Biomass Energy in India: Policies and Prospects

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Abstract

Despite rapid growth of commercial energy, biomass remains principle energy source in rural and traditional sectors and contributes a third of India's energy. Technologies like biogas and improved cook-stoves exist in India since half a century. The national biomass policy however has a two decades of history, emanating with the rural energy policies. In mid-seventies decade, a rural energy crisis manifested as a fallout of high oil price, population growth and depletion of wood fuel resources. Import of oil was resorted to as a short-term supply-side solution. But this was unviable in the long run. India's oil imports rose rapidly in 1970s, rising from 8% of total imports in 1970 to 24% in 1975 and 46% in 1980. High oil imports led to growing trade deficit and balance of payment crisis. At household level, a vast section of rural poor had little disposable income to spend on commercial fuels. Policy makers perceived biomass as an energy alternative that could alleviate the crisis.

The biomass strategy was multi-pronged. It focused on improving efficiency of traditional technologies, enhancing supply of biomass, introducing modern biomass technologies to provide reliable energy services at competitive prices and establishing institutional support. The DNES, established in 1982, implemented the programme for biogas and improved cook-stoves with moderate success. The programmes such as fuel-wood plantation and biomass based electricity generation have begun recently. There is a growing experience of managing biomass projects. Despite some successes, the overall impact of biomass programmes on the Indian energy scene is marginal.

The policy perspective was too narrow and supply dominated. Biomass programmes were confined to traditional applications. Market was given little role in energy supply as well as conversion. Lately, under the economic reforms, the market oriented policies are given a greater role. The upgradation of DNES to MNES in 1992, has accorded a higher status to renewable energy technology programmes. The new policies aim to promote modernization and commercialization of biomass production, combustion, densification, and electricity generation. The ninth five year plan proposes a higher support to biomass energy. A long-term techno-economic analysis using the MARKAL model shows that biomass electricity technologies have significant potential to penetrate Indian market under a fair competition with the fossil technologies. Under an optimal greenhouse gas mitigation regime, biomass electricity penetration can reach 35 gigawatt in 2035.

It is too premature to judge the effectiveness of these policies. Myriad economic, social, technological and institutional barriers remain to be overcome. The future prospects of biomass technologies depend considerably on removing these barriers. The key issue before the Indian policy makers is to develop the market for biomass energy services by ensuring reliable and enhanced biomass supply, removing the tariff distortions favouring fossil fuels and producing energy services reliably with modern biomass technologies at competitive cost.

Biomass Energy: Background

Biomass has been used as a fuel since millennia. Until the mid-19th century, biomass dominated the global energy consumption. With rapid increase in fossil fuel use, share of biomass in total energy has declined steadily over a century. Yet, biomass still contributes 14% of the world energy and 38% energy in developing countries (Woods and Hall, 1994). Globally, the energy content of biomass residues in agriculture industries annually is estimated at 56 exajoules, nearly a quarter of global primary energy use of 230 exajoules (WEC, 1994). Wood fuels, including charcoal, are the most prominent biomass energy sources. Substantial use of biomass energy in the developing countries continues to be in the rural and traditional sectors of the economy. Most biomass is not traded, but is homegrown or collected by the households. It is used very inefficiently and causes substantial health damages due to indoor air pollution.

Renewed Interest in Biomass: The improvements in biomass technology, environmental concerns like global climate change (Shukla, 1996), acid rain and the deterioration in local air quality from the use of fossil fuels have lately revived the interest in biomass energy as a renewable, sustainable and environmentally benign energy source. The rural energy crisis emanating from the low purchasing power of rural poor and the shortages of commercial fossil fuels have also contributed to the rising interest in the biomass energy. Developing country policy makers are also perceiving other economic benefits of commercial biomass, like energy availability for rural industries, rural employment and saving of foreign exchange for oil imports. Besides, energy plantations on deforested and degraded lands can also restore these lands.

Commercial Viability of Biomass: The cheapest biomass sources are the waste products from wood or agro-processing units. Their supply is however limited. The plantation grown fuels are more expensive. The average cots of plantation grown biomass in five bio-geoclimatic zones in Brazil is estimated at $1.4 per GJ (Hall et. al, 1993). Estimates of biomass feedstocks vary from $1 to $3 per GJ (Woods and Hall, 1994). At $2 per GJ, the biomass cost is equivalent to the present oil price at $ 20 per barrel. Organized production of wood fuels (through commercial or co-operative sector) and modernized conversion at appropriate scale economies therefore have potential to make biomass a competitive commercial fuel vis-a-vis the fossil fuels (Ahmed, 1993; Ravindranath, 1993). In some industrialized nations, biomass has already penetrated under competitive dynamics. USA and Sweden obtain 4% and 13% of their energy respectively from biomass (Hall et al, 1992). Countries like Sweden, who have decided to phase out nuclear plants and reduce fossil fuel energies in the next century, have plans to dramatically increase the use of biomass energy.

Wood Fuels and the Environment: Globally, carbon emissions released from combustion of wood fuels is equivalent to 0.5 PgC (Houghton, 1996). Eighty percent of wood fuel use is in tropics. If sustainably grown, the wood-fuels are essentially carbon neutral. Attributing an eighth of global deforestation to wood fuel, the contribution to the global warming of the direct CO_2 emissions from wood fuel use is estimated to be 2 percent (Ahuja, 1990). Besides net carbon emissions from deforestation, the products of incomplete combustion of wood are a cause of considerable environmental concern. Wood fuel burning on traditional stoves causes emissions of pollutants such as carbon monoxide, methane, nitrogen oxides, benzene, formaldehyde, benzo(a)pyrene, aromatics and respirable particulate matter. Primary concern of these pollutants is due to their health impacts (Smith, 1987). Annually biomass burning is estimated to emit 22 million tons of methane and 0.2 million tons of nitrous oxides (IPCC (WGII), 1996). These emissions have significant implications for climate change due to their considerably high global warming potential compared to CO_2 (IPCC, 1990).

Biomass Energy Demand and Supply in India: Status

Historically, biomass has been a major source of households energy in India. Biomass meets the cooking energy needs of most rural households and half of the urban households (Shukla, 1996). Despite significant penetration of commercial energy in India during last few decades, biomass continues to dominate energy supply in rural and traditional sectors. Estimates of the share of biomass in total energy in India varies from nearly a third (36%) to a half (46%) of total energy (Ravindranath and Hall, 1995). Biomass energy constitutes wood fuels (including charcoal, wood waste wood), crop residues (such as bagasse, rice husk and crop stalks) and animal dung (including biogas). Wood fuels contribute 56 percent of total biomass energy in India (Sinha et. al, 1994). According to the report of the National Council for Applied Economic Research (NCAER, 1985), biomass fuels contributed 90% energy in the rural areas and over 40% in the cities. According to this report, twigs accounted for 75% of household energy needs. The household energy consumption thus appears scarcely a cause of deforestation. Biomass energy is used by over a two thirds of Indian households.

Estimates of Biomass Consumption: Estimates of biomass consumption remain highly variable (Ravindranath and Hall, 1995; Joshi et. al., 1992) since most biomass is not transacted on the market. Mean estimates of biomass use (Joshi et. al., 1992) are: fuelwood-298 million tons, crop residue- 156 million tons and dung cake- 114 million tons. Low to high estimates in this report vary by over sixty percent for fuelwood to five hundred percent for the dung. Supply-side estimates (Ravindranath and Hall, 1995) of biomass energy are reported as: fuelwood for domestic sector- 218.5 million tons (dry), crop residue- 96 million tons (estimate for 1985), and cattle dung cake- 37 million tons. A recent study (Rai and Chakrabarti, 1996) estimates demand in India for fuelwood at 201 million tons (Table 1).

Table 1: Fuelwood Demand in India in 1996

Consumption of Fuelwood	Million Tons
1. Household	
(a) Forested Rural	78
(b) Non Forested Rural	74
(c) Urban Areas	10
Sub Total	162
2. Cottage Industry	25
3. Rituals	4
4. Hotels etc.	10
Total	201

Source: Rai and Chakrabarti, 1996

Biomass Policies and Programmes in India

India has a long history of energy planning and programme interventions. The programmes for promoting biogas and the improved cook-stoves began way back in 1940s decade. The afforestation and rural electrification is pursued since the 1950s decade. Organized attention to the energy situation was paid a decade before the oil crisis of 1973. The Energy Survey Committee Report was delivered in 1964. The national biomass policy originated later, in the decade of the 1970s, as a part of the rural energy policies.

Biomass as a Response to Rural Energy Crisis and Rising Oil Imports: A rural energy crisis manifested in India during the mid-1970s decade. Three factors contributed to the crisis: i) increased oil price, ii) increased household energy demand due to high population growth, and iii) depletion of local wood resources due to unsustainable use. The national policy makers needed to find economically viable and sustainable energy resource to meet rural energy needs. Although, import of kerosene and LPG for cooking and diesel for irrigation pumping remained a possible short-term supply-side solution, this was not viable in the long run due macro as well as micro economic constraints. India's oil imports rose rapidly during the decade of the seventies. Kerosene and diesel contributed most to the increasing oil imports (Figure 1). Oil imports accounted for 8 percent of total import value in 1970. Share of oil in total imports increased to 24 percent in 1975 and 46 percent in 1980 (Figure 2). Oil imports were the major cause of growing trade deficit and the balance of payment crisis. At micro economy level, a vast poor section of rural households had little disposable income to spend on commercial fuels. To ameliorate the increasing oil import burden and to meet the challenge posed by the deepening rural energy crisis, the programmes for renewable energy technologies (RETs) were developed in the 1970s decade. Biomass, being a local, widely accessible and renewable resource, was potentially the most suitable to alleviate both macro and micro concerns.

Multi-pronged Biomass Strategy: Biomass policies followed a multi-pronged strategy: i) improving efficiency of the traditional biomass use (e.g. improved cook-stove programme), ii) improving the supply of biomass (e.g. social forestry, wasteland development), iii) technologies for improving the quality of biomass use (e.g. biogas, improved cook-stoves), iv) introduction of biomass based technologies (wood gasifiers for irrigation, biomass electricity generation) to deliver services provided by conventional energy sources, and v) establishing institutional support for programme formulation and implementation. The institutional response resulted in establishment of DNES (Department of Non-Conventional Energy Sources) in 1982 and state level nodal energy agencies during the early 1980s decade.

Early Policy Perspective: The RETs programmes received a greater support with the establishment of the Department of Non-Conventional Energy Sources (DNES) in 1982. The DNES since inception had emphasized the decentralized and direct use renewable technologies. The renewable energy sources were then viewed primarily as the solution to rural and remote area energy needs, in locations and applications where the conventional technology was unavailable. In other words, RETs were never viewed as viable competitive options. Direct subsidy to the user remained a major element of the REP. The programme orientation remained supply dominated. The RET projects were pushed by the government. The biogas and improved cook-stove programmes achieved moderate successes in penetrating rural households, although their overall impact remained marginal. The alleviation of DNES in 1992 to a full fledged ministry, MNES (Ministry of Non-Conventional Energy Sources), led to the enhanced status of RET programmes.

Shift in Policy Perspective: It was increasingly realized that the failures of the biomass programmes resulted from the deficiencies in policy perspective. Firstly, the biomass was viewed solely as a traditional fuel for meeting the rural energy needs. Secondly, the policies primarily focused on the supply-side push. The market was allowed little role, both in ensuring economic and sustainable biomass production as well as in promoting efficient use of biomass. Since early 1990s decade, there has been a noticeable policy shift. Under the market oriented economic reforms policies pursued by the Government of India, the market forces are now allowed a greater role. The shift in the policy approach is characterized by: i) higher emphasis on market instruments compared to regulatory controls, ii) reorientation from technology push to market pull, and iii) enhanced role of private sector.

The new policies signify a shift in policy perspective towards biomass. The old perspective viewed biomass as a non-commercial rural resource (poor man's fuel) which has to be pushed by the government programmes. The new perspective considers biomass as a clean competitive energy resource which will be pulled commercially by energy users if the government policies help to internalize its multiple social benefits and the social costs of conventional fuels. The new policy perspective has resulted in enhanced support to the sugar cane bagasse based co-generation, improved biomass combustion technologies, biomass densification, charcoal making and decentralized electricity generation.

Policies and Programmes for Biomass based Electric Power: The organized thrust on biomass based electric power in India has a recent origin. The programme took shape after the MNES appointed the task force in 1993 and recommended thrust on bagasse based co-generation. The National Programme on Bagasse based Co-generation, launched in 1994, provided for i) the subsidies for specific demonstration projects, ii) support for R&D activities, and iii) support for training, awareness activities, and publicity. One ground for justifying the capital subsidy and financial support is that the capital cost of cogeneration plant is too high, almost equivalent to the cost of a new sugar mill. Besides, there is little institutional support for getting economic tariffs for the surplus cogenerated electricity. The programme was modified in August 1995 and subsequently in September 1996 to attract sugar mills in the co-operative and public sector. The important features of the programme are:

1) *Demonstration scheme* provides a subsidy up to Rs. 60 million per project for 12 projects. The co-operative and public sector units are offered additional benefits of 20 million per Mega Watt (MW) of surplus power comprising of subsidies and soft loans.
2) *Interest subsidy Scheme* which provides grants up to Rs. 3.5 million per MW of surplus power to financial institutions for them to reduce the interest rates on loans.
3) *Support to R&D Projects* which contribute to enhancement of power potential.
4) *Indirect Programmes*, like awareness activities such as seminars and business meets in sugar producing centers funded and run by MNES, technical support like making available services of international experts and organizing interaction meetings among

the stakeholders like state governments, utilities, financial institutions, manufacturers, consultants and project parties.

5) *International support* such as i) $ 12.5 million USAID/GEF project for promotion of alternative biomass use in co-generation using off-season and ii) an ADB line of credit of $ 100 million.

Programme for biomass combustion based power has even more recent origin. It began in late 1994 with as a Pilot Programme launched with approval of two 5 MW projects. Interest subsidy programmes on the lines of that for the bagasse based co-generation was extended in 1995. The programme also initiated a grid connected biomass gasification R&D-cum-Demonstration project of 500 Kilo Watt (KW) capacity. A decentralized electricity generation programme initiated in 1995 provided support for total of 10 to 15 MW of small decentralized projects aimed at energy self sufficiency in locals with electricity deficient rural locals.

Biomass Policies Under the Ninth Plan: The policy proposals for the ninth five year plan (April 1997 to March 2002) aim at expanded and ambitious biomass programme. Addition of five more biomass research centers to the existing nine is proposed, thereby covering all fourteen agroclimatic zones. In addition to the four existing Gasifier Action Research Centers, it is proposed establish an International Centre for Biomass Production and Conversion Technologies. Besides R&D, the centre is also proposed to provide technical assistance and training nationally and internationally. The major biomass related rural energy proposals include: i) gasifier demonstration programme for higher capacity (100 KW) systems for captive use, ii) fiscal and financial incentives for biomass briquetting with a view to enhance supply of briquettes to replace coal and oil, and iii) a village electrification pilot project by MNES through biomass gasifiers and biogas in an unelectrified remote village and coverage of 200 villages under biomass electrification during the ninth plan period. Proposals for biomass based power generation are relatively more ambitious. It is targeted to set up 500 MW biomass power capacity during the plan period. Significant allocations are proposed for R&D activities (Rs. 770 million) and technical assistance and publicity support (Rs. 90 million). It is also proposed to estimate the biomass potential in different locations in India to guide the technology promotion effort.

Biomass Technologies in India: Status

Status of biomass technologies in India is a classic reflection of the developing country duality. Technologies in rural and traditional non-market sectors remain highly inefficient. On the other hand, there exist an emerging pool of technological knowledge, experience and commercial acceptance of modern biomass technologies in the niche markets such as in wood and agro-processing industries where biomass materials are cheaply and readily available as byproducts. Whereas the vast traditional sector in India indicates the potential for improved use of biomass energy, the emerging commercial technologies demonstrate the promise to tap this potential. Typical to the developing country dynamics, a myriad barriers stagnate the technological change in the vast traditional sectors. A vast potential thus continues to remain untapped despite the available technological solutions at hand.

Rural and Traditional Biomass Use: Predominant use of biomass still continues to be in the rural household and traditional artisan type craft and industry sectors. In this segment, biomass continues to retain the tag of "poor man's fuel". On the supply side, since most biomass fuels are home grown or gathered by the households for own needs, the market for the biomass fuels does not exist. Under the circumstance, organized technological intervention in biomass production is minimal. The Government sponsored social forestry programme has however reasonably added to fuel-wood supply to the tune of 40 million tons annually (Ravindranath and Hall, 1995). Biomass energy conversion is dominated by inefficient and polluting open hearth technologies like traditional cook stoves, artisan furnaces and open fire baking for pottery and brick making.

India pioneered the biogas technology nearly half a century ago. Biogas, a combustible gaseous mixture of methane (60%) and carbon dioxide (40%) is produced in the process of anaerobic fermentation of cellulosic material like dung or other digestible biomass. India has large livestock population. Animal dung is the most used feedstock for the Indian biogas plants. Two technology designs, the floating dome and fixed dome, are used. India has one of the largest biogas programme in the world. During the last two decades under the push of rural energy programmes, efficient technologies for the household energy use such as the improved cook-stoves (22.5 million) and family sized biogas plants of 2 to 4 cubic meter per day capacity (2.4 million) and community biogas plants (1623) have been added (till March 1996) to the technology stock (CMIE, 1996c). Failures, discontinued use and below standard operation of these new technologies are widely reported (NCAER, 1992; Ravindranath and Hall, 1995). The penetration levels are only a small fraction of the potential. The overall impact of these technologies remains marginal (Ramana et. al, 1997).

Bagasse Based Cogeneration: A specific emphasis of the modern biomass programme has been on the sugar industry as co-generation in sugar mills is especially appealing. In 1993, the Ministry of Non-Conventional Energy Sources (MNES) constituted a task force to assist in the development of a National Programme on Biomass based Co-generation. The task force identified the potential of power generation from the bagasse waste of 420 sugar mills at 3500 MW and suggested initial thrust on bagasse co-generation in sugar industry. The programme began with demonstration schemes, interest subsidy scheme and support to R&D projects. Considerable efforts have been devoted to co-ordination among sugar industry, utilities, co-generation equipment manufacturers and financial institutions. Since 1994, 42 MW surplus power capacity is installed in the sugar mills.

Biomass Gasifiers for Mechanical, Thermal and Captive Power Use: Biomass gasifier technologies for small scale motive power and electricity generation was promoted in mid-eighties decade with an aim to develop and commercialize 5 horsepower engines for farm irrigation. Gasifier engines have been used also for village electrification and for captive power generation in oil extraction, saw mill and chemical units. Small gasifier technology for process heat has found applications in plywood, tea processing, coconut and rice mills. The gasifiers in these applications have penetrated where cheap processing waste, such as in rice mills and plywood units, is available as a feed-stock. In motive power applications, gasifier systems replaces diesel whereas in process heat applications it replaces coal or fuel oil. The wood gasifier engines are commercially available for water pumping (5 to 10 horse power) and power generation (3 to 100 KW). Seven manufacturers are marketing gasifiers for different applications viz. mechanical, thermal and power generation. Over 1600 gasifier systems are installed. The 16 MW capacity installed has generated 42 million Kilo Watt hour (KWh) of electricity and replacing 8.8 million litres of oil annually (CMIE, 1996c).

Despite the minor success of gasifier programme, it is a matter of concern that a quarter of the gasifiers installed are not in use. The primary reason for this failure is the distortion in capital cost of gasifier caused by the subsidy. The gasifier purchases were used as means to obtain a diesel pump-set at low cost (Ramana and Sinha, 1995) since at current subsidy level, the cost of a dual fuel mode gasifier (gasifier coupled with the diesel system) is less than the cost of the diesel set. Besides, the technological problems resulting in low utilization (less than 500 operational hours) persist due to multiple causes like the shortage of wood and substitution of wood for other uses. Technology R&D and reliable biomass supply are thus the key issues which still needs to be sorted out.

R&D and Pilot Project Experiences in Biomass Gasifier Technologies: Four gasifier Action Research Centers (ARCs) are supported at different national institutions. Twelve gasifier models, ranging from 3.5 to 100 KW, have been developed at ARCs for different applications. The large sized biomass power technologies are at R&D and pilot demonstration stage. Two co-generation projects (3 MW surplus power capacity) in sugar mills and one rice paddy straw based power project (10 MW) were commissioned. The co-generation projects have been successfully operated. The 10 MW rice straw based power project owned and operated by the Punjab State Electricity Board was completed in 1992. Immediately after commissioning it first ran into technological problems (ash slogging causing problems with clean combustion of straw) and later operational (inadequate availability of straw of right size due to recently introduced mechanical harvesting) problems. Although the ash slogging problem was solved through modification of boiler by the BHEL, the plant has been closed since last two years due to want of suitable raw material.

A rice husk based co-generation plant of 10.5 MW capacity was installed by a private rice processing firm in Punjab. The project had cost and time overruns due to import of turbine and unavailability of some critical spares (Ravindranath and Hall, 1995). After commissioning in March 1991, the plant faced problems of receiving economic price from the state utility despite power shortage in the state. The rapid escalation in the price of rice husk and low capacity utilization added to the cost making the operation uneconomical.

Biomass Combustion Technologies for Power Generation: Promotion of biomass combustion based power generation is of recent origin. The programme began in late 1994 with approval of two pilot projects of 5 MW capacity which are likely to be commissioned by April 1997. Since 1995, the interest subsidy programme is extended to cover the biomass combustion power projects. The programme aims to utilize some of the 350 million tons of agricultural and agro-industrial residues produced annually in India. The cost of electricity generation from these plants are anticipated to be quite competitive at 5 cents per KWh.

Megawatt Scale Grid Connected Power Generation: The recent thrust of the biomass power programme is on the grid connected megawatt scale power generation using variety of biomass materials such as rice straw, rice husk, bagasse, wood waste, wood, wild bushes and paper mill waste. Power generation potential from biomass gasification is estimated at 17000 MW (MNES, 1993a) and another 3500 MW (MNES, 1993b) using sugarcane residues. Reputed Indian engineering firm, Bharat Heavy Electricals Limited (BHEL) has carried out extensive trials to determine the combustion characteristics of variety of biomass materials. Several other boiler manufacturers in India have acquired the experience in designing boilers for biomass applications. Nearly 55 MW of grid connected biomass power capacity is commissioned and another 90 MW capacity is under construction. Enhanced scale has improved both the economics and technology of biomass power generation. The technology has improved lately to global standards with the Indian companies entering into joint ventures with leading international manufacturers of turbines and electronic governors.

Other Biomass Technologies: Raw biomass materials need to undergo treatment to be converted to energy carriers which are logistically easy to handle and combust. Biomass drying reduces transport load. Besides, drying is essential if feedstock is to be pyrolized, carbonized or gasified. Sorting, sizing and homogenizing of biomass materials is crucial for proper feeding and combustion. These operations are mechanized in industrialized nations and are expensive. In developing countries, manually handling these operations is cost effective. Another important pre-treatment is for increasing the bulk density of biomass materials. The briquetting process using the mechanical pressure is a commonly used technology for the purpose. While briquetting applications exist in India, the market share is still minuscule.

Enhancing Biofuel Supply: An energy crop is needed where waste materials are not available in sufficient quantities or with the suitable characteristics. Guaranteeing biomass supply at competitive costs require highly efficient biomass production system. Biomass productivity depends critically on agroclimatic factors. The Ministry of Non-Conventional Energy is supporting nine Biomass Research Centers (BRCs) in nine (of the fourteen) different agroclimatic zones with an aim to develop packages of practices of fast growing, high yielding and short rotation (5-6 years) fuelwood tree species for the degraded waste lands in these zones. Some centers are in existence for over a decade. Packages of practices for 36 promising species are prepared. Biomass yield of up to 36.8 tons per hectare per year is reported (Chaturvedi, 1993) from some promising fuel-wood species.

Although the packages of practice are developed, the knowledge is yet limited within the research circles. As a result, the benefit of the research remains to be realized. The mean productivity of farm forestry nationally remains very low at 4.2 tons per hectare per year (Ravindranath and Hall, 1995). Exploitation of bioenergy potential is vitally linked to the adequate land supply. While the use of cultivable crop land for fuel remains controversial under the "food versus fuel" debate, there exists a vast supply of degraded land which is available cheaply for fuel-wood plantations. The estimates of degraded land vary from 66 million hectares (Ministry of Agriculture, 1992) to 130 million hectares (SPDW, 1984). With improved biomass productivity and efficient energy conversion, it is feasible to sustain a significant share of biomass in total energy use in India by utilizing even a small fraction of this degraded land for biomass plantation.

Biomass Energy Projects: Selected Case Studies

There is still little but growing experience of biomass energy projects in India. A few selected case studies are briefly described below.

Biomass Gasifier for Gluten Drying: The Universal Starch Chem-Allied Ltd., a private firm, installed a 500 KWh (1.25 GCal/hr) wood gasifier system in Maharashtra State for Gluten drying in August, 1996. The gasifier unit was manufactured by an Indian Company under the demonstration programme of MNES. Gasifier replaced the drying system with a capacity of consuming 135 litres of light diesel oil per hour. The gasifier system costing Rs. 1.9 million (including Rs. 0.3 million subsidy), requires 0.4 tons of wood at capacity operation. The pay-back period for the system was estimated to be less than four years. The gasifier system is attributed with an added benefit of achieving better colour of the product.

Tea Drying System: Coonoor, a tea growing area in Nilgiris in Tamil Nadu state, has two thousand small, medium and large tea estates. Tea drying is normally done by two methods- i) indirect air heating through ducts using combustion furnaces of firewood or coal, or ii) using natural gas by direct combustion and subsequent dilution of the air to the desired temperature level for drying (120 to 130^{o}C). The latter process is common in Darjeeling and Assam tea regions where natural gas is available. In Coonoor, natural gas is not available. Firewood or coal are used for energy for tea drying. In late 1996, M/s. Gur Tea Factory at Coonoor installed a 100 KWh (250 Mcal/hr) gasifier and blower system (retrofitted with dryer) for tea drying with the producer gas at a cost of Rs. 3.1 million. The gasifier system requires only 0.3 kg of wood per a kilo gram of dried tea (3% moisture) compared to 2 to 3 kg of wood for combustion process drying tea to 15% moisture. The quality of gasifier dried tea is better as cuppage and other marketable features of tea are not only preserved but are even enhanced in some batches.

Village Electrification: Two village electrification situations with different local conditions are presented next.

1) Hosahalli, a small non-electrified village of 42 households (population over 200), is located 110 Km. from Bangalore in Karnataka State. In 1988, a small scale energy plantation (2 hectares) and gasifier cum diesel generation (5 KW) demonstration project supported by the MNES was initiated to supply electricity to specified services in the village such as water pumping, lighting and flour mill operation (Woods and Hall, 1994). The engine is modified to operate both on diesel and wood gas to ensure reliable electricity service. The gasifier system replaced 67% diesel. The system is managed by trained local personnel. Economic tariffs for electricity and water locally decided. The project investment was Rs. 350,000 and delivered electricity cost was Rs. 3.5 per KWh (14 cents) for a 4 hour per day operation.

2) Gosaba, an unelectrified remote island village with a population of 16,000, is located in Sunderbans area of West Bengal State. The village is approachable only by boat/barges from Sonakhali, located 100 kilometers from Calcutta. There is an abundant biomass potential in the region. The electricity availability can change the development pattern in the region through myriad means such as improving: i) the quality of domestic life, ii) productivity of agriculture (irrigation and dewatering of low lying areas), iii) development of agro-based and small scale industries, and iv) preservation of fish for transportation to mainland. There is an existing state owned forest on 10,000 hectare land. On a 1000 hectares of land available near the village, a successful captive plantation is promoted with standardized techniques. A quarter of the plantation yield is presently committed for local consumption and remaining is sold elsewhere at a price of Rs. 300-400 per ton. The site is ideal for biomass electricity project. A 500 KW (5x100 KW) gasifier project costing Rs. 9 million is under installation with a full financial support from MNES and the state government. The state forest department has initially guaranteed wood supply. Later, a dedicated energy plantation operated by the local community, is planned. The project anticipated to be operational in February 1997 is estimated to generate electricity at Rs. 2 per KWh (5.6 cents per KWh).

Small Scale Captive Power and Grid Interactive System: Ankur Scientific Energy Technologies, a private firm located at Vadodara city, in Gujarat state is a leading gasifier manufacture in India. The company installed a 40 KW gasifier in 1988 for meeting own power requirement during the periods of load shedding by the utility. A tree plantation with 4000 fast growing trees was set up on a private land to ensure wood supply for the gasifier. The primary aim of the system was to demonstrate the feasibility of integrated energy plantation and power generation for captive use and grid feeding. The system is supplying the surplus power to Gujarat Electricity Board since 1989 at a competitive price (Rs.1.25/KWhr).

MegaWatt Scale Grid-interactive Systems: Kutch, a desert district in the State of Gujarat, is less developed and thinly populated. The average annual rainfall in the locality is only 250 mm. The rainfall pattern is very erratic and dry spells of long duration are common. There is little industrialization in the locality. Electricity supply has the potential to change the development in the region. In 1987, MNES supported energy plantation on 1000 hectares of wasteland in Moti Sindhodi village in Abdasa locality in Kutch. The plantation completed in 1990 is estimated to yield 8-10 tons/ha/year wood in very difficult soil condition and inadequate irrigation. In 1995, a project for installation of 500 KW grid-interactive gasifier-cum-diesel electricity generation was taken up near the energy plantation site. The electricity generation is to be expanded later by adding new gasifier units since the plantations are adequate to support 3-4 MW power system. The project, to be commissioned in early 1997, is expected to generate electricity at Rs. 2.25 per KWh (6.3 cents per KWh).

Long-term Penetration of Biomass Power under Competition Dynamics

It is generally acknowledged that the economic reforms will make the energy markets more competitive in future. We analyse the long-term penetration potential of biomass in the Indian electricity sector under competitive dynamics. The analysis uses the Indian-MARKAL model (Loulou et al, 1996) set up for the next forty years (1995-2035) to examine the future energy and greenhouse gas emission trajectories for India. The analysis presumes a competitive economic environment wherein technologies compete and penetrate in suitable segments. At present, the conventional energy technologies have unfair advantage to the extent they fail to internalize the environmental costs. The environmental externalities of conventional energy resources arise from costs of local pollution as well as the costs of global climate change. Apart from the business-as-usual (BAU), we consider two policy instruments- i) subsidy to biomass technologies, and ii) reduction targets on cumulative carbon emissions, which can annul the unfair advantage to fossil energy and provide level competitive field to biomass technologies. In this perspective, the subsidy to the biomass technologies is not an energy subsidy, but a green subsidy or a credit to compensate for the environmental damage redeemed by the biomass technology.

Under the present policies in India, there are multiple modes for subsidies to renewable technologies (Sinha, 1994). In this analysis, the subsidy package for biomass power is converted in terms of equivalent subsidy on the investment cost. The high level of subsidy under current policies is nearly forty percent equivalent of the capital costs. Two subsidy scenarios with forty and twenty percent subsidies on the investment are considered. Two carbon emission reduction scenario assume respectively a 20% and 10% reduction of cumulative emissions from India over the BAU scenario.

Penetration of Biomass Electric Power Technologies: Penetration of biomass power under different subsidy and carbon emission reduction scenarios is shown in Figures 3 to 6. The biomass electricity generation technologies have substantial penetration potential. However, under the BAU scenario, the penetration in the year 2035 shall be only 4,380 MW. Evidently, the level of subsidy or emission reduction target (or alternatively a carbon tax) has significant impact on the penetration of biomass power (Figures 3 to 6). The push provided by the subsidy prompts rapid early penetration (Figure 3), where as the market pull resulting from carbon emission reduction accelerates the penetration levels only after two decades (Figure 5). Under high subsidy or high emission reduction policies, the penetration in the year 2035 reaches 35,000 MW. At this penetration level, share of biomass power capacity reaches 9 percent of total power capacity in India (Figures 4 and 6). At this level of penetration biomass replaces 80 million tons of coal and saves 40 million tons of carbon emissions annually.

While subsidy produces early penetration, this policy is financially unviable at higher penetration levels. Fortuitously, at high penetration level the generation cost shall reduce and lower subsidy support would become viable to sustain the technology penetration. In the long run, it would be more appropriate to introduce penalties on competing fossil fuels. An appropriate policy can be a mixed subsidy cum carbon tax (or greenhouse gas reduction target) policy wherein the subsidy can be provided in the short and medium run (for next 10 to 15 years) and the tax revenues collected can be recycled to subsidize the renewable technologies. A mixed policy scenario with 20 percent subsidy on biomass till the year 2010 and 10 percent cumulative emission reduction from the BAU emissions. The penetration of biomass technologies under this scenario (Figure 7), although lower compared to the high subsidy or high emission reduction scenario, will be still substantial.

Sustainability of Biomass Electricity: High penetration of biomass technologies shall require abundant supply of biomass resources. The availability of crop residues like bagasse, rice husk, coconut shells and the wood processing wastes is inherently limited by the growth of wood and agro processing industry. The present potential of power from biomass waste is estimated at 10,000 MW. High penetration of biomass power would need substantial wood supply from energy plantations. It is estimated that a 1 MW grid connected biomass combustion power plant operating 5000 hours in a year shall require nearly 6000 tons of dry wood (1.3 kg dry wood per KWh). At productivity of 8 tons per hectare per year, 1 MW plant shall require 800 hectares of land. The plantation for 20,000 MW power shall require 16 million hectares, i.e. 5 percent of total land or 12 percent of degraded land in India. The biomass penetration will be limited by the land availability. Improvements in conversion efficiency and enhanced land productivity shall be vital factors for enhancing biomass power penetration and making biomass power competitive and sustainable. The food versus fuel issue is critical for a densely populated country like India. The policy approach for India at present considers only the use of degraded land for bioenergy rather than switching the land already under crop production for energy crops. For this reason and considering the low oil prices in recent times, serious policy consideration is not given to energy crops (such as sugar cane) for producing liquid fuels to substitute oil products.

Key Issues for Biomass Energy

The most vital issue for biomass energy in India is the development of market for biomass energy services. Two broad responses to this are: i) ensuring reliable and enhanced biomass supply, and ii) provide energy services reliably with biomass technologies at competitive cost.

Reliable and Enhanced Supply of Biomass: The potential availability of agro residues (bagasse, rice husk, coconut shells etc.) and wood processing waste is estimated to sustain 10,000 MW power. The most economical option is to focus on better utilization biomass waste through: i) improved collection of agro residues and dung, ii) better utilization of waste from sugar mills and wood processing units, and iii) enlarging waste product use (e.g. briquetting of saw dust). Sustained supply of biomass will require enhanced production of energy crops (e.g. wood fuel plantations, sugar cane as feedstock for ethanol). The critical factors in this regard are: i) land supply (e.g. use of wasteland, farm periphery, woodlot), technology interventions to enhance land productivity (matching of species, plantation management), and iii) economic operations (optimal harvesting cycle, better storage to reduce losses. Enhanced reliability of biomass supply shall need adequate logistics infrastructure (transport and T&D).

Reliable Energy Services at Competitive Prices: Future penetration of biomass technologies will depend vitally on the cost and reliability of delivered energy services. Foremost option for this is the efficient conversion technologies that deliver reliable, better quality and higher level of energy services for the same biomass input. This will need modernization of biomass conversion technology and taking advantage of applications such as co-generation in sugar mills and wood processing units. A softer but effective response to improve productivity is better management of biomass systems through options like: i) shift of ownership from government to private, co-operative and community organizations, ii) professional management of biomass plantation and end-products systems, iii) improved institutional support by co-ordination with multiple agencies, iv) policy support for awareness, capacity building, technology R&D, and enacting regulations for tariff guarantees, wheeling and banking of electricity by the utilities.

Perspective Shift: In summation, what is needed in India is a shift in perspective of biomass energy strategies in the following respects: i) treating biomass as a competitive modern energy resource rather than a traditional, inefficient unclean and non-commercial "poor man's fuel", ii) enlarging biomass energy applications beyond decentralized niche markets to competitive energy service markets, and, iii) reorienting the technology policy from supply push to demand (market) pull approach, iv) integrating biomass energy policies with developmental and environmental policies.

A primary cause for inefficient biomass use in traditional sector is that the biomass fuels have little or no monetary value since these fuels are collected primarily by family labour which has little or no opportunity value (Mahadevia and Shukla, 1996). The biomass efficiency is linked with the development policies which enhance opportunity value of time such as employment policies, skill development and decentralized industrialization. In commercial energy markets, the lack of competitiveness of bioenergy is due to implicit environmental as well as other subsidies enjoyed by fossil fuels. For instance, a one KWh electricity generation in Indian coal power plants emit 0.3 Kg of carbon. The carbon emission for a one KWh delivered electricity is 0.4 kg. At a $ 50 per ton of carbon tax, the coal based electricity should be taxed 2 cents per KWh delivered. Under no carbon tax regime, coal based electricity implicitly enjoy an equivalent subsidy. Besides, the coal in India also enjoy additional environmental subsidy since it is not taxed to internalize the costs of local pollution.

Another cause affecting biomass penetration is the subsidies to fossil fuels. In India, the substitute commercial fuel for biomass in the domestic cooking sector is kerosene. In commercial energy market, the biomass competes with kerosene in domestic use and with diesel in irrigation pumping and rural electricity generation. The implicit price of biomass on the market is equivalent to replacement price of kerosene and diesel. Kerosene and diesel are subsidized in India. The kerosene is subsidized to the tune of sixty percent. Under the circumstance, the biomass producers are unable to fetch economic prices in commercial energy markets.

Future Biomass Policy and Programme Priorities: The future priorities for policy and programmes briefly shall be as follows.

Short-term (1 to 5 years):
i) enhanced utilization of crop residues and wood waste, ii) information dissemination, iii) niche applications (e.g. remote and biomass rich locations), iv) technology transfer (e.g. high pressure boiler), v) co-ordination among institutions, vi) demonstration projects, vii) participation of private sector, community and NGOs, viii) waste land development, and ix) subsidy to biomass technologies to balance the implicit subsidies to fossil fuels.

Medium Term (5 to 20 years):
i) R&D of conversion technologies, ii) species research to Match agroclimatic conditions, iii) biomass Plantation, iv) scale economy based technologies, v) Local Institutional Developments, and vi) remove distortions in fossil energy tariffs.

Long term (over 20 years)
i) Infrastructure (logistics, T&D), ii) multiple biomass energy products (e.g. gas, liquid, electricity), iii) institutions and policies for competitive biomass energy service market, and iv) land supply for biomass generation

Conclusions

There is large biomass use in India. The bioenergy is confined primarily to traditional uses such as cooking in rural households and heating in rural industries. Most biomass is not traded on the market, but is gathered or homegrown for own use by family labour. The key policy issue is to develop market for biomass energy service. A primary response is to modernize the biomass use. Lately, there has been a growing experience of modern biomass technologies in India. The penetrations of modern biomass energy services at present remain insignificant. The approach is penetrate biomass technologies through government programmes push. Due to high cost and low service reliability, the biomass energy is not yet competitive to cause significant demand (market) pull. Biomass is however competitive in niche applications such as in remote biomass rich locations and agro and wood processing industries generating cheaply available biomass waste. Biomass penetration is also hampered by implicit environmental subsidy enjoyed by fossil fuels.

A long-term techno-economic analysis using the MARKAL model shows that biomass electricity technologies under an optimal greenhouse gas mitigation regime will penetrate to over 35,000 MW of electric power (or 9 percent of India's electricity generation) in the year 2035. A major issue in the long run shall be the supply of land. With improved biomass productivity of land and higher conversion efficiency, a small fraction of degraded land may be adequate to support the market penetration during next few decades. The modern biomass programme in India is in infancy. The environmental and other social benefits shall provide opportunity for enhanced biomass penetration. Low oil prices and continued environmental subsidies to fossil fuels will cause opposite effect.

Under the circumstance, the government policies in India during the next decade shall play decisive role in the future penetration of biomass energy. It is too premature to judge the effectiveness of the present policies. Myriad economic, social, technological and institutional barriers remain to be overcome. The future prospect of biomass technologies depends considerably on removing these barriers. The key issue before the Indian policy makers is to develop the market for biomass energy services by ensuring reliable and enhanced biomass supply, removing the tariff distortions favouring fossil fuels and producing energy services reliably with modern biomass technologies at competitive cost.

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