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Bioenergy in India: Barriers and policy options

Abstract

India offers a conducive environment for accelerating the use and internalisation of bioenergy technologies (BETs). Nearly 25% of its primary energy comes from biomass resources, and close to 70% of rural population depend on biomass to meet their daily energy needs. India has over two decades of experience in demonstrating bioenergy packages. The Ministry of New and Renewable Energy (MNRE) recognizes this potential. MNRE, state governments, and central and state regulatory commissions have developed a number of policy instruments (tariff support) and financial incentives (capital subsidy, interest subsidy, etc.) to support bioenergy development. Despite this, empirical evidence shows that the rate of spread of BETs is rather low because of institutional, technical, informational, market and financial barriers.

This study analyses the barriers and proposes recommendations to overcome them. If carefully constructed, these policy instruments will not only demonstrate the effectiveness of BETs in a developing country such as India but will also help the government meet its renewable energy targets. This is particularly important bearing in mind that India is likely to be at the centre of discussions in the next round of global negotiations in South Africa (December 2011).

Introduction

Energy is the primary driver of the world's economies. Increasing populations and expectations of improved standards of living are accelerating the demand for energy. Theorists have acknowledged the positive or direct relationship between economic growth and greenhouse gas (GHG) emissions. One of the key variables affecting this positive relationship is increased energy demand as a result of economic well-being. India is one of the fastest growing countries in the world, with a GDP growth exceeding 8% consistently for the last two years, and this trend is expected to continue. India's energy demand is expected to be more than three to four times its current level in another 25 years (Planning Commission, 2005).

Present primary energy use in India is dominated by fossil fuels: 40% of primary energy supply and 59% of power generation come from coal (IEA, 2007). The rising energy demand in India is expected to lead to a further increase in the use of fossil fuels. This will not only lead to growing GHG emissions and increased environmental problems, but will also to vast social problems such as inequalities between rural and urban populations, health-related disorders, and other community-level issues.

Whilst looking to reduce fossil fuel use, India faces a tough task in meeting its energy needs, especially rural energy needs. The rural population of India, which constitutes close to 70% of the population, consumes less than 40% of the total energy supply and one-third of the total power generated. Furthermore, though 74% of Indian villages were electrified as of March 2005, only 54.9% of households had access to electricity, compared to 92% of urban households. Close to 45% of rural households still depend on kerosene for lighting and about 75% still depend on fuel wood (in traditional stoves) for cooking (Census of India 2001; NSSO, 2007).

India has large potential for the adoption of renewable energy, a potential that goes beyond addressing environmental concerns. Overall, the underlying principle is to gain from the current worldwide interest in renewable energy for three reasons:

1. To meet the growing demand for energy within the country, especially in rural areas
2. To reduce GHG emissions and help contribute to climate change mitigation
3. To capitalise on the expanding market for renewable energy and secure an early market advantage

India, together with other developing countries, has for the first time given indications that it is reducing GHG emissions, as is evident in the Cancun Climate Agreement of 2010. Although the emissions cuts are not currently legally binding, policy-makers have made it clear that reliance on traditional sources of energy will no longer suffice as a policy option.

The market for renewable energy systems in rural and urban markets in India is set to grow exponentially. Of these, bioenergy is especially prominent. 90% of rural energy needs and 40% of urban energy needs are met by biomass (TERI, 2010). Despite this, bioenergy does not figure in most energy studies and is classified as 'non-commercial' energy. Bioenergy data are considered as 'inadequate and not up-to-date', since it is not transacted on the market (FAO, 2010). While India has progressed well in initiating renewable energy programmes in general, increasing renewable energy (electricity) share from 2% (1628 MW) in 2002 to 11% (18,155 MW) in 2010, bioenergy programmes have not been on par with traditional sources of energy and at their full potential (MNRE, 2010).

The article highlights the evolution of bioenergy from an institutional and policy standpoint, underlines progress and achievements, identifies barriers and proposes recommendations for their removal. Although the article focuses on India, it is hoped that its recommendations are relevant to other developing countries looking to further their bioenergy technology (BET) agendas.

Bioenergy Technologies

Bioenergy consists of organic matter derived from trees, plants, crops or from human, animal, municipal and industrial wastes (Meshram and Mohan, 2007).

Table 1. Key Bioenergy Technologies

	Bioenergy Technologies	Features	Benefits
For Power	**Biomass Gasification**	• Biomass converted to combustible gas for use in internal combustion engines for mechanical or electrical applications • Capacities in the range of 10 kg/h to about 500 kg/h • Possible to meet rural electricity needs and feed into grid • Requires sustainable supply of biomass	• Small-scale gasifiers (of 20–500 kW) have the potential to meet all the rural electricity needs and leave a surplus to feed into the national grid. • Diesel savings of up to 80% possible in dual fuel systems and 100% diesel savings possible in 100% producer gas • Rural employment generation • Degraded land reclamation • Fossil-fuel substitution • Carbon sequestration due to forestry in degraded lands
	Biomass Combustion	• Biomass is burnt in a boiler to generate steam which is used to generate power • Possible to meet rural electricity needs and feed into grid • Requires sustainable supply of biomass	• Degraded land reclamation • Fossil-fuel substitution • Carbon sequestration due to forestry in degraded lands • Relatively more economical • Employment generation
For cooking	**Biogas**	• Ideal fuel for cooking • Simple and indigenous technology • High first cost but economical • Large experience of dissemination	• Forest plantation and tree conservation • Reduced indoor air pollution • Large improvements in quality of life • High forest carbon sink conservation potential due to fuel wood savings
	Efficient cook stoves	• Fuelled by small pieces of wood or special pellets made from dried and compressed agricultural waste • Emit less smoke and give more energy than dried wood or cow-dung cakes • Can reduce wood consumption by 50% or more	• Low cost of device Forest plantation and village tree conservation • Large improvements in quality of life, especially women • Moderate forest carbon sink conservation potential • Can be one of the most cost-effective global and local pollutants
For transport	**Bio-fuels**	• Extracting oil from non-edible seeds in plants like Jatropha curcas, Neem, Mahua and other wild plants; to be mixed with diesel/petrol • Technology not fully evolved in India • Land and water constraint	• Self-reliance • Transport fuel demands can be met • Fossil fuel substitution and therefore GHG mitigation

Source: CGPL, 2010; Pathak, et al., 2009; Ravindranath et al., 2000; Ravindranath et al, 2010

Table 1 presents the features and benefits of key BETs in meeting power, cooking and transport energy requirements.

Biofuels are fairly new to the market, and there are no available examples of projects implemented or lessons learnt. Improved cooking stoves have been in use since the late 1980s and deserve a separate discussion.

Bioenergy in India

Policy and Institutional Evolution of BETs

Renewable energy promotion in India, including bioenergy, was stepped up in response to the oil crisis of the 1970s. The Fuel Policy Committee (FPC) (1974) and the Working Group on Energy Policy (1979) (WGEP) were set up in response to this focus to understand the energy situation in light of developments both nationally and internationally. The two committees were tasked with developing a solid plan and recommendations for appropriate policy measures for available energy resources and non-conventional energy resources for the ensuing five to fifteen years. Despite the emphasis the two committees placed on the need for a new energy plan, no formal institutional mechanism was established immediately.

Institutional mechanisms were first set up in the early 1980s. A Commission for Additional Sources of Energy (CASE) was created in 1981 in the Department of Science and Technology. This was converted into a separate department, the Department of Non-Conventional Energy Sources (DNES), in 1982. In 1983, the Advisory Board on Energy (ABE) was instituted. ABE proposed and provided for the Nodal Energy Conservation Organization (NECO), whose observations and recommendations were binding on all central and state government agencies, as well as on the prescribed authorities (Dey, 2007). NECO was soon replaced by the Energy Management Centre (EMC) in 1989.

Bioenergy policies during this period (1980s) focused on technologies (Shukla, 1997):

- Improving efficiency of traditional biomass use (e.g. improved cooking stove programme)
- Improving the supply of biomass (e.g. social forestry, wasteland development)
- Improving the quality of biomass use through technologies (e.g. biogas, improved cooking stoves)
- Introducing biomass-based technologies (wood gasifiers for irrigation, biomass electricity generation) to deliver services provided by conventional energy sources
- Establishing institutional support for programme formulation and implementation

Shukla (2000) further indicated that the BETs that had been implemented lacked institutional mechanisms to support their continued operation and maintenance, and accelerate replications. Economic and financial support was mainly a matter of capital subsidies. Various evaluations showed a large number of installed devices did not function for a variety of reasons. Strategies to promote devices were oriented by assigning targets to state government agencies for the implementation of programmes and lacked a market-oriented approach.

Following liberalisation in 1992, some changes were made to strategies to accelerate bioenergy to address some of the gaps identified above. To expand further the scope of the activities to promote RE in India, government upgraded DNES to a fully fledged ministry, the Ministry of Non-Conventional Energy Sources (MNES), in 1992. MNES thus came into existence with the responsibility for supporting research and development, and the promotion and coordination of renewable energy sources, including bioenergy (MNRE, 2010). MNES was later renamed the Ministry of New and Renewable Energy (MNRE) in 2006. The Ministry has regional offices, three specialised research institutions and a non-banking financial company, the Indian Renewable Energy Development Agency (IREDA), under its administrative control to promote its policy and programme initiatives.

The Energy Conservation Bill was passed by the Indian Parliament in September 2001. The Act provides for a legal framework, institutional arrangements and a regulatory mechanism at the central and state levels to promote an energy efficiency drive in the country. The Bureau of Energy Efficiency (BEE) was created to implement the provisions of the Act, which was critical in laying the foundations for future energy policy formulation.

The eleventh five-year plan (2007-2012) highlighted the severe shortages of energy, the dominance of coal and the need to expand resources through exploration, energy efficiency, renewables, and research and development (Planning Commission, 2007).

Further to this, the most recent policy initiative to be developed is the National Action Plan on Climate Change, launched in June 2008. This is partially in response to global concerns to address climate change. Though India does not have any binding emissions targets, the initiative is aimed at showcasing national responsibility. Eight national missions comprise the main response to addressing climate change, covering Solar Energy, Enhanced Energy Efficiency, Sustainable Habitat, Water, Sustaining the Himalayan Eco-system, Green India, Sustainable Agriculture and Strategic Knowledge for Climate Change. The National Mission on Enhanced Energy Efficiency estimates that these initiatives will yield 10,000 MW of savings by 2012 and result in business of approximately USD 16 billion. The National Mission for a 'Green India' aims to achieve afforestation of 6 million hectares of degraded forest lands and to expand forest cover from 23% to 33% of India's territory by 2022. (MNREa, 2010). However, there is no emphasis on harnessing and nurturing biomass resources and biomass technologies.

BET programmes and implementation strategies

Biomass Power

MNRE and several other agencies have therefore realised the potential and role of bioenergy in the Indian context. Over the last decade, biomass power has become an industry attracting an annual investment of over USD 130 million (INR 600 crore), generating about 5000 million units of electricity and yearly employment of more than 10 million man-days in rural areas (MNREb 2010).

A key programme of the MNRE is the Biomass Power/Cogeneration Programme under which a number of financial and fiscal incentives for the manufacture and installation of gasifier systems have been provided. Another important programme is the biomass gasifier programme, which promotes demonstrations that can be taken up by village-level organisations such as village panchayats (the Indian government has decentralised several functions to the panchayats, which consist of respected village locals forming a committee to address local problems). The gasifier programme is being implemented through state nodal agencies with the involvement of energy service companies (ESCOs), co-operatives, panchayats, NGOs, and manufacturers or entrepreneurs (TERI, 2010).

The central government has also introduced support schemes such as the National Biomass Resource Assessment Program (NBRAP), aimed at developing biomass assessments. The Indian Renewable Energy Development Agency (IREDA) provides loans for setting up biomass power and bagasse cogeneration projects. State-level actions also support the central initiatives. These include:

- Buyback/Wheeling/Banking of generated electricity by the State Electricity Boards. State-specific incentives in the form of preferential tariffs have been introduced for the purchase of biomass power. For example, in Andhra Pradesh, an incentive has been introduced equivalent to Rs 2.63 per unit at 1% escalation for five years. In Haryana, a much higher incentive of Rs 4.00 per unit at 2% escalation every year is provided.
- State Electricity Regulatory Commissions have been guided to provide Renewable Portfolio Standards (RPS). RPS places an obligation on energy supply companies to produce a specified fraction of their electricity from renewable energy sources. Specified RPSs include 10%

in Tamil Nadu, 7-10% in Karnataka, 3-6% in Maharashtra and 5% in Andhra Pradesh, among others.

- Funding opportunities including grants and contracts, loans, equity investments, and direct incentive payments for bioenergy projects for pre-development activities, the installation of small and large systems, and business development and equity.
- Sales tax exemptions, in certain states from a purchase of biomass gasifiers.
- Accelerated depreciation, i.e. 80% depreciation in the first year, can be claimed for gasifier equipment such as pressure boilers and vapour absorption refrigeration systems
- Concessional import duty, excise duty, tax holiday for ten years. The benefits of concessional custom duty and excise duty exemption are available on equipment required for the initial setting up of biomass projects based on certification by MNRE.

The key achievements of the programmes and incentives provided thus far have been (MNRE, 2010):

- Deployment: a total of 259 biomass power and cogeneration projects aggregating to 2312MW capacity have been installed for feeding power to the grid. In addition, 135 biomass power and cogeneration projects aggregating to 1700 MW of electricity are under implementation.
- Manufacturing capability: a majority of the infrastructure and equipment required for setting up biomass projects can be procured from indigenous sources. For instance, biomass gasifiers in the capacity range of 5 kW to 1 MW equivalent electric capacity have been developed indigenously and are being manufactured by around 15 MNRE-approved manufacturers in the country.
- Supply chain development: a number of multinational companies are currently involved in the supply chain of biomass power plants in India.

Biogas

The Central Sector Scheme on National Biogas Programme, which mainly caters to setting up family-type biogas plants, has been under implementation since 1981-82. The scheme, which is still functional today and is managed by MNRE, is called the National Biogas and Manure Management Programme (NBMMP). Its objectives are as follows (MNREc, 2010):

- To provide fuel for cooking purposes and organic manure to rural households through family-type biogas plants;
- To reduce the drudgery of rural women, reduce pressure on forests and increase the social benefits;
- To improve sanitation in villages by linking sanitary toilets with biogas plants.

The programme is being implemented by State Nodal Departments and Agencies and the Khadi and Village Industries Commission (KVIC), Mumbai. The NBMMP provides for:

- Central subsidy in fixed amounts
- Turn-key job fee linked with three years' free maintenance warranty
- Financial support for repair of old-non functional plants
- Training of users, masons, entrepreneurs, etc.
- Publicity and extension
- Service charges or staff support
- State-level Biogas Development and Training Centres (BDTC)
- Financial support for institutions for cattle dung-based power generation plants, etc.

The key achievements of the programme have been highlighted by MNRE. The estimated potential of biogas plants in India is 12,339,300 units. As of December 2009, the cumulative achievement has been 4,185,442 units. Thus, the programme has been a moderate success only, implementing approximately 34% of the estimated potential as indicated by MNRE (2010). The latest figures for 2009-2010 suggest a similar success rate, with 34% of family-type biogas plants being implemented.

Summary of success of programmes

Table 2 indicates that, despite the enormous potential for BETs to tap into in a country such as India, and taking into consideration the renewable energy policies and programmes set out by the government, actual on-field implementation of BET's is falling short. Overall, the policies and programmes instituted have led to only sporadic success. Looking at the overall picture is disappointing since the policies and programmes put forward by the Government have not succeeded in achieving their optimum technical potential. This has been highlighted on many occasions in the literature (Ghosh S., et al., 2004; Pathak et al., 2009; Ravindranath et al., 2004; Ravindranath et al., 2010; Ravindranath and Balachandra, 2009; Singh and Gu, 2010).

Barriers and Lessons Learnt

The slow rate of spread of BETs such as biomass power and biogas, despite a seemingly strong policy framework, leads to questions concerning the potential barriers to BET dissemination in India. Several studies have identified the existence of a number of barriers, as well as the inadequacy of policies and measures to address them (TERI, 2010; Ghosh, D et al, 2005; Ravindranath and Hall. 1995). These barriers need to be explored in more detail, so that policies and programmes targeting BETs in the future will have a more bespoke role to play in closing the gap between existing and potential capacity.

The existing barriers are divided into technology-specific barriers and generic barriers.

Technology-specific barriers

BETs are multi-faceted and differ in many ways, for instance, input resources needed (i.e. woody biomass, rice husk, cow dung etc.), length of life cycle (short, medium, long-term), types of usage (cooking, thermal etc), and maintenance required (daily, weekly, monthly). Inconsistencies in the nature of bioenergy technologies and uncertainties in technological performance are a key concern for policy-makers (Ghosh, D. et al., 2002). Policies and programmes initiated by the MNRE have made an attempt to address the distinct features of these BETs (Rao and Ravindranath, 2002). The technology-specific barriers are highlighted in Table 2.

Generic Barriers

Generic barriers are barriers that affect all BETs. They include institutional, informational, financial, policy-related, and overall market barriers.

Institutional barriers

Initially, in promoting BETs the government followed a technology-push approach. This approach focuses on introducing new innovative technologies through research and development, regardless of demand. BETs in their nascent stages were offered as possible improvements on existing rural energy sources. The abundance of biomass was initially the push needed to promote BETs. There was therefore little or no interaction with rural communities in formulating the technologies. This approach almost entirely led to the isolation of a multitude of actors, who potentially could become crucial players in the adoption and use of BETs (Shukla, 2000). In traditional innovation theory, the technology-push approach can be differentiated from the demand-pull approach. A demand-pull approach refers to innovation driven by changes in demand through competitive market structures (Scherer, 1982). Stakeholders' demand for and understanding of the economic benefits of the technology are critical to this approach.

The shift in the government's focus to a demand-pull, essentially market-centric approach promised greater inclusion through a more consolidated institutional framework incorporating the whole gamut of potential stakeholders. Participation by the local community,

Table 2. Technology-specific barriers

Bioenergy Technologies	Technology-specific Barriers
Biomass Gasification	**Gasifier-engine and distribution related** • Dual fuel systems do not seem economically feasible, and hence the focus is on producer gas. But 100% producer gas engines still are not very common, not readily available at all capacities • Gas cleaning systems are still not robust and hence high in terms of maintenance • Variations in power delivered depend on quality of biomass – ensuring either quality of biomass or governing the power delivered is still not robust • Tar generated during gasification is still not under control – they vary/increase with time elapsed • Very few systems have gone through life-cycle operations, so there are significant deficiencies in terms of designing operation and maintenance protocols • The complications are much higher with lower kilowatt scale capacities • To evacuate power, an active grid is a necessity. But in rural set-up this is not well established, and dedicated 11 kV lines are essential. • Evacuating small power in the existing grid is still not favoured by utilities (who consider up to 500 kW small). Synchronising quality of power produced by the gasifier power plant and the grid is still not well established. **Biomass-related** • Absence of package of practices and quality seed material or clones for high yields for energy plantations • Sizing techniques (choppers, cutters) used have low processing capacity and are not very safe • Poor understanding of managing moisture content • Biomass drying techniques are not well established
Biomass combustion	• Do not have supply of systems in capacities less than 2 MW • The present biomass combustion system is not very flexible, with varying fuel quality and quantity • Negative impact on flue gas cleaning • Operational risks of boilers **Energy plantations:** • Absence of package of practices and quality seed material or clones for high yields for energy plantations • Techniques for bailing and sizing of biomass are yet to established (choppers, cutters) • Poor understanding of drying and managing moisture content
Biogas units	• Biogas units are less successful in the interiors of villages, due to difficulties in arranging for land and water required for the plant • Biogas plants are successful in homes situated on village outskirts or in fields.

Source: Akshay Urjha, 2010; Ravindranath et al., 2000 grassroots organisations, including NGOs, and local government agencies, among others, was a cornerstone of the new shift in policy (Sudha, et al., 2003). While a more inclusive institutional structure is good strategically, in practice in a country as vast and esoteric as India, it leads to problems in implementation if it is not managed and monitored effectively.

As indicated above, all BET programmes, the Biomass Power/Cogeneration programme, National Biogas and Manure Management Programme (NBMMP) are all budgeted and planned at the national level. A critical problem has been overcoming issues arising out of bureaucracy. In the case of BETs, this includes dealing with cumbersome paperwork, delays in issuing planning permission and other contractual details. Many developers have mentioned the significant periods of delay in obtaining technical approvals.

Additionally the programmes are driven largely by targets. For instance, the NBMMP sets annual targets for the number of biogas units to be installed (Kumar and Mohan, 2005). While a target-driven approach is important to ensure institutions function in an accountable fashion, the targets are not regularly monitored and are mostly based on antecedents. Thus institutions often end up chasing targets that are extraneous and unachievable, instead of developing innovative approaches to sustainable dissemination at the local level.

Further, the institutional framework in India currently lacks a viable strategy to empower local communities. Community organisations and institutions are rarely involved in the planning, implementation and management of, say, the rural electrification programme through biomass gasifiers. The failure of a large number of small village systems, such as biogas plants, and stand-alone gasifiers is to a large extent related to the fact that there is no coordinated local, institutional and government support (Kaundinya et al., 2009).

Informational Barriers

Information asymmetries are present on various levels and between various players, institutions, rural communities, consumers, financing institutions, entrepreneurs, and all other stakeholders in the supply chain. The information barrier is central to any debate on climate change. The Stern Review identifies raising awareness as one of the three elements of the coordinated policy package that is needed to tackle climate change, alongside carbon pricing and innovation support (Stern, 2007). Traditionally, the rural community responds to more conventional fossil fuel-based energy as a 'rich man's fuel' and therefore expectedly believes this to be the most reliable and efficient. Intermediate stakeholders such as NGOs, industry groups and micro-finance institutions that often play a key role in delivering products and services, as well as policy-makers, are also unaware of the benefits of bioenergy, which often results in a greater push for other renewable energy technologies, such as wind and solar (Ghosh, D. et al., 2006).

This represents a critical barrier for the development of BET in India. Such uncertainties for BETs in rural areas could be a result of:

- Lack of knowledge
- Uncertainty and distrust in the source of information
- Climate change is not being seen an immediate threat or priority for rural communities
- Social behaviour and expectations
- Absence of an enabling environment, i.e. government, local organisations, village panchayat
- Inadequate training, capacity-building and user-education programmes

Information and knowledge dissemination, in the right form and using appropriate tools, is not currently available to the larger public using BETs. There is also no monitoring of the translation of theory into practice. Pathak et al. (2009) observed a number of installed biogas units become immediately inoperative under the NBMMP. Agencies are not technically upgraded for periodic collection monitoring on the usage and mitigation potential of biogas plants. A sampling plan can be developed for some representative biogas plants in different districts for regular monitoring of biogas use.

The information dissemination policies of the MNRE are very generic in nature. They seldom provide information on the failure or poor performance of bioenergy systems and the reasons for them. This lack of information and awareness regarding the correct methods of operation and maintenance, as in the case of both biomass gasifiers and biogas plants, acts as a barrier to the long-term acceptance of such systems.

Financial barriers

The high initial costs of BETs are perceived by many as a key barrier to the penetration of BETs vis-à-vis conventional technologies (Bhattachrya and Cropper, 2010; Nouni et al., 2007) The principal capital cost of biomass power projects includes the costs of the gasifier, the engine generator, civil construction, biomass preparation unit, electricity distribution network and electrical and piping connections to the site of gasifier installation and need subsidisation (Buragohain et al., 2010).

While subsidies have been introduced as an incentive to induce early adoption, implementation has not been well thought out. In some cases, subsidies are set too low to overcome the burgeoning gap between the cost of generation and the level of financial assistance provided by the government. In other cases, subsidies which should ideally be phased out in line with cost reductions have continued for more than two decades, thus becoming defunct as an incentive to improve performance. Additional fiscal policies such as depreciation benefits given to biomass power projects by MNRE have had a very marginal impact on BETs.

Mainstream financial institutions have been reluctant to take risks in lending due to a long history of poor recovery of loans in rural areas (Rao and Ravindranath, 2002). Even though IREDA's financial intermediary scheme provides incentives such as interest subsidy and covers the transaction costs, existing financial institutions participating in these schemes have not shown a sustained interest due to falling returns, high technological risks, and the high costs of servicing these dispersed and low-volume markets (Planning Commission, 2006).

Policy Barriers

A fundamental barrier to the diffusion of BETs is government policies. A key government policy that fails the renewable energy sector in general is the distortion of energy prices. Energy pricing policies in India tend to favour fossil fuel-based energy sources (electricity, kerosene, LPG, petrol, diesel). Since the conventional technologies are also supported by subsidies, there is no level playing field for the new technologies that compete with them (UN, 2004).

One example of policy-induced energy inefficiency relates to the low agricultural tariffs (subsidies are as high as 80%– 90% in most states) that have resulted in gross overuse of both electricity and groundwater. For domestic and agricultural suppliers, electricity pricing is kept below the cost of supply with additional subsidies. The energy efficiency of agricultural pump sets in India is extremely low, which coincides with policies that heavily subsidise electricity use for farmers. Replacing most pump sets would be fully cost-effective if electricity were priced at marginal cost; however, the subsidies to electricity have prevented their replacement (Phadke, 2006).

A National Electricity Plan and National Tariff Policy were drafted as part of the Electricity Act in 2003. The National Tariff policy states that the tariffs for all new generation and transmission projects are to be decided on the basis of competitive bidding after a period of five years or when the regulatory commission feels the market is suitable for bidding. Since then, the Central Electricity Regulatory Commission (CERC) has designed a cost-plus approach to determining the tariff levels for renewable energy technologies. In estimating, it sets varying parameters for the individual technologies. For instance, biomass projects based on Rankine Cycle technology (i.e. biomass power plants relying on combustion to generate power) are given their own set of assessment parameters. Individual states can use CERC guidelines and determine variable tariff levels. This system, while an improvement from the previous system, is still riddled with loopholes. Developers complain that tariffs in certain states such as Karnataka (Rs. 2.85/kWh) are significantly lower than the tariffs in Haryana (Rs 5.52/kWh) and Punjab (Rs. 5.49/kWh) (KERC, 2005; CERC, 2010). A key concern is that that there are no agreed centralized or state-level parameters to fix tariffs for biomass gasification projects. CERC indicates that the tariff designed for combustion will also hold true for gasification. However, these are not adaptable in their entirety to biomass gasification projects, and duplicating the assumptions is fallacious.

Ravindranath and Rao (2002) stated that the land-tenure policy acts as a barrier for farmers and communities entering into any long-term contract to supply wood-fuel to the bioenergy utility.

Overall Market Barriers

The BET market is not an easy market for new entrants. For instance, there are only approximately twelve MNRE-approved manufacturers and suppliers of biomass gasifiers in the country. The initial investment required for such technology is huge. Government policies on licensing requirements, limits on access to raw materials, pollution standards and product testing regulations further make it difficult for new competitors to enter the market.

Recommendations

India has one of the most progressive set of renewable energy policies in the world. BETs consist of a number of technologies with diverse applications from cooking to power generation and assisting the poor. Thus the transfer or diffusion of some BETs pose many challenges. First, BETs are still in an evolving phase, which makes it difficult to decide what exactly should be diffused in terms of knowledge, techniques and hardware. Secondly, it requires a series of difficult technological choices concerning biomass sources, production, transportation, conversion and end-use. Finally, a multitude of actors are involved at the various stages, including the poorest. In the above context, appropriate policies, institutions and financing play a catalytic role in technology transfer and the diffusion of BETs (Ravindranath and Balachandra, 2009). The existence of barriers prevents the large-scale dissemination and deployment of BETs. Recommendations and policy options to overcome the barriers need to be assessed. The categories of interventions required include technical, institutional, educational, awareness and regulatory interventions.

Increased assistance to R&D

Rigorous R&D aimed at promoting innovation in BETs, for cost reduction, improved reliability and efficiency is important for the large-scale spread of BETs in India. Investments in R&D on renewables, particularly BETs, has declined (Balachandra et al., 2010). MNRE needs to foster a conducive environment for R&D in India through:

- Increased budget allocation for all R&D activities spawning BETs, including biogas, ICs, biomass power and biofuels. The 11th five-year plan mentions increased R&D to ensure an improvement in the yield of jatropha and other oilseeds for biodiesel. This needs to be further expanded to include other BETs in the new plan.
- Provision of grants and funds for R&D, which would lead to greater interest among the premier research institutions to explore BET and translate R&D leads into scalable technologies.
- Promoting collaboration between industry and academia, for field demonstrations, and promoting feedback and communication between developers and implementers.

Training and skills development

There is need for a large number of entrepreneurs and skilled personnel for building biogas plants and maintaining small-scale biomass power systems. Both current and future suppliers of BETs need to be equipped with the necessary skills to integrate the novel technologies into their functioning. With BETs, it has been observed that, even when the technology is ready and has been demonstrated, a skills shortage has been a hindrance to successful implementation. The development of training schemes could provide a route to alleviating this skill shortage. It is important to ensure that all staff involved in training and development have been adequately trained themselves. Use of R&D institutions in training could be beneficial (see BERI case study, Section 6).

Large-scale demonstrations

Demonstration projects are critical to overcoming technical barriers and creating confidence in the users. They showcase the technologies to prospective developers and investors. Demonstrations are likely to be more successful when they are conducted on a larger scale. The lessons leant must be transferred and publicised by MNRE. Successful pilot schemes must be followed up to ensure implementation. Demonstrations must also incorporate aspects that allow for community participation.

Need for quality control

BETs, especially small-scale systems, are often manufactured by the unorganized sector. Unlike solar photovoltaic or wind turbines, biogas, and even biomass gasifiers, are manufactured in small-scale industries and even in rural areas. Biogas plants are built in situ by local skilled persons so quality control is very necessary for high performance. The issuing of performance and product guarantees needs to be addressed (see BERI case study).

Technology transfer

Technology transfer for BETs poses a challenge due to the small and decentralized scale of operations and the presence of a large number of entrepreneurs. Transferring any new biogas design to thousands of entrepreneurs is a challenge. India may not require import of BETs since most of BETs are designed by Indian institutions.

Revise tariff structures

Feed-in-tariffs (FITs) have been a successful tool in the promotion of renewable energy-based power systems. There is an abundance of literature highlighting the positive relationship between tariffs and accelerating investment in renewable energy (Bilharz 2006), which can provide long-term financial stability for the renewable energy markets. However, if they are not properly designed, FITs can be economically inefficient. Thus tariffs must be designed with care, keeping in mind the individual characteristics of different BETs. Bespoke tariff models must be developed through interactions with the local, rural population, as was the case in Hosahalli in Karnataka (Ravindranath, et al. 2004) and the Sundarbans in West Bengal (Mukhopadhyay 2004).

Performance based subsidies

Since subsidies do not guarantee improved performance or cost reductions, subsidies as a policy instrument must be time-bound with a sunset clause and must be justified on the basis that they are definitely promoting technological advances and organizational learning. Importantly, subsidies should not be based on capital costs but should be linked to performance or output. The costs of the commercial scaling-up of biomass production, processing, transportation, market development, etc., are yet to be established (see Bahalupani case study, section 6).

Awareness and training programmes

Awareness needs to be created in rural areas of the requirement to shift to efficient energy systems. Women will have to be trained in using the new cooking designs. Biogas plant and biomass gasifier operators need to be trained (see Alwar case study, section 6).

Technology-specific programmes

In addition to all-encompassing recommendations and options, each technology is unique and requires prescriptions in line with its idiosyncrasies. Key recommendations are highlighted in Table 3.

Case studies

Case studies are critical in highlighting the barriers and providing recommendations. They show that converging with the application of new technologies

Table 3. Recommendations for BETs

	Technology options	Financial options	Policy and institutional options
Biomass gasification	• Facilitating design change with greater operational effectiveness • Supporting pilot/demonstration projects • Developing information packages on technology to be distributed to all stakeholders	• Innovative loan schemes to reduce costs • Well-designed tariff plans that take into consideration high initial costs of setting up power generation systems • Incentives for enhanced private-sector participation	• Encouraging skilled personnel and entrepreneurship development programs • Effective monitoring and evaluation systems • Increased support for R&D in projects highlighting performance enhancement under practical/field conditions
Biogas units	• Exploring new designs for using organic household wastes and leaf biomass in biogas plants • Supporting pilot/demonstration projects for new designs	• Placing fees on manure treatment in biogas plants. Fees should be paid by farmers in case no organic waste is available. • Facilitating design change and innovative loan schemes to reduce costs	• Increasing public awareness Increasing funding for R&D • Monitoring use of biogas plants

were activities focused on the provision of operational experience, mobilising local community, extensive R&D and firming up institutional arrangements, through the intervention of implementing partners. It should be reiterated that the following examples are studies of projects involving extensive personal field-level expertise of the authors.

Biomass Energy for Rural India (BERI), Tumkur, Karnataka (UNDP, 2010)

Initiated in 2001 by UNDP and the Government of Karnataka, the project aimed at biomass gasifiers to provide electricity to the 24 project villages and community biogas systems for the provision of clean energy.

The project's progress on the overall objectives has been tardy. A host of barriers had to be overcome to get the project to its current stage, including a shortage of biomass feedstock, the availability of land for biomass production, the non-availability of readily available, off-the-shelf gasifier systems, community-level problems in uptake, and the higher cost of biomass power compared to the tariff and subsidized centralized power.

The Indian Institute of Science (IISc), a premier R&D institution, was engaged to supervise, advise and train locals on the gasifier plant operation. Extensive community mobilisation was actuated through the creation of no less than 26 Village Bio-energy Management Committees (VBEMC), 26 Village Forest Committees (VFC) and 72 Self Help Groups (SHGs) led by women, and the strengthening of 68 old SHGs, 31 Water User Associations and 33 Biogas User Groups. The development of biomass was activated through 'energy' plantations. About 2015 ha of common land was taken under forestation. A nursery with nearly two million seedlings was set up, alongside tree-based farming over 900 hectares of land. To address the immediate need for a cleaner cooking fuel, community biogas plants were built. Irrigation problems were reduced through drip irrigation.

On the technical front, the poor performance of the turnkey contractors led to alternative steps being taken to complete performance guarantee tests and warranty runs. Furthermore, the evacuation of electricity produced from gasifiers required the grid to be active. This required dedicated 11 kV lines, which were not present at the gasifier sites and therefore had to be constructed as a priority. All the gasifiers are now connected to evacuate electricity to the grid. A total of 1,050 kW is the cumulative installed capacity through the 11 gasifiers, of which 900 kW is from 100 per cent producer gas.

Operation and maintenance charges are not recovered from users since power is sold to the grid, against which electricity is supplied to the users at subsidised tariffs. The present tariff ranges between Rs.2.85 per kW to Rs.4 per kW. The actual cost of generation ranges from Rs. 7 to Rs. 15 per kW, depending on the plant load factor.

As of July 2010, a total 383 MWh of green energy had been generated, leading to reductions of 11,880 tonnes of CO_2 after taking into account carbon sequestration.

Alwar, Rajasthan

The key to the success of this project was the multi-layered strategy to strengthen the institution of rural women and improve their sources of livelihood, conserve bio-diversity and promote biogas as means of energy, establish mechanisms for better cattle health care and productivity, and enhance incomes from animal and land resources.

To ensure effective implementation and monitoring of the above objectives, institutional links with the government were a pre-requisite. Two federations of self-help groups (SHGs) were set up, all activities being implemented through them subsequently. Women were trained as community leaders, being educated and trained on the biogas project, its objectives, activity implementation and outcomes in relation to livelihoods and bio-diversity conservation. A total of 2500 women emerged as trainees, of whom 45 became the leaders of institutions. Three local masons were also trained and employed to construct and repair the plants.

The successful installation of biogas plants depended on an efficient supply of animal waste. For this, the health of the existing livestock became quintessential to the running of the project, as was the need to purchase more cattle. Women were to be trained as animal health workers or Pashu Sakhis (para-vets), and government resources were mobilised to provide better credit facilities to promote purchases of cattle. To augment the income from land resources, a subsidiary initiative promoting horticulture and organic farming was introduced alongside; however, it did not have much success owing to land constraints.

Today, forty biogas plants are up and running in as many households spread across fifteen villages. Clear evidence of the success of the project lies in the ever-increasing demand for more plants from the villages falling within the project region.

Bahalupani, Orissa

The project's vision was to build a self-reliant, energy-efficient community in a remote biosphere reserve consisting of tribal villages not connected to the grid. A Village Energy Committee (VEC), comprising the villagers themselves, was constituted to spearhead the initiative. To obtain technical expertise and mobilise local resources, links were established with the Light a Billion Lives (LaBL) Campaign supported by TERI (Solar light campaign), the Forest Department and the District Rural Development Authority (DRDA). The project received funding from the Orissa Renewable Energy Development Agency (OREDA). The implementing agencies were quick to identify the pressing need in the village, which was to serve as the first entry point for renewable energy in the tribal realm, thus easing the strain in cooking. Energy-efficient stoves were introduced to gain the confidence of the villagers. Henceforth, it was easier to integrate biomass gasification into the energy mandate.

To feed the Biomass gasification unit, the VEC ensured that fuel wood was planted. The VEC now collects 1.5 kg of biomass daily from each family and Rs. 1.50 as consumer fees. The energy production is 10 kW per day, of which 6 kW is directed towards household consumption and remainder used for commercial purposes as and when required. A block level federation pays Rs. 5 per hour for a commercial honey-processing unit. The biomass power unit is now the mainstay of the energy sphere of the village.

Conclusions

India has an aggressive renewable energy program. It has increased its share of renewable energy (electricity) from 2% (1628 MW) in 2002 to 11% (18,155 MW) in 2010. Though the government has put forward policy instruments to encourage BETs, the strengthening of policy instruments is critical if the full estimated potential is to be realized, especially for the BETs, as they have the potential to energize rural areas, plough back money into rural markets and the rural economy and create employment. Tariff structures for biomass power have been developed; subsidies for improved cooking stoves and biogas units have been introduced, and are continually being fine-tuned.

BETs consist of a complex mix of technologies that face different types of barriers, requiring different policies for large-scale dissemination. This study has provided a high-level analysis of the opportunities and challenges presented by BETs in India. The barriers identified in the report need to be discussed further with various stakeholders to rank and prioritize the barriers so that targeted policies can be developed. The case studies further highlight the fact that targeted policies can be successful if designed with care. If targeted policies are evolved, these will not only demonstrate the effectiveness of BETs in a large developing country such as India, but will also help the government meet its renewable energy targets.

The key policy options to overcoming barriers and for the promotion of BETs include R&D for cost reduction and reliable performance, large-scale demonstrations, capital cost subsidies and other performance-based financial incentives, competitive tariffs for biomass power, performance guarantees, the creation of a large network of entrepreneurs and skilled persons for the construction, operation and maintenance of bioenergy systems, and education and awareness regarding BETs.

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Design and production:
Magnum Custom Publishing
New Delhi, India
info@magnumbooks.org