Development of biomass as a renewable energy source has drawn increasing interest worldwide in the last few decades. The driving force was the constantly increasing energy requirement, diminishing conventional resources such as oil and coal along with an increasing population. One of the major reasons for it is that all technological developments in the field of production and utilisation of biomass feedstock promise the application of biomass at lower cost and with higher conversion efficiency than was possible previously. For example when low cost biomass residues are used for fuels, the cost of electricity is often competitive with fossil fuel-based power generation. More advanced options to produce electricity are looking promising and will allow a cost-effective use of energy crops e.g. production of methanol and hydrogen by a gasification process. The constantly rising demand for energy will provide an almost inestimable market for energy crops. Secondly, the potential threat posed by climate change, due to high emission levels of greenhouse gases, the most important being CO₂, has become a major stimulus for renewable energy sources in general. When produced by sustainable means, biomass emits roughly the same amount of carbon during conversion as is taken up during plant growth. The use of biomass therefore does not contribute to a buildup of CO₂ in the atmosphere.

India is very rich in three distinct sources of biomass energy namely energy plantations, agricultural crop residue and municipal and industrial wastes. Being an agricultural country, a large population of cattle and livestock exists in India. Thus, Indian villages have always been rich in bio-resources which can easily be converted to energy.

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Biomass production at a sugar factory in Maharashtra, India
Biomass conversion to energy in India has seen many ups and downs during last three decades. A rural energy crisis became discernible in the mid-seventies following the inflated oil prices, growing population, diminution of common lands traditionally supplying wood-fuels, increasing water stress and higher energy demand by irrigation-intensive agriculture in the course of Green Revolution. The instant remedial measure taken was to increase import of kerosene and diesel to take care of domestic and irrigation water pumping energy needs respectively. But this led to bigger import budget and consequent financial deficits since both these fuels were subsidised for meeting the basic needs of the poor.

This was the time when an alternative policy was needed that would also be economically sustainable. In an agriculture based country like India, it was rather imperative for policy makers to perceive biomass as an energy alternative that could reduce the crisis. Thus a diverse biomass strategy was developed in an effort to improve the efficiency of traditional technologies, enhancing supply of biomass, introducing modern biomass technologies to provide reliable energy services at competitive prices, and establishing institutional support. Nodal agencies for energy development and coordination were set-up at the state level in the late 1970s. In 1982, the Government of India established the Department of Non-Conventional Energy Sources (DNES), which together with state agencies initiated programmes for biogas and improved cook-stoves which were aimed at decreasing the rural household energy supply crisis. This impetus faced many barriers to technological change and could achieve only moderate success. The decade of nineties saw a further thrust on the bioenergy promotion with fuel-wood plantation and biomass-based electricity generation.

A need for alternate transportation fuel is on constant increase due to a rising number of vehicles as well as improvement in lifestyles. Therefore in the past few years the main thrust of technologists and policy makers in present decade has shifted to development of transportation fuels. Efforts are now on for development of biomass as a source of liquid fuels which can be used as substitutes for oil used in transport. Improvements in bio-energy technologies, rising environmental concerns like deterioration in local air quality, global climate change due to fossil fuel use, continued lack of access to energy in rural areas and rising imports of fossil fuels have generated sufficient momentum for the use of biomass as a renewable, sustainable and cleaner energy source. The multiple dividends associated with biomass like local employment, land restoration, soil conservation and afforestation, have further added interest for its development.

India is very rich in three distinct sources of biomass energy namely energy plantations, agricultural crop residue and municipal and industrial wastes. Being an agricultural country, a large population of cattle and livestock exists in India. Due to this, Indian villages have always been rich in bio-resources which can easily be converted to energy. The major energy crops in India which have been identified to have a potential of commercialisation are sugarcane, corn, sugar beets, certain oil grains etc. Besides this, a large amount of agriculture residues are produced in India. These constitute a potential biomass feedstock for energy conversion. Here the definition of agricultural residues includes all the by-products from harvesting and processing of agricultural crops. These residues can be further categorised into primary residues, which are generated in the field at the time of harvest (rice straw, sugar cane tops) and secondary residues, co-produced during processing (rice husk and bagasse). Availability of primary residues for energy application is usually low since collection is difficult and they have other uses as fertiliser, animal feed, etc. However secondary residues are usually available in relatively large quantities at the processing site and may be used as captive energy source for the same processing plant involving no or little transportation and handling cost. Apart from the residues from the agricultural farms and fields in urban areas certain other residues and wastes also constitute a potential source of the energy. The agro processing industries, urban vegetable market places, road sweepings and road side...
plantations are some areas which generate significant biomass waste. Unfortunately the management of these areas is generally in the hands of poor farmers and the unorganised sector, rural households and the low income tiny agro based industry sector. According to a recent report almost 200 million tonnes of household and agro processing wastes are generated annually in India and disposed in a dispersed manner. Since they are associated with little or no production costs they are either unused or utilised inefficiently. On the other hand, a colossal amount of leafy wastes are burnt resulting not only in air pollution, but also wastage of useful energy.

Waste effluents from many industries, especially food industries such as black liquor from pulp and paper industry, wastewater from slaughterhouse, milk processing units, breweries, vegetable packaging industry and animal manure can be converted into energy. Though energy production potential may depend upon the nature of effluent as well as reactor efficiency of the used reactor, but these wastes can effectively be used as feedstock for the biofuel production. The estimated biogas production potential is in the range of 0.15–0.45 m$^3$ CH$_4$/kg of COD removed, calculated on a basis of an average value of 0.3 m$^3$
CH₄/kg. The hotel, restaurants and community kitchens produce waste such as vegetable peels, uneaten food e.g. rice, bread, vegetables, meat, etc., plate and dish washings, fruit and vegetable rejects. Similarly, huge amount of wastes are generated from confectionary industry. Solid wastes from these industries include peeling and scraps from fruit and vegetables, food that does not meet quality control standards, pulp and fibre from sugar and starch extraction, filter sludge and coffee grounds. All these wastes make a potential feedstock for biogas generation by anaerobic digestion. These wastes are usually disposed off in landfill dumps. Liquid wastes are generated by washing meat, fruit and vegetables, blanching fruit and vegetables, pre-cooking meats, poultry and fish, cleaning and processing operations and wine making. These wastewaters contain sugars, starches and other dissolved and solid organic matter. The potential exists for these industrial wastes to be anaerobically digested to produce biogas, or fermented to produce ethanol. Several commercial examples of waste-to-energy conversion already exists using these feedstocks.

Animal manure is principally composed of organic material, moisture and ash. Under aerobic conditions, CO₂ and stabilised organic materials (SOM) are produced. Under anaerobic conditions, CH₄, CO₂, and SOM are produced. Since the quantity of animal manure produced annually can be substantial for a country like India, the potential for CH₄ production and hence energy potential of animal manure is significant.

Another potential source of biomass in India is municipal solid waste (MSW). The biomass resource in MSW comprises the paper and plastic and averages 80 per cent of the total MSW collected. This can be converted into energy by direct combustion, or by natural anaerobic digestion in the engineered landfill. The organic fraction of MSW can be anaerobically stabilised in a high-rate digester to obtain biogas for electricity or steam generation. Energy can be extracted from sewage using anaerobic digestion to produce biogas. The sewage sludge that remains can be incinerated or can undergo pyrolysis to produce more biogas. Data regarding some of the existing agencies and/or industries practicing the conversion of different waste biomass to energy in India and reported benefits from these are listed in Table 1. Many of these technologies have profitably been implemented and are being used by industries by in-house energy saving and thus adding up to their profits. These technologies are being adapted by similar industries with the help of various government agencies i.e. MNRE, academic institutions like Indian Institute of Science (IISc) and Indian Institutes of Technology (IITs), as well as certain non-government organisations.

It seems clear from the scenario prevailing during the last three decades that biomass conversion to energy has gained gradual momentum with increasing energy demand patterns. In the present day scenario, top priority has been given to search the potential biomass as well as effective routes to convert them in transport fuels. Nevertheless, technologists are also exploring the possibilities of developing integrated bio-refineries which can utilise the available biomass to convert it to green chemicals as well as liquid fuels. A number of power generation projects based on gasification based cogeneration rural electrification plants is successful in India. Recently a concept of village level bio-refinery is being conceived in which farmers may be trained to setup the plants for biofuel production in their villages and produced biofuels can be utilised to run their pumping sets and other agriculture equipment. It would eliminate the transport cost of biomass as well as produced bio-fuels. With steady upward demand for the petroleum-based fuels, and constant increase in demand of electrical power generation, cogeneration based gas power plants and integrated bio-refineries can contribute most to trim down the energy problem of India.

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A NEED FOR ALTERNATE TRANSPORTATION FUEL IS ON CONSTANT INCREASE DUE TO A RELENTLESS GROWTH IN THE NUMBER OF VEHICLES. THEREFORE IN THE PAST FEW YEARS THE MAIN THRUST OF TECHNOLOGISTS AND POLICY MAKERS IN PRESENT DECADE HAS SHIFTED TO DEVELOPMENT OF TRANSPORTATION FUELS.