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Biomass energy strategies for aligning development and climate goals in India

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Rapport in het kort

Biomassa-energiestrategieën om ontwikkelings- en klimaatdoelen te verbinden

De productie van moderne biomassa voor energie biedt een concrete mogelijkheid voor ontwikkelingslanden om ontwikkelings- en klimaatdoelen met elkaar te verbinden. Maar het is ook een optie die omgeven wordt door vragen met betrekking tot de duurzaamheid van de productie en consumptie van biomassa.

Dit rapport illustreert voor India de aandachtspunten die in ogenschouw genomen moeten worden bij de evaluatie van kansen en risico’s van de productie van biomassa voor energie, zoals werkgelegenheid, verminderde afhankelijkheid van de import van olie en competitie voor land en water. Het rapport eindigt met een verkenning van de mogelijke rol van biomassa in toekomstige energiescenario’s voor India.

Dit rapport is geschreven als onderdeel van het Development and Climate Programma, waarbinnen het Indian Institute for Management en het MNP, samen met een aantal organisaties uit Zuid en Noord samenwerken om te verkennen hoe ontwikkelings- en klimaatbeleid elkaar kunnen versterken.

Trefwoorden: biomassa, biobrandstoffen, ontwikkeling & klimaat, India

Abstract

Biomass energy strategies for aligning development and climate goals in India

The production of modern biomass for energy presents a concrete opportunity for developing countries to align development and climate goals, but one that is also surrounded by questions concerning the sustainability of the production and consumption of biomass.

This report illustrates for the case of India the issues that should be taken into account when evaluating the opportunities and risks that are related to the production of biomass for energy. These include employment, reduced dependency on the import of oil and competition for land and water. The report ends by giving insight in the possible role of biomass in future energy scenario's for India.

This report is written as part of the Development and Climate Programme, in which the Indian Institute of Management in Ahmedabad and the Netherlands Environmental Assessment Agency, together with a number of institutions from the South and North collaborate to explore how development and climate policies could be aligned.

Key words: biomass, bio-fuels, development & climate, India

Foreword

The production of modern biomass for energy presents a concrete opportunity for developing countries to align development and climate goals, but one that is also surrounded by questions concerning the sustainability of production and consumption of biomass. This report illustrates for the case of India the issues that should to be taken into account when evaluating the opportunities and risks that are related to the production of biomass for energy.

After providing an overview of the status of biomass in India, the report addresses the multiple dividends and possible trade offs from biomass energy in relation to key development goals of India. These include employment, reduced dependency on the import of oil and competition for land and water. The report ends by giving insight in the possible role of biomass in future energy scenario's for India. We hope that the insights in this report prove to be useful for the (inter)national debates on the sustainability of the emerging international biomass markets. For MNP this study provides important information to arrive at a balanced evaluation of the use of biomass energy in Europe and the Netherlands.

This report is written as part of the Development and Climate Programme, in which the Indian Institute of Management in Ahmedabad and the MNP (Netherlands Environmental Assessment Agency), together with a number of institutions from the South and North collaborate to explore how development and climate policies could be aligned. Finding policies and actions that can drive development and at the same time address the challenge of climate change, which is at the core of the Development and Climate Programme (www.developmentfirst.org). The programme involves case studies in Bangladesh, Brazil, China, India, Senegal and South Africa and takes local development priorities as its starting point for the analysis. A number of lessons will be drawn from national studies as a basis for global cooperation for addressing development and climate change.

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Summary

Biomass supply depends on two limiting resources, land and water. It is in demand for food and energy. In developing countries, the prominent development goals relating to food security and energy security therefore make biomass strategies a vital instrument for reconciling competing needs for land and water. As energy resource, biomass is also an important element in climate change policies. Sustainable biomass production can deliver co-benefits vis-à-vis food and energy goals, while contributing to climate change objectives. This aside, biomass strategies can deliver co-benefits like land restoration, local employment and income from timber, fruits and fodder and enhance mitigating and adaptive capacities for dealing with climate change.

Traditionally, biomass in India is used by rural and semi-urban households for domestic energy needs. Most biomass is collected by family labour – generally women – from common lands. Rising population and competing uses of land have made traditional biomass scarce, leading to unsustainable exploitation of common land and consequent deforestation and land degradation. The energy access problems for poor households are compounded by weak energy and labour markets in rural areas. Recent advancements in bio-engineering, synthetic bio-fuel processing and energy conversion technologies are offering new opportunities for transition of traditional biomass energy uses to modern bio-energy services. This transition is made viable by improving technological, organizational and institutional capabilities in developing countries and ever increasing global linkages. The long-term techno-economic analysis presented in this report shows nearly a tenth of India's electricity needs could be economically supplied by biomass technologies in 2035. Major issues in the long run relate to the supply of land and water. Innovations for increasing land productivity and plant species that grow in arid areas and energy efficient technologies are vital for mitigating competing demands on land for food and energy. While myriad economic, social, technological and institutional barriers remain to be overcome, a main issue before Indian policy makers is to develop the market for biomass energy services by removing tariff distortions favouring fossil fuels and supplying infrastructure to produce and deliver bio-energy services.

Bio-fuels deliver energy services in solid, liquid or gaseous forms. The sustainability of traditional solid biomass, fuel-wood, remains suspect. In the long-term, solid biomass fuels as grown in plantations could be sustained and could substitute coal as a fuel source for electricity and industrial heating. Biomass gasifier technology, where India has made important technology innovations, is suitable for small scale and decentralized electricity applications. Liquid bio-fuels are substitutes in transport for petroleum products, which account for sizable fraction of India's imports. Rising demand for liquid fuels, when compounded by the high prices expected for oil and carbon, portends an ominous scenario.

In conclusion, the paper argues that emerging global instruments and initiatives related to climate change, like Kyoto Protocol mechanisms and Asia Pacific Partnership on Clean

Development and Climate Change to which India is a party, can push biomass energy technologies in the early learning stage. In the long-run, however, the sustained pull for bio-energy will have to come from a competitive global energy market in which distortions in fossil fuel prices have been removed and the value of carbon emissions is accounted for in energy prices.

1 Introduction: multiple dividends from biomass energy

Biomass has been used as a fuel since millennia. Until the mid-19th century, biomass dominated global energy consumption. With the rapid increase in fossil fuel use, the share of biomass in total energy consumption has declined steadily over the past century. Substantial use of biomass energy in the developing countries continues in the rural and traditional sectors of their economies. Most biomass is not traded, but is home-grown or collected by households. It is used very inefficiently and causes substantial health damages due to indoor air pollution. Despite rapid growth of commercial energy, biomass in India contributes a quarter of primary energy use and it remains the principle source of energy for over hundred million rural households and traditional industries.

Biomass policy has nearly three decades of history in India. In the mid-seventies, a rural energy crisis manifested as a result of high oil prices, rising population, depletion of common lands traditionally supplying wood-fuels, increasing water stress and higher energy demand by irrigation-intensive agriculture during the “green revolution”. The short-term response was the increased import of kerosene for households and diesel for irrigation water pumping. But this led to growing trade deficits and balance of payment crises, besides increasing budget deficits since both these fuels were subsidized as “merit goods” needed for meeting the basic needs of poor households and farmers. An alternative policy response was needed that wasn’t economically unsustainable. Policy makers have come to perceived biomass as an energy alternative that could alleviate this crises. A multi-pronged biomass strategy was developed that 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. At the state level, nodal agencies for energy development and coordination were set-up 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 alleviating the rural household energy supply crisis. These push programmes, faced with myriad barriers to technological change, achieved only moderate success. Programmes such as fuel-wood plantation and biomass-based electricity generation followed in the 1990s. In the past few years, concerned with rising oil imports, policy makers have been looking at 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 kept energy policy makers increasingly interested in biomass energy as a renewable, sustainable and cleaner energy source. The interest in biomass energy is also sustained by potential multiple dividends like local employment, land restoration, soil conservation and afforestation, which are vital to achieving national development targets and meeting commitments to Millennium Development Goals (MDG).

2 History and status of biomass energy in India

Biomass contributes nearly a quarter of primary energy consumed in India. Biomass fuels are predominantly used in rural households for cooking and heating water, as well as by traditional and artisan industries. Biomass delivers most energy for domestic use (rural - 90% and urban - 40%) in India (NCAER, 1992). Wood fuels contribute 56% of total biomass energy (Sinha et al., 1994). Consumption of wood has grown annually at 2% rate over past two decades (FAO, 1981; FAO, 1986; FAO, 1996).

Estimates of biomass consumption remain highly variable (Ravindranath and Hall, 1995; Joshi et al., 1992) since most biomass is not traded on the market. Supply-side estimates (Ravindranath and Hall, 1995) of biomass energy are reported as: fuel-wood for the domestic sector- 218.5 million tonnes (dry), crop residues - 96 million tonnes (estimate for 1985), and cattle dung cake- 37 million tonnes. A recent study (Rai and Chakrabarti, 1996) estimates demand in India for fuel-wood at 201 million tonnes (Table 1). Supply of biomass comes primarily from fuels that are home grown or collected by households for own needs. The government sponsored social forestry programme has added to fuel-wood supply to the tune of 40 million tonnes annually (Ravindranath and Hall, 1995).

Table 1 Fuel wood demand in India in 2004

Consumption of fuel wood	million tonnes
1) Household	
a) Forested rural	83
b) Non-forested rural	65
c) Urban areas	17
Subtotal	165
2) Cottage industry	22
3) Rituals	4
4) Hotels, etc.	14
Total	205

Estimated based on Rai and Chakrabarti (1996), Ravindranath and Hall (1995), Pathak et al. (2005)

2.1 Traditional biomass energy in India

Most biomass energy in India is derived from personally owned sources like farm trees or cattle, or is collected by households from common land. Biomass energy consumption is primarily limited to meet cooking needs of households and traditional industries and services in rural areas. In absence of a developed energy market in rural areas, most biomass fuels are not traded, nor do they compete with commercial energy resources. In developing countries, due to excess labour, biomass acquires no resource value so long as it is not scarce. In the absence of an energy market, traditional biomass fails to acquire exchange value in substitution. Absence of market thus acts as a barrier to the penetration of efficient and clean energy resources and technologies.

An additional problem with traditional biomass use is the social costs associated with excessive pollution. Incomplete combustion of biomass in traditional stoves releases pollutants like carbon monoxide, methane, nitrogen oxides, benzene, formaldehyde, benzo(a)pyrene, aromatics and fine particulate matter. These pollutants cause considerable damage to health, especially that of women and children, who are often exposed to indoor pollution for long periods (Smith, 1987; Smith, 1993, Patel and Raiyani, 1997). The twin problems of traditional biomass use are energy inefficiency and excessive pollution.

Exploitation of abundant biomass resources from common lands has sustained traditional biomass consumption since millennia. Increasing pressure from growing population, growing energy needs from rural industry and commerce, and penetration of logistics infrastructure into remote biomass rich areas have now led to an unsustainable exploitation of biomass. Three main problems associated with the traditional biomass are thus inefficient combustion technologies, environmental hazards from indoor pollution and unsustainable harvesting practices. The aim of modern biomass programmes is to overcome these problems.

2.1.1 Consumption of traditional bio-fuels in India

There are three kinds of traditional biomass fuels in India – fuel-wood, crop residues and dry dung. India consumes significant amounts of these fuels (Table 2). These fuels are home grown or collected, primarily by household labour. Since this labour is not paid and since traditional bio-fuels are not traded, there is no direct economic estimate of the value of the traditional biomass. There are two surrogate ways to measure its value. One is to use the value of labour–time at the prevailing minimum wage level. The drawback of this method is that there is significant and persistent unemployment in rural areas. The second method is to value the biomass fuel by the value of the equivalent commercial fuel that would replace it. In the case of traditional biomass, most of which is used for cooking, kerosene is the surrogate replacement fuel. The kerosene replacement value for traditional bio-fuels (Table 3) is significant at US$4.88 billion, which is 0.71% of India’s GDP.

Table 2 Traditional bio-fuel consumption in India (2004)

Biomass	Consumption (million tons)
Fuel-wood	205
Crop residues	116
Dry dung	35

Estimated based on Rai and Chakrabarti (1996), Ravindranath and Hall (1995), Pathak et al. (2005)

Table 3 Kerosene replacement value of traditional bio-fuels

Fuel	billion Rs.	Bill US$	Proportion of India's GDP (%)
1. Fuel-wood	138	3.08	0.45
2. Crop-residue	63	1.39	0.20
3. Dry dung	18	0.41	0.06
Total	319	4.88	0.71

2.2 History of biomass energy policies and programmes

India has a long history of energy planning and programme intervention. Programmes for promoting biogas and improved cook-stoves began as early as in the 1940s. Afforestation and rural electrification programmes have been pursued since the 1950s. A decade before the oil crisis of 1973, India appointed the Energy Survey Committee. The national biomass policy originated later, in the 1970s, as a component of rural and renewable energy policies in response to rural energy crises and oil imports. Rural energy crises in the mid-1970s arose from four factors - i) increased oil prices ii) rising rural household energy demand (following population growth) iii) trading of wood in rural areas and urban peripheries to meet demand of growing industries, such as brick making and services in highway restaurants in the wake of sustained shortages of commercial energy, and iv) over-exploitation of common-land biomass resources. The crises called for a national policy response to find economically viable and sustainable energy resources to meet growing rural energy needs.

A short term response resorted to was the import of kerosene and LPG to meet cooking needs and diesel for irrigation pumping. In the following decade, oil imports became the major cause of a growing trade deficit and a balance of payment crisis. Nor was importing oil a viable solution at a micro-economic level. A vast section of poor households had little disposable income to buy commercial fuels. To ameliorate increasing oil import burden and to diffuse the deepening rural energy crisis, programmes for promoting renewable energy technologies (RETs) were initiated in the late 1970s. Biomass, being a local, widely accessible and renewable resource, was potentially the most suitable option with which to alleviate macro and micro concerns raised by the rural energy crisis.

2.2.1 Biomass as a response to rural energy crises and rising oil imports

In the wake of an enlarging rural energy crisis, national policy makers needed to find economically viable and sustainable energy resources to meet rural energy needs. Although the 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 1970s, with kerosene and diesel contributing most to the rising oil imports bill. The share of oil in the total value of imports, which was 8% in 1970, had increased to 24% by 1975, and by 1980 had further increased to 46% (Shukla, 1997). At a macro-economic level, oil imports became the major cause of a growing trade deficit and balance of payment crisis. At a micro-economic level, a vast – poor – proportion 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, programmes for renewable energy technologies (RETs) were developed in the 1970s. Biomass, being a local, widely accessible and renewable resource was viewed as potentially the most suitable to alleviate both macro and micro concerns.

2.2.2 Multi-pronged policy approach

Biomass policies followed a multi-pronged approach of: i) improving the efficiency of traditional biomass use (e.g. improved cook-stove programmes), 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 the establishment of Department of Non-Conventional Energy Sources (DNES) in 1982 and state level nodal energy agencies during the early 1980s.

2.2.3 Early policy perspective

The RETs programmes received greater support with the establishment of DNES. DNES since inception had emphasized decentralized and direct use renewable technologies. Renewable energy sources were then viewed primarily as the solution to rural and remote area energy needs, in locations and for applications where 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 renewable energy policies. The programme orientation remained supply dominated. 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 elevation of DNES in 1992 to become a fully fledged ministry, MNES (Ministry of Non-Conventional Energy Sources), led to the enhanced status of RET programmes.

Some of the programme achievements include the introduction of efficient and clean technologies for household energy use, like improved cook-stoves (22.5 million), family-sized biogas plants of 2 to 4 cubic meters per day (2.4 million) and community biogas plants (1623) have been added (till March 1996) to the technology stock (CMIE, 1996). Although, the biogas and improved cook-stove programmes have been moderately successful, their overall impact on rural energy remains marginal (Ramana et al., 1997). Two deficiencies in policy perspectives contributed to the slow progress in the penetration of biomass technology. Firstly, biomass was viewed solely as a traditional fuel for meeting rural energy needs. Secondly, the policies primarily focused on supply-push. Market instruments had little role in biomass policies. Under the circumstances, neither modern plantation practices for augmenting biomass supply, nor the growing pool of advanced biomass energy conversion technologies, could penetrate the Indian energy market.

2.2.4 Shift in policy perspective

It was increasingly realized that a limiting factor to the success of programmes was the restrictive perception of biomass as a traditional fuel for meeting rural energy needs and the focus on the supply-push. Since energy markets were non-existent or weak in rural areas, the traditional approach did not consider any role for markets in promoting biomass supply or efficient use. Since the early 1990s, the policy shift towards market-oriented economic reforms by the Government of India has shifted the perspective towards allowing a greater role for market forces. The policy shift is characterized by: i) higher emphasis on market-based instruments compared to regulatory controls, ii) reorientation from a technology-push to market-pull, and iii) an enhanced role for the private sector. In addition, the elevation of DNES in 1992 to become a fully fledged ministry, MNES, led to the enhanced status of RET programmes.

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) that has to be pushed by the government programmes. The new perspective considers biomass as a clean, competitive energy resource that 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 for sugar cane bagasse-based co-generation, improved biomass combustion technologies, biomass densification, charcoal making and decentralized electricity generation.

2.3 Evolution of bio-energy technologies in India

Evolution of biomass technologies in India is a classic reflection of the duality and transitions persisting in developing countries. In rural and traditional non-market sectors, highly inefficient biomass technologies persist. On the other hand, there exist an emerging pool of technological knowledge, experience and commercial acceptance of modern biomass technologies in niche markets, such as in wood and agro-processing industries, where biomass materials are cheaply and readily available as by-products. 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 for developing country dynamics, myriad barriers stagnate technological change in the vast traditional sectors. A vast potential thus continues to remain untapped despite the technological solutions available.

2.3.1 Rural and traditional biomass use

Predominant use of biomass still continues in rural households and traditional artisan type craft and industry sectors. In these segments, 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 households for own needs, a market for biomass fuels does not exist. Under the circumstances, 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 tonnes annually (Ravindranath and Hall, 1995). Wood-based 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.

2.3.2 Biogas Technology

India pioneered 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 a livestock population and 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 programmes in the world. Failure of the equipment, discontinuation of use and below standard operation of these new technologies is widely reported (NCAER, 1992; Ravindranath and Hall, 1995). Penetration levels are only a small fraction of the potential and the overall impact of these technologies remains marginal (Ramana et al., 1997).

2.3.3 Bagasse-based cogeneration

A specific focus of the modern biomass programme has been the sugar industry as co-generation in sugar mills is especially appealing. In 1993, the MNES formed 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 emphasis should be given to bagasse co-generation in sugar industry. The programme began with demonstration schemes, an interest subsidy scheme and support for R&D projects. Considerable efforts have been devoted to co-ordination among the sugar industry, utilities, co-generation equipment manufacturers and financial institutions. In March 2004, sugar mills had 613 MW installed power capacity.

2.3.4 Biomass gasifiers for mechanical, thermal and captive power use

Biomass gasifier technologies for small-scale motive power and electricity generation were promoted in the mid-1980s with the aim of developing and commercialising 5 horsepower engines for farm irrigation. Gasifier engines have been used also for village electrification and for captive power generation in oil extraction, saw mills and chemical units. Small gasifier technology for process heat has found applications in plywood manufacture, coconut processing, tea processing, and rice mills. Gasifiers have penetrated in fields where cheap processing waste, such as in rice mills and plywood units, is available as a feed-stock. In motive power applications, gasifier systems replace diesel, while in process heat applications they replace coal or fuel oil. Wood gasifier engines are commercially available for water pumping (5 to 10 horsepower) 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 have been installed. The 16 MW capacity installed has generated 42 million KWh of electricity and replaces 8.8 million litres of oil annually (CMIE, 1996).

Despite the minor success of the 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 the capital cost of gasifier caused by the subsidy. Gasifier purchases were used as means to obtain a diesel-pump set at low cost, since at current subsidy levels, the cost of a dual fuel mode gasifier (gasifier coupled with the diesel system) is less than the cost of the diesel set alone. In addition, 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. Technological R&D and reliable biomass supply are thus the key issues which still need to be sorted out.

2.3.5 R&D and pilot project experiences in biomass gasifier technologies

Four gasifier Action Research Centres (ARCs) are supported by 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, the project ran into technological problems (ash slogging causing problems with clean combustion of straw); inadequate availability of straw of the right size due to recently introduced mechanical harvesting was a later operational problems. Although the ash slogging problem was solved through modification of the boiler by Bharat Heavy Electricals Limited, the plant has been closed for the 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 the Punjab. The project had cost and time overruns due to the import of the turbine and the unavailability of some critical spares (Ravindranath and Hall, 1995). After commissioning in March 1991, the plant faced problems of getting an economically viable price for its electricity from the state utility – despite a power shortage in the state. The rapid increase in the price of rice husk and the plant’s low capacity of utilization added to the cost, making the operation uneconomical.

2.3.6 Biomass combustion technologies for power generation

Promotion of biomass combustion-based power generation is of recent origin. The programme began in late 1994 with the approval of two pilot projects of 5 MW capacity each. Since 1995, the interest subsidy programme has been extended to cover biomass-combustion power projects. The programme aims to facilitate the utilisation some of the 350 million tonnes of agricultural and agro-industrial residues produced annually in India. The cost of electricity generation from these plants is anticipated to be quite competitive at 5 cents per KWh.

2.3.7 Megawatt-scale grid-connected power generation

The recent focus of the biomass power programme is on grid-connected megawatt-scale power generation using a 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 17,000 MW (MNES, 1993a) and another 3500 MW (MNES, 1993b) using sugar cane residues. The reputed Indian engineering firm Bharat Heavy Electricals Limited (BHEL) has carried out extensive trials to determine the combustion characteristics of a variety of biomass materials. Several other boiler manufacturers in India have acquired 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.

2.3.8 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 are crucial for proper feeding and combustion. These operations are mechanized in industrialized nations and are expensive. In developing countries, manual handling of these operations is cost effective. Another important pre-treatment is increasing the bulk density of biomass materials. A briquette making process using mechanical pressure is commonly used for this purpose. While briquette making technologies exist, their use remains marginal.

2.3.9 Enhancing bio-fuel supply

An energy crop is needed if waste materials are not available in sufficient quantities or with suitable characteristics. Guaranteeing biomass supply at a competitive cost requires highly efficient biomass production systems. Biomass productivity depends critically on agro-climatic factors. The Ministry of Non-Conventional Energy Sources is supporting nine Biomass Research Centres (BRCs) in nine (of the 14) different agro-climatic zones with an aim to develop packages of practices of fast growing, high yielding and short rotation (5-6 years) fuel-wood tree species for degraded waste lands in these zones. Some centres have been in existence for over a decade. Packages of practices for 36 promising species have been prepared. Biomass yield of up to 36.8 tonnes per hectare per year have been reported (Chaturvedi, 1993) for some promising fuel-wood species.

Although the packages of practice have been developed, knowledge is limited within the research circles. As a result, the benefit of the research remains to be realized. The mean productivity of farm forestry remains nationally very low at 4.2 tonnes per hectare per year (Ravindranath and Hall, 1995). Exploitation of bio-energy potential is vitally linked to 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 cheaply available for fuel-wood plantations. Estimates of the amount 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.

2.4 Modern biomass energy transitions and trends in India

Policies under the ninth five-year plan (April 1997 to March 2002) expanded the biomass programme. Biomass research centres were expanded to cover all 14 agro-climatic zones. In addition to the four existing Gasifier Action Research Centres, it has been proposed to establish an International Centre for Biomass Production and Conversion Technologies. Besides doing R&D, it has been proposed that the centre also provide technical assistance and training, nationally and internationally. The major biomass-related rural energy proposals include: i) a gasifier demonstration programme for higher capacity (100 KW) systems for captive use, ii) fiscal and financial incentives for biomass briquette making with a view to enhance the supply of briquettes to replace coal and oil, and iii) a village electrification pilot project by MNES using biomass gasifiers and biogas in a remote village that is unconnected to grid electricity and the extension of biomass electrification to 200 villages during the ninth plan period. Proposals for biomass-based power generation are relatively more ambitious. The target is to set up 500 MW of 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 has also been proposed that the biomass potential in different locations in India be estimated to guide the technology promotion effort.

The two key areas identified for modern biomass energy transitions are: 1) decentralized electricity generation through biomass-based electric power to enhance access to electricity in rural areas and, 2) use of liquid bio-fuels as substitutes for petroleum fuels. There are other reasons that support transition to modern biomass energy like energy security vis-à-vis oil, electricity access, sustainable and affordable energy supply to the poor, employment generation, energy efficiency enhancement and the mitigation of greenhouse gases.

2.4.1 Policies and programmes for biomass-based electric power

The organized emphasis on biomass-based electric power in India has a recent origin. The programme took shape after the MNES appointed its task force in 1993 and recommended focussing on bagasse-based co-generation. The National Programme on Bagasse-based Co-generation, launched in 1994 provided for i) 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 a co-generation plant is too high, almost equivalent to the cost of a new sugar mill. Besides, there is little institutional support for the payment of economic rates for sale of surplus co-generated 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. A demonstration scheme that provides a subsidy of up to Rs. 60 million per project for 12 projects. The co-operative and public sector units are offered additional benefits of 20 million Rs. per megawatt (MW) of surplus power, comprising subsidies and soft loans.
2. An interest subsidy scheme which provides grants of up to Rs. 3.5 million per MW of surplus power to financial institutions, to enable them to reduce interest rates on loans.
3. Support for R&D Projects which contribute to enhancement of power potential.
4. Indirect programmes, such as awareness activities (e.g. seminars and business meetings in sugar-producing centres funded and run by MNES), technical support for making available services of international experts, and organizing interaction meetings among the stakeholders such as state governments, utilities, financial institutions, manufacturers, consultants and project parties.
5. International support such as i) USD12.5 million USAID/GEF project for promotion of alternative biomass use in co-generation and ii) a line of credit from the Asian Development Bank of USD100 million.

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

2.4.2 Policies and programmes for liquid bio-fuels

India's energy system has significant dependence on imported oil and petroleum products. In 2005 India imported 70% of its total crude oil requirement of 130 million tonnes, which cost nearly USD23 billion. This amounts to a fourth of the country's total imports. In 2005, India consumed nearly 50 million tonnes of diesel oil. The dependence on imported oil has emerged as a key area of concern for the country's energy security. Economic assessments show that to sustain the planned growth rates of above 7% per annum, India's petroleum product demand in 2010 would be 204 million tonnes, thus further adding to energy security concerns. The substitution of liquid fuels, especially in rapidly growing area of transportation, is perceived by policy makers as the key to the country's sustainable economic development.

The sustained high price of oil in the recent years has invigorated the search for alternate liquid energy resources. Bio-fuels are seen as eminent options both from energy security as well as rural development perspectives. The Employment Guarantee Act 2005 is another legal instrument which is prompting the integration of bio-fuels with government's economic programmes. The huge labour requirements projected for bio-fuel programmes would get support from this Act, which aims to enhance economic security for the poor by guaranteed employment in rural areas.

Two liquid bio-fuels being pushed through policies are ethanol, to blend with gasoline, and bio-diesel, to blend with diesel. These two fuels are also relatively less polluting, though their demand on land and water remain vital concerns.

2.4.3 Ethanol policies in India

Ethanol is produced in India mainly from molasses, a joint product of sugar industry. In some states, 5% blending with gasoline has already been introduced. The production process for ethanol currently followed uses molasses as the raw material. In the case of higher demand and price, ethanol production from sugar juice is feasible, especially in areas where there is surplus production of sugar cane. Sugar being an essential food commodity, the diversion of sugar cane to produce ethanol has remained a serious question within the classic debate of food versus fuel security. The periodic fluctuation in the price of sugar has been a dampener for policy makers to push for ethanol. The high irrigation and chemical fertilizer requirements of the sugar cane crop, which would divert these resources from other competing crops, has been a factor in the slow pace of formulating ethanol policies.

2.4.4 Bio-diesel programme in India

The bio-diesel programme aims at sustained and large scale production of liquid bio-fuel without impinging on vital production factors and inputs - namely cultivable land, water and fertilizer. The rising interest in bio-diesel derives from the viability to grow the crops in the vast expanses of degraded and waste lands available in the country. The choice crop is *Jatropha curcas,* which has many advantages. The crop yields from the 3rd year onwards and this can be sustained for 25-30 years. It is a sturdy crop and can survive long periods of drought. The crop can be propagated easily and needs minimal inputs or management. The crop is resistant to insect and pests and is not favoured by cattle or sheep for fodder. Jatropha seeds have high oil content and could deliver 25% oil from them by expelling and 30% by solvent extraction. The meal remaining after extraction is excellent organic manure.

India possesses nearly 65 million hectares of wastelands of which major areas could be available for reclamation through tree plantation. Considering the availability of vast stretches of wastelands, the wide adaptability of the Jatropha crop, the presence of appropriate technology for bio fuel, and the increasing demand for crude oil, the Government of India has given much importance and has launched the National Mission on Bio-diesel required for blending to the extent of 20%.

2.5 National Mission on Bio-diesel

India has the potential to plant 13.4 million hectares of land (Table 4) to Jatropha in the immediate future (Planning Commission, 2003).

Table 4 Land available for Jatropha in immediate future

Land Type	Area (million hectares)
Under stocked forests	3.0
Agro-forestry / hedges	5.0
Fallow lands / Integrated watershed development by MORD	4.4
Public land: railways tracks, roads, canals, etc.	1.0
Total	13.4

Source: Planning Commission (2003)

The National Mission on Bio diesel has proposed to cover four hundred thousand hectares under Jatropha plantation as demonstration projects covering forest and non-forest lands in various states across the country under Phase I of the mission.

Phase II of the Mission is to focus on uncovered areas during with a target to achieve 20% blending of bio-diesel with diesel. Phase II of the National Mission proposed to be people-driven with government playing the role of facilitator.

Implementation of the nationwide project for Jatropha plantation and production of bio-diesel are to be phased to meet the required quantity for blending, the percentage of which varying from 5% to 20%, which is reflected in Table 5.

Table 5 Demand for bio-diesel under different scenarios

Year	Diesel Demand Mt	Bio-diesel 5% blend Mt*	Area for 5% Mha	Bio-diesel 10% blend Mt	Area for 10% Mha	Bio diesel 20% blend Mt	Area for 20% Mha
2001-02	39.81	1.99	1.67	3.98	3.34	7.96	6.68
2002-03	42.15	2.11	1.76	4.22	3.52	8.43	7.04
2003-04	44.51	2.23	1.87	4.45	3.74	8.90	7.48
2004-05	46.97	2.35	1.96	4.70	3.92	9.39	8.28
2005-06	49.56	2.48	2.07	4.96	4.14	9.91	8.28
2006-07	52.33	2.62	2.19	5.23	4.38	10.47	8.76
2011-12	66.90	3.35	2.79	6.69	5.58	13.38	11.19

*Mha: million hectares, Mt: million tons. Source : Planning Commission (2003)

2.6 Commercial viability of bio-fuels

The cheapest biomass sources are waste products from wood or agro-processing units. Their supply is, however, limited. Plantation grown fuels are more expensive. The average cost 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 feedstock vary from $1 to $3 per GJ (Woods and Hall, 1994). At $2 per GJ, the cost of biomass is equivalent to a present oil price of $ 20 per barrel. Organized production of wood fuels (through the commercial or co-operative sectors) and modernized conversion at appropriate economies of scale, therefore, have the potential to make biomass a competitive commercial fuel vis-à-vis fossil fuels (Ahmed, 1993; Ravindranath, 1993). In some industrialized nations, biomass has already penetrated their markets under conditions of competitive dynamics. USA and Sweden obtain 4% and 13%, respectively, of their energy from biomass (Hall et al., 1992). The productivity and costs of three types of plantation-grown bio-fuels: fuel-wood, ethanol from sugar cane and bio-diesel from Jatropha plantations are described next.

2.6.1 Productivity of biomass energy plantations

The cultivation of plants for food, timber and fibre is done historically. However, there is a shortage of experience with intensive plantation for energy. Productivity estimates for biomass are based on biomass grown for food and fibre (IPCC, 1996b). The highest biomass yields achieved for large areas are those of sugar cane (Figure 1). In 1987, the global average yield of above-ground biomass was 36 dry tonnes per hectare per year (dt/ha/yr); the yield for Zambia was 77 dt/ha/yr (IPCC, 1996b). The average yield of maize is low compared to sugar cane, but comparable to wood biomass (Figure 1). The yields of woody biomass are much lower in comparison. Average yield of eucalyptus plantation grown for pulp at Aracruz in Brazil (from 1986 to 1991) was 23 dt/ha/yr; with a maximum yield of 52 dt/ha/yr (IPCC, 1996b).

Biomass productivity is lower in temperate climates. In field trials in Scandinavia, 10-12 dt/ha/yr productivity is achieved (Hall et al., 1993). In the U.S.A., the yields for poplar and switch grass are expected to reach 15-20 dt/ha/yr by 2020 under favourable conditions (Walsh and Graham, 1993). The productivity rates achieved from plantations under field conditions are lower. In India, the productivity of social forestry plantation on farm land ranges from 4.2 - 8.2 dt/ha/yr (Ravindranath and Hall, 1995).

2.6.2 Cost of plantation-grown wood fuels

The most vital elements for producing low-cost biomass are land availability and land quality. In North America and Europe, short rotation plantation forestry was initially tried on marginal crop land, poorly stocked forest land and pasture. Later, a shift was made to excess and unutilized cropland, which proved to be economical (Perlack et al., 1995). In tropical developing countries, plantations are grown on cleared and degraded forest land, marginal forest land and also some non-forest lands, including extra marginal crop land, savannah and arid crop land (Perlack et al., 1995). The establishment cost for a plantation depends on the quality of land. The cost on good crop land in U.S.A. is as low as $ 80 per hectare during each 5 to 7 years rotation. The pre-harvest costs (undiscounted) for establishment and maintenance are $660 per hectare for good crop land in U.S.A and $1850 per hectare on cane land in Hawaii. The cost of plantation establishment in Brazil ranged from $580 to $1170 per hectare, with a maintenance cost of $140 to $860 per hectare over a seven-year rotation (Couto and Betters, 1995). Harvesting costs range from $18 to $35 per dry ton for mechanized harvesting. In developing countries, harvesting costs are lower due to the low cost of labour. In China and Philippines, harvesting costs are reported to be $5 per dry ton and in Brazil $7 per dry ton (Perlack et al., 1995).

A summary of the costs and productivity of plantation-grown biomass fuel is provided in Table 6. The costs vary widely across nations, and even for sites within a nation spread across different agro-climatic zones. The costs across nations or locations are also incomparable due to factors such as land rent, government assistance, infrastructure and the quality and type of biomass fuels - which are site specific. In certain locations, the intensive biomass plantation-grown fuel can be competitive vis-à-vis the price of coal at around $2/GJ. The estimates based on commercial experience with intensive eucalyptus plantation in Brazil suggests that biomass production on 50 million hectares of land can produce 13 exajoules energy per year at an average cost of $1.7/GJ (Carpentieri et al., 1993). The average cost of plantation-grown biomass from five bio-geoclimatic zones in Brazil was $1.4 per GJ (Hall et al., 1993). A study in the U.S.A. suggests that with a strong and sustained R&D effort, biomass cost can decline to $1.5/GJ or even less by 2020 (Graham et al., 1995). Another study (Turnure et al., 1995) in the U.S.A. points to the increasing price of land due to additional demand from biomass plantation and estimates the cost of biomass to be $1.8/GJ by the year 2020. The price of coal in the same year in the U.S.A. is projected to be $1.3/GJ (EIA, 1995). Estimated costs of different biomass feedstocks vary from $1 to $3 per GJ (Woods and Hall, 1994). The organized production of wood fuels and other energy crops through intensive farming, and their conversion to useful energy with modern technologies, have the potential to make biomass a competitive commercial fuel vis-à-vis fossil fuels (Ahmed, 1993; Ravindranath, 1993).

Table 6 Summary of the costs and productivity of plantation-grown bio-fuel

Country	Delivered feedstock costs ($/GJ)	Average productivity (dry tonnes/ha/yr)
United States (mainland)	1.90 - 2.80	10 - 15.5
Hawaii	2.06 - 3.20	18.6 - 22.4
Portugal	2.30	15.0
Sweden	4.00	6.5 - 12.0
Brazil (northeast)	0.97 - 4.60	3.0 - 21.0
China (southwest)	0.60	8.0
Philippines	0.42 - 1.18	15.4

Source: Perlack et al. (1995)

2.6.3 Productivity and cost of ethanol from sugar cane

Some key factors determining the production cost of ethanol are sugar cane yield, its production cycle, sugar content in the juice, efficiency of extraction and fermentation, and value recovery from waste. At 2003 prices and cost structures, the producer would get greater value from sugar production than ethanol (Planning Commission, 2003). The cost of direct conversion of sugar to ethanol is estimated to be Rs. 20 per litre (or US$ 45 per litre), which is comparable in 2005 to the prevailing ex-factory cost of gasoline. The internalization of indirect benefits, including mitigation of carbon emissions, would make ethanol more competitive.

2.6.4 Productivity and cost of bio-diesel from Jatropha plantation

The estimate of the cost of bio-diesel production in India is shown in Table 7. The cost of bio-diesel at Rs. 14.98 to 16.59 per litre (2002 prices) is lower than the average ex-factory price of diesel in India in 2005. However, due to significant fluctuations in the oil price, the comparative advantage of bio-diesel varies with the prevailing oil price and this poses significant risk for farmers and bio-diesel manufacturers.

Table 7 Bio-diesel economics

	Rate (Rs./ kg)	Quantity (kg)	Cost (Rs.)
Seed	5.00	3.28	16.40
Collection / Oil extraction	2.36	1.05	2.48
Less cake	1.00	2.23	(-) 2.23
Transesterification	6.67	1.00	6.67
Less glycerol	40-60	0.095	(-) 3.8 – 5.70
Cost of bio-diesel / kg			17.62 – 19.52
Bio-diesel / litre			14.98 – 16.59

Source: Planning Commission (2003)

2.6.5 Environmental performance of bio-diesel cars

Direct costs apart, bio-diesel offers significant environmental advantages. Since most of these are not internalized through standards or economic regulations, neither the shadow price nor the direct environmental costs of higher emissions from unblended diesel are available in India. However, the extent of environmental benefits of bio-diesel can be gauged from the performance characteristics vis-à-vis CO_2, CO and particulate emissions shown in Figure 2.1, 2.2 and 2.3.

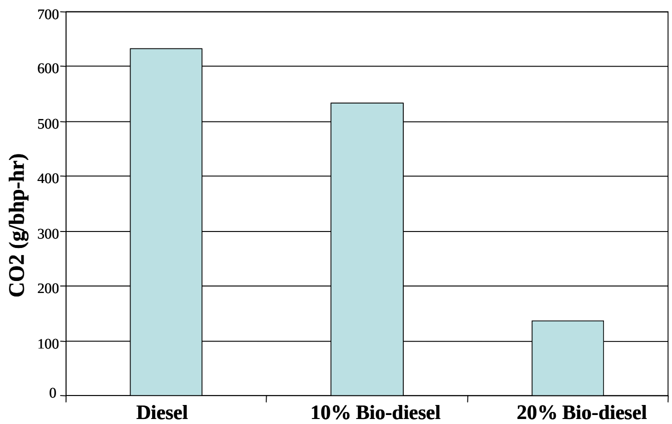
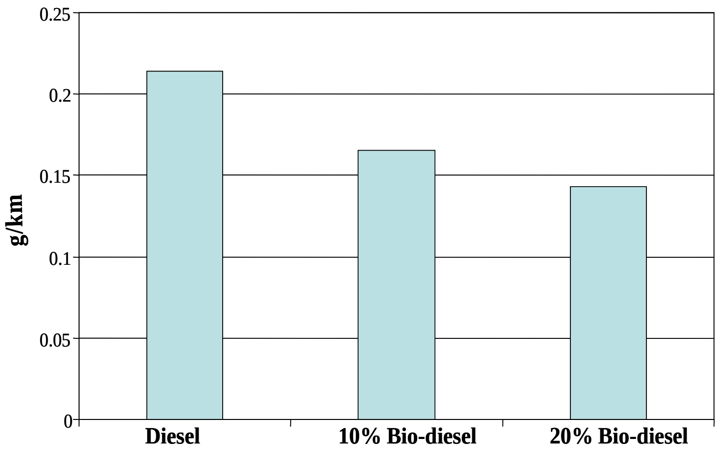
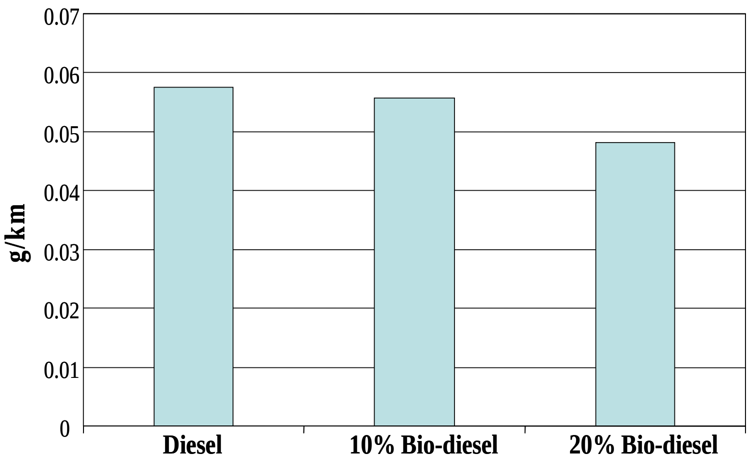


Figure 2.1: CO_2 emissions from diesel cars



Health Effects: Dizziness, Headache, Unconsciousness

Figure 2.2: Carbon monoxide (CO) emissions from diesel cars



Health Effects: Bronchial Tendency / Reduces Visibility

Figure 2.3: Particulate emissions from diesel cars

3 Biomass energy: key development and climate issues

Biomass energy, forests and climate change are vitally linked. Carbon is absorbed by plants and trees through photosynthesis and is emitted while burning or through decomposition. The world's forests, covering 3.4 billion hectares of land (FAO, 1995), or a fourth of the earth's surface, store 340 peta grams carbon (PgC or billion tonnes of carbon) in vegetation and 620 PgC in soil. Land use change contributes net additions of 1.6 PgC to the carbon flux, amounting to a quarter of fossil fuel emissions (Houghton, 1996). Only 11% of forests are managed for goods and services (WRI, 1990; Winjum et al., 1992). Average annual deforestation in the 1980s in the tropics alone was 15.4 million hectares. Forests affect the climate system from local up to continental scales by influencing ground temperature, vaporization, surface roughness, albedo, cloud formation and precipitation (IPCC, 1996a). Conversely, climate change can also impact forest ecosystems. A sustained increase of 1 degree Celsius in mean annual temperature can be sufficient to alter the growth and regeneration capacity of many trees. Warming can affect biodiversity as many tree species may need to change the habitat. Besides, warming can increase growth of pests and other biotic agents that affect forest health.

Globally, carbon emissions from combustion of wood fuels are equivalent to 0.5 PgC (Houghton, 1996). In addition, annually biomass burning is estimated to emit 22 million tonnes of methane and 0.2 million tonnes of nitrous oxides (IPCC, 1996a). These emissions have significant implications for climate change due to their considerably high global warming potential compared to CO_2 (IPCC, 1990). Eighty percent of wood fuel is consumed in tropical regions. If sustainably grown, wood-fuels are carbon neutral. Forest management and biomass plantations for energy and wood products can regenerate deforested and waste lands and create large sinks of carbon. Wood products currently hold 25 PgC (Grayson, 1994) and this amount can double if wood can substitute some other materials. A most promising long-term solution to the energy and carbon emission problem is the replacement of fossil fuels by sustainably produced wood fuels. Estimates suggest that the production of biomass for energy (wood and energy crops) has a potential to offset fossil fuel emissions by 1-4 PgC annually by the middle of next century (Sampson et al., 1993). Wood for fossil-fuel substitution reduces carbon emissions permanently, while afforestation withdraws carbon from the atmosphere for only a few decades.

Better management and a growing use of biomass offer the most promising future carbon mitigation options. Estimates (Richards et al., 1993) suggest that carbon sequestration up to about 50 PgC can be achieved over 160 years through forest plantation, at a total cost of 250 billion USD. At the present value, the average operational cost of mitigation of 77 to 99 billion tonnes through sequestration would fall within the USD1.2 to USD1.4 tC range (IPCC, 1996c). Future development of wood energy and forest policies are therefore vital to the cost effective global climate change regime. Some important biomass related policies in the context of global climate change are: i) commercial biomass fuel production, ii) sustainable wood plantation and biomass cropping practices, iii) conversion of biomass into readily usable energy forms (such as liquid or gas), iv) modernized technologies for combustion of biomass or its energy products, and v) carbon sequestration through wood and forest management practices. These policies suit not only the needs of managing climate change but are also consistent with globally sustainable economic development.

3.1 Food versus fuel security: competition for land and water

Biomass production depends critically on land and water. The key indicators of population, GDP, energy and food grain demand are shown in Table 8 and land-use in Table 9. The land competition has remained high due to fast growing population and the inability of the industrial and service sectors to generate employment-oriented growth which can deploy the increasingly young population in the rural areas. Traditionally, biomass is grown as food crops and biomass energy typically has been a waste product of agriculture production. In this, there was more synergy than conflict between food and energy security goals. The growing of bio-fuels shifts the balance of this conventional paradigm: bio-fuels compete for land and water and thus provide a basis for the food versus fuel security debate.

An enormous and rising population, and low per capita consumption of food grains, underlie the conventional wisdom in the food versus fuel (energy) security debate in India, which has historically given preference to food security over energy security from the primacy perspective. The inability of the closed economy in the pre-reform era to engage in global agriculture trade, and the persistent dual economy providing little outlet for the rural masses to overcome the subsistence mode of agricultural production created barriers to any trade-offs between food and energy security. Bio-fuel promotion policies, therefore, wherever faced with food security concern, were backed out.

However there are four factors which are now changing the logic of this debate. First is the adequacy of food-grain production vis-à-vis domestic demand and food storage. Second is the increasing use of modern inputs like water, fertilizers, pesticides and energy, which have reduced uncertainties of production, though these inputs have made agriculture more resource dependent. Third is the rising foreign currency reserve, which permits to tap into the global agriculture market to meet any short-falls. Fourth is rising global oil prices and an increasing dependency of the economy on oil imports, making energy security a greater risk to competitiveness and sustainable economic growth, which has been a paramount national goal. The bio-energy policies discussed earlier illustrates this shift in the logic.

The food-water-energy-environment nexus (Figure 3.1) manifests at micro and macro levels. At micro levels the issues relate to excess ground water irrigation and distortions in electricity tariffs, potential co-benefits from micro-watershed management, farm-level crop-mix decisions, degradation of local water resources and wood lots, and the increasing household labour time for collection of fire-wood and water. These interfaces, if managed well, also offer climate mitigation and adaptation benefits. At macro levels, the issues in this nexus arise at regional level. The key macro policy issues concern food and energy security, development of a regional energy market, stability of energy supply and prices, affordability and access to energy and water, pricing of energy and water resources, rational management of regional river systems, land competition and sustainability, and environment standards and taxes.

In the case of India, the relevant region is South-Asia. The South Asian region comprising of Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka holds a quarter of the global population, a significant fraction of which is poor. These countries have a diverse geography, climate, energy endowments and political and economic systems. They share the waters of several Himalayan rivers and have borders passing through common forest, desert and mountain lands (Figure 3.2). These countries are also diverse in energy resource endowments - with coal in India, gas in Bangladesh, hydro potential in the Himalayan nations of Bhutan and Nepal, and the strategic location of Pakistan on transit routes linking South-Asia with the vast gas and oil resources of Central Asia and the Middle East. Despite the diversity, there is little energy and electricity trade in the region. The SAARC (South Asia Association for Regional Cooperation) has existed for several decades, though the potential benefits of regional cooperation remains far from realized.

The analysis of the regional cooperation (Nair et al., 2003; Heller and Shukla, 2004) shows substantial direct, indirect and spill-over benefits via economic efficiency, energy security, water security and the environment. Energy trade would yield direct economic benefits due to energy savings from improved and enlarged fuel and technology choices and reduced investments in energy supply due to lower demand. The benefits are valued at US$319 billion for the 20 year period 2010-2030. The economic growth of the region would increase by 1% each year over the 20 year period, benefiting an overwhelming number of world’s poor.

Besides the direct benefits, South-Asia regional cooperation would deliver significant climate and local air quality benefits. The cumulative carbon saving for the period 2010-2030 would be 1.4 billion ton of carbon (or 5.1 billion ton of CO_2); or 70% of the global mitigation target for the Kyoto Protocol, including the USA. The energy changes would also reduce loads of SO_2 in region by nearly 30%, reducing SO_2 emissions by 2.5 million ton each year. In addition, balanced hydro development would yield spill-over benefits that are synergistic with adaptation needs, prominent among which are enhanced water supply and flood control. The regional cooperation would also remove barriers to rational management of common biological resources and yield coordinated actions to adapt to climate threats like the increasing incidence of hurricanes. Regional cooperation in South-Asia would accrue significant economic, environmental and security benefits to the region, besides delivering substantial climate benefits for the global community.

Table 8 India's key indicators: population, GDP, energy, food-grain demand

Year	Population (million)	GDP (billion Rs) 1999-00 Prices	Energy (MToE)	Food-grain Demand (million Ton)	Income/ Person (Rs)	Energy / Person (KgoE)	Food-grain demand/ Person (kg)	References
1980	689	6,261	208	101	9,088	302	147	1- Census, 2 ES, 3 - 10th Plan, 4 - ES Table 1.18
2000	1,021	18,704	438	168	18,318	429	165	1- Census, 2 ES, 3 - 10th Plan, 4 - ES Table 1.18
2010	1,183	32,963	523	238	27,857	442	201	1- UN, 2 IIMAa, 3 - IIMAb, 4 & 7- Cal.
2020	1,332	60,724	667	327	45,587	501	246	1- UN, 2 IIMAa, 3 - IIMAb, 4 & 7- Cal.
2030	1,449	106,712	783	434	73,641	540	300	1- UN, 2 IIMAa, 3 - IIMAb, 4 & 7- Cal.

Notes: Census: Census of India, 2000-01; UN: UN Medium scenario projections; ES: Economic Survey 2005-06, Government of India (2006); IIMAa: IIMA Estimates for GDP assuming a CAGR of 6.1% between 2004 and 2030; IIMAb: IIMA Estimates for energy consumption assuming the above GDP growth rate; Cal: Calculated assuming per capita reaches half the developed country average of 600 kg per capita (Gilland, 2002)

Table 9 Land use in India: year 2003-04

Sr. No.	Land-use category	Net land use (million hectares)	Gross Land Use (million hectares)	Reference
1	Cropland	132.86	175.65	1& 2 - India Stat (2002-03)
1.1	Food grains	--	123.32	CMIE
1.1a	Cereals	--	99.99	CMIE
	Rice	--	42.49	CMIE
	Wheat	--	26.58	CMIE
	Corn (maize)	--	7.32	CMIE
	Other cereals	--	23.6	
1.1b	Pulses	--	23.44	
1.2	Non-food crops	--		
1.2a	Oil seeds	--	23.7	
	Soybean	--	6.5	CMIE
	Castor	--	0.7	CMIE
	Groundnut	--	6	CMIE
	Other oil seeds	--	10.5	
1.2b	Sugar cane	--	4.02	CMIE
2	Forests	69.07	--	1- India Stat
3	Not available for cultivation	43.5	--	1 - India Stat
4	Pastures/ other uncultivated lands	27.42	--	1 - India Stat
5	Fallow lands	33.21	--	1 - India Stat
	Total reporting area	306.06		1 - India Stat

CMIE: Center for Monitoring Indian Economy

3.1.1 Water-energy-development: the river linking project

India receives an annual precipitation of 4,000 Billion Cubic Meters (BCM), out of which 1869 BCM runs off in various rives basins. The utilizable water resource has been assessed as 1132 BCM. Therefore, it is necessary to find out ways for augmentation of utilizable water. A proposal to interlink rivers is one option to increase the availability of utilizable water, which is one of the great advantages of this infrastructure project.

Secondly, the availability of water resources in various river basins of the country is highly uneven. While the availability of water resources in the Brahmaputra basin is of the order of 32% of the total water resources and in the Ganga 28%, it is merely 0.2% in the Sabarmati basin. Any situation with water availability being less than 1,000 cubic meters per capita in a river basin is considered by international standards as a water scarcity condition. The water scarcity in river basins is growing with increases in population. Based on this criteria and the availability of water in different river basins, water in some basins has already become scarce and many more basins are likely to become water scarce by year 2025 with the growing population.

Thirdly, even though a lot of development of water resources, especially in irrigation and hydropower sectors, has taken place in the country during the last 55 years, the situation is still be characterized by the drought–flood–drought syndrome. This is due to the fact that the distribution of India’s water resources is highly uneven. Some parts of the country receive much more than the normal rainfall, leading to floods, especially in the Ganga and Brahmaputra rivers. At the same time, some other parts receive less than the normal rainfall, leading to droughts. Every year, a number of districts in various states are hit by drought and flood, thus compelling us to seriously deliberate on the possible options for lessening the severity of such occurrences. The interlinking of major river systems would provide some respite from this distressful and iniquitous situation and remove to a great extent regional imbalances in the availability of water in different river basins of the country.

The proposed project has its origins in the proposals of the National Water Development Agency set up in 1982. The proposals acquired urgency and legitimacy from an order by the Supreme Court of India that directed the government to consider the linking of rivers by the year 2012. In December 2002, a “Task Force on Interlinking of Rivers” was appointed to prepare the schedule of feasibility studies, estimate the cost of the project, and suggest options for funding. The mega-scheme proposes to link major Himalayan and peninsular rivers through 30 inter-linking canal systems to transfer surplus waters from high rainfall areas to draught-prone areas. The scheme’s objectives include mitigation of droughts and floods, additional irrigation to 34 million hectares of land, provision of drinking water to 101 districts and five metropolises, supply of 34,000 MW of hydropower, and provision of inland water transport. The project is estimated to cost Rs. 5560 billion (or $122 billion), nearly a quarter of country’s current GDP.

Water management is central to the river-linking scheme. Thus, future climate change that could alter monsoon or the rainfall patterns over the sub-continent would also affect the project's performance. While experts and environmental groups have articulated the threat the river-linking project would pose to sustainable development (Bandyopadhyay and Sharma, 2002; Rath, 2003), the threat of climate change on the project performance is overlooked. The monsoon, rainfall patterns and the melt from Himalayan glaciers are the determinants of water flows in the rivers on the sub-continent. If the climatic changes predicted by international scientific assessment (IPCC, 2001) were to be realized during the present century, monsoon and rainfall patterns would alter (Rupa Kumar et al., 2003) and the glaciers would recede (Hasnain et al., 2003; Tangri, 2003), thus changing the annual water flow patterns in the sub-continent's rivers. This would alter the project's assumptions and the costs and benefits assessment.

The project, though itself vulnerable to the climate change, may help to reduce the vulnerabilities of other sectors. It is because this project is estimated to produce substantial amount (up to 34 Gigawatts) of non-polluting hydroelectric power and allow the substitution of a great number of fossil fuel-based transportation systems that currently cause considerable air pollution. The reduced particulate pollution might improve regional air quality, while the greenhouse gas (GHG) emissions avoided could impart benefits from the global climate change perspective. Thus, the interlinking of rivers is likely to play a significant and, at least partially, environment-friendly role in meeting the increasing energy demand of an expanding population and economy of India. That demand would otherwise be met in the long run by the consumption of additional fossil fuels, as well as bio-fuels, which emit a substantial amount of air pollutants and trace gases responsible for deteriorating ambient air quality by reducing the oxidizing power of the atmosphere. In turn, this will influence the solar radiative balance and alter local and regional climate systems (Gurjar, 2003)

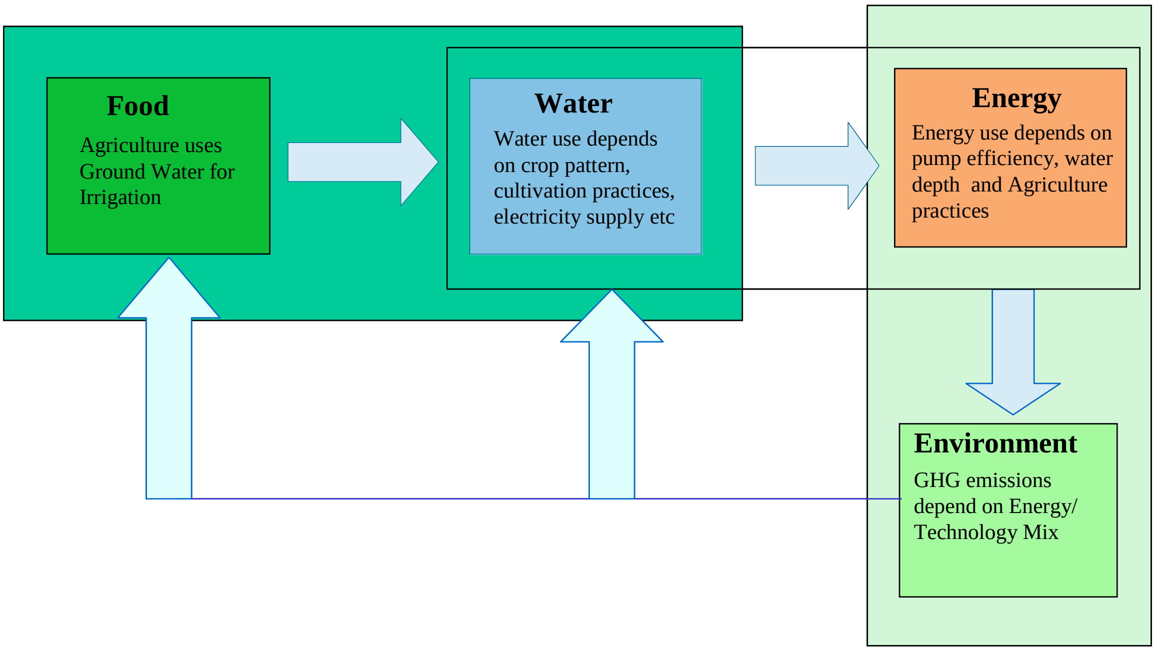


Figure 3.1: Food-Water-Energy-Environment nexus

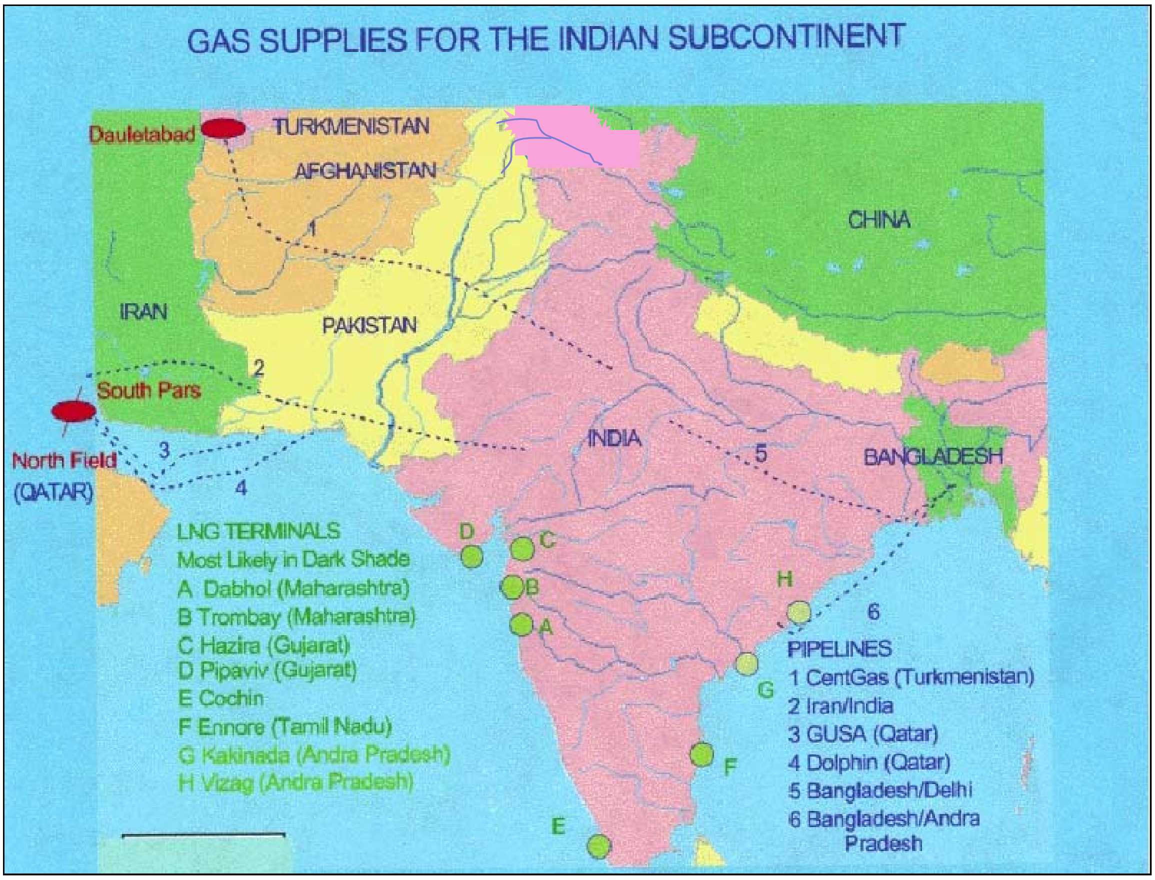


Figure 3.2: South-Asia regional energy markets and river linking

3.2 Biomass: rural energy and environment

Due to extensive use of biomass for cooking, indoor air pollution tends to be very high in rural households. This is especially true for poor households, since their houses are small and ill-ventilated. Traditional biomass stoves are energy inefficient and cause incomplete combustion. As a result, indoor levels of carbon monoxide and particulate matter tend to be very high. During the combustion of a kilogram of firewood in a wood stove, an average of 160 grams of carbon monoxide and 9.2 grams of particulate matter is emitted (Wadden and Scheff, 1983). An inefficient stove emits almost double this amount of carbon monoxide and triple the amount of particulate matter. At the same time, other pollutants such as the oxides of sulphur and nitrogen, benzopyrene, and acetaldehyde are also emitted during the combustion of biomass (Wadden and Scheff, 1983). Indoor air pollution levels are therefore extremely high in the households using biomass fuels (Table 8).

According to World Health Organization guidelines, the maximum (98 percentile limit) standards for the annual mean concentrations for black smoke and particulate matter are, respectively, 150 and 230 micrograms per cubic meter of air. As is evident from Table 10, indoor concentrations of particulate matter are usually over twenty times these levels, and are often even as high as nearly a hundred times these levels. Studies have shown that exposure to concentrations above 4,000 micrograms per cubic meter of air for 2 to 5 hours a day causes respiratory symptoms in patients with chronic bronchitis and asthma and increases the instance of respiratory diseases in children (Wark and Warner, 1981; Wadden and Scheff, 1983). Exposure to concentrations of carbon monoxide in the range of 40 to 120 micrograms per cubic meter of air for the same length of time affects the central nervous system and has significant impacts on psychomotor functions (Wark and Warner, 1981; Wadden and Scheff, 1983). The same duration of exposure to benzopyrene concentrations in the range of 2.4 to 3.7 micrograms per cubic meter of air can be carcinogenic (Wadden and Scheff, 1983).

Table 10 Indoor air pollution from bio-fuel combustion

Year	Measurement conditions	No. of Measurements	SPM concentration (per m^3)
1982	Cooking with wood	22	15,800
	Cooking with dung	32	18,300
	Cooking with charcoal	10	5500
1988	Cooking, measured 0.7 m from ceiling	390	4000-21,000
Individual exposure during cooking (2 to 5 hrs each day)			
1983	in 4 villages[(a)]	65	6800
1988	in 5 villages[(a)]	129	4700
1988	in 2 villages[(a)]	44	3600
1988	in 8 villages[(a)]	165	3700

(a) Approximately half of the cooks used cook stoves fitted with a small chimney. Source: Smith, 1987.

Indoor air pollution levels therefore have greater health consequences than outdoor air quality. Worldwide, people spend 74% of their time indoors (Smith, 1988). This is especially significant for women in developing countries, who spend longer hours indoors than men. Women spend four to five hours per day cooking (Appendix I) and are highly prone to the adverse health impacts from indoor air pollution. The indoor air pollution problem is associated with the energy crisis in the traditional sectors of developing countries and originates from biomass use. Its origin and cause is therefore identical with that of deforestation and the consequent addition of carbon flux to the atmosphere. Global warming and outdoor air quality has received greater attention from energy and environment policy makers than indoor air pollution. The health consequence of indoor air pollution is very severe and immediate, and affects most women in rural areas of developing countries, who form nearly a fourth of the population. The indoor air pollution problem deserves greater attention from policy makers of developing countries, especially if energy and environmental planning is to be gender-sensitive.

Globally, combustion of wood fuels adds an equivalent of 0.5 billion tonnes to carbon emissions (Houghton, 1996). Eighty percent of wood fuel use is in tropics. If sustainably grown, wood-fuels are essentially carbon neutral. Attributing an eighth of global deforestation to wood fuel, the contribution to global warming of direct CO_2 emissions from wood fuel use is estimated to be 2% (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 also causes emissions of other pollutants that have serious health impacts (Smith, 1987). Annually, biomass burning is estimated to emit 22 million tonnes of methane and 0.2 million tonnes of nitrous oxides (IPCC (WGII), 1996). These emissions have significant implications for climate change due to their considerably higher global warming potential when compared to CO_2 (IPCC, 1990).

3.3 Removing barriers: rural development and employment

The majority of the 700 million people inhabiting rural India live in a subsistence economy based on agriculture. After food and water, energy is perhaps the most important need for them, and given the magnitude of the population, the requirements are enormous. An overwhelming proportion of rural energy needs is for meeting the household requirements of cooking, heating and lighting. Traditionally, rural people are dependent on biomass fuels for most of their requirements. Lack of purchasing power and supply constraints have restricted the penetration of commercial fuels in rural areas and this situation is likely to continue for a long time. Excess labour and accessibility of biomass from common lands have acted as barriers to the development of energy market in rural areas. This is in sharp contrast with the urban energy system, where “commercial” fuels are supplied through organized market distribution systems.

Since biomass fuels are not purchased from the market, but are collected from various land sources by excess labour, they have “zero market cost”. In absence of an energy market, biomass energy fails to acquire monetary value. Excessive dependence on biomass for energy, in addition to growing agricultural and commercial demands, is putting enormous pressure on the natural resource base of the country, threatening the long-term ecological sustainability. The ramifications of this problem, which is inexorably assuming crisis proportions, are thus poignant for local people, especially women. Additional time and effort for collecting from depleting firewood sources not only deteriorate the women's quality of life and their reproductive functions, but also restrict access to developmental choices such as education, skills development, entrepreneurship and productive employment. Added to these are the health impacts of pollution from burning smoky biomass fuels in ill-ventilated kitchens. The rural energy system is thus not only ecologically unsustainable, but it has also become a vital barrier to human development. Solutions to the rural energy problem, therefore, lay not with energy technology responses alone, but also in development.

Despite serious developmental consequences, rural energy issues have received scant attention from the country's energy planners and social scientists. Technological and programmed interventions attempted during the past two decades - since rural energy has been recognized as an issue – have had little impact. In fact, several programmes met with failures due to a variety of techno-economic, socio-cultural and political-institutional factors, which have not been thoroughly analyzed. Whatever analysis there is, clearly points out that decentralization of planning and implementation, and involvement of local communities, are sine qua non for any rural intervention programme. While the same can be said to apply for various other rural development and welfare programmes, such an approach has yet to be adopted in a big way in the country, which entails a massive building of capacities at the micro level. Thus, rural energy interventions not only require engineering in the technological sense, but also social engineering in the sense of involving the people at the grassroots and tapping into local knowledge and innovations.

3.3.1 Bio-energy and development: employment and women’s labour

The poor in developing countries mainly consume energy for cooking and lighting. Their fuel choices are limited to bio-fuels and kerosene; the latter is used both for cooking and lighting. Electric lighting, even by an incandescent bulb, is ten times more energy efficient that a kerosene lamp. Even at subsidized prices, kerosene remains the most expensive lighting fuel. For cooking, the rural poor use biomass which is collected by family labour. If collection time is valued at the minimum wage (Mahadevia and Shukla, 1997), biomass energy is the most expensive cooking fuel. However, rural labour markets are incomplete and inefficient and there is little or no opportunity value of labour time, especially that of women. Land rent is also not paid since the bio-fuels are collected from common land. Thus, biomass energy appears as a “free” good to the family and is neither substituted nor used efficiently. Harvesting from open access lands has reached an unsustainable level, causing deforestation (WRI, 1996) and adding to the greenhouse gas flux.

Labour spent on domestic activities and many traditional sector activities is not paid for monetarily. The lack of overall employment opportunities affects women more. Since men are not responsible for reproductive activities, they have greater flexibility and get preference when applying paid jobs. Women are thus relegated to unpaid and casual tasks. Their time has little opportunity value. Consequently, the penetration of technology in the traditional sector tends to first ease the jobs done by men. For instance, manual ploughing which is a heavy task performed by men, is substituted for by tractors. Women's tasks, such as weeding or plucking tea leaves and berries, are still performed by hand. For the same reason, domestic appliances that ease women's household work, many of which are also more energy efficient and less polluting, also find slow penetration in the traditional sector.

The traditional division of labour that allocates women’s time to reproductive activities deprives them of education and formal training for skills. The low value of women’s labour translates into a low economic value of life, and emotions and, social values aside, has provided little reason for correcting indoor air pollution as a cause of the large death toll and ill health in the world (Smith, 1987). The solution lies not in the energy or technology domains, but in development that enhances rural employment and women's education, alters land relations and creates infrastructures. The resulting income augmentation, greater education opportunities and improved market access would promote development goals like employment, gender justice and also, simultaneously, climate goals.

3.4 Biomass, national development goals and climate

In many other developing countries, national development policies are capitalizing on synergies between development priorities and climate benefits. Since the beginning of the new millennium, at various global forums policy makers have committed to goals that are synergistic to both development and climate change, such as the Millennium Declaration at the UN Millennium Summit (2000), the Johannesburg Declaration at the World Summit on Sustainable Development (2002) and the Delhi Declaration on Sustainable Development and Climate Change at the Eighth Conference of Parties (COP 8) to the UNFCCC (2003). Initial National Communications (NATCOM) from key developing countries amply articulate the close nexus between national sustainable development and climate change strategies.

India's national communication refers to the close relationship between millennium development goals, India's Tenth Five Year Plan targets and climate change concerns (Table 11). The debate in India (Shukla et al. (eds.), 2003) suggests explicit attempts for linking national development targets and climate actions with globally agreed sustainable development goals (Table 11). According to India's NATCOM, several environmental measures taken for reasons other than climate change, though keeping in view the commitment to UNFCCC, have been synergistic to the needs of future climate actions: "… the introduction of landmark environmental measures in India that have targeted conservation of rivers, improvement of urban air quality, enhanced forestation and significant increase in installed capacity of renewable energy technologies. These deliberate actions, by consciously factoring in India's commitment to UNFCCC, have realigned economic development to a more climate friendly and sustainable path." India's NATCOM further articulates the relationship between development and adaptation to climate as under: "Though the Government of India has taken many policy decisions that reduce risks and enhance adaptive capacity of the most vulnerable sectors and groups by promoting sustainable development, considerable scope exists for including more measures to cover the entire range of impacts due to present climate variability. Faster economic development with more equitable income distribution, improved disaster management efforts, sustainable sectoral policies, careful planning of capital intensive and climate sensitive long life infrastructure assets are some measures that will assist India in reducing its vulnerability to climate change." India's NATCOM discusses a variety of case examples in vital areas like water management, soil conservation, sustainable agriculture, health policies, disaster management, infrastructure design and energy policies where development and adaptation actions would benefit through an integrated and long-term approach.

Table 11 Selected Millennium Development Goals (MDGs), related Indian targets, climate change and bio-energy interfaces

MDGs and global targets[1]	**India's 10th plan (2002-2007) & beyond targets**[2]	**How are these linked to climate change and bio-energy?**
MDG 1: Eradicate extreme poverty and hunger **Target 1**: *Halve, between 1990 and 2015, the proportion of people whose income is less than $1 a day* **Target 2**: *Halve, between 1990 and 2015, the proportion of people who suffer from hunger*	▪ Double the per capita income by 2012 ▪ Reduce poverty ratio by 15% by 2012 ▪ Reduce decadal population growth rate to 16.2% between 2001-2011 (from 21.3% during 1991-2001)	▪ Bio-energy can be a key resource for achieving the income targets since its production could enhance rural employment and substitute oil imports ▪ Sustainable biomass production shall mitigate carbon mitigation emissions by substitution of fossil fuels ▪ Achieving poverty targets would enhance adaptive and mitigating capacity for climate change. ▪ Lower population will reduce pressure on land, water and energy consumption.
MDG 7: Ensure environmental sustainability **Target 9**: *Integrate the principles of sustainable development into country policies and programmes and reverse the loss of environmental resources* **Target 10**: *Halve by 2015 the proportion of people* without sustainable access to safe drinking water **Target 11:** *Have achieved by 2020 a significant improvement in the lives of at least 100 million slum dwellers*	▪ Increase forest/tree cover to 33% by 2012 (23% in 2001) ▪ Sustained access to potable drinking for all villages by 2007 ▪ Commission 14.4 GW hydro- and 3 GW other renewable power capacity between 2002-2007 ▪ Electrify 62,000 villages by 2007 through conventional grid expansion; remaining 18,000 by 2012 through decentralized non-conventional renewable energy sources. ▪ Clean all major polluted rivers by 2007 and other notified stretches by 2012	▪ Increased forest/tree cover will create a carbon sink ▪ Sustained and higher supply of biomass will enhance energy security and reduce fossil-fuel emissions ▪ Reduced pressure on land, water and ecosystems will enlarge adaptation options ▪ Better quality of life and adaptive capacity from access to electricity and clean resources ▪ Enhanced reach of health/education facilities dependent on electrical equipment and flexibility of economic activities in rural areas

MDG 8: Develop a global partnership for development **Target 18**: *In cooperation with the private sector, make available the benefits of new technologies, especially information and communications technologies*	▪ Greater integration with the global economy ▪ Create 50 million employment opportunities by 2007 and 100 million by 2012 (current back-log of unemployment is around 9%, equivalent to 35 million persons)	▪ Higher mitigative capacity from access to global energy resources and technologies, including emerging bio-energy technologies ▪ Greater adaptive capacity from access to global technologies and access to advanced information and communication systems ▪ Enhanced flexibility of jobs and migration

[1] Human Development Report, 2003, United Nations Development Programme

[2] Planning Commission, Government of India, 2002a, Tenth Five Year Plan, Vol. 1 (pp 6-8), Vol. 2 (pp 108, 117, 909, 914, 927

4 Integrating climate with economic sustainable development

The growing literature on this theme (Munasinghe and Swart, 2000; Banauri et al., 2001; Markandya and Halsnaes, 2002; Heller and Shukla, 2003; Swart et al., 2003, Wilbanks, 2003) follows two alternate perspectives. The conventional view, reflected in much of the literature, emphasizes the co-benefits of climate change mitigation and adaptation actions on sustainable development goals, such as enhancing local air quality or land conservation. The focus is to ensure that climate actions are not adversarial to local or national development goals. The alternate approach views climate change through the lens of sustainable development. It acknowledges that the driving forces of emissions as well as the adaptive and mitigative capacities (Yohe, 2001) are shaped by the development path. This view frames the debate from the starting point of development priorities rather than environmental concerns.

The IPCC Third Assessment Report (IPCC, 2001) concluded that alternative development paths can result in very different greenhouse gas emissions. Decisions about technology, investment, trade, poverty, biodiversity, community rights, social policies, or governance, which may seem unrelated to climate policy, may have profound impacts upon emissions, the extent of mitigation required, and the costs and benefits that result. Development paths leading to low emissions depend on a wide range of policy choices and require major policy changes in areas other than climate change. Different development pathways have a large effect on the costs of mitigation and the path chosen can be as important as the emissions target in determining overall costs (Hourcade and Kostopoulou, 1994). Conversely, climate policies that implicitly address social, environmental, economic and security issues may turn out to be important levers for creating a sustainable world.

Studies in developing countries shows significant greenhouse-gas emissions reductions through development actions motivated by poverty alleviation, local environmental protection and energy security. Six developing countries – Brazil, China, India, Mexico, South Africa and Turkey – have reduced their GHG emissions over the past three decades by approximately 300 million tonnes a year (Chandler et al., 2002). The emissions for these six countries, excluding these measures, would have been 18% higher in the year 2000. Their emissions reduction was not far from the annual mitigation target of emissions by the industrialized nations in Kyoto protocol (Chandler et al., 2002), including the commitment made by the United States of America at Kyoto in 1997.

4.1 Mainstreaming climate change into development choices

The question to be addressed in future climate agreement is: “how can climate change be mainstreamed into development choices to create pathways having lower emissions and higher mitigative and adaptive capacities? Heller and Shukla (2003) argue the case for mainstreaming by an inclusive strategy that promotes the climate cause through innumerable economic development actions that happen daily everywhere, rather than following the current climate strategy that marginalizes the climate cause by pursuing exclusive climate specific actions. Based on a number of Indian case studies, Heller and Shukla (2004) propose operational guidelines to integrate development and climate policies in the future development pathways of developing countries.

Among the most important development choices to be made with relevance to climate change are those in the energy sector. Energy services are crucial for development and for providing adequate food, shelter, clothing, water sanitation, medical care, schooling and access to information. Availability of energy is one of the key determinants of poverty and development. Increased access to safe energy and energy services can have several consequences for climate change, depending on the pathway. Specifically in the field of energy, the results of some policy actions aiming at advancing energy efficiency and renewable energy use confirm that although developing countries need to increase their energy consumption in order to fuel their social and economic development, there are policy options for advancing a cleaner and more sustainable energy future and these policy choices can have a significant impact on energy trends, social progress and environmental quality in developing countries (Geller et al., 2004). Access to clean energy has several direct and indirect effects on well-being, including reduced birth mortality rates, increased life expectancy and reduced pressure on resources. The net effect of enhanced access to sound energy on greenhouse gas emissions depends on the balance of all direct and indirect effects.

There are a host of other development policies and actions that relate to climate change. Urban development is one key aspect. Differentiated structures of settlements, in turn generate widely differentiated emissions through transportation. Nivola (1999) shows how divergent policies in Europe and the United States since 1945 have shaped widely different structures for cities, and in turn widely different demands for transport services, energy consumption (Newman and Kenworthy, 1991) and CO_2 emissions. Financial policies, like differentiated taxes on gasoline, which are implemented for budgetary reasons and not for environment or climate change reasons have led over the course of half a century to the higher energy efficiency of cars in Europe than in the United States, and therefore to lower emissions per passenger-km travelled.

It is possible and advisable to incorporate climate concerns into evolving political and economic conditions. The resulting new political framework can stimulate that climate-benign, non-climate actions lead to new commercially sustainable markets. Organizational and political changes can create opportunities that can be taken up by existing businesses into innovative ventures, requiring the forging of coalitions between mainstream policy agencies and private actors (Heller and Shukla, 2004). Within such wider and inclusive contexts, marginal instruments like CDM can still play a role as one element of national sustainable development strategies that tie in with climate mitigation.

Evidently, the policies implemented to meet sustainable development goals can have important impacts on national greenhouse gas emissions and the capacity to mitigate and adapt. The direction and magnitude of the changes vary depending on the policy and on national circumstances. Some general lessons that emerge are: i) in a country, the sectors that are farther away from the production frontier offer opportunities for multiple dividends by freeing resources to meet sustainable development goals and, in addition, reduce GHG emissions, ii) national circumstances, including endowments in primary energy resources and institutions (World Bank, 2003), matter in deciding the extent to which development and climate benefits are ultimately realized, iii) over time, win-win opportunities would diminish as markets and institutions in developing countries get organized; therefore global climate agreements in any period should pay special attention to accrue direct multiple dividends in the near-term and avoid the risk of lock-in from high-emission scenarios due to path dependence.

4.2 Combining mitigation and adaptation policies

The Third Assessment Report (TAR) of the IPCC brought into focus the institutional and developmental context of climate change mitigation and adaptation policies. The key concepts introduced were those of mitigative and adaptive capacity (Yohe and Moss, 2000), their commonalities and their links to development and institutional policies. Policies that enhance adaptive and mitigative capacities can include a wide range of general development policies, such as market reforms, education and training, improving governance, health services, infrastructure investments and so on. Adaptation and mitigation can come about from individual or public initiatives such as investments in protective measures like dikes, new crops, low-carbon emitting technologies, carbon taxes, etc., that are implemented taking into account the institutional structure of the society and the state of nature.

There are numerous synergies and trade-offs between the adaptive and mitigative capacity elements of socio-economic and natural systems, as well as between specific adaptation and mitigation policies. Building more highways, for example, can generate more traffic and more GHG emissions. However, highways can also improve market access, make agriculture less vulnerable to climate change, help in evacuation prior to big storms, and can support general economic growth and thereby investments in new efficient production technologies. The mitigation cost of wind turbines that can substitute for alternative coal power projects depend on the power market, grids, land costs, financial markets, etc.; many of these also influence how adaptation measures like irrigation and improved management practices can be implemented in agriculture. The GHG mitigation potential and cost of energy efficiency policies for households and industry sectors depend on the dynamics of the economic structure and policies vis-à-vis energy-intensive industries, investments in new production facilities, and the lifestyle of households. Similarly the vulnerability of resource-dependent sectors to climate change, and its impacts for the economy at large, will depend on the extent of flexibility or lock-ins inherent in the structure of industry or lifestyles of households.

4.2.1 Combining mitigation and adaptation: policies and projects

Global climate policies have traditionally focused on mitigation, as it deals with the origin of the climate change problem. Lately, adaptation is receiving due attention within the comprehensive global climate policy framework (Smith, 1997; UNEP/IVM, 1998; Kates, 2000; IPCC, 2001; Adger, 2001; Burton et al., 2002; Huq, 2002). There is also a growing recognition of the significant role of developing countries in the mitigation and adaptation policies (Müller, 2002). As evident from national communications of key developing countries, their governments are committed beyond addressing whether or not to implement climate measures; The questions now are how involved these measures should be, which of the committed measures are climate-friendly, and how to design integrated climate policies that are aligned with national sustainable development paths (Brazil’s INC, 2004; China’s INC, 2004; India’s INC, 2004; South Africa’s INC, 2001)? Despite increased awareness of the need to link climate policy with national sustainable development plans, there is little evidence of integrating climate mitigation and adaptation policies. This can be attributed to the perception that commonalities are small, jurisdictions are different, and the costs and benefits are differentially distributed.

Recent literature reports some national studies that address linkages between mitigation and adaptation (South Africa’s INC, 2003; India’s INC, 2004; Shukla et al. (eds.), 2003). There are also a few studies which suggest policy frameworks for harmonizing climate change mitigation and adaptation responses (Burton et al., 2002; Kapshe et al., 2003; Dang et al., 2003). Several of these studies also highlight co-benefits from investments in human development, technology cooperation and transfer, and local initiatives. There are three areas in developing countries where co-benefits from integrating mitigation and adaptation actions are significant: i) biomass, land-use and unmanaged ecosystems, ii) water management, and iii) agriculture.

Biomass and land use policies have high synergies and substantial co-benefits for climate change mitigation and adaptation. For instance, the PROALCOOL in Brazil, illustrates the substantial benefits from policies that promote biomass energy as a substitute for fossil fuels. In addition, biomass energy delivers added benefits from local employment, energy security and foreign exchange savings for countries that import fossil fuels. The stored energy in synthetic biomass fuels could flexibly replace fossil fuels in direct applications and could also be a potential feed-stock for renewable hydrogen and electricity generation (GTSP, 2001). Biomass plantations on surplus land and waste lands could offer several spill-over benefits such as income for forest dependent communities, employment of surplus agriculture labour (Planning Commission, 2002b) and land conservation, in addition to enhancing the adaptive capacity of local communities. Opportunities for developing bio-energy exist in many developed countries that can use and also transfer these technologies to developing nations under global cooperative agreements (Faninger, 2003).

In the forestry sector, opportunities for linking mitigation and adaptation exists in afforestation and reforestation projects, such as commercial bio-energy, agro-forestry, forest protection and forest conservation through sustainable management of native forests (Masera et al., 2001). There are many country specific case-studies highlighting these options (Fearnside, 2001; Ravindranath et al., 2001; Asquith et al., 2002). For example Amazonia contains more carbon than a whole decade of global, human-induced CO_2 emissions (60–80 billion tonnes). Projected increases in Amazon deforestation due to investments in roads and other infrastructure could increase carbon emissions, counterbalancing nearly half of the reductions in carbon emissions that would be achieved if the Kyoto Protocol were implemented (Carvalho et al., 2004). Projects that help contain deforestation and reduce frontier expansion can play an important role in climate change mitigation. In addition, these projects have other developmental and adaptation benefits, such as decreasing migration of young rural population to cities, protection of biodiversity and conserving watershed and soils.

In most developing countries, incomes of farming communities derive from rain-fed cultivation. Changing precipitation patterns and enhanced evaporation due to higher temperatures could alter water demand for agriculture. The increased water stress, due to the dual effects of unsustainable water consumption and climate change, would make these communities more vulnerable. Water deficits increase greenhouse emissions because of the dual effects of increased energy demand for pumping and reduced electricity generation from hydro-electric projects (Shukla et al., 2004). Sustainable water management projects like rainwater harvesting, watershed development, drip irrigation, zero tillage, bed planting, multiple-cropping systems, crop diversification, agro-forestry and animal husbandry are win-win-win solutions as they simultaneously deliver development, mitigation and adaptation benefits. Policies such as those aimed at changing cropping practices and patterns, flood warning systems and provision of crop insurance also deliver similar multiple benefits (India's INC, 2004).

5 Biomass strategies for aligning development and climate goals

The most vital factor underlying future trends in biomass use is the increasing commercialization of biomass energy. In rural areas of developing nations, the energy market is underdeveloped. Most biomass fuels are therefore not traded, nor do they compete with commercial energy sources. In the presence of excess labour, biomass energy acquires no resource value so long as it is not scarce. Due to underdeveloped energy markets, traditional biomass fails to acquire exchange value in substitution. The absence of markets has thus far acted as a barrier to the penetration of efficient and clean biomass energy technologies.

5.1 Transition to modern bio-fuels

As incomes rise in developing nations, traditional biomass is increasingly substituted by more efficient and cleaner fuels along the fuel ladder, thereby causing a steady decline in its share in total primary energy. The shift has a history. The oil crisis of two decades ago prompted governments of oil-poor countries to look for energy alternatives. Brazil responded with an ethanol programme and the Philippines promoted a biomass power programme. It is well recognized that the future of biomass is along the commercial route. Policies to internalize the externalities of competing fuels will play a vital role in the future penetration path of biomass energy. Modern technology and markets are set to transform biomass from an inefficient and unclean traditional fuel into an efficient and clean fuel that is produced and consumed using modern technologies and that can compete in a market. Modern biomass technologies are now achieving performance standards (Reddy et al., 1997) which make them competitive vis-à-vis conventional energy forms, especially if the social and environmental benefits of biomass are internalized.

Technological progress in biomass energy is derived from two spheres: biomass energy production practices; and energy conversion technologies. A rich experience of managing commercial energy plantations under varied climatic conditions has emerged during the last two decades (Hall et al., 1993). Improvements in soil preparation, planting, cultivation methods, species matching, bio-genetics and pest, disease and fire control have led to enhanced yields. Development of improved harvesting and post-harvesting technologies has also contributed to a reduction in production costs of biomass energy. Technological advancements in biomass energy conversion come from three sources:

enhanced efficiency of biomass energy conversion technologies; improved fuel processing technologies; and enhanced efficiency of end-use technologies. The versatility of modern biomass technologies to use a variety of biomass feedstocks has enhanced the supply potential. Small economic size and co-firing with other fuels has also opened up additional applications.

Biomass integrated gasifier/ combined cycle (BIG/CC) technology has the potential to be competitive (Reddy 1997; Johansson et al., 1996) since biomass as a feedstock is more promising than coal for gasification, due to its low sulphur content and less reactive character. Biomass fuels are suitable for the highly efficient power generation cycles based on gasification and pyrolysis processes. A steady increase in the size of biomass technologies has contributed to declining fixed unit costs.

For electricity generation, two of the most competitive technologies are direct combustion and gasification. Typical plant sizes at present range from 0.1 to 50 MW. Co-generation applications are very efficient and economical. Fluidized bed combustion (FBC) is efficient and flexible in accepting varied types of fuels. Gasifiers first convert solid biomass into gaseous fuels, which is then used through a steam cycle or directly through gas turbine/engine. Gas turbines are commercially available in sizes ranging from 20 to 50 MW. Technology development indicates that a 40 MW combined cycle gasification plant with efficiency of 42% is feasible at a capital cost of 1.7 million USD with electricity generation cots of USD 4 cents/ KWh (Frisch, 1993). In decentralized applications, the cost of delivered electricity from biomass units is comparable to coal plants (Figure 5.1) due to the low transmissions and distribution requirements of decentralized units. In the case of niche applications like co-generation in sugar mills, biomass electricity is competitive at current costs. Besides, biomass electricity generation has advantage of lower emissions (Figure 5.2).

In recent times, Indian policy makers are paying serious attention to liquid bio-fuels to substitute rising demand for liquid petroleum products in the transport sector. At the current oil price level, ethanol and bio-diesel are economically viable. Persistent distortions in prices of fossil fuels, including environmental subsidies, remain hindrances to the penetration of liquid bio-fuels. On the other hand, the policy makers are convinced by the multiple dividends being offered by bio-diesel, including benefits like additional employment, land restoration, and mitigation of carbon and other pollutants.

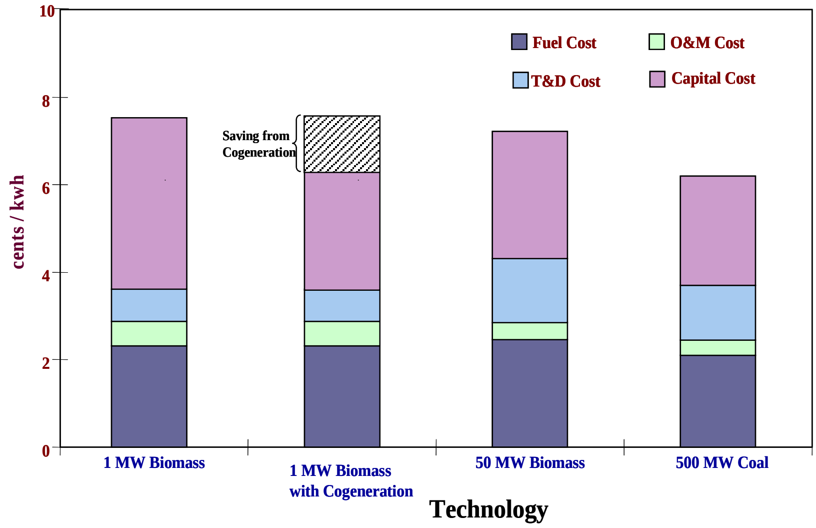


Figure 5.1: Cost of delivered electricity

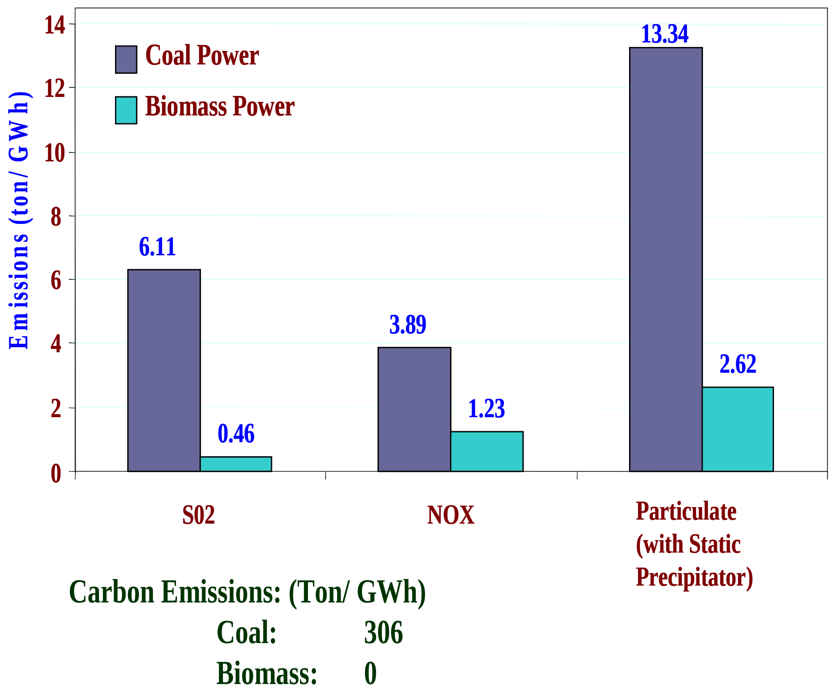


Figure 5.2: Ancillary benefits of biomass

5.2 Bio-fuels in future energy and climate-policy scenarios of India

The assessment of future bio-fuel scenarios discussed below is based on results of various studies carried out using an integrated modelling framework, which comprises three types of models: i) national level top-down macro-economic models, exclusive or embedded within global models, ii) national level bottom-up energy system models, and iii) local level bottom-up models (Nair et al., 2003; Shukla et al., 2004). The specific models used include the Second Generation Model (SGM) (Edmonds et al., 1993; Fisher-Vanden et al., 1997), which is a top-down, computable general equilibrium model, and a combination of bottom-up model applications (Kapshe et al., 2002; Garg et al., 2003; Rana and Shukla, 2003, Shukla et al., 2004) using MARKAL (Shukla and Kanudia, 1996; Shukla, 1996; Loulou et al. 1997; Kanudia and Shukla, 1998) and the Asia-Pacific Integrated Model (AIM) (Kainuma et al.; 2002; Matsuoka et al., 1995; Mortia et al., 1994, Shukla et al., 2004). The long-term analysis uses results from the Edmonds-Reilly-Barns (ERB) model (Edmonds and Reilly, 1983 and 1985), a global top-down energy sector partial equilibrium model in which India is considered a separate region for the long-term analysis within the global framework (Rana and Shukla, 2003) and ANSWER-MARKAL model (Nair et al., 2003) set-up for India.

Economic reforms in India have opened the doors for a competitive electricity sector in future. The long-term penetration potential of biomass power has been analyzed by presuming the energy sector to be driven by competitive dynamics. Under a competitive economic environment, different electricity generating technologies compete and penetrate in suitable niches. At present, conventional energy technologies have an unfair advantage to the extent that they fail to internalize environmental costs. Under fair competition, these externalities need to be internalized. The analysis considers four scenarios. The Indian reference scenario, called IA2, is equivalent to the IPCC A2 scenario. Two other scenarios presume a future global climate regime at a stabilization target of 550 ppmv (parts per million volume of CO_2 concentration) and 650 ppmv, along with the underlying economic assumptions equivalent to IA2 scenario. The fourth scenario presumes a subsidy push for renewable energy technologies, including bio-fuels. At present, government policies in India provide subsidies to renewable technologies through different modes. The entire subsidy package for biomass power, when converted in terms of equivalent subsidy on the investment cost, turns out to be equivalent to about a quarter of capital costs.

Penetration of biomass power under different subsidy and carbon emission reduction scenarios is shown in Figure 5.3. Biomass electricity generation technologies have substantial penetration potential. However, under the reference scenario, penetration in year 2035 is low at 4,380 MW. Under subsidy policies, penetration in year 2035 reaches 20,000 MW. The share of biomass power will then be 5% of the total power capacity in India. Biomass electricity in the year 2035 would replace 41 million tonnes of coal and save 23 million tonnes of carbon emissions annually.

The real push in the penetration of biomass technology comes in the case of climate policies. A 550 ppmv regime would provide substantial push for biomass technologies, making biomass electricity penetration reach 55,000 MW in year 2035. The biomass share in electricity capacity then would be 14% and this would lower carbon emissions from India by 63 million ton. Thus, market pull from global climate policies would have a higher effect on the penetration of biomass technologies than subsidy policies. While subsidy produces early penetration, this policy is financially unviable at higher penetration levels. Fortuitously, at high penetration levels the generation cost would be reduced and lower subsidy support to sustain technology penetration would become viable. In the long run, it would be more appropriate to introduce penalties on competing fossil fuels. While in the short run, subsidies can help, medium- and long-run policies will have to use environmental taxes or limitations.

The long-run modelling analysis for 100 year scenarios show significant potential for penetration of biomass technologies in the case of stringent climate change constraints (Figure 5.4). The top line in the figure is the baseline CO_2 emission path of the IA2 scenario. The top-line of the lowest area is the optimal stabilization path for India in the IA2 scenario. It is constructed by using the marginal mitigation cost for each period that is identical to the global permit prices imported from the modelling run of MiniCAM model (Brenkert et al., 2003; Edmonds and Clarke, 2005) set-up to achieve the 550 ppmv stabilization vis-à-vis the global SRES A2 scenario. The shaded areas show the mitigation contribution of different technologies as a result of their additional penetration beyond the baseline IA2 scenario, in order to reach the stabilization baseline.

Evidently, the global stabilization regime would induce significant technological changes in India, especially in the energy sector. Coal, which is otherwise the main fuel, will have to be replaced substantially and throughout the century in the stabilization scenario by gas, nuclear and renewable energy. The demand for energy will fall due to enhanced penetration of energy efficient technologies. These low or non-carbon intensive technologies are among the endogenous technology stock in IA2 scenario, though their shares would be lower in the IA2 scenario compared to those under stabilization. The technologies, such as carbon capture and storage, would never penetrate in the non-climate intervention scenarios since their outputs are singularly aimed at reducing externalities from greenhouse gas emissions. Such technologies, including those that remove carbon from energy use, or others like soil-carbon fixation or biomass sequestration, would penetrate in stabilization scenarios. These technological changes, induced by exogenous stabilization signals, would cause economic losses vis-à-vis the endogenous economy, whereas biomass technologies which have substantial co-benefits would be the preferred pathway for developing country policy makers. The global agreements would need such information and also insights from global, regional and national scenario assessments, to be able to address the complex equity and efficiency concerns.

5.2.1 Sustainability of biomass energy

High penetration of biomass technologies will require an 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 the wood- and agro-processing industries. 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 to a biomass-combustion power plant operating 5000 hours a year would require nearly 6000 tonnes of dry wood (1.3 kg dry wood per KWh). At a productivity of 8 tonnes per hectare per year, a 1 MW plant would therefore require 800 hectares of land. The plantation for 20,000 MW of power would require 16 million hectares, i.e. 5% of total land, or 12% of degraded land, in India. Land supply could be the key limiting factor for biomass penetration. Land competition for higher bio-fuel production could conflict with food security goals. The research and development programmes for improvements in conversion efficiency and enhanced biomass productivity would be vital factors in making higher penetration of biomass power sustainable. The food versus fuel issue is critical for a densely populated country like India. The policy approach of India at present considers only the use of degraded land for bio-energy, rather than switching the land already under crop production for energy crops.

In 1990s, low oil prices prevented serious policy consideration of energy crops (such as sugar cane) for producing liquid fuels to substitute oil products. In more recent times, the prevailing high oil price and expectations for the sustained higher prices for fossil fuels has prompted the push for bio-energy. The policy for the mandatory mix of ethanol with gasoline has pushed ethanol prices upwards and this has prompted farmers to grow sugar cane in areas which were traditionally growing wheat and other staple food crops. In the future, an improved trade balance and enhanced agriculture productivity would further permit access to better lands for competitive production of bio-fuels. The high price expectations for biomass would enhance the competition for land and water as a result of for rising demand for both food and fuel by a growing population enjoying higher incomes. Climate stabilization will make this competition fiercer as increasing carbon prices in the later part of the present century would make bio-fuels more competitive vis-à-vis fossil fuels.

5.2.2 Increasing competition for land and water for food and fuel

India's growing population and rising incomes are generating high demand for food, which is expected to grow at 3.2% per year over the period 2000 to 2030 (Table 12). Traditional bio-energy production during the period is expected to marginally decline as labour costs rise in rural areas and income effects lead to substitution with cleaner fuels. India's replenishable water resources are nearly 1500 billion cubic meters annually (Table 13). Thus, by 2020, the increased crop production will cause acute water stress as the demand for water would exceed recharging capacity. Besides, there will be additional stresses that will increase water demand from households and industries. The water demand will increase two-fold over the period 2000-2030 since the water productivity of food-grain production is expected to stagnate, despite increasing land productivity, since in the transition stage of agriculture the productivity transformation is water-intensive, with water as the a key input substitute for land. The variable availability of water resources and the depths at which the water is available (Table 14) generates variable energy demand for the same food-grain production across the country. In the absence of substantive land-reforms, a large fraction of land and the sizable food-grain market remain fragmented and governed by the subsistence mode of production, creating barriers to high specialization and high productivity. Trends in agriculture therefore portend increasingly fierce competition for land and water over the next decades.

Table 12 India - food grain production, traditional bio-energy, water demand

Year	Food grain production (million tons)	Traditional bio-energy (MToE)	Water demand (billion m^3)	Remarks
1980	130	108.48	623	1 - ES, Table 1.12, 2 - 10th Plan, 3 Cal
2000	197	139.02	946	1 - ES, Table 1.12, 2 - 10th Plan, 3 Cal
2010	238	124	1,145	1 & 2- IIMA, 3 - Cal
2020	327	120	1,574	1 & 2- IIMA, 3 - Cal
2030	435	120	2,091	1 & 2- IIMA, 3 - Cal

Notes: ES: GOI (2006), Economic Survey 2005-06, New Delhi; 10th Plan: GOI, Planning Commission, http://planningcommission.nic.in/plans/planrel/fiveyr/welcome.html; Bio Energy: Non-commercial energy consisting of fire wood, cow dung and crop residue; Cal: Calculated on the basis of average water consumption of 4,800 m3/ton for food grain production for the year 2003-04. A similar crop proportion has been assumed for all years. This excludes water requirements for bio-energy.

Table 13 Total water resource balance

	billion m^3
Annual precipitation	3700
Less evaporation	(1200)
Available	2500
Ground water	800
Rivers/ Streams	1700
Less not exploitable	(1034)
Net available	1466

Reference: Indian Council of Agriculture Research ICAR (2005). Handbook of Agriculture

Table 14 Land productivity in India and water demand: year 2003-04

Crop/Bio-Fuel	Gross land area (million hectares)	Land productivity ton/ gross hectare	Water depth per crop (mm)	Water depth assumed (mm)	Water (m^3/ton of Production)	Water (billion m^3)	Reference
Food grains	123.32	1.735			4,824.99	1,032.06	0&1 - CMIE
Wheat	26.58	2.707	250- 400 (North), 500-600 (Central India)	400	1,478	106.61	0&1 –CMIE, 2- ICAR(2005), Pg 194
Rice	42.49	2.051	1000-1500 (high water table),1500-2000 (Medium), 2000-2500 (deep water table)	1750	8,532	755.38	0&1 –CMIE, 2- ICAR(2005), Pg 193
Corn (Maize)	7.32	2.046	100-150 - North, 100(Kahrif) - 550 (Rabi) Orissa, 500 (Kharif) Raj	400	1,955	29.29	0&1 –CMIE, 2- ICAR(2005), Pg 195
Other food	46.93	0.81		300	3,682	140.79	
Sugar cane	4.02	58.13	1400-1500 Bihar, 1600-1700 AP, 1700-1800 Punjab, 2000-2400 Karna, 2800-3000 Mah	1800	310	7.24	0&1 -CMIE, 2- ICAR(2005), Pg 198
Soybean	6.5	1.203	150-200	400	3,325	26.00	0&1 - CMIE, 2- ICAR(2005), Pg 196 (Avg for Oil Seeds)
Castor	0.73	1.088	150-200	200	1,838	1.45	-do-
Groundnut	6	1.355	400-500	450	3,321	27.00	0&1 - CMIE, 2- ICAR(2005), Pg 196
Energy Crops							
Jatropha		2.25 - 5	-	150	375		1- PC, 2 - Remark

Notes: ICAR (2005): ICAR (2005), Handbook of Agriculture, New Delhi; PC: Planning Commission (2003). Report of the Committee on Development of Bio-Fuel; Remark: As Jatropha can grow in areas having 600 mm of annual rainfall and assuming a 25% seepage into ground.

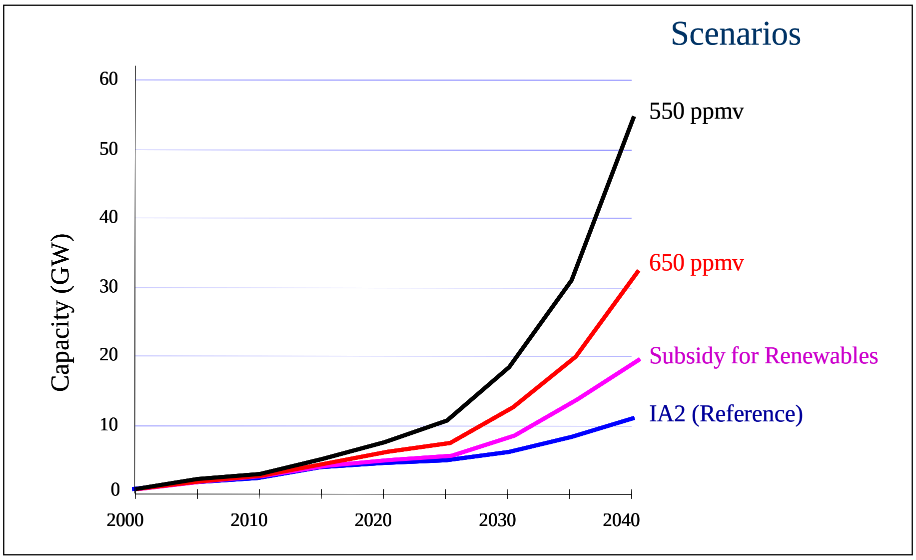
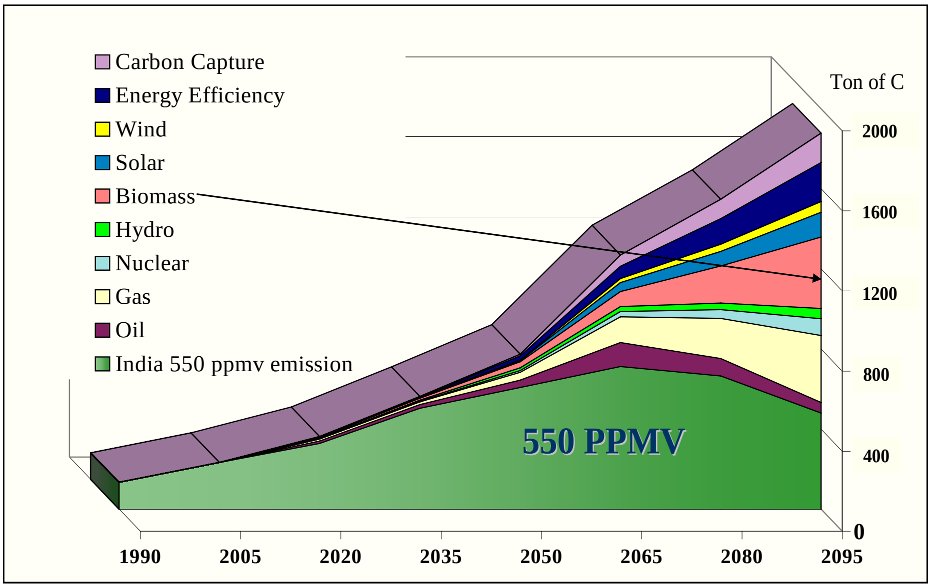


Figure 5.3: Biomass electricity – impact of climate stabilization regimes (MARKAL analysis for this report)



Reference: Shukla, 2006

Figure 5.4: Technological change in India from global 550 ppmv stabilization regime – increased role of biomass energy

To further explain Figure 5.4. The figure plots carbon emissions over time and not energy. Since biomass is carbon neutral, there is no contribution to carbon by biomass emissions (in the base case, which is represented by the top line of the figure). The base case includes reasonable substitution of traditional biomass by first- and second-generation commercial biomass technologies. While the first- and second-generation commercial biomass technologies penetrate, initially there is stagnation and then a decline in traditional biomass use, which partly off-sets the rising biomass value even in the base case.

To further emphasize the point, one should keep in mind that at present traditional biomass already contributes nearly 20% of energy in India. In the next few decades, this figure will decline and will, therefore, off-set the increasing contribution of commercial biomass. While traditional biomass is collected from commons or as waste, commercial biomass requires land. The scenario assumption about food security in the next two decades is much more stringent when per capita income is still expected to be below US$5000. The growth of commercial biomass is thus hampered by land supply when carbon prices are still not very high in initial periods, besides the declining numbers of traditional biomass off-sets the commercial biomass numbers (since the reporting here is not done separately for what is traditional biomass or commercial biomass, but includes both). Also note that this is a 550 ppmv CO_2 concentration scenario and not CO_2 equivalent scenario. The wedges in Figure 5.4 show how much additional mitigation is done by biomass in the 550 ppmv scenario over the base case. Given the explanation in the points above, during the initial decades, biomass contribution to carbon mitigation is low, since commercial biomass penetration beyond the base case is severely constrained by land supply and also by competition from other low-carbon or carbon-free energy sources. (And, as said earlier the declining contribution of traditional biomass further reduces whatever contribution comes from commercial biomass). Significant mitigation in general, as Figure 5.4 shows, begins only after 2030, due to the inertia of the energy system. The next two decades are for preparing to transit to a low-carbon economy rather than actually doing it. Under the 550 ppmv target another decade or two would be needed to break free from the food security constraint. Then, together with rising carbon prices, biomass transition would get greater impetus.

5.3 Bio-energy: the future strategies

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 a reliable and enhanced biomass supply; and ii) providing 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 a better utilization of 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. briquettes from saw dust). Sustained supply of biomass will require enhanced production of energy crops (e.g. wood-fuel plantations, sugar cane as a feedstock for ethanol). The critical factors in this regard are: i) land supply (e.g. use of wasteland, farm periphery, woodlots); ii) technology interventions to enhance land productivity (matching of species, plantation management); and iii) economic operations (optimal harvesting cycle, better storage to reduce losses, and enhanced reliability of biomass supply, which will need adequate logistics infrastructure (transport and R&D)).

Reliable energy services at competitive prices: Future penetration of biomass technologies will depend vitally on the cost and reliability of delivered energy services. The foremost option to achieve this is the choice of 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, of electricity by the utilities.

6 Implementation

There is large biomass use in India, though most bio-energy use remains confined to traditional uses such as cooking in rural households and heating in rural industries. Most biomass is as yet not traded, but is gathered or home-grown for own use using family labour. Lately, experience with modern biomass technologies has been growing in India, though the penetration of modern biomass energy services still remains insignificant. The implementation of biomass programmes still follows typical top-down and government-sponsored push strategies. The programmes and actions pushed from the top can at best operate in niche markets and deliver a few model projects; where as in a country of a billion people with six hundred thousand villages and diverse socio-economic and agro-climatic conditions, the best strategies are those that generate social and economic signals, motivate decentralized and bottom-up participation and lead to informed decisions. In the case of bio energy, the optimal social and economic signals are best delivered through policies that integrate and align development goals and market signals.

Efficacy of implementation requires paying attention to: i) institutions for coordinating programmes, activities and actions, ii) synergy among policies developed for different domains to harness co-benefits, iii) technology development, transfer, adaptation, demonstration, deployment and diffusion to optimize energy service delivery, and iv) information and communication for creating awareness, directing actions and motivating participation. In each of these four areas, implementation strategies need to be crafted for different time frames, ranging from short to long term. Table 15 summarizes the key elements of such implementation strategies for biomass energy.

Bio-energy competes with other primary energy resources in diverse energy service applications. Bio-energy use in rural households and traditional industries still predominates, however the future of bio-energy rests in realizing a transition to competitive bio-energy supply to meet rapidly growing demand for modern energy services. The implementation of bio-energy programmes in India should follow a three-stage strategy. First, in the near-term, there is a need to ensure the sustainability of traditional biomass use by enhancing supply of local biomass and improving the efficiency of conversion technologies. In the second stage, in the medium term, the focus should be to develop national market and supply capacity for bio-energy fuels and services, to meet energy security and development objectives. In the third stage, the long-term strategy should be to develop linkages with international bio-fuel and technology markets and to help create a competitive international energy market that incorporates the cost of carbon emissions.

Table 15 Elements of implementation strategies for biomass energy

	Short-term (up to 5 years)	Medium-term (> 5 to 20 Years)	Long-term (> 20 Years)
Institutions	▪ Initiate biomass network for coordination with local NGOs, community and private firms ▪ Initiate process to develop inter-connected local markets for bio-fuels and technologies	▪ District level nodal organization to coordinate biomass activities ▪ National market for bio-fuels and technologies ▪ Integrated supply-chain of biomass energy service ▪ Linkages with regional/ global biomass markets	▪ Regulatory institutions for competitive biomass energy service market ▪ Mechanisms in global and regional agreements on sustainable development and climate change to support biomass energy
Policies	▪ Incentives to utilize crop residues/wood waste ▪ Promote niche applications ▪ Incentive for domestic manufacturing capacity ▪ Incentives to off-set subsidies to fossil fuels ▪ Develop CDM projects ▪ Link with rural land-use and employment policies	▪ Incentives for commercial plantations ▪ Link with global climate change instruments ▪ Remove distortions in fossil fuel prices ▪ Policies to enhance land supply for biomass generation and resolve potential conflict between energy and food security	▪ Incentives for investment in infrastructure related to bio-energy services ▪ Promote joint products/ services (e.g. bio-gas, liquid, electricity, waste as animal feed) ▪ Promote Indian bio-energy multinationals to compete in global energy supply chain
Technology/ Infrastructure	▪ Technologies transfer for efficient biomass use ▪ Pilot/demonstration projects ▪ Match plant specifies with agro-climatic conditions	▪ R&D of plant species ▪ R&D/ technology transfer for scale economy ▪ Local distribution for liquid bio-fuel and biomass-based electricity	▪ Incentives for creating intellectual property rights and export of biomass energy ▪ Develop regional/ multinational bio-fuel distribution infrastructure
Information	▪ Initiate biomass resource and technology database ▪ Database for inventory of best practice of biomass energy production and use ▪ Generate & disseminate information about sustainability of bio-energy	▪ Map factors and resources for biomass production ▪ Inter-connected decentralized database of bio-energy innovations ▪ Information interface with biomass networks	▪ Global biomass information exchange to share best practices and innovations ▪ Information system linking resources database (e.g. land & water) and pointing to synergies and conflicts

7 Discussion and conclusions

Biomass is a product of two limiting resources - land and water. The two key economic uses of biomass in consumption are food and energy. Hence biomass is a vital link in the food-energy nexus. In developing countries, sizable employment is tied to agriculture production. Development progresses through the transition of traditional agriculture to modern market-oriented forms, and in the process labour gets substituted. The growing modern economy, though, generates an ever increasing energy demand. India now imports nearly 70 % of its liquid fossil-fuel consumption and the increasing demand for energy is adding to energy security concerns. Bio-energy is an important option for enlarging the energy portfolio to hedge against the supply-side risk. More importantly, bio-energy can potentially employ the mass of labour freed up by the modernization of agriculture.

Bio-energy strategies are thus vitally linked to development goals relating to food security, energy security and the economic security of the poor. In addition, bio-energy also provides additional options for deployment of land, labour and water. As an energy resource, biomass is an important element in climate change policies. Sustainable biomass production delivers not only the co-benefits vis-à-vis food and energy goals but can also contribute to climate change objectives. Innovative bio-energy strategies can deliver development benefits such as restoration of waste land and co-products like timber, animal feed and inputs for the agro-processing industry. Bio-energy, thus, is also a vital link in the “development and climate” nexus; to augment rural income, substitute oil imports and enhance mitigative and adaptive capacity to deal with climate change.

Biomass programmes in India over the past three decades were guided by the persistent energy crisis arising from increasing population, depleting woody biomass and rising fossil fuel prices. Traditional biomass continued as a relic, though stubbornly surviving within the dynamics of this crisis. The biomass policy perspective in India is changing and bio-energy is now viewed as a key constituent of energy security and sustainable development (Planning Commission, 2005). This new perspective: i) views biomass as a competitive modern energy resource rather than a traditional, inefficient, unclean and non-commercial “poor man’s fuel”; ii) aims to enlarge biomass energy applications beyond decentralized niche markets and towards competitive energy service markets; iii) seeks to reorient the technology policy from supply push to demand (or market) pull approach; and iv) considers bio-energy as a key resource for achieving development and environment goals. The new understanding needs to be translated into policies, mechanisms and instruments whereby bio-energy can operate on a level playing field to deliver its multiple benefits.

One of the main reasons for persistent inefficiency of biomass use in the traditional sector is the lack of monetary value of biomass, since traditional bio-fuels are collected primarily during family labour in their spare time (Mahadevia and Shukla, 1996). Such unpaid work is variably valued at 2–3% of GDP, involving nearly 10% of labour equivalent time. Biomass and employment policies are thus intricately linked. Employment policies that could generate income for rural households would lead to substitution of traditional bio-fuel. Whether this would lead to modernization of biomass use or its substitution by fossil fuels would depend on how energy policies influence the competitive dynamics between bio-energy and fossil fuels. There are tremendous economic advantages, to the household as well to the national economy, if bio-energy policies and development policies such as for employment, water and land-use are synergized.

The long-term techno-economic analysis presented in this paper shows that by the year 2035 nearly a tenth of India’s electricity could be economically supplied by biomass electricity technologies. During the initial decades, biomass contribution to carbon mitigation is low, since the commercial biomass penetration beyond the base case is severely constrained by land supply and also competition from other low-carbon or carbon-free energy sources. Significant mitigation, begins, in general, only after 2030, due to the inertia of the energy system. The next two decades are needed to prepare for transit to a low-carbon economy rather than actually achieving that state. The 550 ppmv scenario and another decade or two would be needed to get free from food security constraints. Then, together with rising carbon prices, biomass transition would enjoy greater impetus.

A major issue in the long run is the availability of land. Improved productivity, innovations to adapt biomass species to grow in arid land, and higher conversion efficiency are all essential to ensure that land competition for energy will not conflict with food security. Government policies during the next decade must pay attention to land supply as a preliminary step for preparing the ground for optimal penetration of bio-energy. Land markets are among the most underdeveloped in the country and myriad economic, social, technological and institutional barriers remain to be overcome. This aside, other issues for developing a biomass energy market include the removal of tariff distortions that favour fossil fuels and the creation of infrastructure for the production and delivery of bio-energy services.

In the final use, bio-fuels deliver energy services in solid, liquid or gaseous forms. As a solid fuel, fuel-wood is the most commonly used bio-fuel, providing energy to rural households. The sustainability of traditional fuel-wood, though, remains suspect. Immediate responses are needed to enhance land supply for biomass production, improve end-use efficiency and deliver fossil-derived substitutes in areas dependent on traditional bio-fuels and where energy crisis is imminent. Woody bio-fuels are well suited for substitution of coal, such as in electricity generation and industrial heating. Biomass gasifier technology, in which India has made important technology innovations, is suitable for small-scale and decentralized electricity applications. The sustained supply of woody and waste biomass and the up-scaling of technologies are vital to make biomass electricity a competitive option.

Demand for liquid bio-fuels, bio-diesel and ethanol is to substitute liquid petroleum products, which account for an overwhelming import expenditure in India. Demand for liquid fuels, driven by transport sector, is increasing at a rate higher than the growth rate of the Indian economy. The rising import of liquid fuel, rising prices and associated future carbon emission costs are already posing energy and environmental security dangers. Globally, this is an important area, inviting technology research and innovation. Emerging global instruments and initiatives related to climate change, like Kyoto Protocol mechanisms and the Asia Pacific Partnership on Clean Development and Climate Change to which India is a party, promises to facilitate a technology push for biomass energy which is so essential at the early learning stage. In the long-run, the removal of distortions favouring fossil fuels, including a true reflection of the value of carbon in fuel prices, would create a sustained pull for bio-energy which will deliver significant co-benefits for development and climate. In the long-run, the sustained pull for bio-energy would come from a competitive global energy market in which distortions in fossil fuel prices are removed and the value of carbon emissions is accounted for in energy prices by an efficient global climate regime. Then bio-energy would best deliver its promised benefits for development and climate.

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