CLEANER USE AND MANAGEMENT OF AGRICULTURAL WASTE FOR BIOGAS FUELLED POWER GENERATION AND BIOFERTILIZERS PRODUCTION

MIRO R. SUSTA
IMTE AG POWER CONSULTING ENGINEERS

Electrical power is an essential element in all productive processes of agricultural enterprises; but its irreplaceable importance is in many countries very often underrated.

However, after last year's serious blackouts in USA, Canada, England, Denmark, Sweden and Italy also governments of high developed countries realized that lack of electrical power may:-

- Cripple country economics;
- Cause chaos in the cities;
- Have a significant impact on production costs, and
- Pose important technical problems to key consumers.

A study measuring the economic impact of the North American power blackout in August 2003 has concluded that the blackout will have far-reaching, long term economic implications in the affected region.

Among others, one key finding of the study was:-

- 38% of the business surveyed said that they would be likely to invest in the alternate power generation systems.

The main questions related to electrical power supply and to the choice of appropriate power generating technology are usually concentrated to the following main criteria:-

- Grid availability;
- Fuel availability;
- Consumers structure;
- Production reliability and costs.

Most of the time the major power consumer centres, like townships and large industrial enterprises have good access to reliable and safe electrical power.

On the other side, rural agricultural communities and small enterprises are very often facing problems related to unsafe electrical power supply.

This is either due to non availability of power transmission and distribution network or because the electrical power supply from existing grid is not reliable.

Another constraint in the way to reliable power supply is the availability of necessary primary energy (fuel) at affordable price.

The complete absence of electrical power supply means that self-sufficient solutions should be considered and the use of traditional fuel sources (coal, natural gas or oil) versus renewable resources (solar, wind, geothermal, hydro, ocean or biomass) for power generation has to be evaluated.

The availability of reliable renewable ocean, geothermal or wind energy is rather limited in Malaysia. On the other hand, Malaysia has considerable hydro and solar energy potential as well as abundant biomass resources. Hydro energy, highly developed technology in Malaysia, is not subject of this paper.

The solar energy for power generation is still considered high cost technology, not affordable for small and medium size agricultural enterprises.

Biomass waste is well available and accessible throughout the country. Major biomass energy resources for power generation include:

- The Forest Residue PRODUCTION OF → STEAM (DIRECT COMBUSTION-DC) & SYNGAS
- The Free Field Residue PRODUCTION OF → STEAM (DC) & SYNGAS
- Waste from Wood Processing Industry PRODUCTION OF → STEAM (DC) & SYNGAS
- Urban Wood, Paper & Cardboard Waste PRODUCTION OF → STEAM (DC) & SYNGAS
- Waste from Agricultural Products Processing Industry PRODUCTION OF → BIOGAS & SYNGAS
- Organic Components in Town Waste PRODUCTION OF → SYNGAS & BIOGAS
- Solid & Liquid Animal Manure PRODUCTION OF → SYNGAS & BIOGAS
- Agricultural Plant Waste PRODUCTION OF → STEAM (DC), BIOGAS, SYNGAS, METHANOL & ETHANOL
- Waste Waters PRODUCTION OF → BIOGAS
- Landfills PRODUCTION OF → BIOGAS (LANDFILL GAS)

Unlike any other energy resources, biomass use for energy production is often a way to dispose biomass waste materials that otherwise would create environmental risks.

Almost all biomass products can be converted either into thermal energy or into commercial fuels, suitable to substitute for fossil fuels.

These can be used for electricity and heat generation and anything else fossil fuels are used for.

The conversion is accomplished through the use of the following distinct processes:-

- Direct Combustion PRODUCT→ STEAM, HOT WATER;
- Thermo-Chemical Conversion PRODUCT→ PYROLYSIS, CHARCOAL, SYNGAS;
- Bio-Chemical Conversion PRODUCT→ METHANOL, ETHANOL, BIOGAS.

There are a number of challenges that inhibit the development of biomass energy.

In this regard, formulation of sustainable energy policy and strategies in addressing these challenges is indeed a pre-requisite for the development and promotion of biomass energy.

Direct combustion, gasification, methanol & ethanol production has been discussed in [1], [3], [4] and [5]. This paper describes utilization of biomass waste for biogas production and power & heat generation with the following topics:

- DEMONSTRATION PILOT PROJECT FOR BIOGAS PRODUCTION FOR POWER AND HEAT GENERATION;
- PROJECT PLANNING EQUIPMENT, DESIGN, DIGESTION PROCESS;

- USING THE EFFLUENTS;
- PROJECT ECONOMICS;
- APPLICATION POSSIBILITIES IN MALAYSIA;
- BENEFIT & CONSTRAINTS;
- CONCLUSIONS.

1. Demonstration Pilot Project for Biogas Production for Power and Heat Generation (Case Study)

1.1 Introduction

The biogas production & power generation project under reference was designated to establish at a pilot level the technical and economic viability of the production of biogas and fertilizer from sisal[1] waste in East Africa.

Produced biogas will be fired in spark ignited biogas engine to generate electrical power.

The waste heat from the engine will be used for heating of biogas reactor (further called as '**digester**').

Figure 1
Sisal Plant

While the primary use of the produced electrical power will thus be at Estate 415V-level, excess electrical power may be exported to 11 kV national power distribution network. Optionally, the project will assess the use of biogas for direct delivery to Estate households.

Both, the solid and the liquid waste from biogas production process will be utilized as fertilizer in Estate's agricultural activities.

A major positive effect of the project is the considerable reduction of environmental degradation caused by wild disposal of enormous quantities of sisal waste (Figure 2).

[1] **Sisal is long hard fiber used primarily in cordage (ropes, cords, and twine). They are obtained from the 1- to 1.5 m long leaves of agaves plants (Figure 1).**

The technologies developed and the market information that will be generated by this project shall be disseminated widely to promote commercial adoption.

In order to achieve these objectives the Project will seek conversion of currently unused sisal decortication plant process wastes into valuable electrical and thermal energy, and in this way to improve production economics.

Figure 2
Sisal Waste Dumping Place

After successful completion, this will be the first demonstration project for the utilization of sisal waste in an economically feasible and environmentally friendly way.

Extremely positive effect is the possibility to produce biogas, for electricity generation and for domestic utilization in rural areas, from locally available renewable sources.

1.2 Technology Choice

Biogas is distinguished from syngas in that it is made through decomposition of organic waste to gaseous fuel by bacteria in the absence of molecular oxygen.

The process that is called anaerobic digestion, occurs in stages to successively break down the organic matter into simpler organic compounds.

The process is carried in airtight digester. Most digestion systems produce biogas that is between 55% and 75% CH_4, about 25% - 45% CO_2, the remaining gases are usually traces of H_2S, N, H_2, methylmercaptans and O_2.

The amount of biogas produced varies with the amount of organic waste fed to the digester and temperature influences the rate of decomposition.

To promote bacterial activity, the digester must maintain a temperature of at least 20°C (ideal 25°C - 35°C, mesophilic).

Higher digester temperatures, above 50°C - 65°C (thermopilic), shorten processing time, allowing the digester to handle a larger volume of organic waste.

The biogas energy content depends on the amount of CH_4 it contains. Typical biogas, with a CH_4 concentration of 65%, contains about 23 MJ/Nm^3 of energy that is equivalent to 0.55 kg of light diesel oil.

The process of biological anaerobic digestion occurs in a sequence of three major steps, hydrolysis, acidogenesis and methanogenesis as illustrated in the following picture, Figure 3.

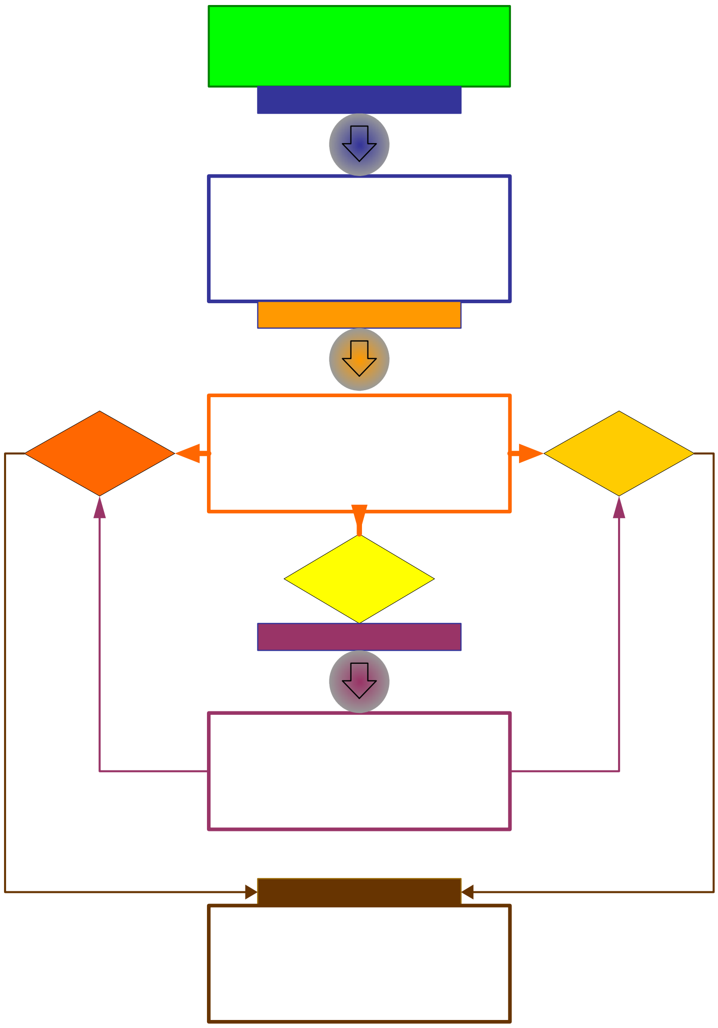

Figure 3
Anaerobic Digestion Process

The acetogenic bacteria grow in close association with the methanogenic bacteria during the last stage of the process.

The reason for this is that the conversion of the fermentation products by the acetogens is thermodynamically only possible if the hydrogen concentration is kept sufficiently low.

Both, the residence time and the acidity (pH-value) are considered most important factors for proper anaerobic digestion process. Residence time has to be well balanced and optimized.

The longer a substrate is kept under proper reaction conditions the more complete its degradation will become.

But the reaction rate will decrease with increasing residence time. Longer residence time requires automatically larger reactor for a given amount of substrate to be treated.

Shorter residence leads to a higher production rate per reactor volume unit, but a lower overall degradation.

Acidity (pH-value) is important for bacteria digestion process. It is important to balance the acidity in reactor in such way that the bacteria become most productive.

Unfortunately, for the different groups of bacteria the optimum acidity is not the same. The complexity of the entire system is increased by the fact that the intermediate products of the digestion have a tendency to lower the acidity, making the later steps in the process more difficult.

An Upflow Anaerobic Sludge Blanket (UASB) type digestion in combination with separate hydrolysis system for the solid parts of sisal residues was chosen for the project.

Beside of UASB, also expanded granular sludge bed (EGSB) digester was taken under consideration, however according to worldwide experience, the EGSB system is more attractive for treating cold and low strength waste liquids, after primary settling and that why this system was finally not considered for the project.

UASB has gained more importance because of low cost associated with the process as there is minimal electrical power usage.

The requirement of packing material and the recirculation of sludge are reduced to absolute minimum unlike in other anaerobic treatment processes.

The digester consists of two zones; reaction zone and settling zone. The reaction zone is divided to granular sludge bed and fluidized zone.

The settling zone has an expanded section which reduces the turbulence of up-flowing stream. The inverted cone in settling zone acts as a gas liquid separator.

The UASB process is a more economical and efficient process as the sludge bed is capable of withstanding high organic loading and in the present case, the digester could take up a loading rate as high as 50 kg COD/m^3 corresponding to an HRT of approximately 5 hours.

The shutdown of the digester for a period couple of weeks up to one 1 month shall not have any effect on the methanogenic bacteria activity of the granular sludge as the normal biogas production might be restored within 10 days.

The UASB process has been more frequently applied to tropical areas where wastewater temperatures are usually at least 20°C and that why this system is preferable for South East Asia.

Comparison of various anaerobic digestion process parameters is shown in the Table 1.

Digestion Process	Description	Advantages	Disadvantages
Dry	**Dry solids content of > 25-30%**	**Compact, lower energy input, better**	**Restricted mixing possibilities**

Digestion Process	Description	Advantages	Disadvantages
		biogas quality (<80% CH_4), maintenance friendly	
Wet	Dry solids content of < 15%	Better mixing possibilities	Higher energy input, lager reactor
Mesophilic	Digestion temperature between 25°C and 35°C	Longer process time, slower rate	Low energy input
Thermophilic	Digestion temperature between 50°C and 70°C	Shorter process time, higher degradation, faster rate	Higher energy input
Batch	Substrate in closed reactor during whole degradation period	Suitable for small plants with seasonal substrate supply	Unstable biogas production
Continuous	Reactor is filled continuously with fresh material	Constant biomass production through continuous feeding	

Table 1
Anaerobic digestion process parameters

1.3 General description of basic design features

The system was designed for biogas production capable for fuelling a 150 kW range biogas driven engine which is direct coupled to 175 kVA, AC, three-phase generator. The general flow diagram is shown in the following picture, Figure 4.

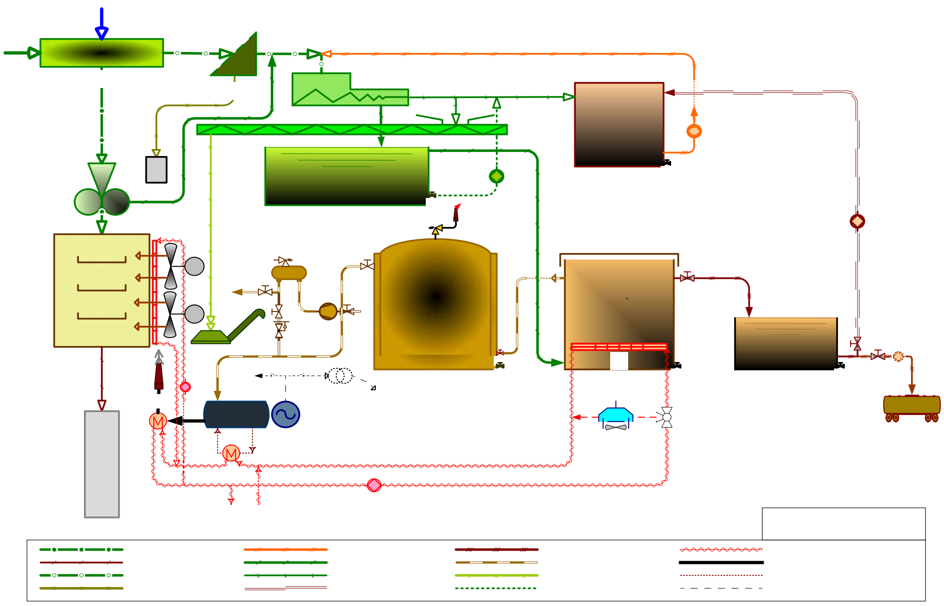

Figure 4
Process Flow Diagram

The waste from decortication plant (1, Figure 5), separated from long fibers, which are forwarded via mill press to fiber drying area, enters the flume tow recovery system (2) consisting of screen and squeezer, where the short fibers are separated from the waste.

Figure 5
Sisal Decortication Plant

The balance of sisal waste, approximately 98% of decortication plant mass input (fresh leaves & water), enters the main screw separator (3) where the sisal waste juice is separated from solid particles.

The sisal juice flows then to inlet storage tank (4) and after settling-down; the clean juice is led to the digester (6).

Sediments from inlet storage tank are pumped to hydrolyze tank (5) where they are mixed with solids from screw separator. $Ca(OH)_2$ or H_3PO_4 can be used as pre-treatment hydrolysis agent.

Sediments from hydrolyze tank are returned to the screw separator for further separation from water.

Part of heavy solids from screw separator are converted to solid fertilizer (6 ton/day) and forwarded by conveyor (29) to the solid fertilizer storage (14) and distribution (30) area.

Biogas produced in digester is stored in the biogas storage tank (10). The sludge from digester flows to the open outlet storage tank (7). Around 98% of this sludge (170 ton/day) is used as liquid fertilizer (13) and the balance is fed to the hydrolyze tank for further processing.

Biogas from the storage tank is fuelling the gas engine (15) that is powering electrical generator (16) to produce electricity (± 37% from biogas fuel energy) and usable waste heat energy (± 46% from biogas fuel energy).

The generator is feeding Estate Power Supply system. Excess power may be exported via 0.4/11kV transformer (17) to 11 kV distribution network (19).

Part of biogas engine waste heat energy is utilized for digester heating (22). In this way, the engine cooling water is re-circulated through water/water heat exchanger that is providing heat energy for digester heating.

The proposed biogas storage tank has 30% capacity of daily biogas production.

This means that in order to consume the produced biogas without un-economical flaring the over-produced balance, the biogas engine generator has to be operated continuously at almost base load 24 hour per day 365 days in year.

This is practically not possible. In order to improve this situation, the following two optional alternatives have been proposed:

- Larger biogas storage tank; and /or
- Incorporation of pressurized biogas system.

The first alternative is not enough attractive. The volume of biogas storage tank would be several times larger, comparing to basic storage tank. The second alternative offers many following flexible features:

- Relative small storage tank;
- Possible biogas supply to the Estate and Estate housing;
- Better utilization of biogas engine generator during daily peak period;
- Using the power from biogas engine generator for gas compression during low power demand period.

The main condition was to design the biogas engine generator to cover the daily maximum average peak load demand (plus 20% margin) during daily 8 to 10 hours shift, approximately 210 kW.

In this way the biogas engine generator would satisfy the power demand during daily (Mon-Sat) shift operation.

During random hours, holidays and weekends, as well as during night, the engine would run at part load as necessary for Estate supply and biogas compressor (25) drive.

The excess biogas that is produced during off-peak period will be stored at appropriate pressure in compressed biogas tank (26). This tank may be designed for storage of several days' biogas production.

The following layout sketch, Figure 6, gives the overall general view on the logical placement of individual components and systems.

The same numbering as used in process flow diagram is applied also in this layout sketch.

In order to preserve appropriate area for possible extension to future full scale biogas production and power generation plant, the area for proposed plant was chosen in the immediate neighborhood of existing sisal waste dumping area.

This concept has two major advantages, shortest way for sisal waste supply to the plant and shortest way for balance of un-utilized sisal waste to the dumping area.

From the topographical point of view, the Facility Site is sloping from the highest point (decortication plant level) to the lowest point (sisal waste dumping area) between 10 and 20 degree.

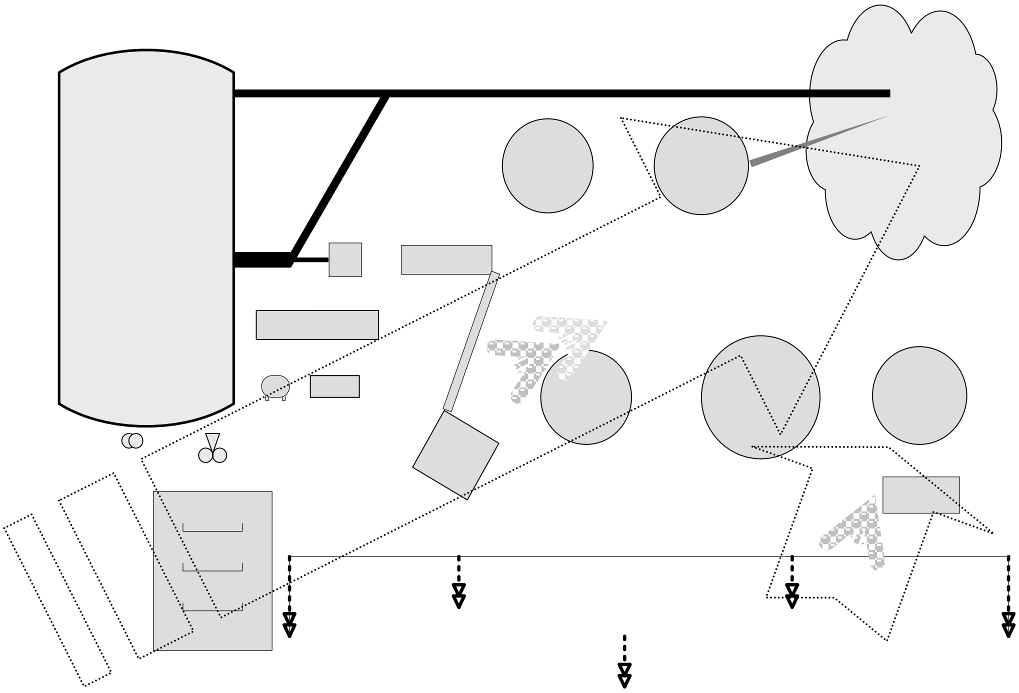

Figure 6
Plant Layout

This sloping will be utilized for gravity flow between individual fluid tanks. Even though that this natural gravity flow will be maximized; a use of limited number of electrical driven pumps cannot be avoided. The sisal liquid waste inlet tank (4) will be placed at lower level. In this way a natural flow from decortication plant to the inlet tank (the biggest liquid volume) is ensured.

The digester tank (6) will be partly buried underground, in this way the system will have sufficient pressure head between outlet of inlet tank and inlet of digester tank; a gravity free flow from inlet to digester tank is possible.

Cross-sectional sketch showing the level of individual storage tanks is shown in the following picture, Figure 7. Most probably only the streams **K**, **M** and **P** will require a fluid-forwarding pump.

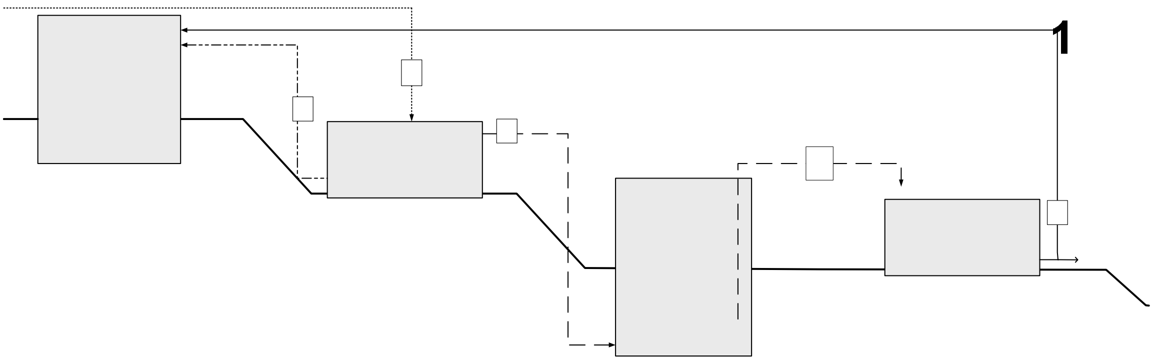

Figure 7
Plant Elevation View

1.4. Project Economics

Anaerobic digester and gas engine power generation system costs vary widely. Such system is usually a combination of off-the-shelf imported equipment with local materials.

Factors that affect the overall cost are the plant size and design, the local climate, and the availability and type of biomass waste material.

Partly below-ground, concrete digesters (as proposed for the project) have proven to be especially useful to agricultural communities in parts of the world such as Africa, South-east and East Asia and South America.

The economy of proposed pilot demonstration plant consists of large investments costs, limited operation and maintenance costs, mostly free sisal biomass waste, electricity purchase savings, and possible income from sale of electricity to power distributor and biogas to households.

Additionally improved value of sludge as a fertilizer can be added to projected income source.

Major parameters:

- Project Cost → 440'000 USD
- Electricity Production → 1'050 MWh/year
- Specific Investment → 0.042 USD/kWh/year (12 years period)
- Solid Fertilizer Production → 6 ton/day
- Liquid Fertilizer → 170 ton/day

O&M will be normally 10-20% of annual (12 years period) investment costs, but it may vary much with later Facility organization, wages, type of Facility operation and eventual transport of sludge.

If O&M is 10% of investment costs, simple pay-back requirement is 12 years at zero interest, and no price can be set to value of the sludge (liquid and solid fertilizer), the power generation tariff will be around 0.10 USD/kWh, positive cashflow with IRR=0%.

However, the dynamic approach deals with a consideration of benefits and costs over several years and therefore shall be pointed out more detailed.

Main investment criterion is the net present value (NPV), which is defined as follows:

$$NPV = \sum_{t=1}^{n} \frac{C_t - B_t}{(1+k)^t}$$

C_t - Costs in year t
B_t - Benefits in year t
k - discount rate
t - number of years from the present
n - total number of the years of the analysis period

Calculated, expected, Project cashflow and NPV is shown in the following Figure 8 and 9 respectively.

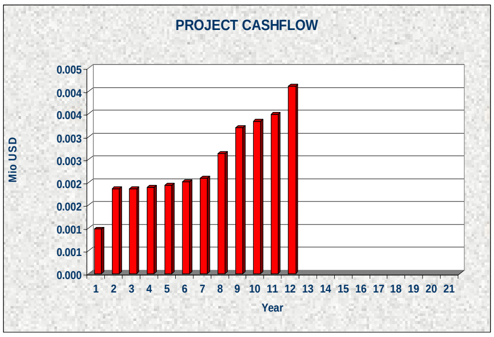

Figure 8
Project Cashflow

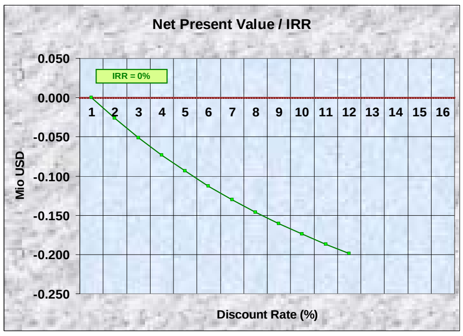

Figure 9
Net Present Value

Additional bonus, which has not been figured out will be the sale of liquid and solid fertilizer as well as commercial use of excess waste heat.

The above given project costs are applicable for first pilot plant. Considerable savings are expected for repeat orders, i.e. for similar plants which will follow pilot plant design and technology.

1.5. Anticipated Time Schedule

It is important to make correct assumptions for time period necessary for the Project development activities and design engineering. The delivery time for major equipment supply is also one of key components for work plan preparation. Facility modularized design can considerably shorten both, the delivery as well as the construction time.

Reasonable anticipated work plan includes the following major four tasks:

- Project Development including also Tendering Stage and Bid Evaluation → 3 moths
- Design, Equipment Procurement & Delivery to Site → 5 months
- Construction & Erection → 5 months
- Commissioning & Trial Run Start-up → 2months

2. Application Possibilities in Malaysia

As already explained in this paper, anaerobic digestion is very effective to break down the organics in the waste; this means that anaerobic digestion systems reduce the BOD in the waste. Biogas is an important product from this process.

In Malaysia there is a great opportunity to produce biogas from the **Pome** in the palm oil mills.

The produced effluent, the Pome, is causing major environmental impact to the atmosphere. Existing treatment in a series of open lagoons at high ambient temperatures, results in the uncontrolled production of methane (CH_4) and carbon dioxide (CO_2), which both belongs to greenhouse gases (CO_2, CH_4, N_2O and O_3).

It is well known, that natural greenhouse effect keeps global temperature is in fact 33°C higher than it should be. Greenhouse gases absorb electromagnetic radiation at some wavelengths but allow radiation at other wavelengths to pass through unimpeded.

So far so good, as long as we do not overheat our planet. However, during last two centuries, mankind has been releasing substantial quantities of extra greenhouse gases to the atmosphere, through the burning of fossil fuels and deforestation.

These extra gases are trapping more heat in the atmosphere, and it is obvious that the observed warming of the Earth by about 1°C during said period is due to man-made enhancement of the natural greenhouse effect.

Though CO_2, CH_4 and N_2O occur naturally in the atmosphere, their recent atmospheric build-up appears to be largely the result of human activities.

In agriculture CH_4, a gas with a 21 times higher greenhouse potential as CO_2 (**this means that 1 g CH_4 has 21 times the impact of CO_2 over a 100 years period**), is produced in herbivores and as a by-product from uncontrolled decomposition of agricultural waste and manure under anaerobic conditions.

N_2O, which is mainly released by chemical fertilizers and by burning fossil fuels, has a global warming potential 310 times that of CO_2.

Therefore it has to be emphasized that especially biogas technology takes important part in the global struggle against the greenhouse effect**.** It reduces the release of CO_2 from burning fossil fuels in two ways.

- First, biogas is a direct substitute for natural gas, oil and coal for electricity and heat generation as well as wood for cooking and heating.
- Additionally the replacement of chemical, artificial, fertilizer by natural fertilizer, that is a valuable by-product from biogas plants, reduces not only CO_2 emissions that would otherwise come from the fertilizer producing industries but also N_2O emissions.

In 2003, Malaysia produced around 13 millions ton of palm oil from 42 millions ton Fresh Fruit Bunches (FFB). From every ton of FFB round 0.8-0.9 m^3/ton of Pome is generated.

This means that Malaysian palm oil mills produce between 33 and 38 millions ton of Pome every year.

The Pome is a highly polluting process waste. In Malaysian palm oil mills, the Department of Environment (DOE) requires the treating of the Pome to an acceptable standard before it can be discharged.

Table 2 presents some comparative figures of POME characteristics and the DOE standards.

Parameters	Unit	POME	DOE Standards
pH	-	4.0	5 - 9
BOD	mg/L	25,000	100
Suspended Solids	mg/L	19,000	400
Total Nitrogen (N)	mg/L	707	200
Ammonia Nitrogen (NH_3-N)	mg/L	35	100
Oil and Grease	mg/L	8,000	50
Temperature	^oC	80-90	45

Table 2
Pome Characteristics vs. DOE Standards

Anaerobic digestion is adopted in the industry as a primary treatment for Pome, but still not foe power generation. Biogas is produced in the process in the amount of 20 m^3 per tone FFB.

At many palm oil mills the anaerobic digestion process is only done in order to meet water quality standards for industrial effluent and the biogas is flared off.

Malaysian palm oil mills have sufficient supply of energy from the use of solid residues. Energy surplus and the simplicity as well as low investment and operation cost of the opened pond Pome treatment system make the closed anaerobic digester at present not applicable in palm oil mills.

Various systems of closed anaerobic reactors are available such a completely mixed, fixed bed and up-flow UASB reactors.

To achieve operational stability in the anaerobic digester, intense fluctuation organic loading has to be avoided. This can be achieved by using the existing cooling pond as equalization tank for continuous feeding to the anaerobic reactor.

Considering 20 m^3 of biogas per one ton of FFB, the total energy potential of one FFB ton is around 446 MJ.

Translating these figures to Malaysia's total FFB production and assuming that all POME undergo treatment for biogas production, the country has an energy potential over 19 billions GJ/year which is around 200 MW power generation capacity.

Translated to kWh terms, this represents annually 1'400 GWh from Pome.

The raw material for palm oil production are fresh fruit bunches. If the palm oil mill and the power generation facility are located near the oil palm plantation it will reduce the cost of transportation and get good quality raw material as well as solid and liquid biomass waste.

Proper treatment of palm oil mill biomass waste in combination with power generation and liquid & solid fertilizer production will make the zero discharge concept possible.

Then the palm oil mill will become energy self-sufficient and environmental friendly industry.

3. Benefits & Constraints

Unfortunately, biomass is still not a very well documented source of energy in many countries worldwide, consequently lack of data has hampered sound decision-making when it comes to utilization of biomass energy.

The inability to fully address the indigenous biomass resource capability and its likely contribution to power generation development is still a serious constraint to the full realisation of this renewable energy.

The growing interest in last decade is the result of a combination of following beneficial factors:

- Growing concern with global climate change that may eventually drive a global policy on pollution abatement → no additional pollution from renewable energy.
- Biomass availability, versatility and sustainability → locally available and sustainable energy source.

- Expected increases in energy demand, combined with current rapid growth of renewable energy → fossil fuels are deplorable.
- Greater recognition of the current role and future potential contribution of biomass as a modern energy carrier, combined with a general interest in other renewable energies → increase of importance as major energy carrier.
- Growing recognition among international institutions (WB, UNO, Phare, etc.) of the importance of biomass energy → stronger support for dissemination and implementation of biomass conversion technologies.

However, there are still many obstacles in the way to successful implementation of biomass conversion technologies, mainly:-

- Funding limitations due to absence of proven technology demonstration/usage.
- Lack of statutory framework and credible leadership and/or constituency at the country and local level, including also coordinated and streamlined regulatory framework, to promote biomass conversion and utilization technologies and statutory disincentives.
- Biomass conversion technologies are still not economically competitive under current market conditions.
- Lack of proper biomass technology dissemination knowledge to general public, governmental institutions, public leaders and elected officials as well as to education centers regarding benefits of biomass conversion technologies.
- Lack of feedstock delivery infrastructure.
- Lack of reliable data on lifecycle benefits and emissions, technology performance and feedstock availability.

4. Summary – Conclusions

Rapid changes in the energy market worldwide, driven by privatisation, deregulation and decentralisation as well as better understanding of global and local environmental benefits and perceived potential of biomass conversion technologies role in climate stabilisation make biomass preferable renewable energy source.

In relation to biomass conversion and its utilization for power and heat generation, the following shall be highlighted:

- Governments shall strongly promote implementation of biomass waste for “green” energy generation because it would help improve the productive value of the finite energy resources.
- A 15 % saving in fossil fuel consumption will immediately translate into 15 % reduction in emissions into the environment.
- Modern biomass conversion technologies in particular offer one of the best prospects for generating “green”, decentralized, electricity in the remote rural areas, which have neither or only limited access to the grid and to fossil fuels.

- Despite the fact that some of these technologies have failed to live up to commercial expectations, biomass conversion technology is evolving rapidly and the time-span is being reduced. Significant advances have been made in gasification, co-firing, biogas and bio-fuels production.
- The "green" energy generation is not competitive at present market conditions; therefore, subsidies in the form of guaranteed higher tariffs, exemption of import duties and investment tax allowances have to be used to compensate for higher generation cost.
- However, environmental pressures will increase the price of fossil fuels as the cheaper sources are will be depleted. Biomass based renewable energy will be put onto a more equal footing with fossil fuels.

There are a number of challenges that inhibit the development of biomass energy.

In this regard, formulation of sustainable energy policy and strategies in addressing these challenges is indeed a pre-requisite for the development and promotion of biomass conversion energy.

"The worst thing that can happen - will happen - is not energy depletion, economic collapse, limited nuclear war or conquest by a totalitarian government.... the one process that will take millions of years to correct is the loss of genetic and species diversity by the destruction of our natural habitats.

This is the folly our descendants are least likely to forgive us. Humans would not survive more than a few months if all the insects and other land-dwelling arthropods were all to disappear ". E.O.Wilson, Professor at the Harvard University.

References

[1] Advantages of Combined Wind-Biogas Energy Utilization for Distributed Power Generation, Powergen International 2003, Las Vegas, USA; Miro R. Susta & Kurt Stangl

[2] Cleaner Use and Management of Sisal Waste for Biogas and Biofertilizers Production, United Nations Industrial Development Organization Report, December 2003; Miro R. Susta

[3] Biomass Energy Utilization & Environment Protection - Commercial Reality and Outlook, Powergen Asia 2003, Ho Chi Min City, Vietnam; Miro R. Susta & Peter Luby & Dr. Sohif Bin Mat

[4] Opportunities for Biomass Power Plants in Southeast Asia Region, Powergen Asia 2002, Singapore; Miro R. Susta & Tan Cheng Huat

[5] Advanced Systems in Biomass Gasification - Commercial Reality and Outlook, Biomass Forum 2003, Bratislava, Slovak Republic; Peter Luby

[6] Advanced Clean Coal Technology for Power Generation - an Opportunity for Southeast Asia, Malaysia Power 2003, Kuala Lumpur, Malaysia; Miro R. Susta & Dr. Sohif Bin Mat

[7] Contribution of IGCC & PFBC to Global Fuel Consumption Trends, Powergen Europe 1998, Milan, Italy; Miro R. Susta & Peter Luby

[8] Power Generation Technological Determinants for Fuel Scenario Outlook, ASME 1998, Stockholm, Sweden; Miro R. Susta & Peter Luby