Sustainable Bio Economy of Food and Fuel Based on the Industrial Ecology of Innovative Process Design of Biomass Solid Wastes Technology Management

PANNIRSELVAM, P. V.; [A], MATHIAS, J. M.; TAMIL, S. S. [A], VIKASH K. [B]

a. Gpecufrn CT/DEQ, Universidade Federal do Rio Grande do Norte, Natal, RN, Brazil,
pannirbr@gmail.com

b. Dept. Of Chemical Engineering, IIT Bombay, India, vkiit18@gmail.com

Abstract

Energy demand and the price for energy is increasing day by day everywhere as global economic problems. Renewable energy from waste is one of the alternative source which can be use parallel to conventional energy resources. 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 Process Systems (SIPS) 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 small process system design using innovative process equipment 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 SIPS approach has many benefits and potentials. The system design use Biodigestion process, hydrogen and methane bio-fuels and internal combustion (IC) engine. The project was developed using simulation system tools for the process analysis (synthesis, modelling and design) of two stage anaerobic bio process and its integration. Super Pro Designer Process simulation software was used to make synthesis and evaluate these options and performs material balance, environment impact analysis. Towards the economical valorisation product development from municipal solid wastes (MSW), agro wastes and municipal waste water sludge solid wastes as the raw material biomass ,the H2 rich gas (H2, CH4 etc.) was found to be the main product using the two stage process design of anaerobic bio digestion from liquids, where as the ammonium and water recovered as liquid fertilizer and carbon dioxide are co products . The economic viability reports, environmental emissions reports, systems tools and methods used for several preliminary project developments of clean SIPS are obtained. The integrated biosystem system design are under developments of industrial ecological production using solar energy as base case ,yet this system designed need to adopted for the present and future need of optimized clean production of bio energy production with the economic and ecological sustainability from biomass wastes to the local energy and bioeconomy demand.

Keywords: *Biomass, Bio energy, Municipal Solid Waste, Auto thermal, IC Engine*

Introduction

First, bioenergy is analysed in the broader context of climate change, energy systems and land use in order to estimate the sustainable potential of global bioenergy and Brazilian bioethanol concepts. Second, to solve this bioenergy bottleneck, a new approach of converting renewable power into bio hydrogen and methanol via hydrogen and CO_2 synthesis is developed. It can be produced basically anywhere where water, air and renewable biomass waste are available and thus decrease import dependence on fossil fuels. It can recycle water, CO_2 in the SBS system proposed in this work. Third, the necessary transformation of energy systems from waste is performed. The key elements are direct renewable power generation, renewable electro-mobility, renewable power methanol and overcoming traditional biomass technology.

Source of Biomass:

Agricultural	food grain, bagasses, corn stalks, poultry, hogs
Forest	trees, wood waste, wood or bark, sawdust, timber slash, mill scrap
Municipal	sewage sludge, refuse derived fuel, food waste, waste paper
Biological	animal waste, aquatic species, biological wastes

There is a need to decrease the pollutants emitted by these wastes as very huge quantities, nearly 70% 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, cogeneration of energy and also the sustainable development approach for the small scale energy production from wastes (1-10). The main objective of the present work also is related to the current research study made on the system design, analysis and optimization tools and methods which made possible to the best value of the input variables and/or model parameters of the complex integrated biomass projects for the total integral utilization agro wastes .The system design for small scale energy production from wastes integrated with small enterprise related to agro wastes involve dynamic system models. This system need to attain economic and ecological viability leading to the sustainable development of rural villages with green SBS. The novel flow sheet development for maximum output energy and minimum wastes is also our main objective of the present work. Brazil is the leader known for its soya bean, sugar ethanol, biomass development, but also for biomass charcoal, yet lacks biomass waste resource based clean rural biofuel production. This paper deals with the system design for sustainable bio economy of cleaner feed, fuel bio energy. This study focus is about the Innovative process engineering study with closed loop, bioreactor design and the process optimization. The economic objective towards sustainable clean small scale energy production from waste, and also the co-production of hot, cold thermal energy was the main goal. Several preliminary elements of the integrated system had been developed and analysed and come with the detailed process and project engineering and the economic results on viability were projects. The dynamic material, energy and cash flow models of the complex process and small scale energy productions were at first constructed using google online electronic spreadsheet. Comps of the cost and investments of the integrated process biomass utilization projects included for this study are: biological anaerobic process, ethanol and methane gas production. Animal feed production using silage anaerobic ferment, process. Effluent treatments using high rate algae ponds, biogas and bio-methanation from synthesis gas production as well as integrating with cogeneration of energy production for drying using biogas energy. These dynamic material, energy and cash flow models study carried out allowed us the identification of techno-economical and scale up problems. (1-4)

Selected Paths and Methods for generating energy from biomass and municipal solid 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 anaerobic digestion combined with pyrolysis. The main products of some of these processes is power and heat which is presently studied in application of small scale fruit processing and milk dairy industry to generate heat via methane 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 equipment (1) as well as the refrigeration (24-30)

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 has 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 800-900oC are intensively studied under pilot plant scale. The slow pyrolysis data has been compared to with the yields as shown in Table 1.

	Torrefaction	Slow pyrolysis	Fast pyrolysis	Gasification
Gas	5	35	13	85
Liquid (Bio Oil)	20	30	70	5
Solid	75	35	12	10

Table 1: Slow Pyrolysis reactor data designed to maximize the energy recovery compared to conventional charcoal making system

Sugar Cane Bagasse and Napier Elephant grass was studied in Brazil for the pyrolysis, had as little as 10% of the material as solid char and converts some 60% into a gas rich in hydrogen and carbon monoxide. This makes the fast hydro pyrolysis a competitor compared with conventional gasification methods but like the latter, it has yet to be developed as a treatment for biomass on a commercial scale. For this same we have joint research effort.

Anaerobic bio digestion: The bioconversion method for Bio fuel production

The gas (Marsh Gas) obtained from the natural waste decomposition process, is a mixture of Methane (CH_4) and Carbon dioxide (CO_2). This gas 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. The input is in batches, and digestion is allowed to continue for a period of ten days to a few weeks. A well-run digester using plug flow bioreactor design operating at the farm in Brazil produce 200-400 m^3 of biogas with a methane content of 50% to 75% for each dry tone of input. The biogas-production will normally be in the range of 0.3 - 0.45 m^3 of biogas (60%methane) per kg of solid (total solid, TS) for a well-functioning process with a typical retention time of 20-30 days at 32°C. The lower heating value of this gas is about 6.6 kWh/m^3. Often the production is given per kg of volatile solid (VS), which for manure without straw is about 80% of total solids (TS). Biogas applications from animal wastes or a large centralized manure processing system are constrained by limited energy needs, storage complications, difficulties in exporting the energy, high capital requirements, and complexities in operation and maintenance. Many such systems use engine waste heat in Europe, but mostly it is used for anaerobic digester heating. Biogas-fueled engine-driven chillers are probably not suitable for most operations that are needed for fruit processing that would like cooler temperatures than 42ºF to 44ºF for raw material and product storage, as the cooler temperatures are obtained by direct electric unit. In this work we study the slow and hydro pyrolysis for clean SBS.

Integrated Bio system design for cleaner bio energy production

Brazilian project for small system for energy generation using biogas: This technology is currently working based on the energy conservation strategy and efficient energy use. In a confinement of 100 cows, a bio digester was designed to produce a volume of 118 m3 of biogas and a generating group of from 8-15kVA and this to assist with electric energy the demand of the fruit processing installation and water pump. The total demand of the biogas working with this equipment is estimated to be 85.3 m3 of biogas, which can be supplied with rest by the bio digester. This volume of the biogas is enough one to generate mechanical energy using internal combustion engine adopted with the gasoline Otto engine to run biogas and this to assist with electric energy to the demand of the fruit processing installation and the pump for the chilling. The system design of cogeneration of energy and heat is realized after the flow sheeting of several major components: Animal Production Facilities; Manure/Effluent Handling System; Digester Tank Heating & Mixing System Biogas Cleaning & Handling System; Biogas Storage; Energy using biogas engine; The heat pump selected for this work is a novel system design based on the innovative and well optimized design. This is made possible recently by the research group in UNICAMP/Brazil which can run using R22 heat transfer refrigerant fluid. The use of ethanol and water mixture as heat transfer agent for heat pump to produce hot water, chilling and ice making together with IC engine has been also well studied by this group. We apply this UNICAMP/Brazil process to our integrated bio waste energy project. (24, 26, 27)

Project developments methods

Process Flow Sheet development: A conceptual design of the bioconversion process was constructed using current laboratory and technical data. (1-3, 26-27, 10-15) The flow sheet development was done using SuperPro process simulator and other subsystems. Material Balance and Process Yield: The general flexibility of abstract simulation model was used for material, energy balance and production costs calculation of conversion of particular substance and raw material to final product via certain steps (n) and (n-1) intermediate substances. Theoretical conversion factor, the efficient of the conversion, the processing cost of the conversion, the valorisation of by-products and extra cost involved are the parameters used. These process models were initially implemented with electronic spreadsheet and later on SuperPro 4.9, Inteligen.Inc,U.S.A. process simulator under window graphical operating system for microcomputer (26). 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).

Results

The Bioconversion system: This system is used for milk and fruit processing industry for the conservation using the heat for pasteurization the cashew apple juice. The main equipment used are anaerobic bio digester, the combustion furnace, the heat recovery system using heat exchangers are used for food conservations. 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, whereas the second case study involves combined pyrolysis to make charcoal as well as gasification to produce syngas. Synthesis gas was used for the internal combustion heat engine for combined power and energy recovery (4-9) for pyrolysis to make charcoal (9-13). The Cogeneration small energy 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).

Optimum Configuration of integrated Bio nergy Energy system design

The integrated system design approach used in this made possible using combined integrated bio conversion 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. This hydro pyrolysis technology consumes biomass waste streams while producing hydrogen rich syngas and carbon-rich end products called bio char. 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. The bio hydrogen obtained is mixed with the hydrogen rich syngas as a feedstock for downstream processes which refine the syngas into a liquid fuel methanol using low temperature. Bio hydrogen and Small Bio Refinery proposed flow sheet. The flow sheet was proposed after studying various patents. At the present time, dark fermentation and water-gas-shift are the only methods that have feasible reactor dimensions for practical applications [Ginkel, 2001]. Secondly, bio hydrogen production by dark fermentation is most interesting option for the conversion of organic wastes because of its analogies to AD (anaerobic digestion). Two stage reactor comprising dark fermentation and water gas shift photo-bioreactors were considered. In case of bio hydrogen, bio hydrogen produced from the two stage bio reactor, 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 as 30% and the energetic value of biogas in terms of electrical energy is 1.95 kWh/m3.The new bio hydrogen reactor has benefit in terms reduction in residence time and reduced size in tank by half.(11-16),

System design work for decentralized clean bio energy production for agro industrial system is under study to be implemented in Brazil. Several computational models with appropriate implementing environments and several software tool for the system design, analysis and optimization of the complex system design. But the system elements had been successfully integrated to make possible the dynamic study of the flux of the material, energy and cost to make energy from wastes in an economic way. The bio system 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 as raw materials for producing a micro algae poly culture system and reducing levels of pollution of the effluent through the integration of the hydroponic system aquatic plant system.

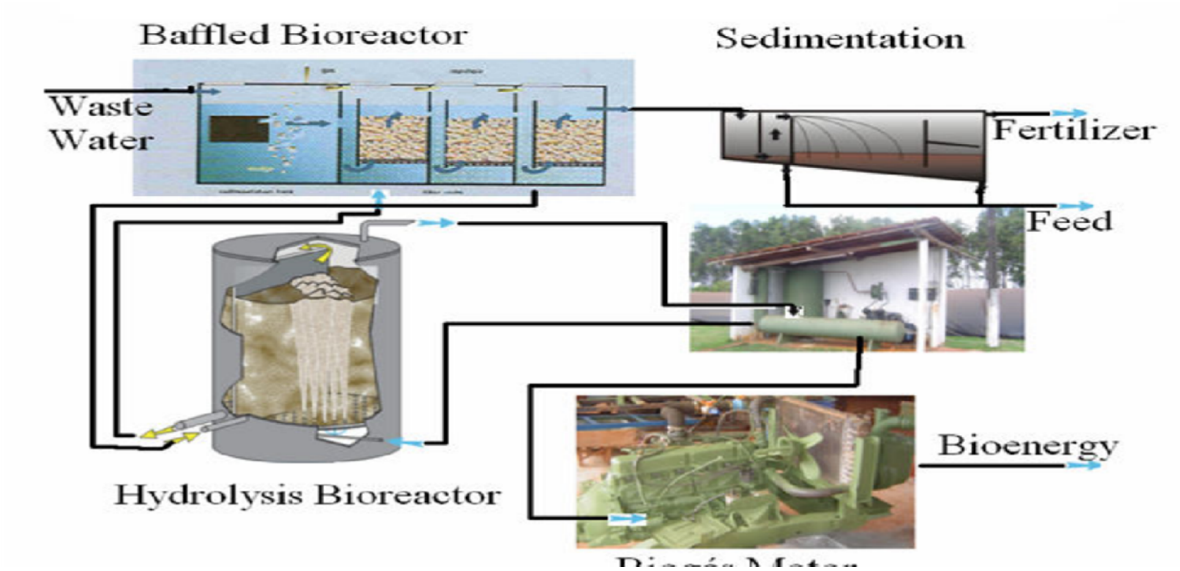

Figure 1. Base case community bioenergy power project for rural power from Waste and gas from power production

The Brazilian Bio systems the figure1, illustrate the detail of bio digestion process and then the cultivation pond for microalgae as a primary product was designed. These technology of complete integrated system biomass produced are then used to design the sustainable and environmentally friendly energy technologies. Seaweed and algae are aquatic plants from brackish, abundant in much of the Northeast Brazil, which perform photosynthesis and capture CO2 from the atmosphere, consuming minerals and generating organic biomass feedstock's for fuel feed and food production. The oil in the algae are extracted for industries of food, drugs and cosmetics, leaving an organic by-product as solid residue that is used in a bio digester as with integrated energy systems component shown in the figure 2 below the integrated system designed. The results obtained from preliminary project developments studies of the integrated bio system development for fuel, feed and food are reported. Several problems related with implementation of the small scale bio economical system, for sustained local developments using energy crops and fruit wastes, were analysed the best integrated closed loop bio system production solution of ecological micro enterprise has been proposed, after optimizing the system design for of waste utilization using simulation tools. New synergetic concepts of innovative bioprocess system have been achieved in this work for the integration of renewable power production from biomass. Also from wastes, CO2, microalgae were produced to make biodiesel. The decentralized food and energy in rural can be soon made possible to improve the bio economy based on microalgae and biogas with significant reduction carbon, using the solar energy available in tropical country into biomass for power and then power to gas closed loop. The process models and system tools were used for design and also to calculate performance values of bio economy, to get the best configuration of process and fuel, feed, food products and also to suggest future research direction.

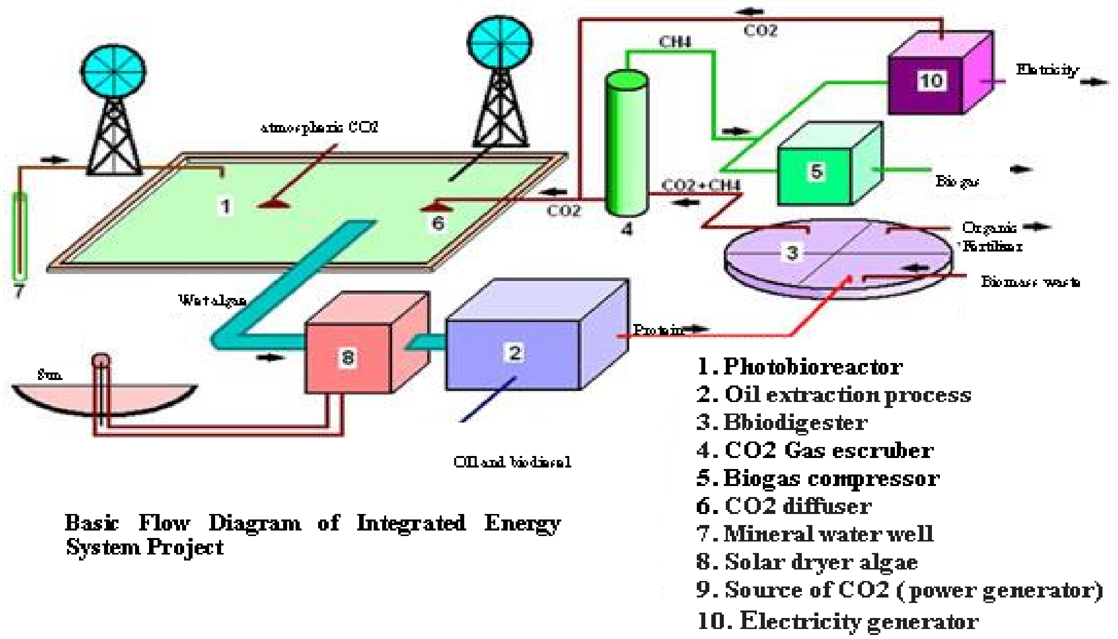

Figure 2. Basic Flow Diagram of Integrated Energy System Project

Integrated scheme for methane production in India. For large-scale CH_4 production by bioconversion, an integrated scheme based on one of the concepts discussed above is illustrated in figure 6. In the process flow sheet, three important raw materials as alternate or simultaneous input resources are indicated as well as energy flow. All of them constitute principally photo synthetically-produced residues in rural areas. Basic studies done at the Bioengineering Research Centre (BERC), Indian Institute of Technology (IIT), Delhi, 1980, indicate that each one of these wastes can serve as a complementary H-donor to the in situ increase of methane production. A two phase system (acid-producing and methane-generating phases) employing a mixed substrate, namely: gobar, water hyacinth, and algae (volatile solids 1:1:1 on dry basis) are presented in Table 1. It can therefore be concluded that by increasing compatibility of digestion of several agricultural! residues used as substrates in biogas production, it is possible to increase not only the quantum of gas by about 100 per cent, but also the methane content by nearly 20 per cent in excess of what is generally available from gobar in most digesters operating in India.

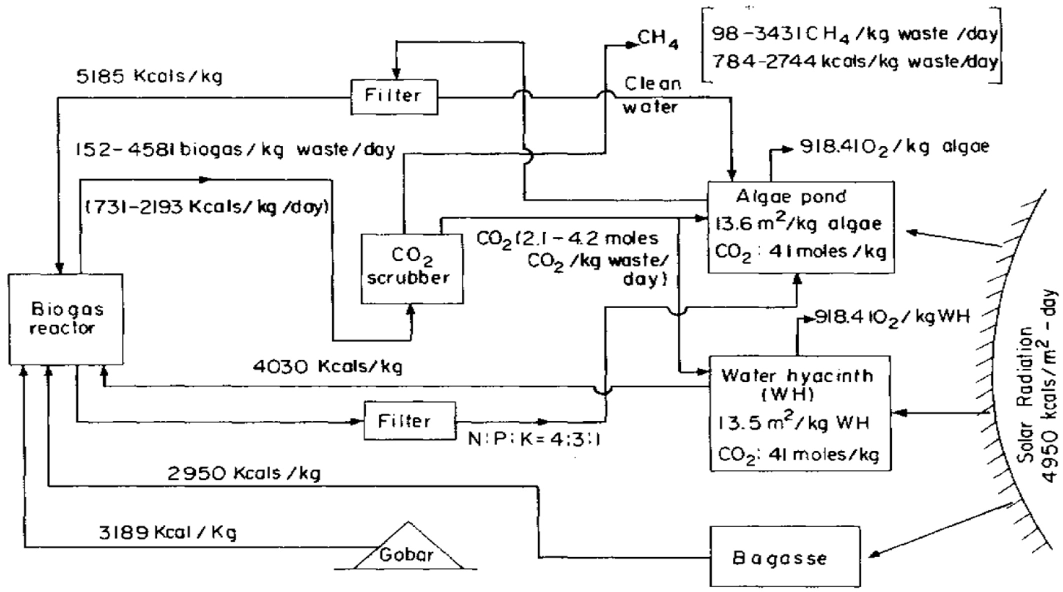

Figure 3. Methane Production and Energy Flow in Integrated Biogas Plant.

Residue(VS = 0.07 kg/iitre of digester volume)	VS kg/litre digested	Gas composition		CH_4 produced litres/kg VS digested
		% CH_4	% CO_2	
Gobar (G)	0.0218	69	28.8	92.6
Algae (A)	0.0280	72.5	26.4	142.4
Water hyacinth (WH)	0.0266	73.0	25.8	119.00
G+A+WH VS ratio 1:1:1	0.0280	79.8	19.6	174.50

Table 1. Removal of Volatile Matter and Production of Methane from Various Agricultural Residues and Gobar

Conclusion

Renewable power methane and energy network integration are key elements of 100% renewable energy supply structures.Biohydrogen technologies are still in their infancy. Existing technologies are potential for practical application, but if biohydrogen systems are to become commercially competitive they must be able to synthesize H2 at rates that are sufficient to power fuel cells of sufficient size to do practical work. Further research and development aimed at increasing rates of synthesis and final yields of H2 as co products are essential to make biohydrogen and biogas more competetive with IC engines operted with biogas fuel system.

Towards the economical valorisation of product development from municipal solid wastes (MSW), agro wastes and municipal waste water sludge solid wastes as the raw material biomass ,the H2 rich gas (H2, CH4 etc.) were found to be the main products using the two stage process design of anaerobic bio digestion from liquids, where as the ammonium and water recovered as liquid fertilizer and carbon dioxide , micro algae are co products.The economic viability reports, environmental emissions reports, systems tools and methods used for several preliminary project are obtained. The integrated biosystem system design are under developments of industrial ecological production using solar energy as base case ,yet this system designed need to adopted for the present and future need of optimized clean production of bio energy production with the economic and ecological sustainability from biomass wastes to the local energy and bioeconomy demand.

The economic viability reports, environmental emissions reports, systems tools and methods used for several preliminary project developments of clean SIPS are reported to build up the integrated system developments of industrial ecological production chain as base case that need to adopted for the present and future need of optimized clean production of bio energy production with the economic and ecological sustainability to the local energy demand.The several process and cost parameters about the viability of this biosystem to make biohydogen and biogas were obtained and this system has shown to me more promissing to rural sustainable energy production and local rural developments.

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