BIOMASS – A SUBSTITUTE FOR FOSSIL FUELS?

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Introduction:

The world population is expected to grow from the present 6 billion to 8 billion in 2020 and 9 billion in 2050 despite drop in population growth rate. There is a usual and consequential energy demand from the present approximate14 billion tce to an estimated 19 billion tce in 2020 and up to 27 billion tce in 2050. Therefore, need of the hour is to conserve the fast depleting fossil fuels by intensifying research on renewable type alternatives, which will also mitigate global warming effect.

Present Global Energy Consumption Pattern:

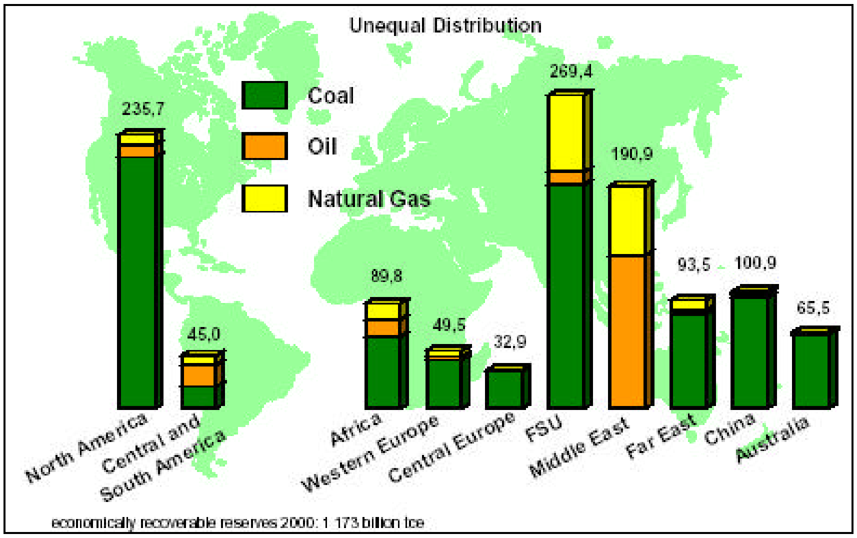
The global share of energy consumption by developed and developing countries is given below (1).

Table-1: Global Energy Consumption Pattern

Block	% Population of the global total of ~ 6 billion	% Energy Cons.
Developed countries	**20** (Expected to decrease to 15% after 25 years)	**60**
Developing countries	**80** (Expected to increase above 80% after 25 years)	**40**

Global Unequal Energy Distribution And The Unstable Resource-Rich Regions:

The unequal distribution of global energy reserves is seen in chart below (1):



Over 80% of the global oil and natural gas resources is concentrated in only two regions of the world - as shown in table below (1), which are unstable and may subject to geopolitical changes, i.e., the former soviet Union and countries belonging to OPEC. A fight from resource-poor regions like the Western Europe and Asia-Pacific is not ruled out.

Table-2: Global Oil & Natural Gas Reserves

Region	Oil	Natural gas
Total Global Reserves (Billion tce)	~200	~175
OPEC	78%	43%
Former USSR Region	6%	38%
Western Europe	2%	5%
Others	14%	14%

Bridging The Gap In The First Half Of 21st Century:

According to Gerhard Ott (1), energy availability warrants a diversified energy portfolio matching with particular national circumstances and all energy resources are needed in the next fifty years without exclusion of any single source. For instance, from the viewpoint of mitigating greenhouse gases, it is suggested that CO_2-free nuclear energy, which contributes to around 18% of global electricity production, needs to be supported for extension plans by sorting out the problems associated with the relatively young nuclear industry. Therefore, this school of thought is unhappy about the fact that nuclear energy is being phased out in some of the countries like Sweden, Germany & Spain.

It is also suggested that, as any amount of investment in improving energy efficiency in industrialised countries will lead to only a marginal improvement in the efficiency, the same effort if put in developed countries, it would result in substantial improvement in energy efficiency, thereby considerably reducing the emissions load as well as the environmental impact from the greenhouse gas. This is more so, because it is feared that environmental problems will shift more and more towards the developing countries from the western world within a few decades and nearly 70% of the global sulphur dioxide and almost 60% of the global CO2-emissions is expected to come from this region.

It is visualized that during the second half of 21st century, population growth may come to a halt, green house gas emissions may be stabilised or decreased and new energy systems may be in place. However, in the first half, during the next 30 years, there lies a lot of challenge and it needs a strategy for "bridging the gap":

The strategy for "bridging the gap" and providing a smooth continuity could be two-pronged:

First, solving short– and medium-term problems all over the world through careful and intelligent use of an energy mix consisting of fossil fuels and nuclear energy, combined with resolute energy efficiency measures, and with enhancement of "new" renewable energies like solar, wind and biomass.

Second, in order to provide a smooth continuity to the next half of the century, dedicated long-term R&D efforts for successfully exploiting new energy systems such as fuel cells, solar, advanced nuclear technologies, super conductors etc.

The World Energy Council has identified three overriding energy goals: "Accessibility, Availability and Acceptability". Accessibility to modern energy means that energy must be available at prices, which are both affordable and sustainable. Availability covers both quality and reliability of delivered energy. Acceptability covers many issues: Deforestation, land degradation or soil acidification at the regional level; indoor or local pollution; greenhouse gas emissions and climate change; nuclear security, waste management and proliferation; and the possible impact of the building of large dams or large-scale modern biomass developments.

The answer for sustainable energy lies in local capacity building and local decision taking.

Total Share Of Renewable Energies - Global Scene:

Global share of the renewable energies is expected to rise from 16-17% during the years 2000-2020 to 22% in the year 2050 (1).

Table-3: Share Of Renewable Energy On A Global Scale – Present & Projected

Source	2000	2020	2050
Wood, wastes etc.	10	8	6
Hydro	4	5	5
New Renewable like solar, wind & biomass	2	4	11
Total % Share of renewable energies	16	17	22

Renewable Energy - The Indian Scene:

The total installed capacity of power generation from all sources in India including captive generation is close to 125,000 MW, out of which the nuclear power is just 3% (2). In the Tenth Plan period (2002-07), out of a set target of 41,000 MW additional power generation envisaged by the Union Power Ministry, about 4,227 MW is expected to be generated from renewable sources and the total plan outlay is US $ 2.2 billion.

Table-4: Break-Up Of Installed Capacity And Potential Against Each Of The Renewable Energy Technology / Sources in India (2)

SL. No.	Sources/Technologies	Unit	Potential (Estimated)	Achieved (2002)	Achievements as % of Potential
1	Wind Power	MW	45,000	1507	2.8

2	Small Hydro (<25 MW)	MW	15,000	1341	8.9
3	Biomass Power Biomass Gasifiers Biomass Cogeneration	MW MW MW	19,500 16,000 3,500	308 35 273	1.6 0.2 7.8
4	Urban & Industrial Waste	MW	1,700	15.20	0.9
5	Solar Photovoltaic	MW/Sqkm	20	47	
6	Solar Water Heating	Million SqmCollector area	140	0.55	0.4
7	Biogas Plants	Million	12	3.1	25.8
8	Improved Biomass (Chulhas)	Million	120	33	27.5

Renewable Energy Systems in India today have an installed capacity of nearly 3500 MW with an investment of around US$ 5 billion.

What Is Biomass Energy?:

Using biomass resources for energy has the potential to greatly reduce global warming effect resulting from greenhouse gas emissions. Even though biomass generates about the same amount of carbon dioxide as fossil fuels, but the carbon dioxide gets cyclically consumed by new plants grown for energy. Thus, the net carbon dioxide emission into the environment is zero. These energy crops, such as fast-growing trees and grasses, are called biomass feedstock. For country like India, predominant in agriculture, this can generate rural employment and improve local economy. Biomass as a resource can be distinctly exploited in one of the three ways: Biofuels for transportation, Biopower for electricity generation and biorefinery products. At present there is worldwide-rekindled interest in biomass energy.

Biofuels For Transportation: Unlike other renewable energy sources, biomass can be converted directly into liquid fuels called biofuels for a variety of our transportation needs like cars, trucks, buses, airplanes, and trains. A variety of biofuels are produced through one or a combination of the following processes: cold pressing, extraction, refining, transesterification, fermentation, distillation, hydrolysis, synthesis, digestion, CO_2/H_2O-

removal, steam reforming, gasification, hydro cracking, pyrolysis, supercritical gasification etc. Some of the conventional biofuels are: Straight vegetable oil, biodiesel from seeds, biodiesel from waste (oil/fats), ethanol from sugar crops, ethyl tertiary butyl ether (ETBE), SNG from biogas, hydrogen from biogas etc. Some of the advanced biofuels are: Fischer-Tropsch (FT) diesel, Methanol, methyl tertiary butyl ether (MTBE), alcohols from syngas, hydrogen form syngas, ethanol from celluloses, pyrolysis-diesel, hydrogen from wet materials etc. Ethanol for instance is used as fuel additive to bring down vehicle's carbon monoxide and smog causing emissions. Also gasoline-ethanol mixtures with ethanol up to 85% are being used in some fuel flexible vehicles. Biodiesel, for example, is made by transesterification of straight vegetable oil or by refining and transesterification of waste oils/fats. Biodiesel is used as an additive to reduce vehicle emissions (typically 20%) or in its pure form as a renewable alternative fuel for diesel engines. As one of the long-term alternatives, biomass derived fuels is proposed for Transportation in India (3)

Daimler-Chrysler's Study On Use Of Biofuels In India: It has been reported (4) that Daimler-Chrysler, one of the world's renowned companies, is doing a test trial with bio-diesel in India through a collaborative project with Council for Scientific & Industrial Research of India and the University of Hohenheim, Germany. The bio-diesel is created from the extracts of Jatropha seeds. On a trial basis, wasteland in two different climatic regions (humid Orissa & semi-arid Gujarat) will be used to grow Jatropha plant for bio-diesel production. These plants are not grazed by animals and disease resistant. The time taken for nut yield is between 2-5 years and the yield varies from 0.5 to 12 tonnes per year and the seed kernels contain about 60% oil that can be converted to biodiesel through transesterification.

Biopower For Electricity Generation: Biopower is the use of biomass to generate electricity through direct burning or converting into gas or into oil. There are six major types of biopower systems: direct-fired, co-firing, gasification, anaerobic digestion, pyrolysis, and small, modular systems.

Most of the biopower plants in the world use direct-fired systems, which burn feedstock directly and produce steam, which in turn run turbine to produce electricity. When a part of this steam is also used for manufacturing processes or heat buildings, then it is called combined heat and power facilities. For instance, wood waste is often used to produce both electricity and steam in paper mills. Co-firing is a process in which coal firing is supplemented by bioenergy feedstock in high efficiency boilers in order to significantly reducing sulphur dioxide emissions.

Gasification systems use high temperatures and an oxygen-starved environment to convert biomass into a gas called ‘Producer Gas’, which is a mixture of hydrogen, carbon monoxide, and methane. The gas is either used in gas turbines or in internal combustion engines to generate captive power.

Composition, water content and morphological properties of the material to be gasified, guide the selection of gasification route based on technical feasibility and economic viability of conversion. For instance, cow-dung, which is rich in water content, is ideal for biological conversion. Whereas solid biomass such as wood and rice husk, which have low moisture content, are thermo-chemically gasified to producer gas - a low energy yield gas.

Anaerobic digestion involves using bacteria to decompose organic matter in the absence of oxygen and methane gas is produced such as landfill gas.

Oils are produced from biomass through pyrolysis – a process, which occurs when biomass is heated in the absence of oxygen. The resulting liquid called pyrolysis oil can be burned like petroleum to generate electricity

A small, modular system generates electricity at a capacity of 5 megawatts or less. This system is designed for use at the small town level or even at the consumer level. For example, farmers can use the waste from their livestock to provide their farms with electricity. These systems apart from providing renewable energy also help in meeting environmental regulations.

Bioproducts Through Biorefinery: Products that are typically made from fossils fuels can be made from biomass. Bioproducts is the result of converting biomass into chemicals through biorefinery concepts and making products such as antifreeze, plastics, glues, artificial sweeteners, and gel for toothpaste.

When biomass is heated in the presence of small amount of oxygen, carbon monoxide and hydrogen are produced. The mixture is called biosynthesis gas and this gas is used to make plastics and acids, which can be used in making photographic films, textiles, and synthetic fabrics.

When biomass is heated in the absence of oxygen, it forms pyrolysis oil from which phenol can be extracted. Phenol is used to make wood adhesives, molded plastic, and foam insulation.

Exploitation Of Biopower / Biomass Power In India:

In India the imports of oil rose rapidly from 8% in 1970 to 24% in 1975 and 46% in 1980. Higher oil imports led to growing trade deficits and balance of payment crisis. In this context, India started slowly working on renewable energy. The Government of India created the Department of Non-conventional Energy Sources (DNES) in 1982 and the department was upgraded to a full-fledged Ministry of Non-conventional Energy Sources (MNES) in 1992. The Ministry formulates and supports overall policy of renewable energy. India is a country blessed with abundance sunlight, water and biomass resources. Accordingly, MNES claims to have running the world's largest programme for renewable energy. Policy makers continue to perceive biomass as one of the important energy alternative that could alleviate the crisis (5), which can be used for water pumping, power generation and rural electrification for better healthcare, better education and improved quality of life.

Creation of Infrastructure for Biopower Exploitation in India:

Biomass Gasification R&D Centres: The Ministry has created Action Research Centres (ARC) on Biomass gasification in 1998 as a culmination of the R&D efforts started in mid eighties at several institutions. Four ARCs were established for gasifier-engine research & development at different premier national institutions. Twelve gasifier models, ranging from 3.5 to 100 kW, have been developed at ARCs for different applications. A Spark Ignition Producer Gas Engine has also been developed at the ARC, IIT Bombay.

Gasifier System & Engine Manufacturers: More than 2200 gasifier systems have been installed in India totaling to more than 22 MW capacities. At present there are several (around 15) gasifier system manufacturers in India like Ankur -Baroda, AEW-Tanuku (AP), MM Fabricators – Bangalore and Cosmo Products - Raipur. Similarly producer gas engines are being manufactured by Pune based Cummins India Ltd and Greaves Ltd.

Biomass Research Centres: There are 9 biomass research centres in India and National Botanical Research Institute- Lucknow, Vishwa Bharti, Shantiniketan are to name a few.

Electricity Generation From Biomass – Potential In India:

A techno-economic model study has shown that biomass electricity technologies have significant potential to penetrate Indian market under a fair competition with the fossil technologies. Under an optimum greenhouse gas mitigation regime, biomass electricity penetration is expected to reach 35,000 MW in 2035, which is approximately 9% of total power capacity in India (5). At this level of penetration biomass replaces 80 million tons of coal and saves 40 million tons of carbon emissions annually. However, there are innumerable economic, social, technological and institutional barriers remain to be overcome. The future prospects of biomass technologies depend considerably on removing these barriers. The key issue before the Indian policy makers is to develop the market for biomass energy services by ensuring reliable and enhanced biomass supply, removing the tariff distortions favoring fossil fuels and producing energy services reliably with modern biomass technologies at competitive cost.

Land Requirement For Biomass Electricity Generation:

The present potential from biomass wastes is limited to 10,000 MW. It is estimated that one MW grid connected biomass combustion power plant operating 5000 hours in a year shall require nearly 6000 tons of dry wood (1.3 kg dry wood per kWh). At productivity of 8 tons per hectare per year, 1 MW power shall require 800 hectares of land. The plantation for 20,000 MW power shall require 16 million hectares, i.e. 5 percent of total land or 12% of degraded land in India. The estimates of degraded land vary from 66 million hectares to 130 million hectares (5). With improved biomass productivity and efficient energy conversion, it is feasible to sustain a significant share of biomass in total energy use in India by utilising even a small faction of this degraded land for biomass plantation.

History Of Thermo-Chemical Gasification:

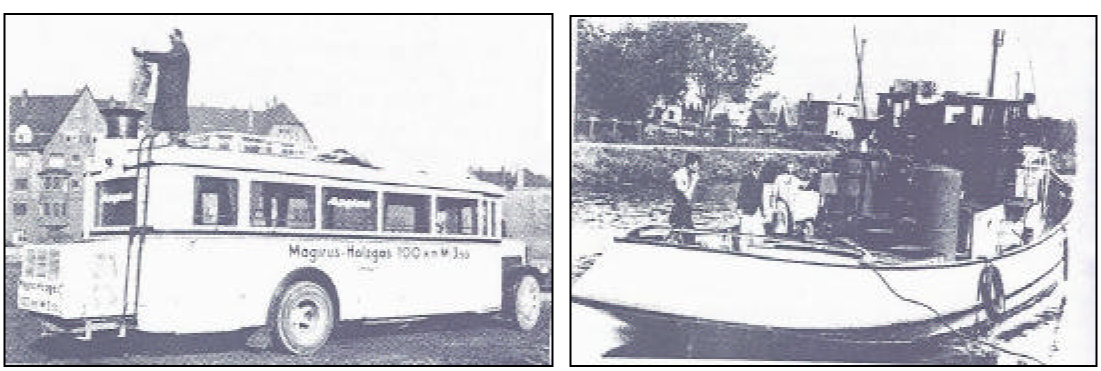
Thermo-chemical gasification is a method of converting biomass into gas using a reactor called gasifier. The first patents regarding gasification of coal were issued to Robert Gardner and John Barber in the year 1788 and 1791 respectively. The latter mentioned use of Producer gas to drive an internal combustion engine. The gas was initially used for domestic lighting, which subsequently declined due to advent of electricity. Later the gas was used for cooking and heating. Wood gasification was attempted as early as 1798. The first commercial coal gasifier, for iron works, was developed in France in 1840. This followed Siemens commercial gasifier in 1861. Dowson's gasifier was developed and successfully used in stationary engines in 1878 and was the starting point of the modern gasifier-engine systems. Producer gas was also used for making chemicals such as ammonia.

Parker of Scotland was the first to operate a passenger vehicle with Producer gas. He covered over 1000 miles with his 2.5 and 25 hp automotive gasifiers during 1901 to 1905. During this period, Producer gas engines replaced the oil engines. Brush Koela plant was designed and patented in England in 1901 for marketing in India and other Developing Countries. "Koela" is the Hindi word for charcoal.

Gasification technology and automotive gasifiers did not have much role in the USA and Canada. The gasifiers made in the USA were meant for sale in China. In 1944, the USA decided not to promote gasification activities except for use in some remote places. It was only in Europe over 150 companies manufactured small and large gasifiers for various applications. In late 1920's, first charcoal gasifiers of downdraft design were made in Sweden for use in farm tractors, trucks and cars. Interest developed in wood gasifiers in early 1930's, but working was abandoned due to tar deposition on engine parts.

Car of yesteryear powered by Wood based Producer Gas (6)

1930 to 1940 is a developmental decade for small portable automotive gasifiers due to liquid fuel shortage. The development reached its peak during World War II. Readily available fuels such as bituminous coal, anthracite and wood were tried in improved gasifier designs for automotive use. Acute liquid fuel shortage prompted even wood gasification in spite of fear of environmental degradation. Germany and Sweden were leading in the use of gasifiers during the war period. In Sweden, about 90% of the 80,000 road vehicles and most of the 20,000 tractors were converted to gas in 1942. The British government successfully employed emergency cross-draft coal gasifier. However, in 1942, the plans for its mass-production were given up due to non-availability of low ash coal. Only some Bus companies used gasifiers in their buses and some private companies used gasifier-engine systems as emergency power supply to factories affected by air bombing.

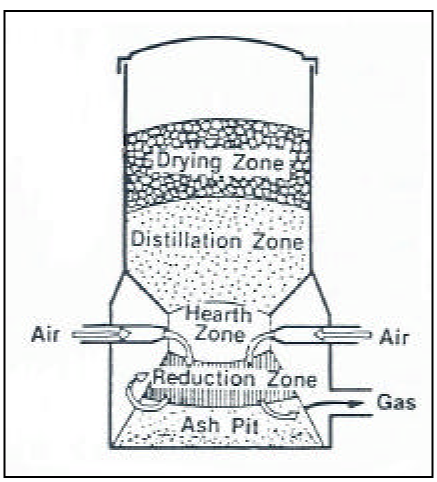


Bus and Boat of yesteryear powered by Wood based Producer Gas (6)

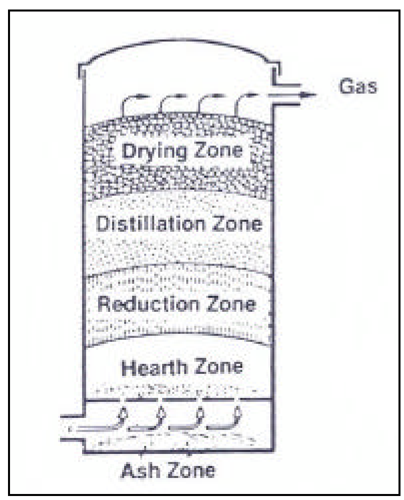
As the World War II came to an end in 1945, gasoline became cheap, and the gasification activities were almost abandoned. The design, research and manufacturing teams became disbanded. The large bulk of firsthand operational experience and design know-how were forgotten and even lost and the number of publications reduced from several hundreds a year to less than 10 a year during the 1950 to 1970 period. However, due to Suez Crisis of 1957-1963, considerable research work took place in Sweden on automotive gasifiers. Again Oil Crisis of 1971 rekindled work on gasification. Thus gasification was always rediscovered in an era of fuel shortages and higher oil prices. In India, since mid-eighties, the union Ministry of Non-Conventional Energy Sources has been coordinating and funding biomass conversion and gasification technology activities including Research & Development, field installation and performance monitoring.

Process Of Thermo-Chemical Gasification:

A typical producer gas composition consists of 15-25% CO, 15-25% H_2, 1-3% CH_4 as combustibles, and 10-15% CO_2 and 40-50% N_2 as non-combustibles. A physical analysis of biomass yields moisture, volatiles, ash and char.



Downdraft Gasifier (6)



Updraft Gasifier (6)

Hypothetically a filled gasifier (as shown in the schematic diagram) under operation can be classified into four physical zones - drying, pyrolysis, oxidation and reduction. The respective zone temperatures are approximately 120 ^{0}C, 350 ^{0}C, 1200 ^{0}C and 900 ^{0}C. In the drying zone the moisture content of biomass is removed. In the pyrolysis zone, dry biomass, which is further heated in the absence of oxygen, produces charcoal, oil and a little gas. The char will have ash as well. In the combustion zone, around 20% of the char along with volatiles undergoes oxidation into CO_2 and H_2O by using oxygen from the limited supply of air (i.e., only 20% of the total air that otherwise would be required for complete combustion). The rest 80% char flows down to form a reduction bed where almost all carbon will be later consumed and the ash flows to ash-pit. The oxidation reactions are heat producing (exothermic) which heats up the carbon bed below. As the CO_2 and H_2O pass through the hot carbon bed below in the absence of oxygen, there will be a series of reduction reactions causing the formation of combustible gases - CO, H_2 and CH_4, called Producer Gas The reduction reactions are heat absorbing (endothermic) and therefore the temperature of the gas exiting out of the gasifier reduces considerably. However, for engine applications, the gas needs to be further cooled to ambient conditions and cleaned to remove tar/volatiles (that escapes combustion) and particulate by passing through gas cooling-cleaning system.

Various Gasifier Designs:

Biomass fuels available for gasification include charcoal, wood and wood wastes (branches, twigs, roots, barks, wood shavings and sawdust) as well as agricultural residues (maize cobs, coconut shells and husks, cereal straws, rice husk, etc.) and peat. As these varieties of feedstock differ greatly in their chemical, physical and morphological properties, there is a requirement for feedstock specific gasifier designs and also gasification technologies. Therefore, there is no "Universal" gasifier, which will have multi feedstock flexibility. The variety of important designs is updraft, downdraft, crossdraft and fluidised bed, and less important designs are double fired, entrained bed, molten bath, etc. Of all these designs, downdraft type is the most suited for engine applications due to its low-tar gas production capability.

Producer Gas Use In Engines In India:

Conventionally producer gas is used in internal combustion engines up to 500 kW power capacities for mechanical (shaft power) or electrical (captive power generation) applications. Accordingly, in India, the gas has been commonly used in four-stroke stationary diesel engines on gas-plus-diesel dual-fuel mode with 70% diesel replacement. As this approach is not independent from the use of fossil fuels, there was a need for designing dedicated SI gas engines for producer gas because such engines were not available in the market. Unlike CNG or LPG, producer gas cannot be used in existing petrol engines because of high power derating caused by extreme fuel characteristics such as low energy yield per cubic metre gas burned. Therefore new engine design was a necessity.

One such dedicated engine was developed at IIT Bombay as a precursor to new design (8). A 15 kW spark ignition producer gas engine (SIPGE) was developed by machine converting a 17 kW diesel engine. The converted wood gas engine starts by battery cranking on gas and develops power at comparable levels with the diesel engine, moreover at higher efficiency. This engine is fuel flexible and also performs well on compressed natural gas just by replacing gas-air carburetor with a different design and retarded spark timing.

Conclusions:

Careful planning and management of renewable energy resources and sound technology development will certainly lead to sustainable development and mitigate the global warming effect caused by greenhouse gas emissions. This will help in overcoming foreseen energy and environmental crisis that otherwise will hit India very hard.

References:

1) Gerhard Ott, 'The Global Energy Scene', Israel, 22, April 2001. (Internet downloaded pdf file, p.19)
2) UK Trade & Investment, 'Power Market in India', 2004, Website: www.uktradeinvest.gov.uk/energy/india
3) Reddy A.K.N., Anand, Y.P. and Antonette D'Sa, 'Energy for a Sustainable Road/Rail Transport System in India", J. Energy for Sustainable Development, Vol IV, No.1, June 2000.
4) Times News Network, 'Bio-Diesel: Fuel in the Reckoning' The Times of India, Bangalore, April 10, 2004.
5) Shukla, P.R., 'Biomass Energy in India: Policies and Prospects', Paper presented at the workshop on Biomass Energy: Key issues and Priority Needs, International Energy Agency, Paris, February, 2000. (Internet downloaded pdf file, p.20)
6) Reed, T.B. and Das, A. 'Handbook of Biomass Downdraft Gasifier Engine System,

NTIS, Springfield, VA, USA, (1988).

7) Shashikantha and Parikh, P.P., '"Spark Ignition Producer Gas Engine and Dedicated Compressed Natural Gas Engine - Technology Development and Experimental Performance Optimisation", SAE Paper, 1999 Fall Fuels & Lubricants Meet, Toronto.