Perspectives of District Heating Biomass Energy Technology Transfer and its Social Factors – A Strategies for Large-scale Diffusion in India

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Abstract: Bioenergy technologies (BETs) have potential to meet India's energy needs in a sustainable way, particularly for the vast rural areas. India is a pioneer in research and development of certain BETs such as biogas, improved cook stoves and small scale biomass gasifiers. However, developments on more advanced BETs have taken place outside India. Unless the process of technology transfer mechanisms at various levels is promoted and managed effectively, the potential benefits of these technologies to the society and environment at large may not be fully realized. This article attempts to understand the technology transfer and diffusion process for BETs, analyzes the barriers to their transfer and diffusion and finally suggests strategies for their large-scale diffusion in India.

INTRODUCTION

Technology plays a vital role in the economic development of a country. In a liberalized and interdependent global economy, technology has emerged as the driving force behind domestic production, competitive advantage, opportunities for cross border trade and higher living standards. But technology-related economic development has increased the demand for energy and, as a result, the emissions of greenhouse gases (GHGs) in all countries. This is of particular concern to developing countries because they are adopting policies to speed up the process of economic development in their attempts to catch up with developing countries. Recognizing the increasing concern about climate change, the international community has again started looking at technology to provide solutions. It is not surprising that a frequently expressed view in the worldwide deliberations on global climate change has been, "if the introduction of new technologies created the problem, other new technologies will help us in solving it." Again technology holds the key to addressing many energy-related environmental problems and achieving sustainable patterns of economic growth. In many cases, appropriate technological solutions already exist. However, the technology may not be in widespread use because of its price, a lack of information on the part of enterprises (both the supplier and the receiver of technology) or other market inadequacies. Technology diffusion is essential to realize sustainable development goals. The emergence of modern bio-energy technologies (BETs) has now made it possible to derive sustainable energy benefits from traditional biomass resources. These technologies are not only more efficient and environment- friendly than traditional biomass energy systems or technologies but also provide high quality energy in different forms- solid, liquid and gas - to meet thermal, electrical and other (transport) energy needs. These technologies are likely to play a dominant role in current discussions on the environment and sustainable development. The carbon sequestration and mitigation potential of biomass technologies make them potential options for mitigating global warming and its associated impacts. India has been in the forefront in developing and disseminating a large number of BETs, but technology diffusion rates remain low, leaving a vast untapped potential, which could be realized through appropriate technology transfer mechanisms. This article assesses technology transfer and diffusion institutions, mechanisms and policies adopted in India to promote renewable energy technologies (RETs), particularly BETs, and highlights the lessons learnt. It also presents technology and diffusion mechanisms needed to enhance the rate of spread of BETs. The article also reviews the Indian experience in the technology transfer and diffusion process of BETs and certain related issues. It points out barriers to the transfer/ diffusion processes and outlines strategies for promoting large-scale transfer/diffusion of BETs in India. Here technology transfer encompasses that which takes place across countries as well as diffusion within countries themselves.

TECHNOLOGY TRANSFER POLICIES

The technology policy of 1983 stipulated the development of indigenous technology; the efficient absorption and adaptation of imported technologies appropriate to national priorities and resources; self-reliance; and a strengthening of the technology base as the basic objectives. Energy was identified as a priority sector, with emphasis on optimal use and improvement in the efficiency of production, distribution, processes and equipment. Diffusion, international competitiveness and technology exports, technical cooperation among developing countries and protection (legislative framework) constituted the elements of the technology transfer process. The liberalization process initiated in the 1990s made major strides for technological upgradation through the industrial policy of 1991. The five major elements of industrial policy were:

1. **Industrial Licensing**: abolished for all sectors (except a few on security and strategic considerations)
2. **Foreign Direct Investment (FDI)**: automatic approval for up to 51.5 per cent equity participation
3. **Foreign technology agreements**: automatic approvals
4. **Public Sector investment**: for improving technology flow through the FDI route, intensive patenting of innovations, increasing R&D emanating from universities, improving technological skills in the national human power pool, and intensive use of venture capital for stimulating innovations; and
5. **Intellectual Property Rights (IPR) protection**: greater attention due to the emergence of the WTO régime and the infrastructure for a globally harmonized approach.

The industrial policy provides for customs duty concession for renewable energy equipment and spares, including those for machinery required for renovation and modernization of power plants. Excise duty on a number of capital goods has been reduced or exempted. Fiscal incentives comprise special provisions in direct and indirect taxation. Under the direct taxes category, 80 per cent depreciation allowance is permissible for renewable energy technology/ equipment. In the indirect category, customs duty for items in wind energy is 5 per cent basic and 4 percent additional duty, which are lower compared to the prevailing high duty structure. In the case of Solar PV, the basic rates vary from as low as zero for raw materials to as high as 35 per cent for equipment and gadgets. There are customs duty exemptions for goods imported for R&D projects. Most renewable energy systems and devices are exempt from excise duty, but 16 per cent is levied on battery-powered and motor vehicles (*http://mnes.nic.in/*).

TECHNOLOGY TRANSFER STATUS

This section presents highlights of the Indian experience regarding transfer of four selected RETs - wind, biogas, biomass gasifiers and solar PV. While wind and solar PV involve both transfers from outside and within the country, biogas and biomass gasifiers mostly involve diffusion within the country.

Wind

India started off in the 1980s with wind pump installations before venturing into exploration of wind power generation. The first few wind generation plants were installed with DANIDA support by two leading Indian manufacturers of wind energy systems - NEPC and RRB VESTAS. The systems initially failed as the equipment had to be re-engineered to withstand Indian voltage/ frequency fluctuations, grid-interface, high heat and humidity. Siemens took almost a year to design a generator to suit the equipment. In the last two years, the Indian market has been dominated by German wind energy technologies. More than 50 per cent of critical components used in wind turbines need to be imported from Germany. R&D, joint ventures, enterprise-level cooperation and many joint international efforts led to the indigenization of wind turbines and the setting up of a strong industrial base (Figure 1). As many as 15 Indian manufacturers are currently engaged in the production of wind energy generator (WEG) components. A large number of companies have tied up with foreign wind turbine manufacturers for joint ventures or licensed production of WEGs in India. The annual production capacity of the domestic wind turbine industry is about 500 MW at present. The two associations in this sector, the Indian Wind Turbine Manufacturers Association and Indian Wind Power Association are already active.

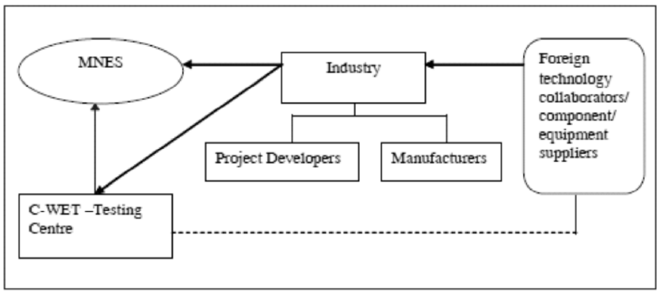

Figure 1: Wind Technology Transfer Flow

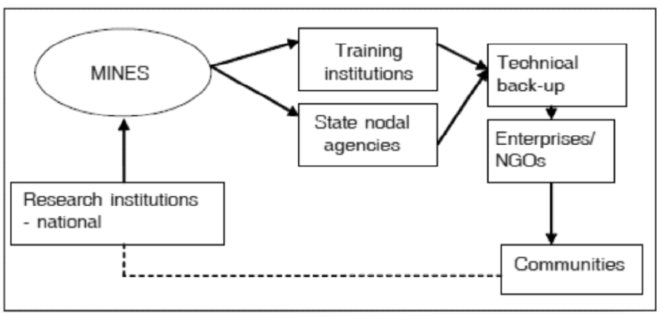

Figure 2: Biogas Technology Transfer Flow

The progress of phased indigenization by the leading manufacturers of WEGs up to a capacity level of 250 kW has been satisfactory and, on an average, 80 per cent indigenization has been achieved. The import content is high in the higher capacity machines, since vendor development for such machines takes longer time. Special efforts are on to indigenize the gearbox and controller. Wind turbines of unit sizes up to 750 kW are being manufactured in the country. Machines of up to one MW capacity are being introduced and are in the process of being taken up for commercial projects, depending on performance. The introduction of higher capacity machines with larger rotor diameters and hub heights will enable more cost-effective harnessing of wind energy. Wind turbines and their components are being exported to Europe. MNES also supports projects in developing and neighbouring countries as this would help in exporting wind turbine technologies. Further, technology transfer would help in reducing the long-term costs of wind power in India. It is also important that technology transfer is accompanied by knowledge transfer and sharing of best practices. Training and exchange programmes could lead to accelerated commercialization of wind energy technologies in India.

Biogas

A biogas plant was developed in India at the Indian Agricultural Research Institute, New Delhi, in 1939. This plant technology underwent several modifications and was later branded as Gramalakshmi III, which was later improved and in the early 60s became known as the Khadi and Village Industries Commission (KVIC) floating drum digester. It was one of several designs approved later by the MNES under the National Programme on Biogas Development (NPBD). Though the KVIC design has been very popular since the beginning, it did have some drawbacks. First, the plant cost was very high. Second, the metal gasholder had to be painted regularly to protect it against corrosion, which meant a high running cost. These were overcome with the introduction of *Deenbandhu* Biogas Plants (Janata Model) developed by Action for Food Production in 1984. Later, in 1987, another model known as Pragati was designed by United Socio-economic Development and Research Programme (UNDARP), an NGO based in Pune. The *Pragati* model was approved under NPBD in 1987. This model combines features of KVIC and *Deenbandhu* designs. The spread of the *Pragati* model has been confined mainly to the state of Maharashtra so far. Under the NPBD programme, various biogas plant models have been approved by MNES for implementation. Some of the MNES approved models include a KVIC floating drum, the *Deenbandhu*, *Pragati*, KVIC plant with Ferrocement digester, the KVIC plant with fibre reinforced plastic gas holder, and the FLEXI. All these models are based on one of two basic designs available - a fixed dome type and a floating gasholder type, including FLEXI, a portable model made of rubberized nylon fabric. Only MNES-approved models qualify for incentives under the NPBD. There are five regional Integrated Rural Energy Programme Training Institutes that deal with biogas technology. In addition, there are technical backup units (TBUs) that are responsible to ensure quality of installation, commissioning of biogas plants, and training of self-employed workers and entrepreneurs at the local level for construction and maintenance of the biogas plants. Figure 2 shows how the technology transfer happened from the lab to the field. India has a manufacturing base in biogas-related technology. Except for the digester, where approved and standard designs are available, other components, such as biogas burners, have been standardized. At least 10 enterprises sell gas burners to Indian Standards specifications. India also has well equipped institutions that organize training courses and provide technical assistance to technicians from other developing countries, who can then fabricate and install biogas plants on a turnkey basis. Training of trainers is also undertaken so that they can formulate projects, and implement and manage biogas plants.

Biomass Gasifiers

The technical feasibility of the biomass gasifiers was proven long back – a gasifier is reported to have existed during World War II. But the commercial viability of biomass gasifiers has been established only recently. The MNES estimated the potential for biomass based power at 17,000 MW. The national programme on biomass power was launched in 1985. This programme has three relevant components for gasifier technology: biomass resource assessment; R&D in advanced biomass gasification; and power generation. A phased commercialization is being attempted through focused R&D, pilot testing and evaluation, including prototype production, demonstration and evaluation, capacity building and manufacturing (Figure 3). Although a few imported designs were introduced initially, the Indian programme is locally driven. A number of R&D groups are working under the programme and a number of designs of varying capacities have been developed. Designs approved by the Ministry are eligible for incentives. Licensing is a major mode of transfer of technologies. Royalties are charged by the licensors. The demonstration programme disseminated 800 small wood gasifiers for irrigation water pumping with a total capacity of 6.5 MW until 1992. Later, from decentralized stand-alone systems, the focus shifted to application of biomass gasifiers for power generation. Five Gasifier Action Research Centres were set up in selected technical institutions in different parts of the country to provide technical support to the gasifier programme. MNES is currently supporting R&D for indigenous technology development and adaptation for advanced biomass gasification involving gas turbines in the combined cycle mode. A joint, coordinated project on advanced biomass gasification is being taken up by the Indian Institute of Science, Bangalore,Indian Institute of Technology,Madras, Indian Institute of ChemicalTechnology, Hyderabad, and Bharat Heavy Electricals Limited, Tiruchirapalli, aiming at advancement of technology for generating power from biomass. India has exported biomass gasifiers to a number of countries in Europe, Asia and Africa. However, the low rate of spread of this technology in the country due to several barriers continues to be a cause of concern.

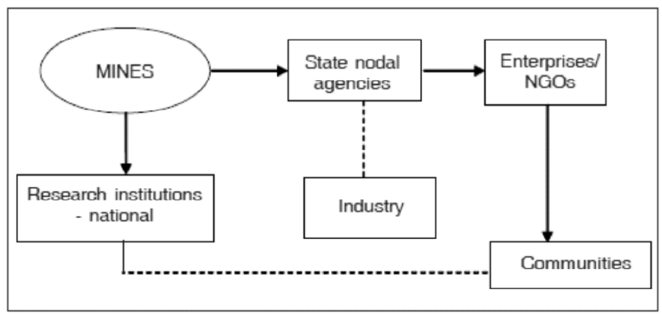

Figure 3: Biomass Gasifiers Technology Transfer Flow

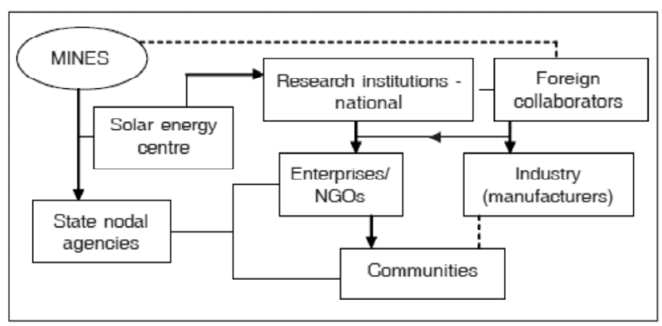

Figure 4: Solar PV Technology Transfer Flow Solar PV

In India, the PV technology research programme was initiated in 1976. Bharat Heavy Electricals Ltd. started the first PV manufacturing industry in 1983. Early applications included PV street lighting. "Demonstration and Utilization of SPV systems" for various applications was one of the early programmes of the then Department of Non-Conventional Energy Sources, which was set up in 1981. The diffusion of these technologies was primarily driven by subsidies. R&D thrust areas included materials, devices and applications. The Solar Energy Centre and three other designated Centres were authorized to issue test certificates to manufacturers to enable them to supply their products to the programmes. Indian standards for PV modules were developed along the lines of International Electrotechnical Commission (ETC) standards. A number of companies have entered into joint ventures with leading global PV manufacturers. Hundred per cent export-oriented units were allowed duty free import of raw materials and components. The PV industry in India is now a mature industry as it has the potential to offer technology for the manufacture of silicon solar cells, PV modules and PV systems. MNES as a coordinating agency in collaboration with research institutes, industry, foreign collaborators and NGOs enabled the transfer and diffusion of solar PV technologies (Figure 4). During the last five years the production of cells and modules has more than doubled.

TECHNOLOGY TRANSFER NEEDS

Transfer of BETs

Modern technologies of converting solid biomass into high quality energy carriers can be broadly classified as based on direct combustion, thermo-chemical processes, biochemical processes and chemical processes. 9, 10, 11 BETs requiring transfer to India from abroad include: biomass combustion and gasification, co-generation, bio-methanation, landfill gas extraction, and methanol and ethanol production. Given the large costs of research and development, it is generally not possible to sustain them by limiting transfer of technologies12 in the name of selfreliance. The limited commercialization of BETs, as seen in the earlier sections, is the result of not allocating significant resources to R&D. Technology transfer mechanisms have been *ad hoc* and diffusion rates have remained low for most BETs. Corresponding impacts are thus low, in spite of the immense technical potential (Table 3) for BETs.

Need for Technology Transfer

Economic Development

Technology transfer brings about substantial economic benefits. Technology development and transfer have an impact on the technological base, industrial growth and associated economic benefits, such as employment and rising incomes. These directly impact overall development. The relevance of BETs in spite of India's high economic growth rates in recent years can be explained by the fact that only about 83.8 per cent of villages have been electrified so far 13 and India's *per capita* electricity consumption remains low compared to that of developed countries. Also, "electrification" of a village implies electrification of only about 40-50 per cent of the households, and not of 100 per cent. The potential macro-economic benefits of BETs include conservation of kerosene (used in the domestic sector for lighting and cooking) and diesel (used for agricultural pumping), leading to reduction in petroleum imports. Savings in subsidies currently expended on petroleum fuels and electricity by national and state governments, improving the financial viability of utilities and stabilization of the national grid are some other benefits.

Climate Change Mitigation

One of the major environmental threats today is global warming and its associated impacts, mostly caused by emission of GHGs from large-scale use of fossil fuels. BETs are uniquely placed in this context as they could mitigate GHG emissions through substitution of fossil fuels and absorption of atmospheric CO2 by plants through the photosynthesis process. A quick estimate of GHG reduction potential from BETs is shown in Table 4. BET-based power generation substitutes conventional grid electricity, which is based on fossil fuels, and mainly coal. It thus reduces SO2 and NOx emissions and ash generation. Sustainable biomass supply would additionally contribute to reclamation of degraded lands estimated at 16-32 million ha.

Energy for the Poor

Biomass has been traditionally used in rural areas, particularly by the poor. The air pollution within rural households resulting from inefficient cook stoves has not yet received the attention that it deserves. 14 The poor cannot access kerosene or LPG for cooking due to high costs and lack of infrastructure. Further, they cannot access centralized or local diesel generator-based electricity for lighting and agricultural pumping, again due to high costs. BETs have the potential to provide access to quality cooking energy as well as electricity to improve the quality of life. Land reclamation, soil conservation, and watershed development are the inherent benefits of developing biomass energy sources.

Table 3
Technical Potential of Bio-energy and Achievements in India (as on 31 March 2003)

Sources/Systems	*Unit*	*Potential MNES estimates*[5]	*Potential II*[8]	*Achievements*[5]
Biogas plants	Million	12	17	3.40
Improved stoves	Million	120	120	35.2
Biomass power (combustion)	MW	16,000	57,000	180
Biomass gasification	MW			53.17
Biomass cogneration	MW	3,500	3,500	304
Urban and industrial wastes	MW	1,700	1,700	15.15

Table 4
BETs' Greenhouse Gases Reduction Potential in India19

Biomass technology	*Technical pontential*	*Global environmental benefit (million t C/year)*
Biogas	17 million	5
Community biogas	150,000 villages	10.8
Improved stove	120 million	4
Biomass	57,000 MW	89
Cogeneration	3,500 MW	6
Urban wastes	1,700 MW	3

Key BETs

Cooking, irrigation pumping and lighting are the dominant energy-using activities, accounting for more than 90 per cent, of rural areas. Any energy interventions for these end uses would have a major impact on the quality of life of a large majority of people. The three BETs selected for assessment of technology transfer therefore are: improved cook stoves, biogas for cooking, and biomass gasifiers for decentralized power generation.

Improved Cook Stoves

The use of fuel wood for cooking in traditional cook stoves is characterized by low efficiency (a range of 10-14 per cent) and smoke emission (a health hazard) in the kitchen. Improved cook stoves are fuel-efficient and are designed to minimize indoor air pollution. In India, more than 30 models of improved cook stoves are available for family, community and commercial applications. The initial dissemination approaches of the improved cook stoves mainly advocated their use for health and convenience reasons. Subsequently, environmental imperatives accelerated the adoption of the stoves.

Biogas for Cooking

Biogas is the product of anaerobic fermentation of organic materials, such as animal dung,plant leaves and waste from food processing and households. Biogas can be combusted directly as a source of energy for cooking and lighting, or used in internal combustion engines for mechanical or electrical applications. The slurry produced after digestion can be used directly as valuable manure for crop

Table 5
Diffusion of BETs through MNES Programmes

BET	Units	TP	Up to 1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
ICS	No. (million)	120	15.53	17	22.2	23.5	25.7	28.5	n.a	32.9	33.8	33.9
BGC	No. (million)	12	1.763	1.98	2.19	2.3	2.54	2.76	n.a	3.13	3.27	3.37
BGP	MW	17,000	9.5	14	14.5	14.5	14.5	35	n.a	35	42.8	53.2
CG	MW	3,500	1.5	8	43	55	69.5	110	n.a	273	358	468
BM	MW	2,500	-	-	-	-	3.75	7	n.a	15.15	17.1	25

Key: ICS - improved cookstoves; BGS - biogas for cooking; BGP - biomass gasifier for power generation; CG - cogeneration; BM - biomethanation; TP - total potential production. Biogas plants in India are largely based on cattle dung, with a capacity ranging from 2 to 6 m3, for cooking applications at family level.

Biomass Gasifiers for Power

Biomass, particularly woody biomass, can be converted to a combustible gas for use in internal combustion engines for mechanical or electrical applications. This is done through a two-stage process known as gasification; in the first stage, biomass undergoes partial combustion to generate gas and charcoal; and in the second stage, charcoal reduces the product gas (mainly CO_2 and water vapour) to a combustible producer gas, consisting of carbon monoxide and hydrogen (and other gases, such as nitrogen). Gasifiers are readily available in India in capacities ranging from 20 kW to 500 kW. The efficiency of conversion of biomass to electricity in the biomass gasifiers is about 17 per cent. Feedstock for gasification could be wood from dedicated plantations, thin twigs and branches from plantations and forests, logging and milling residues or certain crop residues, such as rice husk.

Requirements for Successful Technology Transfer

The major goal for technology transfer is to ensure that technological benefits are passed on to a large section of society in an equitable manner for sustainable human development. It is important to assess the critical factors for success of the technology transfer process. Five of these factors – diffusion potential, acceptability by users, ability to meet development goals, commercialization prospects and local manufacturing and spare parts availability - which could influence technology transfer are discussed in this section.

Diffusion Potential

Diffusion represents widespread adoption of technologies over time and space, and between social strata. Without diffusion, a technology may be a triumph of human ingenuity, but will not be an agent of global change. Diffusion is thus one measure of effectiveness of technology transfer. Unless there is a sizeable diffusion potential, which is the case with BETs, technology transfer becomes meaningless. The potential and current level of diffusion of selected BETs in India are given in Table 5.

Acceptability by Users

Technological acceptance by users is a key factor for sustaining and replicating the use of technology. Technologies compete mainly on performance and costs. The performance aspects could be broadened to include environmental and social aspects. The proposed new technologies must be able to meet user needs better than available alternatives. Technical feasibility does not automatically ensure market acceptance, which is influenced by many factors that are beyond the scope of technology such as institutions, policies and culture.

Ability to Meet Development Goals

Technologies are only means to development and not ends in themselves. BETs, if mainstreamed with conventional energy systems, would not only result in augmented energy supplies but also bring in several social benefits, such as the following:

1. Local employment generation in villages and development of rural energy entrepreneurs - in planning, implementation, operation and maintenance of rural energy systems;
2. Participation of the local community in planning, implementing and managing bio-energy systems; and
3. Improvement in the quality of life of rural people, particularly women.

Commercialization Possibilities

Earlier studies have shown that investments in cookstoves and biogas plants are commercially viable options. Entrepreneurs are involved in disseminating these devices with profit motive in many regions. However, dissemination efforts are spearheaded by government agencies. Biomass gasifiers can be disseminated or marketed commercially through the participation of manufacturers and local entrepreneurs. This would ensure private sector participation, sustained through demand for the services or products. BETs promoted under market-oriented programmes have demonstrated commercial viability. Cogeneration is perhaps the most successful BET from a commercial perspective. From the perspective of business enterprises (private sector players) or technology suppliers, the opportunity to maximize their profits is of utmost concern. However, commercialization prospects can be enhanced through an effective regulatory and policy environment. The commercialinterest in most cases leads to effective technology transfers.

Local Manufacture and Spares

The ancillary industry is as critical as the technology itself. This is as true for BETs as for computers and automobiles. Local manufacturing is vital for reduction of costs, assured availability of spare parts and reliability.

STRATEGIES FOR PROMOTING TRANSFER OF BETS

Barriers to BET Transfer

It is important to recognize that technology transfer and diffusion face a wide range of barriers. IPCC2 identified 42 specific barriers to technology transfer. From a developing country perspective, the major constraints to effective technology transfer lie in a lack of capacity to exploit the diversity of available technological options and services and to adapt them to local conditions. Some of the additional barriers directly relevant to diffusion of BETs are as follows:

1. Limited capacity to assess, adopt, adapt and absorb technological options. These technologies are primarily targeted at rural areas or poor customers, who have limited capacity to absorb them.
2. Inadequate information to assess technological needs. A generic information dissemination approach has had only limited impact. Also access to information remains a key issue.
3. Weak institutional infrastructure for diffusion. There are no institutional mechanisms to provide after-sales support to these technologies. Limited private sector participation and target-linked programmes have not been able to motivate existing institutional mechanisms to cater to the new markets.
4. Lack of access to financing. High first costs and investments associated with mass manufacturing remain barriers.
5. Limited R&D funding. There is inadequate funding for research and development, which limits a focused approach. Over-dependence on the Government for R&D funds also limited the scope for expansion.
6. Subsidies. Since conventional technologies are supported with subsidies, there is no level playing field for new technologies and this distorts markets.
7. High transaction costs. The diffusion of new technologies involves high transaction costs in creating awareness, providing finance, building capacity, and building institutions to provide various services, like training, servicing and maintenance.
8. Lack of private sector participation. In the case of BETs, there are limited partnerships with the private sector in the process of technology development and diffusion.

Table 6
Shows Key Barriers to Selected BETs in India

Bioenergy technology	Key barriers
Family biogas	High first cost; Procedural delay for obtaining subsidy.
Community biogas	Inadequate dung; Low capacity utilization of system due to inadequate demand for electricity; Large investment at village level; Absence of institutions to plan, implement and manage community biogas systems; Absence of strong community organization at village level.
Biomass gasifiers	Land availability and sustainable biomass supply; Energy plantations: absence of a package of practices and quality seed material or clones for high yields; Currently unavailable multi-feed system; Uncertain land tenure for farmers and local communities to undertake long-term commitment for supply of woody biomass; Absence of community organizations to enable community participation; Gestation period in producing biomass.
Improved stoves	Short life of mud stoves; Low performance of improved stoves; Lack of quality control; Lack of user education; Insufficiency of trained builders.

Overcoming the Barriers

In order to facilitate technology transfers and diffusion, it is important to have an environment conducive to promoting renewable sources of energy. The Electricity Act, 2003, makes provision for decentralized generation and distribution of electricity. MNES and State policies for renewable energy exist in addition to a host of other policy incentives related to industrial promotion. But these policies need streamlining to be able to address existing barriers. It is suggested that an integrated framework to combine the components of (1) simplified legal, regulatory and policy frameworks, (2) enhanced technology absorption capacity, (3) improved human and institutional capacity, (4) enhanced market penetration capability and (5) improved infrastructure, might create enabling environments for promoting technology transfer. 17 Some of the key measures to ensure better enabling environment are:

Capacity Building for an Effective and Efficient Technology Transfer Process

This is the most critical component. Capacity requirements at various levels of technology transfer needs to be assessed and capacity building programmes targeting the capacity gaps have to be undertaken. This would also have a huge influence in reducing the transaction costs.

Financing for Technology Transfer

Many a time, the costs of technology transfers are huge. Licensing fees, subcontracting arrangements, etc. do not happen automatically. The hidden costs of technology transfer are usually more than that of the technology itself.

Funding for R&D

There is a need for increased funding by the government for research. The deployment of funds may be taken up on a collaborative basis to raise additional resources from the private sector and from foundations.Because the private sector cannot fully appreciate the benefits of R&D investments and because there exist environmental and other negative external barriers, public funding through the government should be encouraged. 18 There is a need to review existing R&D policies and projects and develop policies to promote coordinated R&D projects, for cost reduction and enhanced performance under practical or field conditions.

Policy to fund large-scale Demonstration Programmes

There is a need for policies to implement large scale demonstration programmes. However, scaling up of demonstration programmes to large-scale dissemination or demonstration programmes should not be based on the experience of installation of some biogas or any other systems in one or two villages. Large-scale demonstration programmes are necessary for several bioenergy technologies such as community biogas (multi-feed), biomass gasifier-based rural electrification in representative locations, on a significantly visible and viable scale. This would have the effect of: _ Generating information on technology performance; _ Creating awareness of the technology potential, feasibility and possible benefits; _ Generating cost-benefit data; _ Developing and testing institutional models and mechanisms; _ Training entrepreneurs, NGOs, etc.; and _ Demonstrating proof of concept.

Rational Energy Pricing Policy

Rational energy pricing is a major policy shift required to promote different technologies, particularly bioenergy forpower generation.

Private Sector Participation

Biomass gasifiers for rural electrification, biomass combustion for power generation and cogeneration in sugar mills can only be promoted through participation of the private sector. Policies to create incentives for private sector participation are necessary. There is a need to evaluate several policies formulated by the MNES. Facilitation of public and private partnerships, with incentives for voluntary participation of the private sector should be evolved.

Policies to Promote Participatory Approach

There is a growing realization of the need to involve communities, particularly rural communities, in planning and disseminating bioenergy technologies. Institutional development and capacity building are necessary to enable communities and households to participate in the bioenergy programmes. NGOs could play a crucial role in developing village-level institutions. Realizing this, MNES has provided some incentives to NGOs. But these have not made sufficient impact.

Periodic Assessment and Evaluation of Technologies, Policies and Programmes

It is crucial to provide information on various aspects of the technologies to policy-makers, manufacturers, entrepreneurs and end-users. In India there is inadequate learning from the technologies disseminated, programmes implemented or policies adopted. There is an urgent need to assess, generate information and disseminate knowledge on: Performance of different bioenergy technology designs in different field situations; Performances and impacts of programmes and financial mechanisms and policies implemented; Costing of technologies; Participation of industry, entrepreneurs, NGOs and communities; Flow of benefits; and _ Environmental and socio-economic impacts of the technologies.

Bilateral, Multilateral Mechanisms

The Global Environment Facility (GEF) and the Clean Development Mechanism (CDM) are the two important global mechanisms that have emerged for addressing climate change. In addition funding is available from traditional bilateral agencies and multilateral institutions, such as the World Bank and regional banks.Technology transfer has been a major component of all major global efforts, such as the Climate Convention and the Biodiversity Convention. The Climate Convention has special funding and programmes to promote technology transfer. The GEF supports technology transfer within the UN Framework Convention on Climate Change. From the technology transfer perspective, the prime goals of GEF are: _ To promote technologies for reducing GHG reduction; _ To facilitate technology leapfrogging; _ To promote environmentally sustainable technology diffusion by addressing barriers to their spread; and _ To bring about cost reductions in non-greenhouse gas (GHG) or low GHG emitting technologies.

An analysis of GEF Technology Transfer (TT) mechanisms in select UNDPGEF- supported projects show that they are catalytic in nature and mainly of demonstration and technical assistance.Further, the effectiveness of technology transfer through GEF is dependent on the GEF project cycle, availability and accessibility to technologies and an enabling environment for implementation of GEF projects.Among the projects funded to India, the projects on Optimizing Development of Small Hydel Resources in Hilly Areas (HH), Development of High Rate Bio-methanation Processes as Means of Reducing Greenhouse GasEmissions (BM), Coal Bed MethaneCapture and Commercial Utilization (CBM), Biomass Energy for Rural India (BERI), and Removal of Barriers to Energy Efficiency improvement in Steel Re-rolling Sector (SRRM) invariably address the barriers through providing demonstrations, scaling-up successful pilots, promoting best practices, and enabling activities for addressing global environmental concerns. These projects have substantial focus on technology and provide valuable lessons on technology transfer issues. GEF has played an important role in attracting foreign suppliers of technologies and equipment. Suppliers from different countries have collaborated in two of the GEF projects. Although, in most cases, they operated with an Indian subsidiary company, the technological access for the industry was strengthened. In the case of the BM project, technologies for five out of six different waste streams were sourced from four different countries. The experience led toindigenously developed BHIMA digestor, which was a UASB modified to suit local conditions. The Clean Development Mechanism (CDM) process took roots in India in the CERUPT Tender in January 2002. At that time an *ad hoc* inter-ministerial group was constituted under the aegis of the Ministry of Environment and Forests, Government of India, to provide provisional host government approval. India ratified the Kyoto Protocol in 2002 and constituted a Designated National Authority (DNA), housed under the Ministry of Environment and Forests, Government of India, with its Secretary as the Chairperson of the DNA. The DNA has set out broad criteria for assessment of contributions to sustainable development, which have been indicated at the Ministry's website. Over 40 projects have already been provided host government approval. MNES is already implementing bioenergy programmes for enhanced synergies with global programmes to create more opportunities for the bioenergy sector. BETs, biomass gasification and sugar cogeneration projects particularly are the most attractive for investors under CDM. BET projects dominate the CDM projects approved, largely due to cost-effectiveness and the direct implications for sustainable development. India is one of the major countries utilizing opportunities created by CDM. One of the fundamental goals of CDM is the transfer of environmentally sustainable technologies to developing countries. There are two categories of CDM projects: firstly, those that try to overcome financial and institutional barriers; and secondly, those that aim to overcome technology barriers by acquiring environmentally sustainable technologies. Advanced biomass-based technologies constitute a significant proportion (four projects out of eight registered) of the CDM projects endorsed by the Government of India.

RECOMMENDATIONSAND CONCLUSIONS

Any strategy to promote BETs need torecognize the distinctiveness of each BET. The technology transfer pathways depend on the target group and goal of technology transfer - social, economic or environmental. The social pathway would cover small-scale technologies for household level energy requirements, such as biogas, improved cookstoves, decentralized biomass gasifiers, etc. The environment pathway would cover large-scale technologies, with greater private sector participation, and catering mainly to institutional and industrial consumers. The technologies would cover biomass power technologies, cogeneration, etc. The five key, generic steps for successful transfer of technology are: _ The establishment of collaborative partnerships between key stakeholders, with the common purpose of enhancing technology transfer and diffusion; _ The assessment of technology transfer needs (including both evaluation of alternative technologies and definition of technology transfer priorities); _ The design and implementation of technology transfer plans and specific actions; _ The evaluation and refinement of the actions and plans; and _ The creation and dissemination of technology information. It is necessary to develop institutions and policies to facilitate these steps or processes. This requires a collaborative partnership among key stakeholders: central and state governments, industry; the legal, financial and academic sectors; and NGOs and community organizations. Their roles, responsibilities, authorities, contributions and activities have to be well defined. Detailed technology-specific transfer assessment needs should be carried out through participatory or "bottom-up" approaches. Technology information is an important issue for successful technology transfer. If complete information on bioenergy technologies – technology sources, technical details, costs, licensing procedures, patenting requirements, financial support available, etc. - are available at one place, the transfer process can be facilitated. It is essential to change the misconception that bioenergy technologies are not commercially viable and that markets do not readily accept them. Technologyspecific transfer plans have to be prepared based on concurrent evaluation of the experience so far. The plans should be responsive to feedback on the mechanisms adopted, stakeholders involved, the status of projects, and the reasons for success or failure. Technology infrastructure needs to be strengthened, as in most cases the payback period for R&D investments may be too long to be of interest to the private sector. Financing thus plays a central role in steering the achievements of the technology transfer goals. A great deal of such effort in the area of renewable energy has been undertaken in government laboratories in industrialized countries, and the intellectual property associated with it thus lies in the public sector. This might facilitate the transfer of environmentally sound technologies dealing with, for example, renewable energy.19 Further, the bioenergy technologies not only meet the energy needs of the developing countries but also can contribute significantly to the mitigation of climate change impacts. Thus, the uniqueness of technology transfer effort in BET is that the benefits accrue not only to participating countries but also to the entire global population.

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