applied baseline and monitoring methodologies.

The barrier analysis must prove that barriers do exist and are significant, if no barriers were observed, then the proposed CDM project activity is not an additional (ibid).

Common practice analysis: This step involves the analysis of other activities similar to the proposed CDM project activity implemented previously or recently in the same region/country where the CDM project is to be implemented. These activities must be using similar technology, similar scale, and implemented in a comparable conditions regarding regulations, technology, and finance accessibility, and they should be not CDM projects (UNEP, 2004) If similar activities can not be observed or observed but are essentially different from the project activity based on reasonable explanations, then the proposed CDM project is additional, if vice versa, the project is not additional and can not be registered as a CDM project (ibid).

4.5 Sustainable development impacts of a CDM project

As mentioned earlier, CDM was designed intentionally to assist developing countries achieve SD and help developed countries meet their GHGs mitigation obligations. The SD criteria of the CDM project is considered as the driver for creating interest for participation of developing countries in CDM and it is seen as an integrated part of the legal framework of CDM activities (UNEP, 2005). The Kyoto Protocol does not provide a generic mechanism for assessing a SD criterion of a CDM project, possibly due to different perspectives every country has on the concept of SD. The SD was defined in the Brundtland Commission as 'development that meets the needs of the present without compromising the ability of the future generations to meet their own needs' (WCED, 1987). Based on this definition and also on different factors perceived by many countries as to influence human ways of life, there is a growing consensus on which items constitute the SD; this includes environmental, economic, and social sustainability.

In the context of CDM, the dimensions of SD can be justified by estimating the impacts of the CDM at project/local situations on the aforementioned factors and link these impacts with the national SD priorities formulated based on key development and economic policies and planning. The suggested SD focus areas in each of the items mentioned above are shown in Table 4.3 below.

Table 4.3 Sustainable development dimensions of CDM projects

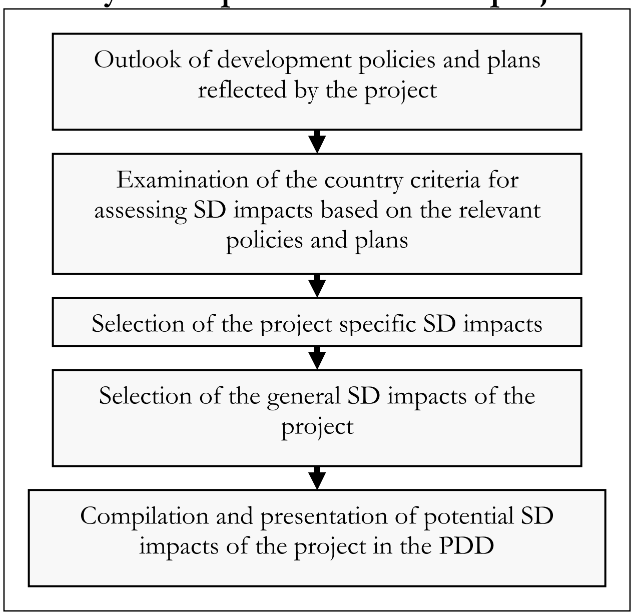
Dimension	Focus areas
Economic dimension	employment generation reducing economic burden of energy imports technological improvement cost effective investments
Social dimensions	increase equity, increase energy, gender issues education and training, health, alleviate poverty legal framework, governance, information sharing
Environmental dimension	GHGs emission reductions, local environmental protection, Use of exhaustible resources Use of renewable resources, biodiversity

Source: UNEP (2005)

Assessment of SD impacts of the CDM projects

The SD impact of CDM project can be assessed by examining the compliance of the project with some or all focus areas mentioned in the table above. Apparently, there is no generic mechanism for assessing the SD impacts; however the developers of CDM projects can follow the following process to identify key SD impacts of the projects based on the SD criteria set by the host country. The steps in Figure 4.2 in the next page were followed in this study when identifying the SD impact of the proposed sisal waste activity. The analysis of the identified impact is done in the Chapter six of this report.

Figure 4.2 Steps to identify SD impacts of the CDM project



Indicators of SD impacts of CDM projects

A convenient approach of creating a connection between a CDM project and country's SD criteria is via the application of project assessment indicators (UNEP, 2005). Basically, the indicators are mainly intended to compare the baseline socio-economic situation with the impacts of the CDM project measured at various changes. The indicators are set by the DNA office to assess the realization of SD by the CDM projects. The selection of indicators can be done by reflecting the key policy areas relating to economic, social, and environmental dimensions. The selected indicators should be comprehensive so that they are complete (in order to ensure adequacy) and unambiguous by reflecting relevant areas to be affected by the policy decisions (UNEP, 2005). Some of examples of indicators that can be applied to assess SD impact of CDM projects are shown in Table 4.4.

Table 4.4 Indicators of SD in CDM projects

SD criteria	Project level indicator	Measurement standard of indicator	
Economics		***Quantitative***	
Cost effectiveness	Net costs Financial flows	Financial costs, Social costs	
Growth	Income generation	Net surplus	
Employment	Employment	Number of man-years created or lost	
Investments	Activity in energy sector, industry, agriculture, etc	Foreign exchange requirement ($ and share of investment)	
Sectoral development	Technological access Market creation	Physical measures like energy demand and supply, economic measures, energy efficiency and affordability, energy security	
Technological change	Innovation, learning	Number of technologies, Cost of technologies and maintenance, etc	
Environmental		***Quantitative***	
Climate change	GHGs emission	GHGs emission	
Air pollution	Local air pollution, environmental health benefits	Emission in physical units, damages in physical and monetary units	
Water	Rivers, lakes, drinking water	Emission in physical units, damages in physical and monetary units	
Waste	Waste discharge and disposal	Emission in physical units, damages in physical and monetary units	
Exhaustible resources	Fossil fuels	Physical units	
Social		***Quantitative***	***Qualitative***
Poverty alleviation	Income for poor	Few people live below poverty limit, service delivery to poor people	Characteristics of poverty in terms of limited capabilities; food, education, health,
Education	Literacy levels	Literacy rates, energy accessibility in schools, etc	
Health	Life expectancy, disease,	Epidemics, energy for clinics	

Source: based on UNEP (2005)

SD criteria in Tanzania

In Tanzanian, the SD criteria are based on the long term developmental ambitious plan called '*Tanzania Development Vision 2025*' which targets to transform the country into a semi-industrialized economy from a low productivity economy. The mission promotes applications of modern and highly effective agricultural systems, enhancing industrial performance, and improving service activities in the country. The expected achievement of Vision 2025 is a strong and competitive economic system characterized by improved quality of livelihood in urban and rural areas, peace and unity; stable democracy, good governance, and a well educated society. The mission therefore delineates the SD priorities for the country which any potential CDM projects to be implemented in Tanzania must focus on including (VPO, 2007):

- Improving livelihood of the marginalized rural society,
- Environmental and socio-economical sustainability,
- Creation of employment opportunities to locals,
- Poverty reduction,
- Improving technology and capacity of local stakeholders, and
- Participation of benefiting local communities and other potential stakeholders in development and implementation of the projects.

4.6 Financing aspects of CDM

One of the most important and most difficult aspects of CDM concerns with financing CDM project activities. The financing of CDM projects can be understood as the task of acquiring the necessary finance required for project planning and registration, project implementation (i.e., purchasing and installation of the machinery), and project operation (i.e., maintenance of the machinery and workforce). Basically, financing CDM projects do not differ much with financing conventional projects. Ironically, the CDM projects can be deemed of as conventional projects but with some extra components peculiar for CDM (UNEP, 2007). See Table 4.5 below for comparison between CDM project cycle and conventional project cycle.

Table 4.5 Comparison between CDM projects and conventional projects

Stage	CDM projects	Conventional projects	Risks
Planning	Project feasibility assessment ↓ Project design and formulation ↓ National approval ↓ Project validation ↓ Project registration ↓	Project feasibility studies and design ↓ Project business plan and stakeholders analysis ↓ Contracts negotiation ↓ Permits applications ↓ Financial arrangement ↓	*High risk capital*
Implementation	Infrastructure construction, machinery installation and testing of monitoring equipments ↓	Construct infrastructure, install and test plants' equipments ↓	*High to moderate risk*
Operation	Project certification ↓ Project verification ↓ CERs issuance	Operation and maintenance of the project	*Low risk (revenue)*

Source: based on UNEP (2007)

The above table shows the three stages of CDM project cycle in comparison with conventional projects. Basically, in all circumstances, the financial acquisition by the project developers is highly dependent on the project risks. The different forms of financing mechanisms can thus be applied in all the three stages based on the risk levels. In both types, the first stage is considered as a high risky stage than other stages. This is due to the uncertainties of whether the proposed project activity will be feasible undertaking or not. If it is realized in the very beginning that the project is '*worthy not to take*', the money invested in carrying out the feasibility studies will be wasted and can not be recovered. However, the financing risky decreases further in other stages, with the implementation stage having a mixed of high and moderate risk and the last stage being less risky. The last stage is less risky due to the fact that a large part of operation and maintenance costs is covered by the revenue generated by the project. Various risks concerning the proposed sisal waste CDM project activity will be identified and analysed in Chapter six.

For a specific CDM project, in each stage of the cycle, a broad range of financing mechanisms can be applied taking into account several key elements including:

- type of the project
- size of the project
- technology to be applied
- amount of CERs to be generated
- crediting period

The above elements can significantly determine the financing volume of the CDM project. In other words these factors will tell how much money is to be invested and what profit is expected from the investment.

In addition to the above costs, some CDM specific are incurred, especially in project validation, registration, verification, and certification. These different costs depend on the size of the project in terms of the amount of CER generation. The following table shows estimated planning costs for a typical CDM project activity. The same cost estimates shown below will be used to analyse economic feasibility of the proposed sisal waste CDM project in Chapter six.

Table 4.6 Estimated costs in planning stage of CDM project

Activity	Cost US$ (large scale)	Cost US$ (small scale)	Type of cost
Feasibility studies (PIN)	5000-30,000	2000-7500	Consultancy fee
Project design & formulation - approved methodology - New methodology	 15000-100000 20000-100000	 10000-25000 20000-50000	Consultancy fee
Validation	8000-30000	6500-10000	DOE fee
Registration	10500-350000[1]	0-24500[2]	EB fee
UN adaptation Fund Fee	2% of CERs	2% of CERs	EB fee
Initial verification	5000-30000	5000-15000	DOE fee
Ongoing verification	5000-25000	5000-10000	DOE fee
Total estimated processing costs			

Source: UNEP (2007)

There are various types of financing sources available to cover the abovementioned costs. In most cases, the fund is provided in the form of equity or grant due to the high risks associated with this stage. The following sources of funds derived from UNEP, 2005, can be approached

- Multilateral and government carbon funds: These pay a part of the total costs in return for a contract to purchase the generated CERs. Basically, the fund is provided to the project which have shown some development and proved to be an economic viable. The project developers need to carry out initial feasibility analyses to document the credibility of the project based on the CDM regulatory framework. The funds are normally provided by government agencies engaged in CDM development.
- Private carbon funds: Same criteria applied for multilateral and government carbon fund apply here, the difference is that the private carbon funds are issued by the private multinational financial institutions rather than government entities.
- Project host: this includes individual or companies that provide resources relevant for project's development such as land and equipments. These entities can use their own funds to finance the planning stage of CDM project development.

Regarding the construction stage of the CDM project, where the costs are normally higher than in other stages, the following sources of financing can be considered (UNEP, 2005).

- Private sector CDM project developers: these are private financial agencies that finance CDM project with their own equity. This can be a 100% financing or less than that and gives the financier a full or partial ownership of the future generated CERs. This source is less risky for project owners as all the risks are taken by the project financier.
- Project hosts: providers of project resources who could use their internal funds to finance the CDM project,
- Equipment suppliers: these are companies which sell equipments for construction of the plant. They may provide equipments on lease or credit and claim payments when the CDM project is operational,
- CERs buyers: these can help by providing up-front payments for CERs to be generated in future when the CDM project is operational, and
- Lenders: normally lenders finance more stable projects with less risk, the fund is provided in terms of low interest loans and debt or micro credits (especially for small scale CDM projects)

Summary

This chapter has given a detailed description of the concept of CDM, specifically CDM project cycle, additionality and baseline in CDM, and the SD impact of the CDM project. As shown, the steps to be followed by a project to become a CDM project are very rigorous which need reliable financing and adequate expertise, especially regarding planning, implementation, and operation of the project. These processes are generic but are also case specific, especially when it comes to approval of the project by the DNA (who will use the country specific criteria) and in project financing.

For additionality and baseline issue, it was shown that, the emission reduction to be achieved by the CDM must be above the reductions that would occur in the baseline situation/in the absence of CDM project. Also, the project should be less financially attractive compared to the identified credible alternative scenario. Together, the above factors will prove the additionality of the project to GHG reduction and income improvement and thus be able to operate as a CDM project. Regarding the SD issue, it has been shown that, in order for the project to become a CDM project it must be able to contribute to the SD of the host country based on the criteria set by the host country. Using the information provided in this and previous chapters, the following chapter makes an assessment of the case study, mainly to examine the possibility of GHG emission reduction based on the baseline scenario described in Chapter two.

5

Case Study Assessment

This chapter offers an assessment of the case areas considered by this study as possible areas for sisal waste CDM in Tanzania. Specifically, the chapter assesses the possibility of GHG emission reduction as a result of using sisal waste in biogas production and electricity generation. The estimations are made using the methodologies and tools described in Chapter Two using data derived from the case areas and the literature. The first section of the chapter gives an overview of the case study and in the second section the calculations of GHG emissions reduction are executed.

5.1 Case study overview

Four sisal estates are considered in this study for the analysis of possible CDM project activity in Tanzania, namely, Ngombezi, Magunga, Mwelya, and Magoma. These four sisal estates are located in Tanga, the north-eastern region of Tanzania. The estates are owned by a company called Katani Ltd, also located in Tanga. The company also owns Hale Sisal Estate, which is located 70 km from Tanga town. As pointed out earlier, a small pilot sisal biogas plant is being installed at Hale Sisal Estate. This biogas plant was implemented through the financial and technical support from the governments of the Netherlands, China, and Tanzania. Basically, the plant uses a small part of the total sisal waste produced at the estate to produce biogas, which is used to generate electricity. A 150kW generator has been installed to generate the electricity consumed onsite by the factory. This study uses some key information from Hale biogas plant as baseline to estimate specific data for the four sisal biogas plants to be located in the aforementioned sisal estates considered in the proposed CDM project activity. The locations of the four sisal estates in relation to Tanga town are as shown below:

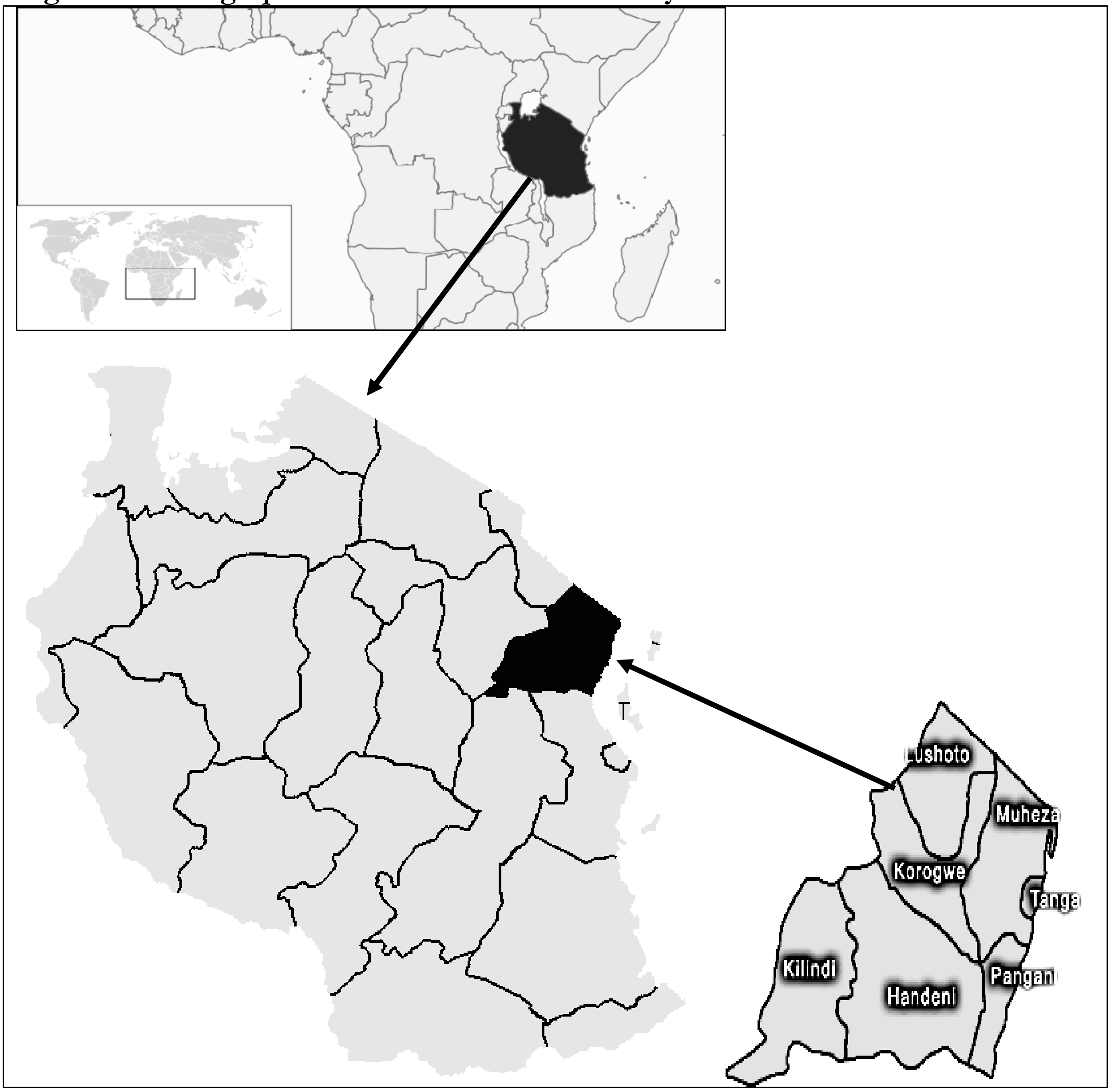
- Ngombezi sisal estate located 100 km from Tanga town
- Magunga sisal estate located 122 km from Tanga town
- Mwelya sisal estate located 132 km from Tanga town
- Magoma sisal estate located 142 km from Tanga town

The above sisal estates are all situated close to the sisal processing factories where fibre production takes place. The factories are located near rivers and permanent water sources where a large quantity of water is drawn for the decortication of sisal leaves, the washing of sisal fibres, and for transporting a large quantity of effluent (sisal waste) to the disposal sites. Each of the factories has two decorticators and all factories have a similar operation system in terms of working shifts and operation hours, amount of leaves processed per day, waste production, and electricity consumption.

In terms of energy accessibility, all four sisal factories are connected to the national grid, meaning that they are totally dependant on grid electricity for their operation. From the economic point of view, the possibility of generating onsite electricity could, to a significant extent, save money spent on exported electricity from the grid and could increase income by selling power to the grid. These two scenarios will be examined in greater detail in the next chapter.

The sisal farming in these sisal four estates is mainly contracted to smallholder farmers and out-growers who farm on land owned by the factory and other small private lands. The company supports the farmers in terms of land preparation, providing seedlings, and farming methods (Katani Ltd, 2008). The geographical location of Tanzania and the Tanga region where the four sisal estates are located is shown in Figure 5.1.

Figure 5.1 Geographical location of the case study



Left: Tanzania, Right: Tanga region (case studies are located in Korogwe District)
Source: http://www.tanzania.go.tz/census/

5.2 Estimation of emission reductions (ERs)

The ERs are estimated by considering two options: avoidance of methane emission from the sisal waste disposal sites and replacement of grid electricity produced by fossil fuels with the electricity generated by the project. Detailed descriptions of the two options are given below.

5.2.1 Emission reduction based on sisal waste consumption

The assessment of baseline emissions based on sisal waste consumption for biogas production is done based on the choice of the most plausible alternative scenario, which is a continuation of the current practices/business without any variation (i.e., disposal of sisal waste in the disposal sites without any methane emission control mechanisms). By applying this scenario, it is assumed that sisal wastes that are dumped at the disposal sites would undergo anaerobic decomposition producing methane, which is emitted into the atmosphere. Therefore, by utilizing waste in biogas production, the methane emission from the disposal sites will be avoided.

Before estimating the emission reduction expected to be achieved by the CDM project, the description of other possible scenarios is done to explain why the chosen scenario is more plausible than others. In other words, the description is made to show why the continued disposal of sisal waste in the disposal sites would be the most likely option in the absence of CDM project activity compared to the other options. Various options (including the chosen scenario) that could be considered as likely options in the absence of CDM project activity are described in Table 5.1.

Table 5.1 Alternative options in the absence of sisal waste CDM project activity

Scenario/option	Description
A. The sisal waste is disposed in the waste disposal site and left to decay uncontrollably (common practice/business as usual).	High quantity of wastes produced by sisal factories are burned, or channelled to the rivers and streams, and large part of it are left to decay in the disposal sites located near the factories without appropriate measures to control methane emission into the atmosphere or other environmental problems.
B. The sisal waste is combusted for heat and or/electricity generation onsite	The combustion technology of sisal waste is currently not available in Tanzania. So it is unlikely that sisal waste could be directly combusted to generate heat or electricity.
C. The sisal waste is used for energy and or/electricity generation in other sites (combustion or other sisal waste conversion energy technologies)	Sisal waste produced onsite could be transported and used to generate electricity and heat in other factories (e.g., cement factory located in Tanga region). However, there exist technological and transporting problem of a bulky amount of sisal waste which could increase the cost of production, especially when the alternatives (i.e. grid electricity) is relatively cheaper.
D. The sisal waste is used for non-energy purposes such as fertilizer and animal feeds	For a long time, sisal waste has been used as organic fertilizer by local farmers or for feeding livestock. However, the abundant amount of sisal waste produced on a daily basis far exceeds the demand for fertilizer or animal feed. Also, there exists the problem of transporting a bulky amount of waste from the factories to, for example, farming fields

Among the four alternative scenarios described above, scenario A seems to be more likely to be followed than the other scenario. As mentioned earlier, most sisal processing factories in Tanzania do not have strict waste management control mechanisms. It is most likely that without the proposed sisal waste CDM project activity, which intends to lower methane emissions by utilizing the waste to produce biogas, the continuation of the common practice/business as usual (i.e., dumping of sisal waste at the disposal sites without proper control mechanisms) would be the only option and this would increase the emission of methane into the atmosphere.

The emission reduction achieved by the CDM project activity is estimated using the UNFCCC default baseline methodology (i.e., III D). The emission from the sisal waste disposal sites is estimated based on the first order decay (FOD) model described in Chapter Two. Basically, the values used in the FOD model are professionally agreed values estimated according to factors such as waste type disposed in the disposal sites, climatic conditions in the countries/regions where the disposal sites are located, time of disposal, decay rate of different types of waste, management of the disposal sites, and the fraction (weight or volume) of waste disposed at the disposal site.

However, due to the huge diversity of wastes disposed of at the disposal sites, the specific values to be applied in the FOD model are not available for each type of waste. Therefore, the generalized values proposed by IPCC can be used taking into account the factors mentioned above. The basic concept of this is that the default values proposed by the PICC for estimating methane emission from the waste disposal sites can be used for any type of waste based on the close similarities of the type of waste considered in the calculation and the generalized estimated values. This basic concept can be followed in the case of sisal waste. Therefore, apart from the weight stream of sisal waste disposed of into the sisal waste disposal site each year, other values to be applied in the FOD model formula are default values estimated by the IPCC. As the proposed CDM project activity is not expected to produce any GHG emission onsite, the leakage and the project emission are assumed to be zero, and therefore the emission reduction based on sisal waste consumption is equal to the baseline emission calculated using the FOD model formula as follows:

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

Description of values used in the formula

Φ: An IPCC default value of 0.9 is used for the model correction factor. Basically, this value was obtained based on different studies on landfill gas projects worldwide (IPCCC, 2006). The value is used to adjust the formula due to uncertainties of the first order decay model and it is applied to ensure a conservative estimate of methane emission from the disposal site.

OX: The value for the oxidation factor is estimated depending on the characteristic of the disposal site. Basically, a default value of 0.1 is applied for a managed solid waste disposal site and a 0 value is applied for unmanaged sites. As far as sisal waste is concerned, a 0 value is applied as none of the disposal sites considered in this study are systematically managed.

F – A volume fraction of CH_4 in the total amount of gas emitted from the disposal site is also estimated using an IPCC default value. The amount of methane emission from the sisal disposal site depends very much on the degradability of the sisal waste materials dumped at the site. Due to the fact that not all waste materials dumped at the disposal site decompose into methane, and to avoid an overestimation of the emission reduction, the recommended IPCC value of 0.5 is applied.

DOC_f - This represents a fraction of the decomposable degradable organic carbon in the sisal waste. An IPCC default value of 0.5 is used.

MCF - Methane correction factor is chosen based on the site characteristics, mainly management and depth level, as shown in the table below

Table 5.2 Methane correction factor selection

Site management	Value
Unmanaged with depth of < 5m	0.4
Unmanaged with depth of > 5m	0.8
Semi aerobic managed	0.5
Anaerobic managed Other	1.0

Source: IPCC, 2006

Basically, all sisal waste disposal sites considered in this study are unmanaged sites and have depths of less than 5m; therefore, a value of 0.4 is chosen. It can be observed that 0.4 is the lowest value indicated in the above table. This is due to the fact that managed disposal sites where waste decays for the most part of the year and methane generation is optimized, have a higher methane production than unmanaged sites where a larger amount of waste decays aerobically in the top layers producing the biogenic carbon dioxide (IPCC, 2006).

DOC_w – The weight fraction of decomposable degradable organic carbon in the sisal waste substrate is estimated from values in Table 5.8 below.

Table 5.3 Estimation of weight fraction of degradable organic carbon of sisal waste

Type of waste	DOC (% wet waste)	DOC (%dry waste)
Pulp, paper , and cardboard	40	44
Wood, wood products and straw	43	50
Garden and park waste	20	49
Food waste, sewage sludge, tobacco	15	38
Glass, plastics, and metal	0	0
textiles	24	30

Source: IPCC, 2006

The sisal waste belongs to the group of pulp wastes and normally occurs in a watery form due to the addition of water during the decortication process; therefore, the value of 40% is used.

k_w – The decay rate for the sisal waste is estimated based on the criteria shown in Table 5.4 below

Table 5.4 Selection of decay rate for sisal waste

Type of waste		Boreal and temperate areas MAT≤20°C)		Tropical areas (MAT >20°C)	
		Dry (MAP/PET<1)	Wet (MAP/PET >1)	Dry (MAP<1000mm)	Wet (MAP>1000mm)
Slowly degrading	Pulp, paper , and textiles	0.04	0.06	0.045	0.07
	Wood, wood products and straw	0.02	0.03	0.025	0.035
Moderately degrading	Garden and park waste	0.05	0.10	0.065	0.17
Rapidly degrading	Food waste, sewage sludge, tobacco	0.06	0.185	0.085	0.40

MAP - Mean annual precipitation, MAT – Mean annual temperature, PET – potential evapotranspiration
Source: IPCC, 2006

Based on climate type criteria, all sisal estates considered in this research are located in Tanzania, which is found in a tropical climate experiencing an annual average temperature of 24 degrees Centigrade and a mean annual precipitation (MAP) of 600mm-1500mm (Tanzania Meteorological Agency, 2008). Thus, the sisal waste is conservatively categorized as slowly degrading waste, and therefore, a value of 0.045 is used.

f_y – The fraction of methane gas recovered at the disposal site is zero as all four sisal waste disposal sites are unmanaged and no gas recovering activities currently undertaken.

GWP_{CH4} – The default value of 21 is used for the global warming potential of methane.

W_y – The amount of waste avoided from disposal in the dumping sites in year y represents the total amount of sisal waste used in biogas production. As this study deals with four differently located sisal estates, which generate similar amounts of waste per year, the figure from one estate is multiplied four times to obtain the total amount in tons. Basically, each of the four sisal estates operates in two shifts of ten hours each. In each shift, 130 tons of sisal leaves are processed making a total of 260 tons per day (2 shifts * 130 tons = 260 tons). Of the 260 tons of leaves processed per day 90% remain as waste, the rest is sisal fibre (10%). This means that each of the factories generates 234 tons of sisal waste per day (260 tons * 90% = 234 tons), making a total of 936 tons per day when four sisal factories are combined (234 tons * 4 = 936 tons/day). The annual total waste production is obtained by multiplying daily waste production by 365 days, which gives 341640 tons/year (see Table 5.11) y – The year for which CH_4 emission from the sisal waste disposal sites starts from year one (2009) to year seven (2015) (for a CDM project opting seven-year two times renewable crediting period) and year one (2009) to year ten (2018) (for a CDM project opting a non-renewable 10 year crediting period). This study offers an analysis of both crediting periods.

e - Exponential constant (2.718).

Table 5.5 Data inputs for calculating CH_4 emission from sisal waste disposal sites

Symbol	Description	Value
φ	Model correction factor to account uncertainties	0.90
OX	Oxidation factor	0.00
F	Volume fraction of CH4 in the SWDS gas	0.50
DOCf	Fraction of degradable organic carbon that decompose	0.50
MCF	Methane correction factor for shallow unmanaged SWDS	0.40
DOCj	Weight fraction of degradable organic carbon that decompose	0.40
kj	Decay rate for sisal waste	0.045
W	Amount of sisal waste prevented from disposal at SWDS	341,640
f	fraction of CH4 captured and used	0
e	Exponential function (constant)	2.72
GWP	Global warming potential (GWP) of CH4	21.00

The calculated yearly and total baseline emissions for both crediting periods are shown in Table 5.6.

Table 5.6 Baseline methane emissions calculated based on first order decay model

Year		Waste (t/yr) from 4 sisal estates	BE (tCO2-eq)
1	2009	341,640	15,152
2	2010	341,640	14,485
3	2011	341,640	13,848
4	2012	341,640	13,239
5	2013	341,640	12,656
6	2014	341,640	12,099
7	2015	341,640	11,567
8	2016	341,640	11,058
9	2017	341,640	10,571
10	2018	341,640	10,106
	Total for a seven-year crediting period		**93,,045**
	Average BE		**13,292**
	Total for a ten year crediting period		**124,780**
	Average BE		**12,478**

The results above show that methane emission from the sisal waste disposal sites is higher in the first years of disposal and decreases relatively throughout the crediting period. This is because the key conditions for anaerobic decomposition are stabilized mainly after a short time at the disposal site, and thus gas production speeds up (IPCC, 2006). Thereafter, the gas production is reduced, as fewer organic carbons are available for microbial digestion. All additional waste disposed of after the first few years will not decompose 100%, and gas production will be attributed partly to the undigested organic carbon left in the waste and the newly added substrates (ibid). In this way, the gas production processes in the disposal sites decrease exponentially over the years mainly due to changes in the volume and organic composition of the waste material; this is the essence of FOD (Bernt and Burtz, 2008). The basic assumption during the period of decreasing gas production is that the gas production rate is proportional to the remaining methane potential to be produced (ibid).

The above table also shows that if a seven year crediting period is chosen, the total baseline emission will be 93,045 tCO_2 e against 124,780 tCO_2 e if a ten-year crediting period is chosen (about 31,735 tCO_2 e more than for a seven-year crediting period). However, it should be remembered here that, the later crediting period lasts for only ten years while the former has the addition of two more periods of seven years each making a total of twenty one years. Subsequently, these additional years will also have an impact on the financial flow of the projects, due to the additional income resulting from CER revenues generated in those extra years, which is 77,940 tCO_2 e (i.e., total for twenty one years (202,719 tCO_2 e) – total for ten years (124,780 tCO_2 e)) - see Figure 5.7. This scenario will be dealt with in detail in the next chapter when analysing the costs and benefits for the proposed sisal waste CDM project activity, especially when comparing the economic viability of the two types of crediting periods.

Table 5.7 Additional emission reductions for the 21 year crediting period

	Year	Waste, yr (t)	BE (tCO_2 e)
1	2009	341,640	15,152
2	2010	341,640	14,485
3	2011	341,640	13,848
4	2012	341,640	13,239
5	2013	341,640	12,656
6	2014	341,640	12,099
7	2015	341,640	11,567
8	2016	341,640	11,058
9	2017	341,640	10,571
10	2018	341,640	10,106
11	2019	341,640	8784
12	2020	341,,640	8397
13	2021	341,640	8028
14	2022	341,640	7675
15	2023	341,640	7337
16	2024	341,640	7014
17	2025	341,640	6705
18	2026	341,640	6410
19	2027	341,640	6128
20	2028	341,640	5859
21	2029	341,640	5601
	Total for 21 years		**202,719**
	Average BE		**9653**
	Addition over the 10 year CP		**77,940**

5.2.2 Emission reduction based on electricity export to the grid

The proposed sisal waste CDM project activity will be generating electricity partly to be consumed onsite to fulfil factory's electricity demand and the rest to be exported to the national grid. In this case, the scenario is that by exporting electricity to the grid, there will be a reduction in carbon dioxide emissions that could have been contributed by fossil fuels used to generate grid electricity. In other words, the project will avoid the consumption of fossil fuels to generate electricity for the grid. The key scenarios that could be followed in part from the chosen scenario are described in the following table.

Table 5.8 Baseline scenario for electricity generation

Scenario/options	Description
A. The generation of power in existing and/or new grid-connected power plants using fossils fuels to help fulfil the demand of electricity by the majority of Tanzanians (business as usual/common practice scenario)	The electricity would most likely be generated from the existing and/or new power stations feeding the grid fuelled with fossils fuels (i.e., diesel, fuel oil, natural gas, coal).. This option would exacerbate emissions of carbon dioxide into the atmosphere and increase the effects of global warming
B. The installation of a number of small scale power plants fuelled with biogas produced from sisal waste but with very low electricity production capacities incapable of exporting power to the grid.	This seems to be the mostly likely scenario as there is already a small scale biogas project at Hale sisal estate. However, this small project is incapable of exporting power to the grid as it is only a demonstration project for future large scale projects. The proposed CDM project activity will be able to generate enough power using biogas produced from sisal waste. This power will be consumed onsite and a large part of it will be exported to the grid. As there is no such kind of project worldwide, it can be described as the 'first of its kind'.
C. Generation of electricity on the sites using only fossil fuel such as diesel or natural gas	The only alternative that was considered is the production of biogas and generation of electricity on the sites using sisal waste. This is based on the fact that there is an abundant production of sisal waste from the sisal factories which removes the problem of fuel availability.
D. The proposed project activity is not implemented as a CDM project activity	There exist significant financial and technological barriers and risks that prevent the implementation of the proposed project activity as a conventional investment without adding CDM values.

Of the four options described above, option A seems the mostly likely option to be considered and, therefore, it was chosen as the baseline scenario meaning that, if the proposed CDM project activity is not implemented (not supplying power to the grid); the electricity to be fed into the grid would mostly likely be generated by fossil fuel-based grid connected power plants.

Therefore, in order to estimate the emission reduction/baseline emission of the sisal waste CDM project, the amount of electricity exported to the grid by the project in year y (EG_y)

must be calculated and multiplied by the grid emission factor (EFy) using the formulae described in Chapter Two of this report.

$$BE_y = EG_y \bullet EF_y$$

However, in order to calculate the amount of electricity generated and exported to the grid, the biogas production capacities for the proposed biogas plants must be estimated.

Biogas production potential

The following parameters are considered for estimating potential biogas production in the proposed biogas plants

- Mean gas yield for sisal waste = 50 m^3/ton VS (Hale estimate)
- Estimated total volatile solids (organic compounds actually converted to gas) in sisal waste = 9%/ton (Mshandete *et al.*, 2008)
- Assumed biogas production efficiency of the digester = 33% (Hale estimate)
- Yearly waste input = 341,640 ton/yr (see previous sections)

The potential biogas production in each of the four biogas plants to be constructed in each of the four sisal estates considered in this study is calculated collectively. In other words, it is assumed that even separate calculations for individual biogas plants will give similar results when productions in each of the four biogas plants are summed up together. The potential production is calculated as follows:

*:: Total volatile solids (VS): 341,640 ton/year * 9% = 30,748 tons VS/year*

*:: Biogas yield: 50 m^3/ton VS * 30,748 tons VS/year * 33%= 507,335 m^3/yr*

The total potential biogas production for the seven- and ten-year crediting periods are summarized in Table 5.9

Table 5.9 Estimated potential biogas production

Year		Waste (ton/yr)	Total VS (t/yr)	Total Biogas (m^3/yr)
1	2009	3,416,40	30,748	507,335
2	2010	3,416,40	30,748	507,335
3	2011	3,416,40	30,748	507,335
4	2012	3,416,40	30,748	507,335
5	2013	3,416,40	30,748	507,335
6	2014	3,416,40	30,748	507,335
7	2015	3,416,40	30,748	507,335
8	2016	3,416,40	30,748	507,335
9	2017	3,416,40	30,748	507,335
10	2018	3,416,40	30,748	507,335
Total for a seven-year CP		**2,391,480**	**215,233**	**3,551,348**
Total for a ten year CP		**3,416,400**	**307,476**	**5,073,354**

Electricity production potential

Having calculated biogas yearly and total potential biogas production for both types of crediting periods, the electricity generation potential is calculated by considering the following parameters, the estimations of which are based on data from a pilot biogas plant at Hale sisal estate and others based on the expected capacity of the proposed biogas plants:

- Generator efficiency = 35% (Hale estimate)
- Onsite consumption =15% (Hale estimates)
- Electricity export = 85% (Hale estimates)
- Total installed capacity of the proposed plants = 8 MW (this average capacity falls in the category of small scale CDM project. It was selected as the total ER by this capacity plus that of methane emission avoidance is less than 60 kt CO_2 e/year – see Table 5.18)
- CH_4 heating value = 22 MJ/m^3 (Nijaguna, 2006)
- CH_4 content in biogas = 60% (Hale estimates)
- 1 GWh = 3.6 GJ
- Yearly biogas production = 507,335 m^3/yr
- Number of operation hours = 8760

The potential electricity production is calculated as follows:

*:: Total potential electricity generation: 507,335 m^3/yr * 60% * 35% * 22 MJ/m^3= 651 GWh/yr*

*:: Total potential capacity: 651 GWh/yr * 8760 = 74 MW*

*:: Generation based on expected installed capacity in all four sisal estates (i.e., 8 MW): 8 MW * 651 GWh/yr /74 MW = 70 GWh/yr*

*:: Onsite consumptions: 15% * 70 GWh/yr = 11 GWh/yr*

*:: Grid export potential: 85% * 70 GWh/yr = 60 GWh/yr*

The total potential electricity productions for the seven- and ten-year crediting periods are summarized in Table 5.10 on the next page.

Table 5.10 Potential electricity production in the proposed biogas plants

Year		Potential generation (GWh/yr)	Potential capacity (MW)	Actual generation (GWh/yr)	Consumption (GWh/yr)	Grid export (GWh/yr)
1	2009	651	74	70	11	60
2	2010	651	74	70	11	60
3	2011	651	74	70	11	60
4	2012	651	74	70	11	60
5	2013	651	74	70	11	60
6	2014	651	74	70	11	60
7	2015	651	74	70	11	60
8	2016	651	74	70	11	60
9	2017	651	74	70	11	60
10	2018	651	74	70	11	60
Total for a 7 year CP		**4558**		**490**	**77**	**420**
Total for a 10 year CP		**6511**		**700**	**110**	**600**

The potential power export (60 GWh/yr) has to be multiplied by the grid emission factor to obtain the baseline emissions. Basically, this value represents the amount of electricity that could possibly be generated by grid-connected fossil fuel based power plants. The process for calculating the grid emission factor based on the formula described in Chapter Two is explained below.

<u>Grid emission factor</u>

The essence of calculating the grid emission factor is to understand the average emissions for each fossil fuel based-power plant supplying power to the grid. In most cases, the grid emission factor ranges from 1 to 10 tCO_2/MWh; the greater the value of emission factor, the higher the emissions from the grid sources (UNEP, 2005). Thus, it is important that all power plants serving the grid at particular years be identified and quantified. This includes understanding their installed capacities, type and amount of fuel consumed, percentage contribution of the plants to the total grid production capacity, and the commissioning dates of the plants. Apart from these factors, the CO_2 emission factor for each fuel consumed by the power plants and their calorific values must be understood.

The abovementioned factors are crucial in calculating the grid emission factor operating margin, the build margin emission factor, and the combined margin emission factor (which is principally the grid emission factor). Basically, the operating margin emission factor is calculated to estimate the average emission level of the specific existing power plants whose output is reduced in response to a CDM project activity (WBCSD, 2005). The build margin emission factor indicates the average emissions that would have been contributed by the new grid capacity but that are now displaced by a project activity (ibid).

i. <u>Calculating operating margin emission factor</u>

Table 5.12 on the next page shows all power plants currently serving the grid, their installed capacities, electricity generation capacities, fuel consumptions, percentage energy mix, and the commissioning date. The operating margin emission factor is calculated based on data from year 2007 including all displaced grid connected plants, mainly thermal plants. As it can be seen in the table, there was virtually no fossil fuel grid sources in the year 2005 and 2006, which means that there was no emission from the grid based plants. All power sources included in the OM calculation are highlighted in yellow. Other key inputs for the calculations are shown in the Table 5.11 in the next page. Note that, the UNFCCC default values for the power plant efficiencies are applied due to the fact that it is difficult to obtain the raw data for each power plant considered in the calculation of OM emission factor for the Tanzanian grid. The formulae primarily used to obtain data in Table 5.12 are shown after the Table 5.11.

Table 5.11 Key parameters used in calculations

Plant efficiency: Source; UNFCCC, 2007
Efficiency of diesel oil fired plants = 0.3
Efficiency of natural gas turbines = 0.3
Efficiency of coal power plant = 0.37

Capacity factors: Source: TANESCO, 2008
Hydro = 0.48
Thermal (diesel) = 0.20
Thermal (coal) = 0.60
Thermal (natural gas) = 0.60

*:: Electricity Generation (GWh): Installed capacity (MW) * Capacity factor * 8760/1000*

*:: Fuel Consumption (TJ): Electricity generation/Plant efficiency * 3.6*

*:: Energy Mix (%): Total installed capacity (MW)/Plant installed capacity (MW) * 100*

Table 5.12 Tanzanian grid capacity production for year 2005 - 2007

Plant Type	Installed Capacity (MW)			Production (GWh)			Fuel Consumption (TJ)			Energy Mix (%)			
Hydro Capacity	2005	2006	2007	2005	2006	2007	2005	2006	2007	2005	2006	2007	Date of Commission
Kidatu (Morogoro)	204	204	204	858	858	858				36	36	19	
Mtera	80	80	80	336	336	336				14	14	7	
Hale (Tanga)	21	21	21	88	88	88				4	4	2	
New Pangani Falls	68	68	68	286	286	286				12	12	6	
Nyumba ya Mungu (Moshi)	8	8	8	34	34	34				1	1	1	
Lower Kihansi	180	180	180	757	757	757				32	32	16	
Sub-total Hydro	**561**	**561**	**561**	**2359**	**2359**	**2359**				**100**	**100**	**51**	
Thermal Capacity													
Ubungo Gas turbines (Ngas)			100			583			6996			9	October, 2007
Kinyerezi - SONGAS (Ngas)			178			936			11227			16	January 2007
DOWANS (Ngas)			100			175			2102			9	February, 2007
IPTL (Diesel)			103			180			2165			9	January 2007
Grid Diesel			10			18			210			1	January 2007
Mwanza (Diesel)			40			70			841			4	March, 2007
Kiwira (Coal)			1,4			7			72			0,001	January 2007
- total diesel			153			268			3217			10	
- total natural gas			378			1694			18223			25	
- total coal			1,4			7			72			0,001	
Sub-total Thermal			**532**			**1969**			**21511**			**49**	
Grand Total	**561**	**561**	**1093**	**2359**	**2359**	**4328**			**21511**	**100**	**100**	**100**	

Source: based on data from TANESCO, 2008

Other input parameters essential for calculating the operating margin emission factors are summarized in the table below and the formulae used are shown after (also review chapter two for more description of the formulae)

Table 5.13 Other input parameters for OM emission factor calculations

Type of fuel	CO_2 Emission Factors ($kgCO_2$/GJ)	Net efficiency of power units (%)
Natural Gas	56.00	0.37
Coal	94.60	0.30
Diesel Oil	74.10	0.30

Source; based on estimates by IPCC, 2006; UNFCCC, 2007

(a)

$$EF_{grid,OMaverage} = \frac{\sum_{i,y} EG_{m,y} \bullet EF_{EL,m,y}}{\sum EG_y}$$

(b)

$$EF_{EL,m,y} = \frac{EF_{CO2,m,i,y} \bullet 3.6}{\eta_{m,y}}$$

Table 5.14 Operating margin emission factor for a Tanzanian grid (2005 – 2007)

Type of units	CO2 Emission Factors of power units (tCO2/MWh)			Average OM Emission Factor (tCO2/MWh)		
	2005	2006	2007	2005	2006	2007
Natural Gas	0	0	0.54	0	0	0.54
Coal	0	0	1.14	0	0	1.14
Diesel Oil	0	0	0.89	0	0	0.89
Average average **OM Emission Factors (tCO2/MWh)**				**0.86**		

ii. Calculating the build margin emission factor

As defined earlier, the build margin emission factor represents emissions that could have been contributed by the newly grid connected plants but are displaced by the CDM project. In this study, the build margin is calculated using data derived from the recently added capacity to the grid/ex-ante data (see Table 5.15). The calculation is done based on the assumption contributions to the future grid capacity will be largely by fossil fuel-based power plants and that the proposed CDM project will displace the build margin emissions.

Table 5.15 Five most recently built plants (New addition capacities to the Grid)

Plant type	Capacity (MW)	Generation (GWh)	Fuel consumption (TJ)	Energy mix (%)	Comission date
Ubungo (Ngas)	100	583	6996	9	October, 2007
SONGAS (Ngas)	178	936	11,227	16	January 2007
DOWANS (Ngas)	100	175	2102	9	February, 2007
IPTL (Diesel)	103	180	2165	9	January 2007
Grid Diesel	10	18	210	1	January 2007
Total	**491**	**1892**	**22701**	**45**	

Essentially, the main determinant of a project's impact on build margin emissions is the extent to which it can meet the demand for new grid capacity. Therefore, the first step in estimating the build margin is to determine whether the demands for new capacity do exist. Specifically, if the grid has enough capacity to meet future demands, there is no demand for new capacity and thus the CDM project will have no impact on the build margin emissions and vice versa (UNFCCC, 2007). According to WBCSD (2005), the project that can reliably and continuously export power to the grid can significantly displace the build margin (WBCSD, 2005)

The Tanzanian electricity system is largely characterized by low capacities in terms of both power generation and power supply. According to the Tanzanian electricity supply authority (TANESCO), the national electricity grid capacity can fulfil the demand of only ten percent of the population (TANESCO, 2008). This implies that are demands for grid capacity that could also be fulfilled by renewable sources, such as sisal waste biogas plants. These renewable sources will be able to supply power to the grid and displace the build margin emissions that would be contributed by the newly built grid-connected fossil fuel power plants. The forecasted four-year production for the Tanzanian grid shows that the hydro capacities will decrease while thermal resources will have a significant share of the capacity (see Table 5.16). The increase in thermal resources will have a substantial impact on the rise of grid build margin emissions.

In addition, the impact of the power project on the build margin is determined by the size of capacity to be added to the grid. According to TANESCO, 500 kW is the minimum allowable capacity the grid can import (TANESCO, 2008). This requirement will be easily fulfilled by the proposed sisal waste CDM project, which is expected to have a total installed capacity of 8 MWe, with each sisal biogas plant contributing 2 MWe.

Table 5.16 Four years projected dispatch for Tanzanian grid

Year	2008	2009	2010	2011
Hydro	2282	2282	2282	2282
Thermal	2129	2408	2670	2905
Total	**4411**	**4690**	**4952**	**5187**
Hydro/Thermal mix	**52/48**	**49/51**	**46/54**	**44/56**

Source: TANESCO, 2007

Using the data provided in Table 5.15 above, the build margin emission factors for each thermal plant were calculated using an UNFCCC approved formula shown below (also described in Chapter Two). These individual build margin emission factors were added together, and then the mean value was obtained (see Table 5.17).

$$EF_{grid,BM,y} = \frac{\sum_{m} EG_{m,y} \bullet EF_{EL,m,y}}{\sum_{m} EG_{m,y}}$$

Table 5.17 Average build margin emission factor for Tanzanian grid

Plant name	CO_2 emission of power units (tCO2/MWh)
Ubungo	0.54
SONGAS	0.54
DOWANS	0.54
IPTL	0.89
Grid Diesel	0.89
Build margin emission factor (tCO2/MWh)	**0.68**

iii. **Calculating the combined margin emission factor**

Having calculated the operating margin and build margin emission factors above, the combined margin emission factor/grid emission factor is estimated as follows using the UNFCCC approved formula (also review chapter two for formula description).

$\therefore EF_{grid,\,CM} = (0.86\ tCO2/MWh + 0.68\ tCO2/MWh) * 0.5 = 0.77\ tCO_2/MWh$

In order to estimate the amount of carbon dioxide avoided being emitted by the fossil fuel based grid sources (i.e., the baseline emission/emission reduction), the grid emission factor is multiplied by the amount of electricity produced and exported to the grid by the proposed CDM project, as shown below. The total emission reductions for both sisal waste consumptions and grid emission avoidance are summarized in Table 5.18.

$\therefore 0.77\ tCO_2/MWh * 60\ GWh/yr * 1000 * 7\ years = 323{,}400\ tCO2\ e/year$

$\therefore 0.77\ tCO_2/MWh * 60\ GWh/yr * 1000 * 10\ years = 462{,}000\ tCO2\ e/year$

Table 5.18 Summary of total emission reduction for proposed CDM project

	Emission Source	7 year crediting period	10 year crediting period
Baseline Emission	Grid power displacement	323,400	462,000
	Avoidance of methane emission	93,045	124,780
	Total baseline emissions	**416,445**	**586,780**
Project Emission	N/A		
Leakage	N/A		
Average emission reduction (tCO2 e/year)		**59,492**	**58,678**

The results show that, the total emission reductions to be achieved by the project for both crediting periods are less than 60 ktCO_2 equivalent per year. This, together with the expected installed capacity of the plant (i.e., 8 MW) means that the proposed sisal waste CDM project falls in the category of small scale CDM project activities. As said earlier, this is preferable for Tanzania due to simplified benefits for a small scale CDM project including possibility of bundling different project into one project during different stages of CDM project cycle, use of simplified PDD, and possibility of using the same DOE in validation and certification stages (UNEP, 2005)

The results also indicate that the project will be able to avoid emissions of more tones of CO_2 per year based on the second scenario (reduction of carbon dioxide emissions by replacing fossil fuel grid sources) than the first scenario (avoidance of methane emissions from sisal waste disposal site). The difference of 32,907 tCO_2 e/yr and 33,722 tCO_2 e/yr can be observed for the seven-year and ten-year crediting periods respectively (i.e., 323,400 tCO_2 e/7 – 93,045 tCO_2 e/7 and 462,000/10 tCO_2 e/yr – 124,780/10 tCO_2 e/yr). However, the potential emission reduction between the two crediting periods can be differentiated by the extra years assigned for a seven-year crediting period. As previously mentioned, the seven-year crediting period has an addition of 14 more years which could add more certified emission reduction (CERs) due to the possibility of continuing avoiding grid emissions. The impact of this inconsistency on the future project revenues will be analysed in greater detail later in Chapter Six.

Regarding grid power displacement, there is the potential for developing a large scale sisal waste CDM project if all the biogas produced will be consumed to generate electricity. If this is adopted, given that in all four biogas plants there is the potential for 74 MW, this capacity will be able to generate about 651 GWh of electricity per year (review Table 5.10 above). This means that each biogas plant will need to install an 18.5 MW biogas engine generator in order to utilize all the produced biogas. As this capacity is more than 15 MW, each biogas plant in each sisal estate will fall in the category of large scale CDM projects, and the project developers must apply baseline and monitoring methodologies specific for large scale project activities. Thus, such a large scale CDM project will not be allowed to apply the simplified procedures and modalities applied to small scale projects.

Based on the above facts, it was decided that, in this study, a realistic approach would be to make an analysis of the possibility of establishing a sisal waste CDM project in the context of the small scale CDM category rather than the large scale category. Therefore, the large scale option (installation of a 74 MWe capacity) was deleted and a 8 MWe capacity was opted. Furthermore, an 8 MWe electricity production capacity was chosen based on the fact that the costs for installing a biogas plant with the electricity generation capacity of 74 MWe is too high and therefore may increase investment risks, especially in securing project financing.

Summary

Generally, this Chapter has introduced the case study and examined the possibility of GHG emission reductions based on sisal waste conversion. Two scenarios were examined, one related to avoidance of CH_4 from the sisal waste disposal sites, and two reductions of grid CO_2 emissions. In both cases, the results showed that the potential for CER generation is high. Using the concept of FOD, the methane emissions from the sisal waste disposal sites were calculated based on default values developed by UNFCCC and IPCC and raw data collected in the field. Regarding avoidance of grid emission, the UNFCCC methodology was applied. The methodology necessitated the use of a specific tool to calculate the grid emission factor. Using the grid data for the year 2007, the grid emission factor of 0.77 tCO2/MWh was obtained. This factor was multiplied by the amount of electricity to be produced by the project to get the yearly emission reductions.

The GHG emission reductions for both cases were examined by considering both a seven-year two times renewable CP and a ten-year non-renewable CP. Both crediting periods showed potential for CER at least to a level of small scale CDM, though a seven-year crediting period showed more potential due to an additional CER achieved in the additional 14 years. Having known all these, the next chapter conducts the feasibility analysis to examine the possibility of implementing the sisal waste CDM project. Basically, the chapter will analyse how this potential can be exploited taken into account other requirement of CDM such as additionality and sustainable development impact.

6

Feasibility Analysis for CDM Possibility

This chapter offers a feasibility analysis for the CDM possibility in Tanzania based on the information obtained in the previous chapters. The idea is to examine whether the proposed CDM project meets the additionality and SD criteria, and if it can be implemented in Tanzania. Specifically, the chapter analyzes the economic viability of the proposed CDM project; it examines the barriers and risks that could hinder project implementation, and discusses the socio-economic impacts of the project. In additional, a SWOT analysis is conducted to assess project implementation based on the results from other analyses.

6.1 Economic analysis

Economic analysis is undertaken to understand the cost effectiveness of the proposed CDM project. Three factors are analysed: identification of a feasible crediting period (i.e., a seven-year two times renewable crediting period or a non-renewable ten-year crediting period), project financial additionality (i.e., financial feasibility of the project with CER income and without CER income), and loan possibility (i.e., financial viability of investing using different loan options or not using loans at all).

6.1.1 Analysis of feasible crediting period

In order to identify the feasible crediting period, the costs and benefits for the proposed CDM project activity are analysed. The feasible period is determined using the economic indicators, mainly the internal rate of return (IRR) and net present value (NPV).

Expected project costs

Various costs are to be incurred to implement the proposed sisal waste CDM project, mainly related to the planning, construction, and operation of the biogas plants. The costs used in this study are estimated based on the costs that were incurred during the construction of the Hale biogas plant. Basically, the construction costs were estimated taking into account the size of the proposed biogas plants while the planning costs were estimated by reviewing various up front cost estimates for small scale CDM projects. Specifically, the following are the anticipated costs for installing, operating, and registering the proposed sisal waste CDM project activity:

- Equipment costs (i.e., biogas plant equipments, biogas engine generators, etc): 2.24 million US$ (33% of the total cost) (Katani Ltd estimates)
- Personnel costs (i.e., plant operators, engineers and constructors, etc): 882,440 US$ (13% of the total cost) (Katani Ltd estimates)

- CDM related costs (i.e., preparation of documentations, EIA, and up-front costs on project registration and validation): 68,000 US$ (1% of the total cost) (UNEP, 2007). The CDM related costs does not include share of proceeds costs payable to the UNFCCC when CERs are issued by the CDM EB.
- Miscellaneous (staff training, permits, etc): 1,697,000 US$ (25% of the total cost) (Katani Ltd estimates)
- Grid connection costs: 1.9 million US$ (28% of the total cost) (TANESCO estimates)
- Operation and maintenance costs: 203,640 US$/year (3% of the total cost) – these costs are incurred on a yearly basis during the lifetime of the project (Katani Ltd estimates)
- Corporate income tax rate: 30% of the yearly profits (tanzania.go.tz/tra.html, 2008) – tax is paid on a yearly basis during the lifetime of the project

:: Total initial costs/cost to be incurred in the first year = **6,788,000 US$**

Expected project incomes

The project is expected to generate a firm income by selling CERs to potential buyers and selling excess electricity to the national power utility (TANESCO). Other expected income sources are savings on the import of electricity and from the selling of organic fertilizer to local farmers and the selling of excess biogas. Only the incomes from CER, electricity export, and the savings from electricity are analysed in this section. The yearly and total incomes for both seven and ten year crediting periods are described below.

a) Income from sale of CER

The income to be obtained from the selling of CER will depend on the price of CER agreed between the CDM project developers and the potential buyer. Basically, the parties involved in trading CER may agree on a fixed or floating price system, or a combination of two systems. On the one hand, the fixed price does not change and it is normally lower than the floating price (UNEP, 2005). On the other hand, the floating price keeps changing depending on the market conditions and thus can be advantageous or disadvantageous to both the CER seller and the buyer (UNEP, 2005). Basically, if all the project risks are taken by the CER seller there is a possibility of higher income due to the higher CER price, and if the buyer takes all the market risks, the CER seller will have less control over the CER price (ibid). The key risks for CDM projects are to be analysed later in this chapter, but such risks may include project investment risks, CDM registration and validation risks, and market contract risks.

At the time of writing, the average market prices for CER yet to be generated from projects under development were 10 and 20 US$/t CO_2 equivalent (carbonpositive.net, 2008). Due to uncertainties surrounding CER pricing, in this research, three different CER prices (5, 10, and 15 US$/t CO_2 e) are conservatively assumed for each crediting period (see Table 6.1 on the next page). The idea is to analyse how these different prices will shape the future income of the project and also to have a picture of what the situation will be if a different price is agreed.

Table 6.1 Expected incomes from sale of CERs for the proposed CDM project

Year		CER produced (tCO_2 e)		Price (US$/$tCO_2$ e) - 7 year CP			Price (US$/$tCO_2$ e) - 10 year CP		
		7 year CP	10 year CP	5	10	15	5	10	15
1	2009	59,492	58,678	297,460	594,920	892,380	293,390	586,780	880,170
2	2010	59,492	58,678	297,460	594,920	892,380	293,390	586,780	880,170
3	2011	59,492	58,678	297,460	594,920	892,380	293,390	586,780	880,170
4	2012	59,492	58,678	297,460	594,920	892,380	293,390	586,780	880,170
5	2013	59,492	58,678	297,460	594,920	892,380	293,390	586,780	880,170
6	2014	59,492	58,678	297,460	594,920	892,380	293,390	586,780	880,170
7	2015	59,492	58,678	297,460	594,920	892,380	293,390	586,780	880,170
8	2016		58,678				293,390	586,780	880,170
9	2017		58,678				293,390	586,780	880,170
10	2018		58,678				293,390	586,780	880,170
	Total	**416,444**	**586,780**	**2,082,220**	**4,164,440**	**6,246,660**	**2,933,900**	**5,867,800**	**8,801,700**

b) Incomes from the sale of electricity

As shown earlier, the expected yearly electricity generation for all four biogas plants is 35 GWh, out of which 30 GWh will be exported to the grid and the rest consumed onsite. The income from the sale of electricity will depend on the buyback price guaranteed by TANESCO. At present, the buyback price for renewable electricity set up by the Energy and Water Regulatory Authority (EWURA) is around 0.08 US$/kWh against 0.1 US$/kWh for thermal resources (TANESCO, 2007). However, TANESCO has set up a buyback price of 0.05 US$/kWh for renewable power plants including sisal waste biogas plant (Katani Ltd, 2008). As a conservative approach, this study uses the TANESCO's price in order to avoid overestimations when using an unguaranteed price of 0.08 US$/kWh set by EWURA. Total incomes from the sale of electricity for both crediting periods are shown in the table below.

Table 6.2 Estimated incomes from electricity sell for both crediting periods

Year		Price (US$/kWh)	Electricity export (kWh/yr)	Income (US$/yr)
1	2009	0.05	6,0000,000	3,000,000
2	2010	0.05	6,0000,000	3,000,000
3	2011	0.05	6,0000,000	3,000,000
4	2012	0.05	6,0000,000	3,000,000
5	2013	0.05	6,0000,000	3,000,000
6	2014	0.05	6,0000,000	3,000,000
7	2015	0.05	6,0000,000	3,000,000
8	2016	0.05	6,0000,000	3,000,000
9	2017	0.05	6,0000,000	3,000,000
10	2018	0.05	6,0000000	3,000,000
	Total for a seven-year CP		**420,000,000**	**21,000,000**
	Total for a ten year CP		**600,000,000**	**30,000,000**

Note: tariff is assumed to remain constant in the whole crediting period

c) Savings from electricity import

Savings from electricity import represent cash that would have been spent on purchasing electricity from the grid for factory consumption. To calculate the amount of cash saved yearly, the price of kWh for grid electricity is multiplied by the total amount of electricity actually imported from the grid every year. TANESCO has set different tariffs for different user categories mainly depending on the amount of electricity consumed each month. The estimated tariff for a kWh of electricity imported from the grid for medium size factories like a sisal factory stands at around 0.11 US$ (TANESCO, 2008). Other costs, such as service charges and electricity import charges, apply but have an insignificant impact on the total yearly expenditure on electricity import and therefore are not considered in this analysis. Table 6.3 below shows the income from electricity savings for the proposed sisal waste CDM project for both a seven year renewable crediting period and a ten year non-renewable crediting period.

Table 6.3 Expected income from savings on electricity import

Year		Price (US$/kWh)	Electricity import (kWh)	Saving (US$)
1	2009	0.11	11,000,000	1,210,000
2	2010	0.11	11,000,000	1,210,000
3	2011	0.11	11,000,000	1,210,000
4	2012	0.11	11,000,000	1,210,000
5	2013	0.11	11,000,000	1,210,000
6	2014	0.11	11,000,000	1,210,000
7	2015	0.11	11,000,000	1,210,000
8	2016	0.11	11,000,000	1,210,000
9	2017	0.11	11,000,000	1,210,000
10	2018	0.11	11,000,000	1,210,000
	Total for a seven-year CP		**77,000,000**	**8,470,000**
	Total for a ten-year CP		**110,000,000**	**12,100,000**

Note: tariff is assumed to remain constant in the whole crediting period

The yearly average income can be obtained simply by subtracting the yearly operation and maintenance costs from the total yearly income for each of the price categories (i.e., income = price category + electricity sell income + electricity saving income) and dividing the outcome by the crediting period. The summary of the results is shown in Table 6.4.

Table 6.4 Summary of incomes and costs for the proposed CDM project

Parameters	Values (US$)	
Incomes	Seven-year CP	Ten-year CP
Income from CER sell		
At 5 US$/tCO2 e	2,082,220	2,933,900
At 10 US$/tCO2 e	4,164,440	5,867,800
At 15 US$/tCO2 e	6,246,660	8,801,700
Income from electricity sell	21,000,000	30,000,000
Saving from electricity import	8,470,000	12,100,000
Costs		
Total operation and maintenance costs	2,118,480	3,026,400
Corporate income tax (30%)		
At 5 US$/tCO2 e	9,465,666	13,510,170
At 10 US$/tCO2 e	10,090,332	14,390,340
At 15 US$/tCO2 e	10,714,998	15,270,510
Average yearly benefit		
At 5 US$/tCO2 e	**2,852,582**	**2,849,733**
At 10 US$/tCO2 e	**3,060,804**	**3,055,106**
At 15 US$/tCO2 e	**3,269,026**	**3,260,479**

After calculating the average yearly incomes for each price category, the feasible crediting period for the proposed CDM project is determined by comparing the NPV and IRR for each price category.

Basically, the NPV represents the sum of the future discounted cash flow of the project. The NPV measures project value directly taking into account the discount/interest rate and changes in the inflation rate and thus gives a precise idea of the values taken into account in the future (Levy and Sarnat, 1994). The NPV is calculated as the sum of the yearly present values of the project plus the initial investment costs using the following formula (ibid). The investment is considered as more feasible when its NPV is more positive compared to the alternatives.

$$NPV = -C_0 + \sum_{t=1}^{N} \frac{C_t}{(1+r)^t}$$

where:

NPV – net present value
N – total number of years
r – discount/interest rate
C_t – yearly income
C_0 – initial investment
t - year in which calculation is made

The discount/interest rate has a significant effect on the NPV result and thus it must be chosen very carefully. According to Markandya (1998), several approaches can be used to estimate the interest rate, including the following (Markandya, 1998)

- Ethical approach based on which discount should be applied by the specific project/firm. This normally gives low rates of discount in real terms, sometimes up to 3%, and
- Descriptive approach based on what rate is actually applied in everyday decision making. This approach leads to a higher discount rate, sometimes up to 25%.

In this study, the interest rate is used in its real terms taking into account the inflation rate (i.e., ´´decrease in the value of the unit of currency/ a rise in general level of prices of goods and services over time´´ (Levy and Sarnat, 1994).) and nominal interest rate (i.e., ´´rate of interest before adjustment for inflation´´ (ibid)). Therefore, the real interest rate refers to ´´interest rate that has been adjusted to remove the effects of inflation; it is the growth rate of purchasing power derived from an investment´´ (investopedia.com, 2008). The inflation and nominal rates are assumed to be 5% and 20% respectively (Bank of Tanzania, 2008). The real interest rate of 15% was obtained using the Fisher equation (i.e., real interest rate = nominal interest rate – inflation)

The IRR is the discount rate when the NPV is zero (Berges, 2004). Basically, the IRR is the interest rate that precisely balances the NPV with the upfront investment needed to develop the project (ibid). In principle, the higher the IRR, the more feasible the project is, at least in terms of return on investment (Levy and Sarnat, 1994). Two types of IRR can be identified: project IRR and equity IRR. On the one hand, in calculating the project IRR, it is assumed that no debt is used for the project; the IRR is the internal rate of return based on the project's incomes (Broverman, 2004). On the other hand, the calculation of equity IRR assumes the use of debt for implementation of the project, so the IRR takes into account debt repayments as well (ibid). In this study the internal rate of returns were calculated using the formula shown below (Levy and Sarnat, 1994).

$$NPV = \sum_{t=0}^{N} \frac{C_t}{(1+R)^t} = 0$$

where:

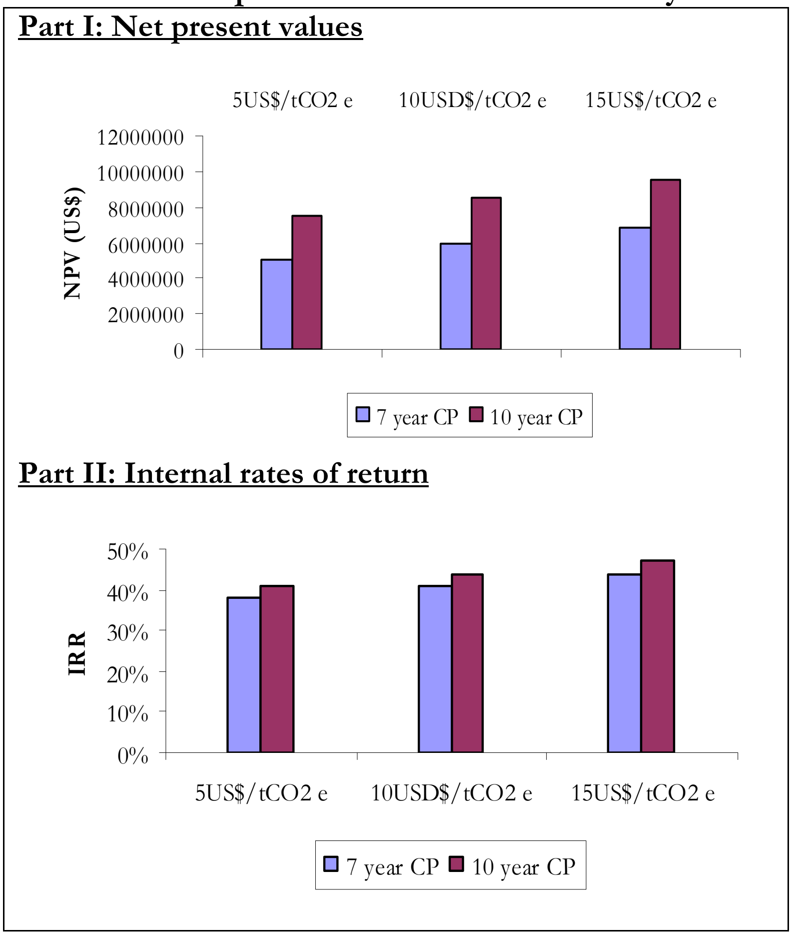
R – internal rate of return

Depending on the price of CER agreed between the CDM project developer and the CER buyer, different results can be obtained as shown in Table 6.5 and Figure 6.1 below.

Table 6.5 NPV and IRR results for the seven and ten years crediting periods

	Seven-yearr crediting period			Ten-yerr crediting period		
CERs prices (US$)	5	10	15	5	10	15
IRR (%)	38	41	44	41	44	47
NPV (US$)	5,079,934	5,946,229	6,812,520	7,514,151	8,544,870	9,575,590

Figure 6.1 NPV and IRR comparison for the seven and ten years crediting periods

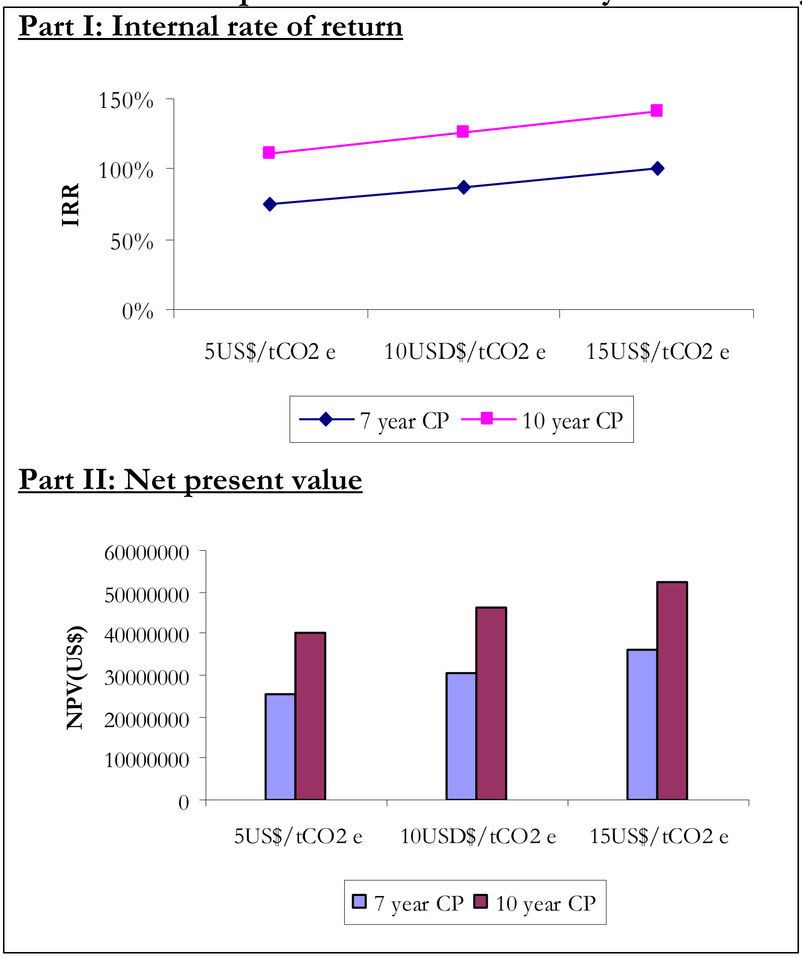


The result above shows that, for both NPV and IRR, a ten-year crediting period at a CER price of 15 US$/t$CO_2$ e is only feasible investment than all other options. Taking this further by assuming that the CDM project activity will generate the same amount of CER in the extra 14 years of a renewed seven-year crediting period, still a ten-year crediting period shows highly feasible results as shown below.

Table 6.6 IRR and NPV results for the 21 and 10 years crediting periods

	Twenty one- year crediting period			Ten-year crediting period		
CER prices (US$/t$CO_2$ e)	5	10	15	5	10	15
Net present value (US$)	25,278,891	30,747,346	36,215,775	40,265,237	46,392,055	52,518,879
Internal rate of return (%)	75%	88%	100%	111%	126%	141%

Figure 6.2 IRR and NPV comparison for the 21 and 10 years crediting periods



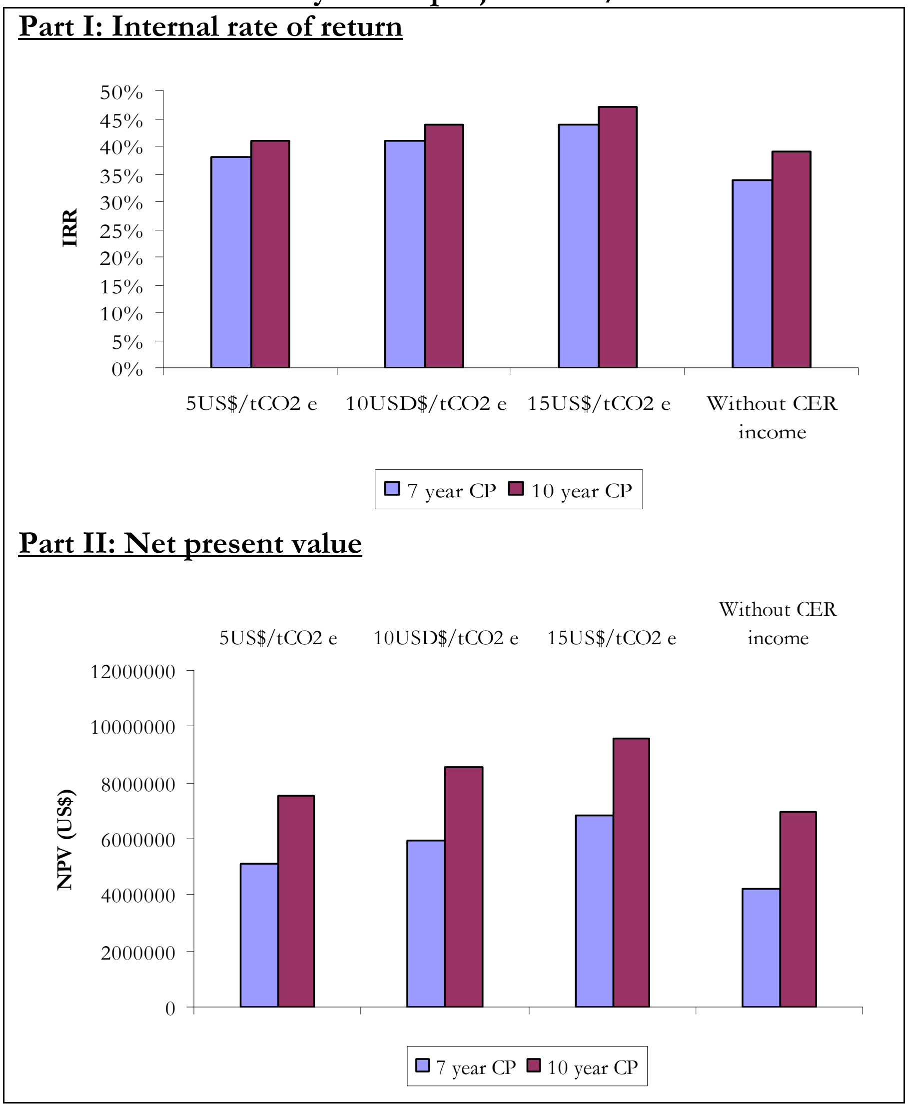
6.1.2 Analysis of financial additionality of the CDM project

The financial additionality of the proposed sisal waste CDM project activity is analysed by comparing the financial viability of the project with CER income and without CER income using the IRR and NPV as indicators. According to UNFCCC, the project activity is additional if it is proved that the implementation of the project would not have been the most financially attractive option except when implemented as a CDM project (UNEP, 2007). But if the financial analysis shows that the proposed project is as financially attractive without CER income as with CER income, then the project is not additional since it would have been implemented anyway (ibid). Table 6.7 shows the results of financial analysis for the two options while Figure 6.3 compares the results.

Table 6.7 Results for financial additionality for sisal waste CDM project

	Project with CER income						**Project without CER income**	
	7 year crediting period			10 year crediting period			7 years invest.	10 years invest.
CER prices (US$/$tCO_2$ e)	5	10	15	5	10	15	N/A	N/A
Internal rate of return (%)	25	28	30	30	32	34	34	39
Net present value (US$)	2,208,080	2,781,947	3,355,813	4,108,730	4,780,543	5,452,355	1,814,084	3,588,806

Figure 6.3 Financial additionality of the project with/without CER incomes



Generally, the investment comparison analysis above show that, the project is additional when implemented as a CDM project activity. In other words, the project would be financially less attractive without the CER incomes.

6.1.3 Analysis of loan possibility

Four credit options to cover the investment costs of the proposed CDM project are analysed in this study. Among these options, the first two options are for a ten-year crediting period and the rest are for a seven-year crediting period including:

- Case 1- Credit to be repaid in eight years at 15% interest rate
- Case 2 - Credit to be repaid in eight years at 15% interest rate (no repayments in the first two years)
- Case 3 - Credit to be repaid in five years at 15% interest rate
- Case 4- Credit to be repaid in five years at 15% interest rate (no repayments in the first two years)

The yearly loan repayment is calculated using the formula below (Barelli *et al.,* 2004) and the results for both cases are summarized in Table 6.8 and presented in Figure 6.4 below. Detailed data and calculations are attached in the appendix section (appendices I to IX)

$$A = I * (1+r)$$

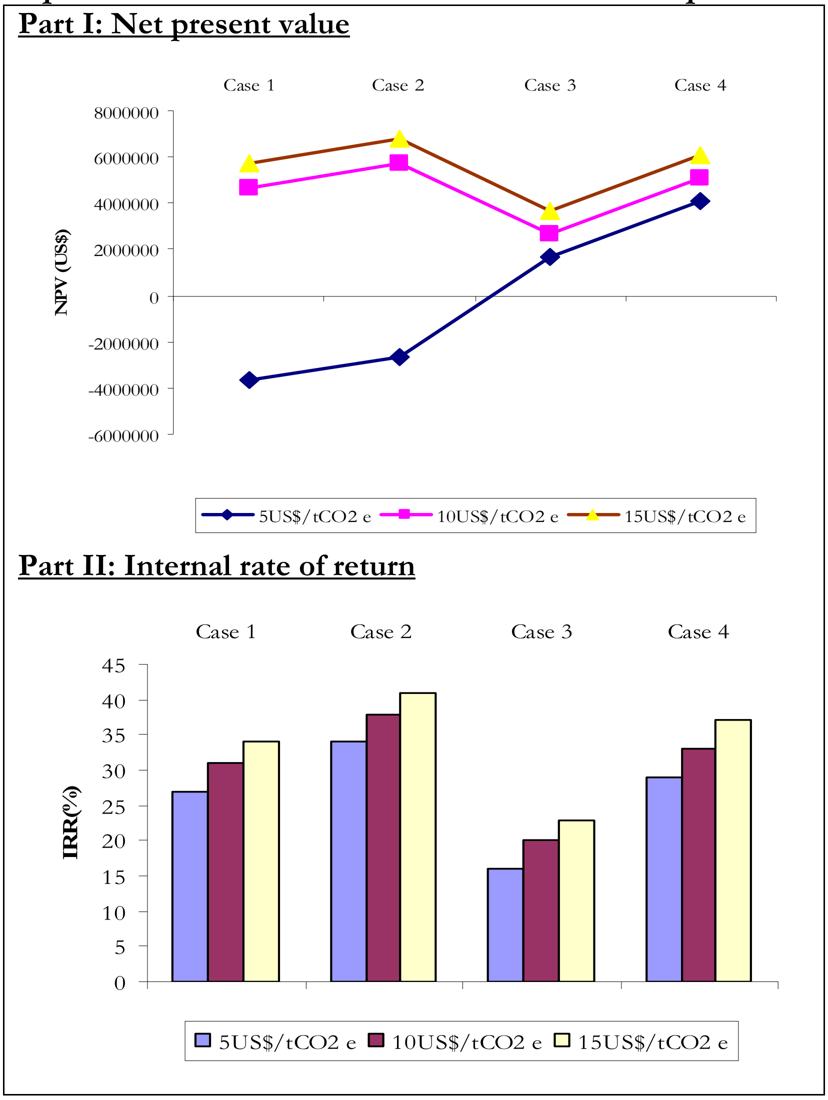
where:

A - yearly loan repayment
I - credit /loan
r – interest

Table 6.8 Results of IRR and NPV for different loan options

	Net present value			**Internal rate of return**		
CER price (US$/tCO2)	5	10	15	5	10	15 e
Case 1	-3,625,370	4,663,112	5,693,832	27	31	34
Case 2	-2,688,483	5,759,462	6,804,480	34	38	41
Case 3	1,649,339	2,649,181	3,649,023	16	20	23
Case 4	4,073,967	5,073,809	6,073,651	29	33	37

Figure 6.4 Comparison of NPV and IRR for different loan options

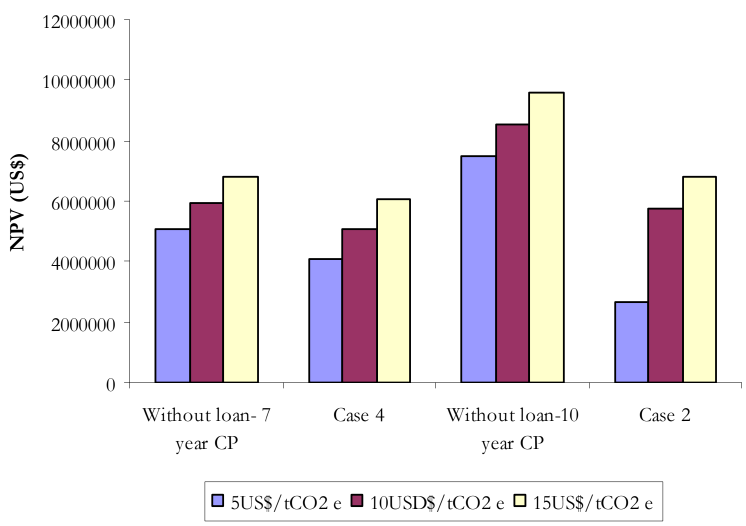


The results above show that, for a ten-year crediting period, it is feasible to invest the proposed CDM project using loan at the interest rates and repayment periods analyzed in Case 2 (i.e., Credit to be repaid in eight years at 15% interest rate (no repayments in the first two years) than Case 1 (i.e., Credit to be repaid in eight years at 15% interest rate) But this is only true if the CER price will be at 10 or 15 US$/t$CO_2$ e as at a CER price of 5 US$/t$CO_2$ e, Case 1 at a CER price of 15 US$/t$CO_2$ e will also be feasible.

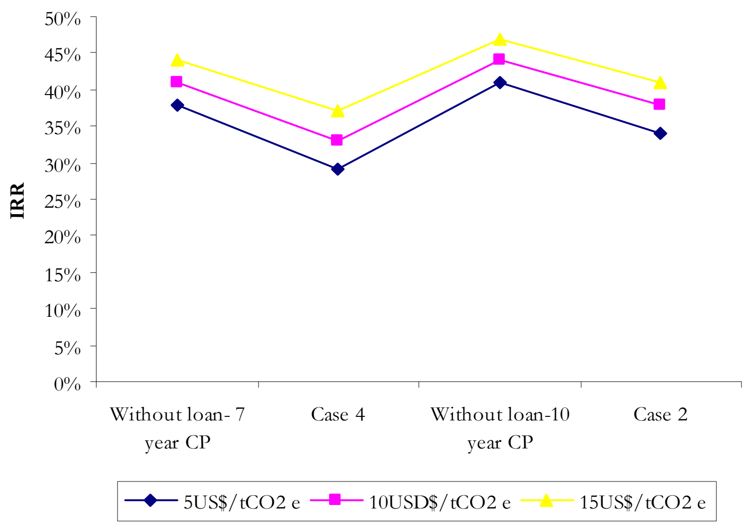
For a seven-year crediting period, Case 4 (i.e., Credit to be repaid in five years at 15% interest rate (no repayments in the first two years) gives feasible results than Case 3 (i.e., Credit to be repaid in five years at 15% interest) at all CER price ranges. By comparing the two crediting periods (i.e., seven and ten year crediting periods), a ten-year crediting period gives, especially Case 2 at CER price of 10 and 15 US$/t$CO_2$ e gives more feasible results than seven-year crediting period, this is probably because of the longer payback period offered to a ten-year crediting period (i.e., 8 years) which may allow necessary financial adjustments. Compared to the investment without credits, the results show that for both crediting periods, it is more feasible if the project is implemented without applying loan financing. Note that, the comparison included only Case 2 and Case 4 since they are more feasible options than Case 1 and 3 (see Figure 6.5 on the next page)

Figure 6.5 Project's investment feasibility with/without loan

Part I: Net present value



Part II: Internal rate of return



CP – crediting period

6.2 Risk analysis for the proposed CDM project

Various risks which might affect the implementation of the proposed CDM project activity. This section analyzes key risks and barriers related to planning, implementation, and the operation of the CDM project. The intention is to identify them, analyse their impacts on the proposed sisal waste CDM project and, finally, identify plausible measures to reduce the negative impacts.

6.2.1 Risks at the planning phase

Several risks can be identified when planning the project including approval risks, registration and validation risks, and up front costs risks. These risks are analysed below:

Project's approval risk

This risk is concerned with the Delay in issuing the letter of approval, or the rejection of approval for a CDM project by the country's DNA. The resultant impacts are failure or delay in implementation of the project as initially planned. While the approval risk cannot be overcome, especially for inexperienced countries like Tanzania with only one registered CDM project, it can be minimized. In countries like China and Brazil, the approval risk is minimized by involving the DNA right from the start of the planning of the project. In some cases, the DNA may issue the document stipulating the conditions necessary for project approval and advise the project developers to address them (UNEP, 2005). In Tanzania, the approval risk can be reduced by ensuring that the PDD is prepared based on the generic CDM requirements and the country's sustainable development criteria. The higher quality of the PDD will help reduce the approval problems and thus secure implementation of the project. The sustainable development impacts of the proposed sisal waste CDM project are analysed in detail in section 6.3 below

CDM registration and validation risk

Like the approval risks above, the validation and registration stages of CDM project cycle increase the risk of project rejection or delay of registration. For sisal waste CDM projects, these two stages seem to be the stages with the highest risk due to a lack of certainty regarding the applied baseline and monitoring methodologies since there are no similar projects registered by the CDM – EB. Basically, the baseline methodologies applied in this study were selected by referring to other closely related registered CDM projects, mainly landfill and palm oil projects. While the results obtained in this study may be absolutely correct, it is important to not that due to it being the first project of its type, that is, sisal waste, the CDM project is not risk free. For example, it has been difficult to decide whether it is correct to consider sisal waste as dry or wet waste, though physically it has all the characteristics of wet waste due to the addition of water during the decortication process.

Basically, if sisal waste is taken as wet waste, the ER results tend to be higher than expected, which increases the risk of CER overestimation. This is because the weight of the water (which is normally equal to that of dry sisal waste) is also accounted for in the calculations of ER as contributing to methane formation, which is not true. To avoid this overestimation, the dry weight of sisal waste was used as a conservative approach.

Another uncertainty concerns the calculation of the grid emission factor. The problem of inconsistency of grid data in Tanzania may render the grid emission factor questionable. The conservative estimates of grid data capacity may help to avoid an overestimation of the emission factor but at the same time may lead to an underestimation, which reduces the volume of CER. The methodology and data uncertainty risks can alternatively be referred to as the baseline risks and should be expected for any CDM project implemented in Tanzania.

Upfront costs risk

The upfront costs include all costs required to cover initial feasibility studies of the CDM project and costs for project registration, validation, and certification. On the one hand, lack of upfront capital for project preparation may pose barriers for CDM project development since it will be impossible to fulfill the basic CDM requirements including preparation of PDD. On the other hand, the upfront cost may pose a feasibility risk, especially when costs are incurred on initial studies and it is found that the proposed project is not feasible.

For the proposed sisal waste CDM project, the upfront costs risk can be reduced by incorporating the initial costs into the company's general budget (in this case, Katani Ltd), and recovering them when the CDM project is operational. Alternatively, the potential CER buyer can take some of the risks, especially those relating to project registration and operation. While this may help reduce risks on the developers' side, the CER buyer will have much more control over the CER price. This will increase the uncertainties regarding future project revenues.

6.2.2 Risks at the implementation and operation phase

There are a number of risks at the implementation and operation stages, mainly related to project investment, performance, market and agreement, and foreign currency exchange. These risks may pose barriers to the implementation and operation of the CDM project and in many cases may lead to project failure. These risks are generic for any CDM project, but they can be analyzed specifically for the case of sisal waste CDM project in Tanzania.

Project's investment risk

It is mostly likely that investors would want to invest in projects that apply already known technologies that are widely practiced. For them, putting their money into such projects will, if all other things are optimal, ensure a financial return. For new technologies such as sisal biogas technology, the perception may be different. Currently, there is only one fully operational sisal biogas plant worldwide, which is located at the Hale Sisal Estate in Tanga. This increases the uncertainties related to securing the potential investors or loans from the creditors who may perceive the technology as too new and thus see the project as too risky.

Other investment risk is linked to loan acquisition processes and the terms of payments of the received loan. For the high risk and high cost investments like a sisal biogas plant, the loan is most likely to have a very high interest rate and a very short payback period. With CDM attachment, which has a limited operation period/crediting period, the shorter repayment period and high interest loan will solidify revenue uncertainty of the project (review economic analysis above). Simultaneously, in the case of a CDM project with the addition of CER revenue, the investors may find that new renewable energy technologies like sisal biogas are a worthwhile investment. In this case, the problem of performance must be addressed, especially by increasing the number of competent technicians who will be able to provide timely and effective repair and maintenance of the biogas plants. This will reduce the risk of failure to deliver CER as per contract.

Project's performance risk

Risks related to project performance may be caused by a delay in the construction and commissioning of the project. These delays may be attributed by complications in acquiring the necessary permits, land tenure issues, and delay in the importation of the biogas equipment. Other factors that could increase performance risks include the availability and effectiveness of the technology and staff competence. Performance risks may negatively influence the timing of the project and ultimately the flow of CER (UNEP, 2005). According to UNFCCC, one of the reasons for rejecting or for requesting a review of the projects applying for certification is the failure of the project to start on time as indicated in the PDD (UNFCCC, 2008).

For the sisal waste CDM project, performance risk can be accounted for mainly by the effectiveness of the sisal biogas technology (as described above) and other bureaucratic processes related to project commissioning. The project's underperformance will be detected by the DOE during the monitoring stage. In this case, all monitoring equipment for biogas plants performance and energy generation (including metre measuring energy actually exported to TANESCO's grid) must be fully operational; otherwise the DOE will not certify the project. Importantly, to ensure project's certification, efforts must be made to reduce the performance risk, as this will lead to a reduction in the monitoring and verification risks as well.

Power purchase agreement risk

As the proposed project will export power to the grid, it is cost effective to keep the price of the exported electricity above the production costs. As mentioned earlier, in Tanzania, the tariffs paid to each independent power producer (IPP) for energy exported to the grid are fixed by the Energy and Water Regulatory Authority (EWURA), based on the costs and operation data supplied by the IPP facility, thus the tariffs differ widely for each IPP. For newly constructed renewable energy plants in Tanzania, prediction of the future tariff is difficult, mainly due to the lack of similar projects for comparison and the lack of any generic methodology for estimating future tariffs. Therefore, any new renewable energy IPP can estimate their revenue only upon completion of the power plants. This increases the risk as there is no guarantee that the calculated tariff will be within the tariff ranges set by EWURA and levels acceptable to TANESCO.

Currently, all IPPs exporting power to the grid use natural gas and diesel mainly at the large scale production (i.e., over 10 MW). For these plants, TANESCO pays the capacity charge every year regardless of whether the power is exported to the grid or not. The capacity charge is intended to cover the plants' operation and maintenance costs and is usually fixed for each power plant. The capacity charge is not expected to be paid to small scale renewable energy plants, as many will have a low capacity. This disparity in payments may render the proposed sisal biogas investment too risky and less attractive.

Note, however, that a newly Standardized Power Purchase Agreement (SPPA) for the purchase of grid-connected capacity is being developed in Tanzania to facilitate power trading negotiations between TANESCO and small IPPs (i.e., 100 kW – 10 MW). The SPPA, which is scheduled to be operational in 2009, is expected to minimize some of the risks associated with tariff setting since power trading agreements will be neutralized (MEM, 2007). The SPPA will also reduce the time taken to negotiate the power tariff, which will secure the implementation of new small scale renewable projects. As far as the sisal waste CDM project is concerned, the SPPA will help guarantee optimal income from the sale of electricity and will reduce CER delivery risk (especially from avoidable grid emissions since it will be possible to export power to the grid).

Foreign currency risk

As it depends on the depreciation of US$ and the rise of Tanzanian shilling, the exchange rate between US$ and local Tanzanian currency (Tanzanian Shillings) may affect the income of small scale renewable energy projects like the proposed sisal biogas power plant. The impact can be calculated by considering project spending, project loan, and project revenue. On the spending side, the project developers will incur investment, operational and maintenance costs in Tanzanian shillings. If the loan is used in the investment, it is always received in US$. The revenues, especially from the sale of electricity are normally received in Tanzanian shillings despite the fact that TANESCO set the price in US$. Therefore, in the situation where the US$ depreciates, the proposed sisal waste CDM project will be negatively impacted by

- Falling income from the sale of electricity since the price paid in Tanzanian shillings per MWh falls due to US$ depreciation
- Declining value of the loan lowering the value of the capital available for covering project costs, since the loan is received in US$.

Post-Kyoto risk

The post-Kyoto risk is concerned with uncertainty in the global demand and recognition of CER beyond 2012, which is the end year for the currently operating Protocol. This risk relates to the choice of crediting period by the project developers (a seven-year renewable or a non-renewable ten-year crediting periods). Both types of crediting periods will bypass the Kyoto deadline of 2012, thus creating uncertainties of whether the current CER pricing system will prevail and whether the global demand for CER will be assured.

For the sisal project, which is scheduled to start in 2009, the choice of the right crediting period is crucial. However, due to the prevailing risks analysed above, it is difficult to predict whether the investment requirements will be easily met on time and whether operations will start as scheduled. Also, based on the economic analysis above, the two times renewable seven-year crediting period was seen as feasible if taken for all 21-years compared to a ten-year crediting period. This means that, if the former crediting period is chosen, the post Kyoto risk will increase as the project will be subject to new regulations and conditions, especially when renewing the crediting period. A ten-year crediting period was seen to be credible compared to the first seven-years for a twenty one-year crediting period, but also it will bypass 2012. For a ten-year period, at least the negotiation on CER price can be fixed and CER trading be allowed to continue uniformly beyond 2012. In general, for both crediting periods, the prediction of future project revenue is very uncertain since very few CER buyers are ready to purchase CERs after 2012, and many will do so only for a very low price (UNEP, 2007)

Importantly, the post-Kyoto risk can be minimized if the project will be able to recover the capital and operational and maintenance costs before 2012. Or else, the investor/developer, who is committed to carrying the risk of financing the project that can in no way recover its costs before 2012, will need a very high rate of return to recover the investment costs (ibid). For the proposed sisal waste CDM project, this option seems to be too unlikely (refer to economic analysis above).

6.3 Socio-economic impact analysis

According to the Tanzanian DNA Office, any CDM project to be implemented in Tanzania is expected to contribute to the socio-economic development of the country (see also Chapter 4). The CDM project activity must result in benefits that will help in achieving the sustainable development, including (VPO, 2007):

- sustainable industrial development,
- poverty reduction through improved rural incomes and livelihoods,
- employment opportunities for the community,
- availability of affordable and reliable electricity to the rural communities,
- improvement of social services, such as education and health, and
- enhancement of technological transfer and development.

This section analyses the socio-economic contributions of the proposed sisal waste CDM project activity to see whether the project can help in achieving sustainable development in Tanzania. The following sections analyze three socio-economic development contributions selected specifically for this study: employment effect of the project, energy accessibility impact, and impact on reduced consumption of chemical fertilizer. The analysis is done to examine how the above-mentioned parameters may influence people's incomes/livelihoods. The quantitative approach is used to analyze these parameters. The positive results will mean that the project can fulfill the sustainable development criteria required for any CDM project activity implemented in Tanzania. Various assumptions and estimations are used in quantifying the impacts; therefore, slightly different results can be obtained when different assumptions are applied.

6.3.1 Employment effect of sisal waste CDM project

During the construction and operation of the biogas plants, there will be an impact on local income improvement through employment creation. Permanent jobs will be created for the operation tasks and there will be an indirect effect resulting from contracts with local companies for the service and maintenance of the plants' equipment. A demand for temporary labour will also be created for unprofessional jobs related to plant construction. Importantly, the socio-economic impacts of employment creation by the proposed CDM project are mainly the reduction of unemployment costs to the society and the enhancement of local livelihoods and welfare.

The socio-economic benefits of employment can be considered to be equivalent to the social and economic costs of the unemployment precluded during the time of employment (Markandya, 1998). Basically, for unemployed people, being employed means ensuring the welfare gains in social and economic terms due to securing an income from the employment after the period of unemployment (ibid). Employment benefits analysis is done by considering various key parameters notably, the length of employment, socio-economic support during the period of unemployment to the presently employed people, and income opportunities during the time of unemployment for now employed people (i.e., values and benefits of unemployment).

It is estimated that the number of people to be employed on a permanent basis at each of the four sisal waste biogas plants is 15, making a total of 60 jobs. Fifty temporary jobs are estimated to be created for each plant making a total of 200 employees. This gives a total of 260 jobs during the project's lifetime. The estimated salary per month for professional permanent jobs is 300 US$/month for duration of the plant, and for temporary unprofessional jobs is 100 US$/month for one year. Furthermore, it is assumed that, in the absence of the CDM project, permanently employed people would have been unemployed for two years. The period of unemployment for temporary employed people is unknown. In addition, 15% of the monthly wage is estimated as the monetary value during the period of unemployment for the now employed people.

The unemployment benefits are estimated to be zero as there are no unemployment benefit programs in Tanzania. All other values are estimated without considering factors such as income tax, pension deductions, or type of activity the currently employed people were doing during the period of unemployment. Using the above estimations, the employment creation benefits of the proposed sisal waste CDM project activity can be quantified as shown in Table 6.9.

Table 6.9 Result for the employment impacts of the proposed CDM project

Part I: Key employment data

Employment type	No. of jobs (people	No. of previously unemployed (people)	Duration of unemployment (year)	Length of employment (year)		Monthly wage (US$/person)
Permanent	60	10	2	7 CP	10 CP	300
Temporary	200	200	n/a	1		100

Part II: Unemployment benefit and Value of unemployment

Group	Monthly benefit	Benefit duration	Value of unemployment period (US$/month/person)	Total monthly benefit (US$/person)
Permanent	0	0	80	80
Temporary	0	0	20	20

Part III: Net benefits of employment for previously unemployed people

Group	Net monthly benefit (US$/person)	Total per year (US$)
Permanent	220	26400
Temporary	80	192000

Part IV: Financial labour costs of CDM project/Financial benefits to newly employed people

Group	Total yearly cost (US$)	
Permanent	216,000	
Temporary	240,000*	
Total financial labor cost/financial benefits	seven years	**1,632,000**
	Ten years	**2,280,000**

* These costs/benefits are incurred only in the 1st year of the project

CP – crediting period

The results above show that there is a financial gain to the people who will be employed by the project. Part IV of the table gives the yearly total gains for both permanently and temporarily employed people. On the factory side, these same figures represent the total financial labour cost to be spent on paying the new employees. The total financial labour costs were calculated by multiplying the total number of employees by the length of employment and the cost of employment (i.e., expected wages). Importantly, the financial gains are expected to enhance peoples' welfare by improving accessibility to other basic needs, such as education or health services. As the results are all positive, it can be concluded that, based on the assumed parameters, the proposed sisal waste CDM project can help in achieving sustainable development through employment creation to local communities.

6.3.2 Impacts on energy accessibility improvement

The proposed biogas plants are expected to produce an excess of 452,488 m^3 biogas per year, which if not consumed in economic ways must be flared. The fact is that only 11 % (or 54,847 m^3) of the total biogas produced per year will be consumed in generating electricity (using an 8 MW installed capacity). As stated earlier, if all biogas produced daily is to be consumed in electricity generation, the 74 MW capacity must be installed, with an 18.5 MW gas engine generator in each biogas plant. Due to prevailing barriers and risks, this is nearly impossible. Alternatively, the gas could be supplied to local communities using pipes or any other mechanism to improve energy accessibility.

Under various key assumptions, it is possible to quantify the benefits of using the biogas by reducing the use of charcoal or kerosene for cooking. For example, in Tanzania, it is estimated that a normal family of 4 - 5 people would need one bag (equivalent to around 30 kg) of charcoal per week, which costs at least 20 US$, or, alternatively, they would consume 10 litres of kerosene per week, which costs roughly 1.4 US$ per litre. If it is assumed that the biogas will be used only for cooking without being supplemented with other fuels like kerosene or charcoal, then the yearly charcoal and kerosene consumptions would be 1560 kg and 3650 litres respectively. Other assumptions to be considered include:

- 1 kg of charcoal = 0.686 m^3 of biogas (i.e., 1560 kg of charcoal = 1070 m^3 of biogas) (Nijaguna, 2006)
- 1 ltr of kerosene = 1.613 m^3 of biogas (i.e., 520 ltr of kerosene = 839 m^3 of biogas) (Nijaguna, 2006)
- Calorific value of biogas – 22 MJ/m^3 (also review chapter three)
- Calorific value of charcoal – 20 MJ/kg (ibid)
- Calorific value of kerosene – 38 MJ/m^3 (ibid)
- Stove efficiency for biogas – 55%
- Stove efficiency for charcoal – 30%
- Stove efficiency for kerosene – 35%
- Price per m^3 of biogas – 1.3 US$ (estimated based on production cost for m^3 of biogas)

Based on the data above, the heat production of charcoal per day is (*1560 kg/365 day * 30% * 20 MJ/kg = 24 MJ/day*), and that of biogas (*1560 kg/365 day * 0.686 m^3 *22 MJ/kg **

55% = 35 MJ/day). The difference between the two values represents the extra amount of energy that is added by biogas (*35 MJ – 25 MJ = 10 MJ*), which is equal to 300 m^3 of biogas per year (*1070 m^3/year * 10 MJ/35 MJ*) or 438 kg of charcoal per year (*300 m^3/year * 1 kg/0.686*). The required amount of biogas to fulfil the household demand per year is (*1070 m^3/year - 300 m^3/year = 770 m^3 per year*), which would be equal to 1122 kg of charcoal (*770 m^3/year * 1 kg/0.686 m^3*).

The monetary value for substituting charcoal with biogas is determined by the amount of money spent on both charcoal and biogas. If there would be no biogas consumption, the cost of charcoal would be 1040 US$ per year (*1560 kg/year /30 kg * 20 US$*). The cost to be incurred on biogas is 1000 US$ per year (*770 m^3/year * 1.3 US$*). The difference between the two values represents cost saved as a result of utilizing biogas instead of charcoal per household per year (*1040 US$/year - 1000 US$/year = 40 US$/year*). In this case, the number of households to be supplied with biogas per year is (*452,488 m^3/770 m^3/year = 588 households*). The total amount of money saved for all households supplied with biogas per year is (*588 household * 40 US$/year/household = 26,506 US$/year*).

In the case of kerosene, the fuel consumption per day is (*520 ltr/365 days * 35% * 38 MJ/ltr = 19 MJ/day*), and that of biogas is (*520 ltr/365 days *1.613 m^3 * 55% * 22 MJ/m^3 = 28 MJ/day*). The extra amount of energy added by biogas is (*28 MJ/day - 19 MJ/day = 9 MJ/day*), which is equivalent to 330 m^3 of biogas per year (*839 m^3/year * 11 MJ/28 MJ*) or 205 ltr of kerosene per year (*330 m^3/year * 1 ltr/1.613 m^3*). The required amount of biogas for a single household per year is (*839 m^3/year - 330 m^3/year = 509 m^3/year*), which is equivalent to 315 ltr (*509 m^3/year * 1 ltr/1.613 m^3)*

Like in the case of charcoal above, the financial value of utilizing biogas in place of kerosene is calculated by considering the costs incurred for both fuels. For kerosene, the yearly cost would be (*520 ltr/year * 1.4 US$/ltr = 728 US$/year*) while for biogas the cost to be incurred per year is (*509 m^3/year * 1.3 US$ = 661 US$/year*). By subtracting one value from the other, the cost saved as a result of utilizing biogas instead of kerosene per household per year is obtained (*728 US$/year - 661 US$/year = 67 US$/year*). The total number of households to be supplied with biogas per year is (*452,488 m^3 /509 m^3/year = 889 households*), and therefore, the total amount of costs to be saved is (*67 US$/year * 889 households = 59589 US$).* The results for the above analysis are summarized in the following table.

Table 6.10 Summarized results for the project's impact on energy accessibility

Fuel	Amount	Consumption	Saved fuel	Cost (US$)	Saved cost (US$/Hh)
Charcoal Biogas	1560 kg/year (A) 1070 m^3/year	1122 kg /year* 770 m^3/year**	438 kg/**year** 300 m^3/year	1040 = A 1000 = Consumed biogas	40 per year
Kerosene Biogas	520 ltr/year (B) 839 m^3/year	315 ltr /year* 509 m^3/year**	205 ltr/year 330 m^3/year	728 = B 661 = Consumed biogas	67 per year

* This represents amount equivalent to biogas in quantity but not capacity
** Actual amount of biogas consumed in place of charcoal
Hh - Household

Based on the above results, there is an indication that the proposed sisal waste CDM project will help local communities save money through the use of biogas for cooking purposes. As in the case of employment creation, the reduced expenditure on fuel by utilizing biogas can be a source of improving accessibility to other basic requirements. Other additional benefits are related to improving health conditions to people consuming the biogas by avoiding the smoke released by kerosene and charcoal. Also, the enhanced energy accessibility will help saving time since people will spend less time in cooking due to the efficiency of the biogas stoves.

6.3.3 Impacts on reduced use of chemical fertilizer

The proposed biogas plants will also produce organic fertilizer as a byproduct of anaerobic digestion. As pointed out earlier, this organic fertilizer consists of about 70% as many nutrients as the original feedstock (Nijaguna, 2006). According to various researches, the use of biogas fertilizer in farming fields may increase crop yield by 6.5% to 16% (Pal *et al.* 1996). Communities living near the sisal factories can therefore use organic fertilizer to improve agricultural production. The sisal company can also use the fertilizer produced on site to improve sisal farming and avoid the use of costly chemical fertilizers. This section analyses the impact of using organic fertilizer compared to chemical fertilizers, specifically Urea, Superphosphate, and Potash. The aim is to understand the impact of the proposed sisal waste CDM project on improving peoples' livelihoods, especially by enhancing food security. The analysis is done based on information provided in the previous sections and various assumptions derived from the literature. The following data and assumptions are used:

- N content in ton of sisal waste (kg) – 6 or (70% * 6 = 4 kg/ton of slurry) (Malavolta, 2007)
- Phosphorus content in ton of sisal waste (kg) – 1 or (70% * 1 = 0.7 kg/ ton of slurry) (ibid)
- Potassium content in ton of sisal waste (kg) – 0.8 or (70% * 0.8 = 0.6 kg/ ton of slurry) (ibid)
- Fertilizer value of biogas per ton of fertilizer (Urea) – 17 kg of N_2 = 37 kg Urea (Nijaguna, 2006)
- Fertilizer value of biogas per ton of fertilizer (Phosphate) – 15 kg of N_2 = 94 kg Urea (ibid)
- Fertilizer value of biogas per ton of fertilizer (Potash)– 10 kg of N_2 = 17 kg Urea (ibid)
- Total organic fertilizer produced by all 4 biogas plants – 382 m^3 * 4 = 1528 m^3/day = 557780 m^3/year (review biogas plant design in Chapter five)
- Price for 1 kg of Urea – 0.5 US$ (estimated)
- Price for 1 kg of Phosphate – 0.5 US$(estimated)
- Price for 1 kg of Potash – 0.5 US$(estimated)

For Urea, the Nitrogen (N) equivalent in a ton of sisal waste is (*6 kg * 37 kg/17 kg = 13 kg of urea*), which is equal to 9 kg of N in a slurry residue (*4 kg * 13kg /6 kg*). The total N content in the total slurry produced each year in all four biogas plants is (*557780 m^3/year * 4 kg/1000 = 2342 kg/m^3/ year*), which is equivalent to 5353 kg/m^3/ year of Urea (*2342* *kg/m³/ year * 9 kg/4 kg*). The difference between the two represents the value added for using biogas fertilizer rather than Urea per year (*5353 kg/m³/ year - 2342 kg/m³/ year = 3011 kg/m³/ year*), which is (*3011 kg/m³/ year * 0.5 US$= 1506 US$/year*). The total avoided cost resulting from utilizing biogas fertilizer in place of Urea is (*5353 kg/m³/ year * 0.5 US$ = 2677 US$/year*)

For Superphosphate, the Phosphorus (P) equivalent in a ton of sisal waste is (*1 kg * 94 kg/15 kg = 6 kg*), which is equal to 4 kg of P in a slurry residue (*0.7 kg * 6 kg /1 kg*). The total P content in the total slurry produced each year is (*557780 m³/year * 0.7 kg/1000 = 390 kg/year/ m³*). This value is equal to 2447 kg/m³/ year of Superphosphate (*390 kg/year/ m³ * 4 kg /0.7 kg*). The benefit added by using biogas fertilizer rather than Superphosphate is (*2447 kg/m³/ year – 390 kg/m³/ year = 2056 kg/m³/ year*) which is valued at (*2056 kg/m³/ year * 0.5 US$ = 1028 US$/year*). The total yearly avoided cost for utilizing biogas fertilizer is (2447 kg/m³/ year * *0.5 US$ = 1223 US$/year*)

For Potash, the Potassium (K) equivalent in a ton of sisal waste is (*0.8 kg * 17 kg/10 kg = 1.4 kg*). This value is equal to 1 kg of K in the slurry (*0.6 kg * 1.4 kg /0.8 kg*) The total K content in the total slurry per year is (*557780 m³/year * 0.6 kg/1000 = 312 kg/year/ m³*), which is also equal to 531 *kg/year/ m³* of Potash (*312 kg/year/ m³ * 1 kg/ 0.6 kg*). The added benefit for using biogas fertilizer is (*531 kg/year/ m³ - 312 kg/year/ m³ = 219 kg/year/ m³*) which is valued (*219 kg/year/ m³ * 0.5 US$ = 110 US$/year*). The total yearly avoided cost for utilizing biogas fertilizer in place of Potash is (531 *kg/year/ m³ * 0.5 US$ = 266 US$/year*). Table 6.11 below summarizes the results of the above analysis.

Table 6.11 Summary of the project's impact on reduced use of chemical fertilizer

Chemical fertilizer (kg)	Amount (kg)	Equivalent to biogas (kg)	Value added (kg/year)	Saved costs (US$/year)
Urea	5353 (A)	2342	3011	1506
Phosphate	2447 (B)	390	2056	1028
Potash	531 (C)	312	219	110

Assuming that the biogas fertilizer is provided to local farmers free of charge, then the only cost to be incurred is for transporting the fertilizer from the biogas plant to the farming fields. It is not easy to calculate the exactly transportation costs as the distances from the biogas plants to the farming fields differ widely. Generally, it is cost effective choice to use biogas fertilizer if the transportation costs from the biogas plant do not exceed the costs avoided by not purchasing chemical fertilizer. However, if the benefit of increased yield per hectare as a result of biogas fertilizer or the avoided environmental and social costs are taken into account in the analysis, it is possible to arrive at the firm conclusion that using biogas fertilizer is more cost effective than using chemical fertilizers. Like in the previous analyses, the use of biogas fertilizer will help people serve money as shown in the table above. The socio-economic impact of reducing expenditure on chemical fertilizer is directly related to an increased in peoples' livelihood (i.e. yield per heater, food security, healthier environment, etc), and thus contributing to the achievement of SD in Tanzania.

6.4 SWOT analysis for CDM project implementation

This section summarizes the analyses done in the previous chapters and sections to examine the possibility of implementing the proposed sisal waste CDM project in Tanzania. The SWOT analysis is used for this purpose. As previously mentioned, an acronym SWOT represents strengths, weaknesses, opportunities, and threats, and SWOT analysis is the analyses of these parameters. In general, the strengths and the opportunities are desirable while the weaknesses and the threats are undesirable as they may lead to failure of the project. The following principles make the better use of SWOT analysis:

- ´´Strengths need to be maintained, built upon or leveraged.
- Weaknesses need to be remedied, changed or stopped.
- Opportunities need to be prioritized, captured, built on and optimized.
- Threats need to be countered or minimized and managed´´ (Chapman, 2008).

Practically, the strengths and weaknesses concern with the present situations while the opportunities and threats concern with the situations in future. For the purpose of this study, which is mainly planning an implementation of the sisal waste CDM project activity in Tanzania, the following factors are considered for SWOT analysis.

Strengths and weaknesses

1. Expertise/skills/experience/knowledge
2. Technology/infrastructure
3. Institutional/organization
4. Financial/likely return
5. Timescale

Opportunity and threats

1. Technology and innovations
2. Economic
3. Environmental effects
4. Socio-economic
5. Political/legal effects
6. Demand for CER /electricity /biogas/fertilizer
7. Competition
8. Other risks/barriers

The influence of these parameters on the implementation of proposed sisal waste CDM project is examined in Table 6.12 and Table 6.13 in the next two pages

Table 6.12 Strengths and weaknesses for CDM project implementation

Criteria	Strength	Weakness
Expertise/skills/experience/knowledge	- There is some expertise on sisal biogas technology	- Lack of enough local expertise/knowledge on sisal biogas technology and on CDM project development. Only few staffs have been sent to China by financiers for training on how to operate the biogas plant at Hale Sisal Estate. No enough experience on the technology. For the proposed biogas plants, more staff trainings are required to ensure an effective performance of the plants. - Regarding CDM development, there is a lack of enough local expertise on project's documents preparation. In general, Tanzania is not experienced in CDM project activities.
Technology /infrastructure	- There is some development on sisal biogas technology due to presence of small scale biogas plant at Hale Sisal Estate in Tanga.	- Sisal biogas technology is new; therefore more researches and development are required for large scale commercial utilizing sisal biogas technology. - The infrastructures for the proposed biogas plants do not exist, only that there are sisal factories which generate sisal waste as residues. New infrastructures are needed.
Institutional/ organization	- The presence of a DNA Office in the country can facilitate an approval of the proposed CDM project. - Local project developers/host company called Katani Ltd is willing and committed to take the project forward - Locally available NGOs may help facilitate project planning	- Other than a DNA, in Tanzania there is no other locally based CDM accreditation Offices such as DOE. Locally available DOEs would help fasten validation and certification of the CDM projects.
Financial/likely return	- High global demand for CER at least for now. - Financial analysis shows that the proposed CDM project is financially viable once it is operational - Various loan options also show financial viability.	- Changes in inflation and interest rates may jeopardize results of financial analysis. - Investment cost may be far higher than the ones estimated in this study. - Lack of capital to finance the implementation of the project, difficulties to obtain loans from local and international financiers, and difficult terms of payments for issued loans. Also, lack of subsidies from the government for renewable technology like sisal waste biogas, and lack of financial incentives for CDM related activities in Tanzania
Timescale		- Due to the prevailing risks, it is unlikely that the project will be implemented in 2009 as planned. Key hindrances include methodology for baseline calculations and finance for project investment. Some key adjustments in timing are required.

Table 6.13 Opportunities and threats for CDM project implementation

Criteria	Opportunity	Threats
Technology and innovations	- There is potential for growth of sisal biogas technology.	- Risk of technology failure when applied in a large scale commercial purposes
Economic	- Economic analysis shows that the project is economically feasible.	- Risks concerning price of CER especially beyond Kyoto. - Risk concerning power purchase agreement with TANESCO. - Risk of underestimation of investment costs - Risks of higher operation and maintenance cost when the project is operational. - Changes in inflation rate - Foreign exchange rate changes
Environmental effects	- High potential in future for reducing environmental pollutions. This will help maintain the credibility of the project.	
Socio-economic effect	- Increased acceptance of the project in future due to its impacts on socio-economic improvements (employment, energy accessibility, cost saving, etc). This will guarantee market for biogas and fertilizer and also maintain project's credibility.	
Political/legal effects/	- Prevalence of government policies that favour renewable energy technology and CDM - Prevalence of more welcoming investment policies	- Changes to legislations for example restricting the IPPs selling power to the grid. - Changes to tax policies - Possible increase in trade regulations
Demand and prices for CER/electricity /biogas /fertilizer	- If the project is implemented on time, there is guarantee for CER market. - Guaranteed biogas and electricity demand - Guaranteed fertilizer demand	- No guarantee of CER demand after Kyoto Protocol. - Uncertainty in CER prices - Uncertainties in electricity tariff /buyback price
Competition		- Competition in CER market if the projects conditions are not satisfactory - Competition in biogas and fertilizer market from new comers/similar CDM projects
Other risks/obstacles/ opportunities		Most risks are unmanageable for example; - No guarantee that the project will be approved, or validated, or certified due to methodological and performance risks. - Foreign currency exchange risk - Project investment risk - Project performance risk - CER delivery failure risk - Partners' withdrawal

In general, the SWOT analysis above shows that there is a possibility of implementing the proposed sisal waste CDM project in Tanzania. However, if this is to happen, it is important to maintain and prioritize all the identified opportunities and strengths and to minimize/remove all weaknesses and threats. It is beyond the scope of this Thesis to conduct an in-depth analysis of the mechanisms required to deal with the identified weaknesses/threats and/or opportunities/strengths.

Summary

In this chapter, the key aspects of the research were analysed. The aim was to examine the feasibility of implementing a sisal waste CDM project activity in Tanzania. Specifically, the chapter analysed the project's economic viability, project's risks, and the project's socio-economic impact. The SWOT analysis was also conducted.

In the case of economic viability, the analysis showed that the proposed CDM project is feasible if it is implemented in either of the two CP, though a ten-year CP gave more feasible results than a seven-year CP. However, further analysis showed that, if the additional 14 years for a seven-year CP are considered, this CP can surpass a ten-year CP. Therefore, the choice of CP for the proposed CDM project is determined partly by the expected performance of the plants in terms of CER generation and partly by the possibility of renewal of the CP for a seven-year CP. This means that, if the seven-year CP is chosen in place of the ten-year CP and the project developers fail to renew the CP due to underperformances, then the ten-year CP is feasible than the seven-year CP since no renewal is required. In addition, the analysis of financial feasibility showed that the project is financially viable if it is implemented as a CDM project than a conventional project, and thus the proposed project is additional. Lastly, the analysis on loan possibility showed that it is feasible to implement the project using loans which allow non-payments in the first two years of investment. This was observed for both crediting periods. However, in general, the investment without using loans proved to be highly feasible for both, seven-year and ten-year crediting periods.

Concerning the impact of the project on the socio-economic development, the results showed that, the project can to a significant extent contribute to enhancement of local livelihood, specifically by creating employment, improving energy accessibility, and reducing the use of chemical fertilizer. Generally, these impacts have chain of effects all related to achievement of SD. Through this, considerable incomes will be gained when the people are employed in the newly built biogas plants, when costs spent of fossil fuels are reduced, and when the chemical fertilizer are substituted with the biogas fertilizer. The general implications of this is that, by saving the costs and increase the incomes, people will be able to access other needs like paying for their children's education, paying for their health services, etc. These are social benefits obtained as a result of the project that substitute costs that would be incurred if the project would not be implemented. In this way, the project is credible since it will contribute in achievement of the SD in Tanzania.

Lastly, the SWOT analysis was conducted using the results of the above analyses plus other information obtained in the previous chapters. The aim was to analyse the strengths and the weaknesses and to predict the opportunities and the threats regarding the implementation of the sisal waste CDM project activity in Tanzania.

7

Conclusion

This is the final chapter of the report which concludes the study based on the analyses done in the previous chapters. Basically, this chapter is a summary of the individual chapters' summaries. The chapter focuses mainly on answering the research question and on discussion of validity of the findings of analyses carried out throughout the report.

7.1 General conclusion

Based on the analyses presented in this study, it is clear that the implementation of CDM project activity based on sisal waste is a feasible investment. The CDM possibility was analysed based on various factors which include sisal waste production potential; biogas and electricity generation potentials; GHG emission reduction possibility; and CDM project implementation possibility. These factors were altogether derived from the research's problem question which was ´´Is it feasible to implement the CDM projects based on the biogas production and electricity generation from the sisal waste in Tanzania?´´ and research's objectives which were ´´to estimate the greenhouse gases (GHGs) emission reduction if sisal waste is used in biogas production and electricity generation in the selected sisal factories in Tanzania´´ and ´´to examine the viability of implementing sisal waste CDM project in the cases by assessing key factors such as project additionality and sustainable development impacts of the project´´.

i. Potential for sisal waste production

The key focus here was to examine if there is enough production of sisal waste in the case study. This was assessed in Chapter five and it was revealed that, there is a huge potential for sisal waste production in all four sisal estates considered for CDM project activity. In total, at least 341,640 tons of sisal waste are expected to be produced each year with each sisal estate contributes at least 234 tons per day. Sisal waste production is also expected to remain constant throughout the project's lifetime. That means any increase in waste production will not be relevant for the proposed CDM project since it won't be included in the calculations of ER. The decrease in waste production is not expected throughout the whole period. However, if sisal productions fall below the level initially estimated in the PDD, eventually, the project will fail to generate CER and will not be validated.

ii. Potential for biogas and electricity generation

The intentions here were to examine how the abundantly produced sisal waste can potentially be used in biogas production and electricity generation. Further, the study looked at the possibility of exporting excess electricity to the grid and supplying excess biogas to the local communities. Generally, the results show high potentials for biogas and electricity generation from sisal waste. Based on various parameters determining the performance of anaerobic digestion technology, a total of 507,335 m^3 of biogas per year is expected in all four biogas plants (each plant producing 126,834 m^3 of biogas per ear). Of this amount, only 10% (54,857 m^3) of it will be consumed as fuel in generating electricity of 8 MW; a 2 MW biogas engine generator will be installed in every sisal biogas plant. The results showed that, a total of 70 GWh of electricity will be generated, 60 GWh to be exported to the grid and 10 GWh to be consumed onsite.

However, both biogas and electricity production were estimated based on the assumptions that there will be a reliable availability of sisal waste, optimal performance of anaerobic digestion technology, and a year round operation of both biogas plants and engine generators (i.e. 8760 hrs). Though, the calculations on productions may be absolutely correct but the results are subject to problem of overestimations. For example, there is no guarantee of the complete optimal performances of the biogas plants and the gas engines generators as unscheduled technical problems may occur.

iii. Potential for GHG emission reduction

The main focus in this case was to examine if the GHG emissions can be reduced as a result of the project. Based on the results obtained, even in the lowest value of range, there is potential for reduction of GHGs (i.e. CH_4 and CO_2). Two levels of GHG emissions were investigated; one emission of CH_4 from the sisal waste disposal sites, and two emission of CO_2 caused by fossil fuels used to generate grid electricity. In the former case, the underlying assumption was that there is generation and emission of CH_4 from the sisal waste disposal sites and that by avoiding disposal of waste at the disposal sites the methane emissions will be avoided. In the later case, the assumption was that the grid electricity will, in the longer term, be produced by fossil fuels resources which generate and emit CO_2, and that electricity produced from the biogas will marginally replace the fossil fuel resources and thus avoid CO_2 emissions.

Using a FOD model which considers the period waste actually disposed at the disposal site and other factors such as decay rate, type of the disposal site, composition of waste itself, and the amount of waste disposed each year, the CH_4 emission from the disposal sites were calculated. Using default and calculated values for the model, the average CH_4 emission per year were 13,292 tCO_2 e and 12,478 tCO_2 e for the seven-year crediting period and a ten-year crediting period respectively. Generally, throughout the years the methane generation and production were seen to be decreasing. The potential emission reduction was calculated using the UNFCCC approved methodology III.D (i.e., Methane recovery from agricultural and agro-industrial activities). The values above represent potential emission reduction as both leakage and project emissions were assumed to be zero.

Regarding an avoidance of grid emission, the baseline methodology I.D (i.e., Grid connected renewable electricity generation) and the methodological tool (i.e., tool to estimate grid emission factor) were applied. The grid emission factor of 0.48 was obtained and used to estimate the emission reductions for both a seven-year crediting period and a ten-year CP. For both cases the emission reduction of 46,200 tCO_2 e/year were obtained. Note that, data used to calculate the emission factor are the ex-ante data for the past three years (2007). Therefore, the calculated grid emission factor represents emission for the year 2007 only where fossil fuel plants started to operate. However, in the coming years, the Tanzanian grid is expected to involve many more fossil fuels based resources, this means that the calculated emission factor will no longer be valid, and a new emission factor should be calculated using data available at that time, in this way, the potential emission reduction will also be higher than the ones calculated in this Thesis.

*iv. **Possibility of implementation of sisal waste CDM project***

Generally, the focus here was to examine if (based on the observations above) the implementation of sisal waste CDM project is feasible in Tanzania. Several factors were analysed some related to the fulfilment of the CDM requirements, mainly additionality and SD impact and some related to structural issues, mainly finance and risks. The additionality was analysed based on the ideas from the tool to assess additionality of CDM project while SD impacts of the project were analysed based on the country's criteria for SD.

In general, the results showed that the proposed CDM project is additional both in terms of GHG emission reduction (as it can reduce CH_4 and CO_2 emissions) and financially (as the project is able to generate more incomes when it operates as a CDM project than when it operates as a conventional project). The economic analyses were performed using various economic indicators mainly IRR and NPV. Basically, the analysis for additionality involved the comparison of a seven-year crediting period and a ten-year crediting period using various assumptions such as CER prices of 5, 10, 15 US$/t$CO_2$ e. In both crediting periods, the results showed that the better the price for CER, the more the feasible the project, and thus the more the additional the CDM project. In general, a ten-year crediting period at a CER price of 15 US$/t$CO_2$ e gave more positive results compared to all other options and it was seen as the only credible option even if all 14 additional years for the seven-year crediting period are taken into consideration.

In addition, this Thesis also analysed the feasibility of loans to finance the implementation of the project. Four different loan options were analysed including: i) loan to be repaid in eight years at 15% interest rate ii) loan to be repaid in eight years at 15% interest rate (no repayments in the first two years) iii) loan to be repaid in five years at 15% interest rate, and iv) loan to be repaid in five years at 15% interest rate (no repayments in the first two years). The results showed that, the options ii and iv are the only feasible options than options i and iii. However, further analysis showed investment without loan is more cost effective than all other feasible loan options.

Using the specific parameters relating to national criteria for SD , it was demonstrated that the proposed sisal waste CDM project can potentially contribute to SD by enhancing socio-economic conditions of local communities. Three key parameters were analysed including employment creation, improve energy accessibility to local people, and benefits of using biogas fertilizer in place of chemical fertilizers. In terms of employment, the results showed that at least 260 temporary and permanently employment will be created. The impact on employment creation were quantified in monetary terms where the financial gains due to employment was seen to be higher that the unemployment gains.

Due to this, it was concluded that project will help people fulfil other social and economic needs due to the additional incomes from employment.

In terms of energy accessibility improvement, it was shown that the proposed biogas plants will be able to supply biogas to 588 - 889 households depending on the type of fuel replaced by the biogas (kerosene or charcoal respectively). The analysis was done based on various assumptions related to prices of biogas and the replaced fuels, efficiency of stoves, and amount of fuel consumed. Basically, these three factors plus the calorific values of fuels had huge impact on the results which showed that each household will be able to serve 40 - 67 US$/year spent for charcoal and kerosene respectively.

Furthermore, the possibility of implementation of sisal waste CDM project was analysed by examining various risks which could potentially affect the project. The key project's risks were identified in different stages of project development mainly planning, implementation, and operation and the following key risk were identified and analysed with respect to the cases study:

- Project approval risk
- CDM registration and validation risk
- Upfront cost risk
- Project's investment risk
- Power purchase agreement risk
- Project's performance risk
- Foreign currency risk
- Post Kyoto risk

Generally, the results showed that each risk may delay or prevent the implementation of the proposed sisal waste CDM project. Though, various measures can be implemented to reduce some risks, but it is difficult to completely eliminate them. Therefore, it is important for the project developers to realize or predict the key risk in advance, examine the extent at which they can affect the project, and then develop measures to reduce them for example by transferring the risks to parts who are willing and able to handle them.

Lastly, the SWOT analysis was done to categorically summarize the results of various analyses in terms of strength, weakness, opportunity, and threats. Some factors were identified to belong in each of the category and others in more than one category. Basically, the SWOT analysis offered an overview of CDM possibility for individuals/organizations interested in sisal waste CDM project activities in Tanzania.

As it can be observed, this Thesis has used a number of assumptions in analysing various parameters. There could be no other approach; after all, because this research envisages/plans the future situation, and everything about the future is basically assumptions. Nonetheless, the problem of assumptions is that the results obtained always tend to rely on the type of assumptions used and changes when the different assumptions are used. Basically, there is no generic guidance on how assumptions should be chosen and used. In realizing this, the following factors were considered in order to reduce the impact of assumptions on the validity of the analysis:

- Only those realistic assumptions on the condition where there is no CDM project (baseline situation) and when there is CDM where considered, for example assumption on the amount of sisal waste disposed at the disposal site.
- Avoiding an excessive use/use of highly sensitive and highly fluctuating parameters such as tax, inflation, and depreciation rates.
- Avoid an inclusion of some income and cost into the CDM financial feasibility analysis. For example the incomes from fertilizer and biogas, expenditure on biogas pipes, or transportation cost of fertilizer from the biogas plants to the farming fields were ignored. These incomes and costs would involve many more assumptions which would eventually jeopardize the validity of the analyses.
- Applying a sensitivity analysis by using for example different interest rate, CER prices, and crediting periods.

7.2 Recommendations

Various recommendations can be developed to help ensure the implementation of the sisal waste CDM project activity in Tanzania including:

Technology

1. More research and development (R & D) on sisal biogas technology are required targeting mainly at large scale consumption of sisal waste. The researches should focus on various factors such as biodegradability characteristics of the sisal waste, optimal retention time of waste in the digesters, and optimal sizes of the digester and gas storage tanks (as smaller sizes tanks will cover small areas and may reduce the implementation costs).
2. It is important to ensure that all the produced biogas is economically utilized, therefore, for the newly built sisal biogas plants; there must be technological mechanisms to ensure the economic utilizations of all biogas. Basically, this should include not only piping of gas to the residential houses but also use of biogas as fuel in tractors owned by the sisal factories. This will help reduce cost currently spent on diesel/petroleum and will help avoid GHGs pollution as well.

CDM project activity

1. Based on the fact that the CDM methodologies/tools change from time to time, in order to reduce the risks of project's rejection it is important that the project developers use the appropriate baseline and monitoring methodologies. This is very important especially for sisal waste CDM which is implemented for the first time.
2. Other baseline scenario should be analysed as well and if they are found feasible they should also be considered in CDM project activities using sisal waste. These may include scenarios involving production of biogas specifically for flaring or GHGs emission reduction by replacing household fossil fuels consumptions, etc.

3. Involving the DNA from the planning of the project in order to reduce risk of rejection of approval of the project.
4. Though emission reduction by marginal replacement of grid resources was observed to generate more CER than methane avoidance from the disposal site, however, this option is too risky. This is because of grid data inconsistence which increases the risk of emission factor overestimation or underestimation. Therefore, the project developers should be aware of it and find the remedial measures or opt for other credible baseline scenarios.
5. Awareness raising on CDM in general should be emphasized. Efforts should focus on enhancing capacities of local stakeholders to identify and implement the CDM projects. For the sisal waste CDM, more training of the relevant staffs should be prioritized. This will reduce all risks of project rejection/delay during various stages of the CDM project cycle.

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Appendices

Appendix I

Interview Guideline

Field work period: 15.01.2008 – 02.02.2008
Locations:

1. Hale sisal estate and Katani Ltd Head Office, Tanga, Tanzania (visits to case areas Ngombezi, Magunga, Mwelya, and Magoma)
2. Environmental Protection and Management Service (EPMS), Dar es Salaam, Tanzania

Type of information required	Source of information
1. Sisal production - Area under sisal agriculture in Tanzania - Trends and status of sisal production in Tanzania - Sisal production in future - Sisal production on farms and factories owned by Katani Plantation Limited (Ngombezi, Magunga, Mwelya, and Magoma.) :: Include the visits to the sisal estates/factories for observations	Interviews with Mr Francis Nkuba (Director of Planning, Katani Limited: Tel: +255 784260263; E-mail: fcnkuba@katani.co.tz) and Mr. Yunus A. Mssika (Quality Assurance Officer, Tanzania Sisal Board: Tel: +255 272645060; E-mail: yamssika@yahoo.co.uk)
2. Hale Biogas Plant/Sisal Estate - History of the Hale Sisal Biogas Plant - Sisal production at Hale - Sisal waste production at Hale - Sisal waste management at Hale - Sisal waste consumption at Hale biogas plant - Biogas production - Biogas consumption - Electricity generation - Biogas fertilizer production - Plant operation and technological performances - If there is any treatment of sisal waste - Cost of investment of Hale biogas plant - Electricity consumption onsite - Cost of imported electricity - Plans of selling power to the grid/expected tariffs - Other future plans :: Include observations of the performance of sisal biogas plant	Interview with Mr. Gilead Kissaka (General Manager, Hale Biogas Plant: Tel: +255 714 097463; E-mail: gekissaka@katani.co.tz)
3. Sisal waste production in the case areas - Size of the factories - Sisal waste productions status - Waste management/waste disposal/disposal sites - Power consumption/import from the grid - Cost of imported power - Use of fertilizer on sisal plantation - Future plants/other information	Interview with Mr. Francis C. Nkuba (Director of Planning, Katani Limited)
4. CDM in Tanzania - Number of registered CDM projects in Tanzania - Project under consideration - Sectors potential for CDM activities in Tanzania - CDM potential of sisal waste(biogas and electricity production) - Other information related to CDM in Tanzania	Interview with Miss Rose Mero and Mr Damian Casmir, EPMS (Program Officers– CDM) Tel: +255 22 2120429 E-mail: epms@bol.co.tz

Appendices of loan feasibility analysis

Case 1: Credit to be repaid in eight years at 15% interest rate

Appendix II

	Year	Cost (US$)	Credit payment (us$)	Total cost (US$)
0	0	6788000	0	6,788,000
1	2009	0	975,775	1,179,415
2	2010	0	975,775	1,179,415
3	2011	0	975,775	1,179,415
4	2012	0	975,775	1,179,415
5	2013	0	975,775	1,179,415
6	2014	0	975,775	1,179,415
7	2015	0	975,775	1,179,415
8	2016	0	975,775	1,179,415
9	2017	0	0	203,640
10	2018	0	0	203,640

Appendix III

Year		Income from el. export (US$)	Saving from el. import (US$)	CER income (US$)			Credit income (US$)	Total benefits (US$)		
				5	10	15		5	10	15
0	0	0	0	0	0	0	6,788,000	6,788,000	6,788,000	6,788,000
1	2009	3,000,000	1,210,000	297,460	586,780	880,170	0	4,507,460	4,796,780	5,090,170
2	2010	3,000,000	1,210,000	297,460	586,780	880,170	0	4,507,460	4,796,780	5,090,170
3	2011	3,000,000	1,210,000	293,390	586,780	880,170	0	4,503,390	4,796,780	5,090,170
4	2012	3,000,000	1,210,000	293,390	586,780	880,170	0	4,503,390	4,796,780	5,090,170
5	2013	3,000,000	1,210,000	293,390	586,780	880,170	0	4,503,390	4,796,780	5,090,170
6	2014	3,000,000	1,210,000	293,390	586,780	880,170	0	4,503,390	4,796,780	5,090,170
7	2015	3,000,000	1,210,000	293,390	586,780	880,170	0	4,503,390	4,796,780	5,090,170
8	2016	3,000,000	1,210,000	293,390	586,780	880,170	0	4,503,390	4,796,780	5,090,170
9	2017	3,000,000	1,210,000	293,390	586,780	880,170	0	4,503,390	4,796,780	5,090,170
10	2018	3,000,000	1,210,000	293,390	586,780	880,170	0	4,503,390	4,796,780	5,090,170

Appendix IV

Year		Total costs (US$)	Total benefits (US$)			Balance (US$)		
			5	10	15	5	10	15
0	0	6,788,000	6,788,000	6,788,000	6,788,000	-6,788,000	-6,788,000	-6,788,000
1	2009	1,179,415	4,507,460	4,796,780	5,090,170	1,975,807	2,178,331	2,383,704
2	2010	1,179,415	4,507,460	4,796,780	5,090,170	1,975,807	2,178,331	2,383,704
3	2011	1,179,415	4,503,390	4,796,780	5,090,170	1,972,958	2,178,331	2,383,704
4	2012	1,179,415	4,503,390	4,796,780	5,090,170	1,972,958	2,178,331	2,383,704
5	2013	1,179,415	4,503,390	4,796,780	5,090,170	1,972,958	2,178,331	2,383,704
6	2014	1,179,415	4,503,390	4,796,780	5,090,170	1,972,958	2,178,331	2,383,704
7	2015	1,179,415	4,503,390	4,796,780	5,090,170	1,972,958	2,178,331	2,383,704
8	2016	1,179,415	4,503,390	4,796,780	5,090,170	1,972,958	2,178,331	2,383,704
9	2017	203,640	4,503,390	4,796,780	5,090,170	2,948,733	3,154,106	3,359,479
10	2018	203,640	4,503,390	4,796,780	5,090,170	2,948,733	3,154,106	3,359,479
	Net present value (US$)					**-3,625,370**	**4,663,112**	**5,693,832**
	Internal rate of return (%)					**27**	**31**	**34**

Case 2: Credit to be repaid in eight years at 15% interest rate (no repayments in the first two years)

Appendix V

	Year	Cost (US$)	Credit payment (US$)	Total cost (US$)
0	0	6,788,000	0	6,788,000
1	2009	0	975,775	1,179,415
2	2010	0	975,775	1,179,415
3	2011	0	975,775	1,179,415
4	2012	0	975,775	1,179,415
5	2013	0	975,775	1,179,415
6	2014	0	975,775	1,179,415
7	2015	0	975,775	1,179,415
8	2016	0	975,775	1,179,415
9	2017	0	0	203,640
10	2018	0	0	203,640

Appendix VI

Year		Income from el. export (US$)	Saving from el. import (US$)	CER income (US$)			Credit income (US$)	Total benefits (US$)		
				5	10	15		5	10	15
0	0	0	0	0	0	0	6788000	6,788,000	6,788,000	6,788,000
1	2009	3,000,000	1,210,000	297,460	586,780	880,170	0	4,507,460	4,796,780	5,090,170
2	2010	3,000,000	1,210,000	297,460	586,780	880,170	0	4,507,460	4,796,780	5,090,170
3	2011	3,000,000	1,210,000	293,390	586,780	880,170	0	4,503,390	4,796,780	5,090,170
4	2012	3,000,000	1,210,000	293,390	586,780	880,170	0	4,503,390	4,796,780	5,090,170
5	2013	3,000,000	1,210,000	293,390	586,780	880,170	0	4,503,390	4,796,780	5,090,170
6	2014	3,000,000	1,210,000	293,390	586,780	880,170	0	4,503,390	4,796,780	5,090,170
7	2015	3,000,000	1,210,000	293,390	586,780	880,170	0	4,503,390	4,796,780	5,090,170
8	2016	3,000,000	1,210,000	293,390	586,780	880,170	0	4,503,390	4,796,780	5,090,170
9	2017	3,000,000	1,210,000	293,390	586,780	880,170	0	4,503,390	4,796,780	5,090,170
10	2018	3,000,000	1,210,000	293,390	586,780	880,170	0	4,503,390	4,796,780	5,090,170

Appendix VII

Year		Total costs (US$)	Total benefits (US$)			Balance (US$)		
			5	10	15	5	10	15
0	0	6,788,000	6,788,000	6,788,000	6,788,000	-6,788,000	-6,788,000	-6,788,000
1	2009	1,179,415	4,507,460	4,796,780	5,090,170	1,975,807	2,178,331	2,383,704
2	2010	1,179,415	4,507,460	4,796,780	5,090,170	1,975,807	2,178,331	2,383,704
3	2011	1,179,415	4,503,390	4,796,780	5,090,170	1,972,958	2,178,331	2,383,704
4	2012	1,179,415	4,503,390	4,796,780	5,090,170	1,972,958	2,178,331	2,383,704
5	2013	1,179,415	4,503,390	4,796,780	5,090,170	1,972,958	2,178,331	2,383,704
6	2014	1,179,415	4,503,390	4,796,780	5,090,170	1,972,958	2,178,331	2,383,704
7	2015	1,179,415	4,503,390	4,796,780	5,090,170	1,972,958	2,178,331	2,383,704
8	2016	1,179,415	4,503,390	4,796,780	5,090,170	1,972,958	2,178,331	2,383,704
9	2017	203,640	4,503,390	4,796,780	5,090,170	2,948,733	3,154,106	3,359,479
10	2018	203,640	4,503,390	4,796,780	5,090,170	2,948,733	3,154,106	3,359,479
	Net present value (US$))					**-3,625,370**	**4,663,112**	**5,693,832**
	Internal rate of return (%)					**27**	**31**	**34**

Case 3: Credit to be repaid in five years at 15% interest rate

Appendix VIII

	Year	Cost (US$)	Credit payment (US$)	Total cost (US$)
0	0	6,788,000	0	6,788,000
1	2009	0	1,561,240	1,764,880
2	2010	0	1,561,240	1,764,880
3	2011	0	1,561,240	1,764,880
4	2012	0	1,561,240	1,764,880
5	2013	0	1,561,240	1,764,880
6	2014	0	0	203,640
7	2015	0	0	203640

Appendix IX

Year		Income from el. export (US$)	Saving from el. import (US$)	CER income (US$)			Credit income (US$)	Total benefits (US$)		
				5	10	15		5	10	15
0	0	0	0	0	0	0	6788000	6,788,000	6,788,000	6,788,000
1	2009	3,000,000	1,210,000	293,390	586,780	880,170	0	4,503,390	4,796,780	5,090,170
2	2010	3,000,000	1,210,000	293,390	586,780	880,170	0	4,503,390	4,796,780	5,090,170
3	2011	3,000,000	1,210,000	293,390	586,780	880,170	0	4,503,390	4,796,780	5,090,170
4	2012	3,000,000	1,210,000	293,390	586,780	880,170	0	4,503,390	4,796,780	5,090,170
5	2013	3,000,000	1,210,000	293,390	586,780	880,170	0	4,503,390	4,796,780	5,090,170
6	2014	3,000,000	1,210,000	293,390	586,780	880,170	0	4,503,390	4796,780	5,090,170
7	2015	3,000,000	1,210,000	293,390	586,780	880,170	0	4,503,390	4,796,780	5,090,170

Appendix X

Year		Total costs (US$)	Total benefits (US$)			Balance (US$)		
			5	10	15	5	10	15
0	0	6,788,000	6,788,000	6,788,000	6788,000	-6788,000	-6,788,000	-6,788,000
1	2009	1,764,880	4,503,390	4,796,780	5090,170	1,387,493	1,592,866	1,798,239
2	2010	1,764,880	4,503,390	4,796,780	5090,170	1,387,493	1,592,866	1,798,239
3	2011	1,764,880	4,503,390	4,796,780	5090,170	1,387,493	1,592,866	1,798,239
4	2012	1,764,880	4,503,390	4,796,780	5090,170	1,387,493	1,592,866	1,798,239
5	2013	1,764,880	4,503,390	4,796,780	5090,170	1,387,493	1,592,866	1,798,239
6	2014	203,640	4,503,390	4,796,780	5090,170	2,948,733	3,154,106	3,359,479
7	2015	203,640	4,503,390	4,796,780	5090,170	2,948,733	3,154,106	3,359,479
	Net present value (US$)					**1,649,339**	**2,649,181**	**3,649,023**
	Internal rate of return (%)					**16**	**20**	**23**

Case 4: Credit to be repaid in five years at 15% interest rate (no repayments in the first two years)

Appendix XI

Year		Cost (US$)	Credit payment (us$)	Total cost (US$)
0	0	6,788,000	0	6,788,000
1	2009	0	0	203,640
2	2010	0	0	203,640
3	2011	0	1,115,171	1,318,811
4	2012	0	1,115,171	1,318,811
5	2013	0	1,115,171	1,318,811
6	2014	0	1,115,171	1,318,811
7	2015	0	1,115,171	1,318,811

Appendix XII

Year		Income from el. export (US$)	Saving from el. import (US$)	CER income (US$)			Credit income (US$)	Total benefitS (US$)		
				5	10	15		5	10	15
	0	0	0	0	0	0	6788000	6,788,000	6,788,000	6,788,000
	2009	3,000,000	1,210,000	293,390	586,780	880,170	0	4,503,390	4,796,780	509,0170
	2010	3,000,000	1,210,000	293,390	586,780	880,170	0	4,503,390	4,796,780	509,0170
	2011	3,000,000	1,210,000	293,390	586,780	880,170	0	4,503,390	4,796,780	509,0170
	2012	3,000,000	1,210,000	293,390	586,780	880,170	0	4,503,390	4,796,780	509,0170
	2013	3,000,000	1,210,000	293,390	586,780	880,170	0	4,503,390	4,796,780	509,0170
	2014	3,000,000	1,210,000	293,390	586,780	880,170	0	4,503,390	4,796,780	509,0170
	2015	3,000,000	1,210,000	293,390	586,780	880,170	0	4,503,390	4,796,780	509,0170

Appendix XIII

Year		Total costs (US$)	Total benefits (US$)			Balance (US$)		
			5	10	15	5	10	15
0	0	6,788,000	6,788,000	6,788,000	6,788,000	-6,788,000	-6,788,000	-6,788,000
1	2009	203,640	4,503,390	4,796,780	5,090,170	2,948,733	3,154,106	3,359,479
2	2010	203,640	4,503,390	4,796,780	5,090,170	2,948,733	3,154,106	3,359,479
3	2011	1,318,811	4,503,390	4,796,780	5,090,170	1,833,562	2,038,935	2,244,308
4	2012	1,318,811	4,503,390	4,796,780	5,090,170	1,833,562	2,038,935	2,244,308
5	2013	1,318,811	4,503,390	4,796,780	5,090,170	1,833,562	2,038,935	2,244,308
6	2014	1,318,811	4,503,390	4,796,780	5,090,170	1,833,562	2,038,935	2,244,308
7	2015	1,318,811	4,503,390	4,796,780	5,090,170	1,833,562	2,038,935	2,244,308
	Net present value (US$)					**4,073,967**	**5,073,809**	**6,073,651**
	Internal rate of return (%)					**29**	**33**	**37**