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## Biomass-Energy: Retrospect and Prospect
(Extended Summary)

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The goal and role of biomass energy in the Indian context, particularly for rural poor, where firewood is still the principal form of energy, is discussed. It brings out the immediate research needs in firewood forestry which can be taken up on marginal land to bridge the widening gap between supply and demand of firewood. There is also need to undertake R and D on agricultural alcohol, hydrocarbon plants, algae, biological hydrogen, etc. Most of these are in urgent need of domestication and genetic upgradation. Biomass cannot supply all our energy needs, but will supplement the same. There is a nexus between food, firewood and fodder as reflected by the three land-based vacations: agriculture, forestry and animal husbandry. There are many social, economic and environmental advantages of such a agri-silvi-pastord system.

**Key Words:** ?

Ever since the human being discovered fire some 150,000 years ago, firewood provided him with warmth when it was cold, protection from predators, more digestible food, higher survival rate and colonisation of habitats which were inhospitable earlier. Firewood soon became the principal source of energy and even today over 50% of wood is put to its original use, i.e. as fuel. Firewood and charcoal gave way to coal, coal to electricity, and since 1859 oil has been the major source of energy.

Two important points emerged from the First Energy Crisis in 1973. Firstly, all nations suddenly became aware of their total dependence on only one form of energy and realized that they were, in fact, living in a Petroleum Society. Secondly, it became clear that such a crisis would not have affected any nation if a broad energy policy, involving many sources, had been adopted. There then followed the Second Energy Crisis due to scarcity of firewood for cooking and heating. This crisis has been more serious, as it affects a very large rural population in the entire developing world. In India, 68.5% of the energy used in households is in the form of firewood and 64.2% of it is collected from natural sources. For a variety of reasons, wood is still the principal source of energy in rural areas and nearly half of

the world's wood production goes into its original use, i.e. cooking and heating. However, on account of population pressure, the demand for firewood has outstripped natural regeneration and planting, so much so that in some areas, though there is food to eat, not enough wood is available to cook it. At present, there is a big gap between demand and supply of firewood resulting in depletion of the forest cover, which, in turn, has proved to be ecologically disastrous, as it leads to floods, soil erosion and, ultimately, shortage of water.

One of the important methods of insulating the country against impending disaster is to take to the photosynthetic model of development through large-scale use of biomass, particularly firewood. Such an option, apart from meeting energy needs, would help to restore the relationship between man and his environment. Therefore, a very massive tree plantation programme is necessary both for energy needs and overall eco-development.

In India, the shortfall in firewood production by 2000 AD has been estimated to be of the order of 137 million tonnes, which would require 34 million hectares of land, at about four oven-dry tonnes of wood per ha/year, and a minimum annual outlay of Rs. 500 crore for 17 years, to be made good. Once such a programme is successful, dung and plant-based residues would become available as organic fertiliser and industrial feedstock.

Among the renewable alternatives, solar energy, captured by the plants through the process of photosynthesis, is the most important, especially because photosynthesis is the key process in the life-support system of this planet. Furthermore, the plant, based energy systems are not only renewable but they also remove carbon dioxide from the atmosphere before turning it back, with no overall quantitative increase: thus; they help to contain environmental pollution. Photosynthesis is at the base of all biomass production and food chains. It converts physical energy into chemical energy and generates oxygen, the life sustaining gas. Whereas net photosynthesis uses only 0·1% of sunlight, it produces organic matter only 10% of which accounts for the total energy used by humankind and only 0·5% accounts for the entire food requirement of the human race. Increase in photosynthetic efficiency automatically increases production of organic matter. Various types of biomass and/or biofuels available are: firewood, agricultural alcohols, vegetable oils, hydrocarbon plants, particularly those yielding rubber and petroleum-like materials; fresh weeds, sewage-grown algae, algal hydrocarbons, and biologically produced hydrogen using halobacteria, algae, azolla and even higher plants. Every feedstock or bioconversion process has its own merits and demerits, and the different routes available to generate solid, liquid and gaseous fuels are: anaerobic and enzymatic digestion and thermochemical conversion.

The basic premise for raising firewood plantations is that firewood needs cannot and should not be met from the natural forest stands, as it would reduce the forest area, which is now only 14% in India, although 33% is envisaged under the National Forest Policy Resolution (1952) of the Government of India. The destruction of our forests will not stop as long as fuel for cooking is either not provided free to the rural poor, or is not made very cheap. In fact, the time has come when we must plan for meeting timber and wood needs for industrial purposes from plantations captive to industry and not from natural forests. In order to obtain the maximum productivity of firewood in the minimum time, high-density and short-rotation biomass of fast and hardy species of deciduous trees and shrubs should be grown exclusively on

non-agricultural or marginal lands, so as to avoid competition with food crops. The yields of firewood reported so far are indeed over-optimistic and there is a need to conduct meticulous scientific experiments, because estimated yields are a very crucial factor in planning firewood plantations for domestic use and for generation of electricity. The numerous advantages of large-scale firewood plantations range from the strictly local to environmental and social imperatives.

Another dimension to the problem is that the degraded lands proposed to be used for biomass production are at present used, free of cost, for grazing. If used for firewood biomass, such lands will have to be closed to grazing immediately. To meet the situation thus created, either tree species with a fodder value will have to be grown or fodder legumens and/or grasses will have to be produced in conjunction with firewood species.

The immediate research needs are:

—To select tree/shrub species for wide genetic variation and adaptability to marginal or low nutrient soils. Thus, the selected species should be hardy and require low inputs of water, fertilizer and plant protective measures.

—To choose species with multiple uses, like fuel, fodder, fertilizer and fibre and high regenerative potential and/or coppicing ability, without loss of vigour under conditions of competition; with minimum amount of bark wood with high calorific value and capability to burn without sparks and toxic smoke, etc.

—Nitrogen-fixing capacity of the species would be an additional advantage, and other methods of biological soil fertilization for deficient soils need to be worked out in view of the fact that high density and short rotation will cause a very high drain of nutrients from soil with hardly any litter fall available for recycling.

—Agro-technological package of cultural practices for individual species and specific habitats needs to be looked into in combination with appropriate fodder legumes and/or grasses.

—Standardization of tissue culture techniques for production, on a mass scale in a very short time, of elite clones will be required to meet a very large demand for planting material (10,000 and above per hectare).

—Germ plasm collection of all the relevant species and their variants will have to be made for purposes of location-specific adaptability trials as also for incorporation in breeding programmes.

—Breeding procedure for genetic upgrading for the parameters listed above will need standardisation.

Agricultural alcohol, though a successful transport fuel in Brazil, is not relevant to India, as it may be more economical to use it as an industrial feedstock. Furthermore, it may not be wise to displace sugarcane and/or tapioca as food crops. Sugarcane, besides, is now a 'political' crop. However, the future feedstock for alcohol is lignocellulose and research and development (R&D) work has to be intensified to make it a commercial raw material. Similarly, although vegetable oils are a promising fuel for diesel engines, due to acute shortage of edible oils, as also their higher price as compared to petroleum in India, these oils do not have an immediate future as fuel.

The new hydrocarbon plants, such as guayule and euphoribias, are hardy and most relevant to India and can be grown in arid regions. The demand for natural rubber is unabated, because, it is preferred to synthetic elastomers; besides, the latter are based on petroleum feedstock. To meet a shortfall of 65,000 tonnes of natural rubber, guayule needs to be raised in over 26,000 ha in arid zones by 1985.

Among the aquatic biomass, water weeds, such as water hyacinth, common in water bodies, are already being used. Sewage, though an environmental hazard, can be a source of biogas as also a culture medium for single cell protein for poultry. During the process, sewage itself is rendered benign.

Algae are a very promising source of hydrocarbons and deserve attention for production and processing by catalytic hydrogenation. The whole area of marine biomass has been badly neglected and requires examination in veiw of the fact that the sea constitutes about 71% of earth's surface.

Production of biological hydrogen through bio-photolysis, as also bio-electricity, involves the use of hydrogenase and halobacteria with purple membranes, respectively. Both of these merit serious consideration and have a long-term potential.

There is an urgent need to domesticate as also genetically upgrade all the new and upcoming energy crops, microbes and algae, which are at present wild and have low productivity per unit area, per unit time. This can be possible if there is a heavy input of high science. The area of biomass energy is indeed multi-disciplinary and requires R & D in subjects such as botany, phytochemistry, microbiology, agriculture, fuel research, heat physics, different branches of engineering, etc., on plants as alternative sources of diverse types of energy.

In general, energy requirements of the rural poor, who often have food but not enough fuel to cook it, have been neglected so far. In view of the acute shortage of firewood, they perforce poach on forests, plantations, etc. It is, therefore, essential that, like other basic needs, such as food, shelter, clothing and medicare, energy for cooking and heating should also be considered a basic need and guaranteed by the state. This has become all the more necessary on account of the very wide regional disparity in energy use. In fact, affluent nations are using energy in such a reckless manner as to lead to a highly disproportionate use of this finite resource and increased pollution. One way to meet this situation is to follow a broad energy policy in which many forms of energy are utilised, each supplying not more than 20–25% of the total energy requirement. In a country like India, which has achieved food self-sufficiency to an extent, but is deficient in energy, the non-agricultural land will tend to be used for energy crops, in contrast with those countries which are deficient in both energy and food, and have little or no land to spare.

Obviously, biomass, agriculture and animal husbandry form an integrated and symbiotic system. To meet the energy crisis, and the increased demands for food, fibre and feed, the only option for India is to widen her agro-forestry base. Since agriculture is indeed a dynamic, living and continuing system, the role of agro-forestry is to maintain land in a living and productive form, so that human life is sustained for a very long time to come. While agricultural waste residues are a valuable feedstock for bio-fuels which can be utilised in a number of ways for productive purposes, it is necessary to collect all the available waste residues to enable natural soil enrichment to continue through degradation by soil micro-organisms.

Although even enlightened people think that wood is a fuel of the past, it has been gaining in importance steadily as a source of energy in developed countries particularly, important as it is for the developing ones. Since there are several economic, social and environmental advantages accruing from biomass, it must receive greater attention of policy-makers, planners and funding agencies in the developing countries. Although biomass is a dire necessity for the developing world, there is greater awareness about its importance and R & D in the developed countries. Obviously, in the times to come, the latter

would make far greater use of biomass than the developing world.

While biomass goes well with the social, cultural and economic milieu of the country, there is a wide difference between the perception of a villager and a national planner about the crisis: the former sees it as a local problem and feels that wood is a gift of God and he has a right to it even by poaching; the latter sees it as a problem of denudation of forests, leading to ecological disaster. However, for the success of the programmes of firewood plantations, the most critical factor is the villager who is both their guardian and end-user. Unless he is made aware of the dire implications of destruction of forests and plant cover in general and the fact that it is in his own self-interest to preserve and make rational use of the plantations, poaching will never stop. Associated with this is the need to evolve and popularise cooking stoves which are energy efficient and smokeless. The smoke itself sometimes contains materials which may be toxic. There has to be a mass awareness programme encompassing all aspects, with people's participation. For such participatory forestry programmes, apart from the forest departments there is need for a cadre of trained 'barefoot foresters' who can work with the people.

Biomass may not be the panacea for all our energy problems, but it will, no doubt, help to reduce substantially our dependence on fossil fuels. Being socially and environmentally relevant, biomass enables us to keep our air, water and land clean and to manage our life support system in a sustained manner. Two things are needed: (i) India being a predominantly agricultural country a perceptible tilt in favour of plants and plant sciences in our planning process by adoption of the Photosynthetic Model of Development, and (ii) India has to be made increasingly greener. Among other things, such a model envisages revegetating the uncultivated half of India to make the country fresh and verdant. This would have distinct environmental, social and economic benefits and will help in the following ways:

—Conservation and improvement of soil and water by reduction of surface runoff, nutrient leaching and soil erosion, and increasing soil nutrients by addition and decomposition of litter fall; abatement of dust pollution;
—Stabilisation of catchments and watersheds;
—Control of floods;
—Better microclimate by decrease in soil surface temperature and decline in evaporation of soil moisture on account of mulching and shading;
—Conservation of biological diversity;
—Resolving energy crisis in a decentralized manner;
—Reduction of pressure on forests;
—Employment generation;
—Creation of aesthetic and pleasing landscapes;
—Better health;
—Better quality of life;
—Halting influx of rural population into urban areas; and
—Decentralised economy.

The only way to restore the forest cover is to take tree and fodder planting programmes on a priority basis under the National Rural Employment Programme (NREP) and/or the recently announced Employment Guarantee Scheme (EGS) of the Government of India. In fact, the people involved in such programmes could be organised in a Conservation Corps. Meaningful results can be obtained only if tree and fodder planting is taken up on a war footing and work started as expeditiously as possible. Even if this programme is started today, the first results would not be discernible before five years. Besides, this would instil in the young people a work ethic and a sense of pride.

The advantages of producing and utilising biomass in the social, cultural and economic milieu of India may now be enumerated.

—It is essential a decentralised energy system, being basically local and utilising locally-produced materials. Thus, it is immune to international political pressures;

—Biomass offers clean fuel/energy and keeps the environment more or less clean, there being no significant environmental pollution as compared to large-scale use of oil, coal and nuclear power. Biomass also helps to correct eco-imbalances;

—Due to fossil fuel energy-based systems, $CO_2$ content of the atmosphere has increased nearly 10 times during the past 100 years. Burning biomass, or fuels derived from it, does not alter $CO_2$ concentration in the atmosphere; in fact, it helps to recycle $CO_2$. The importance of photosynthesis, which is the basic process involved in the production of biomass, can be gauged from the fact that every year 300 billion tonnes of carbon are fixed by this process in the form of terrestrial biomass and it stores 10 times more energy than the world consumes in a year;

—Biomass provides besides fuel, a wide range of feedstocks for the organic chemicals industry, which, at present, is mostly petroleum-based;

—Bioconversion of biomass is less energy intensive and involves high sciences, but not necessarily high and capital-intensive technology;

—Biomass will utilise marginal, arid/semi-arid and uncultivated land at present lying fallow;

—Production of biomass on such land will improve soil and its water re tention capacity and there is likely to be reduction of erosion by wind and water; and

—Biomass is socially relevant, being labour-intensive, with opportunities for generation of employment/income for the poorer sections. Furthermore, the quality of life in rural areas would improve and women and children, who spend most of their time in gathering firewood, would use their time more profitably, such as for their education. It may also help in halting or reducing the rate of migration from rural to urban areas. The overriding consideration is the provision of energy to a large number of poor people very quickly and inexpensively.

Before considering one of the major disadvantages of utilising agricultural and forest residues for fuel purposes it may be pointed out that, while a good portion of crop plants is harvested, the roots and some of the above ground portions as also the leaves are left in the field. Similarly, in the forests, a lot of plant residues, roots, bark, branches and leaves, flowers and fruits that fall from the trees, remain on the ground. All crop and forest residues contain considerable proportion of nutrient elements absorbed from the soil during the growth of the plants. All nutrients in the residues are recycled to enrich the soil. In this way, a sizeable part of organic matter fixed each year is returned to the soil; besides, humus is also formed. There is, thus, a biological turnover in the soil and the cycle operates continuously, depending upon the availability of the substrates (residues). Thus, the nutrients are released in soil through a highly efficient decomposer chain, depending upon biochemical composition of litter, microbial flora and fauna inhabiting the soil and hydro-thermal conditions of the soil. However, with the removal of the residues from the field and forest, the soil would become depauperate, as there would be depletion of nutrients and lack of humus formation as also the conditioning process of the soil. Because of chronic shortage of fertilizer and other agricultural chemicals, it will not be advisable to remove the entire crop and forest residues for utilisation as feedstocks for energy. In addition to the foregoing constraint, the collection and transport of residues, which are dispersed over a large area, to the

utility sites for processing, would reduce energy gains.

Although biomass may not always be profitable on techno-economic considerations, this energy is most relevant, both socially and environmentally, due to the many intangible benefits enumerated above. The techno-economics will change materially as soon as productivity per unit area, per unit time is increased by improving plants and microbes involved in biomass production and conversion through induction of genetical and agronomical research and developmental components. One way to reduce the cost of biomass-fuels is to aim at total utilisation of biomass, e.g. rice husk not only to be used as fuel, but also as a source of a number of chemicals for a variety of uses.

**Research Needs**

Oil was discovered in 1558 and was initially valued only for kerosene, for lighting purposes, Later were developed from it natural gas, liquified petroleum gas, gasoline, fuel oils, lube oils, asphalt, paraffin, etc. By 1975, a stage of complete utilisation of a barrel of oil was reached. Now that oil is fast running out, biomass is regarded important among the promising alternatives, but complete utilisation of a tree to meet the requirements of sugar, natural and synthetic fibres, lumber, wood chemicals (like rubber, turpentine, lignin, phenols, etc.), synthetic chemicals and fuels (methanol, methane, ethanol, ethane, gasoline), etc., has not been possible so far. Technologies to accomplish the same are expected to be developed by AD 2025. Here then lies a challenge for scientists, and a radical research and development approach is needed not only for conversion and utilisation of biomass, but also for its production. The latter, among other things, requires improvement in photosynthetic efficiency. Plants with a high energy potential can be cloned and grown in high plant densities as feedstocks for cleaner fuels and energy.

As stated earlier, the R and D on energy from biomass is at a fairly advanced stage in the developed countries, because they have the requisite wide scientific base, capital and manufacturing capability for its complete utilisation. Obviously, they would reap the benefits of such researches much earlier than the developing nations for whom it is indeed a dire necessity.

Keeping in view some of the foregoing points, the immediate research needs may be enumerated as under:

—While data on commercial energy are reasonably reliable, those on biomass are rather speculative. There is, thus, a need for organisation of a database regarding location-wise pattern of biomass availability and consumption. This also includes availability and use of firewood and agricultural residues/wastes, animal dung, etc., together with information on specific energy plants;

—Before embarking on the "fuel from crop and forest residues programme", it is necessary that critical investigations are carried out on the possible consequences of biomass removal, from agricultural fields and forests in respect of the possible depauperization of soil and degradation of environment. The amount of biomass to be left in the fields and in forests for enrichment of soil by natural processes needs to be estimated, location- and species-wise;

—An R and D programme on identification and development of silvicultural, agronomic and management practices for maximising biomass production under cultivated conditions is urgently called for;

—First-tier performance trials in specific locations with specific plant species, having multiple uses, need to be undertaken as a prelude to massive afforestation/plantations for fire/fuelwood on non-agricultural land;

—Methods need to be evolved to compensate for the faster depletion of nutrients from soil due to short rotation and high density plantations;

—Research on the utilisation of agricultural residues as also aquatic biomass and municipal wastes for biogas generation requires to be undertaken;

—Research on bioconversion of lignocellulose needs to be taken up;

—The micro-organisms involved in bioconversion as also energy plants need to be genetically upgraded for high productivity and photosynthetic efficiency;

—Thermochemical processes/technologies need improvement for getting higher yield of products;

—The energy and non-energy uses of biomass need integration and byproduct utilisation requires improvement so as to enable utilisation of complete biomass;

—Wood burning stoves need improvement for attaining higher heat efficiency;

—A trained cadre of scientific and technical personnel in the area of production and utilisation of biomass needs to be created in order to enhance capabilities in this area; and

—Demonstration and awareness programmes need to be organised:

Production of energy from biomass being a multidisciplinary area, there is an urgent need for cooperation among concerned R and D agencies and departments of environment, science and technology, energy, forestry, agriculture and community development. There is also need for circumscription of the role of biomass energy for continued growth so as to achieve better balance among rural, urban agricultural, forestry and industrial needs. It may, however, be emphasized that biomass can provide most of the products now obtained from oil and, in time to come, cellulosic materials will be increasingly utilised as feedstock for this purpose.

In the end, let us hope that R and D on biomass ushers in a new society in our country, which will rely more on renewable energy, sources, such as biomass and solar technology, with smaller and more widespread industrial establishments that utilise biomass-based fuel/energy systems. This will help us to manage our life support system better, so that existence of humankind as also associated ventures such as agriculture, forestry and the relevant industry are not threatened. To achieve this, India will have to be made greener in years to come.

The domestic energy problems, particularly of the rural community and the urban poor, in a developing country are, indeed, very complex. They are closely linked with poverty and inequality. There are no magic solutions, but given the sustained commitment of the people, they are not insurmountable. If we do not give the highest priority to these questions now, the price we will have to pay in future will be colossal—ecological disaster and an economic crisis. Let us remember that good ecology is good economics.