Sustainable Bioeconomy Using Ecological Industrial Biorefinary Design for Food, Feed and Fuel from Wastes: System Innovation and Techno Economic Analysis Using Process Simulation Tools

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Abstract

Brazil is the leader of ethanol biofuel development and also for biomass charcoal, yet lacks in clean rural biofuel and bioenergy production from waste are common. Agro industrial wastes pose a major concern today due to the increase of production with time and thus needs ecological solution. For this problem, an integrated system, industrial and ecological, using the clean Small Integrated Bio-Systems (SIBS) based on the Zero Waste,industrial ecology , cleaner industrial design and green chemistry concept was studied using the three basic principles. The first principle is to use all components of the biological organic materials of the wastes. The second principle is to obtain more co-products from the wastes. The third principle is to close the loop via reuse, recycle and renewal of the material and nutrient flows.This paper deals with tools and methods used to make the system design based on industrial ecology using innovative process equipments design and the process optimization for waste minimization. The main objective is not only small scale energy production ,but as well as with the co-production of hot and cold thermal energies from agro wastes along with small electric power.The SIBS approach has many benefits and potentials. The system design use hybrid bio-fuels and internal combustion (IC) engine.The project was developed using simulation system tools for the process analysis (synthesis, modeling, and design) of two stage anaerobic bio process and its integration. SuperPro Designer Process simulation software was used to make synthesis and evaluate these options and performs material balance ,environment impact analysis. Case study was made with the anaerobic process, aerobic micro algae production , production of biodiesel from micro alge in several stages and recycle of reactor output are found to be very useful to produce biofertilizer ,bio-methane charcoal,bio electrical energy with recycle of water ,CO2 and microbial biomass,which are integrated to internal Combustion and fuel cell for combined cold ,heat and Existing biogas and biodiesel from micro algae technologies has potential for practical application combined with hydro pyrolysis,as well as green hydrorobiodiesel to make fuel electrical energy towards sustainable local development. The systems tools and methods used for several preliminary project developments of clean SBS are reported to build up the integrated system developments of industrial ecological complex as base case that need to adopted for the present and future need of clean production of fuel ,feed and food with the economical and ecological sustainability.

Keywords: *Waste, Energy, Biomass, zero waste Biogas, Pyrolysis, Biodiesel , System tools*

1. Introduction

It is understood that, in the current mode of production - both primary and industrial - there are at least two common characteristics and these relate to the waste of raw materials and energy. The desire to minimize or eliminate the causes and effects of this are the main goals of clean technology. With its adoption, there will be changes in the environment, however, these impacts begin to be reviewed, aiming at minimization and / or disposal.

In this field, through the research work carried out previously, we have good results, namely:

i. Computational Modeling of processes and clean technology.

ii. Optimization and Simulation of Processes and Costs.

iii. Computacional Simulation Stochastic modeling and Monte Carlo Risk Analysis

The integration of power generation project with the processing of residual biomass, micro mills producing feed for fish and shrimp on the technological aspects, environmental and economic conditions have a significant importance not only for the North and Northeast as well as for all Brazil, also enabling a significant increase in the level of nutrition .Biofuels and bioenergy from biomass waste particularly biogas , bioethanol and Biodiesel have attracted significant attention as one of the routes to address the world's concerns on energy and climate, though their economical potential as a sustainable solution remains some controversial for small scale community power. Principally, substantial doubts remain regarding the economic and greenhouse gas (GHG) reduction performance of biofuels and bioenergy for decentralized power production [1e4]. In the background of these contexts, researchers have continued to focus on solving the challenges that have hitherto limited the commercialization and adoption of biomass waste derived biofuels and bioenergy. It's the outcome of these efforts that will assist in moving toward a consensus, and thus the technological and economic progress brought about by biofuels and bioenergy research must be carefully and repeatedly evaluated using innovative industrial ecology concept design, not to limited to consider.

Several techno economic studies based on process model have provided assessments of the potential of Small Bioenergy Power (SMP) production and have provided invaluable guidance to research, investment, and policy endeavors [5e8]. These studies usually rely on experimentally-derived or assumed parameters obtained from similar equipment literature data to estimate process performance values, including capital and operating.

Several techno economic studies based on process model save provided assessments of the potential of biofuels and have provided invaluable guidance to research, investment, and policy endeavors [5e8]. These studies usually rely on experimentally-derived or assumed parameters to estimate process performance values, including capital and operating costs, GHG emissions, and biofuel yield as a function of feed-stock, among others. They have been also used to analyze how changes in the input parameters translate into changes in overall system performance. Naturally, but unfortunately, these studies can only study a limited set of scenarios, and it is impossible for them to address all possible parameter choices or designs that could be of interest to the biofuels and SBP community.

Moreover, research in the field is highly, is very fast and dynamic and innovation with advances brought about by one research group are rarely considered in models developed by others primarily because there is, at present, no avenue for such an exchange to take place. Thus we are able to have via on line collaboration from several countries such as India.

In response to these challenges, we have constructed a techno economic model of a lingocellulosic biomass agro waste into biogas bio-refinery that is accessible to the SBP community at large.

This open source model is under construction using online social network SAP STREAM WORK and is available for anyone to learn, collaborate or download the system documents. Each unit operation in the process flowsheet has a dedicated discussion thread, making it possible for experts in different fields to collectively and publicly address issues associated with different sections of the biorefinery, contributing in their respective areas of expertise related energy need for food dehydration, smoked shrimp and fish. To make the model more interactive and dynamic, and to ensure its accuracy, the parameters and assumptions is be updated in response to feedback obtained from the community of users, constantly used by engineering students to learn SBP as well make his innovation based on what is there in our systems models. This is an essential feature of the present contribution, as the results of any model are strongly dependent on the assumptions made, and the community as a whole will have the opportunity to monitor all parameter values. The objective of our work is to provide a systems model and tool that can facilitate decision support for project development , with following goals : (1) incorporates assumptions in a transparent open manner, (2) allows comparative analyses to be made from the same starting point, (3) permits its users to analyze the scenarios that are of most interest to them, (4) gathers meaningful parameters and other information from experts across disciplines in a centralized model, (5) directs research efforts by communicating what parameters are in most need of experimental verification, and (6) disseminates findings across by simple spreadsheet and SuperPro Designer process simulation models, but a detailed description of the approach can be obtained from specialized sources [9] and from the software's manual of super pro design available online. In our earlier work the introduction of alternative energy of biogas in agricultural communities for the sustainable development was studied through exploitation of residual biomass and also getting as by-product the biological fertilizer. A fast composting of the domestic residue with the organic was made possible where part of this residue after processing was taken together with effluent to the biodigestor. Brazil is the leader known for its ethanol biofuel development, and also for the biomass charcoal, but yet lacks much regarding the rural energy production. There is a need to decrease the pollutants emitted by these wastes as very huge quantities, nearly 70% (seventh percent) of total generated, are considered to be wasted in Brazil and this makes necessary to consider different alternative process, renewable energy source and co-product design from these biomass residual. This needs focus on system study of the clean biomass technology, co-generation of energy and also the sustainable development approach for the small scale energy production from wastes (1-10).

The general objective: The main aim of the present work also are, system design, analysis and optimization methods and system tools for making possible project model parameters of the complex integrated bio systems developments for the total integrated total utilization agro wastes .This system design for small scale energy production from wastes industrial ecological model based several small bio systems related to agro wastes involve. This system need to have not only dynamic system models but also need to attain economic and ecological viability leading to the sustainable development of rural villages with green SBP.

2. Concepts and Methods

2.1. *Selected Paths and Methods for generating energy from biomass wastes*

In recent years, there has been seen considerable efforts devoted to the search for the best ways to use the potentially valuable of biomass wastes sources for energy production by four different main methods, it is possible to order them by the complexity of the processes involved[1-15] that is direct combustion of biomass; thermo chemical processing to fuel; biological conversion and combined anaerobic digestion with pyrolysis. The main products of some of these processes is power and heat which is presently to generate heat via metane production besides the need of the generation of "cold" effect, is also necessary, the production of hot water (around 50 ºC to 60 ºC) for cleaning of the facilities and processing equipments (1) as well as the refrigeration (24-30).

2.2. *Pyrolysis: The thermo conversion for biofuel (syngas) and energy production*

Pyrolysis is the simplest and almost certainly the oldest method of processing one fuel in order to produce a better one. Conventional pyrolysis involves heating the original material (which is often pulverized or shredded then fed into a reactor vessel) in the near-absence of air, typically at 300 - 500 °C, until the volatile matter has been driven off. The residue is then the char - more commonly known as charcoal - a fuel which as about twice the energy density of the original and burns at a much higher temperatures made in almost all rural areas to make charcoal. Fast pyrolysis of plant material, such as wood, bagasse or nutshells, at temperatures of 800-900.

The slow pyrolysis: We are able to make better reactor for small scale charcoal production using conventional slow pyrolysis using ceramic kiln. Small scale wood gasification project using simple brick wall construction was successfully demonstrated in several remote rural areas, developed mainly in the decade of 80, now not employed much as it is not competitive with the power generated with IC diesel engines. Recently we are designing pyrolysis combined syngas liquification jointly with NTNU ,Norway. Thus a better quality hydrogen rich bio oil can be made possible using this process along with pyrogas .

2.3. *Anaerobic biodigestion: The bioconversion for biofuel (biogas) and energy*

The bioconversion method used for Biofuel and bioenergy production is biogas methane. The techno economic model we presently doing construction is based on a process of flowsheet of a lignocellulosic bioprocess based on biogas, built with the aid of the SuperPro Designer software (Intelligen, NJ, USA),cassva residuos has been used as feed stocks along with cow animal wastes

The process flowsheet built with the program includes all of the unit operations and process flows that are needed to transform the inputs (organic wastes, process water, etc) into outputs (pyrogas , biogas, ice, dried animal feed, CO2, electricity, etc.).

2.4. Collaborative Process Flow Sheet development

A conceptual design of the bioconversion process was constructed using current laboratory and technical data. (10-15) The flow sheet development was done using Superpro process simulator. A conceptual design of the biogas (CH_4, CO_2) and Biogas (CH4,CO_2) utilization in fuel cells were compared and process flow sheet was constructed using current laboratory and technical data. (Hawkes 2004-15) The flow sheet development was done using Superpro process simulator and other subsystems as well as modeling using excell spread sheet. Later pyrogas modeling were made [possible with simple stiochemetric reaction model in excel] latter using Supepro design models (24)

2.5. *Material Balance and Process Yield*

The general flexibility abstract simulation model was used for material, energy balance and production costs calculation. These process models were initially implemented with electronic spreadsheet and latter on SuperPRO 4.9, Inteligen.Inc, and U.S.A. process simulator under window graphical operating system for microcomputer(24,25)

2.6. *Process Economics Parameters and Costs Estimation*

This project model and program had been developed to evaluate rapidly the research and the preliminary biofuel project using limited number of data that was obtained from laboratory research, allowing user to have estimates about the economics of manufacturing in different scale of production. In our earlier work, we described the method of development of this model (1). The input of process are: capacity (ton/year), yield, batch or continuous process, high, average automation, maximum temperature and pressure, alloy factor of construction equipment and the number of processing steps called functional units. These models and program were tied together into an integrated process design in easy to use electronics spreadsheet computer programs or process simulator. [6] A conceptual design of all the process was constructed, then the thermo conversion involving pyrolysis and gasification using current laboratory and technical data obtained from literature. The flow sheet development was done using SuperPro Design, SPD process simulator and other subsystems for future scenarios. Also the integrated system of bioconversion and thermoconversion are also under detailed study at present. The key process economics parameters used are based on our earlier research works. (1,9).

3. Integrated biosystem design for cleaner bio energy production from agro biomass: Description of the base case

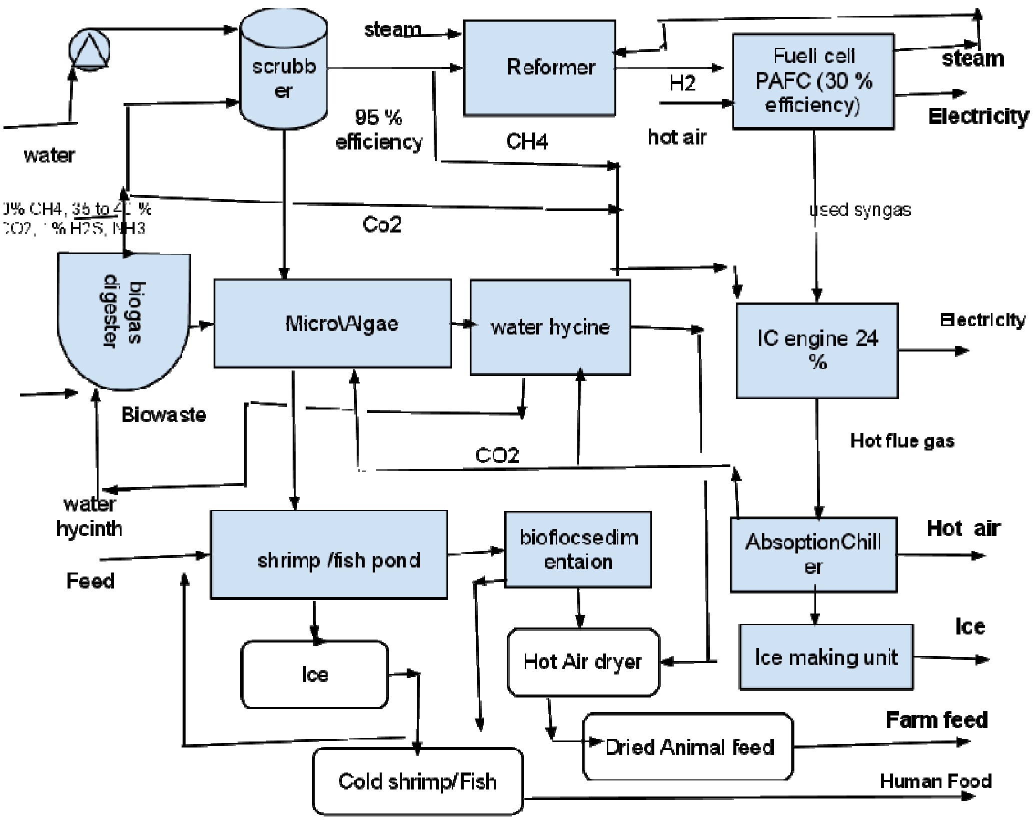

Fig. 1. Ecological Industrial complex open source project development of integrated food, fuel and feed from Agro wastes.

One main reason behind why much innovation and other viable technology may escape to experts is the lack of time and resources needed to develop a full techno economic model. Even if each small research group like us were to create a model of their own, the likelihood of different studies agreeing in the assumptions and parameters is quite low, making the observations and conclusions non-comparable and diminishing their usefulness. Partial analyses are common and have continued to be a weakness of the project viability fostering unrealistic expectations that cannot be fulfilled. Base case study is an essential step.

A diagram illustrating the base case process is found in Fig. 1. The conditions of this case were chosen based on our past 10 years of reserarch work and available literature; thus, the base case was such that it would represent the performance that could be achieved in a plant today. Briefly, cassava biomass waste , sugar cane bagasse , crop waste, elephant grass, water hycine with low cost. This waste can be transported w50 km to the biosystems complex where it is unpacked from the bales, washed, and shredded dried.

Biogas from agrowaste : The gas (Marsh Gas) obtained from the natural waste decomposition process is a mixture of Methane (CH_4) and Carbon dioxide (CO_2) and is commonly called as the 'Biogas'. Anaerobic digestion, like pyrolysis, occurs in the absence of air; but in this case the decomposition is caused by bacterial action. This is a valuable fuel which is in many countries produced in purpose built digesters filled with the feedstock like dung and effluents from the dairy, septic tank sewage sludge. (Kev, 2002; Nijaguna, 2002 Hall, 1992).

3.1. Bioconversion of agro waste :Brazilian, japones and Indian small system anaerobic Digestion (AD)biogas technology

In the recent past the planning, construction, operation or management of low-tech biogas plants has not always been done appropriately, thus many projects failed (Pannirselvam, 1998;Chris,2007). The selection of the following technologies is based on extensive research, means on literature review and e-mail correspondence and has to be seen as scientific founded system analysis . At least, our research revealed that some of the case studies in India are more successful as there is greater demand for energy, but the need for china is more for fertilizer and fish feeding. Where as in Brazil, we have demand for all the three; fuel, feed and fertilizer , as rural area are more under developing stage yet , compared to very well developed cities. Some AD technologies seem to have several successful plants operating on a large scale level in Japanese paper industry waste , whereas others do not have a good reputation. The technologies are primarily recommended and used by after analysis of sustainable or not for further evaluation and system syntheses of our work using alterative innovative design improvements in the general form as base case , which yet need to be adopted to local feed stocks. Figure 2 show a base case of our integrated comunity biopower project under development.

The continuous application of integrated preventive strategy to processes, products and services in order to reduce risks to health and the environment, leading to a better environmental and economic performance, also fits the concept of Cleaner Production (PmaisL). The biosystem is a step towards cleaner production as it implies a change of attitude, exercise responsible environmental management and assessment of technology options. This research aims to elucidate the understanding of this production technique through the explanation of the technical aspects of its operation from an economic model. The technique itself is designed to eliminate waste from processes involved, starting with the treatment of waste, raw materials for producing a polyculture system and reducing levels of pollution of the effluent through the integration of the hydroponic system and hydrophone system.

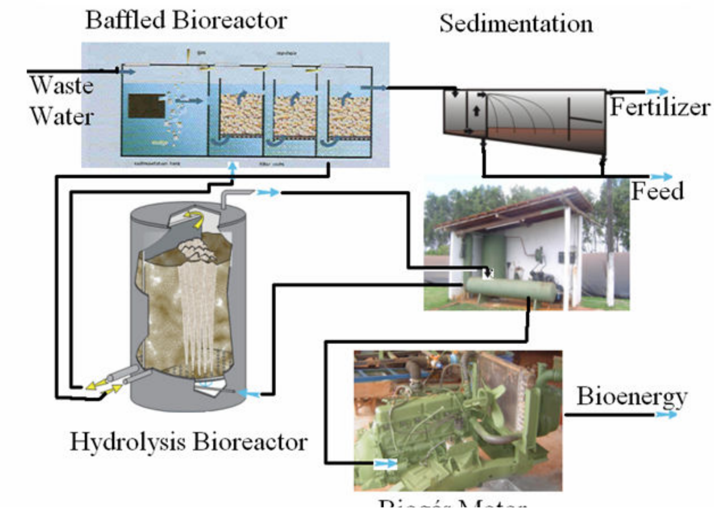

Fig.2. Base case community bioenergy power project for rural trigeneration need.

4. Results

The Bioconversion system: This system is used for feed stocks listed earlier using trigeneration concepts and heat pumps see (figure above). The main equipments used are anaerobic biodigester, the combustion furnace, the heat recovery system using heat exchangers are used . The thermo conversion system: This case study made involves the hydro and slow pyrolysis system, making the charcoal, the heat is recovered from exit flue gas, where as the second case study involves combined pyroysis to make charcoal as well as gasification to produce syngas. Sngases were used for the internal combustion heat engine for combined power and energy recovery (4-9) for pyrolysis to make charcoal (9-13).

The Cogeneration and trigeneration of small bio power system: The main assumptions made in the model are related to the inferred value of the solids properties and the use of transfer coefficients for thermal and kinetics constants. The values of these constants assumed are validated by the simulation results comparing it to the real process published results. In the following Figure 1, the complex process scheme of the final case study made based on the design for environment using computer software. In this work, we designed the flow sheet for the processing the waste and also the whole heat recovery system based on the biomass fuel heating in regard to recirculation of the hot water (26-30).

4.1. Optimum Configuration of integrated Bionergy Energy system design

Obviously there are many path ways and combination permutations that are available for the combined use of the thermo conversion using pyrolysis and gasification or the bioconversion route, many operating as very large capacity. Before we started the detailed case studies, we made with an energy audit of the animal and agro industrial wastes feed stocks both in the production and processing units regarding energy demand and supply. After the detailed study material balance of all the solid liquid flows using super pro design simulation software tool which has tools to make environmental emission report , then we realized a tally of all of the energy uses supplied using biomass. The entire integrated system requirement of the pyrolysis combined heat power (CHP) is first analyzed and the process design was achieved from the result obtained by the process simulations and optimizations and the result of several techno economical parameters (24). The system design approach used in this made possible the combined eco industrial complex design of the integrated bioconversion and thermo conversion process determine whether the economics of selling electricity, fuel, the ice, the liquid fertilizer justifies the higher incremental capital cost of the engine-generator, the associated higher maintenance costs, and increased processing costs. The best optimized system has co-products together with the heat recovery using heat pump coupled to the low cost gasoline engine that can run with the correct mixture of pyrogas , the biogas. and bio hydrogen Thus the present project is ony an base case model , yet need adaptation designed sustainable for rural people food processing and animal production chain and environment too .(see conceptual industrial ecological process flow sheet below). Thus the system is made both economical and environmentally clean using several simulation runs to optimize the system configurations after making the simulation of the process given in the figure below. Our project is an integration of our two stage biodigestor technology and slow pyrolysis process .This later one was adopted from the original conceptual design of BEST Energies Inc., which has been recently developed,, modified latter simple low cost slow pyrolyis process used in japao to obtain bio oil form smoke . This pyrolysis technology consumes biomass waste streams while producing hydrogen rich gas and carbon-rich end products called biochar . The syngas is composed of combustible gases including hydrogen, carbon monoxide, methane, and lower molecular weight hydrocarbons, as well as nitrogen and carbon dioxide. This gas is cleaned by a series of unit operations before being recycled back to the plant or exported. A portion of the gas generated is combusted and used as a heat source on the pyrolysis kiln itself. An additional portion of the gas is combusted and used to dry the incoming feed material for pyrolysis. The excess syngas gas represents the net energy output and can be utilized as a fuel for an engine, an industrial boiler after providing enegy consumed in pyrolysis as recicycle.

The biogas obtained from macro alga , aquatics freed stocks with less lignin content is mixed with the hydrogen rich syngas as a feedstock for down stream processes which refine the syngas into a fuel for ic engine and fuel cell using low temperature for large sacle use or for trigenertion heat and cold utility plants integrated with fuel cell electrical generation .The design involves operation of semi continuous small power plant stand alone or integrated combined heat, Cold and power applications .Our integrated syngas , pyrolysis reactor and biodigestor holds a portfolio of SBS technologies that significantly can improve the economics of pyrolysis and thermo and bio gasification of biomass streams into valuable products.(23-30) as outlined in detail of this ecoindustrial complex.(see details in the figure below)

4.2 .Trigeneration of heat, cold and power using fexivel biofuel power

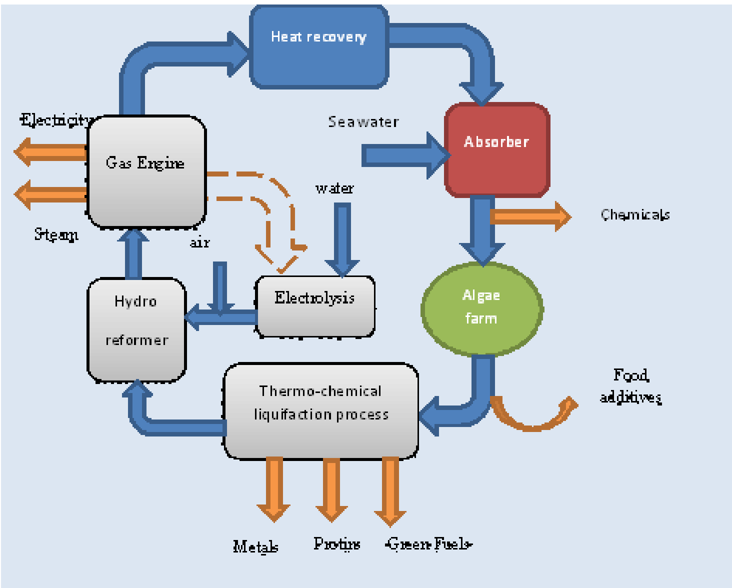

Fig.3. Simplified Flow diagram integrated biorefinery deishn for food , feed and bioenergy under developments.

Biogas production and Small Bio power is proposed. The flow sheet was proposed after studying various patents. Comparative cost analysis of energy production using hybrid fuel cell using biogas has been presented in our earlier work (Small biohydrogen are produced from the two stage bioreactor , the first hydrogen production and then latter to methane production and then the gas obtained was sent after separating CO2 The theoretical energetic value of biogas with 60% methane content is 5.56-6.64 kWh/m3; in general the value can be taken 6.5kWh/m3.If this energetic gas is used in CHP-motor, then the conversion process efficiency must be taken into account. The overall process efficiency can be taken as3 0% and the energetic value of biogas in terms of electrical energy is 1.95 kWh/m3.The combined electrical power production of 150 kW electricity by three sources biohydrogen, conventional biogas and vegetable char coal will have energy generation cost of 0.2 US $/kWh. Thus it is again good proposition to develop district level power production center to meet the cold ,heat and along with steam requirement can be managed by heat recovery from the hybrid fuel cell. The heat required for the reforming is 24 kW is recovered from the hot spent gas heat recovery management. The hot gas CO2 separated from the hybrid fuel cell and internal combustion engine can be circulated indirectly to reduce the char coal to CO for IC engine. The new biogas and bio hydrogen reactor has benefit in terms reduction in residence time and reduced size in tank by half. The char required for the IC engine estimated to be 250 kg/hr (11-16).

4.3. Microalage and biodiesel production

From the results of synthesis and analysis using elaborate design process simulator, it was found that the size of the digester components is very important. Indeed, for small scale system biogas combustion engine, ee bio reformed using HHO gas oil appears to be not very simple, but may be a substitute for robust hot water boiler typically used in a heating system, conventional, but with greater energy loss in the home of cassava flour. The entire system requires the integration of energy to the heat recovery process. In the case studied cogeneration makes the design more complex than a simple system as compared to the heat recovery. This system simply aims to recover the exhaust gas from the engine, as shown in Figure 4.There are two routes of production of biodiesel being investigated , the process using solvent extraction of oil from micro algae with ethyl acetate, the other method by transesterification using enzymatic catalysts heterogenious.The conventional method of extraction of oil were done via mechanics press of oil from micro algae. [

5. **Conclusions**

We present the first open and collaborative model of a small bio gas , biodiesel ,bio oil and bioenergy for local community bioeconomic although the present model is specifically formulated for agro wastes, the flowsheet project desesign can serve as a starting point for considering alternative configuration for diferent local feedstocks suc ass cassava biomass wastes as well as sugarcane . For example, a new pretreatment technology may needed and can be modeled by changing the unit operations of this section, while leaving most others actions unchanged (obviously, one must consider heat and water integration too. New bio fuels such as biohydrogen along within biogas can be considered as well, by modifying the fermentation and product recovery sections accordingly as well the biodeisel from micro algae The integration of thermoconversion, bioconversion, fuel cell and IC engine need specialized expert helps too, but there is demand for both the neat , cold trigeneration of energy.The process model and system tools has made possible not only to calculate performance values for a particular configuration or fuel, but also forsee sensitivity analyses to suggest possible future directions for bioenergy research towards viable innovation. New synergetic concepts of integrated innovative process system have been developed in this work for the integration of renewable power methane plants in biogas plants, biomass gasification plants, and natural gas sites, CO2 intensive industry, landfills and sewage plants. Also from waste c02 , micro alage production as well as biodeisel for decentral rural area may bee soon made possible to imporove the bioeconomy local usando wastes

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