## Chapter 1
# Introduction

**Objectives**

***1.1*** *Biomass*

***1.2*** *Biomass Utilisation Strategies*

***1.3*** *Concept And Principle Of Gasification*

***1.4*** *Chemistry of Gasification*

***1.5*** *The Gasifier*

***1.6*** *Types Of Gasifiers*

***1.7*** *The comparison between IISc open top gasification system and other Gasifiers*

***1.8*** *The Government Programme Safety and Environment Hazards Biomass Availability And Scope Of Utilisation In Kerala*

**1.9** *About the Project*

# Introduction

*Energy consumption is one of the major indicators of physical quality of life. The pattern of energy consumption changed with different stages of human evolution and development. Sources of energy have varied and patterns of use have also changed. These energy resources have been broadly classified into:*

**a. Conventional**

**b. Non conventional**

*Conventional technologies to tap energy include fossil-fuelled thermal plants, atomic reactor and large hydroelectric projects. New and renewable energy sources like small hydro schemes, biomass-based systems, wind, wave, ocean thermal, geothermal, as well as the solar energy are usually termed non-conventional.*

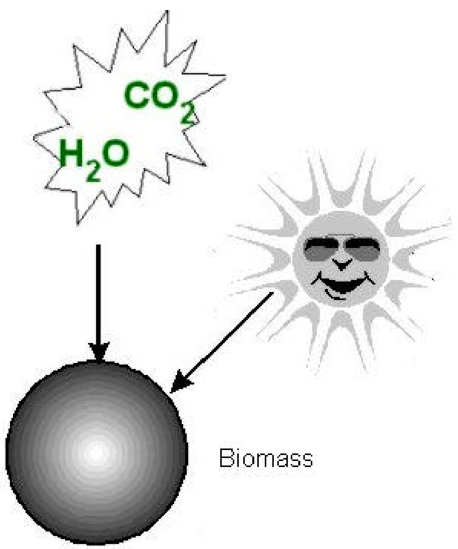
*Wind, wave, ocean thermal currents, biomass, rains, rivers, and fossil fuels represent manifestations of solar energy either in transit or in storage. The fossil fuels are an extreme case, in which the accumulated reserves of millions of years are now discovered and exhausted within a lifetime. But, fossil fuels meet a greater proportion of global energy requirement than any other source. Principal fossil fuels are coal, natural gas, petroleum and its derivatives. However, all these are finite and non-renewable.*

*Major issues regarding energy use emerge as, (a) quantum of energy consumed (b) energy use pattern. The extent of energy consumption has increased due to three major causes (i) energy has been an essential input in economic development (ii) with rapid population growth, energy demand increased (iii) with increased living standards and changing lifestyles, per capita energy consumption is increasing. Also, increased use, inefficient use and wastage of energy sources have led to serious environmental consequences with depletion of valuable resources as well as environmental pollution. Of all forms of energy, electricity has the highest versatility and convenience of use. Per capita electricity consumption in Kerala is only 300 kWh/year, which is lower than the national average (Source: Economic Review 2001, Govt. of Kerala ). Shortage of* *electricity has been one of the major constraints for the industrial advancement and hence the overall development of Kerala.*

*Thermal energy used for industrial as well as domestic purposes is equally important. In Kerala, the major application of thermal energy is in domestic cooking. Cooking is the largest energy consuming end use accounting for almost 90% of total thermal energy consumption of any household. In the rural areas, the fuel mix used for domestic applications is predominated by bio fuels. Bio fuels consist mainly of twigs and dried leaves and other biomass shredding, commercial quality firewood is purchased by rural households only in absolutely unavoidable cases. This means that, to a great extent the rural energy demand is met with the surplus biomass available in the locality without creating any environmental issues.*

*In the last decade, a considerable number of people in Kerala have shifted from biomass to higher order fuels, like kerosene and LPG, due to rise in standard of living in rural areas. But a large chunk of the rural folk is still depending on biomass fuels (firewood) for satisfying their fuel requirements. But they are now facing a problem of 'the other fuel crisis' due to higher price and growing scarcity of firewood. There is no alternative other than biomass because of their inability to purchase higher* *order fuels like kerosene and LPG due to their low purchasing power as well as limited availability of these commercial fuels.*

*Several measures have been taken at the national and state levels to meet the growing energy demand by improving the existing pattern of fuel consumption and harnessing new sources of energy. A variety of technology adaptation and dissemination strategies have been undertaken. These include the National Programme on Improved Chulha Development, national Biogas development programme and the National Biomass Gasification Programme. Obviously, Biomass has to play a key role in any effort to supply energy for rural areas, without affecting ecological sustainability.*




## 1.1 Biomass

*Biomass is the term used for materials or derivatives left behind by the organic living things of both terrestrial and oceanic variety. They generate their energy from the sun through photosynthesis. Biomass* *holds a key role in satisfying the energy needs of humanity. In that aspect, it is the crucial factor for human existence on this earth.*

*Biomass is among the most versatile renewable resources known to man from Stone Age. Until the last few centuries, it was the dominant fuel for heating and cooking in most of the countries. Today, one third of the world's population still depends on wood for heating and cooking. Though its importance as an energy resource in industrialised countries has fallen, its use in developing countries is still pervasive. Biomass also represents stored solar energy. However, biomass (including firewood and agro residues) is more difficult to handle and process.*

*When used for in-house heating, wood has an advantage over direct heating with solar collector panels. Compared with oil and coal, biomass as a fuel is virtually sulphur free and thus does not aggravate sulphur oxide air pollution. Sustainable wood utilisation does not contribute to possible carbon dioxide pollution, which could lead to adverse changes in climate.*

*In India, biomass fuels provide 85% to 90% of the domestic energy and 75% of all rural energy. Fuel wood is the largest resource for energy use in rural areas followed by animal dung and crop residues. (Source: Rural Energy Matters – the Dhanawas Experience, TERI)*

## 1.2 Biomass utilisation strategies

*There are three possible options to meet our energy demand from biomass (a) bio methanation (b) biomass gasification (c) pyrolysis.*

*Large (community type) biogas plants are also being introduced, of late, through ANERT.*

*Bio methanation using the biogas plant is fairly well established. Both the varieties (fixed dome and floating dome) are quite popular in Kerala. The limiting factor in its popularisation is that, it can be economical only in households with three or more cattle. So, to develop and popularise models which can use other types of bio-wastes (eg: night soil, garden litter) along with cow dung has become a need of the hour.*

*The biomass gasifier is not yet common in Kerala. Small pieces of firewood are heated in a restricted atmosphere so that, a mixture of CO and* $H_2$ *is produced. This producer gas can be burnt in a boiler,* *cook stove or even used as fuel in an IC Engine. Centralised production of producer gas in a gasifier and supplying it to the houses through pipelines as cooking fuel is certainly a plausible suggestion.*

*Pyrolysis is a sophisticated process in which the volatiles in a bio-fuel are brought out by heating in a controlled environment. The process can be used to produce char or to produce volatile fuels. A domestic cook stove using pyrolysis technology was developed by IIT Delhi as early as 1988. But unfortunately due to various reasons, it has not yet reached a commercially viable stage.*

*The use of biomass gasifiers to run IC Engines, which can either operate irrigation pumps or power electric generators, is gaining currency in other states. This is yet to catch up in Kerala. This technology is probably awaiting the development of a specialised gasifier, which can burn either coconut wastes or rubber wood, the two assured biomass sources in Kerala. If this dream materialises, surely biomass gasifier will be a very powerful tool in our attempt to bridge the demand supply gap in the arena of sustainable rural energy.*

## 1.3 Concept and Principle of Gasification

*Gasification is the process of converting solid fuels to gaseous fuel. It is not simply pyrolysis.*

*Pyrolysis is only one of the steps in the conversion process. The other steps are combustion with air and reduction of the products of combustion (ie,water vapour and carbon dioxide) into combustible gases (ie,carbon monoxide, hydrogen, methane and some higher hydrocarbons) and inert gases (ie,carbon dioxide and nitrogen). The process leads to a gas which can be used in internal combustion engines with some fine dust and condensable compounds termed tar, both of which must be restricted to less than about 100 ppm each.*

*The producer gas obtained by the process of gasification can have end use for thermal application or for mechanical /electrical power generation. Like any other gaseous fuel, producer gas offers better control for power generation, when compared to solid fuels. This also paves way for more efficient and cleaner operation. The producer gas can be conveniently used in a number of applications as mentioned below.*

### 1.3.1 Thermal application

*For applications, which require thermal energy, gasifiers can be a good option as a gas generator, and retrofitted with existing devices. Thermal energy of the order of 5 MJ is released, by flaring 1* $m^3$ *of* *producer gas in the burner. Flame temperatures as high as 1550 K can be obtained by optimal pre-mixing of air with gas.*

*The following are a few of the devices to which gasifier could be retrofitted :*

a**) Dryers** : *Drying is the most essential process in beverage and spices industry like tea and cardamom. This calls for hot gases in the temperature range of 120 -130 $^{o}$ C, in the existing designs. Typically the heat energy required is equivalent to 1 kg of wood for 1 kg of made tea. Gasifier is an ideal solution for the above situation, where hot gas after combustion can be mixed with the right quantity of secondary air, so as to lower its temperature to the desired level for use in the existing dryers.*

**b) Kilns** : *Baking of tiles and pottery items require a hot environment in the temperature range of 800 - 950 $^{o}$ C. This is presently being done by combusting large quantities of wood, often in an inefficient manner. Gasifiers could be suitable for such applications, and could provide a better option for regulating the thermal environment. There will also be an added advantage of smokeless and sootless operation, thereby enhancing the product value.*

**c) Furnaces** : *In non-ferrous metallurgical and foundry industries high temperatures (~650 - 1000 $^{o}$ C) are required for melting metals and alloys. This is commonly done by using expensive fuel oils or electrical heaters. Gasifiers are well suited for such applications.*

**d) Boilers** : *Process industries, which require steam or hot water, use either biomass or coal as fuel in the boilers. Biomass is used inefficiently with higher pollutants like NOx and with little control with respect to power regulation. Therefore these devices are appropriate to be retrofitted with gasifiers for efficient energy usage. Apart from these, energy requirements in poultry farms, cold storage devices (vapour compression refrigerator), rubber industry and so on could be met using wood gasifiers.*

### 1.3.2 Power Generation

*Using wood gas, it is possible to operate a diesel engine on dual fuel mode. Diesel substitution of the order of 75 to 85% can be obtained at nominal loads. The mechanical energy thus derived can be used either for energising a water pump set for irrigational purpose or for coupling with an alternator for electrical power generation, either for local consumption or for grid synchronisation. An appropriate* *site to realise the above application is an un-electrified village or hamlet. The benefits derived from this could be many, right from irrigation of fields to the supply of drinking water, and illuminating the village to supporting village industries. The other suitable sites could be saw mills and coffee plantations, where waste wood (of course of specified size) could be used as a feed stock in gasifiers.*

### 1.4. Chemistry of Gasification

*Sub-stoichiometric combustion of fuel with oxidant is not simply pyrolysis of the fuel elements, it is stoichiometric combustion (oxidation) + reduction reaction leading to typical products - Hydrogen, Carbon monoxide, Methane, Carbon dioxide, some Higher Hydro Carbons, water vapour and Nitrogen - in proportions depending on the feed stock and reactant used.*

*Most biomass + Air = 20±2% $H_2$, 20±2% CO, 2% $CH_4$, 12±2 %$CO_2$, 8±2%$H_2O$,rest $N_2$ Most biomass with water vapour with added heat from external sources =>55-65 % $H_2$, 3 - 5 % CO, rest Higher Hydro Carbons.*

**Gasification reactions**

*The reaction taking place in a gasifier are shown in the following table (Table 1.4 ). Partial oxidation of the biomass by a gasifying agents usually air or oxygen takes place in the oxidation zone producing* $CO^2$ *and steam. The combustion of the part of the carbon in the solid biomass in this zone is the main source of heat for the subsequent reactions and heating up of the biomass and evaporation of water. Devolatilization takes place in the pyrolysis zone resulting in the formation of char and gaseous products (CO,* $Co_2$*,* $H_2$ *and condensable hydrocarbons ). The other reactions, steam – carbon, reverse Boudouard, water gas shift and to a limited extent the hydrogasification and methanation reactions take place in the reduction zone. The result of the above reactions is a gas consisting of CO,* $H_2$*,* $N_2$*,* $CO_2$*, steam and hydrocarbons. It is disadvantageous to have high moisture content in the biomass since more gasifying agent is needed for evaporating the water. Producer gas from a wet biomass contains relatively high quantities of steam , hydrogen and nitrogen compared to a producer gas from dry biomass.*

Table 1.4

| Reactions | | *Enthalpy of Reaction (kj /mol)* |
|---|---|---|
| *Devolatilization C+ heat* | $CH_4$ *+ condensable* | |

*hydrocarbons + char*

| | | | |
|---|---|---|---|
| *Steam –carbon* $C + H_2O + heat$ | $CO + H_2$ | | 131.4 |
| *Reverse Boudouard* $C + CO_2 + heat$ | $2CO$ | 72.6 | |
| *Oxidation* $C + O_2$ | $CO_2 + heat$ | (-) 393.8 | |
| *Hydro-gasification* $C + 2H_2$ | $CH_4 + heat$ | (-) 74.9 | |
| *Water gas shift* $H_2O + CO$ | $CO_2 + H_2 + heat$ | (-) 41.2 | |
| *Methanation* $3H_2 + CO$ | $CH_4 + H_2O + heat$ | (-) 206.3 | |
| $4H_2 + CO2$ | $CH_4 + 2H_2O + heat$ | (-) 165.1 | |

*The products of combustion,* $CO_2$ *and* $H_2O$ *pass through a reduction zone made of hot char bed, to convert* $CO_2$ *and* $H_2O$ *into CO and* $H_2$ *and in part,* $CH_4$*. The net effect is reduction in air consumed (Source IISc web site).*

*Also the sensible heat in the first part of combustion is converted into chemical heat in the second part. When used as a fuel, biomass feed stocks can be used in power plants the same way any non-renewable fossil fuel would be used to generate electricity. Because the energy in biomass is less concentrated than that in coal, oil, and natural gas, advanced technologies are required to make the biomass energy competitive with fossil fuels. As is evident from the foregoing discussion, the technology that runs a modern biomass power station should be far advanced than the simple burning of wood in a traditional way.*

## 1.5 The Gasifier

The Gasifier system is meant for biomass having density in excess of 250 kg/m$^3$. Theoretically, the ratio of air-to-fuel required for the complete combustion of the wood, defined as stoichiometric combustion ratio is 6:1 to 6.5:1, with the end products being $CO_2$ and $H_2O$. Whereas, in gasification the combustion is carried at sub-stoichiometric conditions with air-to-fuel ratio being 1.5:1 to 1.8:1, the producer gas thus generated during the gasification process is combustible. This process is made possible in a device called gasifier, in a limited supply of air. A gasifier system basically comprises of a reactor where the gas is generated, and is followed by a cooling and cleaning train which cools and cleans the gas. The clean combustible gas is available for power generation in diesel-gen-set. Whereas, for thermal use the gas from the reactor can be directly fed to the combustor using an ejector.

## Types of Gasifiers

*There are four different types of gasifiers and they are differentiated/categorised based on the type of airflow and the method of combustion. The chief models available are of the following:*

### 1.6.1 Up draught gasifier

*In up draught gasifier air enters at the base of the hearth and below the combustion zone where the temperatures of $900^{0}C$ and above are obtained. The producer gas leaves near the top of the gasifier. This type of gasifier is easy to build and operate. The gas produced has practically no ash but contains tar and water vapour because of the passing of gas through the unburnt fuel. Hence, up draught gasifiers are suitable for tar-free fuels like charcoal, especially in stationary engines. With*

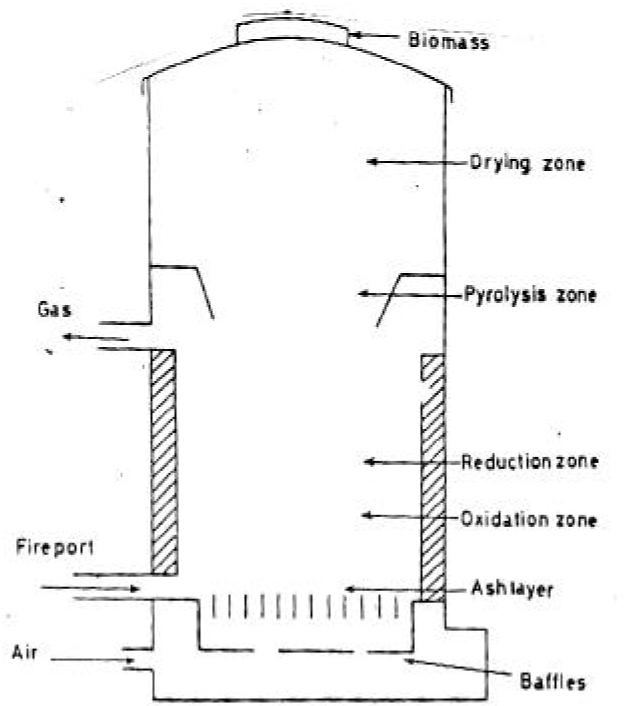



Fig. 4.1. Schematic diagram of an updraft gasifier.

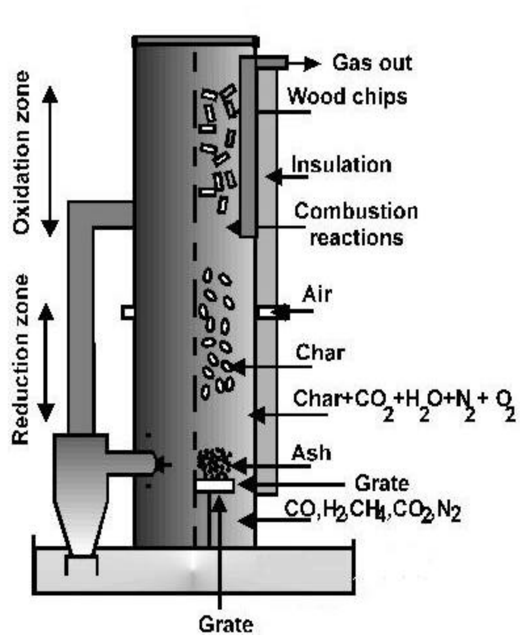
*the large-scale industrial units, the addition of steam helps to reduce the local temperatures in the hearth zone, but in many cases water jacket cooling of this zone is employed to prolong the life of the hearth.*

### 1.6.2 Down draft gasifier

*(a) Closed top down draft gasifier : Air enters at the combustion zone and the gas produced leaves near the bottom of the gasifier. In this type of gasifier, the volatile and the tar produced from the descending fixed bed have to pass through the reaction zone where mostly they are cracked and gasified. Also, a special funnel shaped construction, called the 'throat' is provided in the hearth just below the air entry point, which ensures that the gaseous products pass through the hottest zone. The gas produced contains less of tar and more of ash. These gasifiers are suitable for fuels like wood, agricultural wastes and other uncarbonized residues. They may be used for power generation up to some 150 kW and beyond that there may be geometrical limitations upon gas quality. This type of gasifier is cheap and easy to make. Such systems have shorter contact times and therefore are more responsive than up draught gasifiers to surge in gas demands that are experienced when fuelling engines.*

**1. Open top, down draft, twin air entry gasifier :**

*This is a technically advanced design of gasifier by Indian Institute of Science which has many novel features when compared with closed top deign*




**(i) Theoretical Aspects**

*Our experiments were conducted in an IISc designed down draft gasifier system. From an initial study, it was found to be mote appropriate for coconut fronds as fuel. The technical details of a down draft gasifier system are explained in this section.*

## (ii) Characteristics of Producer Gas from Down Draft Gasifier

*Based on analysis of producer gas obtained from their down draft gasifier, following results have been reported by IISc.*

*2.Direct use of combustible gas in reciprocating engines or gas turbines for electrical applications*

***3.Low Tar***

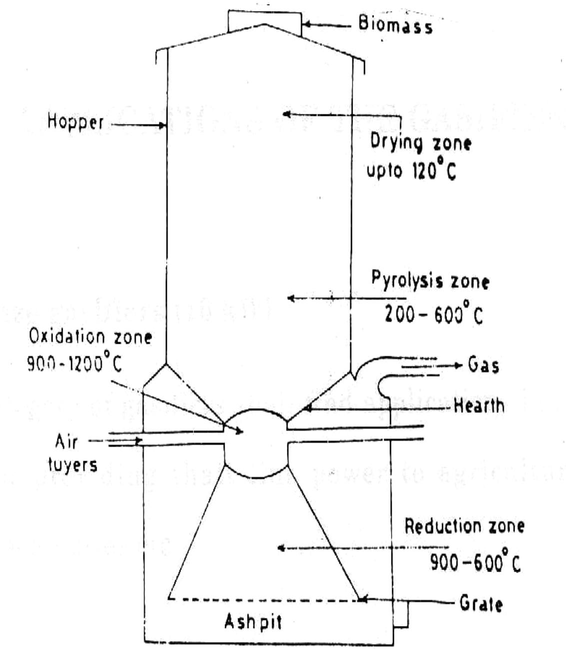



Fig. 4.2. Schematic diagram of a downdraft gasifier.

*4.Low Particulate - Size & Amt < 50mg/m$^3$*

*5.Size ~ A few microns or less.*

*6.Combustible gas for use in burners & combustors.*

*7.Low $NO_x$ 150ppm @ 3% excess $O_2$*

(iii) Gas Composition (Projected)

| | |
|---|---|
| *Hydrogen* | *18-20%* |

| | |
|---|---|
| *Carbon Monoxide* | *18-20%* |
| *Methane* | *1-2%* |
| *Carbon Dioxide* | *12-14%* |
| *Nitrogen* | *45-48%* |
| *Calorific value* | *4.5-4.8 Mj /m$^3$* |

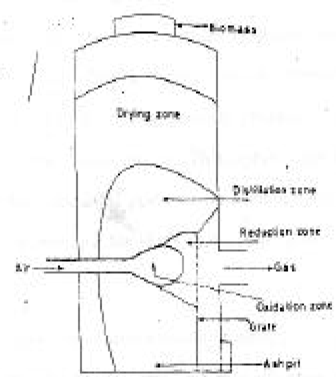
**(iv) Dust and Tar**

Before Cleaning/Cooling

| | |
|---|---|
| *Dust* | *1000 ppm* |
| *After* | *100 ppm* |

*After Cleaning and Cooling*

| | |
|---|---|
| *Dust* | *< 50ppm* |
| *Tar* | *< 30ppm* |

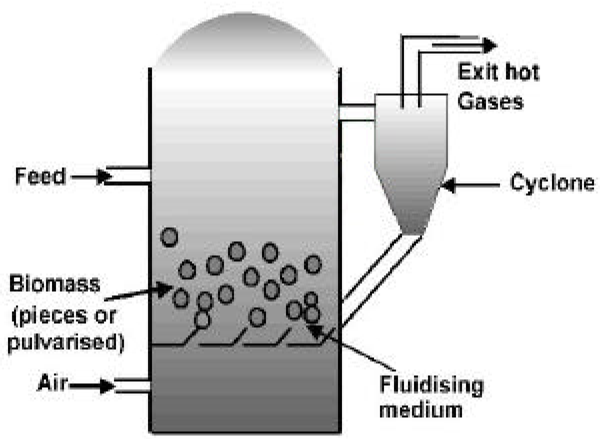



Schematic diagram of a crossdraft gasifier.

### 1.6.3 Cross draught gasifier

*In the cross draught system the flow of air and gas is across the producer, although not necessarily in the horizontal plane. Such systems operate at very high temperatures and confine their combustion/reduction zones by using a small diameter air inlet nozzle. Temperatures up to 2000 $^0$K are obtained and normally water cooling of the cast iron or steel tuyere is essential. In view of low contact times it is important that low tar fuels are used. In this type of gasifiers, the gas produced passes upwards in the annular space around the gasifier that is filled with charcoal. The charcoal acts as an insulator and a dust filter. The fuel in the hopper behaves as a heat shield against the radiant heat and when operated with charcoal the reactors do not need to be refractory lined. They are usually suitable for power generation up to 50 kW.*

**1.6.4. Fluidised bed gasifier** *The selection of the design of the gasifier, either fixed bed or fluidized bed, will depend on the actual application. However, at this stage, it is worth noting that the performance of a fixed bed gasifier will depend on fuel properties, such as chemical composition, volatile content, calorific value, size distribution and ash characteristics.*

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*On contrast, a fluidised bed gasifier is more versatile and any biomass (including sewage sludge and pulping effluents) can be gasified using this type of gasifier. The calorific value of biomass is not a constraint. Besides being highly efficient because of high heat release rates as well as effective heat transfer resulting from rapid mixing and turbulence within fluidised bed, such a gasifier can even handle biomass with high ash*

*content (for example, rice husk)*

## 1.7 The comparison between IISc open top gasification system and other gasifiers

- *All the existing designs are closed top designs using MS as outer wall and the reactor also acting as storage bin. They are all based on World War II class designs.*
- *The IISc design is the only open top twin air entry system in the world for woody class of biomass. This included briquetted biomass – agro residues and urban solid waste. The reactors for rice husk from China and adopted by other manufacturers noted above are also open top designs. But they are not twin air entry. The twin air entry system is crucial to good quality gas.*

- *The advantages of open top twin air entry system are (a) low tar fraction in the gas at a wide variety of loads demanded of the gasification system, (b) gas quality which permits diesel replacement in diesel engines up to 85 % in non-turbo-supercharged engines, whereas even according to the best claims of closed top WW II class designs in our country the maximum diesel replacement is 70 %. If we remind ourselves that the purpose of gasification system is to replace fossil fuels which are expensive, it is clear that IISc design is superior because of the advantage of higher diesel replacement. The economics of operation for a private power producer is far superior to other designs.*
- *The IISc design has a ceramic shell in the most critical zone and thus promises much higher life compared to other systems. Even in other chemically or thermally affected zones specific coatings are provided to prevent corrosion.*
- *The IISc system has been tested by an international team of experts at IISc and in Switzerland. The test reports have been published and examined by a large number of experts in India and overseas.*

- *This testing of the system has taken place at 100 kWe and 500 kWe levels. At power levels of 500 kWe, no gasifier in the world has been tested and this is unique to IISc system.*
- *Performance of the systems in field locations are documented and made available to users, scientists, senior administrators so that better appreciation of the problems, solutions and status of systems is possible. This is particularly needed with new technologies of the kind discussed here.*
- *An additional advantage of the adoption of this technology is that IISc will provide technical back up on all difficult-to-resolve issues that may crop up from time to time.*

## 1.8 The Government Programme

*The Ministry of Non-Conventional Energy Sources (MNES) Govt. of India has many programmes aimed at minimising the use of conventional sources of energy and for propagating new and renewable energy sources. Gasification of biomass is sought to be popularised because it helps to reduce the firewood consumption. The first gasifier of each model manufactured will be tested and certified by the respective Gasifier Action Research Centres (GARCs) following the rules and regulations of MNES and report will be sent to MNES for approval. GARCs are also helping* *manufacturers in modification of gasifier systems according to field adaptation requirements. The GARCs and address of manufacturers are given in Annexe 3.1.*

### 1.9 Safety and Environment Hazards

*The safety from exposure to the poisonous contents of the gas, namely carbon monoxide is an issue to be addressed. Since the entire operation is such that the pressure in the system is below ambient, air can leak into the system and not the gas to the outside. The air leakage at points where temperatures are high may lead to burn-off of some components and in some instances of transient operation, flame propagation at large rates. These could cause explosion. In the early developmental trials with closed top design, these were reported. In the current design, however, no problem of this nature has been reported. Even if a flash-back of the flame were to occur, the pressure is released at one of the water seals-near the filter/cooler or the reactor with no untoward effect other than splashing of water. With regard to the effluents taken in by the wash water, it is necessary to treat them before discharge into streams or agricultural fields.*

### 1.10 Biomass availability and scope of utilisation in Kerala

*In a state like Kerala, noted for its abundant natural resources, biomass certainly ought to play a key* *role in the fuel scenario.*

*in fact it does. Even now, about 70%of our households in the rural areas use firewood as the main cooking fuel. Majority of people are forced to use the smoky, sooty, firewood chulha and it is the ambition of every housewife to switch to a more convenient, sootless, smokeless hazardous stove. But the biomass based cook stove will be the only option for the people with low income, for a long time to come. The improved chulha with higher efficiency and less smoke can only be a partial solution to the problem. It can not match the liquid or gaseous fuelled stoves in convenience or cleanliness.*

## 1.1 About the Project

*Kerala is facing an acute power crisis. This crisis is not due to lack of resources, but due to non-utilisation of available resources. Kerala has abundant resource of biomass. But this alternative is not scientifically utilised so far. In this juncture, biomass gasifier can be used as a supplementary source of power. However, this technology is still in a developing stage. Several experiments and field trials remain to be done before it is ready for wide adoption. One special area is the use of commonly available fuels like coconut fronds and rubber tree droppings. The research area of this* *project was to assess the techno-economic feasibility of a gasifier with coconut fronds as fuel, for rural energy applications.*

**Chapter 2**

## Project Details

2.Objectives

3.Methodologies And Work Plan

4.Experimental Setup

5.System Elements

6.Experiments Performed - An Overview

7.Test on Gasifier

8.Test on Various Biomass as Fuel

9.Fuel processing

## 2.0 Objectives

*The objectives of present investigation are :*

1. *Identifying and testing a suitable gasifier with coconut fronds as fuel and to find out the problems, if any, and to evolve the solutions for them.*
2. *To optimise the fuel specifications for best performance of the gasifier.*
3. *Finding out the availability of coconut wastes in Kerala from available data.*
4. *Using the gasifier for power generation for supplying to local community for domestic cooking as well as lighting in a suitable Kerala hamlet where accessibility to grid is a problem.*
5. *Evolving a proper management methodology for such a system with people's participation.*

## 2.2 Methodologies and Work Plan

*It was decided to divide the project into two phases. The first phase of project would be technology development and second phase the implementation of the same in a suitable village through 'peoples participation' and to develop a proper management strategy for its sustainable functioning.*

*The work plan proposed for the first phase (phase-I) is given below:*

1. *Purchase of a suitable 5kVA gasfier according to the results obtained from the initial studies*
2. *Analyse the Calorific value of various fuels that are to be used in the gasifier.*
3. *Proximate analysis of the coconut fronds and other bio-residues, which are to be used as fuels.*
4. *Installation of the gasifier at IRTC for field trials.*
5. *Long duration trial runs using wood as fuel and simultaneous gas analysis.*
6. *Trial run using coconut and palm sheddings as fuel (that is - leaf stems, shell, husk and leaf) at various compositions and proportions.*
7. *Analysis of the producer gas in each experiment.*
8. *Chart the problem encountered and rectification.*

9. *Optimisation of the fuel and its size.*

*8.Design and development of an appropriate fuel cutter, if found necessary.*

## 2.3 Experimental setup

*A 5kVA gasifier of the open top down draft design was procured from ABETS (Advanced Biomass Energy Technologies), CGPL (Combustion Gasification and Propulsion Lab), IISc (Indian Institute of Science) Bangalore and installed in our lab. It was connected to a 5 kVA Suguna Diesel Engine - Generator System for electrical loading of the system. A series of 500W bulbs was connected as resistance load.*

## 2.4 System elements

*The system consists of,*

1. *A 5kW electrical open top, down draft, twin air entry gasifier designed by Indian Institute of Science, Bangalore.*

1. *A diesel engine-generator set (rating: 5kVA, 16Amps, Single phase 230V)*

2. *A blower - Vikrant make.*

*The gasifier is connected to engine and blower through pipeline controlled by a ball valve (manual type). Gasifier is first fired through air nozzle. Producer gas, which is cooled in the cooling tower of gasifier, is allowed to pass through a filter. The cool, clean producer gas thus produced is directed either to an engine or to a blower with the help of a 'T' valve. Producer gas is sucked out by the blower. It will be fired at blower end to conduct experiments in thermal mode. If it is supplied to an engine, the engine will utilise the gas along with reduced amount of diesel to perform engine mode operation.*

*An electronic load manager for measuring electrical parameters like, voltage, current, power factor and power output. Three U tube manometers were used for monitoring pressure drop inside the reactor and along gas line. Thermometer for measuring the coolant water temperature, a calibrated glass beaker to measure the amount of diesel consumed and a stop watch for noting the time intervals of the experiments .*

## 2.5 Experiments performed - an overview

*The gasifier coupled with a diesel engine - generator set was tested to evaluate the performance of diesel engine to find Total Fuel Consumption (TFC), Overall Efficiency, Percentage replacement of diesel and average wood consumption per unit output. Using (a) sun dried fire wood with maximum allowable moisture content of 20% (b) coconut fronds and (c) a mixture of coconut shell and coconut fronds as fuel, the gasifier - engine set was tested both in thermal mode and engine mode for 50 hours continuously.*

*Then gasifier was made to run continuously in thermal mode for 200 hours in four steps (i.e. With an interval of 50 hours each). The details of experiments are explained in the next chapter.*

## 2. Test on Gasifier

*The gasifier was tested both in thermal mode and engine mode. In thermal mode, it was used for heating purposes. In engine mode, it was used for electricity generation by coupling it with a diesel engine - generator set. The gasifier was tested using 3 types of biomass fuels. They were (a) sundried firewood (b) coconut fronds (c) mixture of coconut fronds and coconut shells. Gasifier was tested with all these fuels in both thermal and engine modes for 150 hours each. Quantitative* *parameters like average consumption of biomass, reactor pressure, sustainability of flame and percentage valve opening required for continuous burning were observed and corresponding curves were plotted.*

**1.Thermal mode**

*The gasifier was tested and its performance was evaluated in thermal mode for 50 hours with wood, 50 hours with coconut fronds and 50 hours with a mixture of coconut fronds and coconut shells as fuel. With the help of a blower, the producer gas was channelled out of gasifier. The gas coming out at the blower end was fired in a burner and it was monitored continuously to observe the performance parameters in thermal mode. Parameters noted include (a) amount of biomass consumed per hour. (b) Pressure difference in the reactor (c) flame stability.*

**2. Engine mode**

*In engine mode, the gasifier was tested for 10 hours each with firewood, coconut fro nds and mixed fuel. Here, in engine mode, the producer gas was supplied to a diesel engine along with the air intake, and the gas was burned in the engine resulting in significant saving of diesel. The* *parameters noted were (a) percentage replacement of diesel (b) pressure in the reactor and gas line. (c) stability or continuity of engine operation.*

### 2.6.3 Two hundred hours long run for Gasifier

*The gasifier was started and allowed to run for 200 hours in the thermal mode. This was conducted in four steps of 50 hours each. The fuel used was sun dried coconut fronds with maximum allowable moisture content of 20%. Parameters like average consumption of biomass, reactor pressure, stability of the flame and percentage of valve opening required for a good stable flame were observed. The result of this experiment of 200 hours long run was finished with in 12 days.*

## 3. Test on Various Biomass as Fuel

*Biomass gasification largely depends upon the quality of biomass used. More than the calorific value, the structural status and thermal degradation of biomass are the deciding parameters (Source: S. Shrivasthava, S.H. Power- Isothermal degradation of various wood samples in relation to biomass gasification- proceedings of 3rd national meet/PICCOP/28-29 Nov.1991). For selecting effective biomass, which is good for gasification, the calorific value of the fuel should not be the only criterion.*

*For efficient gasification, the wood samples having more carbon content and less volatile materials are needed. Presence of less volatile materials that produce less tar results in less choking of engines. At the same time, high-density wood samples provide a platform for stable gasification reaction.*

*In the experiments conducted at IRTC, 3 types of biomass were used as fuels for experimentation purposes. The three types of fuels-namely (a) fire wood (b) coconut fronds and (c) a mixture of coconut fronds and coconut shells were used to their performance in the gasifier. All these fuels were used both in engine mode and in the thermal mode for checking their viability to be used as fuel in gasifier*

## 2.8 Fuel processing

*The parameters that control gasification are namely of biomass and moisture content in the biomass. For effective gasification, the size of biomass should be small. From various experiments conducted, the optimum size of biomass to used for efficient gasification was found to be 3 x 3 x 5 cm. First the biomass was cut down to chip from. Then the fuel was dried in sunlight. These dried chips were used for experimentation.*

### 2.9 Cutting of Biomass

*The cutting down of biomass in to small chips was major task. For meeting the task there were two options.*

*(a)Machine cutting and*

*(b)Manual cutting.*

*The machine cutter is an equipment working with the help of a motor. A circular wood saw blade is attached directly to the rotating shaft of a motor. An operator is needed to manage the system. He has to feed the wood piece to the cutter to cut it down to the required shape and length.*

*Manual cutting : This is done by labourers themselves with sharp Chopper. The complete effort is put in by the labour.*

*We experimented with both of these processes to get a good comparison. The details are given below (Table 2.1)*

*Table 2.1 Comparison between two cutters*

| Cutting operation | Biomass cutting rate | Remarks |
|---|---|---|

| | | |
|---|---|---|
| *Machine cutting (using a drum type 3hp multiple disc cutter)* | *150 kg/ hour* | *25 to 30% of this weight will be lost while drying* |
| *Manual cutting (by one male labourer)* | *170 kg/day* | *On drying this, about 30 % was lost as moisture.* |

*For small size gasifiers, machine cutting is found to be expensive and a wastage of energy. But for large size gasifiers machine cutting could be more economical and efficient.*

## *Chapter 3*

## *Results and Observations*

3. *Standard performance characteristics of IISc designed gasifier*
4. *Results obtained at IRTC*
5. *Results / Observations*
6. *Some specific problems encountered in using coconut fronds as fuel in gasifier.*

## ……………………….Results and Observations

*This chapter describes the results of the various experiments done on gasifier at IRTC so as to evaluate the performance of the system and its components.*

*Authentic information about various parameters in gasification have been reported by Indian Institute of Science – Bangalore. Test results have been reported on the Open Top Down Draft Gasifier system at the Combustion Gasification and Propulsion Lab (CGPL) at IISc Bangalore. These test results have been adopted wherever applicable.*

### 3.1 Standard performance characteristics of IISc designed gasifier

#### *3.1.* (a) ***Gasifier performance***

*Performance of the gasifier can be described in terms of the composition of the cold gas, its calorific value, and the particulate and tar levels at various loads. The ratio of the cold gas flow rate to the* *wood consumption rate is about 2.6 $m^3$ of gas per kg of wood. Measurements of basic gas parameters were made on a specially built system with instrumentation and test schedule lasting for 10 hours each as per a procedure adopted from European standards and monitored by Swiss scientists (Mukunda et al, 1994, IISc Bangalore). From the experiments, gas composition and calorific value of producer gas were observed as, $H_2$ = 20 ± 2 %, CO = 19 ± 1%, $CH_4$ = 1.5 ± 0.5 %, $CO_2$ = 12 ± 1%, and the rest $N_2$. The calorific value keeps rising for about a few hours and towards the steady state it approaches about 4.75 MJ/kg. The particulate and tar (P&T) data for both hot and cold ends were measured in these tests. The reason for this is as follows. The amount of P&T generated at the hot end has to be brought down to acceptable levels by the cleaning system. This implies the need for a more elaborate clean-up system or more frequent maintenance. The IISc results indicate that the hot end tar is 100 mg/m3 and comes down to 20 ± 10 mg/m3 at the end of the fine filter (cold end). The cooling water washes part of this tar and a part is deposited in the sand bed filter. The particulate level also comes down to 50 mg/m3 at the cold end from about 700 mg/m3 at the hot end.*

### 3.1. *(b) Operation with Engine – Generator set in dual fuel mode.*

*The commercially available diesel engine needs to be modified only at the air intake region. The air intake is fitted with a manifold into which the air and gas lines are connected. The air line is open to atmosphere through a control valve. The engine sucks both air and gas simultaneously and the gas air ratio can be controlled by operating the air control valve. The mixture also passes through the final oil filter so that any possible residual particulate matter is held back preventing possible deposition at the valve seatings. The dual-fuel operation is aimed at reducing the diesel consumption at any fixed load. This is performed by the governer fitted on the engines. In an actual dual-fuel operation, the desired diesel replacement is achieved by reducing the air flow into the engine by operating the air control valve. The engine draws in a specific flow rate through the air manifold. Hence, the sum of air and gas flow rate is constant and when air flow is decreased the gas flow through the system increases. This increases the contribution of energy from the gas. Hence, the engine governor comes into operation and cuts down the diesel to maintain the speed. Reducing the air flow rate will reduce the diesel flow only as long as the gas air mixture remains lean. If the mixture becomes richer, the engine stalls. Therefore, one has to keep away from such a condition. The diesel replacement under conditions close to stall can be between 90 to 93%. Providing for a safety* *margin of about 5% to 6 %, 85 to 87% diesel replacement can be obtained. This can be done either manually or automatically.*

*About performance in dual-fuel mode, the diesel replacement is around 85% or above over most of the load range. The wood consumption is 0.95 kg/kWhr to 1.4 kg/kWhr depending on the power level and moisture content of wood. The overall efficiency of operation, measured as the ratio of the final electrical energy output to the total input energy of diesel and wood, is another performance parameter. Diesel engines show full load efficiency of about 24% in 3.7 kWe (kilo Watt electrical) engines and 35 % in 100 kWe engines. In dual-fuel mode, efficiency is 21% in 3.7 kWe engines and 27% in 100 kWe engines, at 85 % diesel replacement.*

**Results obtained at IRTC**

*In the course of the experiments at IRTC, many practical observations which have relevance in field applications have been made. For instance, the use of sun dried firewood instead of coal, for firing the gasifier, was found to be perfectly feasible.*

*Another interesting observation was about the time needed for smooth operation of gasifier after firing. If we are firing the gasifier upto about 6 hours after completing one shift of operation, the gasifier will take hardly 5 minutes for a stabilised, smooth operation. On the other hand, if the gasifier is fired "from cold" i.e. after two or three days finishing one shift of operation, the gasifier will take 20 to 25 minutes for a stabilised, smooth operation.*

### 3.2. 1 Parameters Evaluated

*(a) Total Fuel Consumption (TFC) in diesel and dual fuel mode*

*(b) Overall Efficiency of gasifier engine generator system*

*© Percentage replacement of diesel in duel fuel mode*

*(d)Cumulative wood consumption of gasifier both at thermal and engine mode.*

### *3.2. (a) Specific Fuel Consumption (SFC), in Diesel Mode*

*Specific fuel consumption of an engine is the quantity of fuel consumed per unit power out put and* *is indicated by the ratio of total fuel consumption to net power output.*

$$SFC = \frac{\textit{Fuel consumed during a specified period}}{\textit{Rate of Power production during the same period}}$$

*A set up was fabricated to enable the measurement of fuel consumption at measured intervals. The total fuel consumption of the engine was found at various loads by conducting the usual load test. The engine was subjected to loads varying from no load to full load with an interval of 0.5 kW. Fuel consumption was measured at various constant loads. It was then plotted against load to obtain TFC and SFC curves (Fig 3.1)*

**Observations :**

*The curve indicates that the TFC increases with load in a non linear pattern. The specific fuel consumption declines very sharply at first and then attain a steady value. It tends to increase again after on optimum load. It may be mentioned here that the SFC for the engine under experiment was* *a bit on the lighter sides, compared to standard values. This is due to the fact that an old machine, which was readily available, was used for the trials. This does not reflect on the usability of the gas from the gasifier.*

### 3.2. (b) Overall Efficiency of the Gasifier Engine System in Diesel Mode

**Principle:**

*Overall Efficiency is the ratio of final electrical energy output to the total input energy of both diesel and wood.*

$$\eta_{overall} = \frac{\text{Electrical Energy output in kWh}}{\text{Heating value of fuel used during the same duration}}$$

*The overall efficiency of the engine was found at various loads by conducting load test. The engine was subjected to loads varying from no load to full load with variations of 0.5 kW each. The curve is plotted based on observations (Fig 3.2)*

**Observations :**

*The best efficiency point (BEP) for this engine was found at 3.5 kW of load. The maximum overall efficiency was found to be only 13%. The standard overall efficiency of engine – Gasifier system is around 17% and the current result is found to be on the low side. The explanation as mentioned above is the poor quality and condition of the engine, which is of local make, and in an aged condition.*

### 3.2.1.(c) Percentage replacement of diesel in Diesel Fuel Mode.

*Percentage replacement of diesel is the ratio of the amount of diesel used by the engine in dual fuel mode to the amount of fuel used in diesel mode (when running one diesel exclusively), expressed in percentage. In other words, if the engine consumes, X kg diesel for 1 hour in the diesel mode and only Y kg of diesel in the dual fuel mode, the percentage replacement is (X – Y) / X * 100.*

**Observations:**

*The percentage replacement was evaluated at various loads (Fig 3.3). It was found to be varying between 75-80% in the normal condition. If we can adjust the governor of the engine, it can be brought up to 90%.*

*But at this level, the engine would not be able to withstand sudden changes in the load. This will affect the stable and continuous working of engine, and hence is not recommended for normal operation.*

### *3.2.1.(d) Biomass consumption rate of Gasifier*

*Biomass is the fuel of the Gasifier. The gasifier was tested using 3 types of fuels (a) sun dried firewood (b) coconut fronds (c) mixture of coconut fronds and coconut shells. Gasifier was tested with each type of fuel in both modes for 50 hours each. Average biomass consumption per hour for a constant load of 3.5 kW for each fuel was noted.*

**Observations:**

*The rate of biomass consumption was gradually changing from no load to 3.5 kW (Fig 3.3). Then it becomes steady. The biomass consumption per hour for a constant load of 3.5 kW was found to be*

*1.For fire wood 1.08 kg / kW hour*

*2.For coconut fronds it is 1.17 kg / kW hour*

*3.For a mixture of fire wood and coconut frond 1.14 kg/ kW hour*

## 3.3. Results / Observations

### 3.3. a Thermal mode

1. *The major results obtained from each experiment conducted in thermal mode are listed below.*
   - *The average biomass consumption for a constant load of 3.5 kW, for each type of fuel is as follows.*
   - *Firewood: 3.8kg/ hr i.e. @ 1.08 kg / kWhr.*
   - *Coconut fronds: 4.1 kg/hr i.e. @ 1.17 kg / kWhr.*
   - *Mixture of firewood and coconut fronds: 4 kg/hr i.e. @ 1.08 kg / kWhr*
2. *The best valve opening from the starting of the gasifier is more or less same, at around 60%.*

3. *The woody biomass gives absolutely trouble free performance.*

4. *Recommended operating practise: Topping of biomass to be done at intervals of 20 minutes for coconut fronds and 30 minutes for wood.*

**3.3 b Engine mode**

*The highlights of results obtained from each experiment conducted in engine mode are listed below.*

1. *The test was conducted at 3.5 kW load (point of minimum SFC of the engine )*

2. *The average biomass consumption rate for each type of fuel is as follows.*

   a. *Firewood: 1.1 kg/ unit (kWhr) for wood @75% replacement*

   b. *Coconut fronds: 1.32 kg/unit @65% replacement*

   c. *Mixture of firewood and coconut fronds: 1.2 kg/unit @75 % replacement*

3. *In the initial stages the replacement is very low because the Engine aspiration air valve was*

*not regulated to the optimum to get maximum replacement.*

4 *It was also found that the gas quality was very low at the initial stages.*

5 *The gas quality was assured before it was allowed to enter the engine. This was done by running the gasifier in thermal mode for 30 minutes*

6. *The optimum position of closing the valve to ensure maximum fuel replacement was found out by doing trial and error experiments. It was also found that poor gas quality can stop the engine and at that time the gas valve has to be closed and air valve has to be opened fully.*

7 *The producer gas valve was full open through out the operation*

8 *The air valve is around 60 to 70% close during the total operation.*

9 *The fuel replacement value of engine is found to increase with time due to the improvement in gas quality.*

9. *Percentage replacement curve start going up with time and after about 5 hours of continuous run, the curve is more or less following a straight line showing a constancy in performance.*

### 3.4 Some specific problems encountered in using coconut fronds as fuel in gasifier.

1. *The coconut biomass is susceptible to terminate attack. So the storage area has to be protected from termite.*

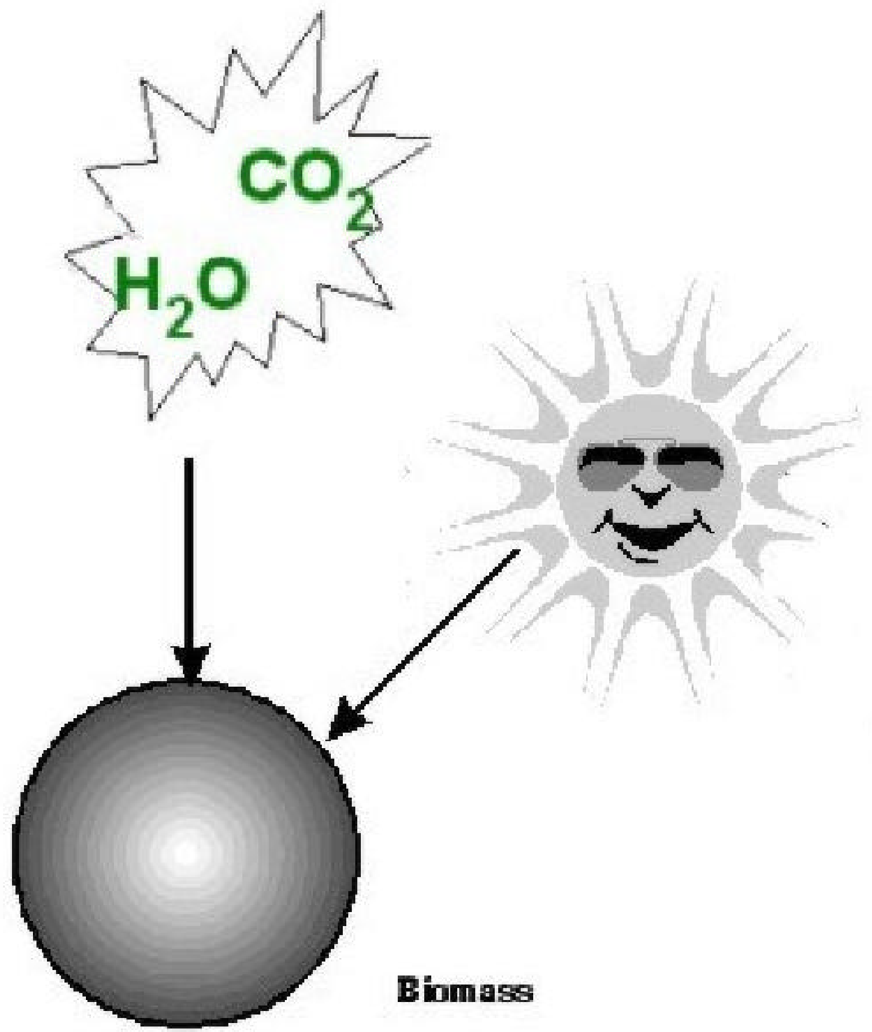
2. *As the bulk density of the coconut fronds is barely equal to the minimum that which is acceptable to the gasifier, it can 'bridge up' inside the gasifier. Frequent poking (pushing down of biomass inside gasifier using a long rod) from the top of the gasifier is recommended to eliminate this. According to the experts at IISc, this problem can be eliminated by increasing the size of the gasifier.*

3. *Another observation was regarding the rising of the combustion zone after prolonged running in the engine mode. Frequent poking from the top and reducing the time interval of biomass loading can eliminate this problem.*

4. *It was also observed that the engine often stalled when suddenly switched over to gasifier mode (dual fuel mode). This is presumed to be a problem of locally fabricated engine parts. The higher specific fuel consumption of the engine compared to the other engines of same capacity, is also presumed to be due the same reason.*

### 3.5 Conclusions

- *It was established that the IISc made Open Top Gasifier can perform satisfactorily with coconut fronds and shells as the fuel, for both thermal as well as engine mode operations.*
- *Appropriate operating practises were evolved for these applications.*
- *Even though the overall efficiencies obtained in the experimental engine set up were comparatively low, the feasibility of using locally available fuels for supplying cooking gas as well as electricity for domestic applications, was established.*


CO2
H2O
Biomass

*PHASE II*

# *Chapter 1 of phase II*

# *Field Applications*

*1. Burner Development*

*2. System Design*

*3. A total village Electrification Project*

*4. Village Electrification project of Kaituva Hamlet*

*5. Performance Test on Gasifier for Tar and Particulate Analysis Using Different Biomass.*

## ……………………………….. Field Applications

*The Gasifier project was planned to be executed in two phases. The two phases targeted were (1) test a gasifier using coconut fronds as fuel to evaluate its performance (2) to install a biomass gasifier in the field for practical application.*

*The results obtained in the laboratory trials show that, if the kind of biomass ordinarily used as fuel in the ordinary wood burning chulhas of our village households, is gasified in a gasifier, the producer gas so produced, will be enough not only to meet the thermal energy requirements of the same home, for cooking, but also will suffice to meet the electrical needs for lighting, if fed to a diesel-generator. This means that if the same quality of firewood, now being burnt inefficiently in household chulhas, is collected and gasified in a central gasification plant, the producer gas so generated, will more than suffice to meet the cooking needs of the same households. The balance, if fed into a Diseal Generator Set, can produce enough electricity to meet the lighting needs of the same households.*

*This is indeed a novel and beautiful concept, and provides a revolutionary idea for village energisation, in a sustainable way.*

*However, it was realized that certain technical pre-requisites have to be fulfilled before this can be taken up for field implementation.*

1. *The development of a suitable burner*

2. *Evolving a proper design for a village gas distribution system, taking into consideration the safety and gas flow aspects.*

## A. Burner Development

*Gas burners for domestic as well as industrial applications are available for Natural gas, LPG and also for Bio Gas (which is mostly methane]. However, the producer gas, formed by gasification of biomass, has a different composition, and needs a different air-fuel ratio. So the currently available burners cannot be used directly for this application. Large burners for industrial use are available. 5* *kW burners for commercial kitchens are also available, but not domestic size burners for ordinary households.*

*So IRTC took up this challenge and preliminary results are very promising. This modified biogas burner has been successfully tested and is now being used for cooking in the IRTC kitchen.*

*System Design*

*This will involve the design of various components of the system like, gasifier, engine, gas storage, piping, burners, wiring, lighting and also provisions for safety.*

*A load survey conducted among the proposed beneficiary households forms the basis of this design. Of course, in the case of gasifier and engine-generator design, the exercise involves*

**mainly the determination of appropriate specifications and performance standards.**

*An Aborted Attempt (The Elikkulam Study)*

*D. A total village Electrification Project*

*A detailed project proposal for the total electrification of a hamlet using biomass gasifier has been prepared as a continuation to this project. Technical support for the IISc Bangalore has been utilised for this purpose. The Kodur hamlet, adjacent to the IRTC campus has been chosen for this project, after short listing from a member of possible choices. The project has been submitted to the MNES, Govt. of India, for funding.*

*A copy of the project proposal is attached as an appendix (Appendix 1) to this report.*

## 10.Village Electrification project of Kaituva Hamlet

*The project is a joint venture of Vengoor Grama Panchayath and IRTC. It aims at electrification of an unelectrified rural hamlet by using a biomas gasifier of 5KW capacity. The project is considered as the first programme of its kind-ie, village electrification-using gasifier-in our state.*

*The proposed site is at Kaituva, in the fourth ward of Vengoor panchayth in Perumbavoor Taluk, Ernakulam district.*

*The MLA of Perumbavoor constituency Mr. Saju Paul is the motivator of this project. The major part of the project outlay for implementing gasifier will be provided from the MLA fund and a small protion will be collected as beneficiary contribution. The Gasifier purchased with the present project funds, will be provided by IRTC for this project.*

*All the 28 houses in the unelectrified hamlet will be provided with electricity for 6 pm-10pm daily, thoroughout the year. This will act as a stand-alone system.*

*A feasibility report was prepared based on the survey conducted at this site and submitted to MLA Sri. Saju Paul for funding.*

*A copy of the project proposal is attached as an annexure (Annexure 3) to this report*

## 11.Analysis Using Different Performance Test on Gasifier for Tar and Particulate Biomass.

*A batch of final year Mechanical Engineering students from the Kannur Engineering college has done a performance evaluation test of gasifier for tar and particulates. These include the coconut fronds and many other biomass that are chiefly avilable around us.*

*A copy of relevent pages of this report is also attached as an annexure (Annexure 4)*

**List of Graphs :**

**The Engine :**

*1.Load Vs Efficeincy of Engine*

*2.Load Vs Total Fuel Consumption*

**The gasifier :**

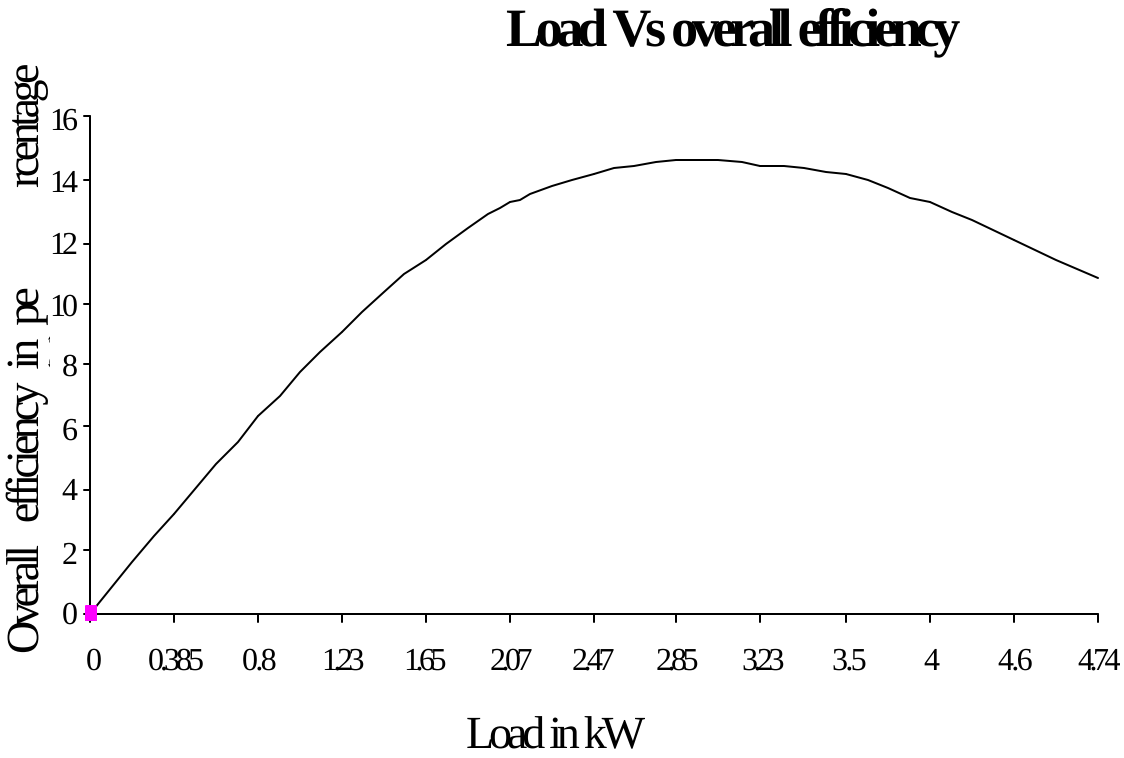
*1.The performance of gasifier in thermal mode using fire wood as fuel*

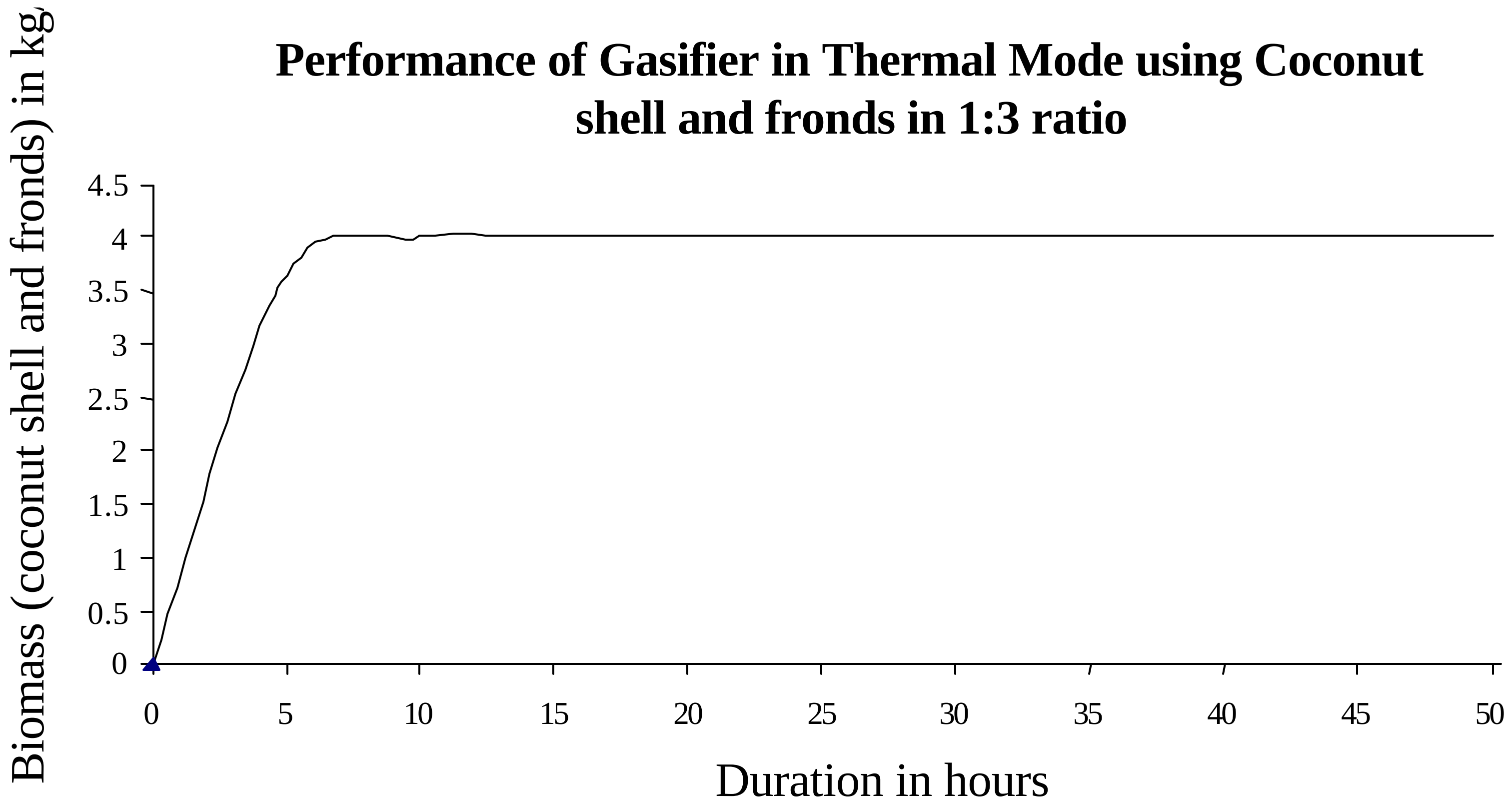
*2.The Performance of gasifier in Thermal Mode using coconut fronds as fuel*

*3.The Performance evaluation of the gasifier using fire wood as in dual fuel mode*

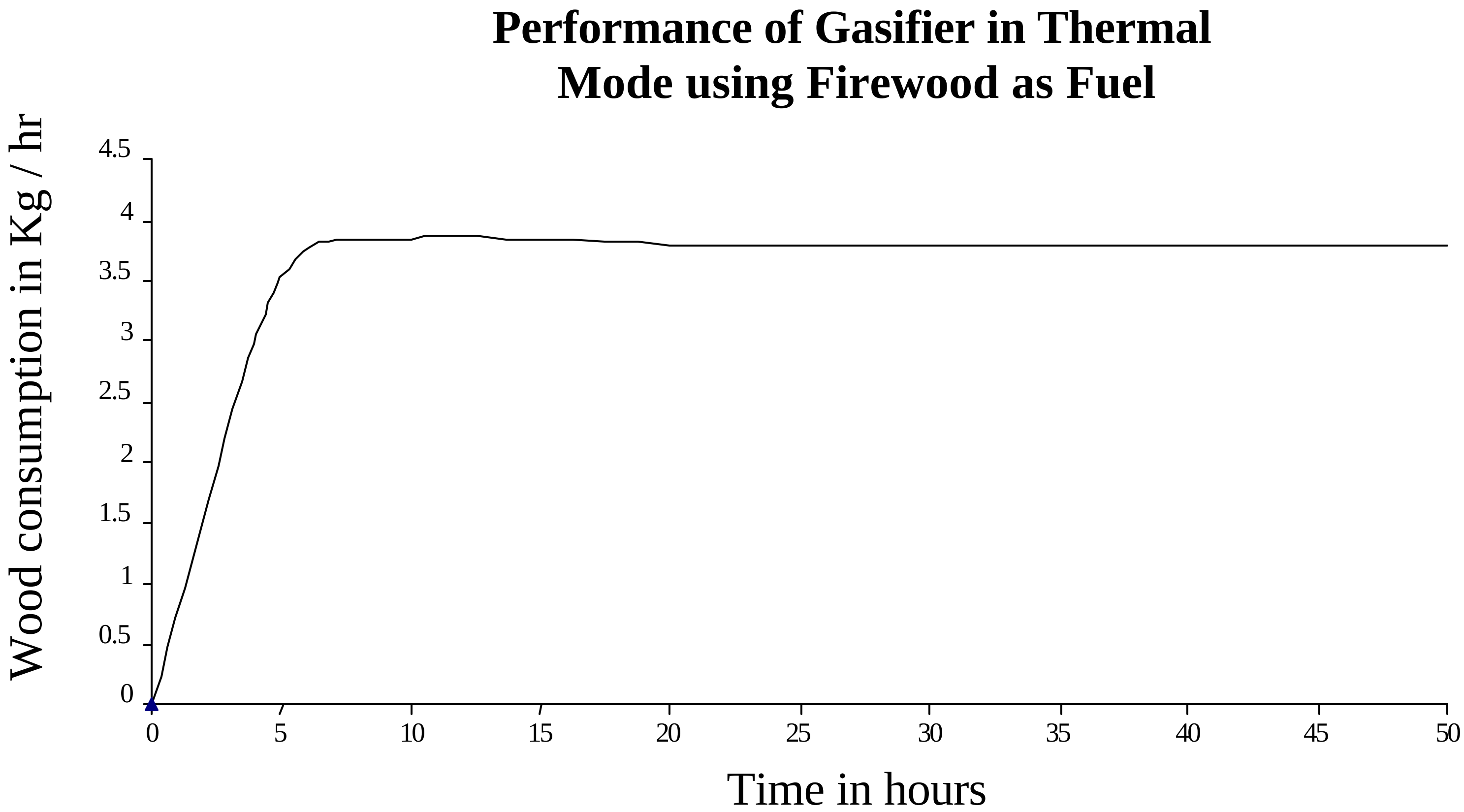
*4.The performance evaluation of the gasifier using coconut fronds as fuel in dual fuel mode*

*5.The performance evaluation of the gasifier using fire wood in long run*


Load Vs overall efficiency
Overall efficiency in percentage
16
14
12
10
8
6
4
2
0
0
0.385
0.8
1.23
1.65
2.07
2.47
2.85
3.23
3.5
4
4.6
4.74
Load in kW

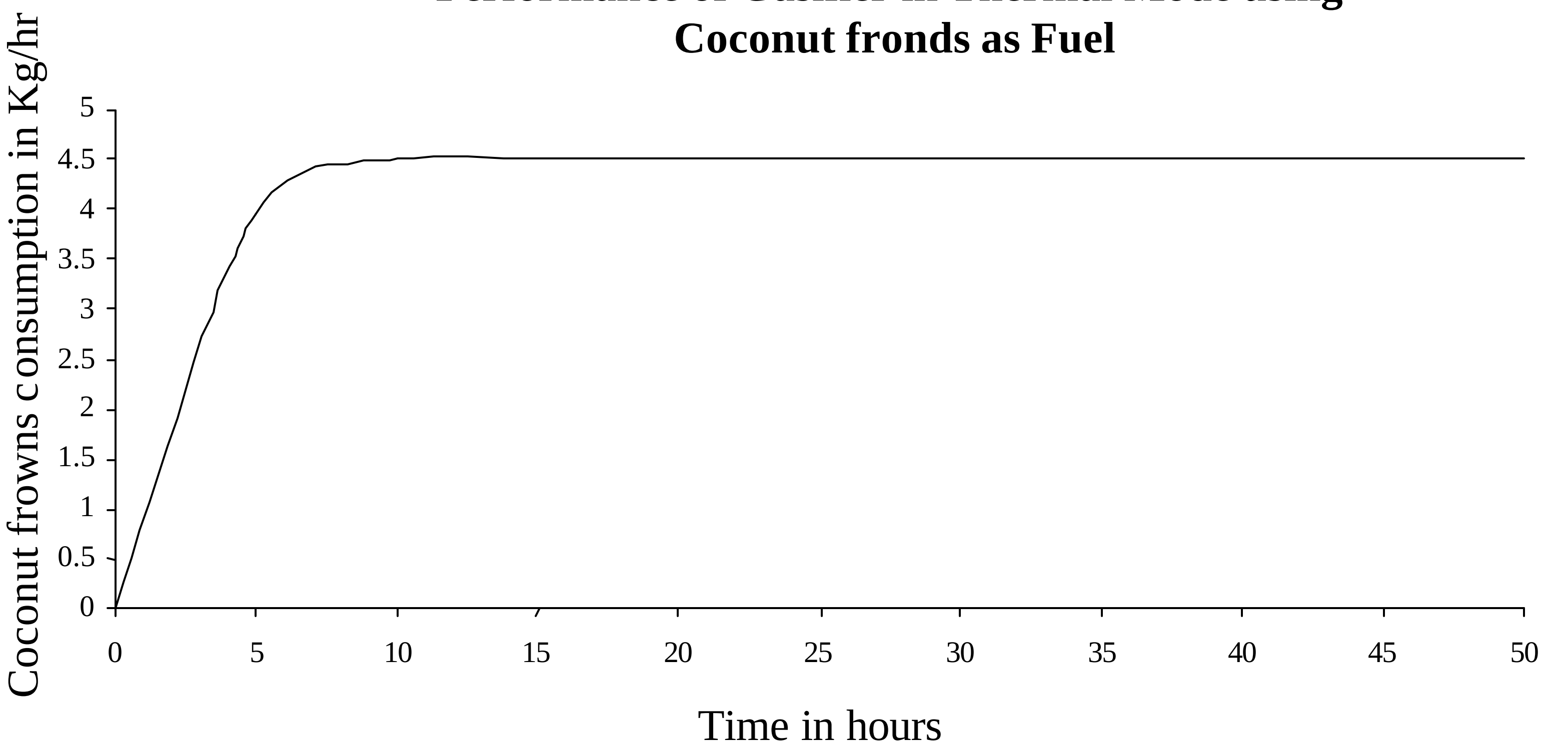


Performance of Gasifier in Thermal Mode using Coconut shell and fronds in 1:3 ratio
Biomass (coconut shell and fronds) in kg
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
5
10
15
20
25
30
35
40
45
50
Duration in hours

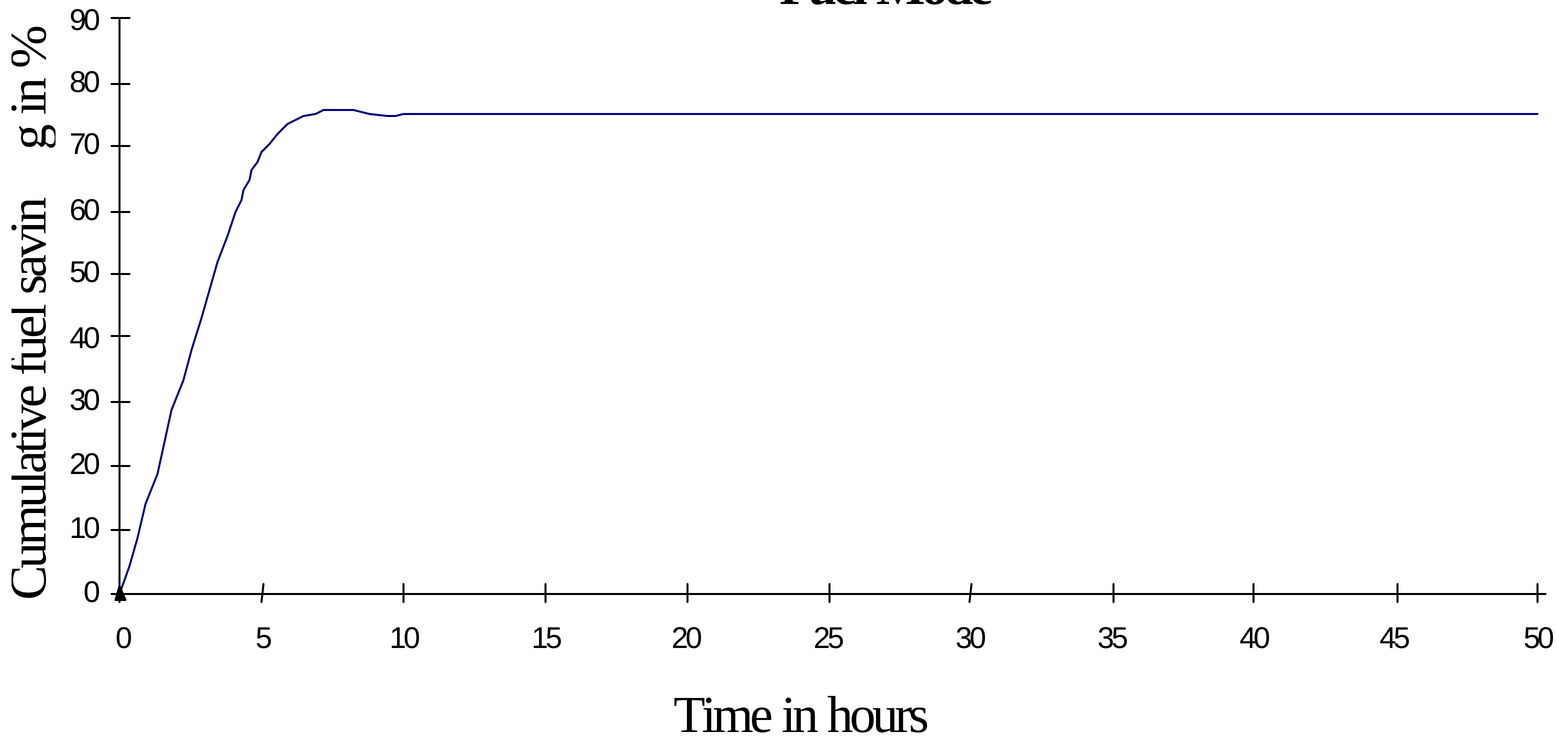


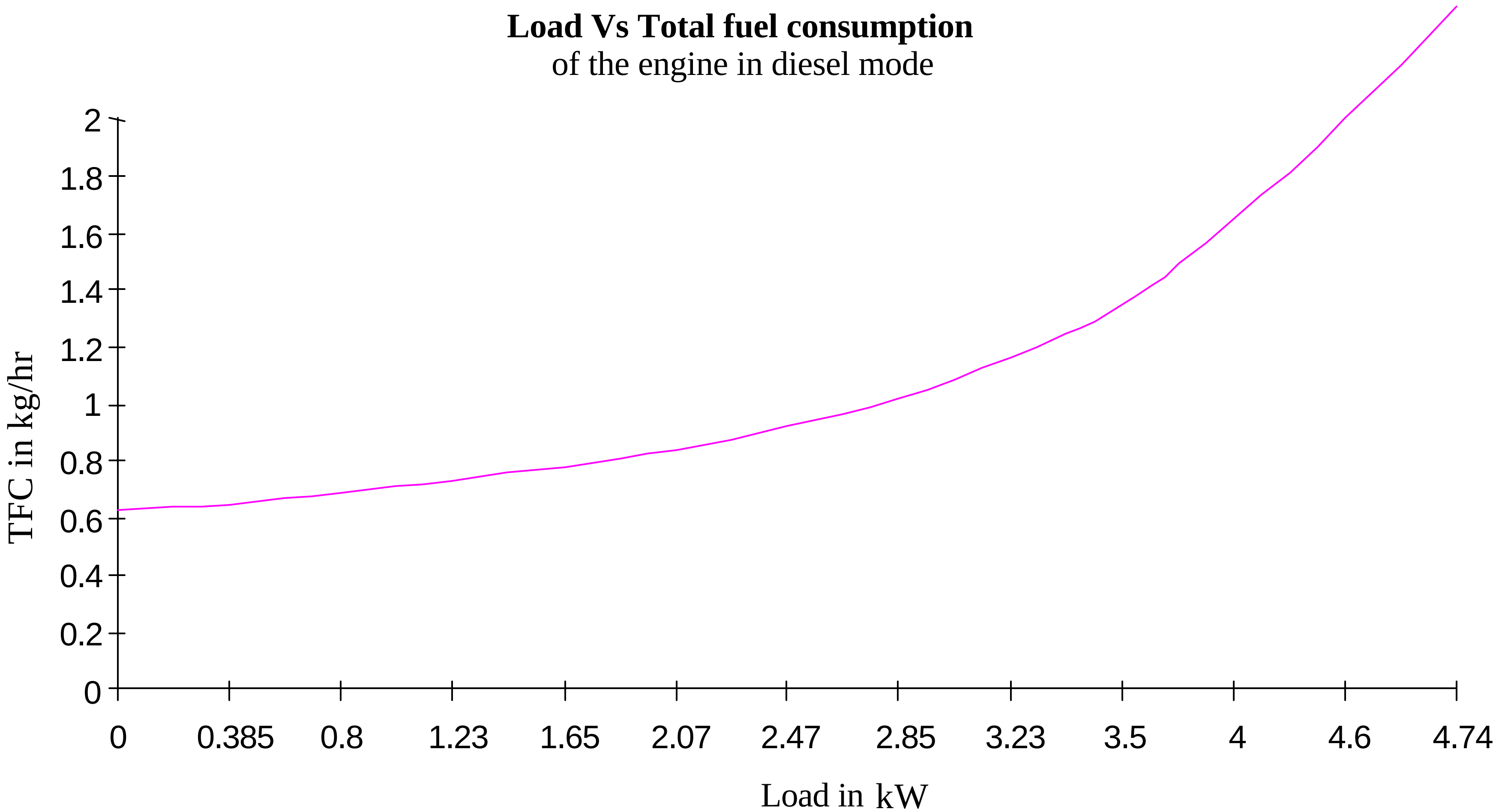
Performance of Gasifier in Thermal Mode using Firewood as Fuel
Wood consumption in Kg / hr
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
5
10
15
20
25
30
35
40
45
50
Time in hours

**Performance of Gasifier in Thermal Mode using Coconut fronds as Fuel**



**Performance of Gasifier Engine System using Wood in Dual Fuel Mode**




Load Vs Total fuel consumption
of the engine in diesel mode
TFC in kg/hr
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
0.385
0.8
1.23
1.65
2.07
2.47
2.85
3.23
3.5
4
4.6
4.74
Load in kW

## Performance of Gasifier Engine System in Dual Fuel Mode using Coconut Fronds biomass consumption Vs duration in hours

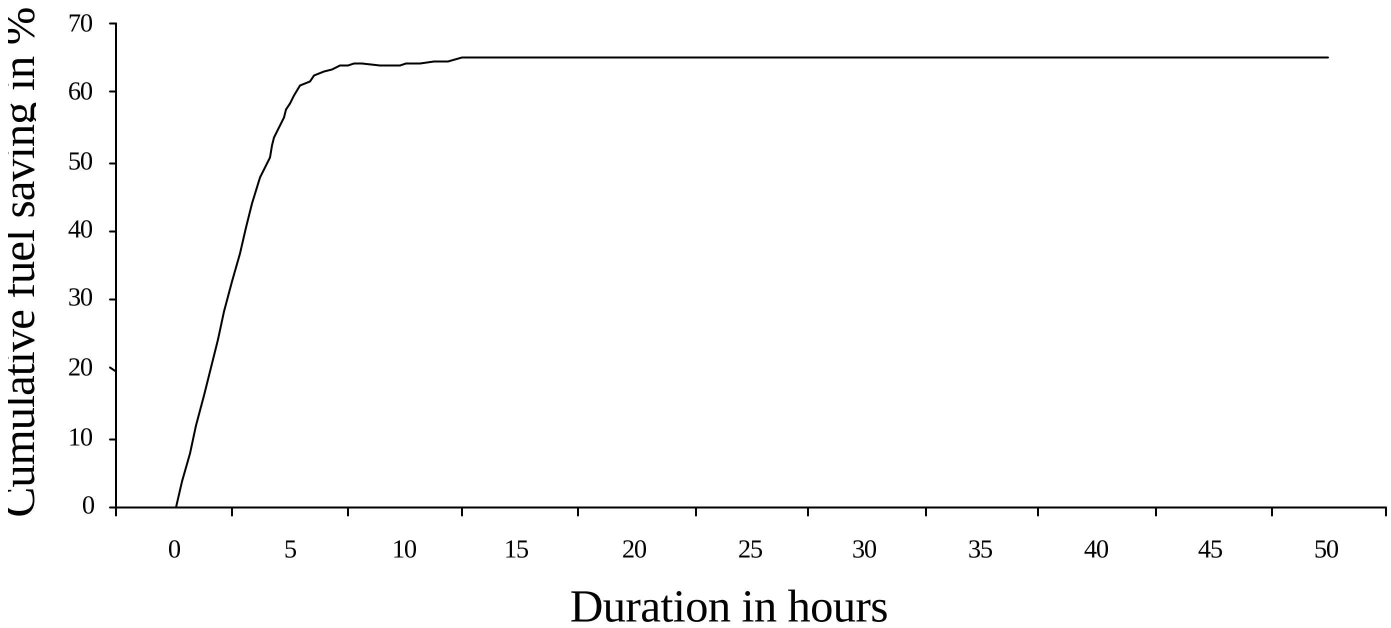


Table 1.4

| Reactions | | Enthalpy of Reaction (kj /mol) |
|---|---|---|
| *Devolatilization* C+ heat | $CH_4$ + condensable hydrocarbons + char | |
| *Steam –carbon* C + $H_2O$ + heat | CO + $H_2$ | 131.4 |
| *Reverse Boudouard* C + $CO_2$ + heat | 2CO | 72.6 |
| *Oxidation* C + $O_2$ | $CO_2$ + heat | (-) 393.8 |
| *Hydro-gasification* C + $2H_2$ | $CH_4$ + heat | (-) 74.9 |
| *Water gas shift* $H_2O$ + CO | $CO_2$ + $H_2$+ heat | (-) 41.2 |
| *Methanation* $3H_2$ + CO | $CH_4$ + $H_2O$ + heat | (-) 206.3 |
| $4H_2$+ CO2 | $CH_4$ +$2H_2O$ + heat | (-) 165.1 |

*Table 2.1 Comparison between two cutters*

| *Cutting operation* | *Biomass cutting rate* | *Remarks* |
|---|---|---|
| *Machine cutting (using a drum type 3hp multiple disc cutter)* | *150 kg/ hour* | *25 to 30% of this weight will be lost while drying* |
| *Manual cutting (by one male labourer)* | *170 kg/day* | *On drying this, about 30 % was lost as moisture.* |

*The results of the stove efficiency tests done are given in Tables A1.2 and A1.3:*

| | gas flow (m3/s) | burner efficiency |
|---|---|---|
| | 2.14E-04 | 16.05 |
| | 3.66E-04 | 19.51 |
| | 4.97E-04 | 27.39 |
| | 5.76E-04 | 19.85 |
| | 6.05E-04 | 20.46 |
| | 6.22E-04 | 17.43 |
| | 6.29E-04 | 23.92 |
| | 6.30E-04 | 19.24 |
| | 7.17E-04 | 17.96 |
| **average** | **5.40E-04** | **20.20** |

*Table A1.2: Burner efficiencies as a function of gas flow, gas pressure 6 cm water.*

| | gas flow (m3/s) | burner efficiency |
|---|---|---|
| | 3.42E-04 | 33.72 |
| | 3.44E-04 | 21.63 |
| | 3.93E-04 | 21.83 |
| **average** | **3.59E-04** | **25.73** |

*Table A1.3: Burner efficiencies as a function of gas flow, gas pressure 36 cm water.*

# SUMMARY

**Title** **:Field Testing of a Biomass gasifier with Coconut Fronds as fuel in Actual Running Condition.**

**Principal Investigator** **:Hassan Sabahudheen**

**Institution** **:Integrated Rural Technolgoy Centre, Mundur, Palakkad**

**Funded by** **:Kerala Research Programme on Local Level Development, CDS, Thiruvananthapuram**

Biomass holds a key role in satisfying the energy needs of humanity. Energy demand is met from biomass by (a) biomethanation (b) biomass gasification and (c) Phyrolysis,

In biomass gasification small prices of firewood are heated in a restricted atmosphere so that a mixture of CO and $H_2$ are produced. Reactions taking place in the gasifier result in a mixture consisting of CO, $H_2$, $CO_2$, $N_2$ steam and hydrocarbons. This gas mixture can be

burnt in a boiler, cook stove or even used as fuel in an IC engine. Centralised production of producer gas in a gasifier and supplying it to the houses through pipelines as cooking fuel is certainly a good suggestion.

As Kerala has abundant resource of biomass, biomass gasifer can be used as a supplimentory source of power. The present project was aimed at studying the suitability of coconut fronds as fuel in biomass gasifier and using the gasifier for power generation for supplying to local communty for domestic cooking and lighting.

As part of the project the following were done.

12. Installation of a 5 kVA gasifier.
13. with the help of IISc., Bangalore and connecting it to a 5kVA Diesel Generator. Estimation of calorific value of various fuels.
14. Trial run using coconut and palm sheddings as fuel.
15. Analysis of the producer gas.

Gasifer was tested using 3 types of biomass fuels. (a) Sundried firewood (b) Coconut fronds and (c) Mixture of coconut fronts and coconut shells.

For a constant load of 3.5 KW the biomass consumption was as given below.

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| For fire wood | 1.08 Kg/Kwh. |
| For Coconut fronts | 1.17 Kg/Kwh. |
| Mixture coconut fronts and coconut shell | 1.14 Kg/Kwh. |

An attempt was made with the help of IISc., Bangalore to develop a burner suitable to burn the gas. This task was accomplished and the burner was tested at IRTC kitchen successfully. A detailed proposal for a village electrification at Paniyeli has been submitted with the assistance of the Perumbavoor MLA Mr. Saju Paul.