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Biomass – An Alternate for Fossil Fuels?

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Abstract

In view of the depleting oil reserves and exponential rise in petroleum prices, the search for alternative sources of fuel is very timely and important. 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.

Keywords:*Biomass, energy, sustainable development, and environment.*

1. Introduction

Energy is an essential factor in development since it stimulates, and supports economic growth, and development. Fossil fuels, especially oil and natural gas, are finite in extent, and should be regards as depleting assets, and efforts are oriented to search for new sources of energy. Systematic 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.

The global share of energy consumption by developed and developing countries is given in Table-1. Over 80% of the global oil and natural gas resources is concentrated in only two regions of the world - as shown in Table-2 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-1: Global Energy Consumption Pattern

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

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%

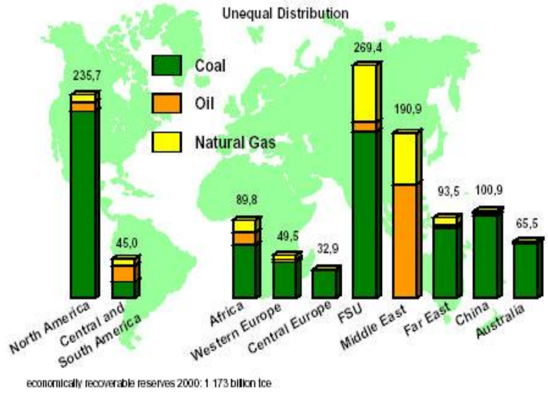

Fig. 1:The unequal distribution of global energy reserves [1]

2. 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 industrialized 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 CO_2-emissions is expected to come from this region.

It is visualized that during the second half of 21^{st} century, population growth may come to a halt, green house gas emissions may be stabilized 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.

3. 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

The main title (on the first page) should begin 1-3/8 inches (3.49 cm) from the top edge of the page, centered, and in Times 14-point, boldface type. Capitalize the first letter of nouns, pronouns, verbs, adjectives, and adverbs; do not capitalize articles, coordinate conjunctions, or prepositions (unless the title begins with such a word). Leave two 12-point blank lines after the title.

4. 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/Te chnol-ogies	Unit	Potential Estimated	Achieved (2002)	Achievem -ents as % of Potential
1	Wind Power	MW	45,000	1507	2.8
2	Small Hydro	MW	15,000	1341	8.9

	(<25 W)				
3	Biomass Power	MW	19,500	308	1.6
	Biomass Gasifiers	MW	16,000	35	0.2
	Biomass Cogeneration	MW	3,500	273	7.8
4	Urban & Industrial Waste	MW	1,700	15.20	0.9
5	Solar Photovolt--aic	MW / Sq.km	20	47	----
6	Solar Water Heating	Million Sq. m Collector 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.

5. 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].

6. 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 biodiesel 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 biodiesel 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.

7. 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.

8. 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.

9. 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.

10. 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, AEWTanuku (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.

Industrial-Scale Biomass Combustion Technologies

Industrial boilers range from 100 to around 300 MWth output. Smaller scale versions are used in district heating and small processes down to as low as 10 MWth, usually without the same level of emissions control. The major types of boilers installed are: pile burners, grate boilers, suspension fired boilers, fluidized beds, and circulating fluid beds. The pile burner is the original, *circa.* 1700, industrial process-scale biomass burner and can be viewed as a sort of enclosed fire. Pile burners have poor load-following characteristics and typically have low efficiencies in the range of 50% to 60%. Stoker grate combustors improve the operation of the pile burners by providing a moving grate, which permits continuous ash collection, thus eliminating the cyclic operation characteristic of traditional pile burners. In addition, the fuel is spread more evenly (in a thin bed, 5 to 15 cm deep), normally by a pneumatic stoker. The thinner layer in the combustion zone produces a more efficient combustion. More modern designs include the Kabliz grate, a sloping reciprocating water-cooled grate. Reciprocating grates are attractive because of simplicity and low fly ash carryover. Furnace exit temperatures are about 980° C; staged combustion processes have been developed to minimize nitrogen oxide emissions and keep the furnace temperature below the ash deformation temperature of most biomass fuels. Stoker-fired moving grates range in size from 20 to 300 MWth . Since suspension burners require finely divided < 1 mm particle size materials with very low moisture contents, they are relatively rare as the fuel preparation from green biomass is very energy intensive.

Fluidized bed combustors are becoming the systems of choice for biomass fuels. One reason for this is that the fluid bed medium (silica sand, alumina, or olivine) provides a thermal “flywheel” that compensates for variation in moisture content and maintains constant heat output and flue gas quality. The medium also gives the advantage of extremely good mixing and high heat transfer, resulting in very uniform bed conditions. Despite the relatively low temperature of combustion, the three T rule (temperature, time, and turbulence) of high quality combustion is well met, with 99% to 100% carbon burnout being typical [4]. Fluidized beds are either bubbling beds (FB) or circulating (CFB). In the former, the material stays in a fixed zone of the combustor, while in the latter, the flue gas velocity is such that the bed material is suspended and circulates through a return loop to the combustor, by means of a mass or cyclonic separator. In both FB and CFB units, the ash removal is by means of complete ash carryover, necessitating the addition of cyclones and bag houses for particulate control to New Source Performance Standards (NSPS). It is the emissions performance that is making these units more attractive. In fluidized beds, the uniform, low combustion temperature gives low NOx emissions, while in the CFB, it is easy to introduce a sorbent solid, such as limestone or dolomite, to control SOx emissions without the need for back-end sulfur removal equipment. Circulating fluid bed temperatures are maintained at about 870° C, which helps to optimize the limestone-sulfur reactions

11. 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.

12. 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. five 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.

13. Economics of Power Boilers and Electricity Generation

The economics of power generation are dependent on the capital cost, the operating cost,

and the fuel cost, in almost equal measure over the generating plant’s life cycle [9-11]. Scale and efficiency are linked and are illustrated in Figure 1, which compares the levelized costs of electricity for biomass-fired systems based on stoker firing and gasification combined cycles, using data from the EPRI - NREL technology assessment [7].

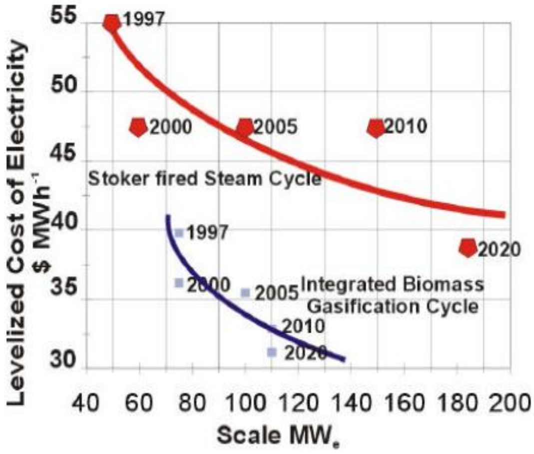

Fig. 2: Levelized cost of traditional direct-fired steam cycle power generation and biomass IGCC

14. Gaseous Biofuels

Gaseous biofuels include biogas from anaerobic digestion (AD), and low and medium heating value gases from thermal processes. Biogas from AD has approximately equal amounts of carbon dioxide and methane, with typically 0.1% to 1% hydrogen sulfide. Thermal processes produce varying compositions of dry gas containing hydrogen, carbon monoxide, and methane, as the fuel gases, in combination with nitrogen and carbon dioxide, as the major constituents. Thermal gases and biogas can be used directly as fuel in gas burners, or in prime movers such as internal combustion engines and gas turbines. Thermally produced gases, after purification and possibly water gas shift to adjust the H_2:CO ratio, can be described as a syngas (a mixture of H_2 and CO), which can be used to manufacture methanol, ammonia, Fischer Tropsch liquids, or hydrogen for use in fuel cells. While thermal gasification is in the early stages of commercial deployment, anaerobic digestion processes are already commercial and widely deployed, either in designed processes for specific environmental problems or in landfills, which are managed to capture the methane that is naturally produced. Presently, the United States has a landfill gas electricity generation capacity of about 1 GWe, using gas engines and gas turbines [12].

Anaerobic digestion has been used for many years in the treatment of sewage and animal
manures to mineralize the carbon in order to reduce the volume of waste sludge for disposal [13]. The carbon is converted into methane and carbon dioxide in about a 60:40 ratio by volume, with a heating value of about 55%–60% that of natural gas. The biomass of the bacteria that carry out the process and the non-digested material remains as a sludge, which can be returned to the soil if there are no heavy metals from the residue stream. A wide range of agricultural, industrial, and urban activities generate residue streams with high organic loadings that are suitable for anaerobic treatment. They include: intensive animal husbandry (excreta, and bedding materials); food processing (sugar production and vegetable preparation); breweries and distilleries; and materials production (such as pulp and paper, pharmaceutical manufacture, and sewage treatment). Absent any treatment, these industries pollute water courses and groundwater with high loadings of biological and chemical oxygen demand, along with large concentrations of nitrates, microbial contaminants, and even pathogens. Progress in the development of high rate AD technologies has increased the reliability, or the effective time-on-stream of the applications, and has also improved the conversion efficiency or reduction in organic loading. The organic loading is measured by means of a chemical reaction in the laboratory and reported as the chemical oxygen demand (COD). This can be converted into a methane potential of between 0.33–0.35 m^3 kg-1 of COD. In a well operating anaerobic process, it is normal to have a COD reduction of between 60% and 80% of the input level.

15. Thermal Gasification

Gasifiers at an industrial scale are generally based on fluidized bed technology. In direct thermal applications, the gas is cleansed of most particulates and passed without any cooling, directly into the process kiln or boiler for combustion. A typical example of this application is the use of a CFB gasifier, fueled with a refuse-derived fuel, wood chips, and peat, to supply a low-heatingvalue gas to an existing large-scale natural gas and coal utility boiler, at the Kymijärvi 167 MWe and 240 MWth fossil fired plant close to the Finnish city of Lahti [14]. This project builds on many years of successful operation of biomass CFB gasifiers in thermal applications, and substitutes biomass for about 15% of the total fuel used in the boiler. Though the possibility of using biomass gasification to produce a syngas for the manufacture of transportation fuels such FT liquids or methanol is feasible, most development effort has been put into demonstrating IGCC (Integrated Gasification Combined Cycle). In IGCC the thermal gas from biomass is used to fire a gas turbine, and the steam generated in a heat recovery boiler on the turbine exhaust is used to generate more electricity in a steam (Rankine cycle) turbine. The extensive developments for coal-based IGCC have resulted in a number of turbines that have already been adapted to low-heating-value gas operation, in the size ranges of interest to biomass developers. A higher quality gas, requiring fewer turbine modifications, can be produced in indirect or oxygen-blown gasification cycles, with heating values in the range of 15–20 MJ Nm-3. Current biomass IGCC projects and demonstrations, which illustrate the development of biomass IGCC, clearly show the diversity of the possible technological approaches.

Charcoal

Charcoal is the world's most significant biofuel, with over 3 EJ of wood feedstocks being converted into between 0.7 and 1 EJ of charcoal (despite its production in many instances at low efficiency). Its energy density is such that it can be transported long distances and, with much reduced emissions in cookstoves, it is a fuel that is better suited to developing country urban use than fuelwood. Charcoal is produced from fuelwood and other biomass resources by carbonization in kilns or retorts. In addition to its use as a cooking fuel, a significant amount is used as a chemical reductant in metallurgy, for example, to produce pig iron in Brazil [15]. The co-products of carbonization are the tars and fuel gases. Together these represent as much as 40% of the energy of the wood. In simple charcoal-making these are often not utilized, creating pollution of the soil, water, and air. In the larger industrial systems the recovery of byproducts may not be economic; however, the fuel value of both the gas and the tars (sometimes called pyroligneous liquids) may be utilized in the carbonization process to reduce energy loss, increase the efficiency, and eliminate pollution. Before there was extensive chemical synthesis of methanol and acetic acid from fossil fuels, these were both byproducts of charcoal manufacture.

Liquid fuels from biomass

There are two biomass-based liquid fuels in the market place today, ethanol and biodiesel. The major research and development area is in the production of ethanol from lignocellulosics (such as wood, straw, and grasses), which contain cellulose (40% to 50%) and hemicellulose (25% to 30%), with considerable ethanol potential (about the same yield per tonne as corn) and a price structure that is more stable than food prices. The conversion process from lignocellulosics is even more complex than from starches, as the complex nature of lignocellulosics requires extensive effort to break down the lignin, cellulose, and hemicellulose structure so that the individual polymers become available for hydrolysis.

16. 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.

17. Conclusions

Modern biomass combustion systems are a cost effective use of biomass, especially in CHP in applications with a high capacity factor. The use of environmental technologies, especially anaerobic digestion, is increasing as water quality issues become more prevalent, due to concentrations of animal production units in areas that no longer can use the land to absorb the impacts of concentrated animal feed operations. The development of high-efficiency electricity generation systems based on IGCC has reached the successful demonstration stage and awaits commercial deployment. The same gasification technology can serve as the basis for hydrogen production or for the 13 synthesis of liquid fuels such as ethanol and Fischer Tropsch hydrocarbons. The largest liquid fuel contribution today comes from the application of biotechnology in the production of ethanol from sugar and starches, and innovative research is opening the way to utilize the large lignocellulosic resource in the same way. The data points are for an investor-owned utility operation of stoker-fired and IGCC units. The data are taken from the renewable energy technology characterizations performed by EPRI, USDOE, and NREL [7]. The years shown on Figure 1 are the study's expectation of when the performance and scale shown would be achieved.

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] IEA, Energy Statistics and Balances of non-OECD Countries. 2000, International Energy Agency: Paris, France.

[7] Holdren, J.P. and K.R. Smith, Energy, the Environment, and Health, in World Energy Assessment: energy and the challenge of sustainability, J. Goldemberg, Editor. 2000, United Nations Development Programme: New York. pp. 61-110.

[8] Nauze, R.D.L., Combustion in Fluidized Beds, in Advanced Combustion Methods, F.J.Weinberg, Editor. 1986, Academic Press: London. pp. 17-111.

[9] Baxter, L.L., et al., Alkali Deposits Found in Biomass Boilers: The behaviour of inorganic material in biomass - fired power boilers - Field and laboratory experiences. 1996, National Renewable Energy Laboratory: Golden, Colorado. p. 82.

10. Tillman, D.A., Biomass cofiring: the technology, the experience, the combustion consequences. Biomass and Bioenergy, 2000. 19(6): pp. 365-384.

[11. McCarty, P.L., ed., One Hundred Years of Anaerobic Treatment. Anaerobic Digestion 1981, ed. D.E. Hughes. 1982, Elsevier Biomedical Press: Amsterdam, Netherlands.

[12] Stahl, K., M. Neergard, and J. Nieminen, Final Report: Varnamo Demonstration Programme. in Progress in Thermochemical Biomass Conversion. 2000. Tyrol, Austria: Blackwell Sciences Ltd., Oxford.

[13] Rosillo-Calle, F., et al., The Charcoal Dilemma: Finding sustainable solutions for Brazilian industry. 1996, London, United Kingdom: Intermediate Technology Publications. 79.

[14] Wyman, C.E., et al., Ethanol and Methanol from Cellulosic Biomass, in Renewable Energy: Sources for Fuels and Electricity, T.B. Johansson, et al., Editors. 1993, Island Press: Washington, D.C. pp. 865-923.

[15] Rosillo-Calle, F., et al., The Charcoal Dilemma: Finding sustainable solutions for Brazilian industry. 1996, London, United Kingdom: Intermediate Technology Publications. 79.