Estimation of Power Generation Potential of Agricultural based Biomass Species

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ABSTRACT

In view of high energy potential in agricultural residues species and an increasing interest in their utilization for power generation an attempt has been made in this study to asses the proximate analysis and energy content of different components of four selected agricultural residues such as maize, coconut, paddy and arhar, and their impact on power generation and land requirement for energy plantations. The net energy content in coconut plant was found to be higher than other studied agricultural residues. The result shows that approximately 717 hectares, 1123 hectares, 1511 hectares and 4319 hectares of land are required to generate 20,000 kWh/day electricity from, coconut, maize, paddy and arhar pulse residues respectively. Coal samples, obtained from six different local mines were also examined for their qualities and the results were compared with those of studied biomass materials. This comparison reveals much higher power output with negligible emission of suspended particulate matter (spm) from biomass materials. It has been observed that coconut, paddy and arhar agricultural residue can be carried out safely (without clinker formation) up to the temperature of 950^{o}C.in case of use of maize agricultural residue, it may be more safe to operate the boiler at temperature below 800^{o}C.Since it has been observed that maize has lowest IDT (Initial deformation temperature) and lowest FT (Flow temperature), while coconut and paddy have highest IDT and FT.

Chapter 1

INTRODUCTION

1.1 INTRODUCTION

Fossil fuel reserves are very limited in nature and these reserves are expected to last up to 100 years more. Thermal power and metallurgical industries are considered to be the mammoth consumers of fossil coals. Thermal power plants produce a large amount of pollutants, such as carbon dioxide, sulphur oxides, fly ash, etc which are hazardous for human survival on the earth planet. Hence, scientists and technocrat’s world-wide are in search of alternative sources of energy whose exploitation is not harmful for the human beings. There are many alternative sources of energy including Biomass.

Due to fast depletion of fossil fuel resources for power generation and growing concern over the environmental degradation caused by conventional power plants, power generation from biomass is becoming attractive through out the world. Sustainable production and utilization of biomass in power generation can solve the vital issues of atmospheric pollution, energy crisis, wasteland development, rural employment generation and power transmission losses. Thus, the development of biomass-based power generation system is thought to be favorable for majority of the developing nations including India. Unlike other renewable, biomass materials, pre-dried up to about 15% moisture, can be stored for a considerable period of time without any difficulty. Besides electricity supply to the national power grids, biomass offers giant opportunities for decentralized power generation in rural areas at or near the points of use and thus can make villagers/ small industries self dependent in respect of their power requirements. It is observed that the decentralized power generation systems reduce peak loads and maintenance cost of transmission and distribution network.

To exploit biomass species in electricity generation, characterization of their various properties like energy values, chemical compositions, reactivities towards oxygen, bulk densities, etc. is essential. The present project work deals with the studies on proximate analysis, ultimate analysis, ash fusion temperature and energy value of different components of Coconut, Maize, Paddy and Arhar biomass species (agricultural residues) and their impacts on power generation. Few times ago, these biomass species have no commercial value and are under-exploited. However, they have several advantages as fuel crops. They are fast growing and reach maturity in two years only. They can be produced on poor and semi-desert land surviving with relatively little water.

1.2 Different Sources of Energy

Having energy and environmental problems associated with the use of fossil fuels in electricity generation, scientist and technocrats, world wide, are in search of the suitable option of fossil fuels for power generation. The various different sources of energy having a potential to be used in electricity generation are as follows:

(a) Nuclear Energy

The energy stored in the nucleus of an atom and released through fission, fusion, or radioactivity is known as nuclear energy. In these processes a small amount of mass is converted to energy according to the relationship $E = mc^2$, where E is energy, m is mass, and c is the speed of light. The most difficult problems concerning nuclear energy are the probability of an accident at a nuclear reactor or fuel plant, such as those which occurred at Three Mile Island of USA (1979), Chernobyl of Russia (1986), and Takaimura of Japan (1999), and the potential threat to the continued existence of the human race posed by nuclear arms.

(b) Ocean Energy

Ocean thermal energy conversion, or OTEC, is a tool to generate power using the temperature difference of sea water at various depths. The method involves pumping cold water from the ocean depths (as deep as 1 km) to the surface and extracting energy from the flow of heat between the cold water and warm surface water. OTEC utilizes the temperature difference that exists between deep and shallow waters — within 20° of the equator in the tropics — to run a heat engine. As the oceans are continually heated by the sun and cover nearly 70% of the Earth's surface, this temperature difference contains a huge amount of solar energy which could potentially be tapped for human use. If this extraction could be done profitably on a large scale, it could be a solution to some of the human population's energy problems. The total energy available is one or two orders of magnitude higher than other ocean energy options such as wave power, but the small size of the temperature difference makes energy extraction difficult and expensive. Hence, existing OTEC systems have an overall efficiency of only 1 to 3%. The concept of a heat engine is very common in engineering, and nearly all energy utilized by humans uses it in some form. A heat engine involves a device that operates between a high temperature source and a low temperature sink. As heat flows from source to sink, the engine extracts some of the heat in the form of work. This same general principle is used in steam turbines and internal combustion engines, while refrigerators reverse the natural flow of heat by consuming energy in the form of either heat or work. Instead of using heat energy by the burning of fuel, OTEC draws power on temperature differences caused by the sun's warming of the ocean surface.

(c) Geothermal Energy

Internal heat of the Earth produces geothermal energy. This heat rises towards the surface, warming volumes of water between a few hundred and about 3,000 metres down. These volumes of hot water (called "geothermal deposits") can be used to provide heat or electricity depending on their temperature. Very low-energy deposits – water between 10 and 50°C at a shallow depth – can be used to heat greenhouses, swimming pools and sometimes buildings (e.g. the Maison de la Radio in Paris). Low-energy deposits – water between 50 and 90°C at a depth of between 1,500 at 2,000 metres – can be used to supply district heating (in France, the largest deposit is in the Paris region). Medium-energy deposits – water between 90 and 150° C at a depth of between 2,000 and 2,500 metres – are used to supply electricity in certain countries (in France, there are only two small deposits). Turbines can be operated directly and supply electricity using high-energy deposits, pressurised steam or water at a temperature of 150 to 350°C not far below the surface (in France, there is such a facility in Guadeloupe).

(d) Wind Energy

Wind turbines are used by Wind energy systems to generate electrical energy by diminishing the power in wind. Wind energy can in stand-alone applications or can be produced centrally and distributed to the electric grid. Wind is a form of solar energy, caused by the uneven heating of the earth's surface. This occurs at local, regional and global scales. Winds which flow close to the earth's surface are slowed down due to friction, which causes turbulence and gusting. The higher above the ground you go, the faster the winds travel due to less resistance. Wind plants or wind turbines are available in a variety of configurations with various outputs. Typically, these plants produce either direct current (DC) or alternating current (AC) electricity. DC wind plants are used to charge batteries or produce heat/electricity without storage. AC wind plants are used to produce electricity for direct use or to supply energy to a utility grid. Water-pumping wind energy systems are another type of wind energy application; these use wind to produce mechanical energy to pump water, typically for agricultural applications. There are several different systems used. Some wind plants have a vertical axis wind turbines (VAWT) and others have a horizontal axis (HAWT). HAWTs are most common; VAWTs may look something like an eggbeater. Various wind plant designs use gearboxes, belts or direct drives. Some have rotor blades which change pitch to reduce loads and speed in high winds. Others have fixed pitch blades. Few HAWT designs face downwind with no tails, others face upwind and have tails.

(e) Solar Energy

The radiant energy produced in the sun as a result of nuclear fusion reactions is known as Solar Energy. It is transmitted to the earth through space in quanta of energy called photons, which interact with the earth's atmosphere and surface. The strength of solar radiation at the outer edge of the earth's atmosphere when the earth is taken to be at its average distance from the sun is called the solar constant, the mean value of which is 1.37×10^6 ergs per sec per cm^2, or about 2 calories per min per cm^2.Out of the energy transmitted from the Sun, the upper atmosphere of Earth receives about 1.5×10^{21} watt-hours (thermal) of solar radiation annually. This huge amount of energy is more than 23,000 times that used by the human population of this planet, but it is only about two-billionth of the Sun's massive outpouring—about 3.9×10^{20} MW. Solar radiation is attenuated before reaching Earth's surface by an atmosphere that removes or alters part of the incident energy by reflection, scattering, and absorption. In particular, nearly all ultraviolet radiation and certain wavelengths in the infrared region are removed. However, the solar radiation striking Earth's surface each year is still more than 10,000 times the world's energy use. Radiation scattered by striking gas molecules, water vapor, or dust particles is known as diffuse radiation. Clouds are a particularly important scattering and reflecting agent, capable of reducing direct radiation by as much as 80 to 90%. The radiation arriving at the ground directly from the Sun is called direct or beam radiation. Global radiation is all solar radiation incident on the surface, including direct and diffuse. Solar research and technology development aim at finding the most efficient ways of capturing low-density solar energy and developing systems to convert captured energy to useful purposes. Solar energy can be converted to useful work or heat by using a collector to absorb solar radiation, allowing much of the Sun's radiant energy to be converted to heat. This heat can be used directly in residential, industrial, and agricultural operations; converted to mechanical or electrical power; or applied in chemical reactions for production of fuels and chemicals.

(f) Biomass and Bio-energy

Biomass is organic material made from plants and animals. Biomass contains stored energy from the sun. Plants absorb the sun's energy in a process called photosynthesis. The chemical energy in plants gets passed on to animals and people that eat them. Biomass is a renewable energy source because we can always grow more trees and crops, and waste will always exist. Some examples of biomass fuels are wood, crops, manure, and some garbage. When burned, the chemical energy in biomass is released as heat. If you have a fireplace, the wood you burn in it is a biomass fuel. Wood waste or garbage can be burned to produce steam for making electricity, or to provide heat to industries and homes. Burning biomass is not the only way to release its energy. Biomass can be converted to other usable forms of energy like methane gas or transportation fuels like ethanol and bio-diesel. Methane gas is the main ingredient of natural gas. Smelly stuff, like rotting garbage, and agricultural and human waste, release methane gas - also called "landfill gas" or "biogas." Crops like corn and sugar cane can be fermented to produce the transportation fuel, ethanol. Biodiesel, another transportation fuel, can be produced from left-over food products like vegetable oils and animal fats. Biomass fuels provide about 3 percent of the energy used in the United States. People in the USA are trying to develop ways to burn more biomass and less fossil fuels. Using biomass for energy can cut back on waste and support agricultural products grown in the United States. Biomass fuels also have a number of environmental benefits.

1.3 BIOMASS POTENTIAL IN POWER GENERATION

Biomass resources are undoubtedly the world's largest and most sustainable energy sources for power generation in the 21st century [1]. Table 4.1 indicates that the annual sustainable world-wide biomass energy potential; is about 104 EJ/a [2]. The share of non-woody biomass is about 60% (62 EJ/a approx.). Large potentials of non-woody biomass are available in Latin America, Africa and Asia. The total potential of non-woody and non-fodder biomass available for energy in India was estimated to be 325 Mt (472 PJ) in 1996-97, and the proposed value for 2010 is 450 Mt (656 PJ) [3]. Table 4.3 clearly indicates that in most parts of the world, the current biomass uses, agricultural residue in particular, in electricity generation is possible. Asia and Latin America have the expected greatest growth of biomass-based power plants.

In Fig. 1 [4], the world-wide estimated potentials of various types of renewable energy sources in electricity generation have been projected. As shown in Fig. 1, the estimated global electricity generation capacity of biomass (about 11,000 Twh) is greater than other renewable energy sources. In Table 4.2, the estimated power generation potentials of renewable energy sources in India have been outlined that the power generation capacity of biomass is considerably greater in the world including India.

The U.S. based economy uses biomass-based materials as a source of energy in many ways. Wood and agricultural residues are burned as a fuel for cogeneration of steam and electricity in the industrial sector. Biomass is used for power generation in the electricity sector and for space heating in residential and commercial buildings. Biomass can be converted to a liquid form for use as a transportation fuel, and research is being conducted on the production of fuels and chemicals from biomass. Biomass materials can also be used directly in the manufacture of a variety of products. In the electricity sector, biomass is used for power generation. The Energy Information Administration (EIA), in its projects reveals that biomass will generate 15.3 billion kilowatthours of electricity, or 0.3 percent of the projected 5,476 billion kilowatthours of total generation, in 2020. In scenarios that reflect the impact of a 20 percent renewable portfolio standard (RPS) and in scenarios that assume carbon dioxide emission reduction requirements based on the Kyoto Protocol, electricity generation from biomass is projected to increase substantially. Therefore, it is critical to evaluate the practical limits and challenges faced by the U.S. biomass industry. This paper examines the range of costs, resource availability, regional variations, and other issues pertaining to biomass use for electricity generation. The technology by which the National Energy Modeling System (NEMS) accounts for various types of biomass is discussed, and the underlying assumptions are explained.

Both dedicated biomass co-firing and biomass are used in the power generation sector. New dedicated biomass capacity is represented in NEMS as BIGCC technology. It is assumed that hot gas filtration will be used for gas cleanup purposes in this technology. Hot gas cleanup technology is relatively new, and the U.S. Department of Energy (DOE) and many industrial partners are conducting tests to demonstrate the technology. The alternative to hot gas cleaning is low-temperature gas cleaning. In low-temperature cleaning the gas is quenched with water, and particulates are removed in a series of cyclone vessels. There are advantages and disadvantages associated with both processes. The advantages of cold gas cleaning are that it is commercially available, the capital cost is relatively low, and the systems are easier to operate than hot gas cleanup systems. The disadvantages of cold gas cleanup are that the cooling process, the cold gas cleanup system, and fuel gas recompression systems reduce the overall process efficiency by up to 10 percent. The gas turbines downstream of the gasifier require the gas at high temperatures and pressure, and therefore the gas that has just undergone cooling for cleanup purposes must be repressurized and reheated in order to confirm to gas turbine inlet specifications. The advantages of the newer hot gas cleanup technology are that it allows the process to be operated at higher efficiencies and it generates less waste water than the cold gas cleanup processes. The disadvantages of the hot gas cleanup methodology are that it has higher costs, operational experience is limited, and it adds complexity to the process, however, it is considered to be the technically more advanced choice for new dedicated biomass plants.

The McNeil Generating Station demonstration project in Burlington, Vermont, is an example of a biomass gasification plant. It has a capacity of 50 megawatts and supplies electricity to the residents of the City of Burlington. This is an existing wood combustion facility whose feedstock is waste wood from nearby forestry operations, including forest thinnings and discarded wood pallets. To this existing wood combustion facility a low-pressure wood gasifier has been added that is capable of converting 200 tons per day of wood chips into fuel gas. The fuel gas, fed directly into the existing boiler as shown in Fig. 1 augments the McNeil Station's capacity by an additional 12 megawatts. The system was designed and constructed in 1998 and attained completely operational status in August 2000.

Having the Vermont project, DOE has funded five new advanced biomass gasification research and development projects beginning in 2001. Emery Recycling in Salt Lake City, Utah, will test new IGCC and integrated gasification and fuel cell (IGFC) concepts based on a new gasifier that uses segregated municipal solid waste, animal waste, and agricultural residues. Sebesta Blomberg in Roseville, Minnesota, has begun a project on an atmospheric gasifier with gas turbine at a malting facility, using barley residues and corn stover. Alliant Energy in Lansing, Iowa, is developing a new combined-cycle concept that involves a fluidized-bed pyrolyzer and uses corn stover as a feedstock. United Technologies Research Center in East Hartford, Connecticut, has begun a project that will test a biomass gasifier coupled with an aero-derivative turbine with fuel cell and steam turbine options, using clean wood residues and natural gas as feedstocks. Carolina Power and Light in Raleigh, North Carolina, will develop a biomass gasification process that will produce a reburning fuel stream for utility boilers, using clean wood residues. After end of research and development tests, these projects are candidates for commercialization over the next few years.

Biomass co-firing includes combining biomass material with coal in existing coal-fired boilers. Coal-fired boilers can handle a pre-mixed combination of coal and biomass in which the biomass is combined with the coal in the feed lot and fed through an existing coal feed system. Alternatively, boilers can be retrofitted with a separate feed system for the biomass such that the biomass and coal actually mix inside the boiler. The portion of biomass consumed varies from less than 1 percent to about 8 percent of total heat input, with two exceptions: Excel Energy's Bay Front plant in Ashland, Wisconsin, and Tacoma Steam Plant Number 2, owned by Tacoma Public Utilities. The Bay Front Station can generate electricity using coal, wood, shredded rubber, and natural gas. Experience has shown that it is better to operate units 1 and 2 on 100 percent coal during periods of high load and on 100 percent biomass during off-peak periods. A blending of coal and biomass can cause ash fouling and slagging problems. So, the heat input from biomass averages about 40 percent in this plant.

1.4 BIOMASS – A SOURCE OF ELECTRICITY GENERATION IN SMALL SCALE INDUSTRIES

There are over 11 million small-scale registered industrial units that provide employment to more than 27 million people [6], in India. They contribute to 40% of the country's industrial production and 34% of exports. A significant number of these units require large quantities of electrical energy. The high cost supply, which is mostly erratic and unreliable on account of scheduled / unscheduled power cuts, drives industries to invest in captive power generation. As fossil fuels are limited and polluting, such demand provides an attractive platform to renewable alternative energy solutions to industrial and commercial establishments, particularly small and medium enterprises. Biomass energy systems can be deployed to meet power requirement in industries. This power generation will help industries in becoming self-reliant and reduce pressure on fossil fuels.

The available biomass-based energy units having capacity ranging from about 100 KW to few MW can be set-up by an industrial unit. In general, combustion-based systems are suited for MW-scale projects, whereas gasifiers are appropriate for small and decentralized power projects up to 1 MW capacity. In addition to power generation, the bio-power plant is also likely to produce activated carbon (a valuable product) that further offsets the operating cost of the plant.

Under a wide rural development policy, the increase in agricultural productivity, crop diversity and the production of rural profit and employment have been given high priority in many developing countries. Promoting and improving rural industries, naturally, is an important strategy for attaining such policy objectives. The majority of small industries are in peri-urban and rural areas. For fuel, majority still uses wood and agricultural residues. The traditional processes in small-scale industries are often traditional and operate under highly competitive conditions. They must compete with both similar scale producers as well as larger scale producers using more modern and technically advanced production facilities. They are relatively isolated from the source of skills, know-how, and technology that would allow improvements in their operations, energy, etc. In addition, the very nature and location of the small industries often reinforce their separation from formal sources of financial, technical, and other assistance.

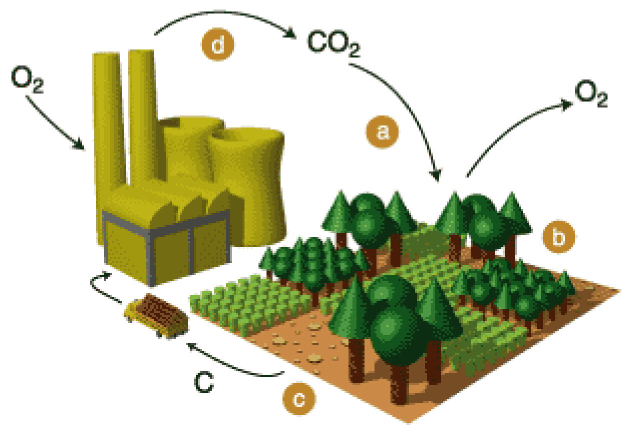
Yet, small industries have been recognized to have important role in the development and stability of national, rural economies and the survival of subsistent economies. The sector provides income and/or local employment to many people. It has also been found that biomass energy typically generates 10 times more employment than oil and coal. For developing countries, the use of biomass energy sources could also reduce dependency on imported energy sources. On the other hand, it is also true that shortage of fuels, in the forms of fuel wood and other biomass are threatening the sustainability of small industries. For example, there have been cases in Cambodia of small enterprises closing down due to fuel shortage. It was also reported that some areas in Nepal where small industries were concentrated, suffered from environmental degradation due to fuel wood extraction for industrial operations. Thus, technology that could provide them in increasing their efficiency and output, accurate study and documentation of industrial stoves is a necessary tool at this time.

Different types of products produced by small-scale enterprise are considered familiar and popular products in many countries in Asia. For example, noodles, soybean sauce, and tofu in Indo-China and Southeast Asian Countries, palm sugar in Sri Lanka, Indonesia, Bangladesh, Thailand, Myanmar; Cotton/Fabrics or silk dying in India, Pakistan, Nepal, Bhutan, Thailand, and Indonesia. In many Asian countries a large proportion of food preparation in institutional kitchens such as in schools, barracks, canteens, hostels, prisons and community kitchens also use biomass fuel. Stoves are one component in the production process that may affect the level of economic benefit of rural producers and entrepreneurs. With the use of better stoves for industrial or institutional production technique can be improved. Their use can save time and fuel, improve quality of their products and also improve the working conditions which influence the health of workers who spend most of their time in the kitchen with smoky stoves. The largest resulting benefit especially for small producers will be an increase in their income, the greatest concern of entrepreneurial producers. At a closer look, it is increasingly obvious that biomass stove issue is not solely the concern at the household level and that industry and institutions are also important stakeholders in the biomass issue. Fuel wood and other biomass fuels are also extensively used for institutional and small industrial activities in most countries specially in Asia as indicated in Table 4.4.

Different types of publications and information on domestic cook stoves are available, but unfortunately very few are on stoves for industrial and institutional use. Relatively simple technical information consisting of pictures and drawings will be appropriately useful as information source for field workers and practitioners as a base from which to start to advance the development of small-scale industries and institutions in their respective areas. It is in this regard that RWEDP and ARECOP jointly embarked to compile necessary information and compiled as compendium. This compendium is a compilation of basic information, designs of improved and traditional stoves for small industries and institutions. This compendium is to give ideas or inspiration to field workers or stove practitioners about various stove designs and technologies used in institutions and small industries in the Asian countries. For policy makers, it will provide clear picture of the development of energy policy and intervention for rural industries in terms of giving an alternative approach to income generation and distribution, employment, resource allocation and environmental conservation within rural economies.

Gasification-based small modular biomass systems are emerging as a promising technology to supply power and heat to rural areas, businesses, and the billions of people who live without electricity worldwide. Biomass Program support through subcontracted efforts with private sector companies over the past several years, has advanced several versions of the technology to the point where they are now approaching commercialization. By adopting a standardized modular design, these 5 kW-to-5 MW systems are expected to lend themselves to high volume manufacturing techniques to bring them on a competitive level with large stand-alone plants. Using locally available biomass fuels such as wood, crop waste, animal manures, and landfill gas, small modular systems can be brought to the source of the fuel rather than incurring transportation costs to bring biomass fuels to a large centrally located plant. Small modular biomass systems also fulfill the great market potential for distributed, on-site, electric power and heat generation throughout the world. Small modular biomass systems typically convert a solid biomass fuel into a gaseous fuel through a process called gasification. The resulting gas, comprised primarily of carbon monoxide and hydrogen, is then cleaned before use in gas turbine or internal combustion engine connected to an electrical generator. Waste heat from the turbine or engine can also be captured and directed to useful applications. Small modular systems allow themselves to such combined heat and power operations much better than large central facilities.

A small Modular biomass system provides many benefits to potential customers. They have minimal environmental impact when compared to other existing technologies using coal or biomass as the fuel. On the flip side, economics can be attractive when owners connect the unit to a power grid that will buy unused power. On the other hand, small modular systems can electrify separated areas for which the cost of connection to the grid is prohibitive. Another economic benefit may be realized if the customer has a biomass waste stream that can be converted into a source of energy instead of being an economic burden. The flexibility to use more than one fuel also appeals to many users. Modern microprocessor control has been coupled to gasification technology to result in systems requiring minimal operator attention. And, in off-grid locations small modular biomass systems provides the potential for lights, refrigeration, heat and power to enable small cottage industries to become economically viable.



1. As trees in the energy plantation grow, they absorb carbon dioxide from the atmosphere.
2. During photosynthesis the trees store carbon in their woody tissue and oxygen is released back to the atmosphere.
3. At harvest, wood fuel is transported from the plantation to the heat or power generating plant.
4. As the wood is burned at the heat or power generating plant the carbon stored in the woody tissue combines with oxygen to produce carbon dioxide, this is emitted back to the atmosphere in the exhaust gases. The amount of additional biomass that grows over the course of a year in a given area is known as the annual increment. Provided the amount consumed is less than the annual increment its use can be sustainable and biomass can be considered a low carbon fuel and biomass CO_2 absorption and emission is in balance. For forestry in the UK, the annual timber increment is of the order of 20

million tonnes. On top of this is the increment of all the agricultural crops and other vegetation.

1.5 USE OF BIOMASS: A REMEDY TO COMBAT POLLUTION EMISSIONS FROM POWER GENERATION INDUSTRIES

Air Pollution is a huge concern faced by the world today and impacts all of us in so many different ways. Importantly, our ability to effectively address air pollution is fundamental to our pursuit of promoting sustained economic growth and sustainable development. Our approach in dealing with pollution issues is, therefore, built around the high priority accorded by developing countries to economic growth and poverty eradication. The decisions concerning the fight against air pollution should be guided by the understanding that economic development, social development and environmental protection are interdependent and mutually reinforcing components of sustainable development. Air pollution has serious negative impacts on human health, socio-economic development, ecosystems and cultural heritage. Urgent and effective actions are, therefore, required in regard to both indoor air pollution from traditional biomass cooking and heating and ambient air pollution from all sources. Indoor air pollution, we believe, must be accorded high priority, as it is in its worst form, a poverty-related manifestation. Air pollution is also increased by factors such as natural disasters including volcanic eruptions, sand storms, desertification and land degradation and another disease which cause health problems and disturb people's daily lives.

Burning fossil fuels also releases air pollutants- sulphur oxides (SOx), nitrogen oxides (NOx), volatile organic compounds (VOCs; there are many), carbon monoxide (CO), and other toxic compounds. SOx and NOx react in the atmosphere to produce particulate matter. NOx and some VOCs react in the atmosphere to produce ground-level ozone. Particles and ozone together make smog, which can travel long distances on the prevailing winds, or can be clamped close to the ground during a weather inversion (often little wind). Thus air pollution and weather are also linked. All of these air pollutants can cause serious health effects. Health effects are best understood for particulate matter smaller than 2.5 mg/m^3 and ground-level ozone. There is no safe level of exposure to either of these substances. Increased levels of exposure may cause congestion, difficulty breathing, asthma attacks and occasionally death. PM2.5 is associated with an increase in heart attacks. Long-term exposure to PM2.5 is associated with low birth weight and reduced lung development in children. Health risks are higher in vulnerable populations - the very young, the elderly, those with pre-existing respiratory (such as asthma or COPD) or cardiovascular disease, or those exercising or doing strenuous work in locations with elevated air pollution. With rising temperatures associated with climate change air pollution may increase as a result of increased use of air conditioners which will cause power plants to burn more fuel. In those regions that have air pollution associated with warm weather (i.e., locations that have warm wind directions coming from heavily industrialized areas) a greater number of hot days will also mean a greater number of days with elevated air pollution and associated deleterious impacts on health. There have been an increasing number of instances where people have been exposed to the combination of unusually high temperatures and elevated air pollution. Days with these combined threats are likely to become more frequent as a result of climate change. High temperatures, especially over several days, and increased air pollution have resulted in high mortality rates in some regions, for example in France in 2003 where thousands of deaths were attributable to air pollution and heat.

Environmentally, biomass has some advantages over fossil fuels such as coal and petroleum. Biomass contains little sulphur and nitrogen, so it does not produce the pollutants that cause acid rain. Growing plants for use as biomass fuels may also help keep global warming in check. That's because plants remove carbon dioxide--one of the greenhouse gases-from the atmosphere when they grow.

The combustion (direct or indirect) of biomass as a fuel also returns CO_2 to the atmosphere. However this carbon is part of the current carbon cycle: it was absorbed during the growth of the plant over the previous few months or years and, provided the land continues to support growing plant material, a sustainable balance is maintained between carbon emitted and absorbed. Biomass is practically free from sulphur, nitrogen and heavy metals (Hg, etc.), and has much lower ash content (1-3 wt. %) than coal [7]. Hence, unlike fossil fuels, biomass use in electricity generation is not likely to pollute the atmosphere with SOx, NOx, SPM, etc.

1.6 MERITS IN THE USE OF BIOMASS IN POWER GENERATION:

(1) Growth of biomass occurs through photosynthesis reaction. Here, the biomass absorbs carbon dioxide from the atmosphere and gives out oxygen. Thus the sustainable generation and use of biomass in power plants will definitely help in reducing carbon dioxide concentration in the atmosphere and thus the green house effect.

(2) In comparison to coal, the ash content in biomass is very less (2-6% approx as against 20-50% in coal). Thus, the use of biomass in power generation will lead to substantial decrease in the amount of suspended particulate matters in the atmosphere.

(3) Energy content in biomass is more than those of E and F grade coals (mostly exploited coals in Indian power plants).

(4) Reactivity of biomass towards oxygen and carbon dioxide is much higher than that of coal. This permits the operation of boiler at lower temperatures resulting in greater saving of energy.

(5) Sustainable plantation and use of biomass in electricity generation will afford tremendous employment opportunity to the people who are highly advantageous for populous countries like India, China, etc.

(6) Electricity generation on decentralized basis is possible by the use of biomass. This will certainly help in uplifting the socio-economic development of the rural areas.

(7) Power generation on decentralized basis will reduce the transmission losses.

(8) Exploitation of biomass in power generation will lead to better utilization of barren lands of India (67 million hectares approx).

(9) Biomass plantation will prevent the soil erosion from floods.

1.7 PLANNING OF THE ELECTRICITY GENERATION STRUCTURE

In planning the electricity generation from biomass on decentralized basis, the following points should be taken into account:

- Kind, quality, quantity, feasibility of transportation and storage, sustainability and cost of biomass to be used.
- Level of customer demand.
- Method and cost of biomass drying
- Method of electricity generation and its economic viability
- Costs and qualities of locally available fossil fuels.

1.8AIMS AND OBJECTIVES OF THE PRESENT PROJECT WORK

The aims and objectives of the present investigation are as follows:

1. Selection of agricultural based biomass species and estimation of their generation by field trial.
2. Determination of proximate analysis (% moisture, % volatile matter, % ash and % fixed carbon contents) of their different components, such as stump, branch, leaf and bark.
3. Characterization of these biomass components for their ultimate analysis (carbon and hydrogen)
4. Determination of ash fusion temperatures (IDT, ST, HT and FT) of ashes obtained from these biomass species
5. Characterization of these biomass components for their energy values (calorific values).
6. Estimation of power generation potentials of these biomass species for a small thermal power plant on decentralized basis.

Chapter 2

LITERATURE SURVEY

2. LITERATURE SURVEY

2.1 Potential biomass resources of Sicily for electric power generation

V. Alderucci, A. Giordano, A. Iovino, N. Giordano and V. D. Phillips

Based on an analogous biomass energy evaluation of the Hawaiian Islands, a methodology for assessing the biomass resource potential of Sicily is described. The methodology features land availability and land suitability criteria for evaluating biomass productivity potential, biomass energy plantation species and site selection, and plantation management strategy. An exploratory survey of Sicily's candidate biomass feed stocks which identify yields and costs of both agricultural residues and dedicated biomass energy crops are featured. A technical and economic comparison of two biomass-conversion technologies for generating electric power, non-catalytic biomass gasification coupled with a combined-cycle gas turbine and catalytic biomass gasification coupled with a molten-carbonate fuel cell, is presented. Recommendations for developing an economically-viable biomass industry in Sicily are also included. Analytical results indicate that of Sicily's 236 × 10^6 GJ total annual energy requirement, approximately 50% or 120 × 10^6 GJ could be supplied with biomass resources, including all of the 13 300 × 10^6 kWh of electricity through an installed capacity of 2000 MW of electricity. By switching to indigenous, renewable biomass energy resources to enhance energy security, the 'greening' of Sicily's electrical-power production system can be implemented at a cost of approximately 3400 million ECU in capital costs and 990 million ECU in total annual expenses.

2.2 Amount, availability, and potential use of rice straw (agricultural residue) biomass as an energy resource

Yukihiko Matsumura ,Tomoaki Minow and Hiromi Yamamoto

This paper discusses the use of agricultural residue in Japan as an energy resource, based on the amounts produced and availability. The main agricultural residues in Japan are rice straw and rice husk. Based on a scenario wherein these residues are collected as is the rice product, we evaluate the size, cost, and CO_2 emission for power generation. Rice residue has a production potential of 12 Mt-dry year^{-1}, and 1.7 kt of rice straw is collected for each storage location. As this is too small an amount even for the smallest scale of power plant available, 2-month operation per year is assumed. Assuming a steam boiler and turbine with an efficiency of 7%, power generation from rice straw biomass can supply 3.8 billion(kW)h of electricity per year, or 0.47% of the total electricity demand in Japan. The electricity generated from this source costs as much as 25 JPY (kW h)$^{-1}$ (0.21 US$ (kW h)$^{-1}$, 1 US$=120 JPY), more than double the current price of electricity. With heat recovery at 80% efficiency, the simultaneous heat supplied via cogeneration reaches 10% of that supplied by heavy oil in Japan. Further cost incentives will be required if the rice residue utilization is to be introduced. It will also be important to develop effective technologies to achieve high efficiency even in small-scale processes. If Japanese technologies enable the effective use of agricultural residue abroad as a result of Japanese effort from the years after 2010, the resulting reduction of greenhouse gas emission can be counted under the framework of the Kyoto Protocol.

2.3 Biomass power cost and optimum plant size in western Canada

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The power cost and optimum plant size for power plants using three biomass fuels in western Canada were determined. The three fuels are biomass from agricultural residues (grain straw), whole boreal forest, and forest harvest residues from existing lumber and pulp operations (limbs and tops). Forest harvest residues have the smallest economic size, 137 MW, and the highest power cost, \$63.00 MWh^{-1} (Year 2000 US\$). The optimum size for agricultural residues is 450 MW (the largest single biomass unit judged feasible in this study), and the power cost is \$50.30 MWh^{-1}. If a larger biomass boiler could be built, the optimum project size for straw would be 628 MW. Whole forest harvesting has an optimum size of 900 MW (two maximum sized units), and a power cost of \$47.16 MWh^{-1} without nutrient replacement. However, power cost versus size from whole forest is essentially flat from 450 MW (\$47.76 MWh^{-1}) to 3150 MW (\$48.86 MWh^{-1}), so the optimum size is better thought of as a wide range.

None of these projects are economic today, but could become so with a greenhouse gas credit. All biomass cases show some flatness in the profile of power cost vs. plant capacity. This occurs because the reduction in capital cost per unit capacity with increasing capacity is offset by increasing biomass transportation cost as the area from which biomass is drawn increases. This in turn means that smaller than optimum plants can be built with only a minor cost penalty. Both the yield of biomass per unit area and the location of the biomass have an impact on power cost and optimum size. Agricultural and forest harvest residues are transported over existing road networks, whereas the whole forest harvest requires new roads and has a location remote from existing transmission lines. Nutrient replacement in the whole forest case would make power from the forest comparable in cost to power from straw.

2.4 Biomass energy in industrialised countries—a view of the future

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Available online 8 December 1997

Biomass fuels currently (1994) supply around 14% of the world's energy, but most of this is in the form of traditional fuelwood, residues and dung, which is often inefficient and can be environmentally detrimental. Biomass can supply heat and electricity, liquid and gaseous fuels. A number of developed countries derive a significant amount of their primary energy from biomass: USA 4%, Finland 18%, Sweden 16% and Austria 13%. Presently biomass energy supplies at least 2 EJ year^{-1} in Western Europe which is about 4% of primary energy (54 EJ). Estimates show a likely potential in Europe in 2050 of 9.0–13.5 EJ depending on land areas (10% of useable land, 33 Mha), yields (10–15 oven-dry tonnes (ODt) ha^{-1}), and recoverable residues (25% of harvestable). This biomass contribution represents 17–30% of projected total energy requirements up to 2050. The relative contribution of biofuels in the future will depend on markets and incentives, on continuous research and development progress, and on environmental requirements. Land constraints are not considered significant because of the predicted surpluses in land and food, and the near balance in wood and wood products in Europe.

There is considerable potential for the modernisation of biomass fuels to produce convenient energy carriers such as electricity, gases and transportation fuels, whilst continuing to provide for traditional uses of biomass; this modernisation of biomass and the industrial investment is already happening in many countries. When produced in an efficient and sustainable manner, biomass energy has numerous environmental and social benefits compared with fossil fuels. These include improved land management, job creation, use of surplus agricultural land in industrialised countries, provision of modern energy carriers to rural communities of developing countries, a reduction of CO_2 levels, waste control, and nutrient recycling. Greater environmental and net energy benefits can be derived from perennial and woody energy cropping than from annual arable crops which are short-term alternative feedstocks for fuels. Agroforestry systems can play an important role in providing multiple benefits to growers and the community, besides energy. In order to ameliorate CO_2 emissions, using biomass as a substitute for fossil fuels (complete replacement, co-firing, etc.) is more beneficial from social and economic perspectives than sequestering the carbon in forests.

Case studies are presented for several developed countries and the constraints involved in modernising biomass energy along with the potential for turning them into entrepreneurial opportunities are discussed. It is concluded that the long term impacts of biomass programmes and projects depend mainly on ensuring income generation, environmental sustainability, flexibility and replicability, while taking account of local conditions and providing multiple benefits, which is an important attribute of agroforestry-type systems. Biomass for energy must be environmentally acceptable in order to ensure its widespread adoptions as a modern energy source. Implementation of biomass projects requires governmental policy initiatives that will internalise the external economic, social and environmental costs of conventional fuel sources so that biomass fuels can become competitive on a 'level playing field'.

2.5 Worldwide commercial development of bioenergy with a focus on energy crop based projects

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Bioenergy consumption is greatest in countries with heavy subsidies or tax incentives, such as China, Brazil, and Sweden. Conversion of forest residues and agricultural residues to charcoal, district heat and home heating are the most common forms of bioenergy. Biomass electric generation feed stocks are predominantly forest residues (including black liquor), bagasse, and other agricultural residues. Biofuel feedstocks include sugar from sugarcane (in Brazil), starch from maize grain (in the US), and oil seeds (soy or rapeseed) for biodiesel (in the US, EU, and Brazil). Of the six large land areas of the world reviewed (China, EU, US, Brazil, Canada, Australia), total biomass energy consumptions amounts to 17.1 EJ. Short-rotation woody crops (SRWC) established in Brazil, New Zealand, and Australia over the past 25 years equal about 50,000 km^2. SRWC plantings in China may be in the range of 70,000–100,000 km^2. SRWC and other energy crops established in the US and EU amount to less than 1000 km^2. With some exceptions (most notably in Sweden and Brazil), the SRWC have been established for purposes other than as dedicated bioenergy feedstocks, however, portions of the crops are (or are planned to be) used for bioenergy production. New renewable energy incentives, greenhouse gas emission targets, synergism with industrial waste management projects, and oil prices exceeding 60 \$ Bbl^{-1} (in 2005) are major drivers for SRWC or energy crop based bioenergy projects.

2.6 Bio resource status in Karnataka

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Energy is a vital component of any society playing a pivotal role in the development. Post oil crises shifted the focus of energy planners towards renewable resources and energy conservation. Biomass is one such renewable, which accounts for nearly 33% of a developing country's energy needs. In India, it meets about 75% of the rural energy needs. In Karnataka, non-commercial energy sources like firewood, agricultural residues, charcoal and cow dung account for 53.2%. The energy released by the reaction of organic carbon (of bio resources) with oxygen is referred to as bioenergy. Bio resource availability is highly diversified and it depends on the region's agro climatic conditions. Inventorying of these resources is required for describing the quality, quantity, change, productivity, condition of bio resources and requirement in a given area. The present study assesses bio resource status across the agro climatic zones of Karnataka, considering the bioenergy availability (from agriculture, horticulture, forests and plantations) and sector-wise energy demand (domestic, agriculture, industry, etc.).

Bioresource availability is computed based on the compilation of data on the area and productivity of agriculture and horticulture crops, forests and plantations. Sector-wise energy demand is computed based on the National Sample Survey Organisation (NSSO study) data, primary survey data and from the literature. Using the data of bio resource availability and demand, bio resource status is computed for all the agro climatic zones. The ratio of bio resource availability to demand gives the bioresource status. The ratio greater than one indicates bioresource surplus zones, while a ratio less than one indicates scarcity.

The study reveals that the central dry zone (1.4), the hilly zone (3.79), the southern transition zone (3.12) and the coastal zone (3.40) are bioresource surplus zones, whereas the north-eastern transition zone (0.48), north-eastern dry zone (0.23), northern dry zone (0.58), eastern dry zone (0.39), southern dry zone (0.93) and northern transition zone (0.45) come under bioresource-deficient zones. Among the bioresource surplus zones, horticulture residues contribute significantly towards bioenergy in the central dry zone, southern transition zone and the coastal zone, while in the hilly zone the main contributor of bioenergy are agricultural residues. Amidst the bioresource-deficient zones, agriculture is the major contributor of bioenergy in the north-eastern transition zone (52%), northern dry zone (59%), and northern transition zone. Based on the bioenergy status of the zones and land use pattern, feasible management and technical options have been discussed, which help in optimising the available bioenergy and in building a sustainable energy society. This study also explores various programmes that can be initiated and implemented like social, community and joint forest management involving public participation. Such schemes will lessen the burden on the existing resources and also help the rural masses to procure biomass on a sustained basis.

Chapter 3

EXPERIMENTAL WORK

3. EXPERIMENTAL WORK

3.1 Materials selections

In the present project work, four different types of non-woody biomass species were collected from the local area and their components (stump, bark, leaf, flower and branch) were removed separately and kept for air drying in a cross ventilated room for about a month. The moisture contents of these components reached in equilibrium with that of the atmospheric air in one month. Three non-coking coal samples of three different mines of Orissa were also collected for comparative study. The local and botanical names of the biomass species, selected for present project work, have been outlined in the table. The air dried biomass samples were crushed into powders and then processed for their proximate and ultimate analysis and calorific value determination.

3.2 Proximate Analysis

Analysis for moisture, volatile matter, ash and fixed carbon contents were carried out on samples ground to -72 mess size by standard method [3]. The details of these tests are as follows.

(1) Moisture Determination

One gram of air dried powdered sample of size -72 mess was taken in a borosil glass crucible and kept in the air oven maintained at the temperature 110˚C.The sample was soaked at this temperature for one hour and then taken out from the furnace and cooled in a dessicator. Weight loss was recorded using an electronic balance. The percentage loss in weight gave the percentage moisture content in the sample.

(2) Volatile Matter Determination

One gram of air dried powdered sample of size -72 mess was taken in a volatile matter crucible (made of silica) and kept in the muffle furnace maintained at the required temperature of 925˚C.The sample was soaked at this temperature for seven minutes and then crucible was taken out from the furnace and cooled in air. Weight loss in the sample was recorded by using an electronic balance having a sensitivity of 0.001grams.The percentage loss in weight – moisture present in the sample gives the volatile matter content in the sample.

(3) Ash Content Determination

One gram of air dried powdered sample of size -72mess was taken in a shallow silica disc and kept in the muffle furnace maintained at the temperature of 775-800˚C.The sample was kept in the furnace till complete burning. Weight of ash formed was noted down and the percentage ash content in the sample was determined.

(4) Fixed Carbon Determination

The fixed carbon content in the sample was determined by using the following formula:

Fixed Carbon Content (Wt. %) =100-Wt %(Moisture + Volatile matter + Ash)

3.3 Calorific Value Determination

The calorific values of the biomass samples were measured in a Bomb calorimeter apparatus by the method outlined in reference [8].In this test an over dried sample briquette of weight 1gm (approx.) was taken in a bomb and oxygen gas was filled into this bomb at a pressure of 25-30 atm. The sample was then fixed inside the bomb and rise in temperature of water was noted with the help of Beckman Thermometer. The calorific value was calculated by using the following formula:

Gross Calorific value = (W.E X Δ T) / Wo – (fuse wire + thread connections)

Where,

W.E = water equivalent of the apparatus

ΔT = Maximum rise in temperature in ˚C.

Wo = Initial weight of briquette sample.

3.4 Ash Fusion Temperature Determination

The ash fusion Temperature, softening Temperature, Hemispherical temperature and Flow temperature) of all the ash samples ,obtained from the presently selected non-woody biomass species were determined by using Leitz Heating Microscope (LEICA) in Material Science Centre of the Institute. The appearance of ash samples at IDT, ST, HT and FT are shown in figure.

Chapter 4

THE RESULT AND DISCUSSION

4. THE RESULT AND DISCUSSION

The results obtained from the work of the present work having listed in tables 4.10 to 4.12

4.1 Proximate analysis of presently selected plant components obtained from agricultural residue:

The studies of proximate analysis of fuels energy sources are important because they give an approximate idea about the energy values and extent of pollutant emissions during combustion. Freshly felled agricultural plant components contain a large amount of free moisture, which must be removed to decrease the transportation cost and increase the calorific value. In the plant species selected for the present study. The time required to bring their moisture contents into equilibrium with that of the atmosphere was found to be in the range 3-3.5 week during the summer season (temp → 37 –42 ^{0} C, humidity 10-25 %.

The proximate and ultimate analysis of different components of maize, paddy, arhar and coconut, agricultural plant species are presented in tables 4.10 to 4.12 as evident from these tables paddy has the highest fixed carbon and ash contents and lowest VM contents in it's stump (stalk) than their stumps of the others agricultural crops. Arhar leaf has the highest fixed carbon content and lowest ash content than the leaves of the others. Coconut bark has the highest fixed carbon content followed by the barks of maize, and arhar. Coconut pitch has the highest fixed carbon contains followed by maize corn pad.

4.2 Calorific values of presently selected agricultural residue components:

The calorific values of the fuel energy source are an important criterion is an important criteria judging its quality to be used in electricity generation in power plants. It gives an idea about the energy value of he fuel and the entrant of electricity generation.

Comparison of the data presented in Table 4.4 to 4.8 Indicate that agricultural residue in general has the highest calorific values in its components of other agricultural residues studied in the present work. Coconut appears to rank second in the calorific value paddy. Paddy and arhar agricultural residues have approximately the identical calorific values in their components and they stand at lowest position among all the studied agricultural residue materials.

The elements which are responsible for imparting calorific value to the fuel are carbon, hydrogen and sulphur. The calorific values of carbon, hydrogen and sulphur are 8080, 34500, 2200 kcal/kg respectively. The aforesaid variations in calorific values of theses four agricultural residues are clearly due to the difference in the contents of these elements.

4.3 Ash fusion temperature of presently studied agricultural residue:

Ash fusion temperature of solid fuel is an important parameter affecting the operation temperature of boilers. Clinker formation in the boiler usually occurs due to low ash fusion temperature and this hampers the operation of the boiler. Hence the study of the ash fusion temperature of solid fuel is essential before its utilization in the boiler.

In the present study the ash fusion temperature in terms of four terminology like IDT, ST, HT and FT. the shapes of the initially taken cubic ash sample at IDT, ST, HT and FT are shown in figure.

HT is the temperature at which softening of ash starts HT is the temperature at which ash material becomes plastic and behaves like a viscous fluid forming hemispherical shape, where FT represents the temperature at which ash become fluid and starts flowing.

Identical shapes at these temperature were obtained for all the studied agricultural residue like maize, coconut, Arhar, and Paddy, Data for ash fusion temperatures (IDT, ST, HT and FT) for maize, coconut, arhar and paddy agricultural residue have been listed in tables. It is clear from table that maize has the lowest values of IDT, ST, HT and FT FOR ITS ASH (795-1130^{0}C) whereas the IDT, ST, HT and FT values of paddy, coconut and arhar ashes are higher ad comparable to each other.

As evident by literature the above difference in ash fusion temperature appears to be due to difference in the amount and nature of the mineral constituent present in the ash materials obtained from the agricultural residue. Form the ash fusion temperature data (Table 4.12), it may be concluded that the boiler operation with coconut, paddy and arhar agricultural residues can be carried out safely (without clinker formation) up to the temperature of 950^{0}C. Table also indicates that in case of use of maize agricultural residue, it may be safer to operate the boiler at temperature below 800^0C.

4.4. Estimation of Decentralize power generation Structure in Rural Areas:

For the estimation of power generation to meet the electricity requirement of villages, a group of 10-15 villages consisting of 3000 families may be considered for which one power station could be planned. The electricity requirement of lighting and domestic work in these villages may be assumed to be order of 6000 kWh/day. In addition to it, a power requirement of 140000 KWh/day (approx) may be considered for agriculture (irrigation and small scale industries installed in the considered group of villages. Therefore a power plant (to be installed in a group of villages) should have a capacity to generate 6000 + 14000 = 20,000 kWh/day (73 x 10^5 kWh/year) for a group of 10-15 villages.

The design of energy, plantations from maize, paddy coconut and arhar biomass. Species for power plant having a capacity, of 20,000 kWh/day have been presented in Table 4.5 to 4.8. The results indicate that in order to meet the yearly power requirement of the order of 73 x 10^4 kWh for a group of 10-15 villages, 717 ha (in case of use of coconut residue), 1123 ha (in case of use of maize residue), 1511 ha (in case of use of paddy residue) and 4329 ha (in case of use of Arhar residue) should always be ready for harvesting, in order to have perpetual generation of power.

Chapter 5

CONSTRAINTS

5.1CONSTRAINTS FOR PROMOTING ENERGY CULTIVATION

In view of the vast natural resources in the form of wasteland, sunshine, etc., the most promising solution to energy crisis in tropical countries (including India) appears to be the utilization of solar energy through energy plantations (Gurumurti et al., 1984; Boyles, 1986; Awasthi et al., 1979). Until recently, biomass production and conversion have attracted little attention from scientists and technologists. The following could be some of the reasons for the lack this lack of interest.

a. Research and development on the production and utilization of biomass falls under different disciplines of science, i.e., agriculture, chemical and metallurgical engineering. The lack of encouragement and recognition of interdisciplinary research in the past might have left a gap, and thus certain areas of science remained neglected.
b. With cheap and abundant supplies of fossil fuel, there has been little incentive to explore renewable energy sources in past. It is the combined effect of awareness of energy and environment problems in the recent past that has led to the development of alternative energy sources. However, a higher pace of development is needed to solve the problem within a certain time frame, before it is too late.
c. Many times, concern is expressed that utilization of wood will further reduce forest cover and spoil the ecology of the region. This concern is unfolded. The present study does not propose the use of existing forest cover but, instead, suggests utilizing wasteland for energy plantation. This energy cultivation in wasteland will aid natural forest cover. From the total man made forest, only 33% of the area would be harvested at one time on a 2-year rotational basis. This process would leave 67% of the area to be added to the natural forest cover, which will help in improving the environment of the region.
d. To design the best use of wastelands, more information is needed regarding topology, climate, existing vegetation, type of soil, the water situation, etc. This information will help determination what type of fast growing plant will thrive in a particular region.

5.2 SUGGESTIONS:

(1) Important knowledge and new technical information related to sustainable biomass production and its efficient utilization need to be synthesized and transferred to the share holders.

(2) The economic, environmental and social aspects of biomass production systems need to be assessed and examined, and the criteria helping to ensure their sustainability must be examined.

(3) A system should be developed for successful collection and transportation of biomass species to energy generation plants.

(4) Care must be taken to ensure that the intrinsic values and benefits, derived from our natural resources, must remain unchanged over multiple generations.

(5) Interdisciplinary research works on production, conversion and utilization of biomass need to be encouraged.

(6) Energy cultivation in wasteland and a system for successful collection and transportation of biomass materials to the power plants need to be developed.

(7) Village energy committees may be set up to look after and ensure the sustainability of biomass-based power plants, need for energy plantation etc should be created.

(8) Awareness among the people about the various aspects of biomass-based power plants, need for energy plantations, etc should be created.

(9) Financial assistance from the government need to be provided to encourage the development of such projects.

Chapter 6

CONCLUSION

6.1 CONCLUSION:

1. In case of coconut residue, shell has higher calorific value, which is slightly higher than pitch and bark, respectively.
2. In case of maize residue corn pad has higher calorific value which is higher than bark, stump and leaf respectively.
3. In case of paddy residue stump and leaf have approximately the same calorific value.
4. In case of arhar residue stumps has higher calorific value followed by leaf, sheed cover, branch respectively.
5. In case of ash fusion temperature coconut has higher IDT, and FT. Arhar has higher ST followed by paddy, coconut and maize. Arhar has highest HT.
6. Calculation result have demonstrated that nearly 717 hectares, 1123 hectares, 1511 hectares, 4319 hectares of land would be required for continuous generation of 20,000KWh electricity per day from coconut, maize, paddy and arhar agricultural residue respectively.
7. In contrast to locally available coals, the studied agricultural residue plant showed higher energy values and much higher energy value and much lower ash contents. This indicates higher power generation potentials in Biomass than coals.
8. The present study could be useful in the exploration of agricultural residue based biomass species for power generation.

6.2 SUGGESTIONS FOR THE FUTURE WORK

The present study was concentrated on four agricultural residue biomass species such as Coconut, Maize, Paddy and Arhar. The following works are suggested to be carried out in future.

(1) Similar type of study need to be extended for another agricultural residue biomass species available in the region.
(2) Pilot plant study on laboratory scale may be carried out to generate electricity from biomass species.

(3) The powdered samples of these biomass species may be mixed with coal in different ratios and the electricity generated potential of the resultant mixed briquettes may be studied.

(4) The biomass species may be mixed with cow dunk, sewage wastes, etc in different ratios and the electricity generated potentials of the mixtures may be determined.

(5) New techniques of electricity generation from biomass species may be developed.

Table 4.1: Biomass energy potentials and current use in different regions (Parikka, 2003)

Region	Biomass energy potentials (EJ/a)		Use (%)
	Woody	Non-Woody	
North America	12.8	7.1	16
Latin America	5.9	15.6	12
Asia	7.7	13.7	108
Africa	5.4	16.0	39
Europe	4.0	4.9	22
Former USSR	5.4	4.6	5
Middle East	0.4	0.3	7
World	41.6	62.2	38
Non – Woody biomass = Energy crops + straw + others (EJ = 10^{18} J)			

Table 4.2: Electricity generation potentials of renewable energy sources in India (Renewable energy statistics, 2005)

Source	Estimated potential (MW)	Cumulative Installed capacity (MW)
Wind energy	45,000	4,434.00
Biomass energy	16,000	376.00
Bagasse	3,500	491.00
Small hydro (up to 25 MW)	15,000	1,748.00
Waste-to-energy	2,700	45.76
Solar photovoltaic	20 MW/km^2	2.80

Table 4.3: Area under different crops and their respective residue production in India

Crop	Economic Produce	1996-97			2010		
		Gross cropped area (Mha)	Total economic production (Mt)	Total residue production Mt (air dry)	Gross cropped area (Mha)	Total economic production (Mt)	Total residue production Mt (air dry)
Rice	Food grain	43.3	81.3	146.5	46.1	118.80	213.90
Wheat	Food grain	25.9	69.3	110.6	28.5	98.50	157.60
Jowar	Food grain	11.6	11.0	22.3	5.3	6.10	12.20
Bajra	Food grain	10.0	7.9	15.8	8.6	6.80	13.60
Maize	Food grain	6.2	10.6	26.3	6.6	13.00	32.50
Other cereals	Food grain	4.3	4.7	9.4	1.3	1.40	2.80
Red gram	Food grain	3.6	2.7	13.5	3.6	2.70	11.20
Gram	Food grain	7.1	5.7	9.3	7.7	7.00	13.50
Other pulses	Food grain	12.5	5.8	17.1	12.5	5.90	17.10
Ground nut	Oil Seed	7.9	9.0	20.7	9.3	12.20	28.10
Rape seed & mustard	Oil Seed	6.9	6.9	13.8	10.7	12.00	24.10
Other oil seeds	Oil Seed	12.1	9.1	18.2	18.0	13.50	27.10
Cotton	Fiber	9.1	14.3	50.0	10.1	15.90	55.70
Jute	Fiber	0.9	9.8	15.7	0.6	6.50	10.50
Sugar cane	Sugar	4.2	277.2	110.8	5.5	463.50	185.40
Coconut +areca nut	Oil + Confectionery	2.0		20.0	2.8		28.20
Mulberry	Silk fiber	0.3		3.0	0.3		3.30
Coffee + tea	Beverage	0.7	0.8	3.42	0.8	1.00	3.90
Total		168.6		626.5	178.2		840.6

Table 4.4: Wood and Biomass Energy Consumption by Industries in several Asian Countries

	YEAR	WOOD ENERGY		BIOMASS ENERGY		TOTAL ENERGY
		TJ	SHARE	TJ	SHARE	TJ
Bangladesh	1995	28,500	15.9%	114,900	64.2%	178,900
Cambodia	1995	383	71.9%	383	71.9%	533
India	1996	375,500	8.1%	1,094,878	23.5%	4,656,003
Malaysia	1995	NA	NA	65,188	16.2%	402,644
Nepal	1997	3,684	23.1%	3,935	24.7%	15,951
Pakistan	1994	NA	NA	92,318	21.9%	422,280
Philippines	1995	38,220	13.7%	77,533	27.8%	279,211
Sri Lanka	1995	21,773	42.6%	26,826	52.4%	51,163
Thailand	1997	42,789	6.1%	194,853	27.8%	700,367
Vietnam	1995	43,500	19.8%	87,250	39.8%	219,427

Table 4.5: Total energy contents and power generation structure from 4 months old (approx), coconut plants

Component	calorific value (kcal /t, dry basis)	Biomass production (t/ha, dry basis)	Energy value (kcal/ha)
Shell	4385×10^3	5.00	21925×10^3
Coir pith	4277×10^3	2.50	10443×10^3
Back	3930×10^3	0.50	1965×10^3

Energy calculations:

On oven dried basis, total energy from one hectare of land

$= (21925 + 10443 + 1965) \times 10^3$

$= 34333 \times 10^3$ kcal

Assumptions:

- Conversion efficiency of wood fuelled thermal generators = 30 %
- Overall efficiency of the power plant = 85 %

Energy value of the total utilizable biomass obtained from one hectare of land at 30% efficiency of Kcal generation = $34333 \times 10^3 \times 0.30$

$= 10300 \times 10^3$ kcals

$= 11968.6$ kWh

Power generation at 85 % overall efficiency = 11968.6×0.85

$= 10173.32$ k W h /ha

Land required to supply electricity for the whole year

$$= \frac{73x10^5}{10173.22} = 7171 hectars$$

Table 4.6: Total energy contents and power generation structure from 4-month-old (approx) maize:

Component	Calorific value (kcal /t, dry basis)	Biomass production (t/ha dry basis)	Energy value (kcal/ha)
Stalk	352×10^3	3.70	13038×10^3
Corn pad	4901×10^3	1.00	4901×10^3
Leaf	3318×10^3	0.85	2820×10^3
Bark	3650×10^3	0.32	1168×10^3

Energy calculations:

On oven dried basis, total energy from one hectare of land

$= (13038 + 4901 + 2820 + 1168) \times 10^3$

$= 21927 \times 10^3$ Kcals

Assumptions:

- Conversion efficiency of wood fuelled thermal generators = 30 %
- Overall efficiency of the power plant = 85 %

Energy value of the total utilizable biomass obtained from one hectare of land at 30% efficiency of Kcal generation = $21297 \times 10^3 \times 0.30$

= 6578.1 kcals

= 7643.75 kWh

Power generation at 85 % overall efficiency = 7643.75 x 0.85

= 6497.18 kWh /ha

Land required to supply electricity for the whole year

$$= \frac{73x10^5}{10173.32} = 1123 \quad hectars$$

Table 4.7: Total energy contents and power generation structure from 4-month-old (approx) paddy:

Component	**Calorific value (kcal /t, dry basis)**	**Biomass production (t/ha, dry basis)**	**Energy value (kcal/ha)**
Stalk	3544×10^{3}	3.50	12404×10^{3}
Leaf	3540×10^{3}	1.10	3894×10^{3}

Energy calculations:

Total energy = $(12404 + 3894) \times 10^3$

= 16298×10^3 Kcals

Energy value of 30% efficiency of power generation = $16298 \times 10^3 \times 0.30$

= 4889.4 kcals

= 5681.4 kWh

Power generation at 85 % overall efficiency = 7643.75 x 0.85

= 6497.18 kWh /ha

Land required to supply electricity for the whole year

$$= \frac{73x10^5}{4830} = 1522 \quad hectars$$

Table 4.8: Total energy contents and power generation structure from 4-month-old (approx) arhar pulse:

Component	Calorific value (kcal /t, dry basis)	Biomass production (t/ha dry basis)	Energy value (kcal/ha)
Stalk	$5815x\ 10^{3}$	0.50	2907×10^{3}
Branch	4081×10^{3}	0.30	1224×10^{3}
Leaf	$5630x\ 10^{3}$	0.10	563×10^{3}
Bark	$3846x\ 10^{3}$	0.05	196×10^{3}
Sheed cover	4081×10^{3}	0.20	817×10^{3}

Energy calculations:

Total energy = $(2907 + 1224 + 653 + 193 + 817) \times 10^{3}$

= 5704×10^{3} Kcals

Energy value of 30% efficiency of power generation = $5704 \times 10^{3} \times 0.30$

= 1712 kcals

= 1986.4 kWh

Power generation at 85 % overall efficiency = 1988.4 x 0.85

= 1690 kWh /ha

Land required to supply electricity for the whole year

$$= \frac{73x10^{5}}{1609} = 4319\ hectars$$

Table 4.9: Local and botanical names of studied agricultural waste residues:

Sr. no	Local name	Botanical name	Family
1	Coconut	Cocos nucifera	
2	Maize	Zea mays	Gramineal
3	Paddy	Oryza satival	
4	Arhar	Cojanus cajan	

Source –www.bawarchi.com

Table 4.10: Proximate analysis and calorific values of different component of coconut and maize

Component	Proximate analysis wt %, air dried basis (Coconut)				Calorific value (kcal /kg, dry basis)
	Moisture	Volatile matter	Ash	Fixed carbon	
Shell	12.50	67.40	5.00	15.10	4285
Pith	15.00	55.00	5.00	25.00	4177
Bark	10.00	65.00	3.80	21.20	3930
(Maize)					
Stump	10.00	69.00	6.00	15.00	3524
Corn pad	8.00	70.00	1.50	20.50	4901
Leaf	4.00	65.00	20.75	10.25	3318
Bark	12.00	59.75	12.25	16.00	3650

Table 4.11: Proximate analysis and calorific values of different component of Paddy and Arhar

Component	Proximate analysis wt %, air dried basis				Calorific value (kcal /kg, dry basis)
	Moisture	Volatile matter	Ash	Fixed carbon	
(Paddy)					
Stump	8.50	55.50	19.50	16.50	3544
Leaf	7.50	57.50	25.00	10.00	3540
(Arhar)					
Stump	9.00	68.00	9.50	13.50	5815
Branch	10.00	69.00	7.50	13.50	4081
Leaf	9.00	65.00	10.50	15.50	5630
Bark	5.00	74.00	8.50	12.50	3846
Shed cover	10.00	65.00	10.00	15.00	4081

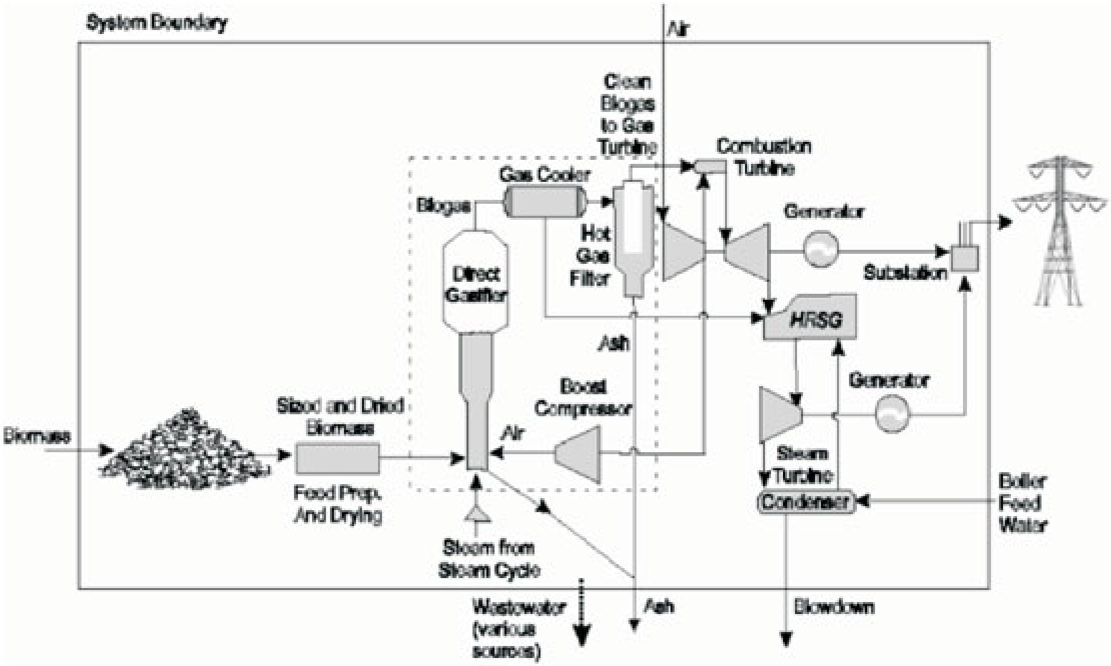
Table 4.12: Ash fusion temperature of selected biomass species

Biomass Species	Ash fusion temperature			
	IDT	ST	HT	FT
Coconut	950	1080	1146	1188
Paddy	935	1090	1160	1181
Maize	795	850	1097	1130
Arhar	965	1130	1150	1166

Table 4.13: Proximate analysis and calorific values of non- cooking coals obtained from different mines of Orissa (INDIA)

Coal mine	Proximate analysis wt %, air dried basis			Calorific value (kcal /kg, dry basis)
	Volatile matter	Ash	Fixed	
Lakhanpur	21.21	52.24	26.55	3938
Siding	30.62	44.30	25.08	495
Hingola	21.90	59.83	18.27	3355
Yeurve	35.66	38.90	25.44	4682
Kalinga	24.77	50.70	24.66	4237
Jagarnath	31.10	52.68	16.22	4660

Figure 1. Biomass Integrated Gasification Combined-Cycle System Schematic

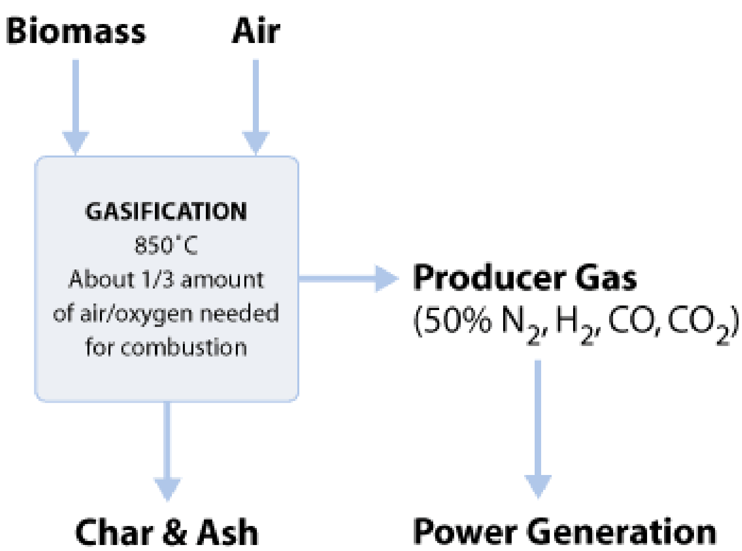


Source: Electric Power Research Institute and U.S. Department of Energy, *Renewable Energy Technology Characterizations*, EPRI-TR-109496 (Palo Alto, CA, December 1997), web site www.eren.doe.gov/power/techchar.html.

Small Modular Applications

Biomass Gasification via Partial Oxidation

(Auto Thermal)



Chapter 7

REFERENCES

REFERENCES

[1] Biomass: "Versatile Source of Energy", 2000. Indian Energy Sector; Newswatch Tracks. Hall, D.O., and K. K. Rao. 1999. Photosynthesis, 6th Edn. , Studies in Biology, Cambridge University press.

[2] Parikka, M. 2004. "Global biomass fuel resources". Biomass and Bioenergy 27: 613-620.

[3] Ravindranath, N. H., H. I. Somashekar, M. S. Nagaraja, P. Sudha, G. Sangeetha, S. C. Bhattacharya, and P. Abdul Salam. 2005. "Assessment of sustainable non-plantation biomass resources potential for energy in India". Biomass and Bioenergy 29: 178-190.

[4] Renewable Energy Statistics : "Renewable energy at a glance in the world", 2006. Akshay Urja 2: 48.

[5] Renewable Energy Statistics : "Renewable energy at a glance in the India", 2005. Akshay Urja 1: 48.

[6] Gupta, A. K. 2006. "Renewable energy in Industry". Akshay Urja 2: 13-15.

[7] Kumar. M., and R. C. Gupta. 1992. "Properties of acacia and eucalyptuus woods". J1. of Materials Science Letters 11: 1439-1440.

[8] Kalika, V., and S. Frant. 1999. "Environmental aspects of power generation". Energy Sources 21: 687-704.

[9] Bureau of Indian Standards. 1969. IS: 1350, Part I. "Methods of tests for coal and coke", p.3, New Delhi.

[10] Agrawal, B. C., and S. P. Jain. 1980. "A Text-Book of Metallurgical Analysis", 3rd Edn., p.277. Khanna Publishers, New Delhi.

[11] Alderucci V., Giordano A., Iovino A., Giordano N. and Phillips V.D." Potential biomass resources of Sicily for electric-power generation", Journal of Science Direct Applied Energy, Volume 45, Issue 3, (1993), p. 219-240

[12] Matsumura Yukihiko, Minowa Tomoaki and Yamamoto Hiromi "Amount, availability, and potential use of rice straw (agricultural residue) biomass as an energy resource in Japan", Journal of Science Direct Biomass and Bioenergy, Volume 29, Issue 5,(November 2005), p.347-354

[13] Kumar Amit, Jay B. Cameron and Flynn Peter C. ," Biomass power cost and optimum plant size in western Canada", Journal of Science Direct Biomass and Bioenergy, Volume 24, Issue 6, (June 2003), p. 445-464

[14] Hall D. O. ”Biomass energy in industrialised countries—a view of the future Forest Ecology and Management”, Journal of Science Direct Volume 91, Issue 1,(March 1997), p. 17-45.

[15] Wright Lynn ,”Worldwide commercial development of bioenergy with a focus on energy crop-based projects”, Journal of Science Direct Biomass and Bioenergy, Volume 30, Issues 8-9, (August-September 2006), p. 706-714

[16] Ramachandra T. V., Kamakshi G. and Shruthi B. V.,” Bioresource status in Karnataka” Journal of Science Direct Renewable and Sustainable Energy Reviews, Volume 8, Issue 1, (February 2004), p. 1-47